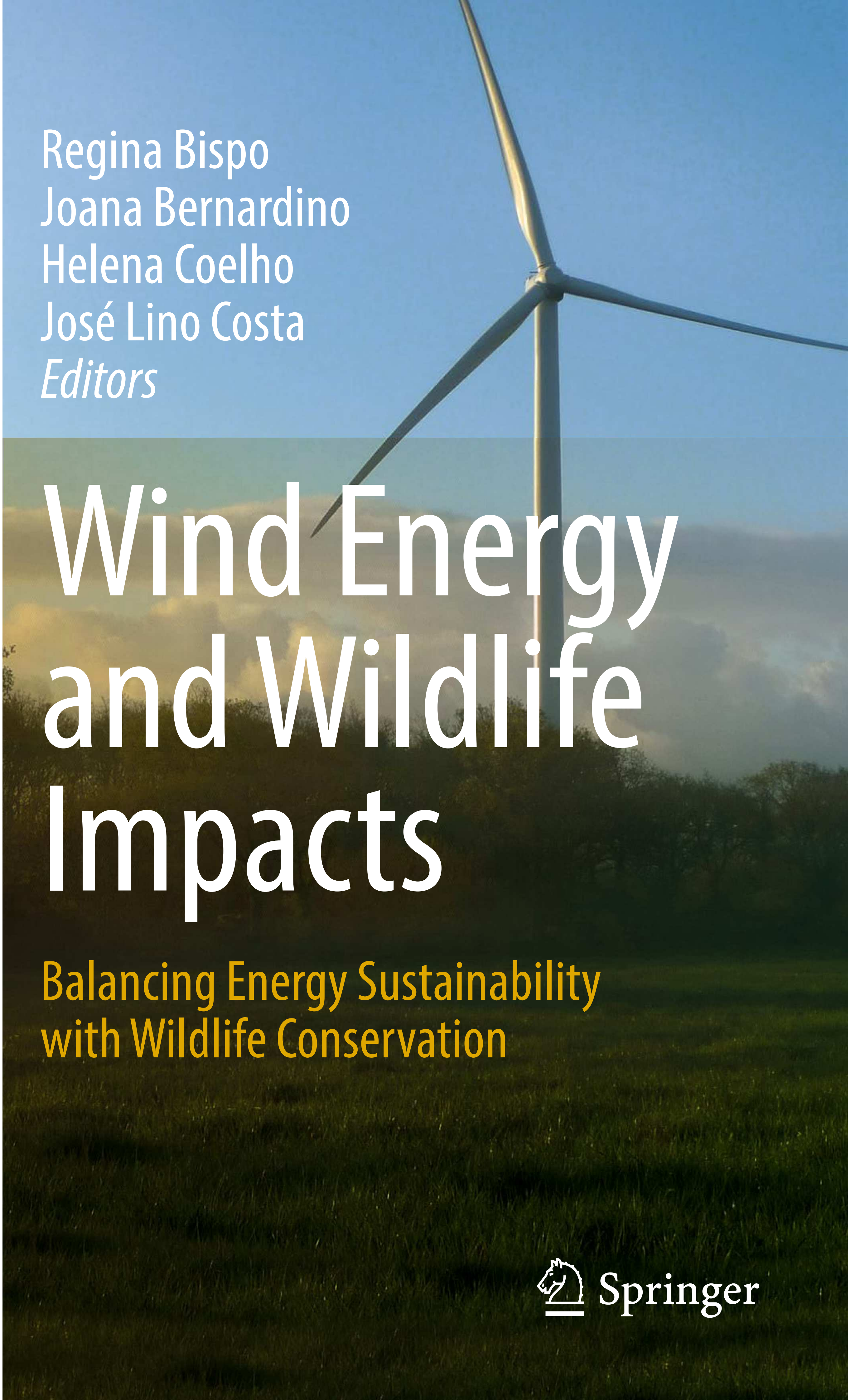

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# Wind Energy and Wildlife Impacts

## Balancing Energy Sustainability with Wildlife Conservation

Springer

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# Contents

# Avoidance Behaviour of Migrating Raptors Approaching an Offshore Wind Farm

**Erik Mandrup Jacobsen, Flemming Pagh Jensen, and Jan Blew**

**Abstract** During three seasons, we studied avoidance behaviour of migrating raptors when approaching an offshore wind farm in northern Baltic Sea 20 km from the coast.

From a substation 1.8 km west of the wind farm, we recorded macro, meso and micro avoidance behaviour of individual raptors approaching the wind farm, using a pre-defined protocol. We defined macro avoidance as when the raptor completely avoids entering the wind farm, meso avoidance as a significant change in altitude or direction before arrival and micro avoidance as a sudden change of flight when passing a turbine at close range.

In total, 466 migrating raptors representing 13 species were observed of which 73% representing 9 species showed macro, meso and/or micro avoidance behaviour.

Macro avoidance was recorded among ten of the species including 59% of red kites, 46% of common kestrels, 42% of sparrowhawks and 30% of honey buzzards. Three quarters of these raptors subsequently left the AOWF in a westerly direction, indicating that they returned to the mainland. The remaining birds flew either north or south parallel to the first row of turbines, suggesting they tried to navigate around the wind farm.

Our study demonstrated a barrier effect from the offshore wind farm influencing the migration of raptors by forcing some birds to use alternative and potentially more risky sea crossings. This may potentially affect survival and fitness of individuals and populations. Accordingly, we recommend that the location of important raptor migration routes is taken into consideration in siting of future offshore wind farms.

**Keywords** Bird migration · Macro · meso and micro avoidance · Behavioural response · Barrier effect

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# 1 Introduction

The last decade has witnessed a massive expansion in large offshore wind farms, in particular in the UK, Denmark, Germany, The Netherlands and Belgium [1]. Potentially, offshore wind farms pose a variety of impacts to birds, most notably: (1) collisions with turbines; (2) displacement of birds due to effective loss of habitat; and (3) barrier effects where the wind farm creates an obstacle to regular movements to and from breeding colonies or migration [2–6].

So far, collision has mostly been the focus of raptor studies at wind farms including the long lasting studies of the impact on raptor populations at Altamont, California [7, 8] and in Spain [9].

Here we focus on the barrier effect of an offshore wind farm constructed within a migration corridor of raptors.

Many raptors tend to avoid crossing open sea when migrating [10, 11]. Instead, they follow land areas until a crossing is unavoidable and therefore concentrate at peninsulas or other narrow stretches of land in order to reduce the risks and energy expenditures associated with active flight over water [12].

Avoiding a wind farm during migration prevents the risk of collisions with the turbines but at the cost of a longer flight route. Obviously, the extra cost of flying around one wind farm is negligible, but the cumulative effect of avoidance behaviour at many wind farms along the flyway could potentially increase the risk for more important and long-term consequences [13]. Furthermore, if the barrier created by an offshore wind farm forces the migrating raptors to turn back and instead use a longer sea crossing in another place, it could lead to significant additional energy expenditure.

At the peninsula Djursland in western Denmark, migrating raptors concentrate each spring [14] before crossing the Kattegat (northernmost part of the Baltic Sea) on their way to Sweden. When leaving the coast at Djursland, the raptors typically take an easterly or northeasterly direction and first cross 45 km of open sea to reach the small island Anholt before continuing for another 50 km to the west coast of Sweden (Fig. 1).

In 2013, a large offshore wind farm was constructed halfway between Djursland and Anholt (20 km off the Djursland coast). Anholt Offshore Wind Farm (AOWF) consists of 111 large 3.6 MW turbines arranged in up to 20 km long rows perpendicularly to the flightpath used by the migrating raptors leaving Djursland. The distance between the individual turbines is between 500 and 800 m (Fig. 1).

During three spring seasons, we studied the potential barrier effect of the AOWF on migrating raptors by quantifying macro, meso and micro avoidance behaviour of individual birds as they approached the turbines.

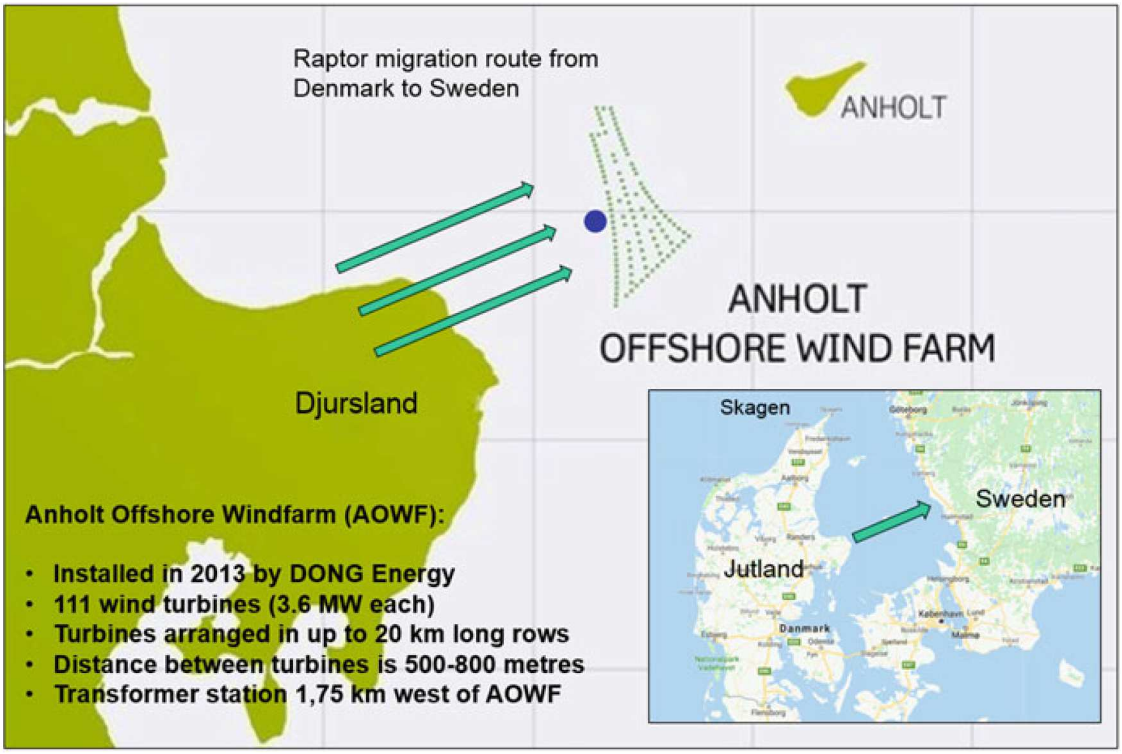


**Fig. 1** Direction of raptors migration from Djursland across the Kattegat (Baltic Sea) to Sweden in spring and the AOWF situated halfway between the coast and the island Anholt. The blue dot indicates the position of the substation used for data collection in this study

**Table 1** Observation periods in spring 2014–2016

| 2014 | 2015 | 2016 |
|---|---|---|
| 20–24 March | 7–10 March | 30 March–4 April |
| 28–31 March | 26–28 March | 12–16 April |
| 10–13 April | 8–11 April | 29 April–2 May |
| 23–27 April | 22–25 April | 7–11 May |
| 7–10 May | 8–12 May | 18–22 May |
| 21–23 May | 20–24 May | 27–31 May |
| 1–4 June | 1–5 June | |

# 2 Methods

## *2.1 Observations*

In spring 2014, 2015 and 2016, we carried out 89 days of standardized systematic recordings of behavioural responses of migrating raptors approaching the AOWF (Table 1). The observations were made from an offshore substation (Fig. 2) located 1.8 km west of the nearest turbine.

Between 7 and 12 h of observations were made each day from early morning (6–7 am) until mid-afternoon (when no more migrating raptors were observed). The


**Fig. 2** The substation used for recording behavioural reaction of migrating raptors. The closest turbines are seen in the background (c. 1.8 km away)

observations were only carried out on days with good visibility (min. 2–3 km), little or no precipitation and low wind speed (<6 m/s).

Observations were made using handheld binoculars (10× magnification) and 30× binoculars mounted on a tripod. To record the movements of raptors flying parallel to the row of turbines outside the range of the binoculars, a horizontally mounted Furuno surveillance radar was used with automatic storage of screenshots of the radar screen every minute.

With a visibility of at least 2–3 km, the migrating raptors could be followed all the way to the first row of turbines and sometimes onwards in between the turbines. When approaching the first row of turbines, the behaviour of the migrating raptor was recorded according to the following pre-defined protocol:

1. Is the raptor avoiding the wind farm by hesitating and starting to circle or flying parallel to the row of turbines or even turning back?
2. What is the altitude and direction of the raptor when it arrives to the wind farm? Examples: it is "flying NE twice the height of a turbine, under the swept area; there is no visible change in altitude or direction etc."?
3. Is the bird changing the flight altitude or direction when passing the first turbines (is the bird for example gaining height and fly over the swept area/losing altitude to fly under)?
4. Is the raptor taking a path between the turbines?

5. Is the raptor (apparently) ignoring the turbines and flying very close or through the swept area?
6. Are any close-range ("last moment") evasive movements visible?

The collected behavioural data range from a few records of the flight altitude and direction close to a turbine to observations lasting more than 40 min when, for example, the birds first hesitated and afterwards were flying parallel to the turbine row before eventually passing the wind farm (or was turning back).

### 2.2 Data Processing

For the purpose of this study, we define macro, meso and micro avoidance as follows:

- *Macro avoidance*: the raptor avoids entering the wind farm by either turning back or flying parallel to the first turbine row.
- *Meso avoidance*: a significant change in altitude or direction before arriving to the first row of turbines (after which the raptor enters the wind farm).
- *Micro avoidance*: a sudden change in the flight pattern when passing the first turbine at close range.

From the number of observed raptors approaching the AOWF, we calculated for each species the number and percentage that showed macro, meso and micro avoidance behaviour.

## 3 Results

In total 466 migrating raptors representing 13 different species were observed approaching the AOWF from mainly western or southwesterly directions (Table 2). Of these 340 individuals (73%) representing 9 species showed macro, meso and/or micro avoidance behaviour (Table 2).

The percentage of the different avoidance types for each species is shown in Table 3. It should be noted that the numbers listed under macro avoidance include birds that did not enter the wind farm at all but either left the AOWF in a westerly direction, indicating that they were returning to the mainland (75%), or flew north or south parallel to the first row of turbines (25%), suggesting they were trying to navigate around the wind farm.

**Table 2** Total number of observed raptors approaching the AOWF and the numbers and percentages showing macro, meso and/or micro avoidance according to our definitions (see text)

| Species | Number observed ($n = 466$) | Number showing macro, meso and/or micro avoidance | % showing avoidance behaviour |
|---|---|---|---|
| Honey buzzard (*Pernis apivorus*) | 27 | 17 | 63 |
| Red kite (*Milvus milvus*) | 32 | 26 | 81 |
| White-tailed eagle (*Haliaeetus albicilla*) | 1 | 0 | 0 |
| Marsh harrier (*Circus aeruginosus*) | 29 | 19 | 66 |
| Hen harrier (*Circus cyaneus*) | 7 | 4 | 57 |
| Sparrowhawk (*Accipiter nisus*) | 119 | 101 | 85 |
| Goshawk (*Accipiter gentilis*) | 1 | 0 | 0 |
| Common buzzard (*Buteo buteo*) | 195 | 133 | 68 |
| Rough-legged buzzard (*Buteo lagopus*) | 2 | 0 | 0 |
| Osprey (*Pandion haliaetus*) | 15 | 12 | 80 |
| Common kestrel (*Falco tinnunculus*) | 22 | 21 | 96 |
| Merlin (*Falco columbarius*) | 14 | 7 | 50 |
| Peregrine falcon (*Falco peregrinus*) | 2 | 0 | 0 |

**Table 3** Percentage of raptors showing macro, meso and/or micro avoidance behaviour when arriving to the AOWF

| Species | % showing macro avoidance | % showing meso avoidance | % showing micro avoidance |
|---|---|---|---|
| Honey buzzard (*Pernis apivorus*) | 30 | 33 | 0 |
| Red kite (*Milvus milvus*) | 59 | 22 | 0 |
| Marsh harrier (*Circus aeruginosus*) | 21 | 38 | 7 |
| Hen harrier (*Circus cyaneus*) | 29 | 14 | 14 |
| Sparrowhawk (*Accipiter nisus*) | 42 | 37 | 6 |
| Common buzzard (*Buteo buteo*) | 27 | 41 | 1 |
| Osprey (*Pandion haliaetus*) | 13 | 60 | 7 |
| Common kestrel (*Falco tinnunculus*) | 46 | 50 | 0 |
| Merlin (*Falco columbarius*) | 14 | 36 | 0 |

## 4 Discussion

Studies of avoidance behaviour of birds around offshore wind farms have so far mainly focused on seabirds [15] although a general avoidance of raptor abundance when (onshore) wind farms are constructed is well known, for example [16]. Strong avoidance of migrating raptors to onshore wind farms has also been documented [17, 18], but a recent Danish study found soaring raptors on migration when leaving the coast displayed a significant attraction behaviour towards an offshore wind farm 12 km away [19]. It is suggested that the most likely driver behind this attraction is an "island effect" [19].

Our findings suggest avoidance behaviour among nearly all raptor species when getting close to the offshore wind farm. With the exception of four species which were only recorded in very low numbers, between half and nearly all the individuals of the different migrating raptor species showed at least one of the three avoidance behaviour types. Most striking was probably the large percentage of some species that completely avoided entering the wind farm and turned back.

The attraction of a distant offshore wind by raptors leaving the coast as shown by [19] suggests that they respond depending on how far they are from the offshore wind farms. Initially the birds are attracted perhaps because they believe the wind farm is an island which could act as a stepping stone during their sea crossing, but as they get closer, they realize that this is not the case and many then change course or turn back. This is supported by the attraction being inversely related to the distance to the wind farm [19].

Because distant offshore wind farms may attract migrating raptors, it has been suggested that this potentially makes the birds far more at risk of colliding with wind turbines at sea than previously assumed [19]. This appear not always to be the case since our findings show that once the migrating raptors get close to the turbines, large numbers avoid the wind farm and are therefore not at risk of collision.

While the increased energy expenditure associated with flying round the wind farm and then continuing towards Anholt and Sweden is probably minor to the raptors in question, there could be significant risks associated with sea crossings in other locations. This is most likely not the case for the raptors that turned back from the AOWF. These raptors will probably continue north over land and make the sea crossing from one of the other well-known migration spots in Denmark, in particular from the northernmost tip of Jutland (at Skagen) where the distance to Sweden is about 55 km. However, in other parts of these birds' range, the turning back from a favoured sea crossing route could lead to a much longer and more risky sea crossing with significant increased energy expenditure.

## 5 Conclusions

Our study showed a barrier effect of an offshore wind farm influencing the migration of raptors by forcing many of the birds to use other and potentially more risky alternative sea crossings. This impact may potentially affect the survival and fitness of individuals and populations.

When siting future offshore wind farms, we therefore recommend planners to take into consideration the location of important migration routes for raptors.

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