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Offshore wind farms and their effects on birds

Anthony D. Fox and Ib Krag Petersen

(Med et dansk resumé: Havvindmøller og deres påvirkning af fugle)

Abstract Exploiting wind energy at sea offers an attractive source of renewable energy avoiding problems on land, but what are the consequences for birds? We review the Danish and European experience of offshore (i.e. marine) windfarms and the effects and impacts which we consider they may have on birds, primarily through barriers to movement, displacement from ideal feeding distributions and collision mortality. We use case studies to demonstrate examples of displacement effects among species such as Red-throated Diver *Gavia stellata*, Common Scoter *Melanitta nigra* and Long-tailed Duck *Clangula hyemalis* but are unable to determine their causes or whether these patterns have population level impacts, assessment of which remains a major challenge. There is accumulating evidence for widespread avoidance of offshore turbines by large-bodied birds at macro-, meso- and micro-scales, but we accept that our knowledge for smaller bird species is less adequate. We conclude that careful siting during the planning phase can avoid a multitude of potential conflicts with avian populations and that despite generally inadequate post-construction monitoring (especially during periods of unusual weather), experience shows low levels of collision rates, especially among long-lived large-bodied bird species considered most at risk. We lack any understanding of the impacts of barrier effects and displacement from favoured feeding areas, but on a single project basis, these impacts to date are considered insignificant at the population level because of the relatively small numbers of birds so affected. Based on experiences from multiple single site studies, it is essential that site specific impact assessments continue to be undertaken to establish the potential effects and impacts of each project development. However, we also urge a more strategic national and international approach to identification, assessment and selection process for sites for potential future development of offshore windfarms. Despite low-level impacts on an individual windfarm basis, cumulative impacts of multiple offshore windfarm development (especially spanning the length of population flyways) have yet to be adequately determined. Developing effective mechanisms to deliver such assessments remains an urgent requirement for the immediate future.

Introduction

The unexpected pace of climate change and the corresponding search for renewable energy resources to reduce CO_2 release into the atmosphere have fuelled the rapid development of wind energy, especially within Europe. Renewable energy supplied 30% of Europe's electricity in 2017, of which 54.6% was provided by wind power (Agora Energiewende & Sandbag 2018). Twenty per cent of this installed wind power generation is situated offshore (Pineda & Tardieu 2018) and a further 25 GW of offshore capacity is projected by 2020 in Europe (compared to 15.7 GW currently in operation; Pineda 2018). Land-based windfarms cause impacts to the visual and sound landscapes, to birds, bats and the human and natural environment in general, while the wind characteristics of the sea offers higher wind speeds and lower tur-

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bulence levels more suited to sustained and consistent electricity generation (Esteban *et al.* 2011). Despite the greater engineering and economic challenges of generating power in the sea (because of the extra complexity and costs of foundations, energy collection networks, construction and operation in the generally more corrosive marine environment), the benefits from such clean renewable energy generation to society, largely out of sight of land, are therefore likely to be great. But what of the hidden cost to bird life? The construction of large aggregations of tall, solid infrastructures with large and rapidly moving rotor blades in the marine environment constitutes a series of novel threats to birds, which have been used to an empty ocean, safe from such threats.

Denmark was the first country in the world to construct eleven 450 kW wind turbines in the sea off Vindeby, Lolland, in 1991, followed by ten 500 kW turbines at Tunø Knob in Aarhus Bay in 1995, the latter subject to considerable avian impact assessment (e.g. Guillemette *et al.* 1999, Larsen & Guillemette 2007). Following these developments, the Danish government embarked upon an ambitious plan to develop five major offshore windfarms, which ultimately resulted in the construction of the first two major offshore windfarms at Horns Rev, west of Blåvands Huk in west Jutland (80 × 2 MW turbines completed in 2002) and at Nysted, south of Lolland (72 × 2.3 MW turbines completed in 2003). Currently, there are 13 off- or nearshore wind farms in Denmark (Vindeby having been decommissioned in 2017 having generated 243 GWh), with a combined installed capacity of 1295 MW (Tab. 1). Many of these projects were subject to considerable environmental impact assessment, including their impacts upon birds. Because of the long-established importance of Danish marine waters for their breeding, staging, moulting and wintering birds (e.g. Joensen 1974, Stone *et al*. 1995, Laursen *et al.* 1997, Skov *et al*. 2011), we in Denmark have had considerable experience in assessing the impact of offshore wind generation on birds, which we summarise here with experiences from elsewhere in Europe, where the majority of development to date has occurred in the world. In this review, we first consider the ways in which birds may be affected by the construction of offshore windfarms, causing disturbance or disruption to normal patterns of behaviour or by collision and then present the results of studies that provide information on the actual effects.

Throughout this article, we differentiate "effects" (which are the responses birds show to the presence of wind turbines, such as avoidance) from "impacts" (which are the results of these responses on populations, for instance, if displaced terns fail to breed because of loss of feeding grounds or birds of prey suffer increased mortality because of collision deaths). Hence, effects may then impact upon populations, in the sense that reductions

Tab. 1. List of offshore windfarms in Denmark, detailing their positions, power rating capacity, number of turbines, commissioning year, water depth range and distance from shore.
Liste med havvindmølleparker i Danmark, deres positioner, kapaciteter, antal turbiner, idriftsættelsesår, vanddybde og afstand fra land.

Name ***Sted***	**Location** ***Længde/ bredde***	**Capacity (MW)** ***Kapacitet (MW)***	**Number of turbines** ***Antal møller***	**Completion year** ***År færdiggjort***	**Water depth range (m)** ***Vanddybde (m)***	**Distance from shore (km)** ***Afstand fra kyst (km)***
Anholt	56°36'N 11°13'E	400	111	2013	15-19	23
Avedøre Holme	55°36'N 12°28'E	11	3	2009	0-2	0.1
Frederikshavn	57°27'N 10°34'E	8	4	2003	1-3	0.3
Horns Rev I	55°32'N 7°54'E	160	80	2002	10-20	18
Horns Rev II	55°36'N 7°35'E	209	91	2009	9-17	32
Middelgrunden	55°41'N 12°40'E	40	20	2000	3-6	4.7
Nissum Bredning Vind	56°40'N 8°15'E	28	4	2018	1-6	1.1
Nysted (Rødsand I)	54°33'N 11°43'E	166	72	2003	6-9	11
Rødsand II	54°34'N 11°33'E	207	90	2010	6-9	9
Rønland 1	56°40'N 8°13'E	17	8	2003	0-2	0.1
Samsø	55°43'N 10°35'E	23	10	2003	10-13	4
Sprogø	55°20'N 10°58'E	21	7	2009	6-16	10
Tunø Knob	55°58'N 10°21'E	5	10	1995	3-7	6
Vindeby*	54°58'N 11°08'E	5	11	1991	2-4	1.8

*) Vindeby was decommissioned in 2017 *Vindeby blev nedtaget i 2017*

in breeding success or additive collision mortality could potentially affect avian population size and trends over time, so we also need to consider the differential impacts of fitness consequences on different species. Clearly long-lived birds like divers *Gavia* spp. with relatively low reproductive potential are more susceptible to small increases in annual mortality, than passerines, which die in very large numbers every year, but have the reproductive capacity to replace lost individuals more rapidly.

Finally, we reflect on future needs and in particular the lack of knowledge about the cumulative effects of offshore development. This is because we need to be able to assess the impacts of not just one offshore windfarm development, but the additive effects on specific populations of birds of concern of many such developments in addition to all the other threats and pressures on such populations at other points in their annual life cycle.

Effects and impacts of offshore windfarms on birds

At the very beginning of the work on assessing the impacts of the first large Danish offshore windfarms, it was generally agreed that the conceptual effects/impacts on birds largely fell into three major categories, each of which were considered to have differing fitness consequences (that is impacts on breeding potential and/or survival rates) for the populations involved. It was considered that birds encountering an offshore windfarm, whether for the first time or not, would be exposed to three major hazards (after Fox *et al.* 2006a), namely a visual stimulus, physical change to their environment and a risk of collision, as follows:

1. A visual stimulus that may or may not result in an avoidance response

Birds may react to encountering a set of wind turbines

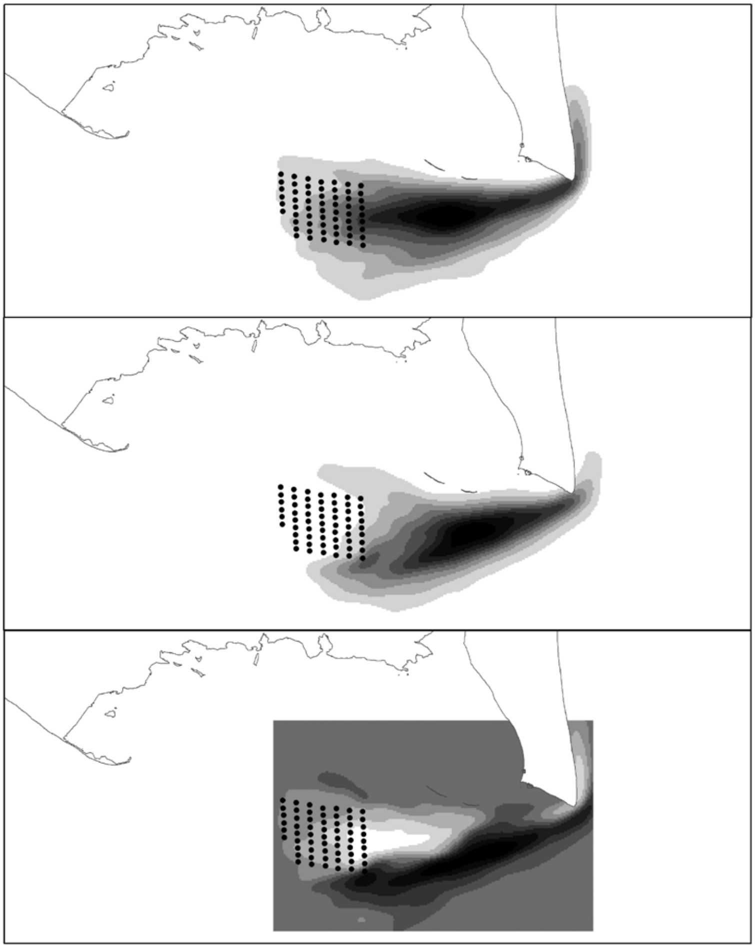


Fig. 1. Kernels of space use by autumn migrating Common Eiders flying around Gedser and onwards across the area of the Nysted Offshore Windfarm off southern Denmark. The space kernels represent the intensity of radar tracks of migrating individuals across the study area (a) pre-construction, (b) post-construction and (c) the difference in space use between (a) and (b). Darker shading represents the greatest use, white in (c) indicates reductions between (a) and (b). The black dots denote the ultimate positions of the individual turbines. Reproduced with permission from Masden *et al.* (2009).

Kernel-beregning af passagen af efterårstrækket af Ederfugle fra Gedser og vestpå til Nysted Havvindmøllepark. Kernel-værdierne repræsenterer intensiteten af radar-trækspor af flokke af Ederfugle (a) før opførelsen af Nysted Havvindmøllepark, (b) efter opførelse af vindmølleparken og (c) forskellen imellem intensiteterne før og efter opførelse af parken. Lyse/hvide områder i (c) repræsenterer områder med reduceret intensitet mellem (a) og (b). Sorte prikker angiver positioner for de enkelte turbiner.

by showing an avoidance response as soon as they are aware of the object, or at distances closer and closer to the turbines, depending on weather, visibility, species and other conditions. A very distant avoidance response by a bird flying towards the windfarm avoids collision risk totally, because that individual is unwilling to come anywhere close to a turbine or to risk collision. However, as a consequence, this response may result in a barrier to that individual's movement. For instance, many day-flying spring-migrating birds of prey approaching the Anholt Offshore Wind Farm were seen to turn back in the face of the turbines and return to the safety of the shore (Jensen *et al*. 2016). Day-flying waterbirds (mostly autumn migrating Common Eiders *Somateria mollissima*, hereafter Eider) also showed evidence of modifying their flight direction at distances up to 3 km away from the newly constructed Nysted Offshore Windfarm, although most modification occurred within 1 km (and less at night; see Kahlert *et al.* 2004). In the case of migrating birds, this may mean flying horizontally around the turbines and at night flying up over them, both of which incurred extra flight costs (e.g. Desholm & Kahlert 2005). This was very clearly the case for migrating Eiders at Nysted when comparing the maps of the densities of flight trajectories of these birds before and after the construction of this windfarm (Fig. 1).

Looking more closely at the radar traces of the routes taken by migrating waterbirds post-construction shows individuals or flocks flying along and around the periphery of the windfarm. The very few birds flying between the turbines did so equidistant between turbine rows (and always low over the sea and usually took the shortest possible routes out of the windfarm; Fig. 2).

These responses clearly minimised the risk of collision posed to otherwise very large numbers of birds passing through this potentially dangerous area. Furthermore, if this avoidance occurs only twice each year travelling between breeding and wintering areas, the extra energetic costs that result from this detour is biologically trivial (as was the case for Eider migrating past Nysted, adding just 500 m to a 1400 km flight; Masden *et al.* 2009). However, incurred energetic costs may become significant if the frequency of avoidance behaviour increases. For instance, in the case of breeding birds commuting between offshore feeding areas and a breeding colony to provision young many times each day, the energetic costs of avoiding a windfarm suddenly constructed in their path would be considerably greater and could potentially affect their survival and reproductive success. In this case, the degree of cost would be determined by the length and frequency of such flights, as well as the body mass and flight characteristics of the species concerned, being highest for seabirds with high wing loadings such as Great Cormorants *Phalacrocorax carbo* (hereafter Cormorant) and species such as terns that commute most frequently between offshore feeding grounds and their nesting colonies (Masden *et al.* 2010a).

In the case of non-breeding sea ducks at the mercy of the wind and current, these birds may need to reposition themselves over optimal feeding areas after being displaced during rest, so they too may show daily flights between feeding areas and roosting sites which could be affected by inappropriate positioning of turbines, although this seems not to be the case at one studied site (Piper *et al.* 2008). Nevertheless, Masden *et al.* (2010a) considered that for all species, costs of extra flight to avoid a windfarm appeared much less than those imposed by low food abundance or adverse weather, but with the growth in size and number of offshore windfarms, this was likely to become more of an issue in the future. In addition, there are strong indications from modelling the behaviours of birds studied close to turbines, that the geometric arrangements of turbines in clusters could have considerable effects on how best to minimise barriers to movement and reduce collision risks, for instance by creating corridors within offshore windfarms to allow passage of birds through large extensive concentrations of such structures (Masden *et al.* 2012).

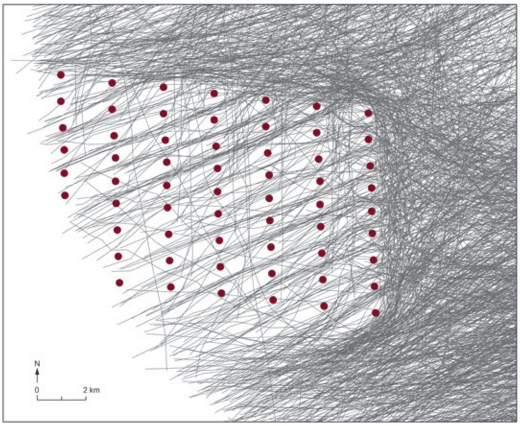


Fig. 2. The south-westerly and westerly orientated flight trajectories of waterbird flocks and individuals based on radar traces within the Nysted Offshore Windfarm during the initial post-construction operation of wind turbines at the site. Red dots indicate the positions of individual turbines, the scale bar represents 1000 m. Reproduced with permission from Desholm & Kahlert (2005).
Vandfuglenes sydvestlige og vestlige trækruter baseret på radarspor indenfor og omkring Nysted Havvindmøllepark efter opførelse af turbinerne. Røde prikker angiver positionen af de enkelte turbiner. Målestoksforhold er angivet ved den sorte bjælke under nord-pilen, som repræsenterer 1000 m.

It has been suggested that offshore wind farms act as an attractant to migrating birds of prey, as was suggested to be the case for the Anholt Offshore Wind Farm, the site of 111 wind turbines situated in Kattegat, halfway between northeast Djursland and the island of Anholt. Modelling suggested that the passage of species like Common Buzzard *Buteo buteo*, Sparrowhawk *Accipiter nisus* and Honey Buzzard *Pernis apivorus* potentially would encounter relatively high collision fatalities post construction, but observations showed high level of macro-level avoidance of the wind farm that rather suggested the alternative problem of a barrier effect. Although this may prolong migration routes and affect survival and/or reproduction, this behaviour did at least reduce the probability of collision mortality among such relatively long-lived bird species (Jensen *et al*. 2016).

Another consequence of avoidance responses to the visual stimulus of novel rotating turbine blades and towers was to displace birds from ideal feeding distributions. If, for any reason, birds are unwilling to approach an actively operational turbine to within a distance that is half of the distance between adjacent turbines, the area within the area of a windfarm becomes behaviourally inaccessible to them, even if the physical feeding habitat and prey are still present, theoretically available and even potentially improved as a result of the construction of the wind turbines. In other words, functional habitat loss results from the behaviour of the birds, because the food supply and habitat remain intact, but the presence of the turbines inhibit the birds from approaching and using such areas. This seems to be the case for certain species, such as the Common Scoter *Melanitta nigra* and Red-throated Diver *Gavia stellata*, species which seem to avoid foraging in waters between the turbines in windfarms in Denmark (Fig. 3; Petersen *et al.* 2006, 2014), although small numbers of Common Scoters (at much lower densities) have been recorded between turbines on occasions in both Horns Rev I and II windfarms (e.g. Petersen & Fox 2007). It seems likely that variations in food supply could explain this variable response, but it is generally the case that these two species are extremely reticent to forage between the turbine rows in those windfarms where they were formerly common. At Horns Rev, Red-throated Divers which had been present in the pre-construction windfarm footprint area were not seen within the newly built windfarm during the post construction monitoring, although a very few individuals have been seen between turbines in subsequent years. In the Netherlands, Red-throated Divers were not detected between turbines at one site but did so at another Dutch windfarm (Lindeboom *et al.* 2011) confirming responses can be variable, even within species. Comparison of the before- and after distributions of Red-throated Divers in the German Bight suggest a major displacement effect from newly constructed windfarms out to at least 16 km and reductions in bird densities of more than 60% in an area within 10 km of the turbines (Mendel *et al.* 2019). More perplexing is the case of the Long-tailed Duck *Clangula hyemalis*, which foraged in the area of the subsequent Nysted Offshore Windfarm before its construction, but has done so since the site became operational in densities much less than those prior to construction and compared to areas where it occurs immediately adjacent to the windfarm (Fig. 4; Petersen *et al.* 2011). This seems to imply that while some individuals are willing to forage between the turbines, others that formerly did so are not now willing to do so, for whatever reason (Petersen *et al.* 2011). Razorbill *Alca torda* and Common Guillemot *Uria aalge* also tend to occur in lower numbers post-construction of offshore windfarms (e.g. Dierschke & Garthe 2006). However, without understanding the relative importance of a given feeding area and the likelihood, possibility and energetic costs of shifting elsewhere to feed when displaced by wind turbines, it is difficult to determine the true costs (in terms of energy balance, for example) to the individual of being denied a feeding area in this way or the consequences for the population. It is even more difficult to assess the impacts on populations from multiple such developments along waterbird migration corridors (see the later discussion on cumulative effects). For these reasons, it can be extremely difficult to conclude about the true level and impact of displacement of birds from formerly good feeding areas, as it seems to be a complex response likely mediated by site and species concerned, but also potentially on individual responses, levels of habituation and the richness of the food supply in ways we have yet to understand.

2. Physical habitat loss/modification or gain

In the case of the well-studied Nysted and Horns Rev offshore windfarms, the extent of physical loss to turbine foundations and of habitat modification to anti-scour protection never amounted to more than 2% of the total area of the windfarm (Fox *et al.* 2006a). For most recent offshore developments, these assessments would be similar, because anti-scour, foundation and cable disruptions to the general seabed inside and in the vicinity of wind turbines tend to be limited to a similar proportional area. Foundations and anti-scour provisions may also attract the settlement of flora and fauna which are "alien" to that specific local seabed habitat, as in the case of providing a solid hard substrate and crevices within areas of sandy-bottomed habitat which have become favoured sites for rammed foundation turbines. As a result, fish and invertebrates that seek shelter in crevices may occur around turbine anti-scour foundations and blue mussels *Mytilus edule* may settle on foundations in densities not formerly possible on sea-beds which formerly consisted of bare open sand substrates. Although not totally insignificant, the areas over which such effects are manifest constitute a biologically trivial proportion of the total area. Some foraging Eiders (presumably taking blue mussels) have been seen associating with turbine bases, but there is no evidence for any significant effects on bird distributions. Species such as the larger *Larus* gull species and Cormorants are undoubtedly attracted to the superstructure of turbines, meteorolo-

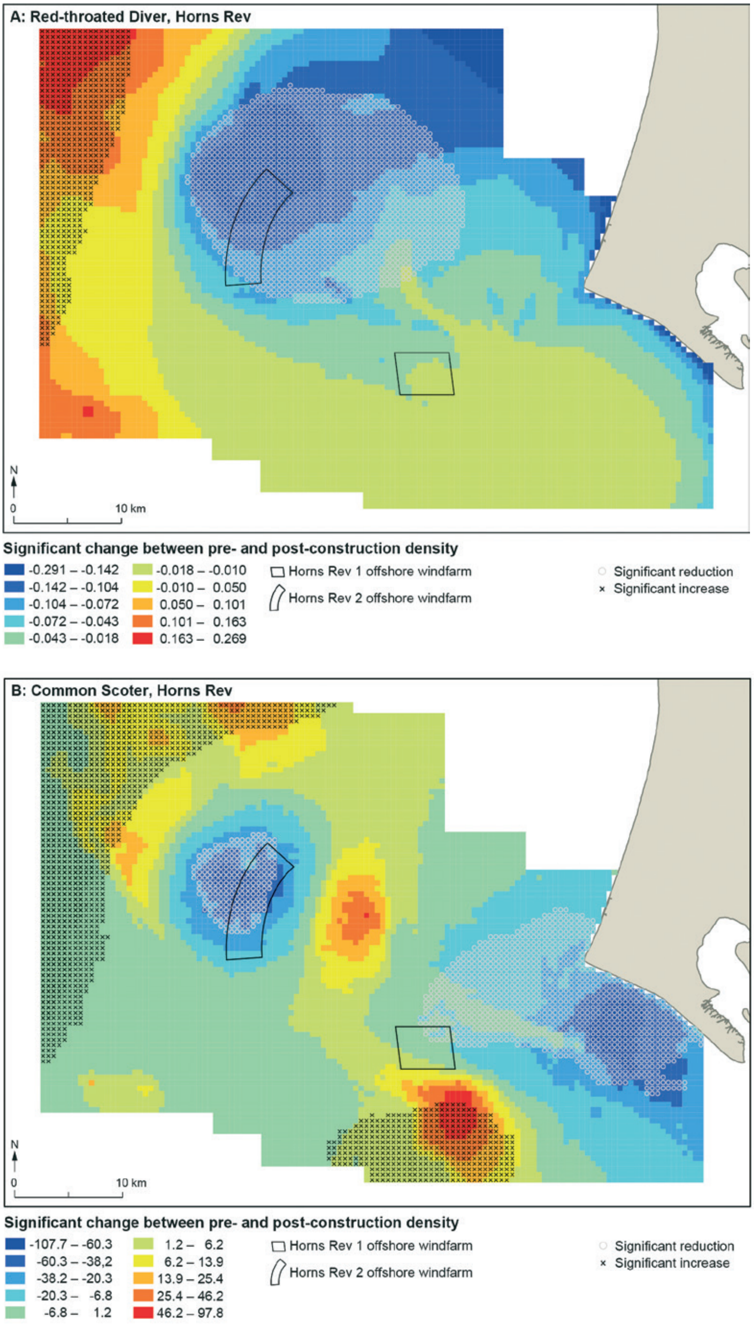


Fig. 3. Map of the Horns Revs 2 Offshore Windfarm Study Area. The map shows estimated differences between pre- and post-construction densities of Red-throated Diver (A) and Common Scoter (B) estimated by generalised additive models in each 500 × 500 m grid square averaged over the survey period. The legend defines the colour codes for the level of changes in each of the maps. Black plus-symbols indicate grid squares, which showed statistically significant increases, and open white circles those with significantly reduced numbers. Open polygons indicate the Horns Rev I (constructed prior to this investigation, closest to land) and Horns Rev 2 offshore wind farms.

Kort over forandring af tætheder af rastende Rødstrubet Lom (A) og Sortand (B) ved sammenligning af gennemsnitlige tætheder for perioden før opførelsen af Horns Rev 2-havvindmølleparken og perioden efter opførelsen af denne. De modellerede værdier blev beregnet for et kvadratnet med 500 × 500 m celler. Farveskalaen angiver, hvorvidt tæthederne er forøgede eller reducerede, røde og gule farver angiver forøgelse, grønne og blå farver angiver reduktion. Sorte krydser angiver celler, hvor en tæthedsforøgelse er statistisk signifikant. Åbne hvide cirkler angiver celler, hvor en tæthedsreduktion er signifikant. Åbne sorte polygoner angiver hhv. Horns Rev 2 og Horns Rev 1 havvindmølleparkerne. Horns Rev 1 blev opført før starten på indsamlingen af data til disse sammenligninger af før- og efterfordelinger af fugle ved Horns Rev 2. De neutrale værdier for Horns Rev 1-området indikerer, at fx Sortænder var flyttet bort fra området før indledningen af denne undersøgelse, og at de ikke inden for perioden har vist tegn på tilvænning til parkens tilstedeværelse.

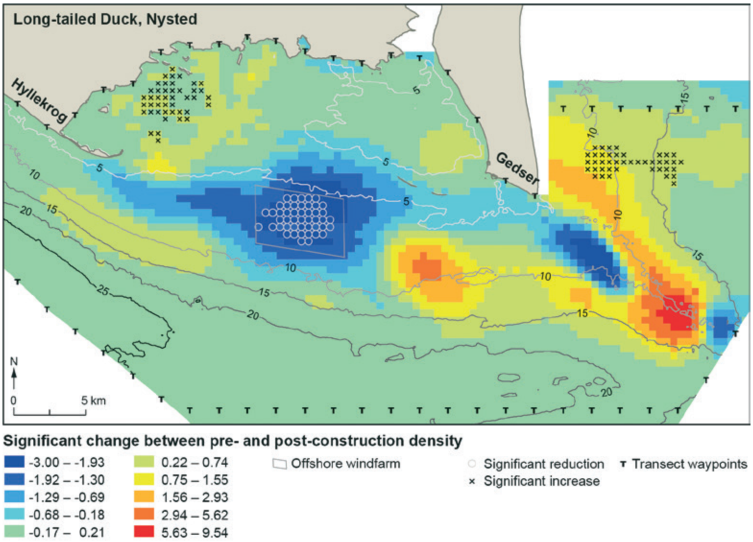


Fig. 4. Map of the Nysted Offshore Windfarm study area showing estimated differences in Long-tailed Duck numbers within grid cells of 500 × 500 m distributed across the entire study site generated from a spatially-adaptive generalized additive model pre- and post-construction of the windfarm. Estimated abundances were derived from combined aerial survey data that counted birds along transects and adjusting abundance for detection probability. Negative differences (shades of blue) indicate fewer individuals in cells post-construction than prior, positive differences (yellow-orange-red grid squares) indicate increased numbers post-construction. Black cross symbols indicate statistically significant increases and open white circles indicate statistically significant decreases in these numbers when comparing pre- and post-construction abundance in these grid cells based on model estimates. Contour lines indicate depth intervals as labelled in metres. The ultimate position of the windfarm is identified by the light grey polygon outline and aerial transects waypoints are indicated by the T symbols.
Kort over forskellen mellem tætheder af Havlit før og efter opførelse af Nysted Havvindmøllepark. Forskellen i tætheder er beregnet for hele undersøgelsesområdet og som gennemsnitlige værdier hhv. før og efter opførelse af parken. Der blev beregnet tæthedsværdier i et kvadratnet med celler på 500 × 500 m beregnet med rumlig modellering, og baseret på optællinger af fugle fra fly langs forudbestemte transekter, hvorved en kompensation for detektions-sandsynlighed kunne indregnes. Blå farver indikerer reducerede tætheder ved sammenligning af tætheder før og efter parkens opførelse, mens røde og gule farver indikerer forøgede tætheder ved samme sammenligning. Sorte krydser indikerer celler med en statistisk signifikant forøgelse af tætheder efter etablering af mølleparken, mens åbne sorte cirkler indikerer celler med statistisk signifikant reduktion i tætheder efter etablering af parken. Den lysegrå firkant midt i figuren indikerer placeringen af Nysted Havvindmøllepark. Sorte T-symboler viser endepunkter for transektlinjer anvendt under optællingerne.

gical masts and transformer stations, associated with offshore windfarms, but Danish studies found no increased densities of these species post construction (Petersen *et al.* 2006), in contrast to findings in the Netherlands (Lindeboom *et al.* 2011).

3. Collision mortality

Of all the potential effects of offshore windfarm construction, deaths from collisions have always attracted most attention as the primary impact on bird populations. Birds may die by hitting stationary superstructures, the stationary or rotating rotor blades or by being caught and mortally injured in the vortices created in the wake of the rotor blades (Fox *et al.* 2006a). Many birds (but especially night migrating passerines) collide with stationary objects on land and at sea (e.g. Kerlinger 2000), especially when these are illuminated, so much effort has been put into fitting navigation lights to offshore wind turbines that avoid the need for illumination and at the same time do not attract birds (Drewitt & Langston 2008). Studies suggest that birds show avoidance of turbines at three spatial scales, the macro-scale (within 3 km of the turbine), the meso-scale (within the windfarm footprint, i.e. between turbines) and the micro-scale where birds respond to the proximity of the blades and the monopole (within 10 m; Skov *et al.* 2018), so all these need to be carefully considered in any assessment of potential collision risk at offshore windfarms. However, as we report later on, because of the high levels of avoidance shown by many larger-bodied seabirds to offshore wind installations, the experience has generally been that collision rates are low.

Dealing with potential effects/impacts on birds

Species specific impacts

As is the case for any major development affecting the natural environment, it is important to understand that not all birds are affected equally by the construction of offshore turbines, either in terms of the immediate risk of collision and other effects on their behaviour and ecology, or the effects on their reproductive success and survival and ultimately population dynamics (i.e. whether population size changes as a result of wind turbine impacts). Clearly bird behaviour will affect the chance of collision mortality, because species that habitually fly at rotor sweep heights will be far more susceptible than those that fly low over the sea. Feeding ecology, flight height and visual acuity (see Martin 2011) affect the threats posed to birds by turbines, hence skuas *Stercorarius* spp., Northern Gannets *Morus bassanus*, gulls and terns, which fly relatively high over the water surface and may be visually distracted by concentrating on kleptoparasitic pursuit or subsurface prey may be more susceptible to collisions than, for example, divers *Gavia* spp. and auks, or diving ducks such as Common Scoter and Long-tailed Duck, which tend to fly low over the water surface and feed in the water column or on the benthos.

Avian species that behaviourally show strong responses to man-made objects are more likely to avoid novel structures in the marine environment compared to species such as some gulls and Cormorants, which already exploit (and indeed may be attracted to) human marine architecture throughout their range. Body size and aerodynamics will also affect the ability of birds to make last minute avoidance to turbine blades, so small, highly manoeuvrable birds may have less likelihood of collision than larger birds that present a large surface area and show slower avoidance responses (Drewitt & Langston 2008). Curiously, even the absolute death rate caused to a species may have differential effects on overall population size. Long-lived marine species with low reproductive turnover, such as divers, are far more susceptible to even very small increases in adult mortality compared to small passerines, which are short-lived but which can produce large numbers of young to replace losses, especially in situations where strong density dependent effects may affect demographic rates, so lower breeding densities may enable elevated reproductive success (Desholm 2009). Hence, it is vital to consider which bird species are likely to be affected and in what way by the construction of a specific windfarm.

Site and project specific impacts

The effects of offshore windfarm construction are also highly dependent upon the characteristics of the site and the nature of the construction work that is proposed. Clearly windfarms should not be constructed in areas where migrant birds of any type are concentrated by coastal topography (e.g. at the tips of peninsulas where migrating land birds are classically known to gather; Desholm *et al.* 2014), because birds departing on migration from such "pinch" points will inevitably be highly concentrated as they funnel out to disperse onwards on migration. Given these topographical concentrations of migratory avian traffic in specific airspace, avoiding construction of turbines in these areas will avoid any risk of collision mortality in particular areas of likely conflict. Likewise, narrow sea passages between landmasses or promontories rounded by large numbers of migrating waterbirds may also create concentrations, making such sites highly unsuitable for the siting of turbines. Feeding marine bird species are not randomly distributed at sea, so regular aggregations of seabirds attracted to known food resources should also be avoided as potential areas for offshore windfarms. Unfortunately, assessments of the feeding resources of piscivorous birds may not be constant, nor simple to predict, although divers (e.g. Skov & Prins 2001) and Little Gulls *Hydrocoloeus minutus* (Schwemmer & Garthe 2006) clearly associate with oceanic surface front systems, which despite being ephemeral marine features, can show seasonal predictability in time and space. Even benthos feeding birds, such as scoters and Eiders, may shift between different feeding areas between years because spat-settlement of their essentially bivalve prey may result in major differences in prey availability between years, due to age and size class distributions affecting the annual profitability of their food supply. Nevertheless, in Denmark, there is a presumption to avoid development in very shallow waters (< 10 m) to avoid major conflicts with potential feeding areas for seabirds feeding on benthos and on aggregations of organisms in the water column that are typically most common in such shallow waters. All other things being equal, the size, layout, distance between individual turbines, location and siting of turbines will also affect the likely impact of windfarm construction of birds using the general area and these also need to be taken into consideration when attempting to predict the specific avian impacts of a given development (e.g. Masden *et al.* 2012).

Environmentally determined impacts

The interactions between weather and local topography also create unique conditions that potentially impact differentially upon bird species. Mist, rain and snow showers, especially in situations of rapid meteorological change, can all result in disorientated migrant birds colliding with illuminated structures, potentially causing catastrophic (if highly infrequent) mortality events that can affect one or many species (see Newton 2007) and these considerations are also by nature, site-specific.

Temporal patterns of impacts

Finally, the extent to which impacts may be manifest for bird populations vary greatly with season. The Eider neither breeds nor winters in any substantial numbers in the vicinity of the first Nysted offshore windfarm.

However, the entire breeding population of the northern Baltic (200 000-300 000 birds) passes through this very restricted area every spring and autumn on annual migration *en route* to and from the winter quarters (Desholm & Kahlert 2005). Self-evidently therefore, any impact assessment of wind turbines constructed at sea needs to take account of avian movements throughout the entire annual cycle. Many waterbird species (especially scoters and Eiders in Danish waters) undergo a simultaneous wing moult that renders them flightless for some three or so weeks while remigial feathers are replaced. At this stage in the annual life cycle, the birds are highly sensitive to disturbance and show a much stronger avoidance response to human structures and activities at sea than at other times of the year (Petersen & Fox 2009, Petersen *et al.* 2017). Since the moult period is a particular energetic bottleneck for these birds and because of their heightened sensitivity to human disturbance at this time of year, particular attention should be given to siting windfarms in relation to concentrations of these birds, which often draw birds from along large expanses of their flyway.

For all of the above reasons, it is therefore very evident that any environmental impact assessment of a new offshore windfarm needs to take into consideration the specific challenges of the project and site, especially with regard to the species presence, their abundance, sensitivity and conservation status. Such assessments also need to cover the entire annual cycle to take account of seasonal changes and should be based on more than just one year (and ideally more than two) to assess the degree of within and between year variations in the patterns observed. They also need to consider the nature of the proposals, with regard to construction, operation and decommissioning activities, turbine height, sweep area, numbers and the associated infrastructure and their impact on the environment (such as transformer stations, buried underground cables, lighting, disturbance from maintenance traffic, etc.). Hence, it is impossible to conclude on a general level about the scale and magnitude of effects and impacts of offshore wind farms are likely to have upon the bird populations which encounter them based on our experience of those constructed so far. It is also the case that lamentably few offshore wind farms have been adequately monitored for prolonged periods post construction (rarely more than two years) to provide a sufficiently rich record of the true consequences (rather than the more speculative pre-construction environmental impact assessments) to inform future development. Although monitoring is inevitably costly, the value of such long-term monitoring of effects and impacts cannot be overvalued. Nevertheless, our experience to date enables us to say a great deal about the general effects (proximate changes in bird behaviour, local distribution and abundance) and impacts (defined as ultimate changes in population size because of reduced reproduction or survival) of the construction and operation of the existing Danish offshore windfarms, especially with additional experiences from other countries.

Sequential assessment of effects

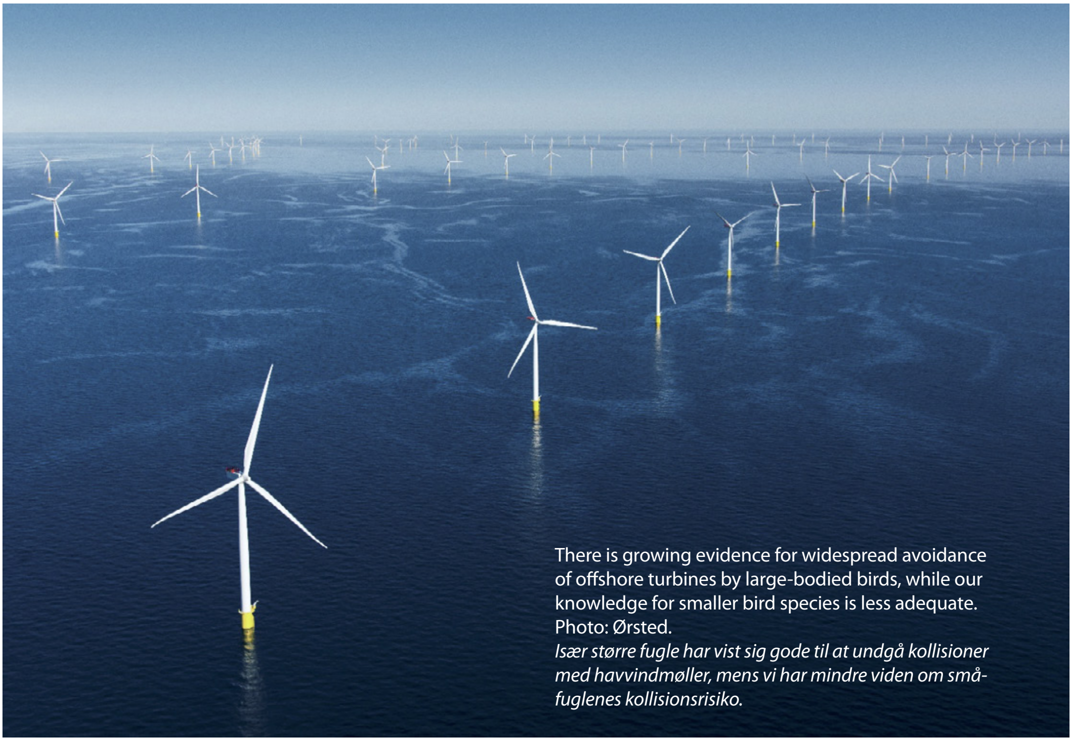
Construction and decommissioning phases

There has been hardly any study of the effects on birds during the period when offshore turbines are being constructed, but there is no doubt that enhanced ship and maintenance traffic, noise, lighting and concentrated activity in the development footprint of the windfarm are likely to be highly disruptive, and of a different nature, compared to the prior undisturbed situation, as well the subsequent operational phase. During this period, changes to shipping lanes and traffic and modification of fishing activity in the vicinity will also come into effect, while extreme disturbance (e.g. pile driving) can have profound potential effects on birds, as well as their prey. On the other hand, the limitations of day length and availability of good weather tends to constrain construction to a short period of duration in the summer when there tend to be fewer birds present, with the result that any potential effects are of very short duration and of minimal impacts. Unfortunately, there have been no assessments of the effects of windfarm decommissioning, but these are likely to be of short duration and of similar nature to the construction phase.

Operational phase

The effects of offshore windfarms on birds during the initial operation stage have been much studied in relation to points 1, 2 and 3 above. In the case of studying the effects of the appearance of turbines in areas of open sea formerly devoid of such structures, the main approach to understand avoidance by flying birds has been to examine the directions of flight before and after construction using marine surveillance radar, mounted both vertically and horizontally to generate the intensity of bird movements in three dimensional space (e.g. Desholm & Kahlert 2005, Desholm *et al.* 2006, Petersen *et al.* 2006, Krijgsveld *et al.* 2011, Plonczkier & Simms 2012, Leopold *et al.* 2013, Skov *et al.* 2018). These results generally show major macro-scale adjustments. For instance, migrating Eiders rounding the southern tip of the Gedser peninsula approaching the Nysted Offshore Wind farm showed adjustments to flight trajectories to avoid the turbines at distances up to 3 km away (Kahlert *et al.* 2004). Some species were almost never seen flying between the turbines (Red-throated Divers and Northern Gannets), others rarely (Common Scoter), while yet others showed little avoidance (e.g. Cormorants and large gulls). At Horns Rev, 71-86% of all large bird flocks heading towards the windfarm at 1.5-2 km distance avoided entering the wind farm and flying between the turbine rows (Petersen *et al.* 2006). The same pattern was confirmed at Nysted (78%) predominantly amongst waterbirds, mostly migrating Eiders, but including a wide range of species (Petersen *et al.* 2006). The relatively few birds entering the Nysted Offshore Windfarm also flew midway between turbines rows at low altitude (below rotor sweep height) and exited the wind farm by the shortest routes more quickly than could be expected by chance (Desholm & Kahlert 2005). This resulted in considerable movement of birds up and down the periphery of both windfarms as birds preferentially flew around rather than between the turbines (Fig. 2). Such avoidance rates were also confirmed at night by radar, when it was also shown that although the response distance occurred much closer to the turbines, birds also tended to fly much higher. However, in a few regrettable cases, impact studies failed to establish the predicted impact of wind turbines, as in the case of 25 medium turbines established on eastern port breakwater at Zeebrugge, Belgium. These turbines were constructed on a breakwater encircling a breeding colony of Common *Sterna hirundo*, Sandwich *Thalasseus sandvicensis* and Little Terns *Sternula albifrons*, and post construction studies revealed that a mean of 6.7 terns collided per turbine per year for the whole wind farm (with highest rates at turbines closer to the breeding colony within 10 m of the nearest turbine). Many gulls were also recovered dead under the turbines confirming the need to avoid constructing wind turbines close to any important tern, gull or other sea bird colonies, especially those associated with frequent foraging flight paths of these species, because of the high risk of associated collision mortality (Everaert & Stienen 2006).

Unfortunately, few observational data relating to any of the study species were obtained during periods of poor visibility, but generally this was because bird migration slows and ceases under such circumstances, as confirmed by radar studies (Petersen *et al.* 2006). These studies also confirmed that for large bodied species such as the larger seabirds, sea ducks (such as Common Scoter and Eider) and geese (all species particularly susceptible to additional mortality) as well as migrating dabbling ducks, there were good grounds to suspect avoidance behaviour at macro- (< 3 km distance) and meso-scales (e.g. avoiding flying anywhere near turbines and midway between rows within wind farms) substantially reduced the probability of any collisions with turbines.



There is growing evidence for widespread avoidance of offshore turbines by large-bodied birds, while our knowledge for smaller bird species is less adequate. Photo: Ørsted.
Især større fugle har vist sig gode til at undgå kollisioner med havvindmøller, mens vi har mindre viden om småfuglenes kollisionsrisiko.

To predictively attempt to estimate the collision rates of birds, based on the level of avian flying activity recorded by radar and other methods in advance of construction, several modelling approaches have been developed to try and predict the annual numbers of birds which will collide with turbines ahead of construction (see Chamberlain *et al.* 2006 and Masden & Cook 2016 for reviews). All of these models rely ultimately on determining the probability of last minute (i.e. micro-level) avoidance that birds are able to make when close to the blades. This parameter is highly dependent upon species, weather conditions, visibility etc., and is notoriously difficult to estimate or quantify. Nevertheless, one of these stochastic models was used to predict that out of 235 000 Eiders passing the Nysted Offshore Windfarm, 0.018-0.020% of these would collide with turbine blades in an autumn (Fox *et al.* 2006b). With such a low probability, it was predicted that the infra-red (i.e. thermal) video monitoring system set up to detect such collisions would fail to detect a single collision during 2400 hours of monitoring, which proved to be the case. The system detected only 11 birds, all well away from turbine sweep area, two passing bats, two passing objects (either bats or birds), a moth and one collision of a small bird with a turbine blade (Petersen *et al.* 2006).

Since that time, much effort has been invested in creating improved models to estimate collision rates given bird flight trajectories generated from two- and three-dimensional radar tracking (e.g. Skov *et al.* 2018). This has also resulted in much effort measuring flight heights probabilities to parameterise such collision risk models (e.g. Johnson *et al.* 2014, Cleasby *et al.* 2015, Fijn *et al.* 2015). There have also been advances in the techniques available to enable the field validation of collision rates and avoidance of turbines among birds (and bats) at offshore turbines (Dirksen 2017). Recent results from monitoring detailed movements of a range of species previously thought to be at risk (large gull species and Northern Gannet) show meso- and micro avoidance behaviours that substantially reduce the risk of collision and contribute to very low observed collision rates (Skov *et al.* 2018).

It is also fair to say that we remain sadly ignorant of the actual rates of collision of smaller birds with offshore turbines. Generally, attention has been focussed upon the larger bodied species because of their relative

Long-tailed Ducks used to forage in the area of the subsequent Nysted Offshore Windfarm but has done so much less since the site became operational than prior to construction. Photo: Hans-Henrik Wienberg.
Havlitten er blandt de arter, der er blevet fortrængt fra tidligere fourageringsområder ved opførelse af havvindmølleparker.

vulnerability to elevated death rates (primarily from collision) and because larger bodied birds are easier to monitor using techniques such as infra-red videometry and radar. This is not to say that there is (or is not) a major problem with smaller species, merely that to date, they have not been subject to robust levels of monitoring. Generally, it is considered that there is no major problem with other species, and infra-red videometry at Nysted confirmed this to be the case at that site. However, there remains the minimal risk that under certain (likely very rare) prevailing weather conditions, circumstances may conspire to cause major collision mortality and we would urge more low-key long-term monitoring to better determine the levels of such risks. If there are conditions under which unacceptable levels of collision deaths occur for any species, we should be thinking in terms of developing forms of mitigation, for instance implementing early warning devices to warn of the approaching risk and potentially using remote sensing to detect bird movements close to rotor blades to cease electricity generation under such circumstances (Dirksen 2017).

Finally, it is important to remember that wind turbines require regular maintenance and irregular repair, necessitating support vessels, cranes, helicopters and operating crews being active in waters which were often not subject to frequent ship traffic pre-construction. Although designation of windfarms as “no-go” fishing areas may reduce the physical presence of boats in an area of constructed turbines, intense maintenance traffic in formerly undisturbed areas and along routes to and from their home harbours may add substantially to the sources of surface anthropogenic disturbance to seabirds out in the open sea. This is most likely to have effects on the distributions of birds foraging in the area but will also affect other species.

The greatest future challenges

It is very evident from where we are now that we need to take a more strategic national and international approach to the identification, assessment and selection process for the selection of areas suitable for future offshore windfarm developments. However, our greatest challenge for assessing the impacts of offshore windfarms on birds is an assessment of their so-called ”cumulative impacts”. As clearly recognised here, individual windfarms may have minor effects on the environment, but collectively, many of these developments, especially spread out to confront individuals from a migratory avian population along the entire length of its migration corridor may have a significant effect. This effect may be far greater than the sum of the individual parts acting alone, especially if contributing adversely to the fitness of many individuals. EU Directives 85/337/EEC (as amended) and 2001/42/EC both require that a cumulative impact assessment is undertaken as part of an environmental impact assessment of an individual proposed offshore windfarm development. However, to date, we still lack detailed guidance about how to tackle such cumulative assessments and those that have been attempted have generally been inadequate and not subject to retrospective review. We therefore remain remarkably ignorant about the cumulative impacts of many offshore windfarms on bird populations, although happily there continue to be new attempts to create a conceptual framework for such analysis (e.g. Masden *et al.* 2010b, Poot *et al.* 2011, Busch *et al*. 2013, May *et al.* 2018). In our humble opinion, this remains one of the single most important areas to address in the future, as we see more and more development of offshore potential for electricity generation. As our seas become increasing enclosed and covered with turbines, there clearly will be major cumulative effects on bird populations of which we remain ignorant at the present time.

Conclusions

The hazards presented to birds by the construction of offshore windfarms remain primarily (i) the barrier they present to movement, (ii) loss, gain and enhancement of habitat and (iii) collision risk. Most studies to date have used radar and thermal infra-red monitoring as well as range-finding and visual observations to confirm that most of the more abundant and especially large bodied birds show major avoidance to offshore windfarms, minimising the probabilities of collision. Slightly extended migration distances are unlikely to have consequences for these species. Effects on breeding and wintering birds interrupted during their commuting flights remain less well studied, but avoidance of conflict is easily achieved by siting offshore wind turbines well away from important concentrations of breeding and wintering seabirds and their respective feeding areas.

Avoidance also extends to some species of birds which affect their feeding distributions (usually outside of the breeding period). Such physical displacement as a result of individuals avoiding to feed in the vicinity of turbines means that the species suffers effective habitat loss, even though the habitat and even the food supply may remain intact. From studied locations, this seems to be the case for Red-throated Divers, Common Scoters, Long-tailed Ducks, Razorbills and Common Guillemots, but for most species, we lack sufficient data of sufficient quality to make a judgement. While it has been possible to demonstrate such effects, it remains a major challenge for the future to understand how increasing displacement from ideal foraging habitat may impact upon population processes, especially as a result of cumulative effects along the flyways of the migratory waterbirds concerned.

Avian avoidance at long distances reduces the collision risk to individuals and this seems to be the case for many study species. Although this has mostly been studied for the large-bodied bird species considered most at risk, we suspect this to be the case for smaller bird species as well. Recent results from monitoring detailed movements of a range of species previously thought to be at risk (large gull species and Northern Gannet) show meso- and micro avoidance behaviours that also substantially reduce the risk of collision and contribute to very low observed collision rates. However, we lack long-term and intensive effective monitoring of the numbers of bird collisions at offshore turbines under a vast range of differing seasonal and weather conditions and at different sites to be truly confident that this impact is as minimal as all studies suggest they are. Still, our experience to date has provided a very solid foundation upon which to propose robust impact assessments following specific methods to determine the effects on bird populations from the proposed development of new windfarms in offshore waters.

One of the greatest historical challenges in the early days of offshore windfarm development was the rather piecemeal nature of the development. Windfarms were proposed in areas which were good for windfarms (in the sense that the wind profiles, suitability of substrates, connections into the electricity grid and economic considerations mitigated in favour of their construction), but for which we lacked good biodiversity information (including birds). This meant, for example, that biological assessments undertaken as part of the impact assessment of windfarms in Britain discovered previously unknown concentrations of wintering Common Scoters and Red-throated Divers that ultimately stopped or caused major modification to the proposed construction of windfarms, at great expense to the developers. In Denmark, we are now in a better position to combine strategic marine planning layers that describe shipping routes, buried submarine cables, military restriction areas, fishing banks, protected areas and other sites of important biodiversity interest (including historical bird distributions) and other features of stakeholder interest to look more strategically at where best to site windfarms to avoid conflicts with other users of the marine environment at a preliminary stage. However, it remains essential to undertake detailed bird surveys to determine the true current importance of areas proposed for windfarm development and to set the derived knowledge in the context of the potential effects on their flyway populations.

EU Directive 2001/42/EC requires a strategic environmental assessment (SEA) of national wind energy plans and programmes that have potential adverse effects on biodiversity, which would also help guide marine wind power developments, both nationally and internationally. International coordination and collaboration is required under the United Nations Espoo Convention (UNECE 1991) where there are potential transboundary effects regarding the placement of offshore windfarms. While obligatory EIA legislation (EU Directive 85/337/EEC and 97/11/EC) requires project level environmental impact assessment, these tend to take account of effects on birds only at the local geographical scale. The SEA and EIA Directives require assessment of the cumulative effects of each proposal (including associated on- and offshore infrastructure development, such as road improvements, power lines, etc.) in conjunction with other projects and factors (not necessarily only other offshore windfarms, so including pollution, fisheries, ship traffic, mineral extraction from the sea bed, etc.) that impact upon the same flyway populations of birds. These requirements make it even more essential that we use our current knowledge to become better able to model the cumulative effects of many such windfarm developments in the context of the many other development pressures that currently threaten our bird populations. In the meantime, our planet warms and the pressure to provide renewable non-fossil fuel electricity increases. There is no doubt that offshore windfarms can make a major contribution to providing such power, and we therefore need to find innovative solutions to ensure we do not save the planet at cost to migratory bird populations.

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Resumé

Havvindmøller og deres påvirkning af fugle

Udfordringerne for fugle ved etablering af havvindmølleparker kan samles i tre hovedkategorier, nemlig 1) barriereeffekt i forhold til fuglenes bevægelser, 2) forandring af habitatet, der kan medføre tab, forbedring eller udvidelse af areal og 3) kollisionsrisiko. Langt de fleste undersøgelser, der har anvendt radar og infrarød overvågning kombineret med laser-afstandsmålende kikkerter og menneskelige observatører til at registrere fugles reaktion på møllerne, har kunnet konstatere, at talrige fuglearter, og specielt de større fugle, undgår havvindmølleparkerne på ret stor afstand og reducerer på den måde risikoen for kollision med turbinerne. Det er derimod mindre grundigt belyst, hvordan ynglende og overvintrende fugle kan blive påvirket under deres – ofte daglige – flyvninger, men sådanne påvirkninger kan let undgås ved at projektere nye vindmølleparker på afstand af vigtige yngle- eller overvintringsområder, og dermed undgå eller reducere potentielle barriereeffekter.

Undvigende adfærd omfatter imidlertid ikke bare forbitrækkende fugle, men kan også omfatte tab af fourageringsområder (oftest uden for yngleperioden). En sådan reaktion, forårsaget af fuglenes uvilje til at fouragere tæt på turbiner, forårsager et effektiv habitattab, også selv om det marine habitat og den tilgængelige føderessource forbliver uændrede. På grundlag af undersøgte etablerede havvindmølleparker er der stærke indikationer på, at det er tilfældet for lommer, Sortand, Havlit, Alk og Lomvie, men for hovedparten af disse arter mangler vi data af tilstrækkelig robust karakter til at foretage en tilstrækkelig velunderbygget vurdering. Og selv om det har været muligt at konkludere sådanne effekter for nogle få arter, forbliver det en stor udfordring at undersøge, hvordan stadigt stigende tab af habitat fra foretrukne fourageringsområder kan have en effekt på den samlede flywaybestand af en given art og artens demografi – i særdeleshed når man tager de kumulative effekter af mange vindmølleparker langs en arts trækrute i betragtning.

Fuglenes afvigereaktion på stor afstand af turbinerne reducerer risikoen for kollision, og dette ser som nævnt ud til at være tilfældet for en lang række arter. Selv om dette hovedsagelig har været undersøgt for større fuglearter, der betragtes som mere i risiko for kollision end små arter, forventer vi, at det samme vil være tilfældet for mindre fuglearter. Nylige detaljerede moniteringsundersøgelser af passage af arter, der tidligere blev betragtet som værende i risiko for kollision (større mågearter og Sule), viste undvigelse overfor turbinerne på mellem- og kort afstand, hvilket samtidig reducerer risikoen for kollision markant og gav meget lave antal observerede kollisionsrater. Vi mangler imidlertid moniteringsprogrammer med større varighed og intensitet til at beskrive antallet af kollisioner ved turbiner til havs, og som strækker sig over forskellige årstider og vejrmæssige forskelligheder og fra geografisk forskellige områder for at få vished for, at denne indflydelse på fuglene er så beskeden, som de foreliggende studier antyder, at de er. Vores hidtidige erfaringer har imidlertid givet os et solidt grundlag for at definere specifikke undersøgelsesmetoder til at beskrive de potentielle effekter af etableringen af nye havvindmølleparker.

En af havvindmølleparkernes tidlige udviklingsmæssige udfordringer var den ”bid for bid”-udvikling, som man var nødt til at gennemgå. Vindmølleparker blev projekteret i områder,

Many bird species most often fly low over the water and thereby out of risk; here Barnacle Geese. Photo: Lars Maltha Rasmussen.
Mange fuglearter flyver oftest lavt over havoverfladen og dermed udenfor fare fra møllevingerne, som disse Bramgæs.

der var gunstige for havvindmølleparker, dvs. steder, hvor vindprofilen var optimal, hvor havbundens sediment var velegnet til fundering af turbinerne, og hvor der var mulighed for tilkobling til aftagende el-netværk, og hvor de økonomiske betingelser var optimale. I England betød det blandt andet, at de biologiske undersøgelser, der blev foretaget som del af VVM-redegørelserne, opdagede hidtil ukendte koncentrationer af overvintrende Sortænder og Rødstrubede Lommer, hvilket i sidste ende satte en stopper for udviklingen af projekter eller afstedkom store ændringer, med store økonomiske konsekvenser for projektholderne. I Danmark er vi med tiden blevet bedre til at foretage marin planlægning ved at kombinere informationer om sejlruter, nedgravede kabler, militære restriktionsområder, fiskeriinteresser, råstofindvinding, beskyttede områder og andre områder med vigtige biologiske forekomster (inklusive historiske informationer om vigtige fugleforekomster) samt beskrivelser af andre interessegruppers interesser. Med disse er der skabt mulighed for på mere strategisk vis at undgå konflikter med andre interesser ved etablering af nye havvindmølleparker. Det er ikke desto mindre af stor vigtighed at gennemføre grundige undersøgelser af fugleforekomster forud for etablering af nye havvindmølleparker for at kunne beskrive den aktuelle betydning af et områdes ornitologiske kvaliteter og sætte disse informationer i relation til et vindmølleprojekts potentielle effekt på flywaybestanden af en given fugleart.

EU-direktiv 2001/42/EC fordrer, at der i forbindelse med nationale havvindmølleplaner, der kan have negativ indvirkning på biodiversiteten, gennemføres en strategisk miljøkonsekvensvurdering (SEA). Sådanne strategiske undersøgelser kan reducere potentielle effekter af vindmølleprojekterne, til glæde for både industri, administration og generelle brugere af vores omgivelser. FN's Espoo-konvention (UNECE 1991) fastsætter bestemmelser om nationale nabohøringer for projekter, hvor grænseoverskridende effekter kan komme på tale, fx i forbindelse med havvindmølleparker. Når vi taler om trækfugle, så kan Espoo-høringer blive aktuelle for en række nabolande. VVM-direktivets (EU Directive 85/337/EEC og 97/11/EC) bestemmelser om miljøkonsekvensvurderinger på projektplan har tendens til udelukkende at forholde sig til effekten på fuglearter i et meget afgrænset geografisk område, selv om der er krav om at evaluere potentielle kumulative effekter. Evaluering af kumulative effekter skal inddrage effekten af afledte aktiviteter, såsom etablering af ny infrastruktur både til havs og på land. Den skal samtidig vurdere bidrag til potentielle effekter fra helt andre menneskelige aktiviteter som fx forurening, fiskeri, skibstrafik og råstofindvinding langs en given arts flyway. Sådanne krav nødvendiggør, at vi bliver bedre til at udnytte vores nuværende viden til at vurdere effekten af mange havvindmølleparker i kombination og kombineret med effekten af andre menneskelige påvirkninger af vores fuglefauna. Samtidig fortsætter de globale temperaturer med at stige, og der er et akut og stigende behov for generering af fossilfri energi. Der er ingen tvivl om, at havvindmølleparker kan bidrage markant til sådan en CO_2-neutral energi. Det er vores klare overbevisning, at det kan opnås til gavn for det globale klima og – med grundig strategisk planlægning – uden at påvirke vores trækfuglebestande unødigt.

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