RWE Renewables UK Dogger Bank South (West) Limited

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Dogger Bank South Offshore Wind Farms

Environmental Statement

Volume 7

Appendix 12-11 Review of Turbines Lighting - Furness 2018

June 2024

Application Reference: 7.12.12.11

APFP Regulation: 5(2)(a)

Revision: 01

Company:	**RWE Renewables UK Dogger Bank South (West) Limited and RWE Renewables UK Dogger Bank South (East) Limited**	Asset:	**Development**
Project:	**Dogger Bank South Offshore Wind Farms**	Sub Project/Package:	**Consents**
Document Title or Description:	Environmental Statement – Appendix 12-11 Review of Turbines Lighting - Furness 2018		
Document Number:	004300153-01	Contractor Reference Number:	PC2340-MAC-OF-ZZ-AX-Z-0099

Rev No.	Date	Status/Reason for Issue	Author	Checked by	Approved by
01	June 2024	Final for DCO Application	MacArthur Green	RWE	RWE

Dogger Bank South Offshore Windfarm

Ornithology Technical Appendix 12-11

Consequences for Birds of Obstruction Lighting on Offshore Wind Turbines

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Document Quality Record

Version	Status	Person Responsible	Date
0.1	Draft	Prof Bob Furness	05/04/2018
0.2	Reviewed	Dr Mark Trinder	09/04/2018
0.3	Updated	Dr Mark Trinder	23/03/2023

CONTENTS

SUMMARY

We review the literature on effects of artificial lights on birds and on seabird prey, in order to assess whether obstruction lighting on offshore wind farm turbines as required by the Civil Aviation Authority (CAA) might have any detectable effect on birds. Eight categories of effect are considered: disruption of photoperiod physiology; extension of daytime activity; phototaxis of seabirds; phototaxis of nocturnal migrant birds; ability of birds to use artificial light to feed at night or to feed on prey aggregating under artificial lights; increased predation risk for nocturnal migrant birds; birds better able to avoid collision when structures are illuminated; displacement of birds due to avoidance of artificial lights. Evidence suggests that birds are considerably less likely to be affected by intermittent red lights than by steady white lights, so that use of flashing red lights would represent mitigation. However, we conclude that the available evidence suggests that obstruction 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.

1 INTRODUCTION

The Civil Aviation Authority (CAA) requires that structures representing a collision risk for aircraft are marked by nocturnal obstruction lighting as close as possible to the top of the structure. For terrestrial structures, the use of medium intensity (ca.2000 candela) steady red lights is mandated (CAA 2016). The CAA Guidelines (CAA 2016) indicate that for offshore wind farms, because there could be confusion between aircraft avoidance (obstruction) lighting and marine navigation lighting, offshore wind farms could, with agreement from CAA, be fitted with flashing red obstruction lights rather than steady lights. They also indicate that, with the agreement of CAA, it may be appropriate to fit obstruction lighting only to peripheral turbines of offshore wind farms (CAA 2016). This review summarises the impacts of artificial light on birds and considers whether any of the known impacts might arise in birds as a consequence of deployment of nocturnal obstruction lighting on offshore wind turbines.

2 METHODS

A literature search was carried out, using tools such as Web of Knowledge and Google scholar, to identify relevant published work. Identified publications were obtained and read, in order to prepare this review paper.

3 RESULTS OBTAINED FROM LITERATURE SEARCH

There is a large literature identifying a wide range of impacts of artificial lights on birds, and especially on some species of seabirds that are particularly sensitive to artificial lighting (these being petrels, shearwaters, puffins). The identified impacts all relate to effects occurring at night, as artificial lighting during the day represents a very small addition to natural daylight so will not have detectable effects on birds during daylight. These nocturnal impacts on birds include:

- Disruption of photoperiod physiology of birds due to artificial light;
- Extension of daytime activity (earlier start at dawn, later end at dusk);
- Phototaxis of seabirds (birds attracted to light sources and therefore at risk of disorientation and/or collision);
- Phototaxis of nocturnal migrants (birds attracted to light sources and therefore at risk of disorientation and/or collision);
- Ability of some birds to use nocturnal visual feeding assisted by artificial light or to feed on marine animals aggregating under artificial lights;
- Increased predation risk for nocturnal birds resulting from artificial lighting;
- Birds better able to avoid collision when structures are illuminated;
- Displacement of birds due to avoidance of lights;

These impacts are considered in turn in the same order as listed above, in the subsections below. This sequence does not rank impacts according to severity, as in many cases the impacts apply to only a few particular species or types of bird or to specific situations. The sequence of presentation is, therefore, from physiological to ecological, rather than related to impact severity.

3.1 Disruption of photoperiod physiology of birds due to artificial light

In theory, low levels of artificial light have the potential to affect the physiological photoperiod experienced by birds, and thereby to affect the timing of their onset of activity in the morning and end of activity in the evening, as well as potentially affecting the seasonal triggers for activities such as deposition or shedding of fat stores, moult, breeding and migration (Titulaer et al. 2012, Gaston et al. 2012, 2013, 2015, De Jong et al. 2017, Da Silva et al. 2017a,b). However, there are no published studies or observations reporting clear examples of any seasonal activities of birds being affected by exposure to artificial light.

Exposure to artificial light is very much greater in urban birds than in rural or marine habitats, and therefore any effect on photoperiod would be most likely to be seen in urban birds residing among artificial lighting. There are a few anecdotal examples of urban birds starting to nest in winter, and this could possibly be interpreted as birds coming into breeding condition early because their photoperiod had been affected by artificial light. However, such early breeding is generally seen only in a few bird species that are often able to breed successfully in winter if weather conditions permit. That suggests that such cases represent opportunistic breeding in urban environments rather than disruption of natural photoperiod responses.

De Jong et al. (2017) experimented with birds in captivity, exposing them to different colours of light at night. Birds advanced their onset of activity in the morning when exposed to light at night, and advanced timing more in response to red and white light than to green light. Birds advanced timing more in response to higher intensity of artificial light. However, there have not been similar experiments with free-living wild birds, so it is uncertain if such effects occur in wild birds. Since such effects have not been reported in wild birds, even in urban environments, it seems more likely that there is very little, if any, effect of artificial light on photoperiod responses of wild birds. Furthermore, it seems extremely unlikely that avoidance lighting on offshore wind turbines would have any effect on photoperiod responses of birds given that birds would be unlikely to remain in close proximity to those lights for any extended period of time. Since there is little or no evidence of photoperiods of urban terrestrial birds being affected in this way despite the widespread presence of nocturnal light pollution in terrestrial environments and especially in urban environments, the chances of photoperiods of birds at sea being affected by avoidance lighting seem negligible.

We conclude that obstruction lights on offshore wind farm turbines will not be a significant issue for birds in terms of effects on photoperiod physiology.

3.2 Extension of daytime activity

Da Silva et al. (2017a) used an experimental approach with wild terrestrial birds, exposing the area around an automated feeding station in a forest to artificial light at night. They found a small response in some bird species, with blue tit and great tit starting to forage earlier during experimentally lighted mornings. However, no response was shown by willow tit, marsh tit, nuthatch, jay or blackbird, and the response of great tits was weak. The authors concluded that 'our results suggest that artificial light during winter has only small effects on timing of foraging'.

Da Silva et al. (2017b) used an experimental approach to test whether woodland birds start singing earlier in the morning when their forest habitat was illuminated with artificial light. They found no effect of artificial light (testing a variety of different light colours) on the timing of the dawn chorus.

These results suggest that artificial light has very little, if any, impact on the available daylength for day-active birds, possibly because the natural variation in light levels is so large that artificial light makes very little difference to the natural diurnal cycle of light levels (essentially daylength remains unaltered by artificial light because the natural cycle of light is so strong that artificial light has no detectable influence on perceived daylength). In the case of marine birds, or terrestrial birds migrating over the sea, any effect of artificial light on the available daylength for visual foraging can be considered negligible, especially because birds over the sea are unlikely to spend prolonged periods at offshore wind farms, so would be unlikely to be able to benefit from the very slight added light during the transition from night to twilight or vice versa (bearing in mind also that the obstruction lights on a turbine will be more than 100 m above sea level and directed predominantly upwards).

We conclude that obstruction lights on offshore wind farm turbines will not have any significant effect on birds in terms of the extension of the duration of daylength, so will not alter the behaviour of birds in terms of the duration of 'daytime' available to them.

3.3 Phototaxis of fledging seabirds

Most burrow-nesting shearwaters and petrels are nocturnally active. Adults rear a single chick, and 'desert' it when fully grown, following which it will fledge independently. Chicks fledge at night, usually just after dark, and show strong positive phototaxis; they are attracted to light. This allows them to navigate from the dark burrows at the colony to the sea, as light intensity is naturally higher over the sea than onshore. This phototaxis is therefore important to allow fledglings to find the sea when they first leave their burrow (especially important for those petrel species that breed at colonies some distance inland from the sea; some petrels breed in inland mountain ranges tens of kilometres from the coast, so chicks need this ability to find their way to the sea when they fledge at night for the first time). Phototaxis is also seen in hatchling sea turtles and has the same function, so it is a widespread mechanism for marine animals. Puffins, which are also burrow-nesting seabirds that desert the chick and leave it to fledge alone at night, show the same response to light as petrels.

There are numerous examples of shearwater, petrel, and puffin chicks (and sea turtles) being attracted to onshore artificial lights at fledging and being exposed to high mortality as a consequence of being misdirected by artificial lights (Montevecchi 2006, Wilhelm et al. 2013, Rodrigues et al. 2012, Rodriguez et al. 2014, 2017, Gineste et al. 2017). This is well known, for example, at colonies in Hawaii, Balearic islands, Canary Islands and Azores where fledglings collide with street lights and car headlights (Fontaine et al. 2011, Troy et al. 2011, 2013, Rodrigues et al. 2012, Rodriguez et al. 2012a,b, 2015a,b). It also occurs in the UK, for example at the islands of Rum and St Kilda (Harris et al. 1978, Miles et al. 2010) where Manx shearwaters, European storm-petrels, Leach's storm-petrels and Atlantic puffin fledglings are grounded at street lights and illuminated windows.

In virtually all of these examples, only fledglings and not adults are attracted and grounded, during the short period in late summer when chicks are departing from nesting burrows (Harris et al. 1978, Miles et al. 2010). Adults of these species appear to be unaffected by artificial lights. Miles et al. (2010) reported that only very small numbers of storm petrel and shearwater fledglings were grounded at lights on St Kilda, and that most of those were on nights around the period of new moon. Harris et al. (1998) reported that numbers of fledglings attracted to artificial lights on Hirta, St Kilda, varied between 18 in 1985 and 1,409 in 1978, with higher numbers tending to occur in years of higher breeding success. Reducing light use on St Kilda dramatically reduced numbers of attracted petrels and shearwaters (Miles et al. 2010). Wilhelm et al. (2013) reported that Atlantic puffin fledglings were attracted to the artificial lights of coastal villages in Newfoundland, but mostly on nights with little moonlight, and with only about 20 birds collected per night in total across several villages during the fledging period in August. Although for most colonies the numbers of fledglings distracted by artificial lights is trivial, the impact on survival of fledglings can be significant in a few cases where large colonies are close to extensive artificial lighting. In Reunion Island, 13,200 tropical shearwater fledglings were found grounded due to artificial lights, with numbers increasing from 1996 to 2015 (Gineste et al. 2017). At Phillip Island, Australia, 8,871 short-tailed shearwater fledglings were found grounded by lights along the roadsides, with at least 40% of these dead or dying (Rodriguez et al. 2014). Turning off the street lights mitigated this mortality (Rodriguez et al. 2014). In Kauai, Hawaii, more than 30,000 grounded fledglings of the federally threatened Newell's shearwater have been collected under lights, an impact that may be contributing to the decline of this population (Troy et al. 2011).

Lights on offshore wind turbines are unlikely to affect fledging puffins, shearwaters or petrels from most UK colonies of these species, as most of those colonies are on offshore islands, immediately overlooking the sea, and in most cases in areas remote from proposed development areas for offshore wind farms. Fledglings from most of those colonies are likely to disperse over the sea without seeing lights on wind turbines. There are no colonies of European storm petrels, Leach's storm petrels or Manx shearwaters on the UK east coast between Wick in Caithness and Dover in Kent; nor do they breed anywhere along the south coast of England (Mitchell et al. 2004). There are numerous small colonies of Atlantic puffins along the coastline between Caithness and Northumberland, plus small numbers of puffins on the coast of North Yorkshire and Humberside (Mitchell et al. 2004). By far the largest of these colonies, with tens of thousands of burrows, are in the Firth of Forth (Isle of May, Inchkeith) and Northumberland (Farne Islands, Coquet Island). Puffins from the Isle of May and Inchkeith (Forth Islands SPA) fledging past offshore wind farms in the Forth and Tay area, and puffins from the much smaller most southerly east coast population at Flamborough and Filey Coast pSPA fledging past offshore wind farms in the Hornsea, Dogger Bank and East Anglia zones would therefore be populations of potential concern in relation to phototaxis of fledglings.

Obstruction lights on wind turbines would be likely to represent a trivial amount of lighting relative to the street lights and house lights of local harbours, towns or villages, or from lighthouses or ships. For example, while obstruction lighting on an offshore turbine may be about 2,000 candelas, a lighthouse beam may typically be between 100,000 and 1,000,000 candelas. At St Kilda, there were about 300,000 pairs of puffins with about 60,000 pairs nesting on the slope of Dun that faces across Village Bay to the military base on Hirta when numbers attracted to lights on Hirta were monitored at the end of each breeding season (Harris 1984, Harris et al. 1998, Miles et al. 2010). When these puffin chicks fledged, some hundreds of fledglings per year were attracted to the 32 fixed outdoor street lights and 20 or so building lights on Hirta, only about 1-1.5km away from the colony (all of which are white continuous lights that would provide stronger attraction than red flashing lights), and became grounded (Harris and Murray 1978, Harris et al. 1998, Miles et al. 2010). Some tens per year were recorded to die as a consequence, though most found their way to the sea as soon as it began to become light in early morning (M.P. Harris pers. comm., R.W. Furness pers. obs.). This probably represents mortality of considerably less than 0.03% of the cohort of puffin fledglings from St Kilda, so is negligible at the population level (Harris 1984). In contrast, there seems to be no record of puffin fledglings being attracted to street lights of coastal villages in Fife despite their proximity to the large puffin colony on the Isle of May. It seems likely that a much smaller proportion of fledglings (probably several orders of magnitude smaller) would be attracted by obstruction lighting at offshore wind farms, which would be orders of magnitude further from the relevant colonies as well as potentially carrying less attractive lighting. Puffins tend to fly low over the sea, rather than at high altitudes, and so would also not be likely to be particularly close to lights at the tops of turbines (Johnston et al. 2014). Phototaxis of fledging seabirds is, therefore, very unlikely to be a problem in relation to obstruction lighting on wind turbines, especially if obstruction lighting was directed mainly upwards (towards aircraft) rather than towards the sea surface.

We conclude that obstruction lights on offshore wind farm turbines will not be a significant issue for fledging seabirds in terms of phototaxis.

3.4 Phototaxis of nocturnal migrants

This section refers to birds that migrate at night. These are almost exclusively terrestrial birds, and these terrestrial birds may migrate either or both over land and over sea, depending on the locations of their breeding and wintering areas. It has been recognised for a very long time that nocturnal migrant birds are attracted to artificial light while migrating (Harvie Brown et al. 1881, Horring 1926, Mehlum 1977, Montevecchi 2006). This topic has recently received considerable attention specifically in relation to lighting at communication towers (Longcore et al. 2008, Gehring et al. 2009), wind farms (Kerlinger et al. 2010, Hüppop and Hilgerloh 2012), oil and gas production platforms (Day et al. 2015, Ronconi et al. 2015), cruise ships (Bocetti 2011), lighthouses (Jones and Francis 2003) and in general in relation to bird ecology (Zhao et al. 2014, Watson et al. 2016, Cabrera-Cruz et al. 2018).

The strongest and most dramatic examples of phototaxis in nocturnal migration birds are the 'falls' of migrants that can occur at lighthouses and lightships, especially during foggy weather in autumn. These were studied in detail in the 1880s to 1920s. For example, Harvie Brown and Alfred Newton established a committee of the British Association for the Advancement of Science in the 1870s and sent questionnaires to lighthouse keepers throughout the British Isles to obtain data on nocturnal bird migration and the numbers of birds killed by collision with lights. As long ago as 1881, they reported that 'the brightest, whitest, fixed lights attract the most birds', that most collisions occurred during autumn migration rather than during spring migration, and that most collisions occurred when the weather was foggy and windy (as also concluded over 100 years later by Mehlum 1977). These same factors were identified as affecting collision rates in a study by Zhao et al. (2014). The British association annual reports show the large numbers of birds that can be killed; for example 600 thrushes killed by collision with Skerryvore lighthouse in October 1877. A high proportion of the birds killed were juveniles, which probably at least in part explains why numbers killed tended to be much higher in autumn than in spring. Similar surveys were conducted around the same period in many different European countries. For example, the 41st annual report on birds at Danish lighthouses, for the year 1923, was published in 1926 (Horring 1926). That report mentions that at least 4,600 birds, mostly thrushes and starlings, were killed by collision at Danish lighthouses and lightships in 1923. Study of birds at lighthouses fell out of favour around the 1930s, and there is very little literature on this topic after that period, although it was recognised that large numbers of migrating birds were still being killed by collision at lighthouses (e.g. Mehlum 1977, Jones and Francis 2003). Jones and Francis (2003) reported that from 1960-1989 there were kills of up to 2,000 birds in a single night in autumn at Long Point lighthouse (Ontario, Canada), with the lighthouse beam being approximately 100,000 candelas. However, this light was fitted with a new beam in 1989, which was narrower and less powerful (<50,000 candelas), and this resulted in a huge decrease in numbers of migrant birds killed. From 1990 to 2002 the mean numbers known to be killed were reduced to only about 30 birds per year. The authors point out that this highlights the 'effectiveness of simple changes in light signatures in reducing avian light attraction and mortality during migration'.

Ronconi et al. (2015) and Day et al. (2015) both report that poor weather (e.g. fog, rain, low cloud cover) exacerbate nocturnal attraction of bird migrants to lights at oil and gas production platforms, with on occasions thousands of birds being killed in a night, especially where gas is being flared. Kerlinger et al. (2010) report that bright artificial lighting may have caused 'multi-bird fatality events' at terrestrial wind farms in North America, but that there was no apparent difference in bird collisions at turbines with obstruction lighting (flashing red lights, as recommended by the Federal Aviation Administration, FAA) compared with turbines at the same wind farm, where there was no obstruction lighting (see also this same conclusion in Manville 2009). Gehring et al. (2009) reported that communication towers equipped with non-flashing/steady-burning lights in addition to red or white flashing obstruction lights were responsible for much higher numbers of bird collisions; towers with fixed lights and flashing lights were responsible for 13 bird fatalities per season, whereas towers with only flashing obstruction lights were responsible for 3.7 bird fatalities per season. They concluded that having only flashing obstruction lights reduced bird collisions significantly, a conclusion supported by Patterson (2012). Longcore et al. (2008) reported that steady-burning lights increased the numbers of birds colliding with communication towers. Evans et al. (2007) showed that migrant songbirds were attracted much less to red light or to flashing light than to blue, green or white light, or continuous light. They therefore concluded that flashing red obstruction lighting is least likely to have any adverse effect on nocturnal migrant birds.

Watson et al. (2016) report that more nocturnal flight calls can be detected over artificially lit areas than over dark areas. They conclude that artificial lighting changes behaviour of nocturnal migrant birds, either by changing their flight paths to pass over lit areas, by flying at lower altitudes over lit areas, by increasing their call rates over lit areas, or by remaining longer over lit areas. Hüppop and Hilgerloh (2012) suggest that nocturnal migrants are more vocal when conditions are adverse, so that vocalisations do not indicate bird numbers but rather the stress levels of the birds. Cabrera-Cruz et al. (2018) identified that light pollution was most severe during the autumn which coincides with the period of migration by northern hemisphere birds to lower latitudes. The high incidence in autumn but low incidence in spring probably relates to the fact that many birds attracted in autumn are inexperienced juveniles, whereas by spring these birds have learned not to be distracted by light pollution. The highest concentrations of major urban areas are along coasts of Europe and North America, so are within the main migration passage flyways of nocturnally-migrating birds. McLaren et al. (2018) reported that nocturnal bird migration was influenced at a regional scale by the most brightly-lit towns and cities, with increased stopover of migrant birds within a few km of these brightly lit sites during autumn. Van Doren et al. (2017) showed that even within brightly lit cities, high-intensity illumination can alter nocturnal bird migration behaviour. However, these effects were found with many orders of magnitude higher light intensity than is used for avoidance lighting of structures. Bocetti (2011) identified that cruise ships, which often have bright external lighting during the night, also represent a collision hazard for nocturnal migrant birds, although it seems likely that the numbers of birds killed at cruise ships are rather small compared to numbers killed at lighthouses.

The evidence indicates that lights on offshore wind turbines could increase numbers of nocturnal migrant birds that collide. However, increases would be mainly related to steady-burning lights, whereas the available evidence indicates there will be very little increase in collisions when lights are flashing. Furthermore, obstruction lighting on wind turbines (ca. 2000 candelas) is several orders of magnitude less powerful than the light from lighthouses and lightships (often 100,000 to 1,000,000 candelas), with a consequently much lower likelihood of attracting nocturnal migrant birds. Survival rates of small birds (e.g. passerines) are low, and it is recognised that many birds die during migration, especially juvenile birds during autumn migration (Newton 2008). Individuals that are attracted by artificial light are likely to be birds that are already at high risk of mortality because they are experiencing adverse weather conditions (e.g. high winds, fog) and are lost or exhausted (Newton 2008), so population-level impacts of this mortality for nocturnal migrating passerine populations is likely to be slight. Furthermore, Welcker et al. (2017) reported that, despite the apparent attraction of nocturnal migrating birds to lights, nocturnal migrants represented only 8.6% of all fatalities at a sample of German wind farms. Welcker et al. (2017) concluded that 'nocturnal migrants do not have a higher risk of collision with wind energy facilities than do diurnally active species, but rather appear to circumvent collision more effectively'.

We conclude that obstruction lights on offshore wind farm turbines is extremely unlikely to be a significant issue at the population level for any species of nocturnal migrant terrestrial birds in terms of phototaxis.

3.5 Phototaxis of other birds

Attraction of fledgling shearwaters, petrels and puffins, and attraction of nocturnal migrating birds to lights is well established and has been studied in detail. In contrast, there is no clear evidence from research studies or observations to suggest that other kinds of birds show attraction to lights. There seems to be little or no phototaxis shown by adult shearwaters, petrels or puffins around the British Isles, despite the strong response seen in fledglings. There is some evidence of adult petrels being attracted to bright artificial lights at night at colonies in the sub-Antarctic (e.g. Furness 1985), but that may simply be a disorientation and grounding of birds that fly into strong beams of light such that they are unable to see where they are going. There is little evidence to suggest that those birds are attracted towards artificial light. There is little or no evidence to suggest that birds that are not undertaking migration are attracted to artificial light. While nocturnal migrants are found as collision casualties at lighthouses during the migration seasons (section 3.4), resident birds in summer or winter, wintering birds in winter or breeding birds in summer are not found as collision casualties in summer or winter. In this regard it is notable that seabirds breeding close to lighthouses are not found as collision casualties at lighthouses, even when conditions are foggy. The evidence strongly indicates that resident, breeding and wintering birds do not show phototaxis. Therefore, there appears to be no risk due to phototaxis for resident birds, breeding or wintering birds in the vicinity of offshore wind farms as a direct consequence of deployment of obstruction lighting on offshore wind turbines.

We conclude that obstruction lights on offshore wind farm turbines will not be a significant issue for adult seabirds or other birds not undergoing migration in terms of phototaxis.

3.6 Ability of some birds to use nocturnal feeding assisted by artificial light, or to feed on marine animals aggregating under artificial lights

Birds that are visual feeders and feed only during the day may benefit from artificial light that allows them to feed visually at night. This has been reported, for example, in intertidal waders. Santos et al. (2010) found that visual feeding shorebirds fed at night in areas of the Tagus Estuary (Portugal) where artificial light allowed them to see prey. Tactile-feeding waders did not show any change in distribution attributable to the distribution of artificial light. Similarly, Da Silva et al. (2017) found that blue tits and great tits started foraging earlier in the morning when artificial light was available (section 3.2). The availability of artificial light did not alter feeding times of willow tits, marsh tits, nuthatches, jays or blackbirds, and the effect on great tits was weak and only evident during nights when weather was poor. There are anecdotal observations of birds such as robins feeding under street lights during winter darkness in urban environments.

In the context of obstruction lighting on offshore wind turbines, it is highly unlikely that the amount of light provided would allow birds to feed at times when natural light levels were too low to permit visual foraging (particularly at the sea surface), so this effect is very unlikely to be seen at offshore wind farms.

If artificial lights attracted the prey of seabirds to aggregate at the sea surface, that could increase food availability to seabirds around offshore wind turbines at night. It is well established that marine animals of many taxa can be influenced by bright artificial lights that light into the water column (Davis et al. 2014). Barker and Cowan (2018) investigated responses of different fish species to intense artificial lighting of some oil and gas platforms in the Gulf of Mexico and found only very small differences in fish community structure between lit and unlit platforms. They also noted that there was no attraction of fish to the lit platforms at night. Bolton et al. (2017) showed that many marine interactions could be affected by bright artificial lighting underwater, but concluded that, overall, fish tend to avoid artificially lit areas rather than being attracted, which partly counteracted the artificial reef effect that did result in fish abundance increasing around structures. Since obstruction lights will be about 100 m above sea level, and directed predominantly away from the sea surface, it is extremely unlikely that fish or other marine animals would be influenced by those lights.

In addition, the marine animals most sensitive to being attracted to artificial lights are squid and lanternfishes (Montevecchi 2006), both of which taxa are rarely found in shallow continental shelf seas such as the North Sea, but rather tend to occur in deep oceanic waters. Where fishermen use lights to catch such prey at night they use very bright white lights directed downwards through the water (Montevecchi 2006), which would be very different from obstruction lighting use of red lights 100 m above the sea surface and directed primarily upwards.

We conclude that obstruction lights on offshore wind farm turbines will not be a significant issue for birds in terms of permitting visual foraging at night or in terms of attracting prey to aggregate.

3.7 Increased predation risk for nocturnal birds resulting from artificial lighting

Canario et al. (2012) observed short-eared owls and long-eared owls catching migrating songbirds that had been attracted to artificial lights. Oro et al. (2005) found significantly lower survival rates of breeding adult European storm-petrels at a colony in Benidorm Island (Spain) that was illuminated by artificial lighting shining across the sea from Benidorm city compared to a control colony on the dark side of Benidorm Island. The low survival of the population exposed to artificial light was due to yellow-legged gull predation on the storm petrels which was facilitated by the artificial light allowing gulls to see, and catch, storm petrels attending the colony at night. There have also been observations of birds of prey (including owls, falcons and hawks) resting on offshore structures such as oil platforms while themselves on migration, and opportunistically killing migrant passerine birds attracted to those structures (Thorpe 2000).

The intensity of light produced by obstruction lighting at the top of offshore wind turbines will be far less than produced by the lights in the studies reported above. It is, therefore, extremely unlikely that the lighting on offshore wind turbines would affect predation risk for nocturnal birds in the vicinity of wind farms. Although birds of prey may use these structures for roosting and for hunting migrant passerines, obstruction lighting is unlikely to strongly alter the hunting success of predatory birds.

We conclude that obstruction lights on offshore wind farm turbines will not be a significant issue for birds in terms of increasing hunting opportunities for birds of prey or predation risk for their victims.

3.8 Birds better able to avoid collision when structures are illuminated

Day et al. (2017) reported that migrating eiders showed higher avoidance at night of an oil-production facility in Alaska when it was illuminated with a hazing light system. However, obstruction lighting on offshore wind turbines would be at much lower light intensities than was the case in that study. Blackwell et al. (2012) showed that artificial lights on aircraft reduced the risk of bird strike because lights made the aircraft more detectable to birds, so allowed earlier avoidance behaviour. This conclusion was further supported by Doppler et al. (2015) who showed that birds responded faster when lighting was tuned to the most sensitive wavelengths for bird vision (the blue portion of the human visual spectrum).

A study of bat collisions at wind farms in Texas found that bat fatalities were more frequent at turbines without aviation lights compared with turbines with synchronised red flashing aviation lights (Bennett and Hale 2014). The lower mortality at turbines with lights applied for only one species of bat, the other species showing no difference in mortality between turbines with or without aviation lights. However, the study suggests that at least one of the bat species avoided turbines more successfully when the turbine was equipped with obstruction lighting, and this might apply to seabirds flying past offshore wind farms at night and to nocturnal migrating terrestrial birds. Nevertheless, the benefits to birds from such lighting seem likely to be small.

We conclude that obstruction lights on offshore wind farm turbines will probably not be a significant issue for birds in terms of reducing collision risk, although empirical evidence from studies of collision rates at turbines with and without nocturnal lighting would be useful to test this.

3.9 Displacement of birds due to avoidance of lights

Day et al. (2017) reported that migrating eiders showed higher avoidance at night of an oil-production facility in Alaska when it was illuminated with a hazing light system. This seems to be a rare example of birds being displaced by artificial lights. However, there seems to be little or no evidence in the literature of birds being displaced from favoured habitat by lights.

We conclude that obstruction lights on offshore wind farm turbines will almost certainly not be a significant issue for birds in terms of altering the extent of displacement/habitat loss.

4 CONCLUSIONS

Offshore wind farms in the UK have obstruction lighting consistent with the requirements of the CAA, and maritime navigational safety lighting compliant with Trinity House Light House service safety requirements. Lighting is typically placed on widely spaced turbines on the periphery of a wind farm and are generally oriented horizontally or upwards. The lighting on turbines is orders of magnitude lower light intensities than produced by ports, towns, lighthouses, oil and gas platforms or ships.

A review of the literature shows that obstruction lighting has negligible impacts on birds compared with impacts of brighter lighting. Even in urban environments with the highest levels of light pollution, disruption of avian photoperiod physiology is not clearly evident, so can be scoped out from concerns about birds in the offshore environment.

Extension of the available day for foraging is extremely unlikely to arise because obstruction and navigation lights are very low intensity compared with natural daylight, so could only extend the period above any given light threshold during twilight by a trivial, probably undetectable, amount.

Phototaxis of seabirds can be a serious hazard for petrel and puffin fledglings but occurs over short distances (hundreds of metres) in response to bright white light close to colonies of these species. It is not seen over large distances or with the moderate light levels used in obstruction or navigation lighting. 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); there are no records of phototaxis of nocturnal migrating birds to obstruction or navigation lights.

There is no evidence to suggest that obstruction or navigation lights affect ability of marine birds to feed at night, or attract marine prey animals to aggregate, or that they could affect predation risk for nocturnal migrant birds. There might be a slight reduction in collision risk for birds where turbines are illuminated, but the evidence suggests that any such effect is likely to be very small. There is no evidence to suggest that obstruction or navigation lights cause displacement of marine birds due to avoidance of light.

Therefore, we conclude that the evidence indicates that obstruction or navigation lights on turbines will have no significant effects on marine birds or on migrant terrestrial birds passing nearby.

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