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GPS tracking reveals the timing of collisions with powerlines and fences of three threatened steppe bird species

Ana Teresa Marques[1,2,3], Carlos Pacheco[1,3,4], François Mougeot[5] and João Paulo Silva[1,2,3]

[1]CIBIO, Centro de Investigação em Biodiversidade e Recursos Genéticos, InBIO Laboratório Associado, Campus de Vairão, Universidade do Porto, Vairão, Portugal; [2]CIBIO, Centro de Investigação em Biodiversidade e Recursos Genéticos, InBIO Laboratório Associado, Instituto Superior de Agronomia, Universidade de Lisboa, Lisbon, Portugal; [3]BIOPOLIS Program in Genomics, Biodiversity and Land Planning, CIBIO, Campus de Vairão, Vairão, Portugal; [4]Estação Biológica de Mértola (EBM), Praça Luís de Camões, Mértola, Portugal and [5]Instituto de Investigación en Recursos Cinegéticos, IREC (CSIC-UCLM-JCCM), Ciudad Real, Spain

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Corresponding author:
Ana Teresa Marques;
Email: anateresamarques@cibio.up.pt

Summary

Collision with powerlines is a major cause of mortality for many bird species, including bustards and sandgrouse. In this work, we used GPS tracking data to identify the hour of collision of three threatened steppe birds, i.e. Little Bustard *Tetrax tetrax*, Black-bellied Sandgrouse *Pterocles orientalis*, and Pin-tailed Sandgrouse *Pterocles alchata*. Out of a data set of 160 GPS-tracked individuals collected over a 13-year period, we detected eight collision events with powerlines or fences. Of these, we were able to determine the timing of 87.5% of the collision events with a resolution accurate to within two hours. Our results reveal that collisions occurred throughout the year and at different hours of the day, presenting a challenge for implementing effective mitigation strategies. The use of dynamic and reflective or luminescent devices may therefore be appropriate to prevent collision of steppe birds with powerlines during the day and night. Overall, this study adds evidence to the utility of using tracking data to better understand anthropogenic mortality in birds.

Introduction

Collision with powerlines is recognised as a major source of direct anthropogenic mortality of birds (Loss et al. 2015), which is expected to increase due to the current global expansion of electric grids (Bernardino et al. 2018). Although this mortality factor has been referenced in the scientific literature since the early 1970s, its mitigation is not fully effective, particularly in collision-prone species (Barrientos et al. 2012; Bernardino et al. 2018, 2019; Shaw et al. 2021; Silva et al. 2023). Despite their smaller magnitude, collision with fences is also a mortality factor for some bird species (Drewitt and Langston 2008).

Powerlines bisecting open areas such as steppe habitats pose high collision risk (Bernardino et al. 2018) and several threatened steppe bird species, such as bustards and sandgrouse, are known to be impacted by collisions with these infrastructures. Bustards are highly susceptible to collision with powerlines, as they combine multiple behavioural and morphological traits that significantly increase their risk of collision (Silva et al. 2023). As bustards encompass several endangered species, many studies have focused on understanding patterns of mortality and finding efficient mitigation measures. However, due to the uncertainty of the mitigation measures, burying the powerlines or routing them away from bustards are the most recommended solutions to avoid mortality (Silva et al. 2023). Similarly, collisions with powerlines have also been reported for different threatened sandgrouse species (Barrientos et al. 2012; Gómez-Catasús et al. 2020; Purevdorj and Sundev 2012). Collisions with fences have been recorded for bustards (Silva et al. 2023) and sandgrouse (C. Pacheco, personal data), but they appear to be less common.

The use of high-resolution tracking technology has contributed to our increased knowledge of birds' interactions with anthropogenic infrastructures by providing detailed temporal and spatial information on birds' movement patterns. Key information includes precise data on mortality rates (Marcelino et al. 2017; Sergio et al. 2019b), predictions of collision risk (Murgatroyd et al. 2021; Schaub et al. 2020), characterisation of bird displacement (Marques et al. 2021), and response behaviours in close proximity to the structures (Jiguet et al. 2021). However, to our knowledge, no studies have assessed the timing of collisions even though modern tags provide almost "real-time" monitoring (Sergio et al. 2019a). In this study, we present, for the first time, evidence on the timing of collision with powerlines and fences of three threatened steppe birds, i.e. Little Bustard *Tetrax tetrax*, previously identified as a collision-prone species, Black-bellied

Sandgrouse *Pterocles orientalis*, and Pin-tailed Sandgrouse *Pterocles alchata*. We discuss the implications of our findings for the mitigation of collisions.

Methods

In this study, we used three GPS tracking data sets one of which was a long-term data set of 93 Little Bustards tagged in Alentejo (Portugal) and Extremadura (Spain) from 2009 to 2022. Little Bustards were fitted with different tracking devices: 30 g solar GPS ARGOS Platform Transmitter Terminals (PTT tags) (https://www.microwavetelemetry.com/) and solar GPS/GSM tags from Movetech Telemetry (25 g; https://movetech-telemetry.com/), 25 g E-Obs (https://e-obs.de/), and 15 g, 20 g, and 25 g from Ornitela OT (https://www.ornitela.com/). The devices were set to collect GPS information at different temporal resolutions, from 20 minutes up to 2 hours. PTT devices contained a sensor that indicated when movement ceased to be obtained, while all the remaining devices were equipped with a 3D accelerometer, measuring acceleration of surge, sway, and heave at a frequency between 1 Hz and 20 Hz for bursts of 10 and 4 seconds, respectively. A fraction of the mortality data set of the Little Bustard, representing two collision events with powerlines from 2009 to 2013, was previously reported in a study on the species survival in the Iberian Peninsula (Marcelino et al. 2017).

A total of 38 Black-bellied Sandgrouse were tracked in Extremadura and Castilla-La Mancha (Spain) and Alentejo (Portugal) in 2021 and 2022 using 10 g Ornitela OT and 6 g Druid loggers (https://interrex-tracking.com/), set with 10-minute or 30-minute resolution. Ornitela OT delivered 3D accelerometer data at 20 Hz frequency for 4-second bursts, and Druid provided overall dynamic body acceleration (ODBA) from an accelerometer recording acceleration at 25 Hz frequency for bursts of 3 seconds.

In addition, a total of 29 Pin-tailed Sandgrouse were tagged in Extremadura in 2021 and 2022 using 5 g and 6 g Druid loggers set to a minimum of 30-minute resolution. These devices provided ODBA data derived from an accelerometer recording acceleration at 25 Hz frequency for bursts of 3 seconds.

Devices were deployed using a similar attachment method for the three species which was a full thoracic harness made of ribbon Teflon, representing less than 3.1% and 4.7% of the weight of sandgrouse and Little Bustard, respectively.

In all cases, the tracking devices transmitted data at least once per day, allowing daily checks on the birds' movements and activity, and to confirm that each bird was alive. The mortality of the bird was considered probable when: (1) the tracking signal was lost for a long period; (2) overlapping locations were registered; (3) the mortality sensor was activated; (4) the accelerometer readings indicated immobility for a long period of time (Burnside et al. 2016) (Figure 1). In these cases, the last GPS position of each bird was checked in the field, confirming mortality by locating the bird's remains and tag, and, whenever possible, identifying the cause of death. Collisions with powerlines or fences were considered the cause of mortality when the bird remains was found near or underneath a powerline or fence, with clear signs of trauma (Marcelino et al. 2017).

The time of collision was assigned to the time-period between the last GPS-fix with the last evidence that the bird was alive and the first GPS-fix with a suspicion of mortality. When tracking devices included an accelerometer, we used the data delivered by this sensor to identify the hour of bird death more accurately, as mortality can be easily spotted by the lack of acceleration values in the *X*, *Y*, and *Z* axis (Figure 2).

Results

Out of a data set of 160 tracked individuals, we detected eight collisions involving adult birds, six Little Bustards, one Black-bellied Sandgrouse, and one Pin-tailed Sandgrouse (Table 1). Six collisions were with powerlines (five Little Bustards and one Pin-tailed

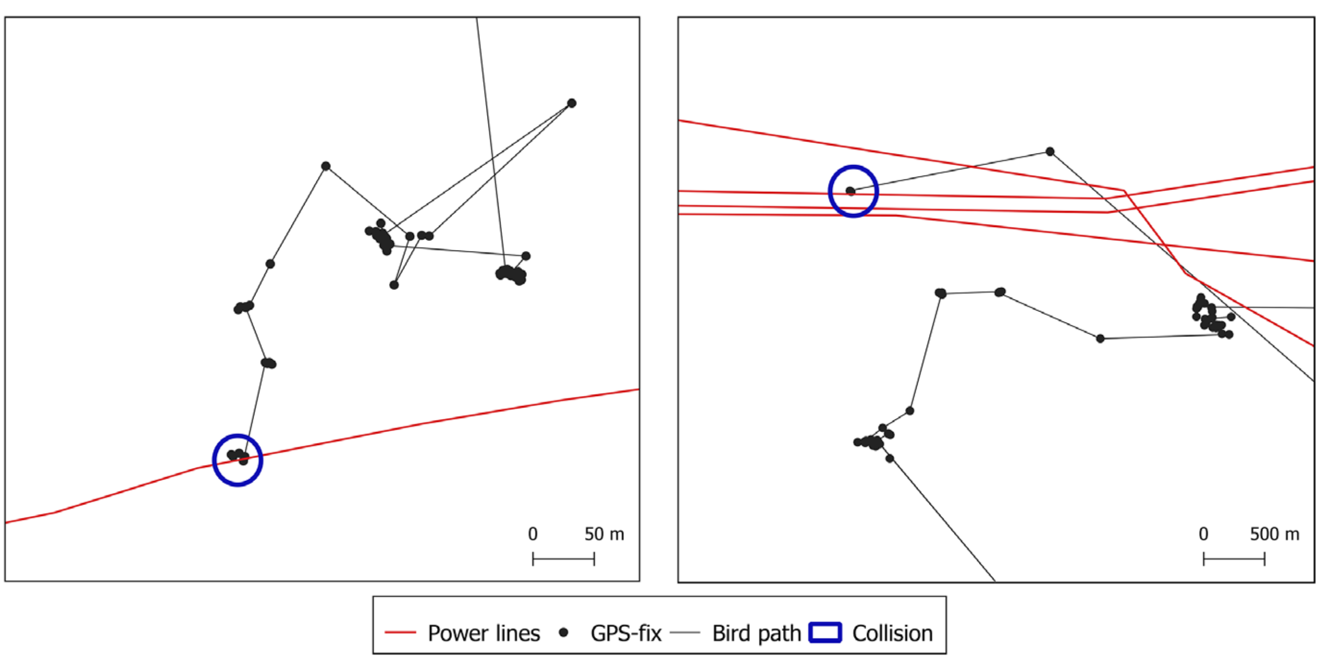

Figure 1. Examples of collisions with powerlines detected by analysis of GPS tracking data.

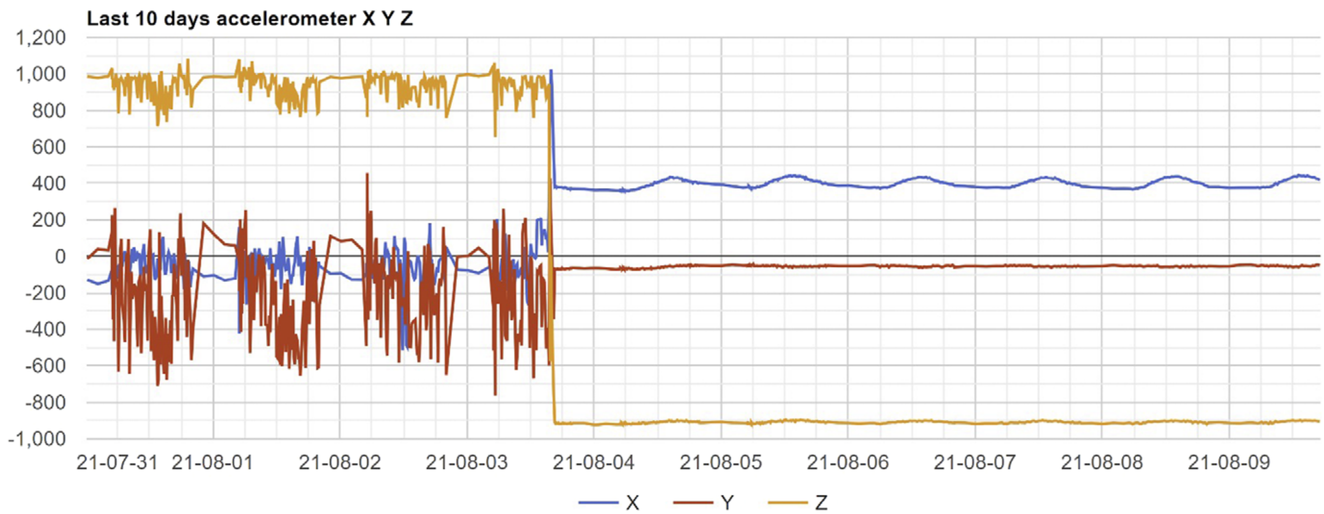

Figure 2. Example of an accelerometer signature of a mortality generated at the Ornitrack website (https://cpanel.glosendas.net/).

Table 1. Summary of collisions between steppe birds and powerlines (PL) or fences, recorded using tracking data. The path from the last GPS-fix with evidence that the bird was alive to the first GPS-fix with a suspicion of mortality was used to determine heading. For infrastructure both minimum and maximum heights (below and top wire levels) are presented. W = winter; PB = post-breeding; B = breeding

Species; bird sex	Season	Sampling frequency	Hour	Period of day	Heading	Infrastructure		
						type	height	features
Tetrax tetrax	W	2–hour	17h00–19h00	dusk/night	SE – NW	Distribution PL	8.5–10 m	15 kV; 2 collision plans*: 3 conductor wires
Tetrax tetrax	PB	2–hour	00h00–06h00	night/dawn	–	Distribution PL	10–11 m	30 kV; 2 collision plans*: 3 conductor wire
Tetrax tetrax	PB	30–minute	14h20–14h53	day	N – S	Distribution PL	7–7.5 m	22 kV: 1 collision plan*: 3 conductor wires
Tetrax tetrax	B	30–minute	2h42–03h13	night	NE – SW	Transmission PL	24–46.6 m	400 kV; 4 collision plans*: 2 + 2 + 2 conductor wires + 2 earth wires; marked with large spirals (30 cm)
Tetrax tetrax	W	30–minute	11h37–12h08	day	SE – NW	Distribution PL	8.5–10 m	15 kV; 2 collision plans*: 3 conductor wires
Tetrax tetrax	PB	30–minute	08h00- 08h30	day	N – S	Fence	1.2 m	Fence (20 × 20 cm mesh); 2 top rows with barbed wires
Pterocles orientalis	PB	10–minute	11h41–12h25	day	S–N	Transmission PL / fence	5–17 m 1.2 m	220 kV; 3 collision plans*: 2 + 2 conductor wires + 1 earth wire / fence (20 × 20 cm mesh); no barbed wires
Pterocles alchata	B	30–minute	09h24-09h54	day	NE – SW	Transmission PL	15–23 m	132 kV; 4 collision plans*: 2 + 2 + 2 conductor wires + 2 earth wires; marked with large spirals (30 cm)

*Number of sets of wires arranged at different heights.

Sandgrouse); four in distribution powerlines and two in transmission powerlines. There was one collision in a fence (a Little Bustard) and, in one case, it was not possible to confirm if the collision occurred in a fence or in a powerline (a Black-bellied Sandgrouse).

The height of the structures ranged from 1.2 m to 46.6 m, demonstrating a wide variety of collision risk heights. Two of the transmission powerlines had large spirals (30 cm diameter) as wire marking devices. Both fences were 1.2 m and used for sheep herding, and one of them had two barbed wire rows on top of the fence. Further details on the infrastructure's features can be found in Table 1.

Mortality was recorded throughout the year, with four events occurring during the post-breeding (summer) season, two events during breeding, and another two during winter. It was possible to trace the hour of collision in seven of the eight events, and with a precision of less than two hours: five collisions occurred during daytime and one at night. In two other cases it was not possible to discern if the collision occurred at sunset/sunrise or during the night. The data collected suggest that no movement at the origin of a collision was performed in counter-light, as indicated by the direction of the movement path (Table 1).

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Discussion

In this study, we present the first data on hour of bird collisions with powerlines or fences using GPS tracking data. Using a large GPS tracking sample size, the number of collisions found was relatively small but revealed the potential of using tracking data to better understand the interactions of birds with anthropogenic infrastructures, such as powerlines or fences. From eight events, we were able to determine precisely the hour of seven collisions (87.5%), even with devices programmed to collect information at a relatively coarse sampling frequency (every two hours). Precision is related to the settings of the tracking devices, such as sampling frequency, which can be greatly improved if GPS location is used in combination with raw accelerometer data or processed ODBA estimates that can be provided at a higher rate, which have limited impact on the tag battery (Brown et al. 2012). Birds were tagged in accordance with the best practices and guidelines described for the target species (Casas et al. 2015; Ponjoan et al. 2010), and we did not foresee any obvious effect of the GPS devices and respective attachments that would favour collisions on powerlines or fences, unless they increased the area for collision and so could increase the risk of collision.

Collision risk has been described as increasing with bad weather and poor light conditions (Anderson 1978; Bernardino et al. 2018; McNeil et al. 1985). However, our data indicate that this is not the case for the studied species: five of the eight incidents (62.5%) occurred during the day, and four of those occurred during the summer (n = 3) and spring (n = 1), when visibility is usually favourable in the studied areas. This highlights the fact that visual perception plays an important role in the collision risk of these species (Bernardino et al. 2018; Martin 2011; Martin and Shaw 2010), putting them at risk of collision irrespective of the visibility conditions.

Regarding collisions with powerlines, we found more collisions in distribution lines than in transmission lines, which supports earlier suspicions that the distribution network could be responsible for a higher number of fatalities (Marques et al. 2020; Silva et al. 2023). Most studies on bird collisions have focused on transmission networks (that carry electricity at high voltages from electrical production plants to substations), as these are larger and taller infrastructures, resulting in a larger number of collisions per kilometre of line (Bernardino et al. 2018; Silva et al. 2023). The larger and more dispersed distribution networks (that deliver electricity at lower voltages to individual consumers), however, increase the likelihood of a collision with a distribution line.

For the Little Bustard, a collision-prone species, our results suggest that collisions occur throughout the year, as previously described (Marques et al. 2020), and at different hours of the day, even in periods of good visibility. This pattern of sporadic mortality throughout the year and the day makes minimising impacts more complex. Little Bustards are mostly migratory in Iberia, performing movements between specific breeding, summering, and/or wintering sites (García de la Morena et al. 2015), and using stop-overs in between areas (Alonso et al. 2020). Also, Little Bustards are night migrants (Villers et al. 2010), performing nocturnal flights interspersed with frequent stops, and do not appear to avoid areas with powerlines as stop-over sites (Alonso et al. 2020), making collision during migration a potential hazard. Therefore, it is essential that mitigation actions consider the species' whole range.

Whenever building a new overhead powerline, the most effective strategy to mitigate bustards' collisions lies in careful and adequate route planning to avoid areas used by these birds (Marques et al. 2020; Silva et al. 2023). Wire marking is a common mitigation measure, but its effectiveness is highly variable and dependent on the type of marker (Barrientos et al. 2012; Ferrer et al. 2020; Marques et al. 2020; Shaw et al. 2021; Silva et al. 2023). In fact, in the present study we found two mortality events at powerlines marked with large spirals. However, when deploying "bird flight diverters" (BFDs), i.e. devices fitted to wires to increase the visibility of the cables, in powerlines routed in areas with Little Bustards, devices should incorporate (1) reflective and/or luminescent parts to signal the powerline during night-time, with the aim of reducing collision risk during this period and (2) dynamic/moving parts to increase birds' awareness of the structure in both good and bad visibility periods. Our data also highlighted that fences can be a threat to steppe birds, increasing the anthropogenic mortality of these species. Therefore, barbed wire fences should be avoided or marked in key steppe areas. Steppe bird collision with fences is an overlooked topic and should be the object of future studies.

The data presented in this study provide additional evidence on the risk of collision of steppe birds with powerlines, adding to previous studies on this topic (e.g. Janss and Ferrer 2000; Marques et al. 2020; Silva et al. 2023). Little Bustard fatalities are documented across the entire species' range (Silva et al. 2022), with an estimated adult yearly mortality rate of 3.4–3.8% in the Iberian Peninsula (Marcelino et al. 2017), one of the highest mortality rates due to collision ever recorded (Silva et al. 2022). Such high figures suggest that collisions have the potential to affect the population dynamics of the species and are considered a significant threat to Little Bustards (Morales and Bretagnolle 2022). Iberian sandgrouse populations have a very low productivity (Mougeot et al. 2021a, 2021b) and any additional mortality is also likely to have a significant impact on the viability of their declining populations. This work highlights the value of high-resolution tracking studies to better understand and mitigate anthropogenic mortalities in steppe birds and other threatened species.

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