OWSMRF III Knowledge Gap 5 Report Summary

Advancing knowledge of non-breeding seabirds, in the context of offshore wind impact assessments

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JNCC

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1. The context

To combat climate change, the UK Government has committed to large-scale deployment of offshore wind in the UK, with ambitions to increase capacity to 50 gigawatts by 2030. This increase in renewable energy capacity will contribute to UK Government's target of decarbonising UK energy by 2035, and to achieve Net Zero by 2050. However, there is currently a limited understanding of the effects of large-scale offshore wind development on marine wildlife, particularly seabirds. Uncertainty around environmental impacts can in some instances lead to increases in precaution within impact assessments, leading to delays, or risks to offshore wind consenting decisions.

The Offshore Wind Strategic Monitoring and Research Forum (OWSMRF) is an industry-led, UK region specific, and collaborative partnership that aims to identify and develop research to fill critical knowledge gaps in our understanding of the impact of offshore wind development on seabirds. During the third phase of OWSMRF (2025–2026), stakeholders identified uncertainty around key aspects of the ecology and behaviour of non-breeding seabirds as a critical issue that is currently posing, or in the near future will likely pose, a challenge to the offshore wind consenting process.

In seabird populations, many birds do not breed every season. In a given year, some birds are reproducing at colonies ("breeders") while others do not reproduce at all ("non-breeders"). Non-breeders include:

- young birds that are not mature yet and can wait several years before reproducing at colonies (referred to as "immatures" or "pre-breeders"), and
- adult birds that are old enough to reproduce 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").

In this context, non-breeders need to be differentiated from "birds during the non-breeding season", which is a period of the birds' life cycle when they are not actively breeding, typically encompassing winter months.

Non-breeding birds form a large component of populations for most seabird species. One potentially important role of non-breeders is to buffer, regulate and stabilise seabird populations. Non-breeders act as a "reservoir" of individuals that are ready to supplement and/or replace breeding individuals, hence compensating for sudden adult mortality (e.g. from environmental and anthropogenic pressures). However, non-breeders are challenging to observe at sea and are often overlooked in seabird research and conservation, typically focusing on breeding individuals attending colonies. This creates a challenge for undertaking robust assessments of seabird populations and trends.

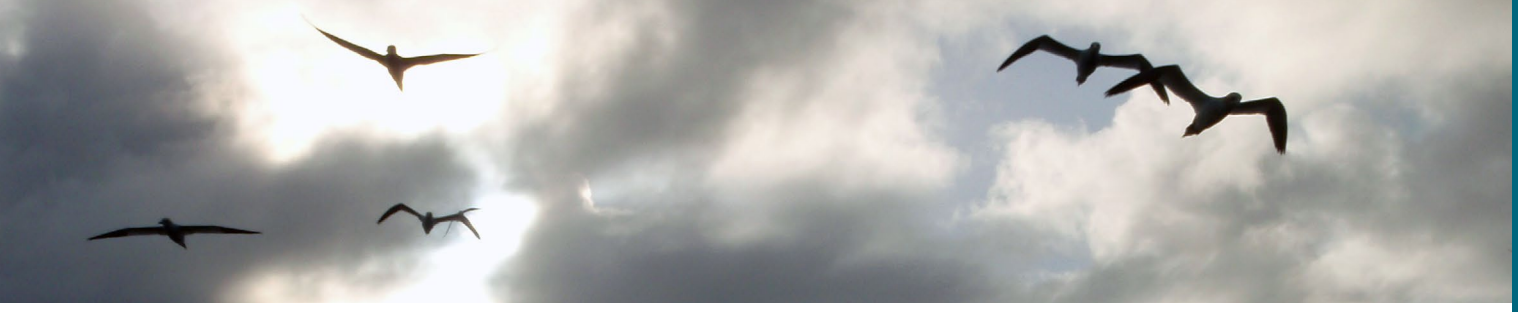
It is likely that non-breeders spend more time at sea than birds looking after a nest and occupy areas further offshore, although it is unclear to what extent this is true for both immatures and sabbaticals, and how this may vary across species and times of year. Non-breeder distribution may therefore overlap more frequently with future offshore wind development areas, built further from the coast, compared to breeding individuals attending colonies. Non-breeders' behaviour at sea may also differ to breeding birds; their sensitivity to collision and displacement, and therefore risk from offshore wind impacts, may differ too. However, a fundamental lack of understanding of the ecology and behaviour of non-breeders makes them difficult to factor into offshore wind impact assessments.

2. Scope of this report

Hall & Ruffino (2026) presents a detailed assessment of non-breeding birds in seabird populations within the context of offshore windfarm impact assessments. It reports on the current treatment of non-breeders in seabird impact assessments in the UK, highlighting where the main areas of uncertainty lie. It then delivers a review of the current evidence base and understanding of key aspects of non-breeders' ecology and behaviour, including:

- at-sea distribution;
- behaviour at sea and how it relates to risks from collision and displacement;
- non-breeding numbers and demographic rates (e.g. survival rates, likelihood of producing offsprings in future years);
- role of non-breeders in seabird population resilience.

The report finally presents a list of tangible research avenues, identified by a consortium of experts, to address knowledge gaps, contributing altogether to reducing uncertainty in offshore wind impact assessments.



3. Non-breeders in offshore wind impact assessments

Seabird impact assessments for offshore wind comprise several stages, including:

- characterisation of a proposed offshore windfarm site in terms of species composition, distribution and abundance;
- predicting seabird mortalities from collision with turbines, and from displacement and barrier effects;
- apportioning mortality estimates to different components of seabird populations (e.g. breeding adults, immatures, sabbaticals);
- apportioning mortality estimates to relevant Special Protection Areas (SPA), and
- modelling population-level responses to predicted offshore windfarm impact through Population Viability Analysis (PVA).

Evidence is however limited in allowing a robust understanding of where immatures and sabbaticals are likely to occur at sea at different times of year, how sensitive they are to the impacts of offshore windfarms, their numbers and demographic rates. This creates several challenges within impact assessments, for example:

- assessments tend to focus on breeding birds, especially within Habitat Regulation Assessments / Appraisals (HRAs), and do not take account of potential offshore wind impacts on all non-breeding components of populations;
- current approaches to derive site-specific population composition and specify impact levels on different classes of individuals rely on unverified assumptions;
- there is currently no framework or set of methodological standards, approved by regulators and their advisers, for the treatment of non-breeders in impact assessments, leading to inconsistencies in advice between UK countries;
- it remains unclear at what stages of the assessment non-breeders should be included, and how they should be best considered, within both HRA and Environmental Impact Assessments (EIA).

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 seabird conservation (e.g. under-estimations of offshore wind impacts).

4. Review of evidence

The published literature was searched for studies on non-breeding birds, focusing on species occurring in the UK, supplemented by key pieces of evidence from other species around the world. The review suggests that non-breeders can play a role in the long-term persistence of seabird populations, yet detailed information about key aspects of their ecology and behaviour is lacking, particularly for species breeding in the UK, such as northern gannet (*Morus bassinus*), black-legged kittiwake (*Rissa tridactyla*), greater black-backed gull (*Larus fuscus*), lesser black-backed gull (*Larus marinus*), common guillemot (*Uria aalge*), razorbill (*Alca torda*), Atlantic puffin (*Fratercula artica*) and Manx shearwater (*Puffinus puffinus*).

The at-sea distribution of non-breeding seabirds has been studied for species largely occurring outside the UK, such as albatrosses and skuas. Little is known about non-breeder distributions of species occurring around UK waters, with the exception of larger species such as northern gannet and Manx shearwater for which tracking of immature movements at sea is technically possible, and has been undertaken in few UK marine regions.

Similarly, the behaviour of non-breeders, and how this may influence their risk of collision or displacement requires further evidence. Most parameters required to estimate risk of collision (e.g. flight heights, flight speeds) and displacement (e.g. susceptibility to disturbance, habitat flexibility) are not known for non-breeders. Without these key pieces of information, non-breeder-specific risk cannot be fully understood, or at least is assumed to be the same as breeding birds. Research on UK seabird species, with sufficient sample sizes, addressing knowledge gaps around behavioural and distributional traits is required to inform more robust impact assessments.

The relative importance that non-breeders play in seabird population resilience likely depends on the proportions they make up in populations. Currently available adult non-breeding rates are based on old (10-25 years) and/or sparse (1-2 studies per species) data collected on a handful of species and sites. These rates are not readily comparable due to the disparity of metrics, terminology and methods used to define and quantify adult non-breeding rates in the literature. When assessing seabird population responses to impacts from environmental or anthropogenic pressures, vast assumptions are often made, and data is lacking to carry out robust modelling of UK seabird populations that include both breeding and non-breeding components of populations.

5. Research Opportunities

Hall & Ruffino (2026) outlines a list of six Research Opportunities (ROs), which will improve understanding of the at-sea distribution of non-breeders, their behaviour in relation to offshore windfarms, the proportion of the whole population that they make up, and their role in seabird populations.

These ROs have been developed in collaboration with a consortium of species and industry experts. Suggested project ideas mainly focus on collating existing data, making assessments of that data with a view to undertaking gap analyses, which will then inform the expansion of monitoring to new sites or scaling up of existing studies. These projects are seen as part of a dynamic process to improve knowledge of non-breeders, either working synergistically or undertaken in sequence to contribute to subsequent ROs. By and large, each of the ROs represent a single coherent piece of work of varying resource requirements. Many are entirely desk-based but there are several that involve further data collection, informed by tactical feasibility studies. This represents an appropriate balance between making the most of any data that are already available, and where required, collecting additional data to answer the questions that are unable to be fully addressed with existing data.

A total of five main ROs (RO5.1 – RO5.5) are presented in the Knowledge Gap 5 report, with an additional RO on seabirds' behavioural response to artificial light (RO5.6) identified by experts. Light attraction, disorientation and avoidance are well-recognised issues for a number of seabird species, particularly nocturnal burrow nesting seabirds such as Procellariiformes. Whilst juvenile birds appear to be highly susceptible to light-induced behavioural change, a number of critical knowledge gaps are pertinent to all age classes. Moreover, it remains unclear to what extent lighting effects differ between immature and adult birds. This is therefore an important knowledge gap for both breeding and non-breeding seabirds, and there are efficiencies to be made by addressing this issue across age groups.

The ROs described have been specifically developed to feed directly into seabird impact assessments for offshore wind, targeting multiple parts of the process (Figure 1) to ensure non-breeders are considered at each relevant stage. Hall & Ruffino (2026) follows on from the OWSMRF Pilot Year Knowledge Gaps (KG1, KG2 and KG3) and the Continuation Year Knowledge Gap (KG4), hence these ROs are numbered from five.

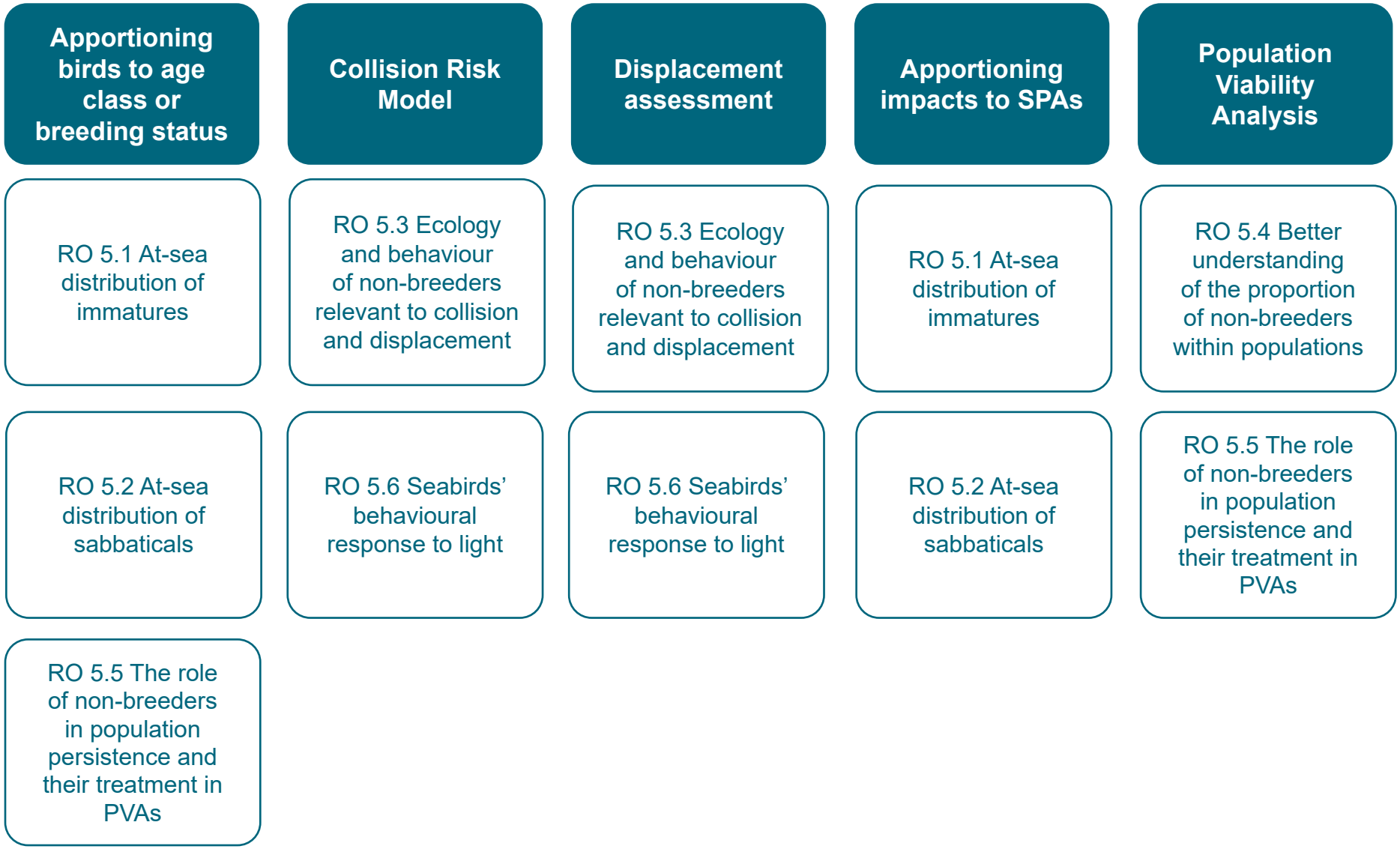


Figure 1. Summary of the six research opportunities (RO 5. 1 to RO 5.6) showing how the proposed research links to the specific stages of an impact assessment. This is outlined as follows: Apportioning birds to age class or breeding status – RO 5.1, RO 5.2, RO 5.5; Collision risk modelling – RO 5.3, RO 5.6; Displacement assessment – RO 5.3, RO 5.6; Apportioning impacts to SPAs – RO 5.1, RO 5.2; Population viability analysis – RO 5.4, RO 5.5.

5.1. Main Research Opportunities

RO 5.1 At-sea distribution of immatures

This work aims to acquire a better understanding of the at-sea distribution of immatures and how this may differ from breeding birds, and to test the validity of common apportioning assumptions within impact assessments. This will help assess exposure of immatures to future offshore wind development, therefore informing marine spatial planning. It will also allow for improvements in the apportioning processes of impact assessments.

This RO will be delivered through a series of eight steps, grouped within three main elements:

A. Literature review and feasibility study

- RO 5.1a Literature review of immature distribution
- RO 5.1b Feasibility of using existing data to improve understanding of immature distribution

B. Planning for new data collection, collection of new data and analyses

- RO 5.1c Planning for new immature tracking deployment and/or Digital Aerial Surveys
- RO 5.1d Tagging immatures and new Digital Aerial Surveys to improve understanding of at-sea distribution
- RO 5.1e Generation of immature distribution maps
- RO 5.1f Comparison of immature and breeding adult distribution
- RO 5.1g Comparison of proportion of immatures from distribution maps, stable age structure and Digital Aerial Surveys

C. Integration into impact assessments

RO 5.1h Integration of improved understanding of at-sea distribution of immatures into the impact assessment

RO 5.2 At-sea distribution of sabbaticals

This work aims to investigate the feasibility of generating distribution maps of sabbaticals, which will then be compared to the distribution of breeding adults. This will help estimate with more confidence where sabbaticals are most likely to occur at sea, therefore informing marine spatial planning. It will also allow for improvements in the apportioning processes of impact assessments.

This RO will be delivered through a series of six steps, grouped within three main elements:

A. Feasibility study

- RO 5.2a Feasibility of using existing data to understand sabbatical distribution

B. Planning for new data collection, collection of new data and analyses

- RO 5.2b Planning for new sabbatical tracking deployment
- RO 5.2c Targeted tagging programme to improve understanding of sabbatical at-sea distribution
- RO 5.2d Generation of sabbatical distribution maps
- RO 5.2e Comparison of sabbatical and breeding adult distribution

C. Integration into impact assessments

- RO 5.2f Integration of improved understanding of at-sea distribution of sabbaticals into the impact assessment

RO 5.3 Ecology and behaviour of non-breeders relevant to collision and displacement

This work investigates the parameters influencing collision and displacement risk in non-breeders, and how risk may differ from breeding birds. This will inform how mortalities of non-breeders should be quantified in impact assessments.

This RO will be delivered through a series of six steps, grouped within three main elements:

A. Feasibility study

- RO 5.3a Strategic review of tracking data on non-breeder collision and displacement parameters

B. Planning for new data collection, collection of new data and analyses

- RO 5.3b Planning for new non-breeder tracking deployment to understand risk of collision and displacement
- RO 5.3c Tagging non-breeders to understand risk of collision and displacement
- RO 5.3d Generation of collision and displacement parameters
- RO 5.3e Comparison of non-breeder and breeder collision and displacement risk

C. Integration into impact assessments

RO 5.3f Integration of non-breeders into collision and displacement impact assessments

RO 5.4 Better understanding of the proportion of non-breeders within populations

This work aims to produce robust estimates of adult non-breeding rates, based on a combination of desk-based and field-based approaches, including modelling studies, expert consultation and the deployment of remote monitoring technology. This will lead to updated recommended rates for use in assessments, and reduced uncertainty when modelling population trajectories in PVA.

This RO will be delivered through multiple possible lines of research combining desk-based and field-based elements:

A. Desk-based studies

- RO 5.4a Estimating sabbatical rates using population modelling approaches
- RO 5.4b Generation of generic sabbatical rates through expert elicitation
- RO 5.4c Feasibility of and planning for improved colony monitoring and use of novel technology to understand rates of non-breeding

B. Field-based studies

- RO 5.4d Deployment of improved colony monitoring and novel technology to understand rates of non-breeding
- RO 5.4e Generation of rates of non-breeding, including variation in rates

C. Integration into impact assessments

- RO 5.4f Integration of rates of non-breeding into population viability analysis

RO 5.5 Role of non-breeders in population persistence and their treatment in population viability analysis

This work aims to provide a quantitative evaluation of the relative importance of non-breeders in seabird population dynamics and growth, test common assumptions around the current treatment of non-breeders in impact assessments and identify an appropriate framework for the inclusion of both sabbaticals and immatures in PVA. This will enable assessments to be undertaken in a more holistic and biologically-realistic manner, considering both breeding and non-breeding components of populations. This RO is seen as a key first step towards addressing the "does it matter" question, with direct applications to impact assessment tools and guidance.

This RO will be delivered through a series of four steps, grouped within three main elements:

A. Modelling studies

- RO 5.5a Simulation of the role of sabbaticals in seabird populations
- RO 5.5b Sensitivity analyses

B. Collection of new data to improve modelling

- RO 5.5c Targeted collection of demographic data for population viability analyses

C. Integration into impact assessments

- RO 5.5d Integration of non-breeders into population viability analysis

5.2. Additional Research Opportunity

RO 5.6 Seabirds' behavioural response to artificial light

This work focuses on understanding the behavioural response of nocturnal burrow-nesting seabirds (Procellariiformes, puffins) to artificial lighting, and how this differs between breeding adults and immatures. This will help improve understanding of immature sensitivity to offshore windfarm-induced lighting, as well as possible lethal and sub-lethal consequences from collision, displacement and barrier effect. Novel evidence will then be used to inform how light effects, such as attraction, could be quantified in collision and displacement assessments.

This RO will be delivered through a series of seven steps, grouped within three main elements:

A. Collation of existing data

- RO 5.6a Making use of historic datasets to assess seabirds' behavioural response to light

B. Planning for new data collection, collection of new data and analyses

- RO 5.6b Planning for new studies to understand behavioural response to light
- RO 5.6c Deployment of new studies to understand behavioural response to light
- RO 5.6d Analysis of behavioural response to light
- RO 5.6e Comparison of non-breeder and breeder behavioural response to light
- RO 5.6f Investigate drivers of behavioural response to light

C. Integration into impact assessments

- RO 5.6g Integration of seabirds' behavioural response to light into impact assessments

Each of the six ROs are presented in Figure 2 below in terms of their level of priority, timescale and indicative budget. The integration of new evidence into impact assessments (not captured here) is a final and vital step across all ROs and will become possible as/when new evidence is delivered.

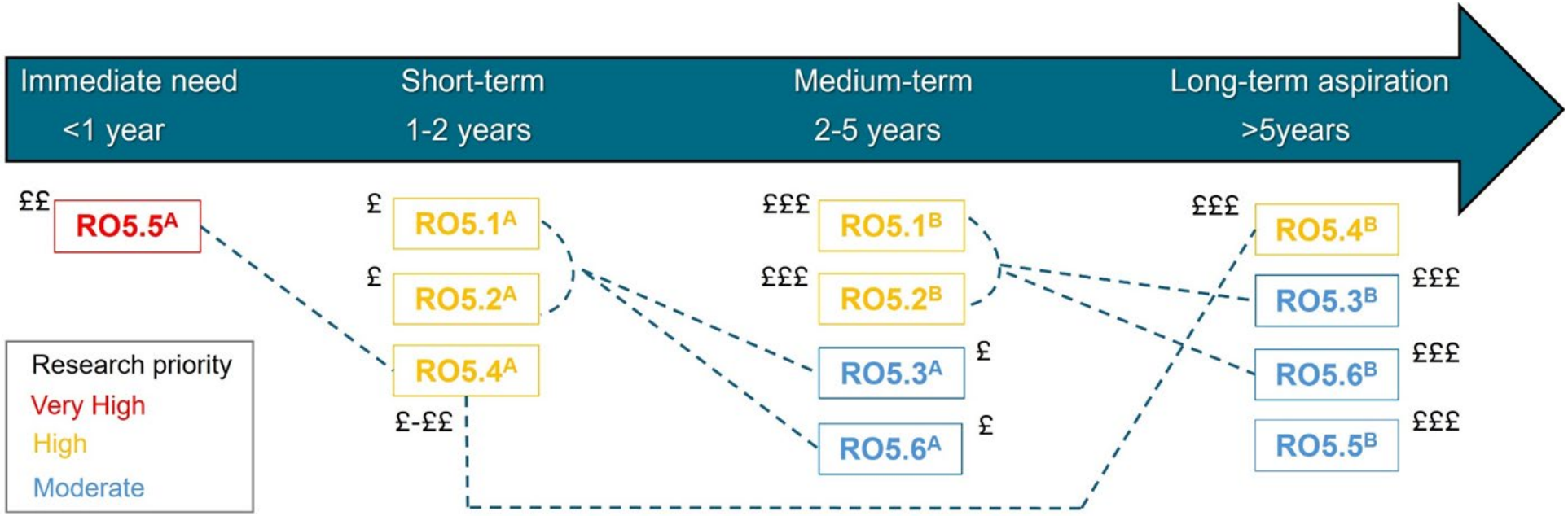
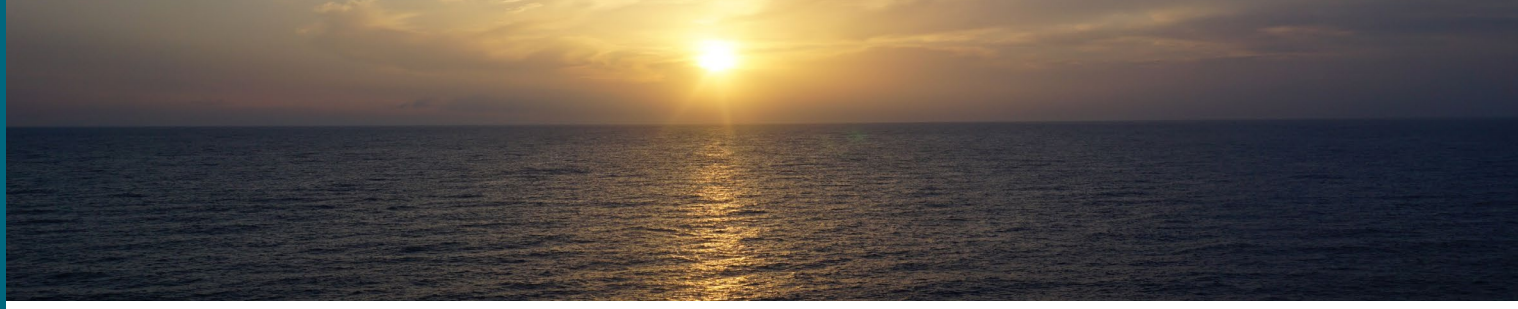


Figure 2. Synthetic diagram presenting all six Research Opportunities (ROs) in terms of their level of priority (very high, high, moderate), timescale (immediate, short-term, medium-term, longer-term) and indicative budget (low < £150,000, medium £150,000–300,000, high > £300,000). Dotted lines indicate where synergies between ROs may lie, leading to reductions in overall project costs. “A” superscripts represent desk-based elements of a research project (typically feasibility studies), while “B” superscripts refer to work packages involving field data collection.

6. Impact of research

Undertaking the proposed research will provide a range of direct benefits (Figure 3) to the UK offshore wind sector, through informing strategic planning and impact assessments. The research will also provide the necessary tools to enable holistic assessments of seabird populations, status and trends, accounting for their resilience potential to both anthropogenic and environmental pressures, which will help identify meaningful compensatory measures for offshore wind. This will also inform the management of Spatial Protection Sites (SPAs) and evaluate the effectiveness of targeted conservation actions. Additional benefits include feeding into wider UK and international seabird conservation mechanisms.

Figure 3. Diagram representing linkages between OWSMRF III research and relevant policy, management and conservation impact pathways.



7. Concluding remarks

The intention is that the Hall & Ruffino (2026) report represents a reference resource, laying out current understanding of non-breeders in seabird populations and key evidence gaps in the context of offshore wind impact assessments. It also provides a signpost towards research that can contribute to reducing uncertainty in offshore windfarm impact assessments for seabirds, specifically around apportioning of offshore wind impacts and modelling population outcomes. Improving understanding of non-breeders in seabird populations is becoming more important given the influence of extrinsic pressures such as climate change and periodic mass mortality events on seabird population dynamics. In the context of current and future offshore windfarm expansion, incremental reductions in uncertainty through research will facilitate meaningful and precise impact assessments, therefore maximising the potential for sustainable marine development within the limits set by environmental protection and regulation.

Photo credits

Cover: Offshore wind turbine with seabirds in the foreground © mcKensa/iStock

Pg.3: Greater Gabbard offshore wind farm © Creative Commons License

Pg.4: Seabirds at sea © MMO

Pg.5: Seabirds in flight © MMO

Pg.6: Northern Gannet © Rebecca Walker/Natural England

Pg.7: Guillemots © Ben Dean

Pg.13: Kittiwakes in flight © Alphotographic/iStock

Pg.14: Sunrise over the sea © Pixabay

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