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

Appendix: RO 5.6 Seabirds' behavioural response to artificial light

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Background

This appendix describes a Research Opportunity (RO) on seabirds' behavioural response to artificial light. This topic was discussed by academics, technical experts and Key Stakeholders during a non-breeding bird workshop in September 2025, delivered through the Offshore Wind Strategic Monitoring and Research Forum (OWSMRF) Phase III. This appendix relates to the main Knowledge Gap 5 report ("Advancing knowledge of non-breeding seabirds, in the context of offshore wind impact assessments"; Hall & Ruffino, 2026). The KG5 report (Hall & Ruffino 2026) presents a summary of existing evidence, and potential research avenues, to improve the understanding of non-breeding birds in seabird populations in relation to offshore wind farms. Here, non-breeding birds are defined as birds not engaged in reproduction during the breeding season, as opposed to birds during the non-breeding season.

OWSMRF is an industry-led 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 marine bird populations. During the third phase of OWSMRF (2025-2026), stakeholders identified uncertainty around the ecology and behaviour of non-breeders (immatures, sabbaticals), their specific level of risk from offshore windfarm impacts, and how they should be considered in offshore wind impact assessments, as a critical issue that is currently posing, or will likely pose in the near future, a constraint or challenge to the offshore wind consenting process.

Light attraction, disorientation and avoidance are well-recognised issues for a number of seabird species, particularly nocturnal burrow nesting seabirds such as Procellariiformes (Deakin *et al.* 2022). 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 (Deakin *et al.* 2022). 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.

RO 5.6 is presented as an appendix to the main KG5 report in acknowledgement of the fact that this knowledge gap does not solely apply to non-breeding birds. The outputs of this RO will however help improve understanding of non-breeder (i.e. immatures) sensitivity to artificial 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 non-breeder mortalities should be treated within the Population Viability Analysis stage of impact assessments.

Contents

1. RO 5.6 Seabirds' behavioural response to artificial light

1.1. Rationale

A growing body of evidence suggests that, for some seabird species, artificial lighting is a source of disturbance affecting behaviour (e.g. attraction, avoidance), which could lead to injury and death (through disorientation or collision to structures) (e.g. Montevecchi 2006; Kerlinger *et al.* 2010; Laguna *et al.* 2014; Rodriguez *et al.* 2017; Deakin *et al.* 2022). There is an assumption for some species, such as nocturnal burrow nesting seabirds, that the issue could be particularly important for inexperienced juvenile birds (Deakin *et al.* 2022), potentially increasing collision risk with offshore windfarm infrastructures as young fledge from their nests. Lighting effects may also lead to effective loss of foraging habitat (displacement) or changes in at-sea movements (barrier effect). It is currently unknown how important is the phenomenon across seabird species, what the main drivers are, to what extent lighting effects differ across age classes, and what implications these effects have on collision and displacement risk from OWFs.

Although these issues are acknowledged, impacts of lighting on at-sea behaviour are not currently considered in offshore windfarm impact assessments. There is currently no mechanism for accounting for effects of attraction to turbines within Collision Risk Models, or effects of avoidance of lighting sources in displacement assessments. The outcomes of this RO will be, where required, updated methods of estimating collision and displacement risk, accounting for behavioural responses to lighting.

1.2. Work required and predicted resources

This RO would focus on understanding the behavioural response to lighting of nocturnal burrow-nesting seabirds (Procellariiformes, puffins), and how this differs between breeding adults and immatures. Work will include sourcing and potentially collecting new data on seabird at-sea behaviour around sources of lighting to determine whether and how offshore wind farms may impact populations. This will be related back to impact assessments by considering how methods of assessing collision and displacement may be adapted to account for changes in behaviour in response to light. Alternatively, or in addition, new methods of assessing impacts induced by changes in behaviour may be required.

There is a particular order to these sub-ROs based on the outcome of the RO 5.6a. This sub-RO investigates whether historic data can be accessed and used to understand behavioural responses to light; if this is possible then comparisons between responses of breeding adults and immatures are undertaken, if not then new data collection is recommended, then continuing through the remaining sub-ROs. This process is explained in Figure 1.

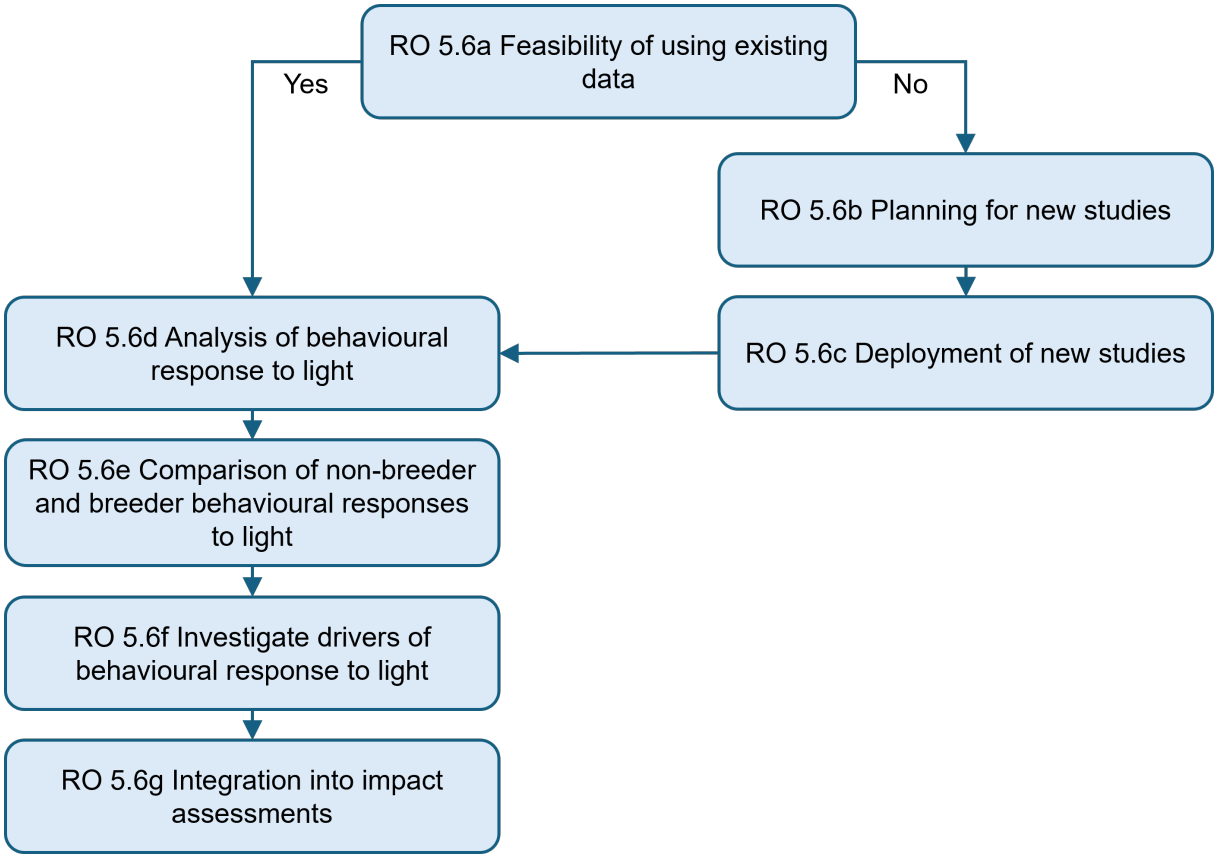

Figure 1. Order of RO 5.6 research.

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

There may be a wealth of existing data that could be interrogated to evaluate the risk of lighting attraction or avoidance in nocturnal burrow-nesting seabirds, using historic datasets. The work would start with a review of data available on light sources from different at-sea structures (including both fixed and moving, e.g. vessels) around the UK. This could include for example remote sensing data, vessel tracking data, and locations and types of offshore structures equipped with lights. Emphasis would be to collect information on different light characteristics, such as intensity, frequency, duration, colour and height.

Then, a review of available tracking data for several key species (likely including Manx shearwater, European storm-petrel, Leach's storm petrel, Atlantic puffin) would be undertaken, focusing on obtaining information on both adult breeding birds and immatures (fledgling juveniles and older immatures). Available information on light sources and seabird at-sea distribution would then be mapped together to ensure spatial scales are matching. Spatial resolutions of datasets would also need to be assessed to gauge feasibility of assessing behavioural responses to different types of artificial light disturbance in a robust manner. It may also be possible to assess the extent to which lighting effects are exacerbated by specific meteorological conditions (e.g. fog, rain).

An important part of this review exercise would be to explore the challenges related to obtaining access to both tracking and light data including legal implications of sharing data, processing data, and potential biases (e.g. tag effects, sample sizes, data resolutions).

As this is desk based, the resource requirements will be restricted in terms of time and cost. Familiarity with data of various types and format is required and experience of extracting, manipulating and combining datasets from disparate sources and in various formats is required.

Therefore, predicted resources for this sub-RO are low (less than one year and less than £100,000).

1.2.2. RO 5.6b Planning for new studies to understand behavioural response to light

If existing tracking data provides insufficient evidence to test differences in behavioural response to light between breeding adults and immatures, or is not available for certain key species, then consideration would be given to new evidence collection studies. The work would include the development of methods to test specific questions around light attraction, disorientation, attraction. This could include learning from previous experimental studies, for example, on Manx shearwater attraction to lighting on land (Syposz *et al.* 2021), and research recommendations from recent evidence reviews (e.g. Deakin *et al.* 2022). It may also use tracking data that does exist and is accessible to aid a power analysis to determine both logger deployment and tag retrieval efforts needed to achieve a robust understanding of behaviour of both adults and immature birds, capturing inter-individual/colony/annual variation. This would include, for selected species, potential monitoring sites, sample sizes, duration of study, and logger type. This may include a combination of logger types to obtain sufficient information.

As this is desk based, the resource requirements will be restricted in terms of time and cost. Familiarity with tracking deployment and experience of power analysis is required.

Therefore, predicted resources for this sub-RO are low (less than one year and less than £100,000).

1.2.3. RO 5.6c Deployment of new studies to understand behavioural response to light

If the outcome of RO 5.6b is that new studies investigating behavioural response to light are feasible, then this next phase of work would be to collect new data, on both breeding adults and immatures, as required. The resulting behavioural data would be interrogated to assess collision and displacement risk, and any other mechanism of impact, such as disorientation.

Resources required will be better understood based on the outcomes of RO 5.6b but are likely to be on the higher range.

Therefore, predicted resources for this sub-RO are high (several years and over £500,000), best achieved through a collaborative approach, e.g. combining elements from RO 5.1d (tagging immatures) and RO 5.2c (tagging sabbaticals), as described in the main KG5 report (Hall & Ruffino 2026).

1.2.4. RO 5.6d Analysis of behavioural response to light

This work would undertake the synthesis of data, whether existing or new, to understand behavioural responses to light in relation to offshore wind. This includes the interrogation of tracking data, lighting data, weather conditions, and other factors to understand how birds respond to different light sources. This will be synthesised to identify how impacts may occur, such that they may be assessed and mitigated.

As this is desk based, the resource requirements will be restricted in terms of time and cost.

Therefore, predicted resources for this sub-RO are low (less than one year and less than £100,000).

1.2.5. RO 5.6e Comparison of non-breeder and breeder behavioural response to light

This work will use the information from RO 5.6d to assess whether and how behaviours, and therefore risk from offshore wind, differ between breeding adults and immatures.

As this is desk based, the resource requirements will be restricted in terms of time and cost. Familiarity with data of various types and format is required.

Therefore, predicted resources for this sub-RO are low (less than one year and less than £100,000).

1.2.6. RO 5.6f Investigate drivers of behavioural response to light

The work would investigate the drivers of behavioural response to light, in both adult and immature birds, to gain better understanding of the variability in responses, predict level of impact, and inform mitigation. Potential factors include distance to coast or to colony, weather conditions and light source characteristics (e.g. intensity, frequency, duration, colour, height).

As this is desk based, the resource requirements will be restricted in terms of time and cost.

Therefore, predicted resources for this sub-RO are low (less than one year and less than £100,000).

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

This last step is to synthesise the work of RO 5.6a to 5.6f on seabirds' behavioural response to light across age classes to ensure the outputs can be utilised within impact assessments. Currently there is no method for quantifying lighting effects within seabird impact assessments. There is large uncertainty around the consequences of interacting with artificial lights, for example under what circumstances attraction and disorientation can lead to seabird mortality, and how collision risk related to light effects should be accounted for, and quantified, in impact assessments. This work will therefore consider whether current collision risk models and displacement assessments require adjusting to account for lighting effects, and if so, how. Required modifications will subsequently be made to assessment currently available methods and tools. Alternatively, new tools may need to be developed.

As this is desk based, the resource requirements will be restricted in terms of time and cost.

Therefore, predicted resources for this sub-RO are low (less than one year and less than £100,000).

1.3. Benefits and outcomes

This RO should provide information on seabirds' behavioural response to artificial light, and how this may influence collision and displacement. From this, the risk of both breeding adults and immatures interacting with offshore wind developments can be quantitatively analysed. It will inform whether changes to existing collision and displacement assessment methods is required, what these changes should be, or whether new light response specific models are needed. The relative risk to non-breeders compared to breeders can be analysed from this, which will then inform how mortalities of non-breeders should be treated within PVAs (as per RO 5.5 in Hall & Ruffino 2026).

1.4. Existing work, synergies, and risks

Multiple studies have been carried out and are ongoing to investigate behaviour of birds in response to offshore wind farms, however none have investigated lighting effects and how these may exacerbate offshore wind impact pathways such as collision and displacement. The OWEC-funded ProcBe (Procellariiform Behaviour and Demographics) project is tagging fledgling and adult Procellariiformes, the data from which may be useful in studies (e.g. RO 5.6a) assessing behaviour in response to light.

Reviews of evidence around lighting effects in Procellariiformes exist (Deakin *et al.* 2022), informing future research avenues and the feasibility of collecting new data from, for example, tracking studies, which this work will build on.

It is likely however that addressing the question of lighting effects on seabird behaviour and mortality using tracking data, either historic or new, will not be straightforward, due to the challenges associated with capturing potentially rare interactions at sea and the current limitations of tracking deployment for both adult and immature individuals. RO 5.6a will be a key step to assess feasibility of this work.

Work from this RO will increase the accuracy of collision and displacement mortalities of non-breeders by accounting for behavioural responses to artificial lighting and will also inform how non-breeder mortalities are treated within Population Viability Analysis, and hence feed into RO 5.5 (see Hall & Ruffino 2026).

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