OWSMRF III Scope of Work 5a

Role of non-breeders in population persistence and their treatment in offshore wind impact assessments

July 2026

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Contents

Definitions

Age class: A group of individuals from the same species that are of similar age.

Life stage: A life stage is characterised by specific development milestones and behaviours. Typically, in seabirds, key life stages include chicks, juveniles, sub-adults and adults.

Breeding status: A group of adult individuals from the same species that are either “breeding” or “not breeding” in a given year.

Breeder: An adult bird of breeding age that attempts to breed in a given year.

Non-breeder: A bird, either sexually mature or not, that does not breed in a given year. For the purpose of this work, non-breeders include immatures and sabbatical birds, as opposed to birds during the non-breeding season.

Immature: A bird that is not yet physiologically mature and has not reached breeding age. Immatures include juveniles and sub-adults.

Sabbatical bird: An adult bird of breeding age that does not attempt to breed in a particular year but may attempt to breed in subsequent years.

Population model: A mathematical representation of the population dynamics of a given system. In ecology, population models describe changes in the size and structure of populations of given species over time and are often used to understand drivers of population change.

Population projection model: A specific type of population model used to forecast future population sizes and structures based on current demographic trends.

Population Viability Analysis (PVA): A quantitative risk-assessment approach that incorporates stochasticity in environmental and demographic processes to assess the viability of a population, usually in terms of probability of a population dropping below a certain size (extinction risk), depending on different management scenarios. PVAs offer a useful modelling framework for better understanding how a population is likely to respond to external pressures.

1. Background

1.1. The context

Offshore wind farms (OWF) are a key part of the transition to renewable energy generation as the UK seeks to achieve clean power by 2030 and Net Zero by 2050 (The Crown Estate 2024). These ambitious targets have fostered the rapid expansion of offshore wind development in the UK, and the geographic spread is set to increase further offshore with the advent of floating wind. However, there is still considerable uncertainty around the environmental impacts of large-scale developments, particularly on marine birds. To inform the planning process of the potential impacts of proposed offshore wind farms, detailed Environmental Impact Assessments (EIAs) and Habitats Regulations Assessments / Appraisals (HRA) are required. EIAs assess potential impacts to the wider environment, whilst HRAs assess whether a plan or project has the potential to have an adverse effect on the integrity of a site (Special Protection Area, or 'SPA') protected under The Conservation of Habitats and Species Regulations (Amendment) (EU Exit) 2019 and The Conservation of Offshore Marine Habitats and Species Regulations 2017 (as amended).

Seabird impact assessments for offshore wind comprise several stages, including site characterisation surveys, predicting OWF impact mortalities from collision with turbines and from displacement and barrier effects (due to avoidance of the OWF area), apportioning predicted OWF mortality to different age classes and relevant protected sites (the latter within HRA only), and modelling population-level responses to predicted OWF impacts through Population Viability Analysis (PVA). Uncertainty in each step of the impact assessment can lead to increased levels of precaution applied to consenting decisions, therefore risking the rapid roll out of offshore renewable energy that is needed to combat climate change.

Seabird research, conservation and management often focus on the breeding component of populations. In a given year, not all individuals reproduce; some are too young and have not reached sexual maturity (referred to as "immatures" or "pre-breeders"), while others are old enough to breed but skip breeding that year due to poor condition, lack of mate or suitable nesting sites, or low prey availability (referred to as "sabbaticals" or "skipped breeders"). Non-breeding birds form a large component of populations for most seabird species particularly in those that mature late and show high rates of skipped breeding. They play an important role in maintaining seabird populations, by representing a potentially large pool of future reproductive individuals ready to move in and/or supplement lost breeders, thus helping buffer against sudden adult mortality. Ignoring non-breeding portions of seabird populations risks false predictions of population response to change, therefore limiting the validity of offshore wind impact assessments. For the purpose of this work, non-breeders include immatures and sabbatical birds, as opposed to "birds during the non-breeding season".

Due to their lack of reproductive constraints, non-breeders are expected to represent a relatively larger component of seabirds observed further offshore compared to more nearshore areas (Hall & Ruffino 2026). This is a growing concern as future developments expand in offshore areas, potentially overlapping with non-breeder distributions. Non-breeders' behaviour at sea may also differ to breeders; their sensitivity to collision and displacement and therefore risk from OWF impacts may differ too. Furthermore, with predicted increased frequency of extreme weather events, and potentially diseases too such as HPAI, non-breeding rates, as well as non-breeder attendance at or near colonies, are likely to change. This is creating a challenge for undertaking robust assessments of seabird population status and trends.

The Offshore Wind Strategic Monitoring and Research Forum (OWSMRF) Phase III identified a fundamental lack of knowledge of the ecology, behaviour and population dynamics of non-breeding birds, which poses a challenge to OWF impact assessments. Detailed information on knowledge gaps, evidence required to fill those gaps and Research Opportunities (RO) for obtaining evidence is reviewed in the OWSMRF III Knowledge Gap 5 report (Hall & Ruffino 2026) and summarised in JNCC (2026). The report describes several ROs which will help improve understanding of non-breeders, their behaviour in relation to offshore wind farms, the proportion of the whole population that they make up, and their role in seabird populations.

The OWSMRF III Developer Group, after discussions with OWSMRF stakeholders, asked JNCC to produce detailed scopes of work for a selection of ROs. The present scope of work synthesises and elaborates on RO5.4 (Better understanding of the proportion of non-breeders within populations) and RO5.5 (Role of non-breeders in population persistence and their treatment in population viability analysis), as described in Hall and Ruffino (2026), by providing a more detailed set of aims and objectives, possible methods that might be employed and important aspects (e.g. risks, dependencies) that would need to be considered. It should provide the information that is required to draft an invitation to tender and to judge the quality of applications, should any interested funding party wish to proceed with this project.

1.2. The issue

1.2.1. Treatment of non-breeding birds in offshore wind impact assessments

Within an impact assessment, predicted impacts of an OWF project on seabird populations are assessed through a number of steps, which mainly seek to ask the following questions:

1. How many seabird mortalities in total are predicted to occur at an OWF site (based on collision risk and displacement assessments)?

2a. How are these predicted mortalities split between different age and breeding status components of a population (based on proportions of immatures, breeding adults and sabbaticals assumed to be present at an OWF site)?

2b. For HRAs only, how can predicted mortalities be linked back to protected breeding colonies (based on assumed levels of connectivity between birds observed at an OWF site and SPAs)? Steps 2a and 2b together represent the apportioning stage.

3. How do these predicted mortalities affect populations in the long-term (using PVA)?

Non-breeders are primarily considered at the apportioning and PVA stages (stage 2 and 3 above) of an assessment. Evidence is however limited to assess where immatures and sabbaticals are likely to occur at sea at different times of year, how sensitive they are to the impacts of OWFs, their numbers and demographic rates. Consequently, current methods within both EIAs and HRAs do not consider the mortality of all non-breeders and rely on unverified assumptions to apportion impacts to different age classes. There are also inconsistencies in advice between UK countries, and there is currently no framework or set of methodological standards, approved by regulators and their advisors, for the treatment of non-breeders in impact assessments. It remains unclear at what stages of the assessment non-breeders should be included, and how they should be considered, for both HRAs and EIAs. This lack of a clear route for the inclusion of non-breeders in assessments is leading to prolonged conversations during the application stage, creating delays in decision-making. This also creates residual uncertainty in assessments, leading to increased levels of precaution, hence increasing cost and risk to offshore wind consenting. Uncertainty can also have implications for targeting seabird conservation efforts where it is mostly needed (e.g. in the context of under- or over-estimations of offshore wind impacts).

It is worth clarifying however that there is a process in UK impact assessments for the treatment of "birds during the non-breeding season" through the use of the Biologically Defined Minimum Population Scales (BDMPS) approach, initially developed by Furness (2015). The "non-breeding season" is a period when birds are not actively breeding, typically encompassing winter months, whereas "non-breeders" refer to birds that do not breed in a given year (i.e. immatures and sabbaticals in the present document).

1.2.1.1 Sabbaticals

The NE/JNCC PVA tool (Butler *et al.* 2020) is the currently recommended PVA tool in UK offshore wind impact assessments, which only allows the specification of breeding adults and immatures within the model. The PVA population structure does not include sabbaticals as a separate class of individuals with specific demographic parameters and population dynamics. This means that the buffering capacity of non-breeding adults against sudden losses from external pressures, such OWF impacts, is not being considered. In addition, sabbatical mortality from OWFs cannot be currently modelled within a PVA. A sabbatical rate may be applied to account for a proportion of adult birds that skip breeding within the population in a year, thereby reducing the number of breeding adults, although this functionality is only currently available in the R package of the tool, and is less frequently used. There is limited evidence to estimate robust sabbatical rates across species, creating uncertainty in assessments. If a sabbatical rate is not applied, sabbaticals are effectively considered as failed breeders (adults with null productivity) within the population. It is unclear what implications these simplistic approaches to treating sabbaticals in PVA may have on impact assessment outcomes.

1.2.1.2 Immatures

Within the NE/JNCC PVA tool, age classes are split down to yearly immature classes of individuals transitioning to a single adult age class as they reach breeding age. OWF mortality can be applied to both adults and immatures separately, although the focus tends to be on breeding adults within HRA. In addition, the NE/JNCC PVA tool does not allow assigning differential mortality impacts to specific immature age classes such as age 0–1, 1–2, 2–3, etc. (a single mortality impact can only be applied across all immature individuals). In the absence of robust evidence for age-class specific impacts of OWFs, it can be assumed that immatures have either the same or different levels of impact than adults. In the case of the latter, mortality impacts can be assigned proportionally to the relative representation of each age class in populations. This can be done through applying a stable age structure in population modelling, which predicts relative proportions of birds expected to be within each age class in a stable population, and is used to calculate age ratios within a population. A key limitation of this approach is that its underlying theoretical population modelling assumptions may not necessarily reflect variations in age class distributions across areas of seas and times of year, and therefore not represent age-specific levels of exposure at a specific OWF site. Indeed, in some species such as northern gannet (*Morus bassanus*), estimated population-level age class proportions derived from stable age population modelling (Furness 2015) have been shown to differ from site-specific age ratios observed at sea (e.g. HiDef & West of Orkney Windfarm 2024). It remains unclear how deviations from these approaches can influence population modelling outcomes.

Overall, improvements could be made to generate more biologically realistic population structures in PVA and to more accurately reflect predicted impacts of OWFs on seabird populations. To understand the level of emphasis that would need to be placed on this research, a key first step is to develop an understanding of the role of non-breeders in seabird population persistence, and the extent to which non-breeders can influence population responses to OWF impacts. The work described in this scope of work involves testing common assumptions around the specification of age classes and breeding status within PVA and their specific levels of impacts, identifying pitfalls in common approaches but also opportunities for improvement. This will help inform appropriate levels of precaution required when interpreting outputs from various approaches and generate best practice guidance for the inclusion of both immatures and sabbaticals in impact assessments.

1.3. Synergies

This scope of work is complementary to two sister OWSMRF III scopes of work, and we strongly encourage interested parties to review the aims and objectives of these scopes and engage with these proposals or projects (as/when they are delivering), to build on any available outputs and maximise synergies. **Before progressing any of this work, it is also advisable to get in touch with JNCC (feedback@jncc.gov.uk) to receive the latest updates on the status of OWSMRF III scopes of work**.

OWSMRF III produced the following two scopes of work:

- SoW5b: Improving understanding of the at-sea distribution of immature and sabbatical seabirds for use in offshore wind impact assessments – feasibility study. Apportioning impacts is a crucial aspect of ornithological impact assessments and is recognised in the present scope of work (SoW5a). SoW5b looks more specifically into immature and sabbatical at-sea distribution and connectivity to colonies, while the present scope of work (SoW5a) focuses on population modelling processes within an impact assessment.

- SoW5c: Feasibility study for improved understanding of non-breeding birds through the development of novel colony monitoring technologies. This scope focuses on the collection of new empirical data from colonies, which could then be used to refine population modelling parameters (from SoW5a) as evidence becomes available.

2. Aim and objectives

2.1 Aim

This work aims to provide a quantitative evaluation of the relative importance of non-breeders in seabird population dynamics and growth and identify an appropriate framework for the inclusion of both sabbaticals and immatures in Population Viability Analysis, enabling more biologically meaningful impact assessments.

This can be done under five objectives, as presented in Figure 1:

2.1.1 Objective 1 – Define an appropriate modelling framework

Define an appropriate modelling framework to accommodate the specification of non-breeding components and variable levels of offshore wind mortality in impact assessments.

2.1.2 Objective 2 – Produce up-to-date estimates of proportions of sabbaticals and immatures within seabird populations

2.1.2.1 Objective 2a: Sabbaticals

Based on literature searches and expert opinion, generate a range of plausible sabbatical rate estimates across species.

2.1.2.2 Objective 2b: Immatures

Using gannet as a case study, generate site-specific age class proportions from at-sea surveys, and compare them to population-level predictions derived from the stable age structure. These new estimates will be used to parameterise models in Objective 3.

2.1.3 Objective 3 – Test assumptions around the treatment of non-breeders in impact assessments

Using the modelling framework identified in Objective 1 and non-breeding rates estimated under Objective 2, run sensitivity analyses to identify circumstances where non-breeders have most influence on population trajectories. What scale of influence do non-breeders have in PVA, and how do assumptions from currently used approaches for apportioning OWF impacts influence PVA outcomes?

2.1.4 Objective 4 – Synthesis and recommendations

Produce recommendations on how best to consider non-breeders in offshore wind impact assessments through an evaluation of available evidence, current practices and tools, as well as potential meaningful and tractable implementation mechanisms.

2.1.5 Objective 5 – Implementation and dissemination

Implement recommended changes and maximise uptake in impact assessments.

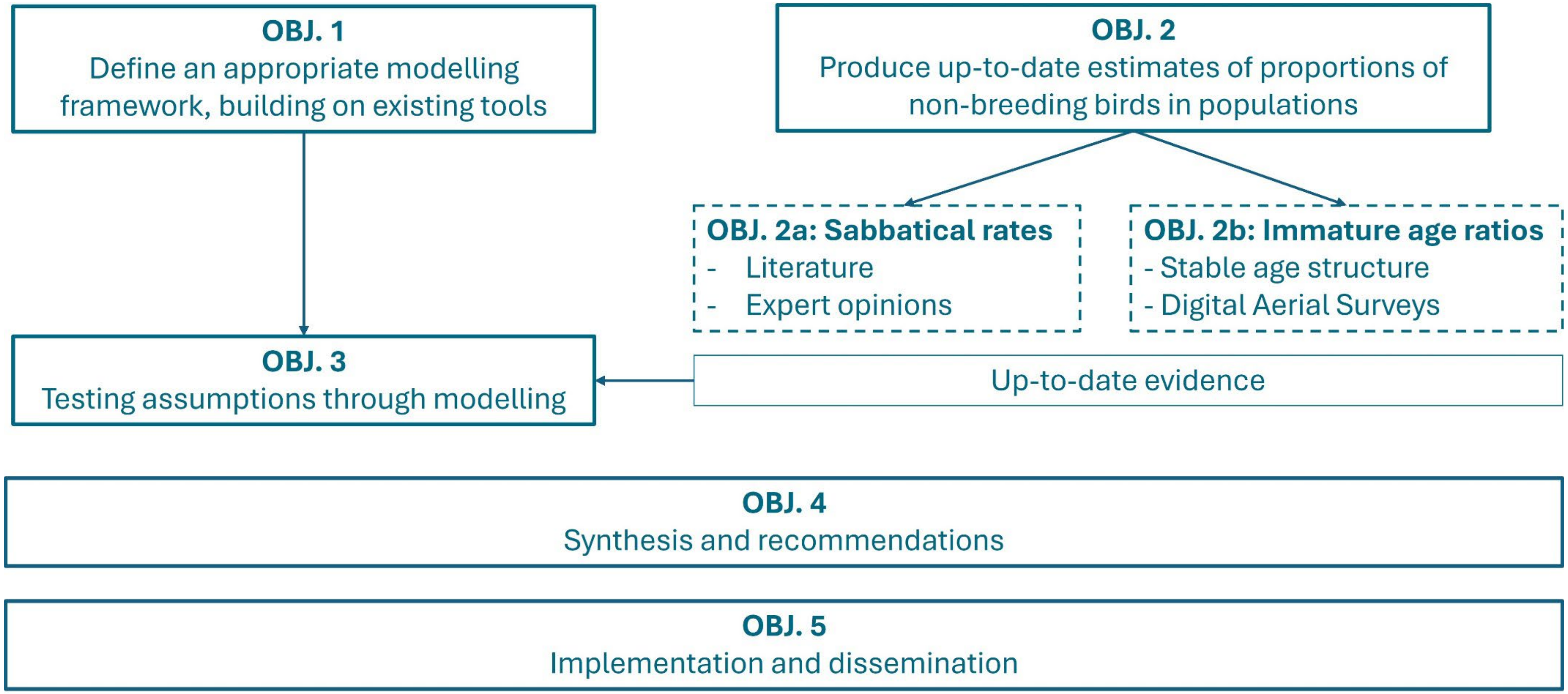

Figure 1. Order of research.

3. Detailed tasks

The Project would involve a series of tasks to meet the objectives listed above.

3.1. Objective 1 – Define an appropriate modelling framework

3.1.1 Task

A first task is to define an appropriate modelling framework to be applied in the more advanced modelling tasks of this project (Objective 3), to evaluate the effects of various components of non-breeding on future population dynamics and growth as well as population responses to impacts from external pressures.

Key model requirements are:

- population projection models that can be applied to a range of UK seabird species and are flexible enough to model different population structures.
- model structures that allow modelling seabird populations with both breeding and non-breeding segments, so that breeding adults, immatures and sabbaticals are explicitly considered as separate classes of individuals contributing to breeding population sizes at various time steps.
- impacts of OWFs can be applied to breeding adults, immatures and sabbaticals, separately, within models.
- a modelling approach that addresses key challenges in current PVA practices and model outputs are directly applicable to offshore wind impact assessments.
- the work should explicitly seek to adapt the NE/JNCC PVA tool, rather than develop a new one.

The NE/JNCC PVA tool is a well-used and recognised model for seabird and offshore wind impact assessments in the UK. It is an age-structured population model, including breeding adults and immatures age classes. It can be parameterised for a number of species and allows demographic stochasticity to be included. However, it does not currently allow the specification of sabbaticals as a separate class of individuals, and OWF mortality can only be assigned to breeders and immatures separately (lumping all immature ages in one category). Progressing work to revise and improve the underlying NE/JNCC PVA model structure will ensure any updates and recommendations emerging from this project are readily accessible and implementable. This Objective should therefore seek to modify the current version of the NE/JNCC PVA tool to allow inclusion of a more complex, but realistic age and demographic structure in the model.

3.1.2 Considerations

3.1.2.1 Existing modelling frameworks

A range of population projection models have been developed in the recent years, on which this Objective could learn and build on; these include:

- work in the Netherlands undertaking cumulative assessment PVAs at regional scales, which included the modelling of sabbaticals as a separate component of populations and assessed the relative sensitivity of population growth rates to sabbatical rates, survival rates and breeding success (Potiek *et al.* 2022).

- a UK-wide meta-population model for the black-legged kittiwake (*Rissa tridactyla*) developed by Glasgow University, as part of the ORJIP 'MetaKitti' project (Matthiopoulos *et al.* 2025), where "floaters" (i.e. unrecruited immatures and adult sabbaticals) are estimated as a separate class of individuals.

- a UK-wide meta-population model for northern gannet developed by Jeglinski *et al.* (2023).

- a Manx shearwater population model for the Isle of Rum (Matthiopoulos & Furness 2024).

- PVA models developed for 31 populations of seabird species breeding in the UK to assess population responses to extrinsic threats (Merrall *et al*. 2024).

- a conceptual modelling framework, developed by Lee *et al.* (2017), for systems where breeding and non-breeding adults differ in demographic rates, incorporating different forms of non-breeding and different life histories.

3.1.2.2 Demographic parameters

A number of demographic components will need to be considered when defining an appropriate modelling structure, such as:

Age structure

Non-breeders can be classified into the following categories:

- individuals that are not old enough to be able to reproduce including:

    i.) "early years immatures", later transitioning to

    ii.) "pre-breeders" as they approach age at maturity.

- adults that have reached sexual maturity, including i. individuals that have bred previously but are skipping breeding in a given year ("experienced non-breeders"); and ii. older adults that are unlikely to acquire the resources needed for further breeding ("senescent non-breeders").

    The immature category may comprise multiple age classes, depending on the age at first breeding, and for some species like gannet, differential mortality rates could be applied in PVA according to the age classes observed at an OWF project site. In other species, for which age cannot be identified based on plumage characteristics, it is often only possible to identify birds in the first calendar year, while older birds (including older immatures or pre-breeders) would be referred to as 'adult-type'. Information on age structure at sea (and hence exposure to OWF impacts) will be species dependent, therefore a key requirement for a population model would be to enable flexibility between species.

Age of recruitment

This is the first age at which individuals are physiologically mature and could breed. Data exist for most seabird species breeding in the UK (Horswill & Robinson 2015). Recruitment age can be affected by density-dependence processes.

Effect of recent breeding history on breeding probability

The probability of an individual breeding at a given time step can be influenced by its recent reproductive history. For example, if breeding is costly, breeding probability might decrease directly after a breeding event (or after several successive breeding events), whereas individuals that have not bred for a year or two gain a higher breeding probability.

Probability of surviving and likelihood of subsequent breeding

There may be instances where breeding adults have lower chances of surviving and of breeding successfully at the next time step than non-breeding adults (due to the cost of breeding), other instances where non-breeders have lower survival and future breeding probabilities than breeders, and other cases where both breeding and non-breeding adults have the same demographic rates.

Density-dependence

Increasing numbers of non-breeding adults can lead to increased levels of intra-specific competition, therefore reducing population growth.

Frequency-dependence

Negative effects can also manifest when non-breeders interfere with breeding, which could lead to reduced survival or productivity when the ratio of non-breeders to breeders becomes high.

For some of these quantities, empirical evidence may not necessarily exist to allow robust parameterisation of models. In addition, complex model structures may be a barrier to direct implementation into a user-friendly tool and therefore prevents wider usability. When suggesting modifications to the NE/JNCC PVA tool, Contractor(s) will therefore be encouraged to consider model complexity and usability, as well as the ability to parameterise models in a robust manner. A key requirement for the modelling framework would be its flexibility – it would need to be generic enough to be applied to several species to maximise benefits to the impact assessments. Assumptions around the structure of the model and its parameterisation will also need to be acknowledged and discussed in a clear and transparent manner.

3.1.3 Ways of working

Crucial to this first task is close engagement with population modelling experts, seabird experts, datasets holders and offshore wind impact assessment practitioners. Seeking contributions from experts with hands-on practice with offshore wind casework and the NE/JNCC PVA tool, particularly UK Government’s statutory nature conservation bodies, will be required for understanding what key barriers and limitations are, but also identifying opportunities for future modelling advances. Deciding on a most appropriate modelling structure for this project will be a trade-off between data quality and availability, ecological realism, model parameterisation requirements and complexity, and resources required (computational time).

3.2. Objective 2 – Produce up-to-date estimates of proportions of sabbaticals and immatures within seabird populations

This Objective is composed of two parts:

- Objective 2a: proportions of non-breeding adults
- Objective 2b: proportions of immatures

3.2.1. Objective 2a: proportions of non-breeding adults

This work will focus on deriving population-level estimates of sabbatical rates in seabird species (as opposed to site-specific ratios of breeding versus non-breeding adults at sea).

3.2.1.1 Key ecological questions

- What proportions of non-breeding adults are represented in seabird populations?
- How do these proportions vary across species?
- How do these proportions vary between colonies and over time, and what factors explain variation?
- What methods are most appropriate to define and calculate adult non-breeding rates in seabird populations?

3.2.1.2 Tasks

The modelling work undertaken as part of Objective 3 will require a good understanding of rates of adult non-breeding in seabird species. Currently the evidence around incidence of missed breeding is old and sparse, with large uncertainty; therefore, it is proposed to combine extensive literature searches with expert judgments to derive plausible ranges of sabbatical rate estimates for a number of key species.

The work will investigate life history characteristics of different seabird species (e.g. demographic rates, breeding phenology and behaviour, foraging) to make an expert judgement as to whether existing evidence for sabbatical rates can be refined and applied to other relevant species. If correlations between life history traits can be identified, it may be possible to generate generic sabbatical rates across similar species.

Proposed activities are as follow:

- Review literature to extract known sabbatical rates in seabird species breeding in the UK, building on the initial review undertaken by Hall and Ruffino (2026).
- Identify and gather a group of experts with substantive knowledge of non-breeders in seabird populations.

- Define a method for seeking and synthesising expert knowledge on adult non-breeding rates, to inform the generation of new rates across species, with associated levels of uncertainty.

- Define a method for formulating agreed standards around terminology, approaches and metrics when estimating sabbatical rates.

- Identify a clear route for critically assessing and updating sabbatical rates as new evidence becomes available. There may be a requirement for developing a new framework, or making use of an existing one, such as the Offshore Wind Evidence and Knowledge Hub (OWEKH), and this work will seek to provide recommendations on next steps.

3.2.1.3 Considerations

Bidders should explicitly detail in their proposal how they would approach the following aspects:

- Expert selection process, including minimal number of participants and levels of expertise.

- Process for gathering and synthesising information from both expert opinions and literature sources.

- Process for deriving updated adult non-breeding rates with associated levels of uncertainty.

- Approach to quantify variability and uncertainty in sabbatical rate estimates between species, and a method for deriving uncertainty that arises from differences between individual experts. Consideration should also be given to colony or population-specific rates, and reasons for these, when generalising from other locations, as well as variation over time, due to, for example, effects of environmental conditions or acute mortality events. This will allow the environmental drivers of non-breeding to be investigated.

- Approach for defining how these quantities should be defined in a way that could be used within the model(s) identified in Objective 1 but also within impact assessments. For example, probability distributions around sabbatical rate estimates may be best suited when parameterising population models or PVAs, whereas a discrete set of fixed values may be more appropriate when applying ratios of breeders versus non-breeders in the apportioning stage of the impact assessment.

There are currently multiple ways to define and calculate the rate of adult non-breeding, methods across the literature are highly variable, and terminology is inconsistent. Adult non-breeding can be reported using different metrics, such as means, ranges, and per year estimates. Rates have been reported as numbers of birds, percentages, and probabilities, using observations and simulated estimates. Experts will therefore be consulted to help formulate agreed standards around terminology, approaches and metrics when estimating sabbatical rates, to facilitate integration of information.

3.2.2. Objective 2b: proportions of immatures

This work will seek to improve understanding of seasonal distributions of immature age classes around UK waters, to inform the population modelling work undertaken under

Objective 3. It will focus on gannet as a case study and make use of both existing Digital Aerial Survey (DAS) data and knowledge of life history behaviour to establish which age classes may more likely be present in specific areas of sea and times of year, around UK waters. Gannet is one of the rare species breeding in the UK for which DAS can be used to age birds with confidence. In addition, estimated gannet age class distributions derived from stable age population modelling (Furness 2015) have been shown to differ from age class proportions observed at sea (e.g. HiDef & West of Orkney Windfarm 2024).

3.2.2.1 Key ecological questions

- Do gannet age class distributions at sea vary between locations and times of year around the UK?
- How do age ratios obtained from at-sea surveys compare to theoretical assumptions derived from stable age population modelling?

3.2.2.2 Tasks

Proposed activities are as follow:

A. apply age-structured population models (Leslie matrices) to derive stable age distributions from which proportions of breeding adults and of immature birds in gannet populations can be estimated. Most up-to-date demographic rates (productivity, survival rates, age at first breeding) will be used to parameterise models for each gannet population of interest.

B. using DAS datasets, extract gannet age ratios from different locations and seasons around UK waters.

C. compare estimated population-level age class proportions obtained in A. with gannet site-specific age ratios obtained in B. This will allow an investigation of differences in approaches to apportion impacts to age classes and identify circumstances where some methods may be more suitable than others. Implications of any differences identified for modelling population trajectories in the context of a PVA will be investigated in Objective 3.

3.2.2.3 Synergies and dependencies

Completion of this task requires access to DAS data; therefore, a key requirement for this work is for interested Bidders to demonstrate how they could access and make use of existing datasets within the timeframe of this project. It is envisaged that this work would be best delivered by a consortium of project partners, with expertise in gannet population ecology and holding access to DAS datasets covering large areas of UK waters. Large-scale collation of at-sea survey data, such as the OWEC-funded POSEIDON and ReSCUE projects, would seem highly beneficial to the present project.

A sister scope of work produced by OWSMRF (SoW5b) is looking at the feasibility of using existing datasets, including both tracking and DAS, to improve understanding of the at-sea distribution of immature birds for use in the apportioning stages of an impact assessment, targeting a range of priority seabird species. There is therefore an opportunity for both projects to build on each other and inform each other.

3.3. Objective 3 – Test assumptions around the current treatment of non-breeders in impact assessments

3.3.1 Key questions

- Does the inclusion of sabbaticals in the population structure change population trajectories compared to models without sabbaticals?

- Can we quantify differences in future population growth rates between populations with and without sabbaticals? What scale of influence do sabbaticals have on population persistence? Do sabbatical rates need to be very high to influence population trajectory?

- Can pressures (chronic versus acute) exacerbate differences in growth rates between population structures?

- How do predicted age ratios derived from stable age population modelling compared to observed age class proportions from at-sea surveys?

- How does the misspecification of age ratios and apportioning of impact values influence modelling outcomes?

- How sensitive seabird population growth rates are to changes in non-breeders' (both immatures and sabbaticals) demographic rates and levels of offshore wind impact?

3.3.2 Tasks

Proposed activities are as follows:

- Test assumptions: once an appropriate modelling framework has been identified (Objective 1), a number of assumptions currently used in seabird impact assessments would be tested. Here, it is envisaged that the specific role of sabbaticals in long-term population persistence would be explored in different contexts. Using a range of biologically realistic parameter values, informed by Objective 2, it is proposed to explore the sensitivity of population growth to changes in proportions of sabbaticals within populations and sabbaticals' demographic rates, as well as how this may vary with different types and levels of impacts.

- Assess implications of different approaches for applying OWF mortality across adult and immature age classes on modelling outcomes.

3.3.3 Modelling considerations

Some modelling considerations are outlined below (this may not be an exhaustive list and will have to be agreed with the Project Team).

3.3.3.1 Sabbatical proportions

- Modelling seabird population dynamics and growth rate with and without sabbaticals; simple Leslie matrix models that do not allow sabbaticals to contribute to breeding population sizes at various time steps will be compared to more complex population projection models that explicitly account for sabbaticals.

- Sabbatical rates; how does variation in sabbatical rates influence population trajectory? Sabbatical rates obtained from the literature and expert knowledge (Objective 2) would be used to inform a plausible range of values to be explored.

- How does the relative importance of sabbaticals in population persistence vary with initial population sizes (e.g. small versus large)?

3.3.3.2 Sabbatical demographic rates

Demographic rates of sabbaticals (as identified in Objective 1) would be varied sequentially (through sensitivity analyses), to determine at which point the value of these parameters makes a significant difference to projected population size and help identify important parameters that have most influence.

3.3.3.3 Age ratios and apportioning of impacts

Site-specific testing of stable-age structure assumptions for apportioning impacts. Different scenarios of age class levels of impacts will be investigated, comparing scenarios where impacts are applied at a similar level to both adults and immatures, with scenarios where impact levels differ between age classes. In the latter, two approaches will be compared: models with apportioned impacts parameterised based on estimated age composition derived from population stable age structures versus models parameterised using age ratio data from DAS.

3.3.3.4 Impacts of pressures

- Do variable impacts on breeding and non-breeding adults influence population responses? Testing out a range of mortality impacts on each class of individuals, separately.

- Do differential levels of mortality across immature age classes (e.g. age 0–1, 1–2, 2–3, etc.) have an influence on population persistence? A range of mortality impacts could be tested to further explore the sensitivity of mis-specifying mortality impacts across immature age classes on the population trajectory.

- Effect of chronic versus acute pressures on breeding birds – how do the frequency and intensity of impacts affect population responses when certain proportions of sabbaticals are included in the population?

3.4. Objective 4 – Synthesis and recommendations

Work under Objective 1 will identify an appropriate framework for modelling more complex age and demographic structures in seabird populations, through adapting the NE/JNCC PVA model. Work under Objective 2 will provide up-to-date evidence of non-breeding parameters, highlighting where important areas of uncertainty may lie. Work under Objective 3 will apply the adapted model to test assumptions and assess the relative influence of a range of age/demographic structures and model parameters on population trajectories.

Objective 4 seeks to:

- synthesise the outcomes of these investigations;
- conclude on the appropriateness of current apportioning approaches for gannet (e.g. through applying stable age structures), and identify alternative practical solutions which could also be considered for other species;
- identify any limitations of the PVA modelling framework currently used in assessments (i.e. the NE/JNCC PVA tool and its simplistic model structure);
- provide clear lines of direction for future PVA improvements within offshore wind impact assessments and identify potential meaningful and tractable implementation mechanisms.

Proposed activities are as follows:

- Hold a workshop with modelling experts, seabird experts and those with hands-on practice in offshore wind casework tools such as the NE/JNCC PVA tool (including end-users such as government advisors, consultancies and tools developers) to assess both the challenges and opportunities of implementing any future advances of the tool, as identified in Objective 4.
- Provide recommendations on the appropriate treatment of both immatures and sabbaticals in impact assessments (i.e. at what stages on the assessment process they should be considered, and how they should be treated).
- Identify necessary amends to the NE/JNCC PVA tool, as agreed by workshop stakeholders, as well as tractable implementation mechanisms.
- Identify future data collection needs to improve confidence in PVA modelling outputs.
- Assess the feasibility of collecting new data on important demographic parameters, through close engagement with seabird monitoring experts.

3.5. Objective 5 – Implementation and dissemination

This objective is an essential final step to ensure there is a clear impact pathway emerging from this work, leading to more robust and biologically meaningful evaluations of offshore wind impacts on seabird populations.

Proposed activities are as follows:

- Implement changes as recommended in Objective 4 and agreed by stakeholders: this would include revising, improving and creating a new version of the NE/JNCC PVA tool to accommodate the specification of sabbaticals and various levels of impacts across different breeding and non-breeding components of seabird populations (as required).
- Produce an updated version of the NE/JNCC PVA tool user-friendly interface (e.g. ShinyApp) to include new non-breeder functionality.
- Produce best practice guidance on a modified and functional version of the NE/JNCC PVA tool (both for the R and Shiny versions of the tool), including model parameterisation, new functionality and interpretation of modelling outcomes. This would be illustrated with worked examples.

- Prepare and deliver a range of dissemination and engagement events targeted to the NE/JNCC PVA tool end-users (i.e. government advisors and consultancies), through webinars, presentations to marine industry groups, hands-on practice and tool demonstration sessions.

4. Outputs

The Contractor(s) will produce a series of resources that include the following:

- Objective 1: a key output will be an agreed modelling framework to be used in advanced modelling work (under Objective 3), as adapted from the NE/JNCC PVA tool model structure. This will be accompanied by a short document detailing the logical process for identifying best modelling framework(s). The document should also identify key seabird species to focus on in this project, as well as relevant datasets (colony monitoring data) to be used for modelling population dynamics.

- Objective 2: a document presenting the methods used to seek expert opinions, synthesise the information and generate up-to-date estimates of sabbatical rates. New rates for a number of UK breeding species, including variation in those rates, will be presented in a separate table. For immatures, estimated gannet age ratios derived from stable age structures will be compared to proportions of age classes observed at various locations and times of year based on DAS.

- Objective 3: a document detailing the modelling approaches used to test assumptions around the current treatment of non-breeders in impact assessments and run sensitivity analyses. It should also provide a clear, concise and accessible summary of the different modelling tasks and outputs targeted to a non-technical audience and be accompanied by a more detailed technical reporting of the work.

- Objective 4: synthesis of Objectives 1–3, and a clear set of recommendations for implementing changes of the NE/JNCC PVA tool within impact assessments.

- Objective 5: a modified and improved version of the NE/JNCC PVA tool, which associated guidance resources, which can be understandable, accessible to and usable by offshore wind stakeholders, followed by a series of dissemination and training events targeted to tool end-users to facilitate exposure and engagement, and hence uptake, of newly developed approaches.

Additional presentations and updates will be given throughout the course of the project, typically following completion of major milestones to allow for any emerging issues to be addressed promptly.

5. Timescale

An indicative timeline of work is provided below, and the Contractor(s) should provide a detailed Gantt chart, showing how long each objective will take to deliver and when delivery will take place. The key objectives, milestones and deliverables of this contract are:

- Week 1: start-up meeting
- Week 12: modelling framework agreed; draft report (Objective 1)
- Week 20: expert workshop (Objective 2a)
- Week 36: draft report (Objective 2)
- Week 56: draft report (Objective 3)
- Week 65: stakeholder workshop (Objective 4)
- Week 69: draft report (Objective 4)
- Week 81: implementation, dissemination and engagement (Objective 5)
- Week 85: final outputs and project close

6. Contractor requirements

The Contractor(s) would need to demonstrate the following expertise and experience:

- Excellent knowledge of seabird ecology and population dynamics (with experience in collecting colony data in the field desirable).
- Strong quantitative analytical skills, with expertise in modelling complex population dynamic systems (e.g. population projection models, population viability analysis) and running sensitivity analyses.
- Experience in analyses of at-sea survey data, especially DAS.
- Can demonstrate access to DAS datasets for analyses of gannet age ratios.
- Good understanding of the interactions between offshore windfarms and seabird populations.
- Good understanding of offshore wind impact assessments.
- Previous experience with delivering similar work.

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