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Endangered species, GPS tracking, non-lethal impact, *Numenius arquata*, renewable energy, wind farm

Abstract

The Eurasian Curlew is an endangered long-lived shorebird breeding in grassland and moorland, with declining numbers across its range due to habitat loss and former hunting. In this context, any additional adult mortality can have a noticeable impact on population dynamics, hence on extinction risk. We report a case of a GPS-tagged individual which track revealed an unusual stopover at the bottom of a wind turbine along its migration route. The curlew rested hours in an unfavourable environment before moving to the adjacent coastal shore, then completed its migration journey the next day. In previous studies, GPS-tags helped to identify death casualties at wind farms, but to our knowledge this is the first detailed report of a non-lethal injury of a tagged animal by a wind turbine, probably by the vortex of rotors. This case alerts on the further potential impacts of wind farm development close to breeding, wintering and stopover sites frequented by Eurasian curlews and other birds. Any wind farm development project should consider the opportunity to avoid, reduce or compensate potential lethal and non-lethal impacts on wildlife.

1. Introduction

Facing recent human-induced climate change, most nations engaged in an energetic transition by developing renewable energy sources to reduce greenhouse gas emissions. Typical schemas include an increasing energy production from solar panels, wind turbines, and tidal power plants, to reduce the use of fossil energies such as petrol and coal [1]. The impact of wind farms on wildlife, especially birds and bats, needs to be evaluated. Biodiversity has been declining for decades [2] for reasons including climate change and habitat loss [3,4]. Solutions to reduce climate change should mitigate, not increase, the ongoing biodiversity crisis. In a changing world, the development of green energy is more important than ever. One of the most well-developed and cheaply available options is wind power, but there is evidence that wind farms can also have a negative impact on biodiversity. There is now a large body of literature assessing the impacts of wind farms on birds and bats [5,6,7] and proposing mitigations to reduce mortality [8,9]. There are few studies reporting the collision of GPS-tagged migratory birds on wind farms leading to the death of the individual [10].

The Eurasian Curlew *Numenius arquata* is a migratory bird threatened mainly by land use changes [11]. It breeds in temperate Eurasia and migrates to spend the non-breeding season (June-July to March-April) on a variety of wetland habitats mainly in north-western Europe. The European population is estimated at 212,000-292,000 pairs and considered to have decreased by 30-49% in 30 years. The species is classified as vulnerable to extinction in the regional IUCN Red List [12]. The species is therefore subject to numerous conservation efforts to preserve the birds and their habitats [13] and is listed on Annex II of the EU Birds Directive (Directive 79/409/EEC of the European Council of 2 April 1979 on the conservation of wild birds), permitting hunting in few listed Member States, e.g. Denmark, France, Ireland and the United Kingdom. A hunting moratorium was implemented in these countries to help breeding populations to recover [13]. The Eurasian Curlew is long-lived with estimated adult survival of 92% [14] and a generation time of approx. 10 years [15] (e.g. average age of active breeding females), so any additional adult mortality can have a noticeable impact on population dynamics, hence on extinction risk. Here we report on a non-lethal interaction between a migrating GPS-tagged curlew and and wind turbine. Data retrieved form the GPS shows potential for use of GPS tracking to detect interactions between wildlife and wind turbine.

2. Material and Methods

Data was collected as part of redsearch into migration connectivity in the Eurasian Curlew [16]. In February 2020, we captured, ringed and GPS-tagged 10 Eurasian curlews wintering in a National Nature Reserve in Western France. One of them left the non-breeding area to reach its breeding grounds on Spiekeroog Island, in the German Wadden Sea (53,77°N 7;74°E). This curlew was captured, ringed and tagged on 23 February 2020 at Moëze-Oléron National Nature Reserve, Charente-Maritime, France (45.90°N, 1.08°W). We tagged the bird with Ornitrack-10 solar-powered backpack tag with Global System for Mobile Communication (GSM) data transmission (weighing 10 grams) and a brown case, the harness being a leg-loop Teflon rubber (2.5mm wide) closed by a glued knot. The device, labelled 200208, recorded time (UTC), geographical position, flight speed, altitude and acceleration along three spatial axes. Data acquisition depended on battery charge, and range from one location recorded every five to thirty minutes. Data transmission occurred once a day. The bird was ringed with colour rings representing a unique combination for identification in the field. The bird weighed 728 grams, so the material (tag, harness and rings) represented, e.g. 1.6% of the body mass. The bird was sexed as a male, because of a short bill length (117mm) [17].

3. Results

The bird stayed in the wintering grounds of Pertuis Charentais until 2nd March 2021, when it left late in the evening between 21:00 and 22:00 (UTC), to arrive on its breeding grounds on Spiekeroog island, Germany, on 4th March at 14:49. On its way, the curlew made a short stopover in Zeeland, the

Netherlands, at 51.457°N 4.284°E during two hours on 3rd March (between 7:54 and 9:54), then a second short stopover in Groningen province, the Netherlands, at 53.288°N 6.970°E during one hour the same day (between 13:48 and 14:55), then a longer stopover west of Eemshaven harbour (53.435°N, 6.883°E) between 16:08 and 17:58. The curlew then flew west and landed exactly under the deployment area of the wind turbine blades before 18:18 (53.4602°N, 6.8221°E), where it stayed without moving for three hours until 21:19. It then moved 1.3 Km west to a coastal mudflat, resting there 7 hours until 4:19 on 4th March (Fig. 1). The curlew left this mudflat to perform a continuous flight to reach its breeding island of Spiekeroog, Germany, where it landed on 4th March at 14:49.

At 18:13, the last recorded data before being grounded under the turbine, the bird was in flight, at an altitude of 27 meters and flying at a speed of 32 km.h^{-1}. After landing, the average altitude recorded by the tag was -4±6 meters (min -13, max 7, n=35) with a nul speed. The average altitude at Eemshaven is reported as 0 meter (sea level, source: topographic-map.com).

Accelerometer values recorded by the GPS tag between 17:30 and 21:50 on 3rd March changed very slightly, indicating that if the bird was stationary and immobile, the tag was not totally immobile, i.e. the bird was not dead (it was at least breathing; Fig. 2). The peak value of the z accelerometer value recorded at 18:13 reflects a sudden change in elevation immediately before ground recordings began. The precise location of the bird in relation to the wind turbine at the time of the elevation change could not be determined, because the gps data were not recorded at the precise time of the turbine interaction. This elevation drop was at least recorded during the last in-flight fix before the bird was recorded as immobile at the ground next to the wind turbine, from 18:18 onwards.

We further compared the x-, y- and z-accelerometer values obtained for early periods after landing, for four examples: (A) bird 200208 during the reported wind turbine interaction; (B) bird 200208 during a former stopover in the Netherlands; (C) and (D), birds 200185 and 200187, respectively, tagged at the same wintering site during the same night, with the same tag and harness material, which started their migration together in spring 2020 and made a stopover near Beauvais, eastern France (Jiguet et al. 2021). The stop duration varies slightly between these examples: (A) 181 minutes (see above); (B) from 13:43 to 15:13 on 3 March 2021 (90 minutes), (C) from 5:33am to 7:53am on 18 April 2020 (140 minutes); (D) from 5:31 to 20:05 18 April 2020 (874 minutes). We considered the first 90 minutes after landing to compare the values of the four examples. To better compare changes in accelerometer values during a stop, we computed the difference between successive accelerometer values, e.g. the differences between the first value and the second, then between the second and the third and so on. Fig. 3 presents the tracks of these four stopovers, and Fig. 4 reports boxplots of changes in accelerometer values, in the three dimensions, for each bird/stop. In all cases, the stop was preceded by a peak in the z-accelerometer value, attesting a landing (as shown by the red arrow in Fig. 2). There was less terrestrial movement for the stopover occurring in the vicinity of the wind turbine (A) than for three stopovers occurring distant to wind turbine sites (B, C, and D). Although there were no significant statistical differences between individuals for the three values (linear models), probably because of the small statistical power for such small sample size, case A has obviously the less variable values, with the smallest differences between the 25% and 75% quartiles and between the minima and maxima (see Fig. 4).

4. Discussion

4.1. Stunned by the vortex of turbine rotors

The movements of turbine rotors create a vortex near-wake [18,19], reminiscent of the helicopter rotor tip vortex [20]. The vortex created by the rotor movements can act as a dangerous trap for fly-by wildlife, as it represents unusual turbulence of the aerial environment [21] that moving birds and bats are not able to predict and anticipate. If not directly hit by a rotor, being stunned by the vortex can provoke a crash on the ground and body injuries, potentially leading to death. There is very little evidence of birds being forced to the ground as a result of being drawn into the vortex created by moving rotors [22], and GPS-tagged migratory birds might provide an opportunity to detect and document such rare casualties. There is also the possibility that the curlew collided with a rotor, was then forced to the ground but suffered no lethal injury, so was able to escape after some rest. The tagged curlew reported here landed on the ground just at the bottom of a wind turbine, but did not die, and later continued migrating. Indications obtained from the data collected by the tag included an extreme altitudinal acceleration just before landing at the bottom of the turbine, and very low acceleration values in all three dimensions during one and half an hour after landing, compared to three examples of normal stopovers for the same and two other individuals. Furthermore, the habitat frequented below the wind turbine cannot be considered as suitable and attractive for a resting stopover, being close to a road and with dry and hard soil where a curlew could not probe for worms.

4.2. Implications for the conservation of the endangered Eurasian Curlew

The majority of studies reporting collisions caused by wind turbines have recorded relatively low levels of mortality [23,24]. This is perhaps largely a reflection of the fact that many of the studies are based only on finding corpses, with no correction for corpses that are overlooked or removed by scavengers [25] or for injured animals that die further from the turbines. If accepting that many wind farms result in only low levels of mortality, even a low additional mortality may be significant for long-lived species with low productivity and slow maturation rates, especially when rarer species of conservation concern are affected. In such cases there could be significant effects at the population level (locally, regionally or nationally), particularly in situations where cumulative mortality takes place as a result of multiple installations or multiple human-induced mortality sources (e.g. including agricultural practices, hunting). This is typically the case for the Eurasian Curlew, which is a long-lived shorebird with a high survival [26], so that any additional adult mortality can have a noticeable impact on population dynamics, hence on extinction risk. For the sample of 10 adult curlews we tagged, a single additional mortality by turbine collision or vortex stunning could double the annual mortality rate, but this of course is based on a small sample. If such events are rare, they should not impact the global population dynamics, but if they are frequent, they might contribute to the decline of the breeding population.

4.3. Conclusion

Acquiring tracking data in the vicinity of wind turbines may be instructive to document such interactions. The current developments in tag programming, including the implementation of multiple geofences, i.e. defined areas where data acquisition can be amplified, will certainly increase the frequency and details of the documentation of lethal and non-lethal interactions. This case alerts on the further potential impacts of wind farm development close to breeding, wintering and stopover sites frequented by Eurasian curlews and other birds. Any wind farm development project should consider the opportunity to avoid, reduce or compensate potential both lethal and non-lethal impacts on wildlife.

Acknowledgements and ethical statement

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FIGURE CAPTIONS

Figure 1. GPS locations obtained from the Eurasian Curlew from February 2020 to May 2021: (a) complete tracks of spring 2020 (yellow), autumn 2020 (blue) and spring 2021 (red) migration, and zooms on: (b) the track between 16pm on 3^{rd} March 2021 and 4am on 4^{th} March 2021, with arrows signalling the direction of the movement, and (c-d) the 37 locations recorded at the bottom of the wind turbine. (e) is a ground view of the bottom of that wind turbine, taken on 6 March 2021 by Henk-Jan Ottens.

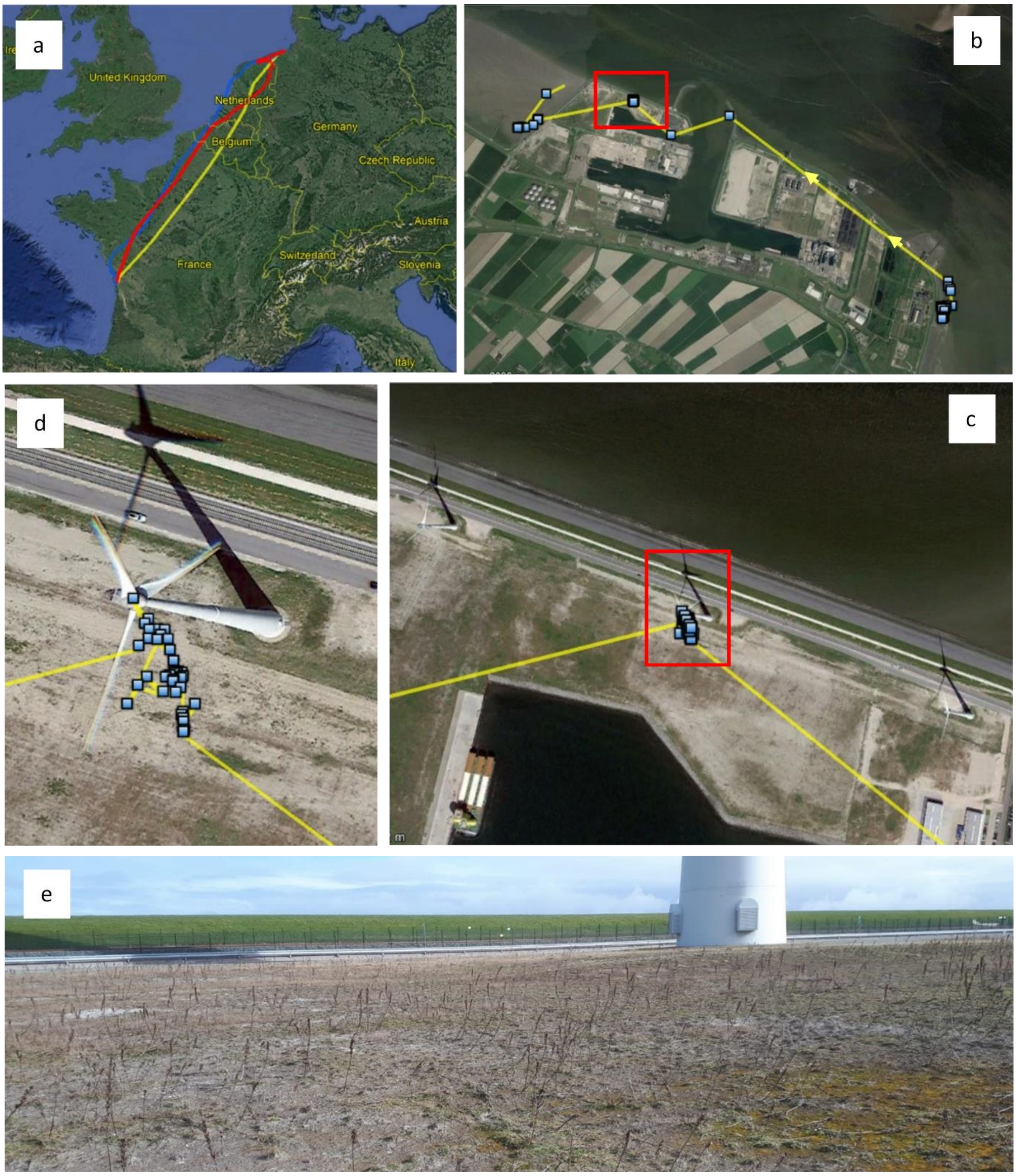
a
United Kingdom
Netherlands
Germany
Belgium
Czech Republic
Austria
France
Switzerland
Slovenia
Italy
b
d
c
e

Figure 2. Accelerometer data recorded during and after the incident. Slightly changing values along the x-axis indicate that the tag is not totally immobile. The peak value of z accelerometer, recorded at 18:13 and signaled by a red arrow, reflects a sudden change in elevation.

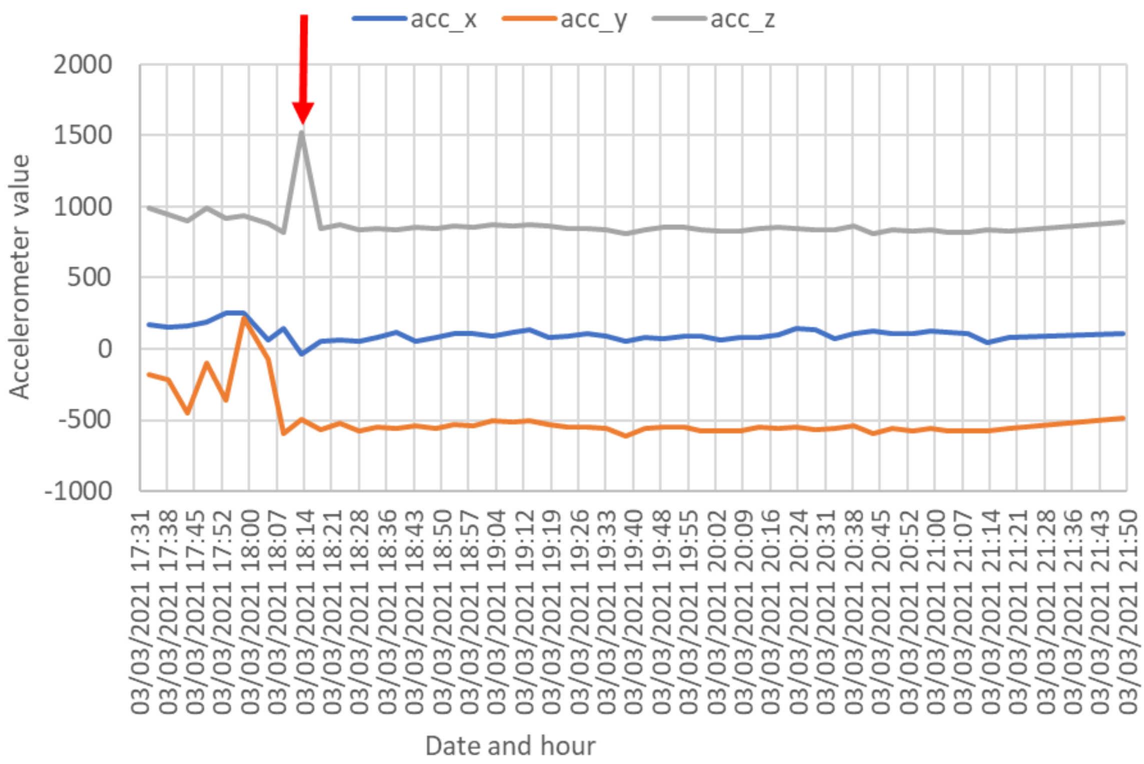

Figure 3. Tracks obtained from the GPS positions for three individuals during short stopovers occurring during spring migration. A: the reported case of bird 200208 at a wind turbine; B: the same individual during a short terrestrial stopover in the Netherlands in the morning of the same day; C and D: stopovers of birds 200185 and 200187 near Beauvais, France (after a joint flight bout).

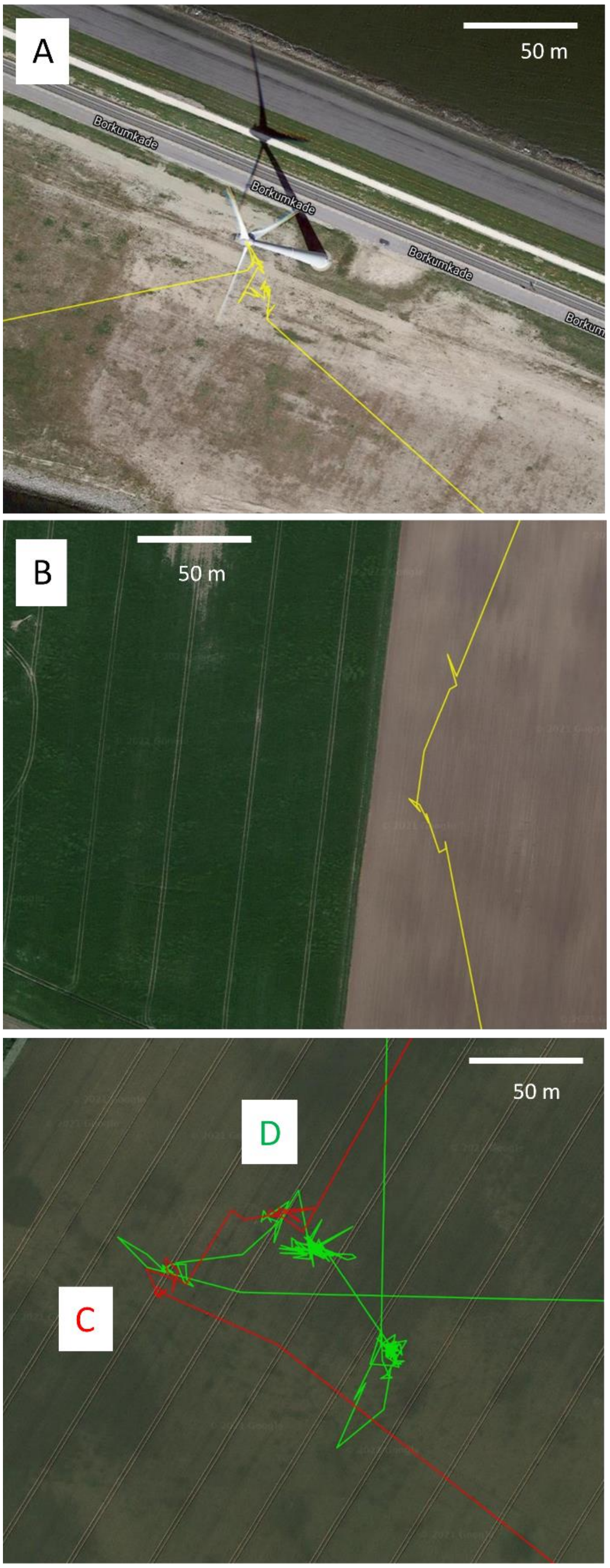

Figure 4. Comparison of differences in successive accelerometer data obtained for three individuals during short stopovers occurring during spring migration; same individuals and stopovers as in Figure 3, labelled similarly (A to D). The boxplots report the median (black horizontal bar), first (25%) to third (75%) quartiles (grey box) and the minimum and maximum values (dotted lines) of each accelerometer value (x,y,z) for each bird/stop. For comparison purposes, the y-axis has been standardized to range between -300 and 300.