Using sensitivity scoring to identify marine bird species for KEC assessments

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Contents

This is an updated version of the report C078/25a that was published in December 2025. In this version, inconsistencies with sensitivity factor descriptions and categorisations, as well as in the assigned factor scores were corrected. The overall recommendations per species remain unchanged. Content updates were made in the sections 4 and 5, and in annexes 1–3. The content in all other sections remains unchanged.

Summary

In the last decade, the situation of built and planned offshore wind farms (OWFs) has changed in the Greater North Sea, including in Dutch waters. Alongside these changes, new information on OWF impacts on wildlife such as marine and coastal birds have been identified and documented. The Dutch *Kader Ecologie en Cumulatie* (KEC) programme quantifies cumulative effects of offshore wind farms (OWFs), for example on a selection of marine bird species.
This selection is based on a bird species list compiled in 2014. However, a clear stepwise approach with clear criteria selecting species for inclusion in the KEC assessment has not been developed yet. This assignment addressed this in multiple steps. Firstly, an expert consultation session was held in July 2025 with partners from five North Sea countries. This provided an overview on how other countries currently identify marine bird species to be included in their national assessments. Practices vary across countries, but criteria such as data availability and species conservation status were highlighted by multiple participants. A stepwise approach was suggested to identify species for future assessments, including the application of an existing or modified sensitivity index. There was strong support for a harmonised North Sea–wide sensitivity approach within the group.

Following this consultation, we performed a targeted literature review of sensitivity index methods readily available. The review shows a shift from single composite indices to frameworks that separate collision and displacement, incorporate demographic context, and treat uncertainty more explicitly. Based on these results, we selected and adapted the structured framework of Certain *et al.* (2015) as the most robust, balanced, and applicable for our purposes. The adapted index defines pressure-specific individual vulnerabilities using primary and aggravating factors (e.g., time spend at rotor height, displacement probability) and combines these with species sensitivity factors (e.g., conservation status, adult survival, fecundity).

As a third step, we reviewed the comprehensive bird species list from 2014 and selected four species to apply the modified sensitivity index to. All four species received a medium or high final score, and we recommended including them in the future KEC assessments. These species are yellow-billed loon (*Gavia adamsii*), Manx shearwater (*Puffinus puffinus*), Arctic tern (*Sterna paradisaea*), and little auk (*Alle alle*).
We discussed data limitations for these species regarding the feasibility of including them in future KEC assessments, with a focus on species distribution maps that form the basis of the KEC assessments. Furthermore, we discussed limitations and challenges of the scoring approach and also addressed factor uncertainty.

Overall, we presented and documented an adjusted, transparent, and reproducible sensitivity index approach that can be used to identified species that are considered vulnerable to OWF effects (collision and/or displacement). This approach can be applied to the Dutch situation, but is easily adaptable to other North Sea countries, and is transferable to the Greater North Sea.

Samenvatting

In het afgelopen decennium is de situatie rond gerealiseerde en geplande offshore windparken (OWF's) in de Noordzee, waaronder de Nederlandse wateren, aanzienlijk veranderd. Tegelijkertijd is er nieuwe kennis opgedaan over de effecten van OWF's op fauna, zoals zee- en kustvogels. Het Nederlandse programma Kader Ecologie en Cumulatie (KEC) kwantificeert de cumulatieve effecten van offshore windparken, onder andere op een selectie van zeevogelsoorten. Deze selectie is gebaseerd op een soortenlijst die in 2014 is opgesteld. Er is echter nog geen duidelijke methode met transparante criteria ontwikkeld om te bepalen welke soorten in de KEC-beoordeling worden opgenomen. Deze opdracht heeft dit onderwerp in meerdere fasen aangepakt.
Allereerst werd in juli 2025 een expertconsultatie georganiseerd met partners uit vijf landen langs de Noordzee. Deze bijeenkomst bood inzicht in hoe andere landen zeevogelsoorten selecteren voor hun nationale beoordelingen. De werkwijzen bleken tussen landen te verschillen, maar criteria zoals beschikbaarheid van data en beschermingsstatus van soorten werden door meerdere deelnemers benadrukt. Er werd een stapsgewijze aanpak voorgesteld voor de selectie van soorten voor toekomstige beoordelingen, inclusief het gebruik van een bestaande of aangepaste gevoeligheidsindex. Binnen de groep bestond brede steun voor een geharmoniseerde Noordzee-brede gevoeligheidsbenadering.

Na deze consultatie is een gerichte literatuurstudie uitgevoerd naar bestaande methoden voor gevoeligheidsindices. Uit deze studie blijkt een verschuiving van enkelvoudige samengestelde indices naar raamwerken die onderscheid maken tussen aanvarings- en verstoringseffecten, demografische context meenemen en onzekerheden explicieter behandelen. Op basis van deze resultaten is het gestructureerde raamwerk van Certain *et al.* (2015) geselecteerd en aangepast, aangezien dit het meest robuust, evenwichtig en toepasbaar werd geacht. De aangepaste index definieert drukspecifieke individuele kwetsbaarheden aan de hand van primaire en verergerende factoren (zoals tijd doorgebracht op rotorhoogte en verstoringskans) en combineert deze met soortspecifieke gevoeligheidsfactoren (zoals beschermingsstatus, volwassen overleving en vruchtbaarheid).

Als derde stap is de uitgebreide vogelsoortenlijst van 2014 herzien en zijn vier soorten geselecteerd om de aangepaste gevoeligheidsindex op toe te passen. Alle vier soorten kregen een middelhoge tot hoge eindscore, en we bevelen aan om deze in toekomstige KEC-beoordelingen op te nemen. Het gaat om de geelsnavelduiker (*Gavia adamsii*), Noordse pijlstormvogel (*Puffinus puffinus*), Noordse stern (*Sterna paradisaea*) en kleine alk (*Alle alle*).
Voor deze soorten hebben we de databeperkingen besproken met betrekking tot de haalbaarheid van opname in toekomstige KEC-beoordelingen, met in het bijzonder aandacht voor verspreidingskaarten, die de basis vormen van de KEC-analyse. Daarnaast zijn de beperkingen en uitdagingen van de scoringsmethode besproken, evenals de omgang met onzekerheidsfactoren.

In conclusie presenteren en documenteren we een aangepaste, transparante en reproduceerbare gevoeligheidsindex die kan worden gebruikt om soorten te identificeren die kwetsbaar zijn voor de effecten van offshore windparken (aanvaring en/of verstoring). Deze aanpak is toepasbaar op de Nederlandse situatie, maar kan ook eenvoudig worden aangepast aan andere Noordzeelanden en is overdraagbaar naar de gehele Noordzee.

1 Introduction

Within the KEC (*Kader Ecologie en Cumulatie*) assessment, the cumulative effects of offshore wind farms (OWFs) on sensitive animal species are quantified. For coastal and marine birds, multiple species are considered and assessed for displacement and collision effects. These are the species regarded as most vulnerable to the effects of OWFs. The original species list is based on an analysis by Leopold *et al.* (2014). Since then, the number of constructed and planned OWFs has increased substantially (European Commission, 2020). Other pressure factors in the North Sea have also grown in magnitude, and environmental conditions are changing, e.g., increases in sea surface temperature (Amorim *et al.*, 2023). Finally, knowledge about the effects of OWFs on different species has expanded considerably (e.g., Peschko *et al.*, 2020a). For all these reasons, it is desirable to revise the current species list and identify potential new species to be considered in future KEC assessments in a transparent and formalised manner.

Table 1 *Marine and migratory bird species used in the KEC 4 assessment (2022) for either displacement effects (DIS), collision effects (COL), or both.*

	English name	Species name	Dutch name	KEC 4
Marine birds	Atlantic puffin	*Fratercula arctica*	Papegaaiduiker	DIS
	Common eider	*Somateria mollissima*	Eider	DIS
	Common guillemot	*Uria aalge*	Zeekoet	DIS
	Common scoter	*Melanitta nigra*	Zwarte zee-end	DIS
	Diver spec.	*Gavia* spec.	Duiker spec.	DIS
	Great cormorant	*Phalacrocorax carbo*	Aalscholver	DIS
	Northern fulmar	*Fulmarus glacialis*	Noordse stormvogel	DIS
	Razorbill	*Alca torda*	Alk	DIS
	Arctic skua	*Stercorarius parasiticus*	Kleine jager	COL
	Black-legged kittiwake	*Rissa tridactyla*	Drieteenmeeuw	COL
	Common tern	*Sterna hirundo*	Visdief	COL
	Great skua	*Stercorarius skua*	Grote jager	COL
	Greater black-backed gull	*Larus marinus*	Grote mantelmeeuw	COL
	Herring gull	*Larus argentatus*	Zilvermeeuw	COL
	Lesser black-backed gull	*Larus fuscus*	Kleine mantelmeeuw	COL
	Little gull	*Hydrocoloeus minutus*	Dwergmeeuw	COL
	Northern gannet	*Morus bassanus*	Jan-van-gent	DIS, COL
	Sandwich tern	*Thalasseus sandvicensis*	Grote stern	DIS, COL
Migratory birds	Bar-tailed godwit	*Limosa lapponica*	Rosse grutto	COL
	Bewick's swan	*Cygnus (columbianus) bewickii*	Kleine zwaan	COL
	Black tern	*Chlidonias niger*	Zwarte stern	COL
	Brent goose	*Branta bernicla*	Rotgans	COL
	Common shelduck	*Tadorna tadorna*	Bergeend	COL
	Common starling	*Sturnus vulgaris*	Spreeuw	COL
	Eurasian curlew	*Numenius arquata*	Wulp	COL
	Red knot	*Calidris canutus*	Kanoet	COL

This assignment concerns the development of a reproducible and transparent approach to select bird species to be added to the KEC species list (**Table 1**), building on upon the species list compiled by Leopold *et al.* (2014; **Table 8** in Annex 4). This assignment explicitly does not revise and reevaluate species already on the KEC species list as shown in **Table 1**, but aims to add species to the list to be assessed for collision and/or displacement effects in future KEC assessments. We explicitly focus on marine and coastal birds, while acknowledging that species of other groups, e.g., (migratory) waterfowl or passerines, may need to be added to the list as well.

1.1 Aims of this study

The aims of this assignment are 1) to develop a reproducible methodology to identify coastal and marine bird species of interest to be included in future KEC assessments, and 2) to compile a list of additional coastal and marine bird species that are most likely to experience above-average population effects from the presence of (future) offshore wind farms in Dutch waters that have not been included in previous KEC assessments. The final list serves as input for the next KEC assessment.
To achieve this, we organised an expert consultation (section 2) and performed a literature review (section 3), prior to working towards the design and application of an adapted sensitivity index that serves the species selection process (section 4).

2 Expert consultation on marine bird species selection for offshore wind farm impact assessment

On 8th July 2025, a three-hour long expert consultation was organised to address a growing need for a transparent, scientifically grounded, and reproducible process for selecting marine bird species in offshore wind farm (OWF) impact assessments. With the rapid expansion of offshore wind energy across the North Sea, the ecological implications for marine bird populations have become a central concern. Wageningen Marine Research (WMR), on behalf of Rijkswaterstaat, initiated this session to re-evaluate the species selection process used in the KEC assessment for OWF, and to learn from the experiences and methodologies of neighbouring North Sea countries. The overarching goal was to explore ways to improve the reproducibility and transparency of the Dutch species selection process for KEC, which has historically lacked clear documentation, and to learn from international best practices and shortcomings of currently implemented approaches.

2.1 Background: the Netherlands

The Netherlands has set ambitious targets for offshore wind development, aiming to install 21 GW of offshore wind capacity by 2030 and 70 GW by 2050. The KEC, updated every two years, is the primary tool used to assess the cumulative ecological impacts of wind farms, with amongst others a focus on marine bird displacement and collision risks. However, the process for selecting which marine bird species to include in these assessments has historically lacked transparency. The original species list, developed in 2014 (Leopold *et al.*, 2014), was based largely on expert judgment and data availability, with subsequent updates made without clear documentation. This has led to inconsistencies and uncertainty about the rationale behind species inclusion or exclusion. In response, RWS commissioned a project to develop a more reproducible and internationally informed approach.

2.2 Individual country practices and selected species

The consultation brought together representatives from five North Sea countries (**Table 2**), each with distinct approaches to marine bird species selection in OWF assessments.

In **the Netherlands**, the process of selecting species to be included in the KEC is guided by the EU Birds Directive and national legislation, with assessment tools such as Acceptable Level of Impact and Potential Biological Removal used to quantify impacts. Species are selected based on their presence in Dutch waters, expected collision risk (typically defined as more than one bird per year) if applicable, and conservation status. However, the lack of transparency and consistency in species list updates remains a key challenge. In the Netherlands, species such as the red-throated diver (*Gavia stellata*), razorbill (*Alca torda*), common guillemot (*Uria aalge*), northern gannet (*Morus bassanus*), black-legged kittiwake (*Rissa tridactyla*.), scoters (*Melanitta* spp.), great crested grebe (*Podiceps cristatus*), and common eider (*Somateria mollissima*) are actively assessed due to sufficient data availability. However, species like the pomarine skua (*Stercorarius pomarinus*) and Atlantic puffin (*Fratercula arctica*), for example, remain difficult to assess due to rarity or unclear inclusion criteria.

Belgium focuses on species that represent more than 1% of their population in Belgian waters or are listed under the Marine Strategy Framework Directive. The country employs a Before-After-Control-Impact design using ship-based surveys and has recently shifted towards habitat suitability modelling to identify sensitive areas in the Belgian EEZ based on displacement of birds due to offshore wind farms (OWFs). A major concern is the cumulative effect of surrounding wind farms, which may restrict marine bird access to Belgian waters. Belgium focuses on similar species as the Netherlands and highlighted their concern for species with decreasing migration corridors or flying pathways to enter Belgium waters due to OWF development. Belgium further studies potential habituation effects in gannets and guillemots.

Table 2 *List of all participants partaking in the expert consultation, the country they work in, their affiliation, and their respective role in the meeting.*

Name	Country	Institution	Role
Eric Stienen	Belgium	Instituut voor Natuur- en Bosonderzoek (INBO)	Expert
Ruben Fijn	The Netherlands	Waardenburg Ecology (WE)	Expert
Volker Dierschke	Germany	Dachverband Deutscher Avifaunisten (DDA), freelancer working for the Federal Agency for Nature Conservation (BfN)	Expert
Ib Krag Petersen	Denmark	Department of Ecoscience - Wildlife Ecology, Aarhus University	Expert
Saana Isojunno	Denmark/Scotland	Centre for Ecological and Environmental Research (CREEM)	Expert
Lise Ruffino	Scotland	Joint Nature Conservation Committee (JNCC)	Expert
Eleni Melis	The Netherlands	Wageningen Marine Research (WMR)	Host
Eileen Heße	The Netherlands	Wageningen Marine Research (WMR)	Host
Susanne van Donk	The Netherlands	Wageningen Marine Research (WMR)	Host

Germany does not maintain a formal species list. To identify species that are most covered in their displacement studies, species importance for these assessments was inferred from their frequency of mention in environmental assessments and reports. However, this was just to highlight species studied often and is not a standard approach to identify species of relevance. The legal framework is based on the German Nature Conservation Act, aligned with EU directives. Challenges include the absence of cumulative impact assessments, inconsistent legal interpretations of current legislation, and a lack of ecosystem-level perspectives. In Germany, common guillemot, red-throated diver, northern gannet, northern fulmar (*Fulmarus glacialis*), and black-legged kittiwake are key species, but Atlantic puffin, coastal diving ducks, and species with unclear population boundaries present ongoing assessment challenges.

Denmark has developed a strategic, data-driven sensitivity mapping framework that uses quantitative risk ratios to assess three impact pathways: habitat overlap, displacement, and collision. The approach incorporates aerial survey data, literature-based displacement and collision rates, and conservation status from the European Red List. The Danish model is notable for its continuous data inputs, propagation of uncertainty, and adaptability. Denmark assesses, amongst others, divers (Gaviidae), common scoter (*Melanitta nigra*), and sea-going ducks like the long-tailed duck (*Clangula hyemalis*), as well as razorbill, gannet, and fulmar. It was further highlighted that some species are harder to evaluate due to data limitations, and therefore the use of proxy species (e.g., related species or species that show similar behaviour) can be required.

The United Kingdom follows a stepwise Habitat Regulations Assessment process, which includes screening, Appropriate Assessments, and Population Viability Analysis to assess effects of OWFs on marine birds. Tools such as foraging range buffers, non-breeding population estimates, and sensitivity maps are used to inform decisions. Displacement is assessed using matrices or individual-based models. The UK faces challenges related to data gaps, high uncertainty, and coordination across devolved administrations. The UK includes kittiwakes, northern gannet, razorbill, and common guillemot in assessments, though challenges persist with non-breeding populations and species with limited demographic data. Included species are identified via spatial and temporal overlap between proposed offshore wind sites and protected marine bird distributions, and sensitivity assessments. The UK applies the precautionary principle, especially where data is limited.

In summary, across all countries represented in the consultation there is a consistent focus on a core group of marine bird species: divers (mainly red-throated diver), auks (common guillemot and razorbill), northern gannet, and kittiwakes. These species are widely distributed across the North Sea (particularly during non-breeding season), regularly present in offshore areas, and have sufficient data available to support impact assessments (primarily on displacement effects) related to OWFs. Overall, European but also national legislation, conservation status, as well as data availability were mentioned several times as criteria used to identify marine bird species for inclusion in assessments or for sensitivity mapping. However, clear step-by-step approaches or screening procedures to assess species relevance for assessments have not been developed and/or implemented yet.

2.3 Key steps for a practical and reproducible species selection process

Across the consultation, there was strong agreement on the need for a structured, stepwise approach to species selection. Drawing on the ecological and management criteria discussed for a species' sensitivity to OWF impacts, we developed a practical sequence of steps that reflect these priorities. These steps emerged from the meeting discussions and were then ordered in a way that makes logical sense and is most feasible in terms of time investment.

This process could begin with compiling a comprehensive list of species that use marine areas for foraging or movement. Terrestrial, coastal or freshwater species are excluded unless they are relevant to the marine environment, such as diving ducks. This initial list is then filtered based on empirical evidence of presence and abundance, using data from aerial surveys, ship-based observations, and tracking studies where available. Seasonal occurrence and life stages, such as breeding, moulting, or migration, are also taken into account, particularly for species that use key habitats or migration corridors.

Next, legal and conservation relevance should be assessed, referencing frameworks such as the EU Birds Directive, national or European Red Lists, and regional importance of a species. Species with small populations or 'Threatened' status, even if locally uncommon, are given due consideration. It was agreed that European rather than global conservation status should guide these decisions, ensuring that regionally important species are not overlooked.

A vulnerability assessment could then be conducted to evaluate species sensitivity to OWF impacts, including both collision risk and displacement. This could be done by developing new vulnerability indices based on ecological traits, exposure, and recovery potential, or by using existing indices and modifying them by e.g., using the European or national conservation status instead of the global one. Expert elicitation was emphasised as essential in data-poor situations, helping estimate key risk parameters through structured expert judgment.

Finally, species are prioritised for detailed assessment (e.g., population-level modelling or cumulative impact analysis) based on their vulnerability scores. Where data gaps exist, proxy species may be used, provided that assumptions are clearly documented. This framework ensures that both common and uncommon but highly vulnerable species are systematically identified and included in OWF planning and impact assessments.

2.4 Challenges and considerations

Several challenges were identified during the expert consultation. Most importantly among them is the issue of data gaps, particularly for rare or morphologically difficult to distinguish species in the North Sea. These species are often underrepresented in surveys, making it difficult to assess their vulnerability accurately. In certain cases, proxy species can help fill these gaps, but their use must be scientifically justified, and the assumptions made must be clearly documented. While the importance of the before-mentioned expert elicitations to deal with data-limited species was recognised, it was also highlighted that this process is very time-consuming. The hosts concluded that this process, unfortunately, would be outside the scope of this project.

Temporal variability in species presence in the study area poses another challenge that should be addressed when using a data-driven approach in identifying species relevance. Averaging data across seasons can obscure critical periods in a species' life cycle, such as breeding, moulting or migration. This poses the risk of incorrectly assessing species vulnerability or exposure to OWFs. A more precautionary approach could be to use maximum abundance values instead of averaged ones. Participants highlighted that adapting established methods within existing policy frameworks can be challenging, particularly when aiming for timely implementation.

2.5 The need for a common North Sea-wide sensitivity index

The experts participating in this session agreed that a North Sea-wide sensitivity index is needed rather than country-specific indices. Such a tool would reflect the ecological reality that marine birds do not recognise national boundaries and would support more consistent and comparable assessments across countries. It was mentioned that sensitivity or vulnerability indices can be limited by outdated or sparse data. They further may not capture a species' capacity to adapt or recover to or from OWF interactions and typically overlook cumulative and ecosystem-level effects. The expert group recommended updating existing sensitivity indices using the latest empirical data and expert input, rather than 'reinventing the wheel' by developing a new indexing method. They emphasised the importance of developing separate indices for different impact pathways, such as collision risk and displacement. A regional, North Sea-wide, index could help to enhance policy coherence and efficiency by avoiding duplication of effort and preferably enabling joint data collection and modelling in the future. Participants recommended building on existing regional frameworks, such as OSPAR and the MSFD, to develop a shared methodology for scoring vulnerability and sensitivity. A cross-national expert group could be established to coordinate updates and ensure the index remains up-to-date and robust.

2.6 Conclusions

A stepwise, data-informed framework was endorsed, beginning with a comprehensive species list and progressing through filters based on presence, if so, abundance, conservation status, and vulnerability towards OWFs, concluding a prioritisation for detailed population-level modelling. The development of a North Sea-wide sensitivity index was viewed as both necessary and feasible, provided financial backing is secured. International collaboration was deemed essential, with strong support for a shared platform or working group (e.g., under OSPAR) to align methodologies and facilitate data sharing. Additionally, the participants strongly emphasised the need to collaboratively act now: with offshore wind development accelerating, robust, science-based tools must be developed urgently to identify low-risk areas and avoid high-sensitivity zones, ensuring marine bird populations are safeguarded, and marine spatial planning remains sustainable.

Disclaimer: The entire expert consultation meeting was transcribed and analysed using MS Teams Copilot. The authors reviewed and edited the content as needed and take full responsibility for the final content of the published report. The content of this summary has been agreed upon by all participants.

3 Literature review on development and application of marine bird sensitivity indices for offshore wind farms

The development of marine bird sensitivity indices has emerged as a pragmatic approach to evaluate potential impacts of offshore wind energy infrastructure. These indices usually integrate species-specific biological traits, behavioural metrics, and spatial distribution data to assess and eventually map species or species group vulnerability, supporting strategic environmental assessments, spatial planning, and monitoring programmes. The creation of sensitivity indices has been driven by rapid OWF expansion, data limitations in large offshore areas, and conservation obligations such as the EU Birds Directive (Garthe & Hüppop, 2004; Furness *et al.*, 2013; Kelsey *et al.*, 2018; Fauchald *et al.*, 2024). For this assignment, we reviewed ten studies developing, adapting, and applying sensitivity indices to marine bird species. Here, we focused primarily on indices applied in the North Sea. However, we also included some examples from outside European waters, provided they were clearly linked to the indices applied in our study area (see section 3.2).

3.1 Purpose, scope, and conceptual basis

The primary purpose of the sensitivity indices discussed here is to prioritise bird species and areas for further assessment of collision and displacement risks, inform site selection, e.g., for OWF development, and guide the design of monitoring programmes (e.g., abundance, distribution, behaviour, and population trends in relation to OWFs). Sensitivity indices combine species-level attributes, such as life history traits, demographic sensitivity, and conservation status, with behavioural metrics relevant to collision risk (e.g., flight altitude, manoeuvrability, nocturnal flight activity) and displacement sensitivity (e.g., habitat specialisation and disturbance sensitivity). Sensitivity scores are then commonly scaled by spatial occurrence or species density to produce seasonal and total sensitivity maps (Bradbury *et al.*, 2014; Certain *et al.*, 2015; Kelsey *et al.*, 2018).

In the following, the focus lies on the calculation of sensitivity indices for marine bird species without taking spatial bird distributions into account. Generating spatial sensitivity maps based on sensitivity scores is beyond the scope of this assignment.

3.2 Evolution of sensitivity indices and their scoring systems

The development of sensitivity indices for seabirds has its foundation in the Species Sensitivity Index (SSI) proposed by Garthe & Hüppop (2004), which combined nine factors grouped into flight behaviour, disturbance sensitivity, and conservation/demographic attributes into a single multiplicative score. This pioneering framework has since been adapted and refined across regions and contexts. Van der Wal *et al.* (2010) applied the original SSI to the entire North Sea but expanded the approach by broadening spatial and temporal coverage, adjusting species scores, weighting abundance using ln(density+1), and mapping sensitivity on a 25 km grid with kriging to generate North Sea–wide outputs. Furness *et al.* (2013) retained the multi-factor structure but introduced a major change by separating collision and displacement risk into two independent ranked lists, thereby avoiding their conflation into a single aggregated score. Gressetvolt (2013) focused on correlations among the underlying factors and recommended supplementing the framework with independent demographic indices such as elasticity of adult survival. Bradbury *et al.* (2014) modified the Garthe & Hüppop approach by giving flight altitude a higher weighting in the collision-risk index and explicitly treating habitat specialisation as a weighted factor in the displacement index. Certain *et al.* (2015) provided a more fundamental critique, identifying methodological issues such as the multiplicative mixing of distinct pressures, equal weighting of individual factors, and over-reliance on abundance. They proposed instead to distinguish between primary factors, which directly determine vulnerability (e.g. time flying at blade height for collision), and aggravating factors, which amplify vulnerability (e.g. nocturnal flight or habitat flexibility), thereby producing separate indices for collision and displacement. This structured framework was also extended to other taxa such as benthic megafauna and will be described in more detail in Section 4, but here we highlight its main departure from the SSI tradition: explicit factor structuring, separation of pressures, and revised aggregation methods. Further developments outside European waters adapted these ideas to new contexts: Adams *et al.* (2017) and Kelsey *et al.* (2018) restructured SSIs for the Pacific by scaling collision and displacement values with a population vulnerability index (including demography, status, range, and survival), updating behavioural metrics such as macro-avoidance and time spent in the rotor-swept zone, incorporating breeding likelihood in the study area, and introducing explicit uncertainty ranges. Searle *et al.* (2019) then implemented the Certain *et al.* (2015) primary/aggravation framework but updated the species scores using alternative expert-derived sources (Furness *et al.*, 2013; Wade *et al.*, 2016), while Fauchald *et al.* (2024) went further by combining vulnerability scoring with habitat suitability models across the Norwegian EEZ. Together, these studies illustrate a clear evolution from a single aggregated SSI to increasingly structured, context-specific, and uncertainty-aware approaches that separate pressures, incorporate demography, and link sensitivity with spatial distribution models.

3.3 Data sources

The sensitivity indices studied typically integrate diverse data sources, including tracking data, at-sea and aerial surveys, citizen science records, and species distribution or density surface models. Where empirical data are lacking, expert consultation can provide essential input for the scoring of the different factors (Bradbury *et al.*, 2014; Fauchald *et al.*, 2024). Many frameworks explicitly separate collision vulnerability from displacement vulnerability to reflect their distinct ecological mechanisms and management implications (Furness *et al.*, 2013; Adams *et al.*, 2017; Kelsey *et al.*, 2018). Authors often acknowledge uncertainties arising from low offshore survey coverage, correlated metrics, and expert-derived scores, recommending regular updates, separation of indices to avoid conflating pressures, and follow-up demographic or population viability analyses (Certain *et al.*, 2015; Fauchald *et al.*, 2024).

3.4 Limitations of current approaches

The main strength of sensitivity indices is their ability to integrate diverse information into spatially explicit outputs and provide consistent, repeatable tools for screening and prioritisation. They enable strategic assessment at scales where detailed empirical data are lacking. However, across the evolution of sensitivity indices, several recurring limitations emerge. The early frameworks relied on heterogeneous factor currencies and scales, ad hoc aggregation rules, and heavy dependence on subjective expert judgement, particularly for poorly studied traits such as nocturnal activity or disturbance responses (Garthe & Hüppop, 2004; Gressetvolt 2013; Furness *et al.*, 2013). Multiplicative aggregation and the inclusion of abundance terms often masked important signals, conflated collision and displacement pressures, and produced counter-intuitive weighting of rare versus common species (Garthe & Hüppop, 2004; Certain *et al.*, 2015; Gressetvolt 2013). Many indices suffered from multicollinearity and potential double-counting among correlated factors, while key empirical inputs such as flight height, avoidance rates, displacement sensitivity, and demographic parameters were sparse, inconsistent, or of low quality (Furness *et al.*, 2013; Bradbury *et al.*, 2014; Adams *et al.*, 2017). Arbitrary thresholds, categorical scoring systems (often ordinal 1–5), and relative rank bins limited the biological interpretability and comparability of results (Furness *et al.*, 2013; Bradbury *et al.*, 2014; Van der Wal *et al.*, 2010), while uncertainty treatment was coarse and approximate (Adams *et al.*, 2017; Kelsey *et al.*, 2018; Searle *et al.*, 2019). Although the structure of more recent indices has improved and certain biases have been reduced, methodological constraints remain, with outputs still highly sensitive to input data quality and the assumptions built into the scoring logic.
Here, we propose an approach to identify marine bird species vulnerable to collision and/or displacement effects from OWFs in the Dutch North Sea which can also be applied to the entire North Sea.

4 Revised sensitivity index and application for KEC

Following the literature review (section 3), the framework of Certain *et al.* (2015) was selected as the most robust and balanced to adapt for application for the purpose of this study and our study area.

The refined framework presented by Certain *et al.* (2015) addresses shortcomings of the method proposed in Garthe & Hüppop (2004) by disentangling the two pressure types, collision and displacement, and treating them separately from each other. Instead of collapsing collision and disturbance into a single metric, the approach computes distinct vulnerability scores for each pressure type and combines them with an independent measure of species sensitivity. This design allows species-specific susceptibility to collisions and to disturbance to be highlighted separately, avoiding methodological biases while still integrating both dimensions into the overall assessment. Importantly, the use of multiple vulnerability factors within each pressure type ensures that outcomes are not overly dependent on any single factor.

Within this framework, individual vulnerability is defined as the combination of behavioural, morphological, and ecological factors that influence the probability of an individual being affected by a given pressure type, e.g., flight height, or disturbance by ships and helicopters. Species sensitivity, represents the intrinsic severity of any impact on a species, reflecting traits such as conservation status at multiple spatial scales and adult survival rate. A key innovation presented by Certain *et al.* (2015) is the introduction of a hierarchy between primary factors which directly determine exposure or sensitivity and aggravating factors which only increase vulnerability if the relevant primary factor(s) indicate exposure. For instance, low flight manoeuvrability (aggravation factor) has no effect on collision vulnerability (primary factor) if a species never flies at rotor height, but it increases species vulnerability to collision if they do.

To integrate primary and aggravation factors, Certain *et al.* (2015) proposed a general formula where a primary value (a) is adjusted by an aggravation value (g):

$$r = a^{1-\frac{g}{g-\gamma}} \qquad (1)$$

with γ (default = 0.5, recommended range 0.1–1) determining the influence of aggravation. This ensures that the score equals the primary factor when aggravation is absent, while vulnerability increases with increasing aggravation factor score(s) in a bounded, nonlinear way. Groups of factors can be combined in two different ways. When factors represent different, potentially compensatory dimensions, they can be. However, when factors are conditional or interacting, Certain *et al.* (2015) proposed to use multiplication instead. The authors highlighted that a careful justification of these choices is critical, as multiplication can strongly amplify differences between species.
Factor scores originally assigned on a scale from low (1) to high (5) vulnerability were rescaled to the interval [0.2–1]. Ten different factors describing collision and displacement vulnerability, and species sensitivity were included in the indexing approach presented by Certain *et al.* (2015; **Table 3**).

Collision vulnerability (c_i) was calculated by combining factors F1 and F2 ('Proportion of time spent flying', 'Proportion of time at rotor height') multiplicatively as primary factors (since exposure to blades requires both flight and overlap with rotor height). Factors F3 and F4 ('Flight manoeuvrability', 'Nocturnal flight activity') were averaged and used as aggravation factors. Disturbance vulnerability (d_i) was derived from the primary factor F5 ('Disturbance sensitivity to ship and helicopter traffic'), and F6 ('Habitat flexibility') as aggravation factor. Species sensitivity (s_i) was calculated as the average of primary factors F7–F9 ('International –', 'European –', and 'National conservation priority'), while 'Adult survival' (F10) was used as aggravation factor.

Finally, species-level vulnerability to each pressure type was calculated by multiplying collision and displacement vulnerability separately with species sensitivity, resulting in distinct indices for collision ($c_i s_i$) and disturbance ($d_i s_i$) vulnerability. This approach provides a transparent, flexible, and ecologically grounded assessment framework. By explicitly separating the pressure types, structuring the combination of factors through a primary–aggravation hierarchy, and using multiple factors per dimension, the Certain *et al.* (2015) method overcomes biases of earlier indices and yields a more balanced representation of marine bird vulnerability to OWFs.

Table 3 *Primary and aggravation factors used for collision and displacement vulnerability as well as for overall species sensitivity within Certain et al. (2015).*

Factor	Description	Factor type	Pressure type	Factor hierarchy
F1	Proportion of time spent flying	Vulnerability	Collision	Primary
F2	Proportion of time at rotor height	Vulnerability	Collision	Primary
F3	Flight manoeuvrability	Vulnerability	Collision	Aggravation
F4	Nocturnal flight activity	Vulnerability	Collision	Aggravation
F5	Disturbance sensitivity to ship and helicopter traffic	Vulnerability	Disturbance	Primary
F6	Habitat flexibility	Vulnerability	Disturbance	Aggravation
F7	International conservation priority	Sensitivity	None	Primary
F8	European conservation priority	Sensitivity	None	Primary
F9	National conservation priority	Sensitivity	None	Primary
F10	Adult survival rate	Sensitivity	None	Aggravation

4.1 Adaptations of sensitivity index

As previously recommended in Certain *et al.* (2015), we used the default γ-value of 0.5 in Equation (1). Further, we applied a comparable scoring system to all factors used here, with initial values ranging from 1-5 (or using categorical levels 1, 3, and 5 to represent low, medium and high; see **Table 6** in Annex 1 for more details). These initial scores were then scaled to values between 0.2 and 1, following the same approach as Certain *et al.* (2015).
In the following, any adaptations or alterations made to the pressure factors used and the calculations performed compared to the approach of Certain *et al.* (2015) are described. For the majority, we used the same pressure factors and factor categorisation as Certain *et al.* (2015; **Table 5**). For any alterations made on the factor scoring categorisations, see **Table 7** in Annex 1. Pressure factors included in the adapted sensitivity index are labelled F_n where $_n$ means new.

Factor F_n1 ('Proportion of time spent flying') was used as described in Certain *et al.* (2015) and originates from Garthe & Hüppop (2004). The collision factor F_n2 was adapted to quantitatively represent the time spent within the rotor swept zone (RSZ), allowing the scoring of data-limited species. The collision factor ranges between little to no time spent within the RSZ to relatively much time spent in the RSZ. The range of the RSZ height was also adapted to reflect the current and planned turbine dimensions in the Dutch EEZ until 2031. The RSZ is now defined as 19–305m above seawater level. The factors for `Flight manoeuvrability' and `Nocturnal flight activity', F_n3 and F_n4, use a quantitative scoring from 1–5, respectively representing decreasing flight manoeuvrability and increasing nocturnal flight activity. Factors F_n3 and F_n4 are therefore comparable with the original factors from Certain *et al.* (2015) but were modified to also accommodate the scoring of data-limited species when expert judgement is used as input.
The factors F_n5 'Micro-avoidance of wind turbines' and F_n6 'Offshore migration percentage' have been added as aggravation factors for collision vulnerability as they provide further insight into collision risks (**Table 4**). Micro-avoidance, here defined as the ability to make last-minute changes in flight path to avoid collision with turbines and rotor blades, is likely linked to manoeuvrability but might not be entirely described by it. Therefore, we decided to add micro-avoidance as additional aggravation factor, accounting for behavioural responses that could substantially reduce effective collision probability. The second factor added is representing

the percentage of time a bird spends offshore during its migration. As a bird migrates along the coastal area, it is less likely to encounter an OWF compared to when it's migrating further offshore where current and future OWFs are and will be situated and the likelihood of an OWF encounter increases. Depending on prevailing weather conditions and the intensity of migration, migrating birds may occur at rotor height. Radar observations have shown that migrants can travel from sea level to higher altitudes during periods of mass migration. The expert team assumed that, during peak migration events, birds generally select optimal flight altitudes that remain above the Migration Traffic Rate thresholds for curtailment. The time spent migrating offshore could therefore increase the collision vulnerability of birds.

The primary displacement factor F_n7 (F5 in Certain *et al.*, 2015) is now defined as 'Displacement probability' instead of 'Disturbance sensitivity to ship and helicopter traffic'. It is based on abundance rates identified in the available literature, e.g., through control-impact or before-after-control-impact (BACI) studies, indicating the reduction of birds in an OWF area compared to a control area or to the area before OWF construction, respectively. If such studies are not available for a species, the scores can also be based on expert judgement and/or displacement probabilities of proxy species. Currently, it is not possible to identify to which degree (visual) disturbances by OWF-related air and vessel traffic and disturbance by the turbines themselves are entangled and influencing the changes in bird abundance and the consequent displacement rates. Therefore, we use overarching displacement probability.
Instead of three conservation statuses (international, European, national), we decided to use the F_n10 Dutch conservation status (*Staat van Instandhouding*; SvI) when assessing marine bird species vulnerability in Dutch waters where available. For species for which no information on F_n10 was available, e.g., because data on species trend or population numbers were limited, F_n9 EU Red List status was used instead. For marine bird species migrating into Dutch waters exclusively from UK colonies without information on SvI, it is also possible to use the UK Birds of Conservation Concern status instead of the EU Red List status which might not accurately represent the UK population status.

New aggravation factors F_n12 'Annual occurrence' and F_n13 'Fecundity' were added to overall species sensitivity to provide additional information on factors impacting species sensitivity. When calculating sensitivity indices for Dutch waters only, the aggravation factor F_n12 should be included in the calculations only if F_n10 (SvI) is unavailable and the European Red List status is used instead. This is because annual occurrence in Dutch waters is already incorporated in the SvI (Foppen & Vogel 2022). Therefore, F_n12 should not be included separately when F_n10 is applied. For other species for which there is no information on F_n10 SvI*,* the European Red List status F_n9 has to be used instead. In this case, we advise to include F_n12 into the calculations to account for species occurrence in Dutch waters. For a North Sea wide sensitivity index, F_n12 'Annual occurrence' refers to the entire North Sea instead of the Dutch waters.

For all factors, for which no information is available in either peer-reviewed publications or 'grey' literature, we suggest using expert judgement to fill these knowledge gaps. Ideally, a full expert elicitation process would be conducted to fill those gaps (see also recommendation from expert consultation, section 2.3). However, as this is a very time-consuming procedure, we recommend using expert judgement from preferably at least two marine bird experts to reduce expert-introduced bias for assignments in which a full expert elicitation process is not feasible.

Following the addition and modification of some of the primary and aggravation factors, small changes in the index score calculations were made. To calculate the updated individual collision vulnerability c_i, the aggravation factors F_n5 and F_n6 were included. In Certain *et al.* (2015), c_i was calculated by applying Equation (1) with $g_i = (F_{i3} + F_{i4})/2$ and $a_i = F_{i1} \times F_{i2}$. Now, c_i is calculated with $g_i = ((F_{ni3} \times F_{ni5})/2 + F_{ni4} + F_{ni6})/3$ instead, as we assume a relationship between manoeuvrability and micro-avoidance. The calculation of a_i remains unchanged. If no value is available for F_{ni5}, the average of F_{ni3}, F_{ni4}, and F_{ni6} is used to calculate g_i instead following Certain *et al.* (2015).
Previously, three conservation status factors were combined as primary factors, and only adult survival was included as aggravation factor in the individual species sensitivity s_i. The primary factors were combined as the mean of $F_{ni7\text{-}9}$ to be used as a_i in Equation (1), while only one factor was included as aggravation factor g_i (F_{ni10}). Now, the score of either F_{ni9} or F_{ni10} is used as a_i. For g_i, the average of F_{ni11} and F_{ni13} is now used if a value for F_{ni10} is available. If not, the average of $F_{ni11\text{-}13}$ is used instead.

The calculation of individual displacement vulnerability d_i remains unchanged with applying $a_i = F_{ni7}$ and $g_i = F_{ni8}$ in Equation (1). Note the change in factor numbering for the displacement vulnerability and species sensitivity between the approach from Certain *et al.* (2015) and the adapted approach here (see **Table 3** and **Table 4** for factor numbers in the original and the updated approach described here, respectively).

In Certain *et al.* (2015), final scores for species displacement vulnerability and species collision vulnerability were provided separately as d_is_i and c_is_i, respectively. In the adapted version, we present both the final scores of c_i, d_i, and s_i separately and their average as final score. The latter allows us to have a combined sensitivity index for each species that combines collision and displacement vulnerability and species sensitivity with equal importance. Having the individual scores for c_i, d_i, and s_i can help determine whether a species should be included in the KEC for displacement, collision risk, or both.

Details on the categorisation of each factor are provided in **Table 6** (Annex 1). For each species, the detailed scores used per factor to calculate the final sensitivity scores can be found in **Table 7** (Annex 2). Species-specific final scores can be found in **Table 5**.

Table 4 *Vulnerability and sensitivity factors according to which species sensitivity has been assessed. Factors with an asterisk are also included in Certain et al. (2015).*

Factor	Description	Factor type	Pressure type	Factor hierarchy
F_n1	Percent time spent flying*	Vulnerability	Collision	Primary
F_n2	Flight altitude within rotor swept zone*	Vulnerability	Collision	Primary
F_n3	Flight manoeuvrability*	Vulnerability	Collision	Aggravation
F_n4	Nocturnal flight activity*	Vulnerability	Collision	Aggravation
F_n5	Micro-avoidance of wind turbines	Vulnerability	Collision	Aggravation
F_n6	Offshore migration percentage	Vulnerability	Collision	Aggravation
F_n7	Displacement probability*	Vulnerability	Disturbance	Primary
F_n8	Habitat flexibility*	Vulnerability	Disturbance	Aggravation
F_n9	European Red List status*	Sensitivity	None	Primary
F_n10	Dutch conservation status (*Staat van Instandhouding*)	Sensitivity	None	Primary
F_n11	Adult survival rate*	Sensitivity	None	Aggravation
F_n12	Annual Occurrence (months in region)	Sensitivity	None	Aggravation
F_n13	Fecundity	Sensitivity	None	Aggravation

4.2 Final sensitivity score

So far, there is no information available at which final sensitivity index scores a species should be included into an assessment or not. Here, we categorised the final scores into three vulnerability levels, low, medium, and high, with intervals set to 0–0.33, 0.34–0.66, and 0.67–1, respectively. These intervals were chosen arbitrarily, corresponding to equal thirds of the possible score range. Compared to a single threshold value, using a categorisation allows us to prioritise species inclusion for the KEC assessment more easily. Here, we recommend including bird species in the KEC assessment if their final sensitivity index score ranks at medium or high, while suggesting prioritising species within the high category if e.g., time constraints in future assessments occur. Including medium scores as well can be considered precautionary. Species with a medium final score could have a high score for species sensitivity or for collision or displacement vulnerability. The population effects for these species should be investigated and analysed further within the KEC assessment. Therefore, including species with 'medium' final scores is recommended. If population effects of these species are consistently found low, the categorisation intervals suggested here should be revised.

5 Potential species to add to the current KEC list

In order to identify marine bird species to apply the modified sensitivity index to, we first reviewed the comprehensive species list for the Dutch North Sea compiled by Leopold *et al.* (2014) in consultation with marine bird experts Martin Poot and Steve Geelhoed (both Wageningen Marine Research). The comprehensive species list by Leopold *et al.* (2014) includes 515 species, of which 66 are marine and coastal birds. As applying the sensitivity scoring to all 66 species was not feasible in this assignment, the list was reduced to four species to perform sensitivity scoring on within this assignment. These steps are in accordance with the recommendations derived from the expert consultation session in July 2025 (see section 2.3).

The following four criteria with respective reasoning were used by the WMR experts to prioritise which species should be assessed and considered for addition to the list before scoring:

1. *Conservation status and vulnerability*
   Species with a declining population trend, low resilience, recognised vulnerability, or high conservation status (nationally or internationally) should be prioritised. Including these species ensures that the list reflects conservation urgency and helps identify where OWF-related pressures could exacerbate existing threats.

2. *Migration behaviour and exposure to OWF impacts*
   Species that migrate close to shore have very limited exposure to offshore wind farms. In contrast, species that migrate offshore are far more likely to encounter OWFs and should therefore be prioritised in the assessment.

3. *Proportion of the population occurring in the North Sea*
   If a significant part of a species' population is present in the North Sea, local impacts can have disproportionate consequences for its overall conservation status. These species should be prioritised.

4. *Alignment with the international protection framework*
   Species protected or considered vulnerable in neighbouring countries or states (e.g., the UK) should also be considered for inclusion in the assessment, even if they are not formally protected in the Netherlands. This ensures alignment with international conservation frameworks and avoids inconsistencies between national approaches.

The species selected for prioritisation in consultation with the two experts were Arctic tern (*Sterna paradisaea*), yellow-billed loon (*Gavia adamsii*), Manx shearwater (*Puffinus puffinus*), and little auk (*Alle alle*). The rationales to select each of the four species for sensitivity scoring can be found in section 5.1. We subsequently applied the adapted sensitivity index (see section 4) to those four marine bird species to evaluate their respective vulnerabilities to OWFs. Where available, we used information published in peer-reviewed and 'grey' literature. One marine bird expert was consulted to fill in any knowledge gaps and potentially suggest corrections in the scores.

The four bird species are presented below in decreasing order of their overall sensitivity to OWFs, based on the newly calculated sensitivity index scores (**Table 5**) with Arctic tern scoring highest at 0.81 and little auk lowest (0.47). Little auk and Manx shearwater rank in the medium sensitivity category (>0.33–0.66) according to their final scores, while Arctic tern and yellow-billed loon received a high final sensitivity score (>0.66) (**Table 5**). Individual scores for each factor are listed in **Table 7** in Annex 2. We recommend considering the inclusion of all four species in the current KEC list. If, however, not all four species can be incorporated due to constraints beyond the scope of this project (e.g., time restrictions, data availability), we suggest prioritising species in order of decreasing sensitivity scores.

Table 5 *Sensitivity scores based on collision vulnerability c_i, disturbance vulnerability d_i, and overall species sensitivity s_i are shown per species. The sum of the three scores per species and the respective average c_i d_i s_i score serving as final sensitivity score are presented. All values presented are rounded to two decimals.*

Species	**Scientific name**	**Dutch name**	c_i	d_i	s_i	**Sum of scores**	**Final score**
Artic tern	*Sterna paradisaea*	Noordse stern	0.76	0.66	1.00	2.42	0.81
Yellow-billed loon	*Gavia adamsii*	Geelsnavelduiker	0.42	1.00	0.83	2.25	0.75
Manx shearwater	*Puffinus puffinus*	Noordse pijlstormvogel	0.38	0.52	0.84	1.74	0.58
Little auk	*Alle alle*	Kleine alk	0.27	0.60	0.54	1.41	0.47

5.1 Recommended species and rationale

The four marine bird species to which the sensitivity scoring framework was applied are presented in decreasing order of their overall sensitivity to OWFs, based on the final sensitivity scores shown in Table 5. For each species, the primary risks posed by OWFs are listed, together with the advice regarding their inclusion on the KEC species list based on the final sensitivity scores. In addition, the rationale provided by the marine bird experts for selecting these four species is outlined.

Arctic tern (*Sterna paradisaea*) - marine bird

Risk(s): Displacement and collision

Rationale: Large passage fluxes through the North Sea (in spring and during late summer/autumn migration) with substantial OWF overlap (Platteeuw *et al.* 1994, Camphuysen & Winter 1996). Species received highest possible score for sensitivity and a medium high score for displacement.

Advice: add to KEC species list.

Yellow-billed loon (*Gavia adamsii*) - marine bird

Risk(s): Displacement

Rationale: Winter and spring occurrence around the Dogger Bank (incl. Dutch part), with a significant proportion of the European-wintering population estimated to use this area (van Bemmelen *et al*., 2011; Dierschke *et al.*, 2026). Abundance numbers and trends are not well known, high estimated displacement sensitivity, and high conservation concern. The species received very high displacement and sensitivity scores.

Advice: add to KEC species list.

Manx shearwater (*Puffinus puffinus*) – marine bird

Risk(s): Displacement

Rationale: Species classified as *Amber* under the Birds of Conservation Concern 5: the Red List for Birds in the UK (Stanbury *et al.*, 2021). Even though only low numbers occur during a limited time in the Dutch part of the North Sea, mainly during the pre- and post-breeding seasons (Hornman *et al.*, 2024), larger numbers can occur in coastal waters during summer storms. The species received a high sensitivity score, mainly because of their high conservation concern, and a medium displacement risk score.

Advice: add to KEC species list.

Little auk (*Alle alle*) - marine bird

Risk(s): Displacement

Rationale: Species winters in the northern North Sea and episodically reach the southern parts of the North Sea in storms, with the Dogger Bank being the limit of their southern range distribution, creating locally high densities relevant for displacement/barrier effects (Hornman *et al.*, 2021). Though collision risk for this species is low and overall sensitivity was deemed moderate, lacking information on the Dutch conservation status (*SvI*) and Dutch population trend, suggest it should be treated precautionary.

Advice: add to KEC species list.

6 Predicting distributions for potential KEC species

Within the KEC assessments on displacement and collision effects, bird distribution maps are used as input data (Soudijn *et al.*, 2024; IJntema *et al.*, 2025). These maps are based on van Donk *et al.* (2024) and use aerial survey data from the MWTL (*Monitoring Waterstaatkundige Toestand des Lands*) program that surveys the Dutch EEZ. For the upcoming KEC assessments, new distribution maps will have to be predicted based on the van Donk *et al.* (2024) methodology or by using inverse distance weighting (IDW) as described by Leopold *et al.* (2014). Therefore, an overview of the recorded observations per year in the MWTL data from 2014-2024 was consulted to provide an informed estimate whether sufficient data would be available to predict the distribution maps for the potential new KEC species within this project.

Arctic tern and common tern (*Sterna hirundo*) are not easily distinguishable in the field. Therefore, the overview presents both observations of Arctic and common terns together ('commic tern') as well as for Arctic and common tern separately. As Arctic terns use the Dutch waters predominantly during migration, it is likely that the majority of the 'commic tern' observations are common terns. However, this cannot be said without uncertainty. For the Arctic tern alone, an average of 31 observations per year between 2014 and 2024 have been reported. In the last five years, however, the average has dropped to 23.5 observations per year. The ten-year average is influenced by particularly high numbers of Arctic terns observed in 2014/2015 (n=101) and in 2021/2022 (n=70). Over the most recently available five years (2020–2024), the number of observations in 2021/2022 is exceptionally higher compared to the other years which range between four and 13 observations per year. In the van Donk maps, the most recent five years of data available are regularly used to predict the maps to account for changes in distributions or numbers over time (van Donk, 2024; van Donk *et al.*, 2024). It is not clear if the data availability for Arctic terns over the most recent five years or even the last ten years would be sufficient to predict van Donk maps. Therefore, it is suggested that the IDW method could be used to generate distribution maps. However, it should be noted that it is highly likely that there is not sufficient data available to see seasonal variation in Arctic tern distributions when using the most recently available five years. Using the full ten-year period over an even longer period might provide more information compared to using a five-year period. It remains unclear if these maps could then be used in the KEC assessments.

The yellow-billed loon is not listed in the overview consulted. Therefore, no species-specific data is available to create a distribution map following either the van Donk or IDW methodology. The yellow-billed loon is potentially included in the 'divers spec.' category of the MWTL data, which only has few observations per year. However, since there is no species-specific data available for the yellow-billed loon, no distribution maps can be generated to be used for its KEC assessment until this knowledge gap is addressed.

Manx shearwater is hardly ever recorded in the MWTL data. On average, there were 0.9 observations a year between 2014-2024 with a maximum number of observations in 2022/2023 (n=4). This can be considered too little information to create van Donk maps, even when combining ten years or more of data. This is based on the experience from van Donk *et al.* (2024) who showed an insufficient data availability for great skua (*Stercoranius skua*) to predict their maps. Instead, they created seasonal IDW maps for four 5-year periods up to 2020. As the MWTL data overview showed, great skua averaged at 14.7 observations per year between 2014–2024 and at 19 for 2016–2020, the latter being the same period van Donk *et al.* (2024) used to create their most recent IDW map for the great skua. With this amount of data, there were no seasonal patterns observable in great skua numbers or distributions (van Donk *et al.*, 2024). As Manx shearwater observations are strongly below these averages reported for great skua, it is suggested to be very difficult to obtain meaningful IDW maps for this species that could be used in KEC assessments.

Little auks are not a common species in coastal Dutch waters. They winter in the Dogger Bank area, and their occurrence in coastal Dutch waters is often linked to strong winter winds drifting them towards the southern

North Sea and Dutch waters. Their low occurrence is also represented in the MWTL data. Over the ten-year period until 2024, little auk has been recorded on average 6.8 times per year in the MWTL surveys due to relatively high numbers of observations between 2014 and 2016 (range 16–19 observations per year). In the most recent five years, however, the average is lower with 1.8 observations per year. In addition to their generally low occurrence in Dutch waters, their small body size reduces detectability and complicates species identification during aerial surveys, which further contributes to their underrepresentation in the MWTL dataset. The amount of data available is most likely insufficient to generate van Donk maps for little auk. As for Manx shearwater, generating meaningful IDW maps for little auk is suggested to be challenging due to the low data availability.

7 Discussion

This discussion interprets the findings from the expert consultation and literature review in light of our adapted, pressure-specific sensitivity index. We assess key uncertainties, including data gaps, attribution of displacement, ordinal scoring choices, and other assumptions. Also, we considered how these affected species selection. Finally, we outline practical priorities to strengthen the evidence base and provide recommendations for updating the KEC list and coordinating North Sea–wide monitoring and methods.

7.1 Migratory species

While this assignment primarily focused on marine birds and coastal birds, a review of the original species list from Leopold *et al.* (2014) highlights the importance of also considering certain migratory species that are not strictly coastal but whose migration and habitat use make them relevant for impact assessments. From the wide array of species crossing the North Sea during migration four species in particular stand out as warranting additional evaluation within the sensitivity index framework. The common snipe (*Gallinago gallinago*) is one of the most numerous wader species in Europe and, due to its cryptic behaviour and nocturnal migration, is often underreported in monitoring schemes (Eaton 2020). The Eurasian woodcock (*Scolopax rusticola*) also deserves special attention. Recent GPS tracking has shown significant migratory crossings over marine areas (Gomez *et al.*, 2025), while both ship-based and land-based surveys confirm its regular presence during migration periods (Hoodless & Heward 2019). Similarly, the pink-footed goose (*Anser brachyrhynchus*), although primarily a terrestrial grazer, has been documented flying along the north-western European flyway (including the North Sea) during migration between Arctic breeding sites and wintering grounds in northwest Europe (Wisz *et al.*, 2008). This behaviour is comparable to Bewick's swan (*Cygnus columbianus bewickii*) (IJntema *et al.,* 2025) and suggests a potential sensitivity to offshore wind development. Finally, the black-headed gull (*Chroicocephalus ridibundus*), while common and often associated with inland and coastal habitats, is known to undertake large-scale nocturnal migrations from the Netherlands to the UK, potentially exposing significant numbers to offshore infrastructure risks (Fijn *et al.,* 2022). While these species were highlighted during the expert judgement (Section 5), two of them, common snipe and black-headed gull, were previously also identified as vulnerable in an assessment of migratory species by SOVON (2024). Taken together, these cases emphasise that assessments should not be restricted solely to typical marine bird species but expanded to include migratory landbirds and waterfowl whose movement ecology brings them into contact with offshore environments.

7.2 Challenges in assessment

Several key challenges emerged during this assignment that complicate the robust assessment of marine bird vulnerability to OWFs. First, data gaps remain a critical issue, particularly for rare, cryptic, or morphologically difficult to identify species such as puffins and divers. These species are often underrepresented in monitoring programmes due to their low detectability, leading to high uncertainty in abundance estimates and risk assessments. Second, temporal variability in species presence and abundance further complicates exposure analyses. Migration pulses, seasonal moulting aggregations, and episodic storm-driven displacements can generate short-lived but ecologically significant peaks in marine bird densities that are not well captured by averaged survey data. Without accounting for such variability, the risk of misrepresenting species vulnerability to OWFs is substantial.

Expert elicitation remains essential in data-poor situations, but it is time-consuming and inevitably subjective. Where uncertainties cannot be resolved in the near term, the precautionary principle should guide decisions, ensuring that vulnerable species are not overlooked.

7.3 Limitations and uncertainty

Although the chosen factors provide a comprehensive basis for assessing marine bird vulnerability, each comes with limitations that should be noted. Flight altitude and the proportion of time flying are often derived from limited tracking or survey data, which may not capture seasonal or weather-driven variability, and often deals with season- and/or colony-biased. Flight manoeuvrability and nocturnal activity are difficult to quantify and therefore often rely on subjective or sparse information. Micro-avoidance of turbines is poorly understood, with current estimates largely based on assumptions rather than empirical evidence. Offshore migration percentages might not be representative for the population as a whole when based on small or region-specific tracking datasets. Displacement probability and habitat flexibility are strongly context-dependent, likely varying with prey availability, turbine density, and behavioural plasticity, yet typically reduced to a single score. Moreover, with current information available it is almost impossible to disentangle displacement caused by the turbines themselves from displacement caused by associated activities such as increased ship or helicopter traffic. Conservation status indicators, such as the European Red List and the Dutch conservation status, are valuable but updated infrequently and may not fully reflect short-term regional trends or the mobility of marine bird populations in a timely manner. Demographic factors such as adult survival and fecundity can come with considerable uncertainty, particularly for less-studied species. The categorisation applied to the factor of annual occurrence expressed in months may obscure short, but ecologically significant, peaks during migration or moulting.

A further limitation lies in the scoring system itself. Assigning final categorising levels such as low, medium, or high sensitivity is inherently subjective, as there is no reference available for where one category ends and another begins. These divisions are often based on what seems most logical rather than on objective, universally accepted criteria. While this approach provides a workable framework, it inevitably introduces subjectivity into the individual factor scores, especially when expert judgement is used, and consequently into the final sensitivity index score. However, as long as the scoring for multiple species is done following the steps described here, it still allows for prioritisation of species to be included in an assessment. Subjectivity or bias introduced by expert judgement can be reduced by following the process of expert elicitation. However, here we suggested the consultation of at least two marine bird experts (see section 4.1) to reduce expert-bias. We consider this a more realistic approach when aiming to score multiple data-limited species.
It should be noted, however, that the sensitivity scores presented here cannot be directly compared to scores from other studies, unless they use the same approach. At present, there is no straightforward way to fully standardise this scoring process.

Uncertainty is therefore an unavoidable but critical part of assessing marine bird sensitivity to OWFs. Many factors contribute to it, including seasonality (e.g., species only present in Dutch waters during migration or moulting periods), variation in flight height (important for estimating collision risk), or whether an OWF is located close to breeding sites, where even small disturbances could have large population effects (Peschko *et al.*, 2020b; Garthe *et al.*, 2023). In North American approaches (Adams *et al.*, 2017; Kelsey *et al.*, 2018), uncertainty is handled quantitatively by assigning each metric a level of low, medium, or high uncertainty based on data quality and reliability, which is then converted into 'uncertainty scalers' to generate lower and upper bounds around the best estimate. This results in a distribution or range of possible values for key indices, such as collision and displacement vulnerability, rather than a single fixed score, and allows identification of which species' scores are most sensitive to uncertainty. Earlier European approaches, such as the SSI (Garthe & Hüppop, 2004) and SeaMaST (Bradbury *et al.*, 2014), recognised uncertainty through expert review and sensitivity checks, but did not include a quantitative scaling method.
We consider the quantitative approach very important and recommend that it be implemented in future assessments. However, such an approach is only feasible if uncertainty values for the underlying factors are assessed beforehand. In practice, most frameworks currently use broad classes of low, medium, or high uncertainty, primarily to prioritise where further data collection is needed. Even if relative vulnerability is expressed as a percentage or probability distribution, the policy challenge of deciding where to set the cut-off value for inclusion on the KEC list remains. In other words, whether a score of 0.6 (or 60%) is high enough to justify inclusion will always involve a management decision informed by ecological reasoning, conservation priorities, and precautionary principles, rather than a purely objective threshold.
Taken together, these limitations underline the need for careful treatment of uncertainty, regular updates of factor scores, and a precautionary approach in cases where empirical data remain scarce.

7.4 Knowledge gaps

For the four candidate species, the largest uncertainties sit in factor scores that relied heavily on expert judgement: F_n4 (nocturnal flight activity), F_n5 (micro-avoidance in the rotor-swept zone), F_n10 (Dutch conservation status (*Staat van Instandhouding*) for several species incomplete), and F_n12 (annual occurrence in the Dutch EEZ). Data scarcity is acute for yellow-billed loon, Manx shearwater and little auk, yielding too few observations to build robust distribution maps or to parameterise displacement probability. Most information available relates to the breeding season, while these species mainly use Dutch waters during non-breeding season. Seasonal dynamics across the North Sea (migration pulses, storm-driven incursions) remain poorly understood. Colony-linked information, especially for Manx shearwater, is limited by the practical difficulty of tagging and coordinating colony work. Finally, and likely one of the most challenging, yet important, knowledge gaps is that observed displacement probability around OWFs cannot currently be attributed purely to the turbines themselves. OWFs are collocated with intense operational traffic (crew transfer and service vessels, helicopters, etc.), and wider shipping routes may be re-routed or intensify after construction. Because turbine presence, vessel/helicopter activity, noise, and visibility co-vary in space and time and pre-construction baselines are often sparse, standard at-sea surveys cannot separate these correlated drivers. Most datasets also lack synchronous, high-resolution AIS/flight tracks, noise metrics, or bird movement data, making causal inference (turbine vs. traffic vs both) impossible.

7.5 Recommendations

There are multiple approaches to address the identified knowledge gaps. First, a prioritisation of targeted survey effort in the Dutch EEZ during key seasons (wintering and migration) would help to improve sample sizes and seasonal coverage and therefore address the lack of knowledge for some species while in Dutch waters.

Second, advances in tracking (e.g., GPS/GLS/accelerometers) studies via international collaboration with source colonies and deployment of nocturnal/radar/thermal methods and turbine-proximate sensors (e.g., 3D radar/LiDAR) to better estimate and understand micro-avoidance. Tagging of focal species while using radar/thermal/altimetric sensors to quantify flight paths and micro-avoidance would further address the some of the knowledge gaps mentioned above. Furthermore, to disentangle the different causes of displacement probability, bird surveys could be paired with fine-scale AIS and helicopter tracks plus noise/visual-disturbance metrics. In addition, exploring natural experiments (curtailment or route changes), and analysis using hierarchical Bayesian models that separate turbine proximity, traffic, noise and weather (with interactions) would be useful to disentangle potential disturbance sources and allow to assess their effects separately in the future. Lastly, updating the Dutch conservation status inputs and annual-occurrence metadata as new data arrive and running a formal sensitivity/uncertainty analysis on factor values and score aggregation would help better understand the adapted sensitivity score presented here.

As next steps, we recommend (i) applying the revised scoring to species already on the KEC list to ensure consistency in species selection for KEC assessments and potentially revising the final score categorisation intervals, (ii) screening migratory bird species likely to be highly exposed but not classified as ‘marine or coastal birds’ and therefore not included in this assignment (see section 7.1), and (iii) adopting a precautionary approach, to be replaced with species-specific sensitivity scores once improved data are available.

8 Conclusions

We developed an adapted sensitivity index scoring for the Netherlands that uses a structured, pressure-specific framework (separating collision and displacement) while also including species-specific overall sensitivity. The method is readily transferable to other North Sea countries by replacing the Dutch conservation status factor with the respective national equivalent and updating factor scores such as annual occurrence while keeping the rest of the framework unchanged. It is also possible to apply this index to a larger scale such as the North Sea. Where data are limited, expert judgement can fill gaps but may introduce bias. This can be reduced through a thorough expert elicitation process or, where not feasible, the involvement of at least two experts. Knowledge gaps can be addressed by targeted data collection (e.g., surveys, tracking, coordinated colony work). Updated regularly with newly available information, e.g., in between KEC assessments, this index provides a transparent, reproducible basis for revising the KEC species list and supports precautionary decisions, cross-border consistency, and a baseline for sustainable marine spatial planning.

9 Quality assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. The organisation has been certified since 27 February 2001. The certification was issued by DNV.

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Justification

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The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

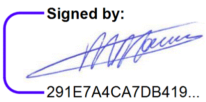
Approved: ir. S.C.V. Geelhoed
Researcher

Signature:

Date: 16 March 2026

Approved: Dr. A.M. Mouissie, PhD
Business Manager Projects

Signature:



Date: 16 March 2026

Annex 1 Sensitivity scoring details

Table 6 *Factors used for sensitivity scoring divided by their corresponding pressure types (collision, displacement), and species sensitivity. All factors (F_n1-13) were scored on a scale from 1-5, following the categorisation provided for each factor. In some cases, only 1, 3, and 5 were used (e.g. for conservation status) to allow for a qualitative scoring of data-limited factors. Only integer values were used when scoring these factors. Additional information such as studies on which a categorisation was based and additional information on a factor is provided in the comments.*

Factor	Type	Description	Categorisation	Comments
F_n1	Collision	Percent time spent flying	1 = 0–20% 2 = 21–40% 3 = 41–60% 4 = 61–80% 5 = 81–100%	Following Garthe & Hüppop (2004).
F_n2	Collision	Flight altitude within RSZ	1 = Relatively little to no time spent inside RSZ 3 = Moderate time spent in RSZ 5 = Relatively much time spent at RSZ	Reflects current and planned rotor swept zone (RSZ) range of 19–305m. Based on the scenario of built and planned OWFs in Dutch waters until 2031.
F_n3	Collision	Flight manoeuvrability	1 = (Very) High 3 = Moderate 5 = (Very) Low	Adapted from Garthe & Hüppop (2004).
F_n4	Collision	Nocturnal flight activity	1 = (Very) Low 3 = Moderate 5 = (Very) High	Adapted from Garthe & Hüppop (2004).
F_n5	Collision	Micro-avoidance of turbines	1 = (Very) High 3 = Moderate 5 = (Very) Low	Here, micro-avoidance refers to the last-minute avoidance of the turbine and its rotor blades. Where data is lacking, micro-avoidance can be inferred from e.g., standard collision risk modelling approaches.

Fₙ6	Collision	Offshore migration percentage	1 = Very Low 2 = Low 3 = Moderate 4 = High 5 = Very high	Proportion of time spent offshore during migration.
Fₙ7	Displacement	Displacement probability	1 = Little to no avoidance or displacement; reduction in abundance: 0–10% 2 = Weak avoidance or displacement; reduction in abundance: >10–30% 3 = Moderate avoidance or displacement; reduction in abundance: >30–60% 4 = High avoidance or displacement; reduction in abundance: >60–90% 5 = Very high avoidance or displacement; reduction in abundance: >90%	Displacement probability inferred from e.g., BACI-analyses quantifying the reduction of bird abundance inside and outside OWF areas, as well as before and after OWF construction. Factor likely also includes effects from sensitivity to disturbances from e.g., the turbines, vessel or aircraft traffic related to OWFs.
Fₙ8	Displacement	Habitat flexibility	1 = Highly flexible; generalist use of habitats 2 = Flexible 3 = Moderately flexible 4 = Specialised 5 = Very specialised; dependent on narrow range of habitat features	Adapted from Garthe & Hüppop (2004).
Fₙ9	Sensitivity	European Red List status	1 = Least Concern / Near Threatened 3 = Vulnerable 5 = Endangered / Critically Endangered	
Fₙ10	Sensitivity	Dutch conservation status (*Staat van Instandhouding*)	1 = Favourable (*gunstig*) 3 = Unfavourable / inadequate (*matig ongunstig*) 5 = Unfavourable / bad (*zeer ongunstig*)	

F_n11	Sensitivity	Adult survival rate	1 = ≤0.75 2 = >0.75–0.80 3 = >0.80–0.85 4 = >0.85–0.90 5 = >0.90	Following Garthe & Hüppop (2004.)
F_n12	Sensitivity	Annual occurrence	1 = <1 month 2 = 1–3 months 3 = >3–6 months 4 = >6–11 months 5 = >11 months to year-round	Number of months a species is present in the area of interest (here: Dutch EEZ).
F_n13	Sensitivity	Fecundity	1 = (Very) High; relatively large clutch sizes, frequent replacement, relatively high chick survival 3 = Moderate 5 = (Very) Low; relatively small clutch sizes, low replacement, relatively low chick survival	

Annex 2 Individual scores per species

Table 7 *Individual scores for all factors (F_n1–13) per species. Factors were originally scored between 1 and 5 before scaling them to values between 0.2 and 1 as described in Certain et al. (2015). For factor descriptions, see Table 6. Highlighted in blue are the species for which no Dutch conservation status (F_n10) information was available. Values presented as x/y indicate the literature-derived value before the slash and the expert-judgement value after the slash. Scores based on expert judgement are indicated in bold. If for any factor no information was found in the literature, this is indicated with a question mark. A list of all sources used to obtain scores are listed in Annex 3.*

Factor	Yellow-billed loon	Artic tern	Manx shearwater	Little auk	Source(s)
F_n1	3/**1**	5	2/**3**	1	14, 10
F_n2	1/**3**	1/**3**	1	**1**	10, 14, 18
F_n3	5	1	3	3/**5**	10, 12, 14, 18
F_n4	1	1	3/**1**	1	14
F_n5	?/**5**	?/**3**	?/**5**	?/**5**	-
F_n6	5	5	5	5	15, 19
F_n7	5	2	2	2	10, 14, 21, 13
F_n8	5	3	1	2	14, 10, 18
F_n9	3	1	1	1	1, 2, 3, 4, 5
F_n10	?	5	3	?	11, 22, 23, 24, 25
F_n11	5	4	5	4	14, 17, 20
F_n12	?/**3**	3	3	3	22, 23, 24, 25
F_n13	?/**5**	5	5	5	6, 7, 8, 9, 16

Annex 3 References used for factor scoring

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Annex 4 Original species list by Leopold *et al.* (2014)

Table 8 *Species selection by Leopold et al. (2014; Annex D of the report) to determine cumulative effects of multiple offshore wind farms in the southern part of the North Sea (515 species in no specific order).*

Species	Scientific name
Red-throated Loon	*Gavia stellata*
Black-throated Loon	*Gavia arctica*
Great Northern Loon	*Gavia immer*
Yellow-billed Loon	*Gavia adamsii*
Northern Fulmar	*Fulmarus glacialis*
Soft-plumaged Petrel	*Pterodroma*
Cory's Shearwater	*Calonectris borealis*
Great Shearwater	*Puffinus gravis*
Sooty Shearwater	*Puffinus griseus*
Manx Shearwater	*Puffinus puffinus*
Balearic Shearwater	*Puffinus mauretanicus*
Little Shearwater	*Puffinus assimilis*
Wilson's Storm Petrel	*Oceanites oceanicus*
White-faced Storm Petrel	*Pelagodroma marina*
European Storm Petrel	*Hydrobates pelagicus*
Leach's Storm Petrel	*Oceanodroma leucorhoa*
Northern Gannet	*Morus bassanus*
Pomarine Skua	*Stercorarius pomarinus*
Parasitic Jaeger	*Stercorarius parasiticus*
Long-tailed Jaeger	*Stercorarius longicaudus*
Great Skua	*Stercorarius skua*
Ivory Gull	*Pagophila eburnea*
Sabine's Gull	*Xema sabini*
Black-legged Kittiwake	*Rissa tridactyla*
Sooty Tern	*Onychoprion fuscatus*
Bridled Tern	*Onychoprion anaethetus*
Little Tern	*Sternula albifrons*
Gull-billed Tern	*Gelochelidon nilotica*
Caspian Tern	*Hydroprogne caspia*
Whiskered Tern	*Chlidonias hybrida*
Black Tern	*Chlidonias niger*
White-winged Tern	*Chlidonias leucopterus*
Sandwich Tern	*Thalasseus sandvicensis*
Cabot's Tern	*Sterna acuflavida*
Forster's Tern	*Sterna forsteri*
Common Tern	*Sterna Hirundo*
Roseate Tern	*Sterna dougallii*
Arctic Tern	*Sterna paradisaea*
Common Murre	*Uria aalge*
Thick-billed Murre	*Uria lomvia*
Razorbill	*Alca torda*
Black Guillemot	*Cepphus grylle*
Little Auk	*Alle alle*
Atlantic Puffin	*Fratercula arctica*
Eurasian Oystercatcher	*Haematopus ostralegus*
Black-winged Stilt	*Himantopus himantopus*
Pied Avocet	*Recurvirostra avosetta*
Eurasian Stone-curlew	*Burhinus oedicnemus*
Cream-colored Courser	*Cursorius cursor*
Collared Pratincole	*Glareola pratincola*
Oriental Pratincole	*Glareola maldivarum*
Black-winged Pratincole	*Glareola nordmanni*
Little Ringed Plover	*Charadrius dubius*
Common Ringed Plover	*Charadrius hiaticula*
Killdeer	*Charadrius vociferus*
Kentish Plover	*Charadrius alexandrinus*
Greater Sand Plover	*Charadrius leschenaultii*
Caspian Plover	*Charadrius asiaticus*
Eurasian Dotterel	*Charadrius morinellus*
American Golden Plover	*Pluvialis dominica*
Pacific Golden Plover	*Pluvialis fulva*
European Golden Plover	*Pluvialis apricaria*
Grey Plover	*Pluvialis squatarola*
Sociable Lapwing	*Vanellus gregarius*
White-tailed Lapwing	*Vanellus leucurus*
Northern Lapwing	*Vanellus vanellus*
Great Knot	*Calidris tenuirostris*
Red Knot	*Calidris canutus*
Sanderling	*Calidris alba*
Semipalmated Sandpiper	*Calidris pusilla*
Red-necked Stint	*Calidris ruficollis*
Little Stint	*Calidris minuta*
Temminck's Stint	*Calidris temminckii*

Long-toed Stint	*Calidris subminuta*	Tundra Swan	*Cygnus columbianus columbianus*
White-rumped Sandpiper	*Calidris fuscicollis*	Bewick's Swan	*Cygnus columbianus bewickii*
Baird's Sandpiper	*Calidris bairdii*	Whooper Swan	*Cygnus cygnus*
Pectoral Sandpiper	*Calidris melanotos*	Snow Goose	*Anser caerulescens*
Sharp-tailed Sandpiper	*Calidris acuminata*	Ross's Goose	*Anser rossii*
Curlew Sandpiper	*Calidris ferruginea*	Taiga Bean Goose	*Anser fabalis*
Stilt Sandpiper	*Calidris himantopus*	Tundra Bean Goose	*Anser serrirostris*
Purple Sandpiper	*Calidris maritima*	Pink-footed Goose	*Anser brachyrhynchus*
Dunlin	*Calidris alpina*	Greylag Goose	*Anser anser*
Broad-billed Sandpiper	*Limicola falcinellus*	Lesser White-fronted Goose	*Anser erythropus*
Buff-breasted Sandpiper	*Tryngites subruficollis*	Greater White-fronted Goose	*Anser albifrons*
Ruff	*Philomachus pugnax*	Cackling Goose	*Branta hutchinsii*
Jack Snipe	*Lymnocryptes minimus*	Canada Goose	*Branta canadensis*
Common Snipe	*Gallinago gallinago*	Barnacle Goose	*Branta leucopsis*
Great Snipe	*Gallinago media*	Red-breasted Goose	*Branta ruficollis*
Long-billed Dowitcher	*Limnodromus scolopaceus*	Pale-bellied Brant Goose	*Branta hrota*
Eurasian Woodcock	*Scolopax rusticola*	Brant Goose	*Branta bernicla*
Black-tailed Godwit	*Limosa limosa*	Black Brant	*Branta nigricans*
Bar-tailed Godwit	*Limosa lapponica*	Ruddy Shelduck	*Tadorna ferruginea*
Whimbrel	*Numenius phaeopus*	Common Shelduck	*Tadorna tadorna*
Slender-billed Curlew	*Numenius tenuirostris*	Red-crested Pochard	*Netta rufina*
Eurasian Curlew	*Numenius arquata*	Common Pochard	*Aythya ferina*
Upland Sandpiper	*Bartramia longicauda*	Ferruginous Duck	*Aythya nyroca*
Terek Sandpiper	*Xenus cinereus*	Ring-necked Duck	*Aythya collaris*
Common Sandpiper	*Actitis hypoleucos*	Tufted Duck	*Aythya fuligula*
Spotted Sandpiper	*Actitis macularius*	Greater Scaup	*Aythya marila*
Green Sandpiper	*Tringa ochropus*	Lesser Scaup	*Aythya affinis*
Solitary Sandpiper	*Tringa solitaria*	White-headed Duck	*Oxyura leucocephala*
Grey-tailed Tattler	*Tringa brevipes*	Steller's Eider	*Polysticta stelleri*
Spotted Redshank	*Tringa erythropus*	King Eider	*Somateria spectabilis*
Greater Yellowlegs	*Tringa melanoleuca*	Common Eider	*Somateria mollissima*
Common Greenshank	*Tringa nebularia*	Harlequin Duck	*Histrionicus histrionicus*
Lesser Yellowlegs	*Tringa flavipes*	Common Scoter	*Melanitta nigra*
Marsh Sandpiper	*Tringa stagnatilis*	Black Scoter	*Melanitta americana*
Wood Sandpiper	*Tringa glareola*	Surf Scoter	*Melanitta perspicillata*
Common Redshank	*Tringa totanus*	Velvet Scoter	*Melanitta fusca*
Ruddy Turnstone	*Arenaria interpres*	Long-tailed Duck	*Clangula hyemalis*
Wilson's Phalarope	*Phalaropus tricolor*	Smew	*Mergellus albellus*
Red-necked Phalarope	*Phalaropus lobatus*	Bufflehead	*Bucephala albeola*
Red Phalarope	*Phalaropus fulicaria*	Common Goldeneye	*Bucephala clangula*
Great White Pelican	*Pelecanus onocrotalus*	Hooded Merganser	*Lophodytes cucullatus*
Dalmatian Pelican	*Pelecanus crispus*	Common Merganser	*Mergus merganser*
Black Stork	*Ciconia nigra*	Red-breasted Merganser	*Mergus serrator*
White Stork	*Ciconia ciconia*	Gadwall	*Anas strepera*
Greater Flamingo	*Phoenicopterus roseus*	Falcated Duck	*Anas falcata*
Mute Swan	*Cygnus olor*	Eurasian Wigeon	*Anas penelope*

American Wigeon	*Anas americana*	Iceland Gull	*Larus glaucoides*
Blue-winged Teal	*Anas discors*	Glaucous Gull	*Larus hyperboreus*
Northern Shoveler	*Anas clypeata*	Great Black-backed Gull	*Larus marinus*
Mallard	*Anas platyrhynchos*	Eurasian Bittern	*Botaurus stellaris*
Northern Pintail	*Anas acuta*	Little Bittern	*Ixobrychus minutus*
Garganey	*Anas querquedula*	Black-crowned Night Heron	*Nycticorax nycticorax*
Baikal Teal	*Anas formosa*	Green Heron	*Butorides virescens*
Eurasian Teal	*Anas crecca*	Squacco Heron	*Ardeola ralloides*
Green-winged Teal	*Anas carolinensis*	Western Cattle Egret	*Bubulcus ibis*
Marbled Duck	*Marmaronetta angustirostris*	Little Egret	*Egretta garzetta*
Pied-billed Grebe	*Podilymbus podiceps*	Great Egret	*Ardea alba*
Little Grebe	*Tachybaptus ruficollis*	Grey Heron	*Ardea cinerea*
Great Crested Grebe	*Podiceps cristatus*	Purple Heron	*Ardea purpurea*
Red-necked Grebe	*Podiceps grisegena*	Glossy Ibis	*Plegadis falcinellus*
Horned Grebe	*Podiceps auritus*	Eurasian Spoonbill	*Platalea leucorodia*
Black-necked Grebe	*Podiceps nigricollis*	Black Grouse	*Lyrurus tetrix*
Water Rail	*Rallus aquaticus*	Grey Partridge	*Perdix perdix*
Spotted Crake	*Porzana porzana*	Common Quail	*Coturnix coturnix*
Little Crake	*Porzana parva*	Brown Shrike	*Lanius cristatus*
Baillon's Crake	*Porzana pusilla*	Red-backed Shrike	*Lanius collurio*
Common Moorhen	*Gallinula chloropus*	Red-tailed Shrike	*Lanius phoenicuroides*
Eurasian Coot	*Fulica atra*	Isabelline Shrike	*Lanius isabellinus*
Common Crane	*Grus grus*	Long-tailed Shrike	*Lanius schach*
Sandhill Crane	*Grus canadensis*	Lesser Grey Shrike	*Lanius minor*
Demoiselle Crane	*Grus virgo*	Great Grey Shrike	*Lanius excubitor*
Common Kingfisher	*Alcedo atthis*	Steppe Grey Shrike	*Lanius lahtora pallidirostris*
Belted Kingfisher	*Megaceryle alcyon*	Woodchat Shrike	*Lanius senator*
Pygmy Cormorant	*Phalacrocorax pygmeus*	Eurasian Magpie	*Pica pica*
Great Cormorant	*Phalacrocorax carbo*	Eurasian jay	*Garrulus glandarius*
European Shag	*Phalacrocorax aristotelis*	Northern nutcracker	*Nucifraga caryocatactes*
Slender-billed Gull	*Chroicocephalus genei*	Western jackdaw	*Coloeus monedula*
Bonaparte's Gull	*Chroicocephalus philadelphia*	Daurian jackdaw	*Corvus dauuricus*
Black-headed Gull	*Chroicocephalus ridibundus*	House crow	*Corvus splendens*
Little Gull	*Hydrocoloeus minutus*	Rook	*Corvus frugilegus*
Ross's Gull	*Rhodostethia rosea*	Carrion crow	*Corvus corone*
Laughing Gull	*Larus atricilla*	Hooded crow	*Corvus cornix*
Franklin's Gull	*Larus pipixcan*	Common raven	*Corvus corax*
Mediterranean Gull	*Ichthyaetus melanocephalus*	Goldcrest	*Regulus regulus*
Audouin's Gull	*Larus audouinii*	Common firecrest	*Regulus ignicapilla*
Pallas's Gull	*Larus ichthyaetus*	Eurasian penduline tit	*Remiz pendulinus*
Mew Gull	*Larus canus*	Azure tit	*Cyanistes cyanus*
Ring-billed Gull	*Larus delawarensis*	Eurasian blue tit	*Cyanistes caeruleus*
Lesser Black-backed Gull	*Larus fuscus*	Great tit	*Parus major*
European Herring Gull	*Larus argentatus*	Crested tit	*Lophophanes cristatus*
Yellow-legged Gull	*Larus michahellis*	Coal tit	*Periparus ater*
Caspian Gull	*Larus cachinnans*	Willow tit	*Poecile montanus*

Marsh tit	*Poecile palustris*	Lanceolated Warbler	*Locustella lanceolata*
Bearded reedling	*Panurus biarmicus*	Common Grasshopper Warbler	*Locustella naevia*
Calandra lark	*Melanocorypha calandra*	River Warbler	*Locustella fluviatilis*
Greater short-toed lark	*Calandrella brachydactyla*	Savi's Warbler	*Locustella luscinioides*
Crested lark	*Galerida cristata*	Icterine Warbler	*Hippolais icterina*
Woodlark	*Lullula arborea*	Melodious Warbler	*Hippolais polyglotta*
Eurasian skylark	*Alauda arvensis*	Booted Warbler	*Iduna caligata*
Horned lark	*Eremophila alpestris*	Sykes's Warbler	*Iduna rama*
Sand martin	*Riparia riparia*	Paddyfield Warbler	*Acrocephalus agricola*
Eurasian crag martin	*Ptyonoprogne rupestris*	Blyth's Reed Warbler	*Acrocephalus dumetorum*
Barn swallow	*Hirundo rustica*	Marsh Warbler	*Acrocephalus palustris*
Western house martin	*Delichon urbicum*	Eurasian Reed Warbler	*Acrocephalus scirpaceus*
European red-rumped swallow	*Cecropis daurica*	Sedge Warbler	*Acrocephalus schoenobaenus*
Cetti's warbler	*Cettia cetti*	Aquatic Warbler	*Acrocephalus paludicola*
Long-tailed tit	*Aegithalos caudatus*	Great Reed Warbler	*Acrocephalus arundinaceus*
Eastern crowned warbler	*Phylloscopus coronatus*	Zitting Cisticola	*Cisticola juncidis*
Two-barred warbler	*Phylloscopus plumbeitarsus*	Bohemian Waxwing	*Bombycilla garrulus*
Greenish warbler	*Phylloscopus trochiloides*	Wallcreeper	*Tichodroma muraria*
Arctic warbler	*Phylloscopus borealis*	Eurasian Nuthatch	*Sitta europaea*
Pallas's leaf warbler	*Phylloscopus proregulus*	Eurasian Treecreeper	*Certhia familiaris*
Yellow-browed warbler	*Phylloscopus inornatus*	Short-toed Treecreeper	*Certhia brachydactyla*
Hume's leaf warbler	*Phylloscopus humei*	Eurasian Wren	*Troglodytes troglodyte*
Radde's warbler	*Phylloscopus schwarzi*	Northern Mockingbird	*Mimus polyglottos*
Dusky warbler	*Phylloscopus fuscatus*	Common Starling	*Sturnus vulgaris*
Western Bonelli's warbler	*Phylloscopus bonelli*	Rosy Starling	*Pastor roseus*
Eastern Bonelli's warbler	*Phylloscopus orientalis*	Daurian Starling	*Agropsar sturninus*
Wood Warbler	*Phylloscopus sibilatrix*	White-throated Dipper	*Cinclus cinclus*
Common Chiffchaff	*Phylloscopus collybita*	White's Thrush	*Zoothera aurea*
Siberian Chiffchaff	*Phylloscopus tristis*	Siberian Thrush	*Geokichla sibirica*
Iberian Chiffchaff	*Phylloscopus ibericus*	Ring Ouzel	*Turdus torquatus*
Willow Warbler	*Phylloscopus trochilus*	Common Blackbird	*Turdus merula*
Dartford Warbler	*Sylvia undata*	Eyebrowed Thrush	*Turdus obscurus*
Spectacled Warbler	*Sylvia conspicillata*	Dusky Thrush	*Turdus eunomus*
Moltoni's Warbler	*Sylvia subalpina*	Black-throated Thrush	*Turdus atrogularis*
Western Subalpine Warbler	*Sylvia inornata*	Fieldfare	*Turdus pilaris*
Eastern Subalpine Warbler	*Sylvia cantillans*	Song Thrush	*Turdus philomelos*
Sardinian Warbler	*Sylvia melanocephala*	Redwing	*Turdus iliacus*
Asian Desert Warbler	*Sylvia nana*	Mistle Thrush	*Turdus viscivorus*
Western Orphean Warbler	*Sylvia hortensis*	American Robin	*Turdus migratorius*
Barred Warbler	*Sylvia nisoria*	Rufous-tailed Scrub Robin	*Cercotrichas galactotes*
Hume's Whitethroat	*Sylvia althaea*	Spotted Flycatcher	*Muscicapa striata*
Lesser Whitethroat	*Sylvia curruca*	European Robin	*Erithacus rubecula*
Common Whitethroat	*Sylvia communis*	Thrush Nightingale	*Luscinia luscinia*
Garden Warbler	*Sylvia borin*	Common Nightingale	*Luscinia megarhynchos*
Eurasian Blackcap	*Sylvia atricapilla*	Bluethroat	*Luscinia svecica*
Pallas's Grasshopper Warbler	*Locustella certhiola*	Red-flanked Bluetail	*Tarsiger cyanurus*

White-throated Robin	*Irania gutturalis*	Common Linnet	*Linaria cannabina*
Black Redstart	*Phoenicurus ochruros*	Twite	*Linaria flavirostris*
Common Redstart	*Phoenicurus phoenicurus*	Lesser Redpoll	*Acanthis cabaret*
Whinchat	*Saxicola rubetra*	Common Redpoll	*Acanthis flammea*
European Stonechat	*Saxicola rubicola*	Arctic Redpoll	*Acanthis hornemanni*
Siberian Stonechat	*Saxicola maurus*	Two-barred Crossbill	*Loxia leucoptera*
Stejneger's Stonechat	*Saxicola stejnegeri*	Red Crossbill	*Loxia curvirostra*
Isabelline Wheatear	*Oenanthe isabellina*	Parrot Crossbill	*Loxia pytyopsittacus*
Northern Wheatear	*Oenanthe oenanthe*	Trumpeter Finch	*Bucanetes githagineus*
Pied Wheatear	*Oenanthe pleschanka*	Common Rosefinch	*Carpodacus erythrinus*
Eastern Black-eared Wheatear	*Oenanthe melanoleuca*	Pine Grosbeak	*Pinicola enucleator*
Western Black-eared Wheatear	*Oenanthe hispanica*	Eurasian Bullfinch	*Pyrrhula pyrrhula*
Desert Wheatear	*Oenanthe deserti*	Hawfinch	*Coccothraustes coccothraustes*
Common Rock Thrush	*Monticola saxatilis*	Snow Bunting	*Plectrophenax nivalis*
Blue Rock Thrush	*Monticola solitarius*	Lapland Longspur	*Calcarius lapponicus*
Red-breasted Flycatcher	*Ficedula parva*	Indigo Bunting	*Passerina cyanea*
Collared Flycatcher	*Ficedula albicollis*	Song Sparrow	*Melospiza melodia*
European Pied Flycatcher	*Ficedula hypoleuca*	White-crowned Sparrow	*Zonotrichia leucophrys*
Dunnock	*Prunella modularis*	White-throated Sparrow	*Zonotrichia albicollis*
Alpine Accentor	*Prunella collaris*	Dark-eyed Junco	*Junco hyemalis*
House Sparrow	*Passer domesticus*	Black-faced Bunting	*Emberiza spodocephala*
Spanish Sparrow	*Passer hispaniolensis*	Pine Bunting	*Emberiza leucocephalos*
Eurasian Tree Sparrow	*Passer montanus*	Yellowhammer	*Emberiza citrinella*
Yellow Wagtail	*Motacilla flavaissima*	Cirl Bunting	*Emberiza cirlus*
Western Yellow Wagtail	*Motacilla flava*	Rock Bunting	*Emberiza cia*
Grey-headed Wagtail	*Motacilla thunbergi*	Ortolan Bunting	*Emberiza hortulana*
White-throated Wagtail	*Motacilla cinereocapilla*	Cretzschmar's Bunting	*Emberiza caesia*
Citrine Wagtail	*Motacilla citreola*	Grey-necked Bunting	*Emberiza buchanani*
Grey Wagtail	*Motacilla cinerea*	Yellow-browed Bunting	*Emberiza chrysophrys*
White Wagtail	*Motacilla alba*	Rustic Bunting	*Emberiza rustica*
Pied Wagtail	*Motacilla yarrellii*	Little Bunting	*Emberiza pusilla*
Richard's Pipit	*Anthus richardi*	Chestnut Bunting	*Emberiza rutila*
Blyth's Pipit	*Anthus godlewskii*	Yellow-breasted Bunting	*Emberiza aureola*
Tawny Pipit	*Anthus campestris*	Common Reed Bunting	*Emberiza schoeniclus*
Olive-backed Pipit	*Anthus hodgsoni*	Red-headed Bunting	*Emberiza bruniceps*
Tree Pipit	*Anthus trivialis*	Black-headed Bunting	*Emberiza melanocephala*
Meadow Pipit	*Anthus pratensis*	Corn Bunting	*Emberiza calandra*
Red-throated Pipit	*Anthus cervinus*	Common Grackle	*Quiscalus quiscula*
Eurasian Rock Pipit	*Anthus petrosus*	Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*
Water Pipit	*Anthus spinoletta*	Baltimore Oriole	*Icterus galbula*
Common Chaffinch	*Fringilla coelebs*	Northern Waterthrush	*Parkesia noveboracensis*
Brambling	*Fringilla montifringilla*	Myrtle Warbler	*Setophaga coronata*
European Serin	*Serinus serinus*	European Honey Buzzard	*Pernis apivorus*
European Greenfinch	*Chloris chloris*	Black-winged Kite	*Elanus caeruleus*
European Goldfinch	*Carduelis carduelis*	Black Kite	*Milvus migrans*
Eurasian Siskin	*Spinus spinus*	Red Kite	*Milvus milvus*

White-tailed Eagle	*Haliaeetus albicilla*
Egyptian Vulture	*Neophron percnopterus*
Griffon Vulture	*Gyps fulvus*
Cinereous Vulture	*Aegypius monachus*
Short-toed Snake Eagle	*Circaetus gallicus*
Western Marsh Harrier	*Circus aeruginosus*
Hen Harrier	*Circus cyaneus*
Pallid Harrier	*Circus macrourus*
Montagu's Harrier	*Circus pygargus*
Northern Goshawk	*Accipiter gentilis*
Eurasian Sparrowhawk	*Accipiter nisus*
Common Buzzard	*Buteo buteo*
Long-legged Buzzard	*Buteo rufinus*
Rough-legged Buzzard	*Buteo lagopus*
Greater Spotted Eagle	*Aquila clanga*
Lesser Spotted Eagle	*Aquila pomarina*
Booted Eagle	*Aquila pennata*
Golden Eagle	*Aquila chrysaetos*
Bonelli's Eagle	*Aquila fasciata*
Steppe Eagle	*Aquila nipalensis*
Eastern Imperial Eagle	*Aquila heliaca*
Spanish Imperial Eagle	*Aquila adalberti*
Western Osprey	*Pandion haliaetus*
Lesser Kestrel	*Falco naumanni*
Common Kestrel	*Falco tinnunculus*
American Kestrel	*Falco sparverius*
Red-footed Falcon	*Falco vespertinus*
Merlin	*Falco columbarius*
Eurasian Hobby	*Falco subbuteo*
Eleonora's Falcon	*Falco eleonorae*
Gyrfalcon	*Falco rusticolus*
Peregrine Falcon	*Falco peregrinus*
Corn Crake	*Crex crex*
Little Bustard	*Tetrax tetrax*
Macqueen's Bustard	*Chlamydotis macqueenii*
Great Bustard	*Otis tarda*
Pallas's Sandgrouse	*Syrrhaptes paradoxus*
Stock Dove	*Columba oenas*

Common Wood Pigeon	*Columba palumbus*
Eurasian Collared Dove	*Streptopelia decaocto*
European Turtle Dove	*Streptopelia turtur*
Oriental Turtle Dove	*Streptopelia orientalis meena*
Great Spotted Cuckoo	*Clamator glandarius*
Common Cuckoo	*Cuculus canorus*
Western Barn Owl	*Tyto alba*
Eurasian Scops Owl	*Otus scops*
Eurasian Eagle-Owl	*Bubo bubo*
Snowy Owl	*Bubo scandiacus*
Northern Hawk-Owl	*Surnia ulula*
Eurasian Pygmy Owl	*Glaucidium passerinum*
Little Owl	*Athene noctua*
Tawny Owl	*Strix aluco*
Long-eared Owl	*Asio otus*
Short-eared Owl	*Asio flammeus*
Boreal Owl	*Aegolius funereus*
European Nightjar	*Caprimulgus europaeus*
White-throated Needletail	*Hirundapus caudacutus*
Common Swift	*Apus apus*
Pallid Swift	*Apus pallidus*
Alpine Swift	*Apus melba*
Little Swift	*Apus affinis*
Blue-cheeked Bee-eater	*Merops persicus*
European Bee-eater	*Merops apiaster*
European Roller	*Coracias garrulus*
Eurasian Hoopoe	*Upupa epops*
Eurasian Wryneck	*Jynx torquilla*
Grey-headed Woodpecker	*Picus canus*
European Green Woodpecker	*Picus viridis*
Black Woodpecker	*Dryocopus martius*
Great	*Dendrocopos major*
Middle Spotted Woodpecker	*Dendrocopos medius*
Lesser Spotted Woodpecker	*Dendrocopos minor*
Red-eyed Vireo	*Vireo olivaceus*
Eurasian Golden Oriole	*Oriolus oriolus*

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