MachairWind Offshore Windfarm

Annex 11.2P Evaluation of Seabird Attraction to Lighting on Offshore Windfarms

Evaluation of seabird attraction to lighting on offshore wind farms

SPR, ESB, Northland Power, Ocean Winds

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Executive Summary

Seabirds, particularly shearwaters and petrels, can be attracted to artificial light at night (ALAN). For new offshore wind farm (OWF) developments, there could be a risk of seabirds being attracted to lighting on turbines and other infrastructure. This could increase their collision risk and be costly in terms of the bird's energetics, resulting in reduced survival and productivity. This report:

- Presents a review of recently published evidence of seabird attraction to and disorientation by ALAN, along with other relevant ecological information on shearwaters and storm-petrels, building on and updating a previous review by Deakin et al. (2022);
- Reviews how OWF project consent applications have considered this impact pathway, to date;
- Describes the current safety lighting requirements on OWF infrastructure;
- Considers whether the risk of seabird attraction to ALAN on OWF infrastructure could be reduced through mitigation.

Manx shearwater *Puffinus puffinus* and European storm-petrel *Hydrobates pelagicus* have increased in numbers at most colonies designated as SPAs for these species as breeding qualifying features. Leach's storm-petrel *H. leucorhous* has declined in numbers in Britain & Ireland as well as in their stronghold in the west Atlantic. Detectability of storm-petrels in digital aerial surveys (DAS) appears to be very low but requires further experimental investigation. New flight height data confirm that all three species tend to fly very low and so are at very low risk of collision at offshore wind turbines. New evidence on flight speed and nocturnal activity data for these species is presented in this report, as is the very limited evidence on turbine avoidance rates and macro-avoidance.

Evidence regarding the extent of shearwater and petrel attraction to ALAN indicates that short wavelength light tends to cause more seabirds to become grounded or to collide with structures than long wavelength light. Constant white light appears to attract/disorient more seabirds than flashing or less intense light. Several recent studies have shown that adult shearwaters and storm-petrels tend to avoid ALAN. In contrast, shearwater and storm-petrel chicks at fledging are attracted to light. Most groundings/strandings of these shearwaters and petrels are of newly-fledged birds rather than adults. Such groundings (called strandings by some authors) almost all occur when there is no moonlight and there is greatly reduced visibility (e.g. fog). Where adult storm-petrels and very occasionally adult shearwaters are grounded, that seems likely to be due to disorientation rather than attraction, with birds unable to see where they are due to bright light in otherwise dark and foggy conditions.

Global evidence indicates that lighthouses, bright coastal industrial lights, oil and gas platform lights, and brightly lit cruise ships and fishing boats are more likely to attract/disorient shearwaters and storm-petrels than are lights on offshore wind turbines because their lights are very much brighter than those required on wind turbines. Many lighthouses, despite being very bright lights, apparently cause little or no grounding of shearwaters or storm-petrels. Collisions of shearwaters or storm-petrels at brightly lit oil and gas platforms are very rare.

Bardsey lighthouse caused groundings of large numbers of birds, including Manx shearwaters and storm-petrels. However, when the bright white rotating light beam was replaced with a red light of slightly lower intensity (but still much brighter than the lights to be used on offshore wind turbines) these collisions and groundings ceased. In that regard, it is notable that feature condition assessment identifying pressures for the Manx shearwater population did not list ALAN from the lighthouse as a pressure despite that 52,277 candelas light being only tens of metres from the colony.

Planning application Environmental Impact Assessments for OWF in areas where Manx shearwater and storm-petrels can be expected to be present in good numbers (Sceirde Rocks, Erebus, Mona, Morgan, Morecambe, West of Orkney, Arklow Bank, US Pacific coastal shelf, Oriel, Robin Rigg) generally provide little detail about ALAN impacts on Manx shearwater or storm-petrels. Currently, there is an absence of evidence of behavioural changes by Manx shearwaters and storm-petrels in response to lighting on offshore wind farms, and any associated mortality. Consequently, OWF consent applications in the near future will need to rely on expert opinion of the likely consequences of ALAN for collision risk or displacement of storm-petrels or shearwaters at offshore wind farms.

Further research to develop our understanding of how shearwaters and storm-petrels respond to ALAN could include appropriate experiments to determine whether or not the kind of artificial lights installed at offshore wind farms result in any behavioural changes of storm-petrels or shearwaters that might influence collision risk or the magnitude of any displacement effect.

A review of evidence of attraction/disorientation to shearwaters and petrels to ALAN found that lower intensity lights are less likely to affect birds. Red lights are less likely to affect birds. Flashing lights are less likely to affect birds. Aviation warning lights required at offshore wind farms are red, flashing, lights of 2,000 candelas, shaded below horizontal, and placed as high as possible on peripheral WTGs. These are much less bright than the flashing red light at Bardsey lighthouse (52,277 candelas) which has no impact on Manx shearwater or European storm-petrel. Navigation lights lower down the tower are less bright still, and so are less likely to affect shearwaters or storm-petrels than aviation warning lights. Lights at the top of towers that are shielded so that they do not light below horizontal will not be visible to shearwaters and storm-petrels flying close to sea level. Given the type of lighting on OWFs and evidence of the lack of birds becoming grounded or colliding with structures with similar lighting, it is likely that lights on OWF turbines will not cause attraction or disorientation of shearwaters or storm-petrels at UK OWFs. However, there is currently no empirical evidence to demonstrate this.

Foraging areas used by breeding Leach's storm-petrels from colonies in Britain & Ireland are almost exclusively off the continental shelf edge over deep water, so OWF are very unlikely to impact breeding adults during the breeding season. Manx shearwater and European storm-petrel foraging areas and commuting routes show overlap with some OWF areas so monitoring of breeding numbers at key SPA colonies should be a priority to monitor whether numbers remain well above the numbers that were present at SPA designation (i.e. the sites remain in Favourable Conservation Status). However, thermal camera systems on turbines would probably provide the best evidence that storm-petrels and shearwaters are not entering the rotor-swept area at night. Research studies at operational OWFs could use suitable camera systems to monitor behaviour of storm-petrels and shearwaters at WTGs. Further tracking studies may also be useful to look for evidence of attraction/disorientation of adult shearwaters and storm-petrels to ALAN. Further tracking of fledging Manx shearwaters and European storm-petrels in the first nights after leaving the burrow would be beneficial to obtain empirical evidence of them showing any attraction to ALAN. These studies would ideally be undertaken as strategic research projects, across multiple colonies and operational OWFs, to enable good experimental design and sufficiently large sample sizes. A good example of this is the ProcBe[1] (Procellariiform Behaviour and Demographics) Project, funded by OWEC (Offshore Wind Evidence and Change Programme).

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[1] ProcBe | Advisor to Government on Nature Conservation | JNCC

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Acronyms and Abbreviations

AIS	Aeronautical Information Service
ALAN	Artificial light at night
AOB	Apparently occupied burrow
AOS	Apparently occupied site
AtoN	Aid to Navigation
CAA	Civil Aviation Authority
CRM	Collision risk modelling
cd	Candelas
DAS	Digital aerial survey
DECC	Department of Energy and Climate Change
DOC	Department of Conservation (New Zealand)
DN	Digital number
EIA	Environmental impact assessment
GLS	Global location sensing (tags using ambient light to geolocate)
GPS	Global positioning system (tags using satellite data to geolocate)
GSD	Ground sample distance
HAT	Highest astronomical tide
HPAI	High pathogenicity avian influenza
HPS	High pressure sodium (light)
HRA	Habitats regulations appraisal
IALA	International Organization for Marine Aids to Navigation
IMO	International Maritime Organization
IPS	Intermediate Peripheral Structure
IR	Infra-red
JNCC	Joint Nature Conservation Committee
LED	Light emitting diode
LiDAR	Light detection and ranging
MCA	Maritime and Coastguard Agency
MD-SEDD	Marine Directorate Science Evidence Data and Digital
NASA	National Aeronautics and Space Administration
NFI	Nocturnal flight index
NLB	Northern Lighthouse Board
NVIS	Night Vision Imaging System
OWEC	Offshore Wind Evidence and Change (programme)
OWEZ	Offshore Windpark Egmond aan Zee
OWF	Offshore wind farm

ProcBe	Procellariiform behaviour and demographics (project of OWEC)
ReSCUE	Reducing seabird collisions using evidence (Natural England project)
RGB	Red green blue
RSPB	Royal Society for the Protection of Birds
SAR	Search and Rescue
SD	Standard deviation
SMP	Seabird Monitoring Programme (database)
SPA	Special protection area
SPS	Significant Peripheral Structures
TDR	Time depth recorder
UK	United Kingdom
UV	Ultra-violet
VMS	Vessel monitoring system
WTG	Wind turbine generator

1.0 Introduction

1.1 Background

1. Offshore wind farms (OWF) may impact seabirds through collisions with rotating turbine blades, or reduced survival and/or breeding success arising from displacement from within or near to the OWF, including macro-avoidance of OWFs or barrier effects for commuting birds (Cook et al., 2012, Furness et al*.,* 2013, Kelsey et al., 2025, Miller et al., 2025). Until recently, very little development of OWFs has been in locations where storm-petrels or shearwaters are frequently found. Consequently, monitoring of the impacts of offshore wind on petrels and shearwaters has been sparse and impacts are highly uncertain (Deakin et al., 2022). However, development of OWFs is now being proposed in UK and Irish waters in areas such as off north and west Scotland, in Irish waters, and in locations such as Australia and New Zealand where there are many species of petrels and shearwaters.

2. Petrels and shearwaters tend to fly low over the sea (Johnston et al., 2014, Miller et al., 2025) and are considered to be at low risk of collision with rotating offshore wind turbine blades (Deakin et al., 2022, Furness et al., 2013, Garthe and Hüppop 2004, Miller et al., 2025). They are also considered to be at low risk of displacement/barrier effects due to efficient flight and large foraging ranges (Deakin et al*.,* 2022, Furness et al., 2013). However, these species can be attracted to lighting. If they are attracted to OWF lighting this could change risk of collision and displacement mortality through (a) increasing flight heights and/or (b) disorientation/attraction reducing foraging time (Deakin et al., 2022). Deakin et al. (2022) concluded that there was a need for better understanding of: (1) biases in detectability of birds at sea; (2) flight height and speed (and their variation); (3) avoidance behaviour; (4) light attraction and (5) foraging ranges from breeding colonies.

3. There is very little evidence on the extent to which these seabird species may avoid OWFs and therefore be vulnerable to impacts of displacement (Deakin et al., 2022). In relation to the distant offshore foraging areas used by petrels and shearwaters, and their highly efficient flight, costs of barrier effects seem likely to be small, and displacement is unlikely to reduce available foraging habitat. However, Deakin et al. (2022) suggested that attraction to or disorientation by light can be considered a form of displacement, for example if birds are drawn away from foraging areas or behaviours. A particular concern is that they might be attracted by artificial lights at OWFs in a way that could potentially increase collision risk (Deakin et al., 2022), for example by being drawn from a distance and spending time circling around lights at the top of wind turbines.

4. Light pollution caused by artificial lighting at night (ALAN) is widespread and is a global concern (Falchi et al., 2016, Mander et al., 2023, Science for Environment Policy 2023). For example, at the March 2026 Convention of Migratory Species 15th Meeting of the Conference of the Parties a resolution was agreed regarding light pollution impacts on migratory species[2].

5. The main sources of ALAN are urban areas, as is clearly evident in Figure 1-1 and Figure 1-2, but sources also include large amounts of lighting at offshore oil and gas platforms, lighthouses, cruise ships and some fishing vessels (Walsh et al., 2025). ALAN affects many aspects of plant and animal ecology and can reshape entire ecosystems (Mander et al., 2023, Marangoni et al., 2022). For obvious reasons of accessibility, the main focus of research on ALAN impacts on wildlife has been in urban areas onshore, with less research carried out into impacts of ALAN in marine habitats, but a review of recent research into effects of ALAN in marine ecosystems shows this to be widespread and pervasive (Marangoni et al., 2022).

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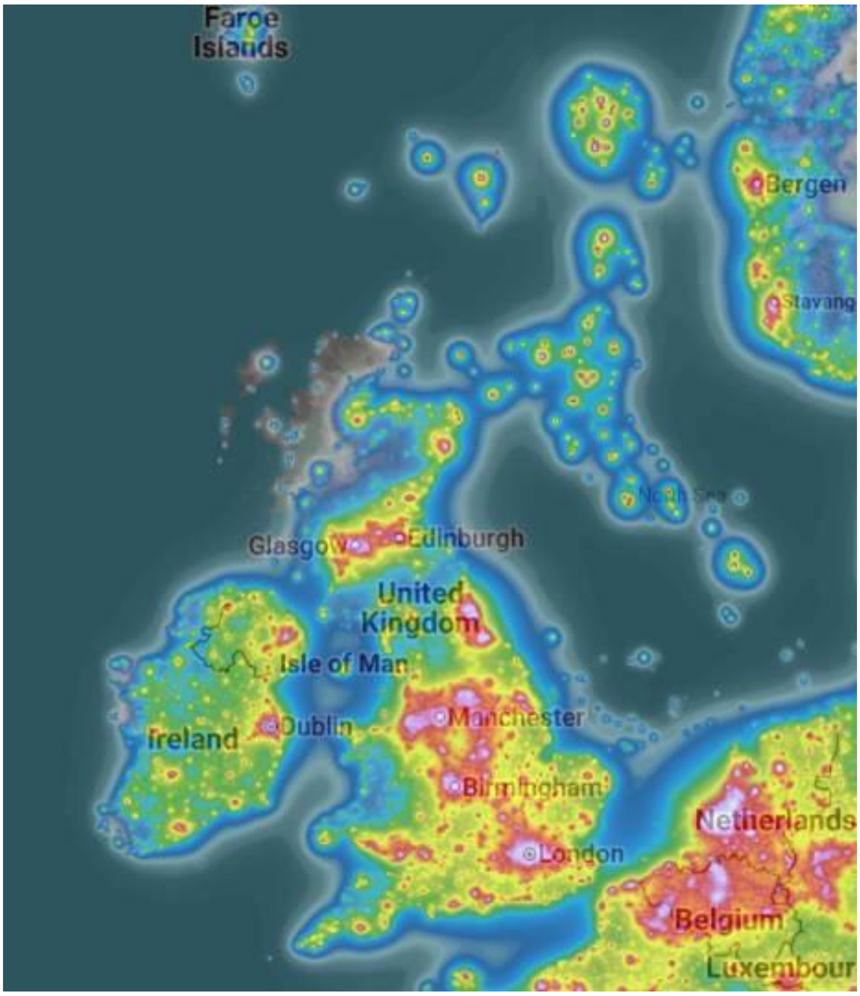
[2] Light Pollution | Convention on the Conservation of Migratory Species of Wild Animals

Figure 1-1. Nocturnal light pollution map of northwestern European waters (see Falchi et al., 2016).



6. Figure 1-2 shows the high amounts of artificial lighting at night (ALAN) in the areas occupied by oil and gas production platforms, especially in the central North Sea and Norwegian Sea, but also off the mainland of northern Scotland. Whereas it is predicted that nocturnal light pollution will increase in terrestrial areas in future (Falchi et al., 2016), it is likely to decrease in UK and Norwegian seas. This is a consequence of reduced oil and gas extraction from European waters, as those industries are the main source of artificial light at sea at night, and are anticipated to decline as the transition to renewables takes place in order to achieve net zero carbon emissions.

Figure 1-2. Nocturnal light pollution map of northwestern European waters, from NASA Earth Observatory images by Joshua Stevens, as presented by Science for Environment Policy (2023).

7. One of the groups of birds affected by ALAN is seabirds (Walsh et al., 2025, Zein et al., 2025). ALAN may provide some benefits for some seabirds, by allowing visual-feeding birds to use artificial lighting to feed at night (Zein et al., 2025). For example, Audouin’s gulls *Ichthyaetus audouinii* (Arcos and Oro, 2002), black-tailed gulls *Larus crassirostris* (Hirata et al., 2012), great black-backed gulls *L. marinus*, herring gulls *L. argentatus*, laughing gulls *Leucophaeus atricilla*, ring-billed gulls *Larus delawarensis* and royal terns *Thalasseus maximus* (Nunnally et al., 1980), southern black-backed gulls (kelp gulls) *Larus dominicanus* (Pugh and Pawson, 2016), and black-headed gulls *Chroicocephalus ridibundus* (Blackett, 1970) have been reported to benefit from ALAN as a means of extending their feeding activity into nighttime or increasing their prey-catch rate at night. Yellow-legged gulls had greater feeding success when catching European storm-petrels *Hydrobates pelagicus* at locations where ALAN was present at the colony (Oro et al., 2005). In contrast, predation of common tern *Sterna hirundo* nests by night herons was less in an artificially lit area of colony than in dark control areas (Jackson et al., 2025), indicating that the specialist nocturnal night herons avoided areas with ALAN. In the Arctic during polar night, black guillemots *Cepphus grylle* and Brunnich’s guillemots *Uria lomvia* fed more frequently at locations with ALAN

(Balazy et al., 2024, Ostaszewska et al., 2017). A study of seabird bycatch found that bycatch (mostly of northern fulmars *Fulmarus glacialis*) was higher when nets were equipped with LED lights, apparently because the seabirds were attracted to feed at illuminated nets during periods of low natural light (Sigurdsson, 2023).

8. ALAN may also have detrimental effects on seabirds. ALAN may disrupt some of the normal physiological processes of seabirds, including orientation, and in some specific cases may attract seabirds into locations of danger. However, there is much confusion in the literature between “attraction” and “disorientation”. In some cases, evidence about birds being attracted to lights may be confounded because birds are disoriented by bright light and so may remain in the vicinity of the light because they cannot see the way forward. This can be interpreted as attraction but it is not necessarily the case that the bird has been attracted at all. Similarly, the evidence that birds avoid or are attracted to ALAN may be confounded by effects of environmental conditions. Birds that would not be disoriented by a bright light under conditions of clear visibility and moonlight might be disoriented under conditions of no moonlight and fog. This does not necessarily indicate attraction to light, and few studies have discriminated clearly between attraction and disorientation.

9. Most species of adult petrels, shearwaters and puffins are not normally attracted by lights. Indeed, Manx shearwater *Puffinus puffinus* adults avoid artificial light (Syposz et al., 2021). However, some adult petrels, such as fairy prions *Pachyptila turtur* can be attracted by artificial light at night (Middlemiss et al., 2025). This issue has been a particular focus of research in New Zealand because there are many endangered species of petrels in New Zealand and these may be subject to additional mortality through bird collisions when attracted by artificial light to fishing vessels and cruise ships in particular (Department of Conservation and Fisheries New Zealand, 2023, DOC, 2025a,b,c, Lukies et al., 2019, Petterson, 2025).

10. There is evidence that fledgling burrow-nesting seabirds, especially storm-petrels, shearwaters and fledgling puffins, are attracted to ALAN as they fledge, and that this occurs mostly during “unfavourable” weather conditions of fog, during periods without natural moonlight (Imber, 1975, Rodriguez et al., 2023). The feature those seabirds have in common is that they are burrow-nesting seabirds, with chicks that depart from their burrow alone and at night, and possibly with incompletely developed vision.

11. Attraction to artificial light is frequently seen in fledging burrow-nesting seabirds during their first flight from their nesting burrow. Fledging burrow-nesting seabirds show a behavioural response to fledge towards the brightest light that they can see, as that normally takes them to the sea. This is the same phototaxis that is seen in marine turtle hatchlings (Arthur et al., 2020, Commonwealth of Australia, 2023). It provides a simple ‘rule of thumb’ that guides the fledgling to the sea because light intensity is higher over the sea than over land, due to the high reflectivity of the sea. Adult burrow-nesting seabirds such as petrels, shearwaters and puffins leave their chick alone to fledge at night without parental guidance (Harris and Wanless, 2011, Warham, 1990). Nocturnal fledging is a response to predation risk, as most predators of burrow-nesting seabirds are restricted to daytime activity and visual hunting. Evidence indicates that fledging storm-petrels, shearwaters, and puffins, are particularly at risk of being attracted by ALAN due to being burrow-nesting and fledging at night.

12. A review to inform the assessment of the risk of collision and displacement in petrels and shearwaters from offshore wind in Scotland was carried out by Deakin et al. (2022). That review concluded that there was a need for more evidence to improve understanding of biases in detectability of storm-petrels and shearwaters at sea, their flight heights and speeds, their avoidance behaviour, responses to ALAN, and their foraging ranges from breeding sites. In particular, Deakin et al. (2022) highlighted the lack of evidence on which to judge the existence and strength of responses to artificial light in European storm-petrel, Leach’s storm-petrel *Oceanodroma leucorhoa* or *Hydrobates leucorhous*, and Manx shearwater in Scottish waters, and the distance over which such responses may occur. Since publication of that detailed and comprehensive review, a number of new studies have been published, allowing some of the knowledge gaps identified by Deakin et al. (2022) to be partly filled.

1.2 UK advisor and regulator concerns

13. Artificial lighting in itself does not impact seabird populations. It is the way that artificial lighting could alter the behaviour of shearwaters and storm-petrels, causing them to be attracted to, disorientated by and/or avoid sources of artificial light. This could lead to an increased risk of mortality through collision with structures including vessels, WTG rotors. It could also alter their energetic budget, through them being displaced from preferred foraging areas or flying around OWF (i.e. barrier effects), or by spending more time in flight through disorientation, resulting in reduced survival and/or productivity.

14. This report reviews new evidence, particularly in the context of concern raised by NatureScot, and the RSPB that storm-petrels and shearwaters being attracted to and/or or disoriented by artificial lighting on OWF infrastructure could result in the following impact pathways:

- Causing birds to fly higher than normal, into the rotor swept zone, thereby increasing collision risk;
- Causing birds to circle around WTGs, thereby remaining in the rotor swept zone for longer, thereby increasing collision risk;
- Causing birds to expend more energy flying close to WTG lighting and possibly spending less time foraging, resulting in birds being in poorer body condition which could result in reduced productivity and/or survival.

15. NatureScot and RSPB have provided project-specific advice in scoping responses and scoping workshops to OWF development consent applicants, stating that these impact pathways should be fully assessed in Manx shearwater, Leach's storm-petrel and European storm petrel EIA (Environmental Impact Assessments) and HRA (Habitats Regulation Appraisals), undertaken by OWF projects, as part of their s36 consent applications. For example, the following responses were received for Arven's Scoping report:

- NatureScot: *With respect to nocturnal species impacts of lighting could be an issue. Species such as European storm petrel, Leach's storm-petrel and Manx shearwater may be attracted to and/or disorientated by artificial light sources. As well as lighting on turbines and other structures, this includes lighting on servicing or construction vessels, particularly if construction will be a 24/7 operation. Such effects could impact assessment of collision and/or displacement* (see p77 of Arven Scoping Report Consultation Response: appendix_i_consultation_responses_advice.pdf)
- RSPB: *Fundamental to the consideration of collision risk for this species is the extent to which nocturnally active seabirds, such as European Storm Petrels, may be attracted to the illuminations required for turbines, support vessels and the construction or expansion of ports. Such attraction will cause behaviour change, which could in turn increase collision risk, for example if birds fly higher when attracted to lights. Furthermore, if light-induced disorientation leads to individual birds circling the navigation lights on the nacelle or tower of turbines for protracted periods (as has been reported for birds disorientated by lighthouses or gas flares) the*

probability of collision with turbine blades or other surfaces is vastly increased (see p87 of Arven Scoping Report Consultation Response: appendix_i_consultation_responses_advice.pdf).

16. Similar responses were received for MachairWind's Scoping report:

- NatureScot: *Species such as European storm petrel and Manx shearwater, which have been recorded during DAS, are vulnerable to both lighting attraction and disorientation. As well as turbine lighting, servicing or construction vessels, particularly if construction or operation and maintenance works are undertaken on a 24-hour basis, are also of concern. Therefore, we advise the potential impact of lighting attraction and disorientation should be scoped in for assessmen*t (see p37 of MachairWind Scoping Report Consultation Response: machairwind_scoping_consultation_responses.pdf);
- RSPB, referring to European storm-petrel, Leach's storm-petrel and Manx shearwater: *All these species can be subject to attraction to light (such as those on turbine nacelles) and subsequent disorientation, (Deakin et al. 2022). Such attraction, and subsequent disorientation, could have both direct and indirect impacts on these species. Direct impacts would be collision of birds that have altered their flight trajectory to enter the rotor swept zone, and it is most likely best considered by amended collision risk models. Indirect impacts could be through the energetic consequences of additional flight, which could result in subsequent mortality or reduced breeding performance. RSPB Scotland welcomes ongoing the discussion with the Applicant as to a suitable methodology for this assessment* (see p8 of MachairWind Scoping Report Consultation Response: machairwind_scoping_consultation_responses.pdf).

17. In response to NatureScot and RSPB concerns, four offshore wind developers commissioned a desk-based review to gather information on shearwater and storm-petrel responses to ALAN. In particular, the review targeted new evidence that has been published since Deakin et al. (2022) undertook a similar review. The review presented in this report enables applicants to present a robust, up to date and evidence-based HRA and EIA for these species, in their applications.

1.3 Aim and objectives

18. This review aims to provide a better understanding of the evidence regarding storm-petrel and shearwater behaviour in response to ALAN on OWF infrastructure, that could influence risk of mortality occurring. Specifically, this review addresses four inter-related tasks:

- Task 1: Provide an updated review of available evidence regarding shearwater and storm-petrel response to ALAN, including information that has become available since the previous review by Deakin et al. (2022) was undertaken;
- Task 2: Summarise how previous OWF applications assessed impacts of ALAN on shearwaters and storm-petrels and options for undertaking future impact assessments, given available evidence. This includes a review of:
    - Use of digital aerial survey for estimating abundance and distribution of storm-petrels and shearwaters;
    - Input parameters to collision risk modelling and matrix-based displacement tools;
    - Current and upcoming research projects of relevance;
    - Use of biologging data in future OWF impact assessments;
    - Key recommendations for assessing impacts of OWF developments in north and west Scotland on shearwaters and storm-petrels.
- Task 3: Synthesise information on OWF navigational and aviation lighting requirements and how that relates to recorded attraction and stranding events involving shearwaters and petrels. This includes consideration of:
    - Characteristics of the lighting;
    - How shearwaters and storm-petrels are likely to response to the specific lighting on OWF infrastructure.
- Task 4: Consider the potential for modification and/or mitigation of lighting for OWFs, especially those located in areas which overlap with high potential for regular interactions with shearwaters and/or petrels, and how to monitor shearwater and storm-petrel behaviour and potential ALAN impacts at OWFs.

2.0 Methods

2.1 Task 1: Update on available information since Deakin et al. (2022).

19. Sourcing evidence that has become available since Deakin et al. (2022) undertook their review, was carried out using Google Scholar and Web of Science searches of the published scientific literature and grey literature (such as planning application EIAs). The review focussed on Procellariiformes, an order that includes the families Diomedeidae (albatrosses), Procellariidae (shearwaters and petrels), Hydrobatidae (storm petrels), and Pelecanoididae (diving petrels). Four species of Procellariiform regularly breed in the UK: Manx shearwater, European storm-petrel, Leach's petrel and Northern fulmar (*Fulmarus glacialis*) (Burnell et al., 2023). The term 'shearwaters and storm-petrels' is used henceforth in this report, to mean Manx shearwater, European storm-petrel and Leach's storm-petrel. This term does not include fulmar.

20. There was a particular focus on the aspects of Procellariiform ecology identified by Deakin et al. (2022) as key knowledge gaps in relation to OWF impact assessments. These were: (i) biases in detectability of birds at sea; (ii) flight height and speed (and their variation); (iii) avoidance behaviour; (iv) light attraction and (v) foraging ranges from breeding colonies. The same search terms as used in Deakin et al. (2022) were used together with any others that appeared to be useful in identifying further relevant publications. In particular, a primary focus of search effort was searching forwards in time from established publications on the subject to find new publications that cite these established works. This review searched also for evidence from overseas studies rather than aiming to focus specifically on Procellariiformes that regularly breed in the UK. This is a much broader topic as it includes many other species besides Manx shearwater, European storm-petrel and Leach's storm-petrel, as well as many other forms of lighting besides OWF infrastructure lighting. This broader review provides the most comprehensive information on the types of lighting that Procellariiformes are attracted to.

21. As explained in the Introduction, if attraction to, disorientation by, or avoidance of ALAN occurs, this can cause a change in the risk of collision and/or displacement mortality for shearwaters and storm-petrels. NatureScot and RSPB, in recent representations for Scottish OWF Scoping Reports, have flagged their concerns about increased collision and displacement risk for these species due to ALAN (see Section 1.2). Consequently, it is important to review and present any new evidence on information used as inputs to collision risk modelling and displacement mortality estimation. Additionally, impact assessments

consider not only the mortality that could arise through a particular impact pathway but how populations (e.g. SPA populations for HRA and wider regional populations for EIA) will respond to that additional mortality. Consequently, understanding the size and conservation status of these populations is also important for impact assessments.

22. Deakin et al. (2022) included information on the spatial and temporal distribution of Manx shearwater, European storm-petrel and Leach's storm-petrel. They also included a review of each species' population status and abundance, productivity and survival and foraging ecology. Deakin et al. (2022) also presented information on flight height, flight speed, avoidance behaviour and temporal activity patterns, as variables that influence collision risk. In addition, the report reviewed the risk of displacement and barrier effects arising for these species. Any new information on shearwater and storm-petrel ecology and collision/displacement risk was included in this current review, alongside existing information, under Task 1, updating the Deakin et al. (2022) review.

23. This current review presented in this report looked in particular at evidence that adult and fledgling birds may respond differently to ALAN, and included evidence on the response of puffins to ALAN, since the behavioural response of puffins is similar to that of Procellariiformes. Information not yet in the public domain was sought from the ProcBe (ProcBe | Advisor to Government on Nature Conservation | JNCC) team along with published reports from this research project (e.g. The Crown Estate, 2026). Whilst the ProcBe project is not looking explicitly at ALAN, it does look at flight heights and at-sea distribution which will help improve our understanding of the risk of ALAN impacts. Additionally, an internet search identified a number of ongoing research projects of relevance that have not yet reported, such as the 2 million Euro "Seaghosts" project https://www.biodiversa.eu/2024/04/15/seaghosts/ aiming to fill key knowledge gaps in European storm-petrel ecology and conservation.

24. This review produced a summary table listing all types of lighting that Procellariiformes were attracted to (or repelled from), in terms of wavelengths of light, intensity, whether continuous or flashing, and any other reported attributes, together with the species that were attracted (or repelled), and where known, the age classes of individuals showing behavioural responses.

2.2 Task 2: Summary of how shearwaters and petrels have been assessed and monitored at UK OWFs and options for future assessment.

25. The purpose of Task 2 was to summarise approaches used in recent OWF impact assessments for storm-petrels and shearwaters, provide information on the uncertainties and limitations associated with currently available approaches, and suggest how assessments could be improved for OWF applications that are planned for submission in the next 12 to 24 months. This involved:

- A qualitative review of the use of commonly deployed methods for OWF baseline characterisation (e.g. Digital Aerial Surveys (DAS)) for deriving accurate and representative abundance estimates of storm-petrels and shearwaters.
- A review of input parameters required to inform quantitative storm-petrel and shearwater collision risk modelling (CRM) and matrix-based displacement assessment, highlighting those which are currently unavailable, and for those which are available and have been used in previous OWF assessments, the level of uncertainty associated with them (based on expert opinion). Relevant input parameters used in the stochastic Collision Risk Model (sCRM) and the displacement matrix are listed. The quality and uncertainty around the empirical evidence for each input parameter to sCRM and the displacement matrix, is considered for Manx shearwater, European storm-petrel and Leach's storm-petrel. The time (of day and stage of the breeding season) and location when data were collected are considered in relation to how representative this is of bird behaviour at night in an OWF, when attraction to lighting could take place. Key sCRM and displacement matrix parameters are considered, including seabird density estimates, flight height information, and estimates of nocturnal activity at sea.
- Consideration of any known recent or upcoming studies (e.g. ReSCUE and ProcBe) which may aid in addressing uncertainties and data gaps. For example, Manx shearwaters and both storm-petrel species have been tagged with GPS tags from several British colonies. ProcBe and some OWF developers are also collecting additional tag data on these three species. These data could be used to improving understanding of the extent of nocturnal activity of these three species, away from the colony.
- How data from tagging projects could be included in future OWF impact assessments, and consideration of the types of information that can be collected by such projects. There already exist GPS tag data from shearwaters and storm-petrels

and more data are currently being collected. These data could potentially be used to look for evidence of tagged birds being attracted to known light sources, e.g. operational OWFs, ships (from VMS (Vessel Monitoring System) or AIS (Automatic Identification System) data) and oil and gas platforms. Consideration would need to be given to the age of tagged birds, e.g. if all are adult breeding birds, this would not provide information on the extent of attraction to lighting by fledgling or juvenile birds.

- Key recommendations for assessing the impacts of OWFs on shearwaters and storm-petrels in the north and west regions of Scotland under EIA and HRA, for projects planning to submit applications in the next 12-24 months.

2.3 Task 3: Synthesis of information on OWF lighting requirements and how that relates to recorded attraction and stranding events involving shearwaters and petrels.

26. This review considers lighting requirements on OWF structures and other OWF infrastructure, to mitigate safety risks to navigation, aviation, and Search and Rescue (SAR) operations. It is recognised that these lights serve an important safety purpose to these users and maintaining marine and aviation safety is a critical consideration of this workstream. The output of this part of the work is a list of the required lighting parameters for each light type which may be of relevance to attraction. This review covers:

- Types of lighting required. Navigational (near bottom of turbine) and aviation (on top of turbine) lighting to be considered separately.
- Colour/intensity/flashing behaviour of different types of lighting – from how far away might it be visible?
- When lighting is switched on, and when it is not (e.g. aviation lighting on most non-peripheral WTGs is often switched off apart from during Search and Rescue operations). Is it day/night specific? Does it only switch on when visibility drops below a certain threshold? Is this automated?
- Number of structures fitted with lighting, and location (i.e. often those just on periphery and/or “corners” of a site are illuminated).
- Where are these lights typically visible from? For example, in the case of aviation lighting, how visible is it from <10m above sea surface?
- Regulations around lighting – how flexible (if at all) are the requirements?

27. Technical details of the required marine, aviation, and SAR lights for a typical OWF based upon the relevant guidance and Anatec's experience have been provided. For each light type, the following parameters have been included, where such information is available either through guidance or where it represents an industry standard:

- Principles around which structures are required to display the light;
- Range;
- Intensity;
- Colour;
- Flashing characteristic;
- Details on when the light must be switched on or off including any automation;
- Night Vision Imaging System (NVIS) / Infra Red (IR) compatibility;
- Typical location of light (from which height can be inferred depending on size of foundation, tower, nacelle etc); and
- Any stipulations or allowances around light divergence, horizontal spill, hooding / baffling.

28. Where a parameter is not defined for any given light, this has been flagged.

29. The following should be considering when reviewing the identified parameters:

- The parameters provided are primarily based on written guidance, and do not account for how the requirements have been applied to lights available on the market. Further, no comment is made on whether any potential modification is possible from a practical implementation perspective by the manufacturers.
- Final lighting and marking requirements for any given project will need to be agreed with the relevant regulators noting from the marine side the relevant guidance (International Organization for Marine Aids to Navigation (IALA) G1162 (IALA, 2022)) states that individual General Lighthouse Authorities (i.e., Northern Lighthouse Board (NLB) for ScotWind projects) may have more stringent requirements. The Civil Aviation Authority (CAA) are responsible for civil aviation, and the Maritime and Coastguard Agency (MCA) for SAR. Where possible, Anatec experience has been applied in terms of known regulator requirements or parameters not specified in written guidance.
- The information presented should not be considered as any form of definitive statement that any given proposal to modify lighting requirements will be accepted.

Any proposal to regulators would need to be accompanied by an acceptable safety case to show that aviation, marine and/or SAR safety was not compromised. Such a step is outside of the remit of this work scope.

- Only lights designed for marine, aviation, and SAR have been included. Other lights including those for internal project use (e.g., working lights) are not included.
- During construction it would be standard to mark the site with lit construction buoys, and there may also be a requirement for permanent operational lit buoyage dependent on circumstances (e.g., large peripheral gaps in a layout). Such buoys have not been included.
- Marking aspects other than lighting will likely be required (e.g., sound signals, AIS), however these are not included as the focus of the work is on lighting.

30. The second part of the review relates the information in that review to what is known about the effects of ALAN on Procellariiformes. In particular, the review considers:

- How the light sources installed on OWFs compare in intensity, colour, duration etc. to other light sources, particularly those that have been implicated in documented petrel and shearwater stranding incidents.
- The appearance of OWFs, and timings of illumination, in relation to the storm-petrel and shearwater breeding season and post-breeding dispersal period.
- The intensity and colour of lighting of OWFs in relation to the petrel and shearwater visual spectrums (where such information is available) and light sources implicated in known shearwater and petrel attraction/stranding events.
- Whether any differences may be apparent in the potential risk to these species of navigational and aviation lighting respectively.

2.4 Task 4: Potential for modification of lighting arrangements for OWFs, especially those located in areas which overlap with high potential for regular interactions with shearwaters and/or petrels, either as mitigation or adaptive management, and how to monitor shearwater and petrel behaviour and potential impacts at OWFs.

31. Depending on the evidence and information gathered under the three tasks above, it may be that there remains the need to mitigate risks of attraction to/disorientation by ALAN for shearwaters and storm-petrels. Consequently, this Task aims to establish what options are available for mitigation and/or adaptive management of potential impacts of lighting on seabirds, within the current regulations. In addition, some thought is required around how

potential impacts/bird activity could be monitored at OWFs (both during the construction and operational phases) to increase certainty and confidence in predictions of potential mortality and associated impacts.

32. Therefore, a review was carried out of potential options available as mitigation, including an assessment of feasibility, and how the suggested measures might fit into existing requirements for OWF lighting. This was a multidisciplinary exercise, with input from both ornithology and lighting specialists to ensure that a thorough understanding of lighting requirements for OWFs is presented, along with the potential for modification of existing arrangements as a potential mitigation measure. Potential solutions considered the current regulatory requirements (e.g. Civil Aviation Authority, Maritime and Coastguard Agency, Northern Lighthouse Board) and feasibility of change from established requirements. The information presented under this task is considered preliminary at this stage, and consultation would be undertaken with the relevant regulators in the event that any potential mitigation was proposed to be explored further.

33. Lastly, recommendations are provided on potential research and monitoring that could be undertaken to better understand the extent of any behavioural changes by shearwaters and storm-petrels in response to ALAN, how this alters collision and displacement risk and consequently reduce survival and/or productivity in these species, and what population-level effects this could have. The recommendations focus on (i) monitoring breeding abundance at colonies, in relation to SPA citation population size, and (ii) monitoring shearwater and storm-petrel behaviour at OWF turbines.

3.0 Task 1: Updated evidence review

3.1 Population status of storm-petrels and shearwaters in the UK

3.1.1 Manx shearwater

34. In the latest national census in 2015-2021 there were estimated to be 921,618 Manx shearwater apparently occupied sites (AOS) in the UK and Republic of Ireland (Burnell et al., 2023). Most colonies showed an increase in breeding numbers since the previous census in 2000 which had counted 336,538 AOS (Burnell et al., 2023). Increases were seen at colonies in Wales, Scotland, England and Ireland. In Scotland the increase was estimated at 133%, from 126,545 AOS in 2000 to 295,194 AOS in 2015-2021. Increases have occurred in most SPAs with breeding Manx shearwater as a feature (Table 3-1).

Table 3-1. Numbers of Manx shearwater AOS at SPA colonies in the UK and Republic of Ireland in 2000 and 2015-2021 (Data from Burnell et al., 2023). Sites in Scotland are shown in bold.

SPA	AOS in 2000	AOS in 2015-2023	Change
Rum	**120,000**	**288,894**	**+141%**
St Kilda	**4,803**	**3,731**	**-22%**
Isles of Scilly	201	568	+183%
Aberdaron Coast and Bardsey Island	16,183	20,675	+28%
Skomer, Skokholm & the seas off Pembrokeshire	151,000	455,156	+201%
Copeland Island	4,633	No count	
Blasket Islands	19,534	109,390	+460%
Cruagh Island	3,286	No count	
Deenish Island & Scariff Island	2,311	15,508	+571%
Puffin Island	6,329	3,381	-47%
Skelligs	738	573	-22%

35. Manx shearwater is thought to be at relatively low risk from high pathogenicity avian influenza (HPAI) (Burnell et al., 2023) compared with other bird species, and there seem to have been no outbreaks of that virus at any Manx shearwater colonies, with only a single positive case recorded (at Rum SPA). Tremlett et al. (2024) identified Manx shearwater as having low mortality from HPAI and so gave this species a low priority for counts post HPAI impact, in 2023. Consequently, unlike seabird species more susceptible to HPAI mortality,

the JNCC SMP database does not hold any Manx shearwater counts at these SPAs for years since the last national census (i.e. for 2022 onwards).

36. Care must be taken in the interpretation of change in numbers, as new census methods have been developed and are inconsistent between time periods (Matthiopoulos et al., 2025). Manx shearwaters are difficult to census, but the evidence suggests a substantial increase in breeding numbers since 2000. There are some colonies where numbers have certainly decreased, including the small colonies of this species in Shetland. Loss of Manx shearwaters from those sites may be due to a variety of factors, including predation by feral cats (Pennington et al., 2004). Rats and mice are also known to impact Manx shearwaters, although the colony at Rum has coexisted with these small mammals for many decades. There is some evidence that productivity is affected in some years but depredations by rats and mice have not been a main driver of population change at that colony (Burnell et al., 2023, Matthiopoulos et al., 2025).

37. A recent study provides updated adult survival data for breeding Manx shearwaters at Copeland Islands where mark-recapture studies began in 1952 and at Skomer where mark-recapture studies began in 1977. Comparison of adult survival between 1977 and 2020 showed mean survival of 0.96 at Copeland (95% confidence interval 0.94 to 0.97) and mean survival at Skomer of 0.94 (95% confidence interval 0.91 to 0.96) and a high proportion of annual variation being synchronous between the colonies (Horswill et al., 2023). The authors interpret the difference between colonies as indicative of a density-dependent effect, the lower survival being at the much larger colony (Skomer) and infer that there is a carry-over effect of competition at the colony associated with foraging distances in the breeding season carried over into overwinter survival rates. Density-dependence of adult survival rate has important implications as it will tend to buffer population size against impacts of additional mortality such as may be caused by OWFs.

38. Recent analysis of existing data sets has provided new estimates of adult survival of Manx shearwaters at Copeland, Skomer, Rum, Lundy, Calf of Man, Skokholm, Ramsey, and Sanda, and of European storm-petrels at Molene, Priest Island, Lunga, Biarritz, Skomer and Sanda, and of juvenile survival of Manx shearwaters at Skomer (The Crown Estate, 2026).

39. Modelling of Manx shearwater population dynamics and change in breeding numbers at Rum, one of the largest colonies of this species, found that the population is robust to strong pulse perturbations, but is vulnerable to small but sustained perturbations in adult survival

such as might be caused by impacts of offshore wind farms close to the colony (Matthiopoulos et al., 2025). However, the analysis also showed that the population has been increasing since the 1980s and may now be starting to reach environmental carrying capacity and is most likely being subject to density-dependent regulation of population size as a consequence of intra-specific competition.

3.1.2 European storm-petrel

40. In the latest national census of breeding seabirds in the UK and Republic of Ireland, in 2015-2021, there were estimated to be 147,578 European storm-petrel AOS (Burnell et al., 2023). That is a 17% increase on numbers counted in Seabird 2000 (125,722 AOS). Changes in count results between these national censuses were highly variable among colonies, with some SPAs with European storm-petrel as a breeding feature showing large increases and some showing decreases (Table 3-2)

Table 3-2. Numbers of European storm-petrel AOS at SPA colonies in the UK and Republic of Ireland in 2000 and 2015-2021 (Data from Burnell et al., 2023). Sites in Scotland are shown in bold.

SPA	AOS in 2000	AOS in 2015-2023	Change
Auskerry	**994**	**692**	**-30%**
Flannan Isles	**7**	**376**	**+5,271%**
Mousa	**5,410**	**10,778**	**+99%**
North Rona and Sula Sgeir	**380**	**999**	**+163%**
Priest Island (Summer Isles)	**4,947**	**4,640**	**-6%**
St Kilda	**1,121**	**952**	**-15%**
Sule Skerry and Sule Stack	**309**	**177**	**-43%**
Treshnish Isles	**5,040**	**10,261**	**+104%**
Isles of Scilly	1,475	1,326	-10%
Skomer, Skokholm & seas off Pembrokeshire	2,501	2,586	+3%
Bills Rocks	500 (guess)	36	
Blasket Islands	52,141	56,147	+15%
Deenish Island and Scariff Island	6,200 (guess)	11,049	
Duvillaun Island	950	134	-86%
Illanmaster	8,625 (guess)	2,400	
Inishglora and Inishkeeragh	3,423	3,677	+7%
Magharee Islands	55 (guess)	923	
Puffin Island	5,177	No count	

SPA	AOS in 2000	AOS in 2015-2023	Change
Skelligs	9,994	7,657	-23%
Stags of Broadhaven	1,912	503	-74%
The Bull and Cow Rocks	3,500 (guess)	No count	

41. Care must be taken in the interpretation of change in numbers, as new census methods have been developed and are inconsistent between time periods (Burnell et al., 2023). European storm-petrels are difficult to census, but the evidence suggests that there has probably been a small increase in breeding numbers.

42. As a burrow-nester, European storm-petrel is thought to be at relatively low risk from high pathogenicity avian influenza (HPAI) (Burnell et al., 2023) and there seem to have been no outbreaks of that virus at any European storm-petrel colonies. Tremlett et al. (2024) classified European storm-petrel colonies as low priority for additional survey following HPAI impacts, due to the low likelihood of populations having changed substantially following HPAI outbreaks.

3.1.3 Leach’s storm-petrel

43. 44. In the latest national census in 2015-2021, of breeding seabirds in the UK and Republic of Ireland, there were estimated to be 10,765 Leach’s storm-petrel AOS, compared to an estimated 48,357 AOS in Seabird 2000 (Burnell et al., 2023). This species has declined significantly at Shetland, no longer nesting at Foula where depredations by feral cats are thought to have caused local extinction (Burnell et al., 2023). It is estimated that Scotland’s Leach’s storm-petrel population has declined by 79% between the two latest national censuses, whereas numbers in Ireland appear to have increased (Burnell et al., 2023) (Table 3-3).

Table 3-3. Numbers of Leach’s storm-petrel AOS at SPA colonies in the UK and Republic of Ireland in 2000 and 2015-2021 (Data from Burnell et al., 2023). Sites in Scotland are shown in bold.

SPA	AOS in 2000	AOS in 2015-2023	Change
Flannan Isles	**1,425**	**229**	**-84%**
Foula	**15**	**0**	**-100%**
North Rona and Sula Sgeir	**1,137**	**435**	**-62%**
Ramna Stacks and Gruney	**20**	**5**	**-75%**

SPA	AOS in 2000	AOS in 2015-2023	Change
St Kilda	**45,433**	**9,233**	**-80%**
Sule Skerry and Sule Stack	**0**	**0**	
Stags of Broadhaven	310	817	+164%

44. There has been a large decline in Leach’s storm-petrel numbers in eastern Canada where the population is very much larger than in the British Isles. A review of expert opinion as to the likely causes of this decline concluded that the main pressures are likely to be avian and mammal predators at colonies and onshore light attraction (Pollet et al., 2023). At-sea threats were less clear, but were thought likely to include offshore artificial lights, spatial shifts in prey, contaminants, and climate change (Pollet et al., 2023). It is unclear how much connectivity there is between UK colonies and those in Canada. A major factor contributing to the decrease in Scotland seems to be depredations by great skuas *Stercorarius skua* at St Kilda (Burnell et al., 2023). As burrow-nesters, Leach’s storm-petrels are thought unlikely to be at high risk from HPAI, but the decrease in the great skua population at St Kilda caused by HPAI in 2021 and 2022 is likely to have reduced predation pressure on Leach’s storm-petrels there (Burnell et al., 2023). As for Manx shearwater and European storm-petrel, Tremlett et al. (2024) categorised Leach’s storm-petrels as low priority for post-HPAI outbreak surveys of numbers of breeding birds, on the assumption that any changes in population size in response to any HPAI mortality would be very small or absent.

3.2 Detectability of storm-petrels and shearwaters at sea in aerial surveys

45. Baker et al. (2022) considered the need for better evidence on at-sea distribution of European storm-petrels and Manx shearwaters, but with a focus on tracking studies rather than DAS. In UK and Irish waters, the standard method for determining baseline abundances of seabirds in areas proposed to be developed for OWF is to carry out DAS, either using still or video photography from aircraft transects (APEM, 2024a,b, Cork Ecology, 2025, MacArthur Green, 2024a,b, RPS, 2019). Deakin et al. (2022) concluded that there is an important need for experimental validation of potential biases in aerial survey methods, including detectability, identification, and diel variation. In particular, there seems to be a lack of validation of DAS for detecting small seabirds, and it is highly likely that detection is particularly low for storm-petrels. There are also difficulties with Manx shearwater. The dark upper surface plumage may render this species cryptic against the sea, especially for birds sitting on the water. Recent DAS include difficulties in identifying Manx shearwaters to

species (often having to group some birds as “shearwater species” or “small shearwater species”) but also in discriminating between shearwaters and auks, using a category “auk and/or shearwater species” (APEM, 2024a,b). It is unclear whether use of artificial intelligence will improve on detectability in future as that has not yet been validated for storm-petrels or shearwaters (Bartlett et al., 2025).

46. Tests with model seabirds over a grass background at an airfield in Cornwall showed that one DAS provider failed to detect any of the dark-coloured storm-petrel models (of birds in flight) while another detected between 30 and 75% of storm-petrel sized models (with many of those being light coloured rather than black). This suggests that real storm-petrels in flight at sea over a marine background of waves may be under-detected to an even greater extent (Rhoades et al., 2025). That study did not deploy any storm-petrel models of birds resting on the sea surface.

47. Detection of seabirds in aerial surveys can be influenced by weather conditions, such as glare from the sun reflecting off the sea surface (which can potentially be accounted for statistically). Seabird detection during DAS can also be influenced by other factors that can be controlled and standardised such as aircraft altitude and speed. There can be issues with species misidentification and non-detection, even for moderate-sized seabirds such as shearwaters and auks (Wilkinson et al., 2025). However, Wilkinson et al. (2025) state, “*there is a considerable lack of knowledge on the detection accuracy and optimum design of aerial surveys for the smallest seabird species in our oceans (i.e. the storm-petrels)”*.

48. Wilkinson et al. (2025) used aerial surveys with observers to record megafauna in Irish waters. Aircraft flew at an altitude of either 76m or 183m, at a speed of 90-100 knots, and all sightings of marine mammals, basking sharks *Cetorhinus maximus* and seabirds, including storm-petrels, within 200m of the transect line on each side of the aircraft were recorded, with 95% of survey effort during surface wind speeds of Beaufort Force 3 or less. Their analysis of storm-petrel sightings assumed 100% detection within the 400m strip width. However, data analysis showed that detection was less during flights at 183m altitude than at 76m and was less under rougher sea conditions (despite surveys being limited to low Beaufort Wind Force conditions). Wilkinson et al. (2025) also noted that storm-petrels resting on the sea surface were largely undetected, but that bias could not be corrected as the proportion of time spent on the sea surface is unknown (although such data could potentially be obtained from tracking studies where bird behaviour can be inferred from tag data, and it

seems likely that the amount of tracking data now available could provide a good estimate of this).

49. Overall, their survey resulted in an estimate of 154,000 storm-petrels in an area extending 200 nautical miles from the west coast of Ireland and throughout Irish waters to the north, east and south of Ireland, but it is difficult to assess how much that estimate is below the true number present (Wilkinson et al., 2025). Contrary to expectation, estimates of at-sea numbers decreased later in the breeding season (during chick-rearing) when an increase had been expected, and the authors concluded that further research is needed into the optimum survey methodology for storm-petrels at sea.

50. There were estimated to be 108,423 AOS of European storm-petrels at Irish colonies in 2015-2021 (Burnell et al., 2023). If it is assumed that half of the breeding adults are attending the nest and half are at sea within Irish waters (which is likely to be the case during incubation and the brooding period but both adults are likely to be at sea during daytime during the post-brooding stage (Bolton, 2021)), and that there are similar numbers of immatures to the numbers of breeding adults (which seems likely based on our understanding of European storm-petrel demography) but with almost all immatures being at sea during daytime when aerial surveys are carried out (which seems likely based on our understanding of European storm-petrel ecology), then we might guess at there being about 300,000 European storm-petrels in Irish waters in summer. This could suggest that the visual aerial survey carried out by Wilkinson et al. (2025) may possibly have detected about one-half of the storm-petrels that were in their survey transects.

51. How DAS performs compared to the lower-flying visual aerial survey method used by Wilkinson et al. (2025) is unknown. Digital photographic aerial survey (DAS) is generally considered to perform better than visual aerial surveys for conspicuous seabirds (Buckland et al., 2012; Zydelis et al., 2019). The current standard method of DAS uses cameras that typically are intended to provide a resolution of 2 cm Ground Sample Distance (GSD) (e.g. MacArthur Green, 2024a,b), but note that apparently the commonly assumed 2 cm GSD seems rarely to be achieved, as analysis of HiDef survey photography found that the outcome, “*was inconsistent across survey frames, with no part of any image achieving 2 cm/px, due to camera angles and aircraft configuration*” (Bartlett et al., 2025). It seems likely that such a limit of resolution will be inadequate to provide high detection of storm-petrels sitting on the sea surface or even of storm-petrels in flight (Bartlett et al., 2025).

52. In all 24 DAS of the Arklow Bank OWF area, only one storm-petrel was recorded (MacArthur Green 2024, a,b). In all 24 DAS at Mona, Morgan and Morecambe (i.e. 72 surveys) only one storm-petrel was detected, but the SOSS migratory bird model predicted much larger numbers in autumn, not detected in DAS. A DAS in the South-West Celtic Sea in late June 2023 as part of the POSEIDON project detected 57 storm-petrels in a survey area of 18,011 km^2 (APEM, 2024a). That survey reported a GSD averaging 1.5 cm but varying according to the position of the target. There is no assessment of detectability of storm-petrels in that survey. Numbers of storm-petrels present in the Celtic Sea are likely to be relatively high in late June and it is notable that the total estimated is considerably lower than for the relatively scarce but much larger Cory's shearwater *Calonectris borealis* in the same survey (APEM, 2024a), which suggests a possible under-detection of storm-petrels. Similarly, a survey in September 2023 detected an estimated 17 storm-petrels in the same survey area but found 316 Cory's shearwaters, 77 great shearwaters *Ardenna gravis* and 96 "large" shearwaters (APEM, 2024b), again suggesting that the numbers of storm-petrels detected probably represent only a small but unknown fraction of those present.

53. It is probably necessary at present to assume that DAS fails to detect many or most storm-petrels present in survey transects, and that any correction for detectability should be based on calibration tests using models, or known locations of tagged birds, as previously suggested by Deakin et al. (2022).

3.3 Flight heights of storm-petrels and shearwaters

54. Flight height, or more specifically, the proportion of birds likely to be flying within the span of the rotor of a wind turbine, is an important parameter used in the assessment of collision risk. Flight heights of seabirds can be estimated, or measured, using a variety of methods, each of which may be subject to high uncertainty and possible bias (Rhoades et al., 2025). Data tags of the sort required to measure flight height may influence seabird behaviour. Estimating distributions of flight heights using radar can miss birds close to the sea surface due to wave clutter. Visual estimates and estimates using rangefinders may be similarly biased by detectability with birds close to the waves or between wave crests being overlooked. LiDAR (light detection and ranging) may provide accurate measurements but has been used very little for seabird flight height measurement and appears to be affected by variable bird-detection rates, this being particularly low (less than 10%) for small and dark-coloured targets such as storm-petrels (Rhoades et al., 2025). DAS seems to provide only very imprecise, and possibly biased, estimates of flight heights (Boersch-Supan et al., 2024, Rhoades et al., 2025). There remains high uncertainty about seabird flight heights.

55. A global review of the evidence on flight heights of storm-petrels, shearwaters and other Procellariiform seabirds was carried out very recently (Miller et al., 2025). That work created a global database. The database can be accessed at https://doi.org/10.5061/dryad.tx95x6b84. Data on flight heights, mean flight height and percentage of time spent at rotor-swept zone (RSZ), and additional anecdotal values were extracted from the literature. Percentage time in the RSZ is represented in the database with a mean value and associated turbine air gap attribute (10 m, 20 m or 30 m), data quality classification (high, medium, low), and study metadata. Mean flight height values are shown in varied formats as they appeared in the literature (means, median, range) with associated sample sizes and study metadata. Values for use in CRM are recommended for each species and, where appropriate, for geographical regions.

56. For Manx shearwater, based on a review of several different studies, Miller et al. (2025) report a mean flight height of 1 m above sea level (SD 0.49m), median range 0-5 m (high data quality) and proportion of flight time in rotor-swept zone (20 m air gap) a precautionary estimate of 0.01% (minimum 0, maximum 0.04) (high data quality).

57. For European storm-petrel, Miller et al. (2025) report a mean flight height of <1 m above sea level, range 0-5 m and proportion of flight time in rotor-swept zone (20m air gap) a precautionary estimate of 1% (low data quality).

58. For Leach’s storm-petrel, Miller et al. (2025) advise for CRM a mean flight height of 1 m above sea level (SD 0.86 m) range 0-5 m (high data quality), time in rotor-swept zone (20 m air gap) a precautionary estimate of 1% (low data quality).

59. Flight heights of shearwaters and storm-petrels are being measured in the ongoing ProcBe project using altimeter tags, high resolution GPS tags and laser rangefinders (The Crown Estate, 2026). Barometric tags deployed on Manx shearwaters indicated that 97.7% of flight occurred at less than 15 m above sea level. High resolution GPS tags indicated that 99.8% of flight occurred at less than 15 m above sea level. These values differ from those reported by Miller et al. (2025) and reasons for that are not clear but may relate to errors in the barometric tag methodology (e.g. see Schaub et al., 2023). Laser rangefinder data indicated that all flight was at less than 20m above sea level with most at less than 5 m above sea level. Flight heights were lower during calmer weather than during windier weather. European storm-petrel flight heights measured with laser rangefinder were mostly less than 0.3 m above sea level and all were below 5m above sea level. These new data further

strengthen the conclusion that collision risks for Manx shearwater and European storm-petrel at OWFs is extremely low, and probably negligible, during daytime flight activity of those species.

3.4 Flight speeds of storm-petrels and shearwaters

60. A global review of the evidence on flight speeds of storm-petrels, shearwaters and other Procellariiform seabirds was carried out very recently (Miller et al., 2025). As mentioned above under ‘flight heights’, that work created a global database that can be accessed at https://doi.org/10.5061/dryad.tx95x6b84. Data on flight speed, whole trip speed, maximum speed and additional anecdotal values were extracted from the literature. The database presents each speed value as a mean and standard deviation, with sample size (number of birds) and study metadata. Values for use in CRM are recommended for each species and, where appropriate, for geographical regions.

61. For Manx shearwater, Miller et al. (2025) advise for CRM a mean flight speed of 8.57 m/sec (SD 3.29 m/sec) (high data quality, based on sample of 197 birds).

62. For European storm-petrel, Miller et al. (2025) advise for CRM a mean flight speed of 4.2 m/sec (SD 2.13 m/sec) (moderate data quality, based on sample of 81 birds).

63. For Leach’s storm-petrel, Miller et al. (2025) advise for CRM a mean flight speed of 6.52 m/sec (SD 2.68 m/sec) (high data quality, based on sample of 120 birds).

3.5 Nocturnal flight activity of storm-petrels and shearwaters

64. A global review of the evidence on nocturnal flight activity of storm-petrels, shearwaters and other Procellariiform seabirds was carried out very recently (Miller et al., 2025). That work created a global database. The database can be accessed at https://doi.org/10.5061/dryad.tx95x6b84. The database contains raw data on nocturnal activity and a Nocturnal Flight Index (NFI). Miller et al. (2025) define the NFI as the difference between the proportions of time spent in flight during darkness and during day-light, divided by the higher of these two values. NFI varies between −1 when all flight activity each day occurs in daylight, and 1 when all flight activity takes place in darkness. Percentage of time flying (day versus night) was extracted from literature, presented in the database as mean and standard deviation, with associated sample size (number of birds) and/or data quality assessment (high, medium, low). NFIs are either as presented in the

literature or are calculated from the raw data presented in the literature. Where available, NFIs are given separately for subsets of birds (e.g. males, females, or adults, juveniles). Each NFI value is presented as a mean and standard deviation with associated sample size and metadata. Values for use in CRM are recommended for each species and, where appropriate, for geographical regions.

65. For Manx shearwater, Miller et al. (2025) advise for CRM a night flight index (NFI) of -0.50 (SD 0.39) based on a sample of 58 birds.

66. For European storm-petrel, Miller et al. (2025) advise for CRM a night flight index (NFI) of 0.42 (SD 0.13) based on a sample of 8 birds.

67. For Leach’s storm-petrel, Miller et al. (2025) advise for CRM a night flight index (NFI) of 0.52 (SD 0.21) based on a sample of 12 birds.

68. A study, published after the literature review by Miller et al. (2025) was completed, deployed geolocator tags on two species of storm-petrel very closely related to Leach’s storm-petrel (previously considered to be a sub-species of Leach’s storm-petrel) (seven Townsend’s storm-petrels *Hydrobates socorrensis* and four Ainley’s storm-petrels *H. cheimomnestes*) breeding on Guadalupe Island, Mexican Pacific. That study found that the proportion of time that these birds flew during the night (73% and 52%) was more than during the day (31% and 33%), giving nocturnal flight indices (NFI) of 0.57 and 0.32 respectively, suggesting primarily nocturnal foraging. The tag data also showed significantly increased nocturnal flight activity on nights with more moonlight (Medrano et al., 2024). The NFI estimates are close to those suggested for Leach’s storm-petrel by Miller et al. (2025) but the observation that flight activity at night is increased during full moon and reduced during new moon periods is highly relevant to considerations around potential impacts of ALAN.

69. As shown in the case of Townsend’s storm-petrels and Ainley’s storm-petrels, the extent to which seabirds fly at night may be influenced by many factors and is likely to be flexible depending on the context. Seabird tracking studies can potentially provide evidence of such flexibility for a range of relevant species. For example, 774 adult Manx shearwaters geolocator-tracked from Lundy, Ramsey, Skomer and Rum during their trans-hemispheric migration primarily migrated during daylight. However, although Manx shearwaters on migration rarely foraged at night, birds spent more time on migratory flight at night if they were late-departing from the breeding colony, and especially when there was moonlight (based on theoretical calculations and not corrected for local weather effects on moon

visibility) providing the light conditions required for visually guided flight (Siddiqi-Davies et al., 2024b). As a consequence, birds took fewer days to complete their migration if they were late to leave the breeding site and if there was moonlight to allow them to fly at night. The authors point out that the shear-soaring or flap-gliding flight of shearwaters requires the ability to assess accurately the distance to the sea surface, which will be possible under moonlit conditions but difficult in darkness and that this is likely to be an important factor determining how much or how little shearwaters fly at night.

70. Deployment of GLS and TDR tags on adult Manx shearwaters breeding at Skomer showed that almost all foraging activity occurred during daylight with little temporal variation other than a large decrease in the evening (especially pronounced in males) and low level in early morning (Siddiqi-Davies et al., 2025).

3.6 Avoidance behaviour of storm-petrels and shearwaters at offshore wind farms

71. Avoidance behaviour, usually expressed as a rate of avoidance, encompasses the extent to which birds avoid the wind farm, the individual wind turbines, or the moving rotors. The avoidance rate is a critical parameter used in the assessment of collision risk.

72. Deakin et al. (2022) found no information in the literature regarding the extent of macro-, meso- or micro-avoidance of offshore wind turbines by European storm-petrels or Leach’s storm-petrels. (See Cook et al., 2014, for definition and further information on avoidance in relation to collision risk modelling.) They also found no quantitative estimates of avoidance by Manx shearwaters but suggested that this species may show slight macro-avoidance of offshore wind farms. They also inferred that the morphology of this species is likely to limit manoeuvrability and so is likely to reduce micro-avoidance capability.

73. Miller et al. (2025) note, “Despite the sensitivity of CRMs to avoidance rate, it is the least well-known parameter because, unlike other parameters, avoidance can only be estimated after windfarms are built. Given that a recent review of Procellariiformes in Europe found avoidance information for only two species (Manx shearwater and northern fulmar; Deakin et al., 2022) despite about 30 years of offshore wind farm operation ….. we have not included avoidance rate in this review”.

74. Kelsey et al. (2025) were unable to find any data on avoidance of offshore wind turbines by petrels or shearwaters apart from an estimated macro-avoidance by northern fulmars of 0.28

(based on Krijgsveld et al., 2011) and the suggestion of Cook et al. (2012) of a macro-avoidance by Procellariiformes of 0.5 (although that also was apparently based on evidence in Krijgsveld et al., 2011). Kelsey et al. (2025) adopted 0.39 as an estimate of Procellariiform macro-avoidance for all species other than northern fulmar which they set at 0.28 based on Krijgsveld et al. (2011).

75. In a statistical meta-analysis, Lamb et al*.* (2024) found slight evidence of macro-avoidance of offshore wind farms by Procellariiformes. In their study these were northern fulmars and Manx shearwaters at Robin Rigg (Canning et al., 2013), Princes Amalia Wind Park (PAWP) and Offshore Windpark Egmond aan Zee (OWEZ) (Leopold et al., 2013), Bligh Bank OWF (Vanermen et al., 2015), Bligh Bank OWF and Thorntonbank OWF (Vanermen et al., 2016); with a significant effect detected at only one of the five data sets for only one of the two species but with an apparently large effect size. It is not clear from the published paper whether the one significant example of macro-avoidance was for northern fulmar or for Manx shearwater (which in the paper were both termed “Taxon: fulmars”), or which of the five reviewed studies showed that significant effect. However, the significant result seems to relate to Robin Rigg OWF, and in the cases of PAWP, OWEZ, Bligh Bank OWF and Thorntonbank OWF, there were only fulmars recorded in surveys and not Manx shearwaters (Leopold et al., 2013, Vanermen et al., 2015, 2016). None of the data sets reviewed by Lamb et al. (2024) had enough data on storm-petrels to allow an analysis for that group.

76. At Robin Rigg OWF, baseline surveys found Manx shearwaters and European storm-petrels during breeding season months, with totals of 1,566 Manx shearwaters and 20 European storm-petrels (Canning et al. 2013). During construction both species were recorded in surveys with a total of 1,685 Manx shearwaters and 19 European storm-petrels. However, during the first three years of operation the numbers of both species were considerably lower; 726 Manx shearwaters and 0 European storm-petrels (Canning et al. 2013), which could possibly be indicative of macro-avoidance, or could have resulted from other factors that changed between pre-construction and operation. This study was by boat-based survey using a vessel with a lower viewing platform than recommended and with a different survey methodology during the operation period surveys, and so there are questions about the suitability of these data for making robust conclusions (Canning et al., 2013).

77. In a review commissioned by Equinor, in particular related to effects on seabirds of ALAN from offshore oil and gas platforms, Zein et al. (2025) state “*Artificial light at night (ALAN) is known to affect navigation skills, lead to attraction and increase collision risks for birds,*

including seabirds". However, in their review of this topic they provide no evidence that indicates any increased risk of collision with OWF turbines as a result of ALAN. Indeed, they define ALAN as "*encompassing direct lighting and skyglow produced by upwardly emitted and scattered light arising from sources such as streetlights, buildings, vehicles, industrial and port facilities, and offshore oil platforms, ships, and fishing fleets*". Their review does not specifically focus on OWF lighting effects on seabirds, and of the records they reviewed, 84 were with the source of ALAN being land-based light pollution, in 19 the source was light from fishing boats, and in six the source of light was from offshore oil and gas platforms. None were based on evidence from offshore wind farms.

78. The ProcBe[3] OWEC research project includes tracking of Manx shearwater fledglings from three colonies as part of WP1 of the project. Fledglings may have higher vulnerability to OWF impacts than adults due to an increased likelihood of attraction to ALAN and their flight inexperience. Both of those factors may result in a different spatial distribution of first-time migrants compared to adults. The ProcBe OWEC programme aims to resolve that gap in evidence by tagging fledging individuals (Siddiqi-Davies et al., 2024a). The only part of that work published up to now (January 2026) is a review of potential tracking technologies that could be used on Manx shearwater fledglings (Siddiqi-Davies *et al*. 2024a). That review concluded that deployment of OrniTrack-T9D 3G solar-powered transmitters was the most appropriate for tracking fledgling Manx shearwaters at the start of their first migration. Tests of these tags on Manx shearwater fledglings were carried out in September 2023 at Lighthouse Island (Copeland). Tags were successfully put onto ten birds and these recorded passage of the fledglings through the Irish and Celtic Seas. However, the tags provided only low temporal resolution in the first few days after fledging because of power drainage during the period between deployment of tags on chicks in burrows (where the solar panel would not provide power) and their departure from the colony. Further work, hopefully with that issue resolved by deploying tags on chicks likely to fledge on the same night as tag deployment, was due to be carried out in late summer 2024 and, depending on results obtained from that sample, again in late summer 2025 (Siddiqi-Davies et al., 2024a). As far as we are aware, results from those deployments have not yet been made public.

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3.7 Empirical evidence of hazard caused by artificial light at night (ALAN))

79. Although attraction of birds to artificial lights has been documented since the 1880s (Allen, 1880), one of the first discussions of this in shearwaters and petrels was Imber (1975) who proposed that a possible mechanism for this attraction could be that these birds are adapted to feed on bioluminescent marine prey. An alternative is that fledglings departing from their nesting burrows at night head for the brightest area they can see, as that will normally be the sea in front of their nesting colony because the sea reflects ambient light strongly so appears much brighter than terrestrial surfaces. There is extensive evidence that adult storm-petrels, shearwaters and puffins are rarely attracted to artificial lights, whereas attraction to lights more often occurs with fledglings (Brown et al., 2023, Imber, 1975, Lukies et al., 2019, Medina-Franco et al., 2025). Fledglings may be found “grounded” at ALAN, where they have apparently been attracted to ALAN, hit objects and fallen to the ground where they may die or may subsequently manage to take off and return to the sea once daylight has arrived. For example, 96% of almost 10,000 birds found grounded over eight years in the Canary Islands were fledglings from nine species (Rodriguez and Rodreguez, 2009). Similarly, 94% of grounded birds on Reunion Island were fledgling Barau’s petrels *Pterodroma baraui* (Le Corre et al., 2002 in Lukies et al., 2019) and almost all of 3,099 grounded birds in the Azores were fledgling Cory’s shearwaters (Fontaine et al., 2011 in Lukies et al., 2019). Over 99% of all grounded Leach’s storm-petrels in Canada were fledglings (Medina-Franco et al., 2025), as were most of those grounded at St Kilda (Miles et al., 2010).

80. There is evidence from experiments that the attraction of artificial lights can be mitigated by shielding upward radiation of lights (e.g. Reed et al., 1985), using sodium vapour lights rather than LED lights (Rodriguez et al., 2017a), turning lights off (Miles et al., 2010, Rodriguez et al., 2014) or changing colour of the lights from white/green/blue to red or orange (Brown et al., 2023).

81. Empirical evidence of attraction to artificial light can be seen from mass strandings of petrels and shearwaters at artificial lights such as at lighthouses, oil and gas platforms, cruise ships, fishing boats, urban lights close to the coastline. Such examples are listed below, before review of experimental studies that have tested how birds respond to manipulations of ALAN.

3.7.1 Lighthouses

82. Mass mortality of birds attracted to the beam of lighthouses has been documented for over 120 years, both in Europe (Harvie-Brown and Cordeaux, 1880) and in North America (Allen, 1880) and includes examples of storm-petrel mortality through collision with lighthouses (Allen, 1880). It was well understood that such mortality tends to occur almost exclusively during conditions of very poor visibility, such as during thick fog, when hundreds of birds may be killed at each lighthouse in a single night (Allen, 1880). Allen (1880) also noted that similar numbers can be killed as a result of colliding with ships; for example lights on the steamer Glaucus resulted in hundreds of bird deaths through collision on a moonless night in Long Island sound with the air thick with smoke from forest fires on Long Island. Harvie-Brown and Cordeaux (1880) concluded that, all else being equal, larger numbers of birds tend to be killed where the light beam is closer to the sea surface rather than high above the water.

83. Long Point Lighthouse, Ontario, Canada, killed up to 2,000 birds per night in 1960-1989, with a mean kill of 200 each night during spring migration and 393 each night during autumn migration. In 1989, a new beam which was narrower and lower power (50,000 candelas compared to the old beam of 100,000 candelas), and a flashing light rather than a rotating beam, reduced kills in 1990-2002 to a mean of 18 each night in spring and 10 each night in autumn (Jones and Francis, 2003). The authors attribute the reduction to the lower intensity of the light and its narrower beam and highlight that this simple mitigation was very effective in reducing bird mortality. However, the conversion to a strobe light rather than a rotating beam may also be relevant. Jones and Francis (2003) note that at Dungeness Lighthouse, bird "*kills virtually stopped after the light was converted to a strobe*".

84. Perhaps one of the best empirical examples of the benefit of converting bright white light to bright red light as a mitigation for attraction of birds is the experience at Bardsey Island, part of Aberdaron Coast and Bardsey Island SPA. Bardsey lighthouse is situated 50 to 700m from Manx shearwater and European storm-petrel colonies (Archer et al., 2015, Trinity House, 2025). Breeding Manx shearwaters are a feature of the SPA (Hatton-Ellis et al., 2025). However, even during the fledging period there have been very few mortalities of Manx shearwater or European storm-petrel fledglings at this lighthouse; Stansfield (2010) and Archer et al. (2015) report up to tens of shearwater fledglings (but no adults) grounded per night during the most misty of nights without moonlight (but almost all subsequently fledging successfully) and one instance of a European storm-petrel killed by collision. Over a 16-year period (1998-2013) a total of 848 Manx shearwater fledglings grounded at the

lighthouse were ringed. Despite the very bright white light at this lighthouse (over 80,000 candelas) being only hundreds of meters from the shearwater colony, this average of 53 birds per year, from a production of about 6,900 Manx shearwater fledglings at this colony, represents only about 0.8% of the fledglings produced (Archer et al., 2015).

85. The lighthouse at Bardsey Island was infamous for attracting large numbers of birds, mostly migrating passerines but also Manx shearwaters and European storm-petrels, with large numbers of passerines being killed by collision with the structures (Stansfield, 2010). However, in 2014, the white light of the lighthouse was replaced with a 52,277 candela red LED light which has an 18 nautical mile range, similar to that of the previous white light (Trinity House, 2025). Since converting to a red light, there have been no significant instances of bird kills at this light; according to Trinity House (2025) "*it was common for birds to be attracted and confused by the light and subsequently collide with the lighthouse*" but "*since the light changed to the red LED there have not been any reported attractions of birds at the light*". A condition assessment of Manx shearwater in this SPA concluded with high confidence that the condition was favourable, with no threat from artificial lighting at this colony (Hatton-Ellis et al., 2025). Census data indicate population increases of both Manx shearwater and European storm-petrel at Bardsey Island despite the high illumination of the lighthouse close to the colonies (Burnell et al., 2023).

86. Bardsey lighthouse is not the only one with a red beam. For example, Rathlin West lighthouse, situated adjacent to the main seabird breeding area on Rathlin Island, also has a red beam, flashing for 0.4 sec every 5 sec with a range of about 22 nm. Despite this very bright light, no mortality of seabirds has been reported at this lighthouse which is now an RSPB seabird viewing visitor centre.

87. Storm-petrels, especially fledging birds from colonies close to strong artificial lights, appear to be the seabirds at greatest risk of being grounded by ALAN (Black, 2005, Burt, 2025, Collins et al., 2022, Gjerdrum et al., 2021, Medina-Franco et al. 2025, Miles et al., 2010, Montesdeoca et al., 2017, Porter, 2025, Ryan et al., 2021). Sanda Lighthouse, which has a high intensity white light, is just 30 m horizontally from one of the largest colonies of European storm-petrels in Argyll. There is a bird observatory on Sanda and mist nets have been used to catch storm-petrels there at night when birds come to or depart nest sites or visit the colony as immatures seeking nest sites. Mist nets are standard methods of catching storm-petrels at colonies or at coastal sites. Catches of storm-petrels at the lighthouse colony at Sanda can exceed 250 birds per night, most of these being breeding adults based

on presence of a well-developed brood patch and high rate of regurgitation of food on capture (Clyde Ringing Group, unpublished data). There are no recorded instances of storm-petrel grounding at this lighthouse despite regular observations by bird observatory ornithologists.

88. Several other Scottish islands with large colonies of storm-petrels that are breeding features of an SPA have a lighthouse with a white beam exceeding 50,000 candelas very close to the storm-petrel colony. At North Rona, both European storm-petrels and Leach's storm-petrels nest within 20 m to 800 m of the lighthouse on the island (Murray, 2009, Murray et al., 2016). The lighthouse has a white light with a range of 22 nautical miles (Northern Lighthouse Board, 2025). There appear to be no records of storm-petrels colliding with that light. At Mousa, Shetland, the largest European storm-petrel colony in the UK is within line-of-sight of the Mousa lighthouse situated on Peerie Bard islet but with most nest sites about 1-1.4 km from the lighthouse (which is a small lighthouse that has a smaller light than most large tower lighthouses). There appear to be no records of storm-petrels colliding with that light. However, great skuas are important predators of adult storm-petrels at that colony (R.W. Furness, pers. obs. from analysis of skua pellets), and these predators may benefit from ALAN at this site facilitating their predatory activity at night, as found for yellow-legged gulls *Larus michahellis* catching European storm-petrels at colonies affected by ALAN (Oro et al., 2005). Auskerry, Flannan Isles and Sule Skerry, all also SPAs for breeding storm-petrels, also have full size lighthouses with lights that have a beam visible up to 20 nautical miles away (Northern Lighthouse Board 2025) but without any apparent incidence of storm-petrel collision kills.

3.7.2 Oil and gas platforms

89. ALAN at oil and gas platforms in the North Sea is comparable in light intensity to that of coastal towns but is concentrated in a much smaller area than in urban settings (see Figure 1-1 and see Gjerdrum et al. (2021) for quantitative data from eastern Canada). Storm-petrels and shearwaters have been observed flying into gas flares at offshore oil production platforms, as have nocturnal migrant passerines (Lukies et al., 2019, Ronconi et al., 2015). Leach's storm-petrel is among the most commonly stranded species on oil and gas platforms, with some records of large numbers being killed in particular incidents (Ronconi et al., 2015). Several European storm-petrels were found dead or exhausted on platforms in the North Sea (Thorpe, 2024) possibly after becoming exhausted from flying around artificial lights or gas flare at night, but there was no evidence of frequent or large falls of storm-petrels or shearwaters despite very high light intensities and gas flares.

90. Radar and visual observations at a gas-flare on an artificial oil-production island in Arctic Alaska found that when the flare was off at night, birds passed the area on predominantly straight-line trajectories, whereas with the flare on at night, birds circled the flare and numbers increased, apparently attracted from some distance, or disoriented locally (Day et al., 2015). The authors concluded that although gas flares attract some seabirds as well as migrating passerines, the seabirds appear to be less at risk of incineration in the flare and that most instances of incineration of birds appear to apply to passerines.

91. Strandings of birds at ALAN in Atlantic Canada occurred most often at offshore oil and gas production platforms in the Newfoundland region, which were on average four times brighter at night than onshore sites, with 87% being storm-petrels, almost all of those being Leach's storm-petrels (Gjerdrum et al., 2021). Strandings were much more frequent during periods with no moonlight, and 84% of strandings occurred during the fledging period in September and October. Average light radiance values (in nano Watts.cm^{-2}.sr^{-1}) were up to 121,000 at offshore platforms, whereas the highest onshore values were for the city of Halifax, Nova Scotia which had a peak of 85,100 (Gjerdrum et al., 2021). Rather few puffin fledglings were stranded at ALAN in this study, suggesting that puffins may be less vulnerable to ALAN distant from their colony than are storm-petrels (Gjerdrum et al., 2021). However, a GPS tracking study of breeding Leach's storm-petrels from a colony in Canada found no clear effect of ALAN from oil and gas platforms on the flight behaviour of the tracked birds (Collins et al*.,* 2022), suggesting that adults were unaffected by ALAN, but that study was based on a small sample of tracks, most of which did not approach the sources of ALAN closely.

92. A gas flare in Australia was reported to have burnt 24 wedge-tailed shearwaters that were attracted to the light and noise of the flare, in a one-off event, but the report does not identify whether these were fledglings or adults (Commonwealth of Australia 2020).

3.7.3 Cruise ships

93. There are several anecdotal records of events when large numbers of birds were attracted to brightly-lit cruise ships, but this has not been subject to detailed research studies. Almost all of the birds colliding with cruise ships in New Zealand were Procellariform seabirds and almost all of those were recently-fledged birds (Morton, 2018). DOC (2023) provides a review of ALAN impacts on nocturnal Procellariiform seabirds and guidance on mitigation standards to reduce light-induced vessel strikes with commercial fishing vessels. However, those standards could be applied also to cruise ships.

94. DOC (2025c) notes that nocturnal Procellariiform seabirds can be attracted to the bright lights of cruise ships and may land on deck where they may be stunned and disorientated. To minimize this impact DOC (2025c) recommends that blinds/curtains are closed on cabin windows, that unnecessary exterior lights are reduced, and that essential external deck lights are shielded to direct light downwards. DOC (2025c) also requests that cruise ships take photographs of birds that have been grounded on decks of cruise ships and send those to DOC together with details of date and location. However, it is unclear whether that monitoring has been effective or informative.

95. Austad et al*.* (2023) investigated the impact of brightly lit ships at night in front of coastal cliffs on which there was a colony of Yelkouan shearwaters *Puffinus yelkouan*. Numbers of shearwaters attending the colony were lower on nights with brightly-lit ships present, with an 18% decrease in numbers of shearwaters entering the colony per hour, implying avoidance by adults when there was ALAN present.

3.7.4 Fishing boats

96. White lights on deck are commonly used for crew safety purposes, for setting fishing gear at night, or to attract nocturnal species of fish and squid (Lukies et al., 2019). The amount of lighting depends particularly on the fishing method being used. In the early 1900s lights were oil or acetylene lights, which have been replaced by more powerful fluorescent, metal halide and halogen lights, and most recently with LED lights (Lukies et al. 2019). One of the largest deck-strike events on record was on a trawler near South Georgia in 2004 when 900 petrels struck the vessel in one night (Lukies et al., 2019). Off Tristan da Cunha and Gough Island in the South Atlantic, 908 petrels and shearwaters of eight species were recorded in nocturnal deck-strikes over a period of two weeks on a fishing boat using lights to fish for Tristan rock lobsters *Jasus paulensis* (Ryan, 1991, in Lukies et al., 2019). However, mitigation by reducing lighting on these vessels at night reduced the seabird deck-strike rate to fewer than two birds per night (Glass and Ryan, 2013, Lukies et al., 2019).

97. Vessel strikes near to South Georgia involved large numbers of storm-petrels, prions, and diving petrels but did not involve shearwaters, large petrels or albatrosses (Black, 2005).

98. “Vessel strikes” (petrels and shearwaters colliding with fishing boats at night after being disoriented by ALAN from the boat) are a conservation concern in New Zealand in particular, where critically endangered seabirds commute through areas used by fishing boats deploying searchlights (Fischer et al., 2021, DOC, 2023). It is recognised that vessel strikes

tend to occur especially under conditions of low cloud, fog and mist, and during the new moon period (DOC, 2023, 2025a,b). DOC (2023) provides a review of ALAN impacts on nocturnal Procellariiform seabirds and guidance on mitigation standards to reduce light-induced vessel strikes with commercial fishing vessels.

99. ALAN at trawlers was estimated to kill 4,561 fulmars, 456 fork-tailed storm-petrels *Hydrobates furcatus* and 41 least auklets *Aethia pusilla* over the entire pollock fishing fleet in the Sea of Okhotsk each year; however, this mortality represented less than half of one percent of the populations of each of these species (Artukhin, 2026).

3.7.5 Onshore building or street lights

100. Numbers of Manx shearwater fledglings grounded in the town of Mallaig, the only site with high ALAN in the vicinity of the large Manx shearwater colony on Rum (Figure 1-1),), were monitored in 2009-2014, with a total of 1,646 fledglings found grounded, mostly in the harbour area (Syposz et al., 2018). These birds fledged from Rum, 27 km from Mallaig and a colony estimated to produce about 76,000 fledglings per year at that time, so that the grounded birds represented about 0.4% of the population (Syposz et al., 2018). Numbers grounded varied among years, with a tendency for more groundings when there was a new moon and when there was a strong wind from Rum to Mallaig.

101. In Newfoundland, 98% of 5,549 grounded/stranded Leach's storm-petrels were found during 19 September to 12 October, coinciding with the peak of fledging of young birds (Burt et al., 2023). Different authors use the term stranded or grounded but these are the same concept. Birds were found at artificial lights around the coast of Newfoundland, but especially in brightly illuminated areas close to the main colonies. Although the numbers grounded were likely to have exceeded the numbers reported, the stranded birds represent a very small fraction of the population (given that there were about 2.4 million pairs of Leach's storm-petrels breeding in Newfoundland when this study was done). At one coastal industrial site that was highly illuminated and close to a large colony, mass strandings of Leach's storm-petrels tended to occur when there was little or no moonlight, and there was heavy cloud cover or fog (Burt et al., 2024). Reducing the amount of ALAN reduced strandings by 57%. Within the longer study period, peak stranding numbers occurred between 25 September and 28 October, with 95% of the birds stranded during that period being fledglings (Burt et al., 2024).

102. While strandings tend to occur more often when there is no moon visible in the night sky, that could result from petrel and shearwater chicks choosing to fledge on darker nights and avoiding fledging on moonlit nights. A four-year study at a Leach’s storm-petrel colony in Newfoundland deployed PIT tags on Leach’s storm-petrel chicks in order to monitor the time and date on which individuals fledged. The median time of fledging was 1.6 hours after sunset. Fledging dates ranged from 13 September to 13 November (median 10 October) but moon phase was not associated with the time or date of fledging (Collins et al., 2023). The authors infer that more frequent strandings during darker nights are a consequence of lower attraction of fledglings to ALAN on nights of higher levels of natural illumination.

103. Friswold et al. (2023) identified a relationship between higher illumination and more groundings of fledgling wedge-tailed shearwaters *Ardenna pacifica* in Hawaii.

104. A study in the area around Auckland, New Zealand, found more seabird groundings at ALAN in urban or rural areas with greater light intensity (Heswall et al., 2022, Heswall, 2024). Most grounded seabirds were fledglings of burrow-nesting species such as petrels and shearwaters, and most groundings occurred during the fledging period of each species. All Cook’s petrels *Pterodroma cookii* necropsied after being killed by collision at artificial lights were found to be fledglings (Heswall et al., 2023).

3.7.6 Offshore wind farms

105. There is no published empirical evidence of lighting on offshore wind farm infrastructure causing mortalities of any seabirds although monitoring mortalities caused by offshore wind farms is challenging due to any carcasses falling into the sea. Collection of appropriate data would previously have been challenging on a technological level. Commercially available systems that could achieve robust monitoring are becoming available but are still a relatively new development. Some trials are presently underway in non-UK regions (which may be more likely to focus on movements of passerines through OWFs at night, rather than seabird attraction to ALAN) but there is not yet any published information available from those studies.

3.8 Research studies of physiological and behavioural responses of shearwaters, petrels or puffins to different kinds of light

106. Birds perceive light differently from humans. Birds are sensitive to short wavelength light that is invisible to humans (ultra-violet light of wavelength <280 nm). This is particularly the case

for Procellariiformes such as shearwaters and storm-petrels (Heswall et al., 2026). Furthermore, different kinds of light produce different amounts of different wavelengths of light even where the overall light effect is “white light” (Adams et al., 2021). In particular, white LED lights produce large amounts of light within the blue wavelength range (Commonwealth of Australia, 2020, 2023) and so may affect birds differently from sodium lights that they may replace. Blue/UV light particularly affects photosensitive retinal ganglion cells (pRGCs). These pRGCs are not involved in image-forming vision but are involved in the regulation of melatonin and in synchronising circadian rhythms. Exposure to ALAN with strong blue/UV content can affect melatonin production which can influence daily waking/sleep, detection of seasonal cues, and feeding (Commonwealth of Australia, 2020, 2023). Perhaps consistent with the effects of blue light, in an experimental choice-test set up, cowbirds showed strongest avoidance of blue lights (Goller et al., 2018).

107. Rebke et al. (2019) showed, by experiments using a spotlight at night at a North Sea island, that passerine birds were less attracted by blinking (strobe) light than by continuous light, and were less attracted by red light than by white, blue or green light. Birds were attracted more during nights that were heavily overcast. Walsh et al. (2025) reviewed ALAN in the North Sea in relation to bird and bat vulnerability, pointing out that further development of offshore wind will increase the cumulative impact of that industry. However, given that there is anticipated to be a long-term trend of decrease of oil and gas production in the North Sea and Norwegian Sea, the net effect may be a cumulative decease since light intensity at oil and gas platforms is very much higher than at other sources in the North Sea (Figure 1-2).

108. All seabirds are sensitive to the violet-blue region of the visible spectrum, and Procellariform eyes are characterised by a high proportion of cones sensitive to short wavelengths. In particular, dark-adapted vision of Procellariform seabirds is most sensitive to short wavelengths (380-485 nm, violet to blue) as they have large tubular-shaped eyes, increased retinal rods, oil drops and rhodopsin (Lukies et al., 2019, Commonwealth of Australia, 2020, 2023).

109. Experimental use of ultraviolet lights showed that 27% fewer birds (predominantly large gulls) flew through the illuminated area when lights were on at night than when they were switched off (May et al., 2017), suggesting avoidance of UV light by birds. No similar studies seem to have been carried out with storm-petrels and shearwaters rather than with gulls.

3.8.1 Adult shearwaters, prions, storm-petrels, puffins (and other seabirds if relevant as context)

110. Experimental use of lights over a Manx shearwater colony tested responses of adults to ALAN (Syposz et al., 2021). Adult Manx shearwaters were repelled by light, and this effect was stronger with brighter light, and with green and blue light compared to red light. The authors recommend use of lower light intensities and red light to minimize impact on adult shearwaters but concluded that adult Manx shearwaters tend to avoid artificial light sources.

111. On a moonless night, Scopoli's shearwater *Calonectris diomedea* chicks in areas of a colony temporarily subject to ALAN gained significantly less weight than those in control areas distant from the source of ALAN, but this effect was absent when moonlight was present (Cianchetti-Benedetti et al., 2018), indicating avoidance by breeding adults when ALAN was not mitigated by moonlight.

112. Experiments with fledging Cory's shearwaters and adults placed into a test chamber showed that fledglings were much more strongly affected by lights in part of the chamber than were adults (Atchoi et al., 2024).

113. From 1-16 September 2015, 123 Newell's shearwaters *Puffinus newelli* and six Hawaiian petrels *Pterodroma sandwichensis* were grounded by very bright green or white lights with little or no shielding at Koke'e Air Force Station, Hawaii, almost all being grounded during a period of new moon with fog (Raine et al., 2024). This site is close to colonies of these two endangered species. Since most of these birds had brood patches it was considered that these were adults, which was further supported by many of the birds regurgitating food when they collided (so were presumably coming to their burrows to feed their chicks). Most grounded birds were at bright green lights at the perimeter of the base. The facility altered its lighting protocol with significantly reduced lighting. Intensive monitoring found only two grounded birds in the following eight years, demonstrating that light minimization reduced this problem to close to zero (Raine et al., 2024). Nighttime artificial light radiance in the ten nights prior to the fallout (grounding event) in 2015 was 3.3 +/- 3.1 nW/cm^2/sr at these perimeter sites whereas after light minimization it was significantly lower at 0.4 +/- 0.9 nW/cm^2/sr. By comparison, an urban coastal area that is a hotspot for fledgling fallout (but not adults) had an average ALAN radiance of 23.55 nW/cm^2/sr (Raine et al., 2024). The authors note that this grounding of adults in 2015 was exceptional and represented 98.5% of all adults grounded due to light pollution on this island. Furthermore, adults of these species pass in large numbers over brightly lit coastal towns on their way to inland breeding colonies

without light attraction issues, suggesting that the problem was having bright lights close to the colonies. Raine et al. (2024) state "*In coastal areas, adults are sometimes seen briefly circling unusually bright lights but they are invariably observed continuing toward their colonies afterwards. Therefore, the effect of lights on adult birds is not equal across the landscape, and resource managers should pay particular attention to lights close to colonies*".

114. Leach's storm-petrel flight activity above a colony at St Kilda was reduced on nights with bright moonlight, which appeared to be a reflection of fewer nonbreeding birds visiting the colony on bright nights (Miles et al., 2012). This appeared to be a strategy to reduce risk of being attacked by avian predators (Miles et al., 2012), which suggests that ALAN at colonies is likely to reduce storm-petrel activity, especially that of immature site-seeking birds, but also to increase predation risk (Oro et al., 2005).

115. Reducing or limiting pressures associated with lighting from shipping (including fishing boats) was identified as a desirable measure at St Kilda SPA (NatureScot and JNCC, 2024), conservation and management advice recommending appropriate mitigation such as seasonal restrictions and management of ALAN from shipping for petrel and shearwater protected features.

116. Using a lighting rig at a colony of fairy prions during the breeding season, a study investigated the effects of LED colour and lumen output on the extent to which adult prions were attracted to artificial lights over their burrows (Middlemiss et al., 2025). The tests used six random treatment groups (control (dark), red light, amber low lumen, amber high lumen, white low lumen, and white high lumen) and measured attraction and disorientation. Data were analysed using generalised linear mixed-effects models while accounting for environmental variables. Results showed that the control ("dark") and red light attracted fewest birds, and attraction/disorientation did not differ between these. Medium responses were elicited by amber low/high and white low, while white high lumen induced the highest attraction/disorientation response.

117. Tracking of breeding adult Cory's shearwaters equipped with tags that recorded GPS location and light level, showed that ALAN was detected during at-sea foraging trips that occurred during the night (Neves, 2024). Lux levels recorded by tags were higher with higher fishing effort of longline and gillnet vessels, suggesting that those types of fisheries attract birds, probably due to the artificial lights they use during fishing, and the food resources they

provide. Similarly, deployment of light loggers on seven species of petrel and shearwater in New Zealand found notable differences in the rates of light exposure between species (varying from 11% of deployed tags in Chatham Island taiko *Pterodroma magentae* to 57% in broad-billed prion *Pachyptila vittata*), with more such events in pelagic areas (Petterson, 2025). The author concluded that light exposure from ALAN had a significant effect on behavioural patterns in some species.

118. GPS tracking of European storm-petrels from their breeding site at Mousa, Shetland, found that their foraging tracks overlapped with 206 active hydrocarbon wells and 14 operating platforms which represent potential threats through attraction of birds to gas flares and lights (Bolton, 2021). It is unclear whether these birds were visiting areas of high fishing activity, as observed in this species breeding in the Faroe Islands (Porter 2025). In this study, GPS frequency was 30 minutes to six hours so while showing clearly the areas used by these birds, it is unlikely to give evidence of fine scale attraction/displacement in relation to individual OWFs or gas platforms.

119. GPS tracking of breeding adult Leach’s storm-petrels in Newfoundland found that birds passed rapidly by oil production platforms during the day on 17.5% of foraging trips, with no evidence of attraction. However, at night the same birds passed close to oil production platforms on only 1% of foraging trips (Collins et al., 2022). The observation that many Leach’s storm-petrels strand on these oil production platforms was interpreted by Collins et al. (2022) as suggesting that almost all strandings are of fledglings rather than of adults.

120. Tracking of two endemic threatened species of storm-petrel similar to Leach’s storm-petrel (seven Townsend’s storm-petrels and four Ainley’s storm-petrels) breeding on Guadalupe Island, Mexican Pacific, with geolocator tags identified six cases of artificial light events occurring with Townsend’s storm-petrels but none with Ainley’s storm-petrels (Medrano et al., 2024).. The tag data also showed significantly increased flight activity on nights with more moonlight (*Medrano* et al., 2024).

121. Studies of the behavioural responses of Leach’s storm-petrels to ALAN found that whereas brighter ALAN resulted in increased numbers of storm-petrels grounded at a highly-illuminated industrial site, it reduced storm-petrel numbers active over the colony when light was present (Burt, 2025). The results suggest that Leach’s storm-petrel adults tend to avoid light at their colony.

3.8.2 Fledging shearwaters

122. Cory’s shearwater fledglings are often grounded at artificial lights in the Azores. The distance each grounded bird was found from the closest colony was best explained by the ratio of satellite-measured light levels at night at the grounding location in relation to the light level at the presumed colony of origin (Rodriguez et al., 2012). That study estimated that 542 fledglings were grounded by ALAN at San Miguel Island from a production of about 3,245 fledglings, giving an estimate of 16.7% being grounded by ALAN. From satellite images, ALAN was estimated in a scale from 0 to 63 digital numbers (DN) rather than in absolute values (Watts per m^2). ALAN at colonies had a mean of 9 DN. The largest numbers of groundings were at sites with high values of ALAN, with the mean score of 30 DN for all grounded birds (Rodriguez et al., 2012).

123. Rodriguez et al. (2023) found that numbers of burrow-nesting nocturnal seabirds that fledge on nights with or without moonlight was no different, but that seabird fledglings were less attracted to ALAN during periods of full moon.

124. Cory’s shearwater fledglings released from an inland site at night and tracked with GPS tags showed that the tortuosity of the flight increased with light pollution levels but decreased with the ambient light from the moon (Rodriguez et al., 2022). However, some birds overflew highly light-polluted coastal urban areas without being grounded, while others were grounded at these sites. Chicks that fledged with more down remaining in their plumage were much more likely to become grounded at artificial lights, which the authors attributed to the higher drag caused by down when the fledgling is flying (Rodriguez et al., 2022).

125. Over 30,000 Newell’s shearwater fledglings, listed as a threatened species in the USA, were collected when grounded at ALAN on the island of Kauai, Hawaii, over the 30 years up to 2010 (Troy et al., 2011). A GIS-based model of ALAN intensity on that island showed that Newell’s shearwater chicks that fledge from colonies on steep mountainsides in the interior of the island (where there were about 12,000 breeding pairs (Hawaii State, 2015)) will almost invariably be subject to ALAN whatever route they take to the sea on their first nocturnal flight from their burrow, with some birds subject to some of the highest intensities of ALAN found anywhere on earth. The data on numbers grounded suggest that a minimum of about 12% (1,000 per year grounded and collected out of about 8,000 fledglings produced by 12,000 pairs) become grounded at ALAN in Kauai.

126. Highway lights on O’ahu, Hawaii, attract fledgling wedge-tailed shearwaters making their first flight from burrows to the sea (Urmston et al., 2022). Lights used before 2016 were unshielded 2200 K high-pressure sodium (HPS) and these were replaced in 2016 with shielded full cut-off 3000K-4000K LED lights. This change to brighter but more energy-efficient lights resulted in no clear change in numbers of shearwater fledglings grounded at the highway lights (Urmston et al., 2022).

127. A controlled field experiment on short-tailed shearwaters *Ardenna tenuirostris* at Phillip Island, Australia, tested the effect of metal halide, LED and high-pressure sodium vapour (HPS) lights on fledgling groundings. The results suggested the shearwaters were more sensitive to the wider emission spectrum and higher blue content of metal halide and LED lights relative than to HPS light. The authors strongly recommended using HPS, or filtered LED and metal halide lights, with purpose designed LED filtered to remove short wavelength light for use in the vicinity of shearwater colonies (Rodriguez et al., 2017a, Commonwealth of Australia, 2020, 2023).

128. Experiments exposing Cory’s shearwater chicks to lights in a test box (Atchoi et al., 2023) found a tendency for chicks of 18 to 83 days old to move to darker locations within the box and no difference in response to red or blue light. However, no tests were carried out with chicks that were fledging from their burrows. A response to move to darker positions may be a natural response of chicks to disturbance or stress, as the darker locations in their burrow will tend to be further from potential dangers such as predators at the burrow entrance. Tests with Cory’s shearwater fledglings in the Azores that had been rescued from being grounded in urban areas found that birds chose the dark part of a test chamber where one side was illuminated and chose the red-lit side over a blue-lit side. The authors conclude that the birds strongly avoid short wavelength light (Atchoi et al., 2024). However, fledglings were slow to react to being in the part of the chamber illuminated with either white or blue light, suggesting that they were disoriented by the light in a way that adults were not (Atchoi et al., 2024, Knight, 2024). White LED lights, often used to replace old street lighting, have a high component of blue wavelength light. Knight (2024) concluded from this research that, “*although LEDs have revolutionised street lighting, the whiter light with more blue tones is playing havoc with shearwater fledglings as they venture for the first time from their burrow nests*”.

129. Of 523 seabirds grounded at artificial lights in New Caledonia, 80% were wedge-tailed shearwaters (almost all the others being gadfly petrels). Most grounded birds were recently

fledged birds, mostly grounded at highly-lit industrial sites close to the shoreline. Grounding sites had four-times higher ALAN than random sites and numbers of shearwaters and petrels grounded correlated with the number of lights (Borsa et al., 2024).

3.8.3 Fledging storm-petrels

130. 131. Medina-Franco et al. (2025) carried out a comprehensive literature review of the impacts of ALAN on storm-petrels world-wide. They concluded "*Storm-petrel fallout occurs primarily in fledglings during their first flight leaving the colony. Our results indicate storm-petrels' groundings were recorded for almost all Hydrobatidae genera. Although inshore and offshore light pollution sources can lead to storm-petrel disorientation, the artificial light source characteristics (e.g., intensity, spectrum) were generally not quantified. Susceptibility to light pollution is associated with environmental factors (e.g., moon phase) and the storm-petrels' age, as fallout occurs primarily in fledglings during their first flight leaving the colony. While a limited number of studies assessing light-induced storm-petrel mortality at a population level suggest that it may not be high enough to be deemed as a substantial threat, further research is required to fully understand the extent of light pollution as a potential danger and develop effective conservation measures*". A summary table in Medina-Franco et al. (2025) is adapted below (Table 3-4).

Table 3-4. Summary of findings reviewed by Medina-Franco et al. (2025) relating to ALAN strandings of storm-petrels world-wide.

<table>
<tr><th>Reference</th><th>Location</th><th>Methods</th><th>Light levels</th></tr>
<tr><td>Wilhelm et al., 2020</td><td>Newfoundland</td><td>Systematic collection</td><td>Quantitative evaluation</td></tr>
<tr><td colspan="4">Main findings: There were 1,156 reports of stranded Leach's storm-petrels in 2018 and 747 in 2019, and the proportion of stranded birds found alive was 40% and 60%, respectively. Of the 686 stranded birds, all but five were aged as recently fledged birds. Most strandings were reported on brightly-lit industry properties, and the highest strandings occurred around the new moon.</td></tr>
<tr><td>Ryan et al., 2021</td><td>Tristan da Cunha</td><td>Vessel observer data</td><td>Not evaluated</td></tr>
<tr><td colspan="4">Main findings: In total, 1,823 birds were reported coming aboard the ship on 118 nights, all at the uninhabited islands. Petrels, shearwaters, and storm-petrels were reported coming aboard the vessel at night. Prions were the most common taxon, followed by two species of Fregetta storm-petrels, white-faced storm-petrels, and Subantarctic shearwaters <i>Puffinus elegans</i>. Birds were killed on 3% of fishing nights, with at least 70 birds found dead overall, most of which were prions.</td></tr>
<tr><td>Gjerdrum et al., 2021</td><td>Atlantic Canada</td><td>Reports by wildlife centres</td><td>Quantitative evaluation</td></tr>
<tr><td colspan="4">Main findings: A total of 7,922 reported stranded birds represented 108 species and 32 families. The majority (87.4%) were storm-petrels, most of them identified as Leach's storm-petrels. Many of the strandings were reported in offshore production platforms and support vessels, followed by onshore refinery and construction facilities, and offshore seismic vessels. The frequency of large stranding events was significantly related to moon phase, as the largest stranding events occurred when the moon was less than 20% illuminated.</td></tr>
</table>

<table>
<tr><th>Reference</th><th>Location</th><th>Methods</th><th>Light levels</th></tr>
<tr><td>Montesdeoca et al., 2017</td><td>Canary Islands</td><td>Reports by wildlife centres</td><td>Not evaluated</td></tr>
<tr><td colspan="4">Main findings: A total of 1,956 seabirds belonging to the Orders Procellariiformes, Suliformes, and Charadriiformes were included in this study. Light pollution (sometimes referred to as “fallout” sometimes as a “grounding event”) was the most frequent cause of admission into the Tafira Wildlife Rehabilitation Center (TWRC), mainly among Procellariiformes species, and white-faced storm-petrel (the fourth species most frequently admitted) had the highest risk of fallout. Light pollution admissions were concentrated around the fledgling periods of the different species affected.</td></tr>
<tr><td>Rodriguez et al., 2015</td><td>Balearic Islands</td><td>Citizen science</td><td>Quantitative evaluation</td></tr>
<tr><td colspan="4">Main findings: A total of 304 fledgling birds were found stranded due to attraction to ALAN, but only 26 were fatally affected by lights. The Scopoli’s Shearwater was the most abundant species found, followed by Balearic shearwater *Puffinus mauretanicus* and European storm-petrel. In general, colonies for all species showed low mean light pollution levels, and the percentage of the population of fledglings grounded by artificial lights was lower than 1%.</td></tr>
<tr><td>Glass and Ryan, 2013</td><td>Tristan da Cunha</td><td>Vessel observer data</td><td>Not evaluated</td></tr>
<tr><td colspan="4">Main findings: Over three fishing seasons 723 seabird strikes were recorded, of which 36% were storm-petrels. The mortality rate varied among species, with storm-petrels exhibiting a lower mortality rate (5%) compared to other procellariids.</td></tr>
<tr><td>Miles et al., 2010</td><td>St Kilda</td><td>Systematic collection</td><td>Quantitative evaluation</td></tr>
<tr><td colspan="4">Main findings: Over four years 45 Leach’s storm-petrels and one European storm-petrel grounded at ALAN were collected. No storm-petrels were found when light reduction methods were applied. Moon phase had an effect on attraction to artificial lights, nights with low moon visibility (i.e. around the new moon) leading to higher storm-petrel grounding records.</td></tr>
<tr><td>Rodriguez and Rodriguez, 2009</td><td>Canary Islands</td><td>Citizen science</td><td>Quantitative evaluation</td></tr>
<tr><td colspan="4">Main findings: During a nine-year study, four species of storm-petrels were recorded as grounded. Almost 94% of all grounded seabirds were fledglings. The number of grounding records varied based on the breeding phenologies of the different species.</td></tr>
<tr><td>Heswall et al., 2022</td><td>Auckland, NZ</td><td>Citizen science</td><td>Quantitative evaluation</td></tr>
<tr><td colspan="4">Main findings: The wildlife rehabilitation centre received 356 seabirds grounded at ALAN of eight different species, and these experienced a 29% mortality rate. Grounded white-faced storm-petrels were found between November to March, which aligns with the fledgling months of the storm-petrel population in Auckland. Areas with higher levels of light pollution (indicated by lower values of maximum natural night sky brightness) had more seabird groundings, with the majority occurring in those areas.</td></tr>
<tr><td>Black, 2005</td><td>South Georgia</td><td>Vessel observer data</td><td>Not evaluated</td></tr>
<tr><td colspan="4">Main findings: A total of 899 seabird strikes were recorded,</td></tr>
<tr><td>Murillo et al., 2013</td><td>Lima</td><td>Citizen science</td><td>Not evaluated</td></tr>
<tr><td colspan="4">Main findings: A total of 62 groundings of Hornby’s storm-petrels *Oceanodroma hornbyi* were recorded. The majority of these groundings occurred in June, and there was a higher frequency of groundings during the waxing gibbous and new moon phases. Although the sex of the storm-petrels was evaluated, no statistically significant effect of sex on groundings was found.</td></tr>
<tr><td>Ryan et al., 2021</td><td>Tristan da Cunha</td><td>Vessel observer data</td><td>Not evaluated</td></tr>
<tr><td colspan="4">Main findings: Despite reduced use of deck lights since 2013, on dark, misty nights, prions and storm-petrels became disoriented by ALAN on ships, with at least 1,823 petrels coming aboard</td></tr>
</table>

Reference	Location	Methods	Light levels
vessels fishing for rock lobsters between 2013 and 2021. Strikes occurred in 13% of fishing nights with 65% on seven nights, with 4% of birds killed.			

131. Leach's storm-petrel fledglings tested in a Y-maze avoided the lit arm and moved more when illuminated than when in the dark (Brown, 2025). Stranded storm-petrels also tended to move out of illuminated locations into sheltered dark locations (Brown et al., 2025).

132. In Canada, members of the public were more concerned about Atlantic puffin *Fratercula arctica* fledglings being grounded by ALAN than about storm-petrels being grounded in the same areas (Aastrup et al., 2025) which the authors felt indicated a need for outreach and education to bolster public awareness about storm-petrel conservation needs.

3.8.4 Fledging puffins

133. Experimental lighting of two beaches near a Newfoundland Atlantic puffin colony resulted in a greatly increased number of strandings of puffin fledglings, with hardly any at the unlit beach acting as a control (Brown, 2025, Brown et al., 2024). Stranded puffin fledglings in a Y-maze test moved towards the lit arm over darkness, and were less active under LED light than under a sodium light (Brown, 2025, Brown et al., 2024) although it was unclear whether the LED light (which has much more blue light in the spectrum) caused the birds more stress or not (Eggleton, 2025).

3.8.5 Summary of evidence on seabird attraction to ALAN

134. Table 3-5 provides a summary of the sources of evidence presented on each topic of research reviewed in this report.

135. Table 3-5Table 3-5 provides a summary of the sources of evidence presented on each topic of research reviewed in this report.

Table 3-5. Summary of evidence on seabird attraction to ALAN

Finding	References
Birds are attracted to ALAN almost exclusively on nights without moonlight	Brown et al., 2023, Lukies et al., 2019 Medina-Franco et al., 2025, Raine et al., 2024, Rodriguez and Rodriguez 2009, Rodriguez et al., 2022, 2023, Ryan et al., 2021, Wilhelm et al., 2020, Zein et al., 2025

Finding	References
Petrels and shearwaters and nocturnal-migrating birds are attracted to ALAN almost exclusively on nights with unusually poor visibility (e.g. fog)	Allen, 1880, Archer et al., 2015, Black, 2005, Brown et al., 2023, Harvie-Brown and Cordeaux, 1880, Lukies et al., 2019, Raine et al., 2024, Ronconi et al., 2015, Ryan et al., 2021, Walsh et al., 2025, Zein et al., 2025
Whereas fledging storm-petrels and shearwaters and puffins tend to be grounded at artificial lights, adults of the same species tend not to be attracted	Archer et al., 2015, Burt, 2022, Heswall et al., 2022, 2023, Heswall, 2024, Imber, 1975, Lukies et al., 2019, Medina-Franco et al., 2025, Rodriguez and Rodriguez, 2009, Syposz et al., 2021, Zein et al., 2025
Adult shearwaters tend to avoid ALAN, especially where lights are white, blue or green, but show less response to red light or to lower intensity of light	Rodriguez et al., 2017b, Syposz et al., 2021, Zein et al., 2025
Fewer birds are attracted by lighthouses when the beam is less bright	Jones and Francis, 2003
Fewer birds are attracted to a lighthouse when the light is a flashing strobe rather than a rotating light (with the same flash pattern); evidence from Dungeness Lighthouse and from Long Point Lighthouse	Jones and Francis, 2003
Fewer birds are attracted to flashing light rather than to continuous light	Rebke et al., 2019
Fewer birds are attracted to a lighthouse red beam than to a white one (evidence from Bardsey Lighthouse)	Trinity House, 2025
Fewer birds were attracted to less bright ALAN and to red light	Middlemiss et al., 2025, Zein et al., 2025
European storm-petrel adults are much less attracted to red light at the colony than to green or blue light and white light results in strongest attraction	Porter, 2025. Full details of this work will soon be published in Ben Porter's PhD thesis at the University of Cardiff.
GPS tracking of adult European storm-petrels from colonies in the Faroe Islands shows high overlap of foraging activity with fishing fleet activity, suggesting risk of deck strikes if fishing vessels use lights at night	Porter, 2025. Full details of this work will soon be published in Ben Porter's PhD thesis at the University of Cardiff.
Cory's shearwater chicks of pre-fledging ages tend to avoid light when tested in an artificial "burrow" box	Atchoi et al., 2023
In a Y-maze test, Cory's shearwater fledglings prefer the darker arm to an illuminated arm and prefer a red-lit arm to a blue-lit arm.	Atchoi et al., 2024
Of 523 seabirds grounded at artificial lights in New Caledonia, 80% were wedge-tailed shearwaters, 14% were Gould's petrels *Pterodroma leucoptera* and 5% were Tahiti petrels *Pseudobulweria rostrata*. Most grounded birds were recently fledged birds, mostly grounded at highly-lit industrial sites close to the shoreline. Grounding sites had four-times higher ALAN than random sites and numbers of petrels grounded correlated with the number and intensity of lights.	Borsa et al., 2024

Finding	References
ALAN may allow gulls and great skuas, which can be key predators of breeding storm-petrels and shearwaters to be more active at storm-petrel and shearwater colonies at night	Bond et al., 2023, Oro et al., 2005, Zein et al., 2025
Higher light intensities tend to result in more groundings of storm-petrel and shearwater fledglings	Atchoi et al., 2021, Burt, 2022, Burt et al., 2024, Deppe et al., 2017, Friswold et al., 2023, Miles et al., 2010, Raine et al., 2007, Rodriguez et al., 2015, Rodriguez et al., 2022, Troy et al., 2013, Zein et al., 2025
There is no consistent difference in grounding rates of storm-petrel or shearwater fledglings with different types of light (sodium, halide, LED) but grounding rates are higher with brighter lights and with more green/blue/violet in the spectrum	Zein et al., 2025
Reducing ALAN, shielding to prevent upward spill of light, and reducing violet/blue/green components of the spectrum all mitigate impacts of ALAN	Zein et al., 2025
ALAN at storm-petrel and shearwater colonies leads to lower attendance by adults	Zein et al., 2025

3.9 Foraging ranges of breeding storm-petrels and shearwaters

136. A review of foraging range data available up until 2024 (Woodward et al., 2024) reported the maximum foraging range of breeding European storm-petrels as 468.7 km, the mean maximum as 400.6 km, and the mean as 227.7 km; the mean for Leach's storm-petrel as 657 km, the maximum for Manx shearwater as 2,890 km, the mean maximum as 1,346.8 km and the mean as 136.1 km.

137. Deployment of GLS and TDR tags on adult Manx shearwaters breeding at Skomer showed that there are differences in spatial distributions of male and female birds pre-laying, with females commuting much further to more distant foraging areas (median distance 243.5 km, S.D. 58.3, n=19) than males (median distance 148.9 km S.D. 29.7, n=17), and that almost all foraging activity occurred during daylight (Siddiqi-Davies et al., 2025). Those sex-differences largely diminish post-laying with female median distance 285.7 km, n=6, and male median distance 224.4 km, n=7.

138. Deployment of GPS tags on adult European storm-petrels at Nolsoy in the Faroe Islands (the largest colony of this species with an estimated 250,000 to 500,000 pairs, found breeding season foraging range of up to about 450 km, the longest track passing slightly SE of Shetland (Porter, 2025). Full details of this work will soon be published in Ben Porter's PhD thesis at the University of Cardiff.

139. Deployment of GPS tags and geolocators on a large sample of Leach's storm-petrels at colonies in eastern Canada (Mauck et al., 2023) showed that breeding females travelled further from the colony than breeding males during the early incubation period but that this difference, and the maximum distance of trips by both sexes, declined with date. Maximum distance from the colony reached during a foraging trip by females was 220.5 km greater than that by males, and the trips by females covered 419 km more total distance during a foraging trip than those by males. Overall, the mean maximum distance for females was 638.7 km whereas that for males was 508.6 km. Trip lengths approximately halved between early incubation and late incubation. The geolocator tags would allow analysis of nocturnal versus daytime flight activity and whether these birds were exposed to ALAN, but those data are not presented in this paper.

4.0 Task 2: Review of the way in which storm-petrels and shearwaters have been assessed in offshore wind farm planning applications and recommendations for assessing storm-petrels and shearwaters in future offshore wind farm planning applications

140. Most OWF developments have been in locations where shearwaters and storm-petrels are rarely seen, and so those species have been scoped out as too scarce to require assessment. The following examples are ones where shearwaters or storm-petrels have been found in the baseline surveys and are presented here as examples of how those species have been treated in assessments. These case studies are given in reverse chronological order as the most recent examples seem likely to be the most useful in terms of shaping future developments of methods to assess impacts of ALAN.

4.1 Assessment of storm-petrels and shearwaters in OWF planning applications

141. All UK projects are within foraging range of a Manx shearwater colony, due to the huge foraging ranges of this species. Consequently, all applications should consider the risk of ALAN on OWF infrastructure and vessels impacting Manx shearwaters. However, projects in the west and north, relatively close to important shearwater and storm-petrel colonies, tend to record higher numbers of these species in their development areas (noting the likely under recording of storm-petrels by digital aerial survey) and so are more likely to have done a more comprehensive assessment. Therefore, only applications from OWF projects in the north and west of the UK and the Republic of Ireland were reviewed. Only projects for which a full s36 consent application has been submitted were included in the review.

4.1.1 Sceirde Rocks OWF

142. Sceirde Rocks OWF was until very recently in the planning process in Ireland but has now been abandoned due to significant structural and technical challenges specific to the seabed geology and severe currents at the site (Sceirde Rocks Windfarm, 2025). The proposed site is located about 5 km off the west coast of Ireland, close to several colonies of Manx shearwater and European storm-petrel that are SPAs with those species as breeding features. Baseline characterisation for this site (plus a 4 km buffer) was carried out through monthly DAS over 24 months (from October 2021 to September 2023) by Hi-Def. Surveys were only carried out during wind speeds at sea surface less than 30 mph and sea state of

less than six, with the aircraft flying at a height of 500-550 m above sea level, with four cameras that covered a transect width of 500 m, and resulting in a coverage of 14.5% of the survey area with data from two of the four cameras being used and the other two cameras remaining unprocessed as archived data (Cork Ecology, 2025, MKO, 2025). Cork Ecology (2025) state "*Overall, it is considered that the digital aerial survey data are representative of the species present in the OWF site and surrounding 4km buffer area throughout the year and that the dataset is both robust and comprehensive and is therefore suitable for the purpose of the impact assessment*". However, there is no discussion of the detectability of storm-petrels in the survey.

4.1.1.1 Manx shearwater

143. Manx shearwaters were recorded in the survey area (including 4 km buffer) between March and August in year 1 with a peak of 28,093 in May 2022. In year 2 they were recorded between April and September with a peak of 3,359 in May 2023. Cruagh Island SPA, 38.6 km from the site, has breeding Manx shearwater as a feature with an estimated breeding population of 32,836 pairs (Cork Ecology, 2025). Mean maximum foraging range of breeding Manx shearwaters plus one SD is 1,347 km (from Woodward et al., 2019) and so there is potential connectivity between the OWF site and several Irish and UK SPAs with breeding Manx shearwater as a feature.

144. Impacts during construction were screened out as the species was considered to have a very low sensitivity to disturbance (Cork Ecology, 2025).

145. Based on an estimated 50% displacement rate and 1% mortality of displaced birds (Cork Ecology 2025, Table 11-17) impact of displacement during operation (assessed across the wind farm site plus 2 km buffer with displacement predicted to impact 3,007 birds) was estimated at mortality of 18 birds per year during the breeding season and none during non-breeding periods, assessed as negligible impact in EIA terms (Cork Ecology, 2025). In the text, Cork Ecology (2025) states that the calculation was based on a displacement rate of 30% and mortality of displaced birds of 1%, different from the statement in Table 11-17. If based on 3,007 birds at risk of displacement with 50% displacement rate and 1% mortality then the impact would be 15.04 birds killed rather than 18. However, their estimate of 18 bird deaths due to displacement is repeated in the text, the same as in the Table, and they then estimate that about 53.2% of the birds in the region are likely to be immatures (based on demographic parameter values in Horswill and Robinson (2015)), and therefore that eight of the 18 birds will be adults and ten will be immatures. That assumes (incorrectly) that

immature shearwaters show the same geographical distribution as breeding adults during the breeding season and are therefore represented as 53.2% of the birds in the OWF plus 2 km buffer area. Cork Ecology (2025) then go on to compute that the loss of eight adults would represent additional mortality of 0.017% of the regional population (estimated to be 363,150 adults) and therefore would be negligible and not significant in assessment terms.

146. Manx shearwater was screened out of CRM assessment based on the absence of an impact pathway due to this species low flight heights (Cork Ecology, 2025; Table 11-28). No account was taken of any effects of ALAN on these parameters and numbers.

4.1.1.2 European storm-petrel

147. European storm-petrels were recorded in the survey area (including 4 km buffer) in May and July in year 1 (2022) with a peak of 25 in July. In year 2 (2023), they were recorded between May and August with a peak of 17 in August (Cork Ecology, 2025, MKO 2025). Mean maximum foraging range of breeding European storm-petrels plus one SD is 336 km (from Woodward et al., 2019) and so there is potential connectivity between several Irish SPAs with breeding European storm-petrel as a feature and the OWF site.

148. Impacts during construction were screened out as the species was considered to have a very low sensitivity to disturbance. Impacts during operation were screened out as the numbers recorded in the baseline survey were small, and storm-petrels were considered at low risk of impact from collision or displacement (Cork Ecology, 2025).

4.1.1.3 Impact from turbine lighting

149. Impacts from turbine lighting were explicitly considered by Cork Ecology (2025), but separately from the CRM and displacement assessments and only in qualitative terms. They stated "*There is the potential that aviation and navigation lighting on wind turbines could attract or repel birds moving through the OAA at night. There is some evidence that nocturnal lighting may cause changes in bird behaviour and habitat selection (Drewitt and Langston, 2008). However much of this evidence is based on oil and gas platforms, and as offshore wind farms are typically less intensively lit than these installations, any impacts are likely to be less extreme. While species such as Manx shearwater and storm petrel could be considered at potential risk of attraction to turbine lighting at night, the potential for impacts is still considered low. Although there is some evidence of foraging occurring at night in Scotland (Kane, 2020), Manx shearwater foraging occurs almost exclusively during daylight*

hours. The majority of nocturnal behaviour would typically be associated with birds rafting close to colonies in the evening and then returning to their burrows after dusk. As there are no Manx shearwater colonies in the immediate vicinity of the Project, and as foraging activity is likely to be low during nocturnal hours, potential impacts from attraction to turbine lighting in terms of impacts on breeding success is considered to be of negligible magnitude. Based on available evidence, it is considered that red lighting (e.g., aviation warning lights) may have minimal effects on seabirds, with yellow lighting (e.g., navigational lighting) also having low impacts (Syposz et al., 2021). Any impacts on birds in the vicinity are considered to be restricted to the operation and maintenance phase, and to the hours of darkness, when the majority of seabirds are inactive. Survival and reproductive rates of key bird species are very unlikely to be impacted to the extent that the population trajectory would be altered. The maximum magnitude of any effect on key bird species from aviation and navigation lighting associated with the Project has therefore been assessed as Low."

150. The Appropriate Assessment and Natura Impact Statement concluded that the Project would have no adverse effect on the integrity of any SPA site, either alone or in combination with other plans or projects (Cork Ecology, 2025). The assessment does not refer to the extensive recent literature on effects of ALAN on storm-petrels and shearwaters, does not consider the extent to which the DAS may have underestimated the baseline abundance of storm-petrels in the development area, and contains inconsistencies in the calculation of impacts of displacement on Manx shearwaters.

151. The Lighting and Marking Plan (MKO and XODUS, 2025) specified marine navigation lights on significant peripheral structures with a yellow 5s flash with at least 5 nm range, and marine lights on selected intermediate peripheral structures with a yellow 2.5s flash with at least 2 nm range, and aviation hazard warning lights on all peripheral structures mounted on the highest point practicable, white with a flash rate of 40-60 fpm, 200,000 candela when background illuminance exceeded 500 candela/m^2, at least 2000 candela when background illuminance was below 50 candela/m^2, and with SAR lights on all structures with 200 candela continuous red light.

4.1.2 Mona Offshore Wind Project

152. Mona OWF lies in the Irish Sea off North Wales. Baseline DAS detected only one storm-petrel in the 24 monthly surveys, but detected up to 1,269 Manx shearwaters, the highest count being during the breeding season (RPS, 2024e,NIRAS, 2024f). No correction was made for low detection of storm-petrels by DAS. Storm-petrels were therefore considered to

have negligible impact from Mona OWF in CRM and displacement analysis based on the DAS data (RPS, 2024e, NIRAS, 2024f-i). However, European storm-petrel and Leach's storm-petrel were also assessed separately as migratory birds using the SOSS Migration Assessment Tool (RPS, 2024e, NIRAS, 2024f-i). That assessment gave much larger estimates of collision numbers, though still regarded as a negligible impact at the EIA level (RPS, 2024e, NIRAS, 2024f-i). Effects of ALAN were not considered in the assessment of migratory bird impacts (RPS, 2024e, NIRAS, 2024f-i) but RPS (2024e) stated "*aviation and navigation lighting at the Mona Offshore Wind Project is unlikely to result in increasing collision risk".* No evidence was presented to explain that conclusion other than the low flight height of shearwaters and storm-petrels.

4.1.3 Morgan Offshore Wind Project

153. Morgan OWF lies in the Irish Sea off North Wales. Baseline DAS detected no storm-petrels in the 24 monthly surveys but detected Manx shearwaters in 11 of the 24 surveys (April to September), the highest count being during the breeding season (NIRAS, 2024a,b). No correction was made for low detection of storm-petrels by DAS. Storm-petrels were therefore considered to have negligible impact from Morgan OWF in CRM and displacement analysis based on the DAS data (NIRAS, 2024c,d). However, European storm-petrel and Leach's storm-petrel were also assessed separately as migratory birds using the SOSS Migration Assessment Tool (NIRAS, 2024e). That assessment gave much larger estimates of collision numbers, though still regarded as a negligible impact at the EIA level (NIRAS, 2024a,e).

154. In relation to effects of ALAN on shearwaters and storm-petrels, NIRAS (2024a) state "A recent review highlighted that certain species of birds (especially those that nest underground such as shearwaters and petrel species) are often attracted to powerful light sources (Deakin et al., 2022) however, in the examples given, the light sources to which birds were attracted are significantly brighter than the lights associated with an offshore wind farm. Lights on offshore structures, including offshore wind turbines must comply with minimum requirements as set out in the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) Recommendation O-117 on 'The Marking of Offshore Wind Farms' for navigation lighting and by the Civil Aviation Authority in the Air Navigation Orders (CAP 393 and guidance in CAP 764). Such lighting is not comparable to the examples given in Deakin et al. (2022) and it is therefore considered unlikely that attraction will occur". On the basis of that conclusion, the assessment made no adjustments of collision or displacement impacts on storm-petrels or shearwaters.

4.1.4 Morecambe Offshore Windfarm

155. DAS recorded no European storm-petrels or Leach’s storm-petrels but did record large numbers of Manx shearwaters during the breeding season, with a peak estimate of 8,699 present in July 2021. Collision risk for Manx shearwater was assessed to be zero because of the low flight height of this species. Displacement/disturbance impact for Manx shearwater was assessed to be negligible. Possible effects of ALAN on Manx shearwaters and storm-petrels were considered in the Morecambe Offshore Windfarm Environmental Statement (Royal Haskoning DHV, 2025) concluding *“it is considered unlikely that the very limited lighting associated with the Project would significantly affect disturbance and displacement effects (and by extension, any collision risk) on Manx shearwater. Therefore, the conclusions of the disturbance and displacement assessment for this species, as set out above, remain unchanged*”.

156. Despite the lack of any storm-petrels in the 24 DAS, analysis of storm-petrel collision risk using the SOSS migratory bird tool predicted small numbers of collisions of both these species, but too few for the impact to be considered significant at the population scale. However, the discrepancy between the DAS results and the SOSS migration tool results was not discussed, and no adjustment was made for any impact of ALAN (Royal Haskoning DHV, 2025).

4.1.5 West of Orkney Wind Farm

157. The West of Orkney Wind Farm is approximately 25 km north of the north coast of mainland Scotland, and 28 km from Orkney. DAS recorded 53 European storm-petrels, no Leach’s storm-petrels and just 12 Manx shearwaters. NatureScot advised that there was no requirement to assess displacement effects for European storm-petrel, and Manx shearwater were also not assessed for displacement effects, due to the low risk of any displacement impacts for both species. Neither species was assessed for collision mortality, with the application stating that, “*European storm petrel and Manx shearwater generally fly too low to be at collision risk height, other than a possible increased risk of collision if attracted to lighting on WTGs. These two species were assessed using a qualitative approach*.”

158. West of Orkney Wind Farm (West of Orkney Windfarm, 2024) concluded that “the impacts of artificial lighting due to the operation and maintenance of the Project is considered to be low, due to the following reasons:

- *The lower intensity and high altitude of WTG lighting compared to other recognised sources of attraction such as oil platforms or lighthouses;*
- *The red lighting on WTGs is less likely to negatively impact Manx shearwaters, compared to white or blue/green lighting;*
- *The long distances between the OAA and most SPAs with Manx shearwater, European storm petrel and puffin qualifying features, with the exception of Sule Skerry and Sule Stack SPA;*
- *The lack of apparent high suitability foraging habitat within the OAA for shearwaters and petrels, based on known species' preferences and survey data;*
- *Due to the Restricted Build Areas, the distance of any WTG from the nearest colonies being at least 7 km from the SPA boundary (the marine extension to the SPA and not the colony itself), reducing the likelihood of attraction by significant numbers of young birds on fledging flights;*
- *The likely low proportion of the overall SPA populations that would be affected; and*
- *The low susceptibility of Manx shearwater, European storm-petrel and puffin to collisions with WTGs due to flight behaviour, even allowing for possible attraction to structures".*

4.1.6 Arklow Bank Wind Park 2

159. Arklow Bank Wind Park 2 is located between 6 and 12 km east of the coast of southern County Wicklow and northern County Wexford, Republic of Ireland. Baseline seabird abundances were primarily informed by DAS carried out monthly from March 2018 to April 2020 by HiDef.

160. At Arklow Bank Wind Park 2, a breeding season mean peak count of 1,015 Manx shearwaters was calculated from baseline survey data (MacArthur Green, 2024a-c). This species was screened out from any further impact assessment on the basis of very low collision risk and low sensitivity to disturbance and displacement (MacArthur Green, 2024a-c). With only one record of a storm-petrel in 24 digital aerial surveys (ten of which were in the European storm-petrel breeding season from May to September), that species was also screened out of any further impact assessment on the basis of very low abundance as well as very low collision risk and low sensitivity to disturbance and displacement (MacArthur Green, 2024a-c). There was no discussion of the extent to which DAS may have underestimated the baseline abundance of storm-petrels in the development area.

161. Effects of ALAN were considered. MacArthur Green (2024a) stated “Lighting of construction sites, vessels and other structures at night may potentially attract birds (phototaxis). Phototaxis can be a serious hazard for fledglings of some seabird species, particularly those that nest in burrows such as petrels and shearwaters (Deppe et al., 2017; Raine et al., 2007; Rodríguez et al., 2015). Research indicates that this impact occurs over short distances in response to bright light close to breeding colonies. It is not seen over large distances or in older (adult and immature) seabirds. Since the Proposed Development is not close to any breeding colonies for burrow nesting species this risk has been scoped out. Phototaxis of nocturnal migrating birds can be a problem, especially in autumn during conditions of poor visibility, but is generally seen where birds are exposed to intense white lighting such as from lighthouses; light from construction sites will be much less powerful than that from lighthouses, and therefore this can be scoped out. A review of the potential effects of operational lighting on turbines on birds considered available evidence to investigate potential impacts across eight categories (MacArthur Green, 2018). This suggested that lights on offshore wind turbines in European shelf seas are extremely unlikely to have any detectable effect on birds as a consequence of any of the processes listed above. The effects of operational lighting are therefore scoped out.”

4.1.7 US Pacific Outer Continental Shelf

162. A revised marine bird collision and displacement vulnerability analysis was carried out for seabirds of the US Pacific Outer Continental Shelf (Kelsey et al., 2025). This considered 89 marine bird species. Within that list are seven species of shearwater, including Manx shearwater, seven species of storm-petrel, including Leach’s storm-petrel, five species of petrel and 12 species of alcids, some of which are burrow-nesting species with high nocturnal activity and potentially affected by ALAN. The authors scored each species for each of the metrics relevant to CRM (nocturnal flight activity, diurnal flight activity, time spent in rotor swept zone, macro-avoidance) and displacement analysis (macro-avoidance, habitat flexibility) in order to rank species by assessed vulnerability. Collision vulnerability of shearwaters and storm-petrels was assessed to be among the lowest of all seabirds considered. Displacement vulnerability of shearwaters and storm-petrels was considered to be lower than for sea ducks, alcids, divers, pelicans and terns,but slightly higher than for gulls. Their analysis also considered data quality and variability but took no account of any effects of ALAN.

4.1.8 Oriel OWF

163. Oriel Wind Farm Project is located close to the northeast coast of the Republic of Ireland, 8 km east of Dundalk Bay and 6 km southeast of Carlingford Lough.

164. Oriel OWF seabird baseline data were mainly collected by boat-based surveys between 2006 and 2008, and between May 2018 and May 2020, but those were supplemented by DAS over one summer (April to September 2020) by APEM. Manx shearwaters were present in baseline surveys only during the breeding season, with peak numbers in the study area of 21,241 individuals in August 2019. The site has potential connectivity with nine SPAs where Manx shearwater is a designated feature. Despite abundance of Manx shearwater being classified as “very high”, this species was scoped out of assessment on the basis of very low sensitivity to collision risk and disturbance/displacement (RPS, 2024a).

165. Only six storm-petrels were recorded in all of the boat-based and digital aerial baseline survey transects between May 2018 and September 2020, so European storm-petrel was scoped out from further consideration, despite potential connectivity with SPAs with breeding European storm-petrels as a feature (RPS, 2024a). Despite their presence in baseline surveys, storm-petrels are entirely missing from the Offshore Ornithology chapter of the EIA, including from Table 11-9 which lists all bird species recorded in the offshore ornithology baseline surveys (RPS, 2024b). All six of the storm-petrel records were obtained from the boat-based surveys; no storm-petrels were identified from the DAS (RPS, 2024c). This difference between results from boat-based surveys and DAS further suggests that storm-petrels are likely under-represented in DAS data sets due to detectability issues (although it is also possible that storm-petrels are over-represented in boat-based surveys).

166. RPS (2024a) stated “There is the potential that aviation and navigation lighting on wind turbines might attract seabirds and thus increase risk of collision. Conversely, aviation and navigation lighting could repel birds moving through the Project. There is little published evidence showing the effects of lighting on seabird collision and displacement”. This is the only consideration given in that assessment to effects of ALAN on storm-petrels or shearwaters.

167. In relation to shipping, Oriel OWF plan to install navigation lights on six peripheral wind turbines with the lateral distance between lit structures not exceeding 3 nautical miles, with the lights shaded to allow only horizontal light emission, flashing yellow, with a range of not less than 5 nautical miles (RPS, 2024d). In relation to aircraft, Oriel OWF plan to install a

white light on the highest point practicable of each fixed structure exceeding 90m, screened to ensure virtually no light below horizontal, with a flash rate of 40-60 flashes per minute synchronous throughout the wind farm, at an intensity determined by ambient light; with ambient light <50 candelas/m^2 the lights will be set at a minimum of 2,000 candelas. With ambient light exceeding 500 candelas/m^2 the lights will be set at 200,000 candelas (RPS 2024d).

4.1.9 Erebus

168. Erebus Floating OWF lies about 40km from Skomer, Skokholm and Seas off Pembrokeshire SPA where European storm-petrel is a breeding feature of the SPA with a population representing about 9.5% of the Great Britain breeding population of this species (HiDef, 2021). Despite the fact that the mean foraging range of European storm-petrel is over 200 km (Woodward et al. 2024), DAS over 24 months at Erebus recorded no storm-petrels. HiDef (2021) concluded "*No European storm-petrels have been observed in 24 months of DAS data. Therefore it is considered that this species is not present at this site*". In the HRA assessment, MarineSpace (2021) concluded, "*Given the lack of European storm-petrels recorded during the digital aerial surveys the likely mortalities arising from displacement would be 0 which equates to predicted displacement mortalities of <1% of regional numbers*". Neither of these reports discusses the likely failure of DAS to detect European storm-petrels efficiently.

169. The Environmental Statement (Blue Gem Wind, OWC, ITPenergised and MarineSpace (2021) noted that in the absence of evidence that European storm-petrels were present, a qualitative assessment of impact was made based on expert opinion. On that basis it was concluded that impacts of vessels, collisions and displacement would all be negligible. However, it was noted that this species may be affected by ALAN. The report states "*Current literature suggests that the magnitude of attractive effects from artificial lighting on project infrastructure is primarily determined by the colour and mode (continuous vs blinking) of the lights. Continuous light has been shown to have a significantly greater attractive effect when compared to blinking lights across all colours, other than red light. Red light has been observed to have a very low attractive effect regardless of mode, with the attractive effect of continuous red light being similar to that of blinking lights of other colours*". "*Lighting used on Project infrastructure will be limited to red continuous and yellow blinking, which are considered to have very low attractive effects. The only use of white lights will be during infrequent maintenance visits to the WTGs. It is anticipated this would be a maximum of 2 x 12 hours visits per WTG per year, which for a maximum of 10 WTGs would result in a total*

of 20 visits per year. The white lights (above doorways and on gangplanks) will be connected to motion sensors and only triggered when someone is present on the WTG." "*The magnitude of the impact has been assessed as negligible and the sensitivity of seabird receptors as high. Therefore, the impact of attraction to lighting on project infrastructure is assessed as having minor adverse effect, which is not significant in EIA terms*".

4.1.10 Robin Rigg

170. Boat-based surveys were used in 2001-2002, 2003, 2004 and 2007 to obtain pre-construction baseline data on seabird numbers. The same boat-based survey method was repeated during construction in 2008 to 2010, and in operational years 1 (2011), 2 (2012) and 3 (2013). This allowed comparison between seabird counts pre-construction with construction and operation phases. Baseline surveys found Manx shearwaters and European storm-petrels during breeding season months, with totals of 1,566 Manx shearwaters and 20 European storm-petrels (Canning et al., 2013). Manx shearwaters and European storm-petrels were considered to be at low risk from this development because of their low flight height and low vulnerability to disturbance/displacement (Canning et al., 2013) but were included in monitoring surveys during construction and operation. During construction both species were recorded in surveys with a total of 1,685 Manx shearwaters and 19 European storm-petrels. However, during the first three years of operation the numbers of both species were considerably lower; 726 Manx shearwaters and no European storm-petrels (Canning et al., 2013). Reasons for this change in abundance are unclear.

4.1.11 Summary of approaches taken to impact assessment for Manx shearwater and storm-petrels

171. A few of the OWF consent applications reviewed above included a quantitative approach to estimating collision and displacement mortality, although most impact assessments screened out this impact pathway due to collision and displacement mortality being presumed to be very low, e.g. due to the low flight heights of shearwaters and storm-petrels. Where a quantitative assessment was undertaken, predicted mortality was sufficiently low that impacts were negligible.

172. No application presented a quantitative assessment to estimate how collision or displacement mortality risk could be elevated by attraction to/disorientation by ALAN on OWF infrastructure or vessels. In all cases, a qualitative evaluation of the extent to which shearwaters and storm-petrels could be attracted to ALAN was undertaken. In all cases,

attraction/disorientation was assumed to be low and consequently no increase in collision or displacement mortality was found.

4.2 Recommendations for future assessments

173. It is clear from the review of evidence on the effects of ALAN on shearwaters and storm-petrels presented earlier in this report, that, although much new material has been gathered in recent research studies, there remains no quantitative approach to assessing potential mortality that could arises through collision or displacement for shearwaters and storm-petrels from ALAN on OWFs. Recent planning applications (section 4.1) have generally used some of the recent work on ALAN effects on seabirds to conclude that lighting at UK OWFs at night is unlikely to have any detectable impact on shearwaters or storm-petrels. That broad conclusion appears to be supported by the new evidence that has been gathered in recent years. The conclusion from this appears to be that the only approach currently available is to make a qualitative assessment rather than quantitative adjustments to CRM and displacement calculations, but that the strength of evidence points strongly to a conclusion that ALAN at OWFs is not bright enough, white enough or continuous enough to cause significant risk to shearwaters and storm-petrels at night, and also that OWFs are generally too far from breeding colonies of these species to be likely to have any detectable effect.

174. NatureScot wish to see detailed and preferably quantitative or semi-quantitative assessments for storm-petrels and shearwaters that might be affected by attraction/disorientation by ALAN on OWFs. There are no data from anywhere in the world on the extent to which ALAN at OWFs attract either storm-petrels or shearwaters. There are no data from anywhere in the world on the extent to which collision risk might increase (or decrease) at offshore wind farms with artificial lighting. Data on displacement/avoidance for these species are extremely scarce. This indicates an urgent need for experimental studies to determine whether or not the kind of artificial lights installed at offshore wind farms result in any behavioural changes of storm-petrels or shearwaters that might influence collision risk or the magnitude of any displacement effect. Without such experimental study, any quantitative or semi-quantitative approach can only be based on expert opinion rather than on evidence.

175. It is for NatureScot (and other relevant statutory advisors) and MD-LOT (and other regulators) to advise applicants on how they wish to see impact assessments undertaken. Applicants should always follow this advice. Below are some recommendations on how

impact assessments could be undertaken, in the context of the updated evidence review presented under Task 1. Any deviation to the approach recommended by NatureScot and MD-LOT should be discussed with them before adopting the recommendations presented in this report.

4.2.1 Recommendation 1. That until experimental data are available, use of expert opinion should be used in assessments of the likely consequences of ALAN for collision risk or displacement of storm-petrels and shearwaters at offshore wind farms.

176. The review under Task 1 has shown that there is no evidence for one of the key parameters for collision risk modelling, avoidance rate. Given that recent evidence has confirmed that Manx shearwaters and European storm-petrels generally fly below the rotor swept area, it is reasonable to assume that the risk of collision mortality is very low and that no collision risk modelling is required for these species, in the absence of any attraction/disorientation caused by ALAN.

177. Deakin et al. (2022) concluded that although there is a lack of empirical evidence relating to displacement, disturbance and barrier effects in shearwaters and storm-petrels, their ecology and response to anthropogenic disturbance means that these species are assumed to have low vulnerability to this impact pathway. The updated review presented in this report also notes the scarcity of information on extent of displacement of these species from OWFs. It may be possible to use expert opinion to generate a displacement rate and estimate of consequent mortality for these species, enabling use of the displacement matrix to estimate displacement mortality in the absence of any attraction/disorientation caused by ALAN. However, under recording of these species, particularly storm-petrels, means that abundance estimates used in the displacement matrix are likely to be substantial underestimates of true numbers of storm-petrels using the development area.

178. Assessing how risk of collision and displacement mortality occurring are altered by attraction to or disorientation by ALAN is challenging due to the absence of any empirical data on how shearwaters and storm-petrels respond to ALAN on OWFs. It is always preferable to use an evidence-based approach rather than expert opinion, but in the absence of relevant evidence from OWFs, a short-term approach could be to use expert opinion until evidence becomes available. Expert opinion could draw on a wide body of global evidence related to observed effects of ALAN on shearwaters and petrels, as outlined in this report. In particular, the known characteristics of lights to be used at OWFs can be put into context in relation to existing ALAN from coastal sources (including lighthouses and coastal industrial sites), from

vessels (fishing boats and cruise ships in particular) and offshore oil and gas which evidently emit much higher levels of ALAN than are likely at OWFs.

4.2.2 Recommendation 2. That appropriate experiments are carried out to determine whether or not the kind of artificial lights installed at offshore wind farms result in any behavioural changes of storm-petrels or shearwaters that might influence collision risk or the magnitude of any displacement effect.

179. Recommendation 1 suggests that expert opinion is used for impact assessments in the short term, in the absence of empirical information. Recommendation 2 identifies research that could be undertaken to obtain empirical evidence, removing reliance on expert opinion in the longer term. Note, timescales for obtaining such empirical evidence from studies such as those recommended below mean that it will be several years before project consent applications can undertake impact assessments using this new empirical data.

180. New empirical data is best collected through a strategic programme rather than individual project-specific post-consent monitoring. This is because the location of colonies of Manx shearwaters and European storm-petrels, and the location of planned OWFs, mean that certain types of studies are best carried out at particular colonies or OWFs. Taking a strategic approach to monitoring and research will enable the optimum experimental design to be implemented, resulting in outputs that have the highest chance of furthering our understanding of how shearwaters and storm-petrels respond to ALAN.

181. Current CRM models assume that density of birds in flight is correct but limitations of DAS mean that numbers of storm-petrels are likely to be underestimated considerably. Models also assume flight heights are as observed during daytime (although data from tracking could be used for nocturnal flight heights). However, it is assumed that flight heights are not influenced by ALAN. CRM models also assume a constant flux of birds through the rotor-swept area, whereas ALAN may result in birds flying in circles.

182. Four approaches might provide data that would allow quantitative adjustments to CRM for storm-petrels and shearwaters.

- One would be derivation of a correction factor for digital aerial surveys to adjust for the failure of DAS to detect some or many storm-petrels.
- The second would be further GPS tracking of the movements of breeding adult storm-petrels and shearwaters (specifically, European storm-petrels, Leach's storm-

petrels and Manx shearwaters) from Scottish colonies that seem likely to have connectivity with operational OWFs.

- The third would be to use existing GPS tracking data and geolocation logger data to investigate whether behavioural responses to ALAN can be detected.
- The fourth would be to establish camera systems at OWF turbines to record numbers of storm-petrels and shearwaters that approach the rotor-swept area during the night with ALAN present or absent.

183. These four possible studies are outlined below.

4.2.2.1 DAS corrections for storm-petrel baseline abundance

184. It is highly likely that DAS data significantly underestimate numbers of storm-petrels in baseline characterisations because these very small birds are cryptic and likely to be overlooked. Greater confidence in baseline density estimates would be obtained by experiments that determine correction factors that should be applied to DAS data for storm-petrels. Detectability could be tested by carrying out DAS where decoy models of storm-petrels (separately for birds in flight postures and birds sitting on the water as the latter are likely to be especially cryptic) have been deployed to quantify detectability under the range of conditions over which DAS are normally carried out.

185. Alternatively, it might be possible to use thermal imaging (potentially using drones rather than aircraft) to conduct surveys to obtain estimates of storm-petrel abundance to compare with data from DAS of the same area. Thermal imaging should allow detection of storm-petrels but may not allow accurate estimation of which detected birds are storm-petrels rather than other species.

186. Boat-based surveys may be inappropriate for counting storm-petrels, as these birds may be attracted to boats (Camphuysen et al., 2004, Thomas, 2024).

187. Baseline densities could also potentially be estimated from known colony sizes and foraging ranges (from tracking data) but such estimates would be difficult as the numbers and spatial distribution of immature and nonbreeding storm-petrels would be difficult to assess, and colony sizes and foraging ranges are rather uncertain, with very limited information on how foraging ranges differ between colonies.

4.2.2.2 GPS tracking of the movements of breeding adult European storm-petrels, Leach's storm-petrels and Manx shearwaters from Scottish colonies that seem likely to have connectivity with operational OWFs

188. Reductions in the size and weight of GPS tags has now made it possible to track over a period of several days movements of seabirds as small as breeding adult European storm-petrels caught at the nest (e.g. Bolton, 2021). Tag attachment has to be by tape onto tail or back feathers as harnesses are not considered suitable for storm-petrels (or shearwaters). As a result, tags are likely to be lost within a few days of deployment as tape on feathers does not last for long. This limits such studies to probably only one foraging trip during the breeding season. In a study with European storm-petrels, Bolton (2021) found that the tag remained attached to one bird for less than one day, up to a maximum of 12 days, but with most tags remaining attached for the duration of one foraging trip. This allowed tracking of one foraging trip by a sample of breeding adults (lasting between one and three days), with no evidence of any adverse effect on body condition of the adult or on breeding success caused by these short-term deployments (Bolton, 2021). Tag recovery rate in that study was high, at 78% for a sample of 58 tagged birds. GPS tagging of European storm-petrels, Leach's storm-petrels and Manx shearwaters at several selected colonies would provide evidence of spatial overlap between the foraging areas (and associated commuting routes) of these birds and OWFs.

189. It is noted that further strategic tagging studies are currently underway (e.g. a two-year storm-petrel tagging study at Mousa, Shetland), which are expected to improve the evidence base on at-sea behaviour, nocturnal activity and potential responses to artificial lighting.

190. Analysis can show overlap (if any) with locations where behaviour might be affected by ALAN. For example, Bolton (2021) showed that home ranges of European storm-petrels from Mousa (Shetland) overlapped with 206 active hydrocarbon wells and 14 operating oil and gas platforms in the North Sea, but that overlap at night (when ALAN effects might occur) was less as birds tend to forage during the day but commute to/from the colony at night so show a more pelagic distribution during daylight hours.

191. Deployment of a GPS tag that also recorded light intensity would allow analysis of the amount of ALAN to which birds were subjected during the nocturnal part of foraging trips. The exact locations where birds were exposed to ALAN and the amount of time birds spent in those locations would help to indicate whether birds were being attracted to artificial lights at sea, and to indicate whether ALAN at OWFs was likely to affect collision risk or

displacement risk. Sample sizes for such studies would need to be of at least about 40 to 60 birds tagged at a focal colony, with an anticipated tag recovery rate around 60% (recovery by Bolton (2021) of 78% may be difficult to achieve at other colonies, but there is useful guidance in Bolton (2021) that higher recovery rates can be achieved during incubation, because adult attendance at the nest is predictable, whereas during chick-rearing adults spend little time with the chick so tag recovery becomes more difficult). It might therefore require tag deployments and recovery in several breeding seasons to accumulate data from an adequate sample size. Alternatively, remote download tags to a base station at the colony could allow higher data recovery but such tags would likely be too large to deploy on storm-petrels.

4.2.2.3 Analysis of existing data from GPS and geolocator studies on European storm-petrels, Leach's storm-petrels and Manx shearwaters to assess the likelihood of behavioural responses to ALAN

192. There are already a number of studies that have deployed GPS tags on breeding adult European storm-petrels, Leach's storm-petrels and Manx shearwaters at colonies around the UK. Data from those completed or ongoing tracking studies might allow analysis of the sort proposed above (see Section 4.2.2.2), though it may be desirable to deploy tags that combine monitoring of light level as well as GPS location, and it seems likely that most existing studies are limited to just GPS data without simultaneous measurement of ambient light levels. There may also be complications with gaining access to existing data sets that have mostly been collected under contracts from various different offshore wind developers.

193. However, several data sets already exist for all of these focal species and it would make sense to explore the availability of those and whether they would provide the relevant evidence, before starting on a relatively long-term (and therefore relatively expensive) new tagging study. Relevant ongoing or recent studies include GPS tag deployments on Manx shearwaters at Rum (OxNav research group at Oxford University led by Professor Tim Guilford), GPS tag deployments on Manx shearwaters breeding at Lunga, Treshnish Isles by NTS for SPR, GPS tag deployments on Leach's storm-petrels at St Kilda by RSPB, led by Dr Mark Bolton, and GPS tag deployments on European storm-petrels also led by Dr Mark Bolton.

4.2.2.4 Camera monitoring of storm-petrel and shearwater flight activity around turbine-mounted ALAN

194. Thermal camera systems at OWF turbines may be able to detect storm-petrels flying into the rotor-swept area, although that would need to be confirmed. Infra-red illuminated camera systems might also be suitable, noting that caution is required to ensure that infra-red illumination does not have an adverse effect on behaviour. If they can detect these small birds then deployment of thermal cameras at the top of turbines close to the aircraft warning lights to record the number of cases where storm-petrels are attracted to the light and whether they enter the rotor-swept area (and any collisions) would provide a direct measure of collision risk in relation to possible ALAN effects. Birds might also be attracted to navigation lights at the base of turbines, but those lights will be much less bright and so will be much less likely to attract birds. Camera systems would also provide evidence to confirm or refute that.

195. However, it would be crucial that the ability of these camera systems to detect birds as small as storm-petrels should be determined first. If that is the case, it may be possible to use thermal camera data to investigate whether storm-petrels (and Manx shearwaters) are attracted to lights at the top of turbines.

196. There would also need to be assessment of whether storm-petrels could be distinguished from passerine nocturnal migrants, which could be difficult, although the shape of storm-petrels and their thermal image would seem likely to be rather different from that of passerines. If such systems were successful at monitoring storm-petrels close to rotor-swept areas, then an experimental approach, comparing numbers present with and without lighting on the tower (potentially with a paired comparison test to have ALAN switched between focal turbines), could provide a statistically robust assessment of the effect of ALAN.

5.0 Task 3: Synthesis of information on OWF lighting requirements and how that relates to recorded attraction and stranding events involving shearwaters and petrels

197. This task sets out the lighting parameter requirements pertinent to OWFs in the UK for the purposes of safety of navigation, aviation and Search and Rescue (SAR). Table 5-1 summarises each navigational safety lighting requirement and their characteristics where such information is available. Following this, Table 5-2Table 5-2 provides a comparison of key parameters of the identified OWF lighting against lighting on lighthouses and oil and gas platforms. For both installation types, exact lighting parameters will vary and therefore the information provided is indicative only. Indicative information on vessel lights is also included based on requirements of the Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs) (International Maritime Organization (IMO) 1972/77) noting requirements for vessels differ depending on size and activity being undertaken.

Table 5-1. Offshore Wind Farm Lighting Parameters. (NVIS/IR: Night Vision Imaging System and Infra Red compatibility)

Type of light	Applicable structures	Range	Intensity	Colour	Flashing Characteristic	Switched on	NVIS/ IR	Location	Light divergence/ spill
Temporary Construction Lights *Industry standard and consideration under IALA G1162*	All surface piercing infrastructure during construction (both WTGs and substations)	Minimum 2 nautical mile (nm) (IALA G1162 states “low range”)	Not specified	Yellow	Flashing special mark characteristic, (typically Flashing (Fl) yellow (Y) 2.5 seconds (s)) visible in all directions Does not need to be synchronised across the site.	Always on during construction phase	No	Not specified, considered reasonable to assume similar principles as other marine Aid to Navigation (AtoN) i.e., between 6 metres (m) above Highest Astronomical Tide (HAT) and 30m above HAT, noting also IALA G1162 states below the rotor arc as an upper limit for isolated WTGs.	Not specified
Marine Lights (Significant Peripheral Structures (SPS))[4] *Required under IALA G1162*	All corner structures and interim periphery WTG positions such that distance between SPS does not exceed 3nm. May also be	Minimum nominal 5 nm	Not specified however IALA R0202 (E200-2) (IALA, 2020) indicates a nominal range of 5nm corresponds to a luminous intensity of between 54 and	Yellow	Synchronised flashing special mark characteristic (typically Fl Y 5s) visible in all directions	No allowance is given in IALA G1162 for lights to be off during daylight	No	Not specified in IALA G1162 for SPS, however the document references heights of between 6m and 30m above HAT for other AtoNs plus an upper	Not specified in IALA G1162[5] however it does state that lights on floating WTGs should have a “large vertical divergence” to account for movement of the

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[4] Note isolated structures outside of an array (e.g., booster stations along an export cable route) have distinct lighting requirements and are not covered in this report, however would typically require white lights with a range of at least 10nm to mitigate marine hazards.

[5] IALA G1065 (IALA, 2022b) references a photometric description developed by the German administration which concluded a minimum value of at least 50% of 120cd at the vertical angles of +/-2.5° was required for SPS. It is noted that SPS lights available on the market do have full width at half maximum (FWHM) larger than this.

Type of light	Applicable structures	Range	Intensity	Colour	Flashing Characteristic	Switched on	NVIS/ IR	Location	Light divergence/ spill
	required on substations if peripheral.		107 candela (cd) at night, and between 268 and 538 kilocandela (kcd) during daylight.					limit of below the rotor arc for isolated WTGs.	structure. IALA G1162 does also state that "divergence should enable the AtoN to be visible to mariners from the immediate vicinity of the structure to the maximum luminous range of the light" for other structure types.
Marine Lights (Intermediate Peripheral Structures (IPS)) *Required under IALA G1162*	Selected peripheral WTGs such that there is no more than 2 nm between the nearest IPS or SPS. May also be required on substations if peripheral.	Minimum nominal 2 nm	Not specified however IALA R0202 (E200-2) indicates a nominal range of 2 nm corresponds to a luminous intensity of between 3 and 9 cd at night, and between 12 and 45 kcd during daylight.	Yellow	Synchronised flashing yellow characteristic distinct from SPS (typically Fl Y 2.5 s) visible in all directions	No allowance is given in IALA G1162 for lights to be off during daylight	No	Not specified in IALA G1162 for IPS, however the document references heights of between 6 m and 30 m above HAT for other AtoNs plus an upper limit of below the rotor arc for isolated WTGs.	Not specified in IALA G1162[6] however it does state that lights on floating WTGs should have a "large vertical divergence" to account for movement of the structure. IALA G1162 does also state that "divergence should enable the AtoN to be visible to mariners from the immediate vicinity of the structure to the maximum luminous range of

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[6] IALA G1065 (IALA, 2022) references a photometric description developed by the German administration which concluded a minimum value of at least 50% of 120cd at the vertical angles of +/-2.5° was required for SPS. It is noted that SPS lights available on the market do have full width at half maximum (FWHM) larger than this.

Type of light	Applicable structures	Range	Intensity	Colour	Flashing Characteristic	Switched on	NVIS/ IR	Location	Light divergence/ spill
									the light" for other structure types.
ID Lights *Required under Marine Guidance Note (MGN) 654 (Maritime and Coastguard Agency (MCA), 2021)*	All Structures (WTGs and substations)	Not specified however MGN 654 states that the ID numbers themselves "must be clearly readable by an observer stationed 3 metres above sea level at a distance of at least 150 metres from the turbine".	Mean luminance – 5 candela per square metre (cd/m^2) ≤ Lmean ≤ 10 cd/m^2 Uniformity factor – better than 1:4	Colour temperature – 2500 Kelvins (K) – 3500 K	Steady	Always	No	Around the tower base or the railings of the transition piece walkways, usually somewhere close to the level of the entrance door area.	Required to be "hooded or baffled so as to avoid unnecessary light pollution or confusion with navigation marks". No allowance is specified.
Aviation warning lights *Required under Civil Aviation Policy (CAP) 764 (Civil Aviation Authority (CAA), 2025) and Air Navigation Order (S.I 765/2016.)*	All peripheral WTGs (peripheral substations may also require depending on height).	Not specified. IALA R0202 (E200-2) (IALA, 2020) indicates a nominal range of 11nm corresponds to a luminous intensity of between 1.76 and 2.84 kcd at night.	2,000 cd	Red	Synchronised flashing Morse 'W' for 5 seconds visible in all directions	Can be off during the day On at night but can be dimmed to 200 cd when visibility is greater than 5 km in all directions The option of Aviation Detection and Obstacle Lighting System (ADLS) is only included	Yes	As close as reasonably practicable to the top of the tower i.e., on the nacelle	When displayed—(a) the angle of the plane of the beam of peak intensity emitted by the light must be elevated to between 3° and 4° above the horizontal plane; (b) not more than 45% (900 cd) or less than 20% (400cd) of the minimum peak intensity specified for a light of this type is to be visible at the horizontal plane; (c) not more than 10% (200 cd) of the minimum peak intensity specified

Type of light	Applicable structures	Range	Intensity	Colour	Flashing Characteristic	Switched on	NVIS/ IR	Location	Light divergence/ spill
						for onshore WTGs in the active CAP 764.			for a light of this type is to be visible at a depression of 1.5° or more below the horizontal plane.
SAR Lights *Required under MGN 654 (MCA, 2024)*	All structures (WTGs and substations) noting aviation light can double as SAR light on peripheral WTGs.	Not specified	200 cd	Red	Fixed illumination visible in all directions	Off under normal operations, switched on at MCA request during SAR operations	Yes	As close as reasonably practicable to the top of the tower i.e., on the nacelle	At least 30cd from 20° below nacelle level up to nacelle level and 200cd from nacelle level up to 90° above nacelle level
Heli Hoist Lights *Required under CAP 437 (CAA, 2026)*	All WTGs where heli hoists undertaken Not required on substations	Conspicuous at a range of at least 500 m and detectable at a range of at least 700 m in a meteorological visibility of 3 km in daylight and, if required, at night.	Up to 750 cd in daylight and up to 60cd at night. Transition from the daylight setting to the night-time setting when ambient illuminance falls below 500 lux and should switch before it reaches 50 lux. Transition from nighttime setting to the daylight setting when ambient illuminance rises above 50 lux and before it reaches 500 lux.	Green	In flashing mode, the light should flash at a rate of 120 flashes per minute (2 hertz (Hz)), ±10%. The maximum duty cycle should be no greater than 50%.	Steady: WTG blades and nacelle are secure, i.e. safe to operate. Flashing: preparation to accept hoist operations or, when displayed during hoist operations, that parameters are moving out of limits. Off when not safe to	No	The light should be located on the winching area platform of the wind turbine nacelle such that it remains within the field of view of the pilot during the approach to the wind turbine and throughout the winching operation, i.e., the coverage should be 360° in azimuth. The preferred location of the light is on top of the Safety Zone railing.	**Minimum Intensity:** Day: 0° to 2°: 16cd 2° to 10°: 410cd 10° to 90°: 16cd Night: 0° to 2°: 3cd 2° to 10°: 16cd 10° to 90°: 3cd **Max. intensity** Day: 0° to 15°: 750cd 15° to 90°: 120cd Night: 0° to 15°: 60cd 15° to 90°: 60cd

Type of light	Applicable structures	Range	Intensity	Colour	Flashing Characteristic	Switched on	NVIS/ IR	Location	Light divergence/ spill
			Transition accomplished smoothly (linear transition to within ±10%) without any noticeable step changes.			conduct helicopter hoist operations (light also off in normal operations when heli hoist not being undertaken)			

Table 5-2. Comparison of OWF Lighting against Lighthouse, Oil and Gas Platforms and Vessels

Type of light	Range	Intensity	Colour	Flashing Characteristic
Temporary Construction Lights	2 nm	Not specified	Yellow	Flashing
SPS	5 nm	Not specified	Yellow	Flashing
IPS	2 nm	Not specified	Yellow	Flashing
ID Lights	Not specified in guidance	Mean luminance – 5 candela per square metre (cd/m^2) ≤ Lmean ≤ 10 cd/m^2	Colour temperature – 2500 Kelvins (K) – 3500 K	Steady
Aviation Warning Lights	Not specified in guidance	2000 cd	Red	Flashing
SAR Lights	Not specified in guidance	200 cd	Red	Fixed illumination
Heli Hoist Lights	Conspicuous at a range of at least 500 m	Up to 750 cd in daylight and up to 60 cd at night.	Green	Steady or flashing dependent on blade status
Lighthouse	Varies by lighthouse but typically greater than OWF SPS lighting (can be in excess of 20 nm)	Varies by lighthouse but often greater than the 2000 cd aviation lights	Typically white	Exact characteristic varies by lighthouse but typically will be flashing
Oil and Gas Platform	>=10 nm (according to IALA G1162, 2022)	12,000 cd (according to the Standard Marking Schedule (DECC, 2011))	White	Flashing
Vessels	Depends on vessel and light type (greatest range referenced in COLREGS (IMO, 1972/77) Rule 22 is 6nm for a masthead light on vessels of length > 50 m).	A 6 nm range corresponds to a 94 cd luminous intensity under requirements of COLREGS (IMO, 1972/77) Annex I Section 8.	White, red, green, yellow depending on light type, vessel and activity	Steady (noting flashing lights are required under certain circumstances)

198. Table 5-1 shows that most WTG lighting is yellow or red, with the exception of the heli hoist lighting which is green. Most lights are flashing, with the exception of the SAR lights and heli hoist lights, although the latter are only steady (not flashing) when helicopter hoisting is imminent and blades and nacelle have been made safe. Heli hoist lights are off during normal OWF operation. The brightest lights are the aviation warning lights, at 2,000 candela, although these are mounted on the nacelle, along with the SAR lights at 200 candela, and will be shielded below horizontal so will not be visible to shearwaters and storm-petrels flying low over the sea. Lighting lower on WTGs is much less bright, e.g. ID lights at 5 candela per square metre, which are mounted on the tower base or transition piece. Other marine lights, including lighting on significant peripheral structures, are typically mounted 6-30 metres above HAT. These have a brightness of less than 107 candela at night.

199. Table 5-2 compares different sources of artificial lighting at night with lighting requirements for WTGs. Making comparisons across sources of ALAN is challenging as most sources vary greatly in intensity, colour, etc. Oil and gas platforms have the highest intensity lighting, followed by lighthouses and then the aviation lighting on the nacelle of WTGs. Lighthouses have lights with the greatest range, followed by oil and gas platforms and then WTGs. Vessels have the greatest variety of colours of lighting with most lighting a steady beam. Oil and gas platforms have white lighting which flashes. Lighthouses generally have a white flashing light. Most WTG lighting is red or yellow and flashing, except for ID lights. Stranding events, or deck strikes, or fallouts of adult shearwaters are very rare. They seem to affect adult storm-petrels more often than adult shearwaters. However, these events are frequent with fledging storm-petrels and shearwaters. For instances reported in the literature there is a tendency for these events to occur during the new moon and not to occur during full moon periods, and to occur when visibility is particularly poor, with either fog or very dense low cloud.

200. Apparently conflicting literature showing that shearwaters and storm-petrels avoid ALAN at their colony, yet nevertheless may be subject to apparent attraction to ALAN might be resolved by considering a simple model in which fledgling shearwaters and storm-petrels (and puffins) are attracted to ALAN as part of the fledging process (as with marine turtle hatchlings) by moving to the lightest area because that is normally the sea under natural conditions without ALAN. This attraction seems to be lost soon after fledging and is not seen in adults. Adults appear to avoid ALAN when natural light at night is good and visibility is good, but it is likely that under conditions with no moonlight and low visibility, ALAN will disorient birds that come close to bright lights and that confusion/disorientation will lead to

birds flying in circles trying to “get their bearings” from landmarks, moonlight or stars. When those features are not visible and birds are subject to bright ALAN, they may circle closer to the source of light until in many cases they hit obstructions that they cannot see because of the dazzle from the bright artificial light. White, violet, blue and green wavelengths of light appear to cause this dazzle more than red light, brighter lights cause the dazzle more than dimmer lights, and continuous lights cause the dazzle more than flashing lights. This model seems consistent with almost all of the literature. Furthermore, a tendency to avoid ALAN in adults seems adaptive in that it is likely that predation risk will be higher where there is more light as that permits hunting by birds such as skuas and gulls which tend not to be active in dark conditions, as seen from the tendency of shearwaters and storm-petrels to be less active over their colonies at night when there is bright moonlight and avian predators are more active at colonies. The examples of adults being “attracted” to ALAN may therefore represent disorientation and confusion rather than attraction as such, but with birds finding it difficult to get away from bright ALAN because of the dazzle and confusion created and lack of visible landmarks.

201. Aviation warning lights required at offshore wind farms are red, flashing, lights of 2,000 candelas, shaded below horizontal, and placed as high as possible on peripheral WTGs. Not more than 10% (200 cd) of the minimum peak intensity specified for a light of this type is to be visible at a depression of 1.5° or more below the horizontal plane, which means that the lights may be less visible to low flying shearwaters or storm-petrels near the turbines. These lights are also much less bright than the flashing red light at Bardsey lighthouse (52,277 candelas) which has no impact on Manx shearwater or European storm-petrel (Archer et al., 2015; Trinity House, 2025). Navigation lights lower down the tower are less bright still, and so less likely to affect shearwaters or storm-petrels than aviation warning lights. Lower intensity lights are less likely to affect birds (Jones and Francis, 2003). Red lights are less likely to affect birds than white or blue lights (Porter, 2025, Rodriguez et al., 2017b, Syposz et al., 2021, Zein et al., 2025). Flashing lights are less likely to affect birds (Rebke et al., 2019). Lights at the top of towers that are shielded so that they do not light below horizontal will not be visible to shearwaters and storm-petrels flying close to sea level.

202. Given the evidence presented under Task 1, above, lighting on oil and gas platforms, being a bright, white light, is much more likely to attract seabirds than lighting on WTGs. The wide range of lighting on vessels means it is difficult to generalise about the extent to which seabirds would be attracted to vessel ALAN but bright white lights close to the sea surface are likely to be more attractive to seabirds than WTG lighting. Lighthouses also have greater

potential to attract seabirds than WTGs, where a white beam is used. Urban lighting will also be highly variable in colour, intensity, etc. making it difficult to generalise about the extent to which it could attract seabirds. The review presents evidence of Procellariformes being attracted to oil and gas platforms, lighthouses, vessels and urban lighting but the review could find no evidence for attraction of seabirds to OWFs. Whilst this may be due to the logistical challenges of recording attraction to OWFs and the few OWFs in the vicinity of Procellariform colonies, it may also be due to the fact that the lighting on WTGs is unlikely to attract seabirds, compared with other sources of ALAN.

203. However, the evidence from studies of seabirds is that environmental conditions (which cannot be mitigated) strongly affect the risk of attraction to ALAN. Nevertheless, it is highly likely that lights on OWF turbines will generally have little or no impact on shearwaters or storm-petrels at UK OWFs.

6.0 Task 4: Potential for modification of lighting arrangements for OWFs as mitigation, and recommendations on how to monitor shearwater and petrel behaviour and potential impacts at OWFs

6.1 Evaluation of potential to mitigate seabird attraction to lighting

204. The review of evidence of seabird attraction to ALAN has shown that seabirds tend not to be attracted to the types of lighting that are required on OWF infrastructure. The colour of the lights, the fact that lights are flashing rather than steady and that the brightest lights are on the nacelle and are shielded from being seen at the sea surface, strongly suggests that OWF lighting will not attract shearwaters and petrels. Therefore, there would be no need for mitigation to reduce impacts from attraction to ALAN by seabirds, as there would be no expected impacts. Nevertheless, the opportunities for mitigation of lighting are considered below.

205. Stranding events are strongly associated with bright ALAN. Mitigation by reducing the amount of ALAN or shifting to longer wavelength light has been shown to be effective in many case studies. While there is guidance from around the world on how to minimize impacts of ALAN on shearwaters and storm-petrels (Commonwealth of Australia, 2020, 2023, Department of Conservation and Fisheries New Zealand, 2023, DOC, 2025a,b,c Hawaii State, 2015, Lukies et al., 2019, NatureScot, 2020a,b, 2024a,b,c), this also raises an obvious question as to how low do ALAN levels need to be in order to ensure that this problem will be unlikely to occur at all.

206. The lighthouse at Bardsey attracted large numbers of migrant passerines but only small numbers of fledging Manx shearwaters and very few adults when it had a rotating white light of over 80,000 candelas. When that was replaced by a static but flashing LED red light of 52,277 candelas, there were no further strandings.

207. Regulations require heli hoist lights that will only be in use for short periods of helicopter activity, and ID lights of relatively low intensity. Marine lights of about 60 to 107 candelas (yellow flashing) will be much less bright than the aviation warning lights (red flashing lights of 2,000 candelas). However, those will be much less bright than the light of Bardsey lighthouse (52,277 candelas but also red flashing). Since the Bardsey light has no adverse impact on local Manx shearwater or storm-petrel adults or fledglings, it is reasonable to expect that the lights on OWF turbines will also have no adverse impact.

208. JFC Marine[7] markets LED lights for deployment at sites such as marine cages of salmon. These lights vary in properties, but one example is the LED160N light which is available as a white, red, yellow or green light. The white version has a 12-17 W LED light that provides 1,850 candelas and has a range of 3-12 nautical miles. Their LED350 light has a 84W LED white light of 14,700 candelas and a range of up to 15 nautical miles. There appear to have been no recorded instances of storm-petrel or Manx shearwater standing events or collision mortalities at these lights in British or Irish waters.

209. A recent planning application for a salmon fish farm in Argyll followed Northern Lighthouse Board’s advice to plan to install a yellow flashing light (exact output not specified) on the highest point of the farm that had sufficient luminosity to provide a range of at least 2 nautical miles (Northern Lighthouse Board, 2021). There was no suggestion in the representations of NatureScot or Marine Directorate of concern that this lighting could cause any problem with dazzling of storm-petrels or shearwaters and there appears to be no record of any UK fish farm lighting causing problems through attracting or dazzling storm-petrels or shearwaters..

210. Martin and Banks (2023) proposed modifications to OWF turbine blades, using achromatic patterning that would be likely to reduce collision risk. However, such mitigation would be less effective at night, and so does not provide a strong mitigation for potential effects of attraction to artificial lights in nocturnally-active seabirds.

211. In the context of adverse effects of ALAN on birds, Commonwealth of Australia (2020) lists best practice as:

- Start with natural darkness and only add light for specific purposes
- Use adaptive light controls to manage timing, intensity and colour
- Light only the object or area intended – keep lights close to the ground, directed and shielded to avoid light spill
- Use the lowest intensity lighting appropriate for the task
- Use non-reflective, dark coloured surfaces
- Use lights with reduced or filtered out blue, violet and ultra-violet wavelengths.

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[7] Aquaculture Navigation - JFC Marine

212. Commonwealth of Australia (2020) advises that where there is a protected area for vulnerable breeding seabirds within 20 km of proposed ALAN, an EIA process should be carried out, since sky glow can affect fledging seabirds up to 15 km distant (Rodriguez et al., 2014). However, 27 grounded wedge-tailed shearwater fledglings from colonies at O’ahu in Hawaii that had been banded at the nest were found at lights that were, on average 24.9 km from the nest site with the longest recorded being 140 km from its nest (Friswold et al., 2023), indicating that attraction to artificial lights can occur over many tens of km in some cases. That study concluded that the unusually long distances between nest sites and grounding sites in Hawaii might relate to the very high ALAN levels created by urban areas in Hawaii.

213. Different LED lights with the same correlated colour temperature can have very different blue content yet can appear similar to the human eye (Commonwealth of Australia, 2020, 2023). As the colour temperature of a white LED increases so can the blue content, but little or none of this increase in blue wavelength light is measured by photometric equipment such as lux meters. However, LED technology allows for tuneable RGB colour management which has the potential to allow for species specific management of problematic wavelengths (e.g. blue/UV light for fledging seabirds) (Commonwealth of Australia, 2020, 2023).

214. Commonwealth of Australia (2020, 2023) also recommends as mitigation the use of flashing/intermittent lights instead of a constant light, and use of red lights rather than white lights, use of automated systems to turn lights on only when essential and keeping light intensity as low as possible. They conclude that white LED, metal halide, white fluorescent, halogen and mercury vapour lights should always be avoided and that LED with appropriate spectral properties should be the preferred lighting system.

215. Mitigations advised by the New Zealand Department of Conservation (DOC, 2023, 2025a,b,c) to reduce risk of petrels and shearwaters colliding with fishing boats and with cruise ships include:

- Lights not essential for fishing operations and/or vessel safety are eliminated;
- All essential lights are shielded, angled and/or positioned to only light areas required for operations and safety and eliminate light spill;
- All essential lights use the lowest intensity as appropriate for operations and safety;

- All essential lights filter light spectra as appropriate for operations and safety (filter out blue/violet wavelengths).

216. To mitigate any impacts arising from seabird attraction to lighting on OWFs it is necessary to assess the potential flexibility in the current regulations. The recommendations and requirements for both marine and aviation lighting of UK offshore wind farms are governed by internationally set standards. Therefore, as a general principal there is unlikely to be scope for any significant change to the existing requirements for ornithological purposes at an industry level given this could lead to a risk of confusion to the relevant users, noting the importance of ensuring that offshore wind farm lighting continues to mitigate aviation and marine navigation risks. Of particular note is lighting colours and flashing characteristics, which are now well established in the UK and align with the international standards. Work has already been undertaken to ensure there is a clear distinction between marine AtoNs and aviation hazard lights, notably through use of a flashing Morse W pattern for the latter.

217. However, the following potential discussion points have been identified based upon the lighting review summarised in Table 5-1.

- Use of ADLS for aviation lights. This is a system which allows for aviation lights to be switched off automatically when no aircraft are detected in proximity and is currently allowed for onshore WTGs under certain circumstances. The technology is not currently included as an option for offshore WTGs under CAP 764 (CAA, 2025), however may be in the future. It is noted that even if ADLS was allowed for offshore WTGs in the future, it may not be applicable or allowed for all projects e.g., those in proximity to licensed aerodromes or regular helicopter flights such as between airports and oil and gas installations;

- Downward spillage of aviation lights. There are thresholds on the angles below the horizontal at which no minimum intensity is specified for aviation, SAR and heli hoist lights. There may therefore be scope to reduce or eliminate current light spillage below these angles depending on the current approaches taken by manufacturers;

- Vertical coverage of marine AtoN in direct proximity to structures. Under MGN 654, the ID lights are required to accommodate visibility of the ID signs at a distance of at least 150m. If it could be demonstrated that the ID lights represented suitable AtoNs for vessels within 150m of a structure then there may be scope for vertical divergence of SPS or IPS to be reduced in these proximal areas. It would also need to be demonstrated that the ID lights were capable of suitable uptime i.e., limited downtime and measures in place to rectify any faults.

218. At an individual project level, developers may also be able to agree bespoke site-specific lighting solutions subject to consultation with the relevant regulators. For example:

- Reduced range of marine lights where it could be demonstrated that this would not impact navigational safety (e.g., for lights pointing towards shore on nearshore projects, where distance to navigable areas was less than the range of an SPS);
- Use of SPS only rather than a combination of SPS and IPS (noting NLB have not required IPS lights on all recent offshore wind farm projects).

219. Any proposed changes would be subject to consultation with the relevant regulators including the NLB, CAA and the MCA, and may require the production of a safety case.

6.2 Potential monitoring and research to reduce uncertainty around how shearwaters and storm-petrels respond to OWF development

220. The evidence presented above, from various sources of ALAN, strongly suggests that there is a low likelihood of shearwaters and storm-petrels being attracted to the type of safety lighting used on operational OWF infrastructure. However, there remains an absence of data, on how shearwaters and storm-petrels respond to OWFs during construction and operation, to confirm this. As mentioned above, these studies would be best undertaken as strategic monitoring or research projects, to ensure optimal experimental design and sample sizes. Additionally, where uncertainty around how OWFs influence shearwater and storm-petrel behaviour and risk of reduced survival or productivity remains high, monitoring of shearwater and storm-petrel demography at colonies near to planned OWF could be beneficial.

221. Two forms of monitoring might be considered: monitoring of breeding numbers at SPAs with potential connectivity; and monitoring of shearwater or storm-petrel behaviour at OWF turbines and associated lights.

- Impacts arising from ALAN would be of concern if they were to lead to population declines/inhibit recovery of SPA qualifying features and/or wider EIA regional populations. In a Habitats Regulation Appraisal context, if monitoring shows that the

Conservation Objectives of a shearwater or storm-petrel qualifying feature of an SPA are not undermined, it can be concluded that the development does not affect site integrity. If monitoring of those features and colonies showed that breeding numbers remained stable or increased, this should theoretically remove any concern around impacts from ALAN. However, it is important to note that these populations are difficult to count with accuracy and individual counts tend to have large confidence intervals around the mean.

6.2.1 Monitoring breeding numbers

222. There are relatively few SPAs where shearwater and storm-petrel breeding populations are qualifying interest features, compared with most other seabird species, e.g. kittiwake. See Table 3-1Table 3-1, Table 3-2Table 3-2 and Table 3-3Table 3-3 for estimates of SPA population size for each species.

- For Manx shearwater in Scotland only Rum SPA, St Kilda SPA and Outer Firth of Forth and St Andrews Bay Complex SPA, plus Copeland Islands SPA in Northern Ireland, Aberdaron and Bardsey SPA, and Skomer, Skokholm and the seas off Pembrokeshire SPA in Wales. The Irish Sea Front SPA is beyond 12 nm, in UK waters.
- For European storm-petrel, there are seven sites in Scotland (Mousa SPA, Auskerry SPA, Sule Skerry and Sule Stack SPA, North Rona and Sula Sgeir SPA, St Kilda SPA, Priest Island SPA, Treshnish Isles SPA). SPAs in England and Wales with European storm-petrel as an interest feature are beyond maximum foraging range (NatureScot advise a foraging of 336 km, in their online guidance notes) from any current Scottish OWF development in the planning system so would be scoped out.
- Further SPA sites for Manx shearwater and for European storm-petrel exist in the Republic of Ireland and could be within range for being scoped into some OWF developments in some Scottish waters.
- For Leach’s storm-petrel, six SPAs are designated for their breeding populations, all in Scotland: Ramna Stacks and Gruney SPA, Foula SPA, Sule Skerry and Sule Stack SPA, North Rona and Sula Sgeir SPA, Flannan Isles SPA, and St Kilda SPA. There are no SPA sites for breeding Leach’s storm-petrel in England, Wales, Northern Ireland. There is one in the Republic of Ireland, Stags of Broad Haven SPA, which has potential to have connectivity to some OWF sites west of Scotland.

223. There are recognised standard species-specific methods for counting breeding numbers of seabirds, which are given in detail in Walsh *et al.* (1995) and with updates on methods outlined in Burnell et al. (2023). For counts to be comparable across years and colonies, it is important that they are made according to the approved methods and within the appropriate seasonal window, and expressed in the appropriate units. Monitoring breeding success and adult survival can also provide insight into population dynamics such as whether a population is acting as a source or a sink population (i.e. whether it produces a surplus of chicks or relies on additional birds from other colonies to maintain breeding population size). This is important as a population may undergo a decline concurrent with an OWF becoming operational, but this could be due to changes in metapopulation dynamics rather than any impact from the OWF. The ProcBe project is obtaining new evidence and developing novel modelling approaches to better understand shearwater and storm-petrel population dynamics.

6.2.1.1 Manx shearwater

224. The recommended count unit for Manx shearwater is Apparently Occupied Burrows (AOBs). That is relatively straightforward where Manx shearwaters breed on accessible slopes on islands with grass-covered soil in which the shearwaters dig long burrows. Burrows can be counted and classified as likely to be occupied based on evidence such as presence of droppings and feathers at the burrow entrance. In more recent counts, tape playback of Manx shearwater calls has been used to determine the proportion of burrows occupied by shearwaters (Burnell et al., 2023). However, at some colonies, Manx shearwaters also nest in boulder fields where there are no discrete burrows and where tape playback may elicit different probability of response than on grassy slopes where the sound can be played into burrow entrances (e.g. Rum). At some colonies Manx shearwaters may nest in caves or cracks in cliffs. In some colonies the occupied slopes are inaccessible areas part way down cliffs so that playback is impossible, or on islands where landing is impractical except under unusually good weather (e.g. Soay and Boreray, St Kilda). As a result, counts of Manx shearwaters vary in accuracy depending on the conditions at particular colonies. St Kilda and Rum, the two colony SPAs for breeding Manx shearwaters in Scotland, and the main colonies of this species in Scotland, both present technical challenges for counts of Manx shearwaters.

225. At St Kilda, there were estimated to be 3,731 AOBs of Manx shearwater in the Seabirds Count census in 2015-21, while there were estimated to be 4,803 AOBs in 1999 but that total is not significantly different from the estimate in 2015-21 (Burnell *et al.* 2023). These

birds were distributed across areas of Hirta, Dun, Boreray, and Soay, and of these the most accessible colony is on Dun, where Manx shearwaters nest mainly on the steep grassy slope of Dun facing towards Village Bay. The number on Dun was estimated to be 222 AOBs in 1999. It would be possible to monitor breeding numbers on Dun as a proxy for the whole of St Kilda, as monitoring numbers on the other islands is very difficult and counts are likely to be of low accuracy. However, that colony is relatively small. The size of the Manx shearwater breeding population in Scotland is almost entirely a consequence of changes in breeding numbers at the huge colony on Rum. Therefore, it may be more useful to monitor numbers on Rum although this would not detect colony-specific differences in any OWF impacts to the size of breeding populations.

226. At Rum, there were estimated to be 120,000 Manx shearwater AOBs in 2001 and 288,894 in 2015-21 (Burnell et al., 2023). This suggests a large increase in the population, which is consistent with findings at other major colonies such as Skomer, Skokholm, Bardsey, Blasket Islands SPA (Burnell et al., 2023). The SPA citation for Rum lists 61,000 pairs (equivalent to 61,000 AOBs) of Manx shearwaters (NatureScot, 2020b), so the population is evidently much larger than when the site was classified as an SPA in 1982. Therefore, this feature is in Favourable conservation status, and assessment of numbers should only require confirming that the population size remains well above 61,000 AOBs for this to continue to be the case. The census of Manx shearwaters at Rum has been carried out by measuring burrow numbers per m^2 in representative plots within the colony and multiplying that burrow density by the total area occupied by the colony. The former is easy to measure at plots put down on suitable ground. The latter has been measured from aerial photographs or from satellite images. The locations where Manx shearwaters breed on Rum are at the tops of the mountains on that island, where the soils are nutrient-poor and thin. Shearwater droppings provide a high input of nutrients within the colony area, resulting in dense bright green grass developing (so called ‘shearwater greens’). These unusual areas of bright green can be identified from aerial photographs, but the most recent census used satellite images to identify shearwater greens (Inger et al., 2022). Estimates of burrow density within the colony showed very little variation between censuses carried out between the 1970s and 2021 but showed huge changes in the estimates of total colony area. Therefore, mapping colony area from satellite images (following the methodology established by Inger et al., 2022) would provide the best evidence for any future change in the size of this population. However, statistical issues were identified with approaches used by Inger et al. (2022) which questions whether the population had actually increased to this extent (Matthiopoulos et al.,

2025). Ground truthing of such evidence is strongly recommended (Matthiopoulos et al., 2025).

227. These challenges of obtaining regular and accurate estimates of breeding population size at these colonies mean that detecting changes in population size attributable to any OWF impacts will be difficult. Only large decreases in population size would be detected.

6.2.1.2 European storm-petrel

228. The count unit for European storm-petrel is Apparently Occupied Sites (AOS). This is essentially equivalent to AOBs but recognises that most European storm-petrels nest in cavities rather than in burrows (e.g. in drystone walls or under boulders). Both units are closely similar to the number of breeding pairs and earlier counts for this species were generally expressed as pairs. In Seabirds Count and in the previous national census (Seabird 2000) most surveys used diurnal playback methods to assess numbers of AOS (Mitchell et al., 2004). That involves playing a recording of European storm-petrel calls in potential nesting habitat to get a response from a bird at the nest. Population estimates are then based on the number of responses multiplied by a correction factor determined either globally or locally, of the response rate of birds at nests. Response rates vary seasonally, between colonies, in relation to nesting habitat, and in relation to weather, time of day and the recording and playback equipment used, so add considerable uncertainty to estimates of numbers in a colony (Burnell et al., 2023). Furthermore, European storm-petrels often nest in inaccessible locations (such as part way down cliff faces) and so estimates may need to add uncertain numbers for areas that are inaccessible. That can be aided by use of night vision equipment to assess how many birds are active over inaccessible areas. An alternative can be to use mist net catches of European storm-petrels to estimate numbers from mark-recapture data (Burnell et al., 2023). Such estimates are also difficult, as a net only catches breeding birds from nest sites close to the net, but may catch substantial numbers of wandering nonbreeders. While breeding birds may be identified from brood patch status and a tendency to regurgitate food on capture or handling, the presence of wandering nonbreeders does add uncertainty to population estimates based on mark-recapture samples.

229. Overall, Burnell et al. (2023) concluded that AOS numbers of European storm-petrel in Britain and Ireland had increased from Seabird 2000 to Seabirds Count by about 17%, with evidence indicating population increase of 48% in Scotland, 11% in Wales, 10% in Republic of Ireland. Few European storm-petrels breed in England, where the number remained much

the same with overlapping confidence intervals. Evidence for population increase is also supported by data from SPAs in Scotland where breeding European storm petrel is a feature (Table 6-1Table 6-1).

Table 6-1. Summary of data on numbers and conservation status of European storm-petrels at sites listed by Burnell et al. (2023).

SPA	Numbers at SPA designation (data from NatureScot sitelink SPA citation)	AOS in seabird 2000 (1998-2002) (data from Burnell et al., 2023)	AOS in seabirds count (2015-2021) (data from Burnell et al., 2023)	Most recent assessment of feature condition (from NatureScot sitelink)
Auskerry	3,600 pairs in 1995	994 (372-3,196)	692 (546-856)	Favourable Declining (2019)
Flannan Isles	Included in list in Burnell et al. (2023) but apparently in error[1]	7 (5-9)	376 (15-7,143)	No assessment
Mousa	4,750 pairs at designation (1994)	5,410 (3,932-7,022)	10,778 (8,857-13,207)	Favourable Maintained (2017)
North Rona & Sula Sgeir	>1% of GB population (number not given in citation) (classified 2001)	380 (344-422)	999 (332-11,680)	Favourable Maintained (2024)
Priest Island	2,200 pairs in 1995 (classified 1986)	4,947 (4,257-5,911)	4,640 (3,689-5,744)	Favourable Maintained (2005)
St Kilda	850 pairs (classified 1992)	1,121 (825-2,242)	952 (728-1,283)	Favourable Maintained (2024)
Sule Skerry & Sule Stack	500 to 5,000 pairs (classified 1994)	309 (309-309)	177 (121-235)	Unfavourable Declining (2024)
Treshnish Isles	5,040 pairs in 1996	5,040 (5,040-5,040)	10,261 (8,349-12,975)	Favourable Maintained (2020)

1. It seems that Flannan Isles SPA was included in error by Burnell et al. (2023) as European storm-petrel breeds in that SPA but apparently is not listed in the SPA citation as a feature.

230. As is evident from the data in Table 6-1Table 6-1, most Scottish SPAs with breeding European storm-petrel are in favourable conservation status, with numbers well above the numbers present at SPA citation. Therefore, monitoring breeding numbers should simply require that it can be shown that these numbers remain above the target set at SPA classification if that is the only conservation objective stated for the feature which seems often to be the case for storm-petrels at SPAs where they are a designated breeding feature. For example, in relation to storm-petrel breeding features at North Rona and Sula Sgeir SPA and at St Kilda SPA and Seas off St Kilda SPA, NatureScot (2024a,b) state "*The*

Conservation Objectives seek to maintain protected SPA features where evidence exists that a feature is in favourable condition in the site, or where there is uncertainty concerning the assessed condition of a feature but no reason to suspect deterioration in condition since designation. Where evidence exists that a feature is declining and/or damaged and therefore not in a favourable condition in the site, the Conservation Objectives will seek to restore the protected feature". Ensuring that the evidence was consistent with the Conservation Objectives could be achieved by colony-specific surveys either of numbers of AOS detected by playback surveys or by mist net mark-recapture analysis of breeding numbers.

231. Playback surveys, although sometimes problematic (Hounsome et al., 2006, Wood et al., 2022), may be most appropriate at colonies where that method was used in the most recent census, as that would give the most comparable outcome by following the same protocol. Successful census by playback requires a team of experienced seabird fieldworkers, and would require an Appropriate Assessment by NatureScot before such work was carried out at an SPA.

232. Mark-recapture by mist net sampling (i.e. using fine nets to capture flying birds and marking them with leg rings, then using the rate at which marked birds are recaptured on subsequent nights to estimate population size) could potentially be easier to carry out than a complete census by playback. Furthermore, mist netting storm-petrels allows other relevant data to be collected, potentially monitoring adult survival rates, inter-colony movements, relative numbers of birds seeking to recruit into the colony, diet and body condition of birds. Mist netting can only be carried out by teams licenced by the UK Ringing Scheme (administered by the British Trust for Ornithology) and would require an Appropriate Assessment by NatureScot before such work was carried out at an SPA. Protocols for mist netting to carry out mark-recapture analysis of storm-petrel populations have been published in several scientific papers (e.g. Insley et al., 2002, Hounsome et al., 2006) and this is a method recognised as appropriate by Burnell et al. (2023). However, it would be sensible to try to match methodology used at any focal colony in previous counts if possible.

6.2.1.3 Leach's storm-petrel

233. As with European storm-petrel, the census unit for Leach's storm-petrel is AOS. However, many Leach's storm-petrels nest in burrows on grassy slopes, similar to nesting habitat of Atlantic puffin and Manx shearwater, and rather different from nesting habitat of European storm-petrel. Most recent counts of breeding numbers of Leach's storm-petrel have been by diurnal playback of calls to elicit responses from birds at nests (Burnell et al., 2023).

However, it is possible to estimate breeding numbers from mist net mark-recapture, as has been done at Dun, St Kilda (Furness, 1984).

234. It is evident from census data that there has been a large decline (of about 78%) in numbers of Leach's storm-petrels in Britain and Ireland between Seabird 2000 and Seabirds Count (Burnell et al., 2023). That overall decline is mirrored at the six SPAs in Scotland where breeding Leach's storm-petrel is a designated feature (Table 6-2).

Table 6-2. Summary of data on numbers and conservation status of Leach's storm-petrels at SPA sites in Scotland listed by Burnell et al. (2023).

SPA	Numbers at SPA designation (data from NatureScot sitelink SPA citation)	AOS in Seabird 2000 (1998-2002) (data from Burnell et al., 2023)	AOS in Seabirds Count (2015-2021) (data from Burnell et al., 2023)	Most recent assessment of feature condition (from NatureScot sitelink)
Flannan Isles	100 to 1,000 pairs (designated 1992)	1,425 (1,232-1,708)	229 (229-229)	Unfavourable Declining (2024)
Foula	50 pairs at designation (1995)	15 (3-30)	0	Unfavourable Declining (2024)
North Rona & Sula Sgeir	>1% of GB population (number not given in citation) in 1986	1,137 (852-1,707)	435 (435-435)	Unfavourable Recovering (2024)
Ramna Stacks and Gruney	20 pairs (classified 1994)	20 (20-20)	5 (5-5)	Unfavourable Declining (2018)
St Kilda	5,000 pairs (classified 1992)	45,433 (34,310-61,398)	9,233 (8,148-10,462)	Favourable Maintained (2024)
Sule Skerry & Sule Stack	5 pairs (classified 1994)	0	0	Unfavourable No change (2024)

235. Leach's storm-petrel is considered locally extinct at Foula SPA (where the loss of the species has been attributed to depredations by domestic cats and feral cats) and at Sule Skerry & Sule Stack SPA. Conservation status is also considered Unfavourable at Ramna Stacks & Gruney SPA and at North Rona & Sula Sgeir SPA, where at both sites the breeding numbers at classification of these SPAs were very uncertain (Table 6-2). The only SPA where conservation status is listed as Favourable is St Kilda (Table 6-2Table 6-2) although there is strong evidence of a very large decline in numbers there between Seabird 2000 and Seabirds Count (Table 6-2Table 6-2). The decline at St Kilda has been attributed in part at least to depredations by great skuas, which have increased in numbers there and feed extensively at night on storm-petrels, especially at Dun (Votier et al., 2005).

236. There is evidence from stable isotopes and genetics that there is exchange of birds between the north-west Atlantic population of Leach's storm-petrels and the populations in Britain (Bicknell et al., 2012, 2014). Therefore, the long-term sustainability of colonies in Britain, on the margin of this meta-population, may be tied up with the meta-population dynamics of this species, primarily driven by demographic changes in the core area of the population in the north-west Atlantic.

237. Leach's storm-petrels are in severe decline in their population stronghold in the north-west Atlantic (Pollet et al., 2023, Wilhelm et al., 2020). If recent trends in Britain continue, this species may well be lost from the remaining breeding sites in Scotland within coming years. It would be extremely difficult to determine from census data what impact OWF and its associated lighting would have on this species alongside the main drivers of population decline. Therefore, monitoring of breeding numbers of Leach's storm-petrels at Scottish colonies is unlikely to be helpful for OWF developers. There may be more merit in GPS tracking foraging trips by breeding adult Leach's storm-petrels from key colonies to infer the extent to which their movements may be influenced by the presence of OWFs and by ALAN.

238. In UK territorial waters, Leach's storm-petrels are known to forage almost exclusively over deep water beyond the edge of the UK Continental Shelf (Burnell *et al*. 2023). European Seabirds at Sea surveys off western Britain found Leach's storm-petrels between May and October "*mainly over the deep North Atlantic and at the shelf break. They were in extremely low numbers over the continental shelf, even near large colonies*" (Webb et al., 1990). It is therefore highly likely that GPS tag deployments recently carried out on breeding Leach's storm-petrels at St Kilda and at North Rona but not yet published (Mark Bolton, pers. comm.) will confirm that foraging areas used by birds from those two largest UK colonies of this species are in deep waters beyond the Continental Shelf edge to the NW of UK territorial waters. Therefore it is extremely likely that Leach's storm-petrels from UK colonies can be scoped out as very unlikely to pass through or near areas with OWFs on the UK continental shelf, except possibly in rare instances of storm-driven migrant Leach's storm-petrels in late autumn, when wrecks of this species occasionally occur and apparently are likely to include or consist primarily of birds migrating from Canadian populations (Webb et al., 1990).

6.2.2 Monitoring behaviour at OWF turbines

6.2.2.1 Thermal and Infra-red cameras

239. Thermal and infra-red (IR) camera systems at OWF turbines may be able to detect shearwaters and storm-petrels flying into the rotor-swept area. Recent technological advances suggest this may be feasible (e.g Solutions — Wildlife Imaging Systems), although this would need to be confirmed and trials carried out. If they can detect these small birds then deployment of thermal and/or IR cameras on turbines where they are able to detect and record the number of cases where shearwaters and storm-petrels are attracted to the light and whether they enter the rotor-swept area (and any collisions) would provide a direct measure of collision risk in relation to possible ALAN effects. However, it would be crucial that the ability of these camera systems to detect birds as small as storm-petrels should be determined first. If that is the case, it may be possible to use thermal camera data to monitor whether storm-petrels and Manx shearwaters are attracted to lights at the top of turbines. There would also need to be assessment of whether storm-petrels could be distinguished from passerine nocturnal migrants, which could be difficult, although the shape of storm-petrels, their type of flight and their thermal image would seem likely to be rather different from that of passerines. If such systems were successful at monitoring shearwaters and storm-petrels close to rotor-swept areas, then an experimental approach, comparing numbers present with and without lighting on the individual tower (potentially with a paired comparison test to have ALAN switched between focal turbines), could provide a statistically robust assessment of the effect of ALAN. This could then provide a test of whether numbers were similar to predictions from baseline data or were increased as a consequence of ALAN. Thermal cameras at the shipping navigation lights (SPS or IPS) at the base of turbines might provide information on whether shearwaters and storm-petrels are attracted to or disoriented by those particular lights. That would be unlikely to alter collision risk but could cause displacement effects. Again, comparison between lit and unlit bases could be made, with experimental changes to which bases were fitted with lights monitored (noting that as per Table 5-1 not all turbines are required to be fitted with SPS or IPS marine lights).

6.2.2.2 Tracking

240. Since thermal and/or IR camera systems might not be practical, depending on their technical development and whether or not they can detect and identify storm-petrels near to turbines, an alternative approach might be based on GPS tracking of breeding adults and fledglings from nearly colonies to examine their detailed foraging tracks and whether there is any

evidence from those tracks of either avoidance of OWFs or disorientation/attraction caused by ALAN. That would depend on whether tracked birds pass close to OWF or not, which of course will be uncertain. However, data from a moderately large number of birds should give a good indication of the extent to which they use the OWF area and whether detailed movements at night are influenced by ALAN at the OWF (or elsewhere). The ProcBe project have already successfully tagged both adults and fledglings and obtained tracks of flight paths of these individuals (The Crown Estate, 2026).

7.0 Conclusions

241. There is evidence that seabirds, particularly shearwaters and petrels, can be attracted to ALAN, e.g., tens of shearwater fledglings were grounded next to the Bardsey Island Lighthouse (Archer et al., 2015). Large numbers of Leach's storm-petrels have been recorded stranded or dying at oil production platforms off east Canada (Lukies et al., 2019, Ronconi et al., 2015). Brightly-lit cruise ships and fishing vessels have caused grounding of shearwaters and petrels (Lukies et al., 2019, Morton, 2018). The lights in the town of Mallaig, in west Scotland, have caused Manx shearwater fledglings, from the large Rum colony, to become grounded (Syposz et al., 2018).

242. Globally, offshore wind development is rapidly growing. The recent ScotWind and InTOG leasing rounds have resulted in offshore wind development taking place in waters to the north and west of Scotland, relatively close to colonies of Manx shearwaters and European storm-petrels. This has led to concerns that lighting on OWF infrastructure and vessels associated with OWFs could cause attraction or disorientation of shearwaters and storm-petrels leading to increased mortality in these species.

243. Currently, there is no documented evidence of how these species respond to ALAN associated with OWFs. Consequently, developers looking to develop OWFs off north and west Scotland, commissioned a review of evidence for how artificial lighting on OWFs could alter shearwater and storm-petrel behaviour and increase mortality risk.

244. The review found that generally:

- Petrels and shearwaters are attracted to ALAN almost exclusively on nights with poor visibility (e.g. no moonlight, fog);
- It is almost entirely fledglings that are attracted to ALAN and become grounded or collide with structures;
- Adult shearwaters and petrels tend to avoid ALAN close to their colonies;
- Fewer birds are attracted to lights that are:

    - Of lower intensity;
    - A red light, compared to a white, blue or green light;
    - Flashing, compared to a steady or continuous beam.

245. Regulations require specific types of safety aviation and navigation lighting on OWF infrastructure. Generally, lighting is yellow or red and most lights are flashing. Search and rescue and helihoist lights can be continuous but these are only turned on in specific circumstances. The brightest lights are the aviation warning lights, mounted on the nacelle. These are shielded below horizontal so are not visible to seabirds flying low over the sea. Lighting lower on the WTG is much less bright.

246. The review also collated new evidence that is used as inputs to tools used to estimate mortality from collision with WTG rotors and displacement/redistribution effects. The review found:

- Storm-petrel density and abundance in OWF development areas is highly likely to be underestimated by digital aerial survey;
- New evidence confirms that shearwaters and petrels generally fly below the rotor-swept zone although birds tend to fly higher in windier conditions;
- There are no estimates of avoidance rates for shearwaters and petrels;
- There is no evidence on storm-petrel displacement and only very limited evidence for Manx shearwater displacement, the latter species possibly showing weak displacement.

247. To date, environmental impact assessments (including HRA) of the risk of population-level impacts arising from attraction to or disorientation by ALAN associated with OWFs have only been able to undertake a qualitative assessment. This is due to the absence of evidence of any behavioural response by shearwaters and storm-petrels to lighting associated with OWFs. All concluded no significant impact from ALAN.

248. Given that the evidence suggests that shearwaters and storm-petrels are not attracted to red lights or flashing lights, it is likely that these species will not be attracted to lighting on WTGs and other OWF infrastructure. However, there is no direct empirical evidence of how these species respond to OWF lighting.

249. At present, impact assessments use a qualitative approach to estimating possible impacts from ALAN on shearwaters and storm-petrels. If a quantitative approach is required, in the short-term it will be necessary to use expert opinion to inform impact assessments as there are no empirical evidence with which to inform an assessment. There are no estimates of avoidance rates for shearwaters and storm-petrels, meaning collision risk modelling is

currently not feasible, although as these species generally fly below the rotor swept zone, estimated collision mortality would be likely to be very low. Displacement rates would also need to rely on expert opinion, given the scant empirical evidence of redistribution effects for these species.

250. Empirical evidence on how shearwaters and storm-petrels respond to ALAN is needed to inform a quantitative assessment. Research to obtain empirical evidence could include further tagging of adults and fledglings and analysing their tracks in relation to sources of ALAN. Cameras mounted on operational OWFs in areas of high shearwater and storm-petrel density would also be beneficial. Monitoring and research would best be undertaken using a strategic approach, rather than project-specific post-consent monitoring, to enable an optimum experimental design and maximising sample sizes. This would produce data that would have the greatest potential to reduce uncertainty around how shearwaters and storm-petrels respond to OWF development.

251. The extent to which mitigation could reduce any risk of impact from attraction to or disorientation by ALAN, is considered. Mitigation has successfully reduced shearwater and petrel mortality at other sources of ALAN, e.g. switching the Bardsey lighthouse light from a constant white light to a flashing red light. However, these mitigation measures have changed lighting to be similar to OWF lighting, e.g. flashing red lights, again strongly suggesting that the risk of attraction to ALAN on OWF infrastructure during project operation is unlikely. Mitigation options for OWF lighting may be limited due to strict regulations regarding safety lighting.

252. Monitoring for any effects from ALAN on protected populations of shearwaters and storm-petrels could include monitoring for changes at breeding colonies close to operational OWF, e.g. breeding abundance, productivity and adult survival. Monitoring at OWF WTGs using cameras, along with tagging studies, would assist with identifying any behavioural responses to ALAN at the OWF. However, evidence presented in this study suggests that shearwaters and storm-petrels will not be attracted to or disorientated by lighting on OWF structures.

8.0 References

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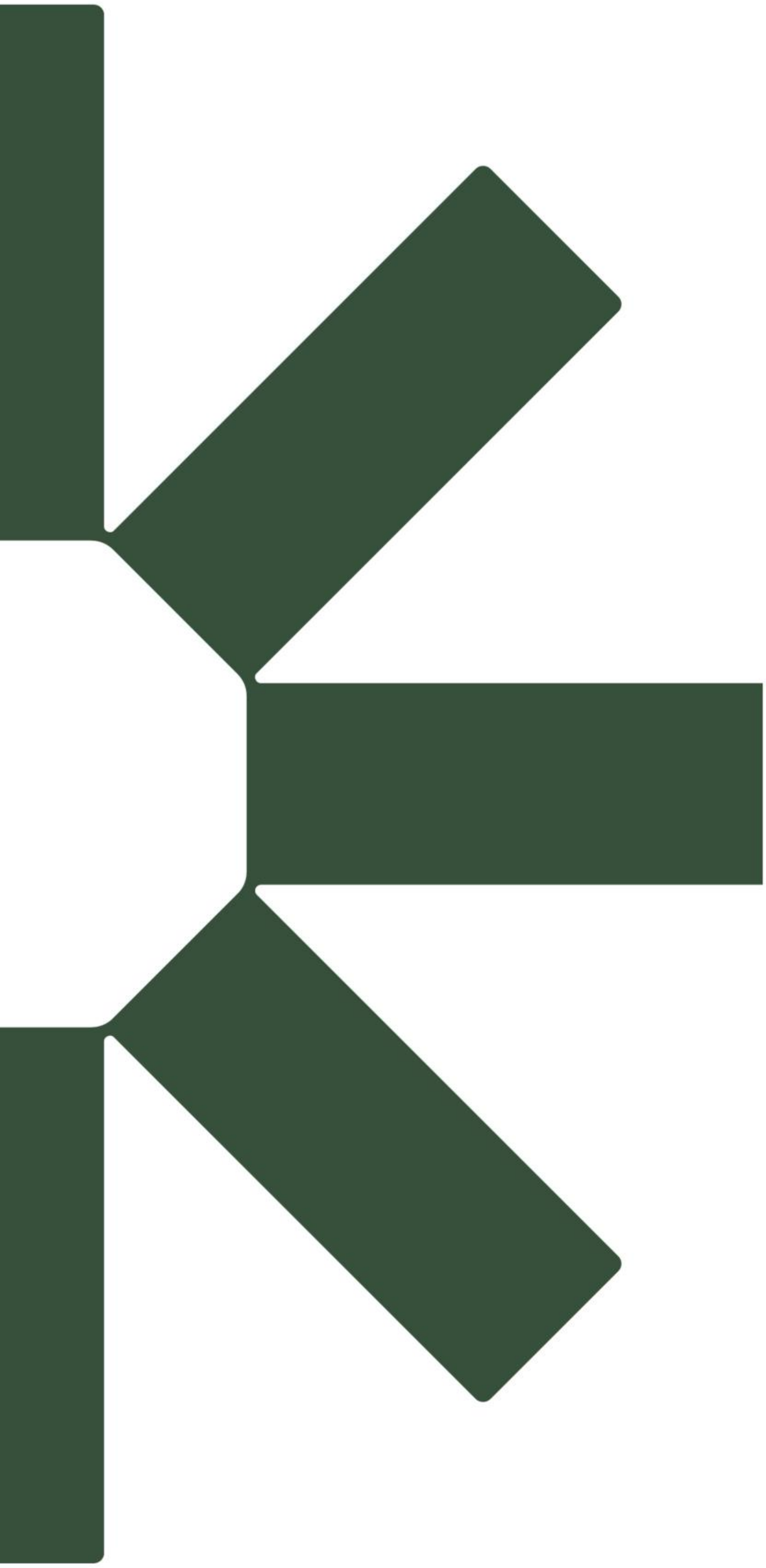

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