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Wire marking reduces bird collisions with a transmission powerline in western Belgium

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Research Article

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Summary

Collisions with powerlines affect birds worldwide, including countries such as Belgium where a nationwide model indicated high avian collision risk in the IJzerbroeken region (seasonally flooded riverside wetlands). Large numbers of waterbirds winter in this area, which is crossed by a 70-kV transmission line. To manage avian collision risk, the transmission system operator, Elia, installed AB Hammarprodukter's FireFly™ FF line markers incorporating reflective, glow-in-the-dark, high contrast, and moving elements intended to increase the visibility of the transmission line to flying birds. We evaluated the effectiveness of FireFly line markers by comparing the numbers of avian carcasses found during 11 surveys annually in 2001 and 2018 (22 total surveys) before line markers were installed compared with 11 surveys conducted in 2021 after line marking. Before line marking, we found 30 avian carcasses attributable to collision in 2001 and 113 in 2018. After, we found six carcasses attributable to collision in 2021. In 2021, FireFly line markers correlated with a reduction in collision rate, depending on the pre-treatment year and species group, of at least 85% and up to 100%. The line was composed of two configurations, with half of the spans (two-thirds of the monitored line length) supported by tall pylons with shield wires, and half of the spans supported by shorter pylons without shield wires. After line marking, six collisions (100% in 2021) occurred on spans supported by tall pylons, and none (0%) occurred on spans supported by short pylons. Thus, in 2021, FireFly line markers correlated with an observed mortality reduction of at least 73% and up to 100%, depending on the configuration being considered. These findings suggest FireFly line markers substantially reduced wintering bird collisions in our study area.

Introduction

Avian collisions with transmission and distribution powerlines are a global conservation concern affecting a wide variety of species (Bernardino et al. 2018; Dwyer and Harness 2022; Loss et al. 2015). Collisions occur on every continent except Antarctica, including Europe where up to one million avian collisions with powerlines occur annually in the Netherlands (Koops 1987), and an estimated 30 million occur annually in Germany (Hoerschelmann et al. 1988). To our knowledge, national estimates are unavailable for other European countries or for Europe as a whole. However, the temporally and geographically widespread documentation of collisions across Europe, for example in Austria (Raab et al. 2012), England (Scott et al. 1972), Greece (Crivelli et al. 1988), Hungary (Raab et al. 2012), Italy (Rubolini et al. 2005), Norway (Bevanger and Brøseth 2001), Poland (Tryjanowski et al. 2013), Portugal (Marques et al. 2020), Spain (Barrientos et al. 2012), and Ukraine (Andriushchenko and Popenko 2012), suggest a continental-scale avian collision problem. Birds with high wing loading and high flight speeds appear to be at particular risk of collision (e.g. Janss 2000; Rioux et al. 2013; Rubolini et al. 2005). This conclusion may be partially influenced by detection bias, because birds with high wing loading and high flight speeds also tend to be relatively large, and thus more likely to be noticed as carcasses and less likely to be removed by scavengers than small, cryptically coloured passerines which may more readily be overlooked (Bernardino et al. 2022). However, passerine collisions have been noted in various studies (e.g. Barrientos et al. 2012; Guil et al. 2015; Rogers et al. 2014; Sporer et al. 2013). Overcoming detection and scavenging biases are likely persistent hindrances to understanding the true scope of the global problem of avian collisions with powerlines.

Powerline configurations also affect avian collision risk. Transmission lines appear particularly dangerous, presumably because they are taller than distribution lines, and because transmission lines frequently include a shield or earth wire above the live conductors. Birds approaching transmission lines appear to see relatively large-diameter conductors, and adjust flight heights upward to avoid them. This causes birds to be flying at about the height of the smaller diameter, harder to see shield wires leading to collisions. Studies using night vision and automated bird strike indicators have documented that it is these shield wires with which birds more often collide (Faanes 1987; Murphy et al. 2016; Pandey et al. 2008).

Collisions are frequently managed through the installation of line markers (also known as bird flight diverters, bird markers), which are devices intended to increase the visibility of powerlines to birds (Baasch et al. 2022; Bernardino et al. 2018; Dwyer and Harness 2022). The effectiveness of line markers varies widely across studies with some reporting no effect and others reporting almost complete effectiveness (see Bernardino et al. 2018). Presumably, differences in effectiveness are driven by a suite of factors including the species of birds involved, the time of day of avian movements, powerline configurations, habitats and environmental conditions, and the specific line markers used (Baasch et al. 2022; Bernardino et al. 2018; Dwyer and Harness 2022; Guil et al. 2011).

In this study, we sought to evaluate whether FireFly™ FF line markers (AB Hammarprodukter, Bjursås, Sweden) might be effective in reducing collisions with a 70-kV transmission line crossing the IJzerbroeken (seasonally flooded riverside wetlands) in western Belgium.

Methods

Study area

The transmission line we studied was owned and operated by Elia, Belgium's Transmission System Operator, with over 8,867 km of 30-kV to 400-kV overhead lines and underground cables throughout Belgium. The line ran parallel to the Ieperlee, a semi-channelled watercourse draining wetlands around our study area to the Yser River (Figure 1).We chose this line segment because a nationwide model-based risk assessment identified it as high-risk for avian collisions based on the combination of land cover, avian use, and powerline configuration (Paquet et al. 2022). The contiguous 10 spans we studied were supported by pylons of two different heights and configurations. The southern five spans were supported on each end by tall lattice pylons (36 m tall) constructed with a vertical configuration with each of three conductor wires at a different height below a single shield wire (four horizontal planes of wires in total; Figure 2). The northern five spans were supported on at least one end by short vault pylons (15 m tall) constructed with a horizontal configuration with two of three conductors at the same height and without a shield wire (two horizontal planes in total). This resulted in five tall spans crossing 2.07 km with shield wires and five short spans crossing 1.03 km without shield wires. Wire heights ranged from a maximum height of 36 m where overhead shield wires connected to tall pylons to as low as 12 m where conductors sagged towards the ground between pylons.

Line marking

We surveyed 10 study spans 11 times in 2001 (5–30 March), 2018 (4 March–7 April), and 2021 (7 March–11 April) for a total of 33 surveys. During the first survey in each year, we removed all carcasses found. We conducted our surveys in March and early April immediately after large flocks of wintering geese departed on spring migration so that our surveys would not disturb the flocks,

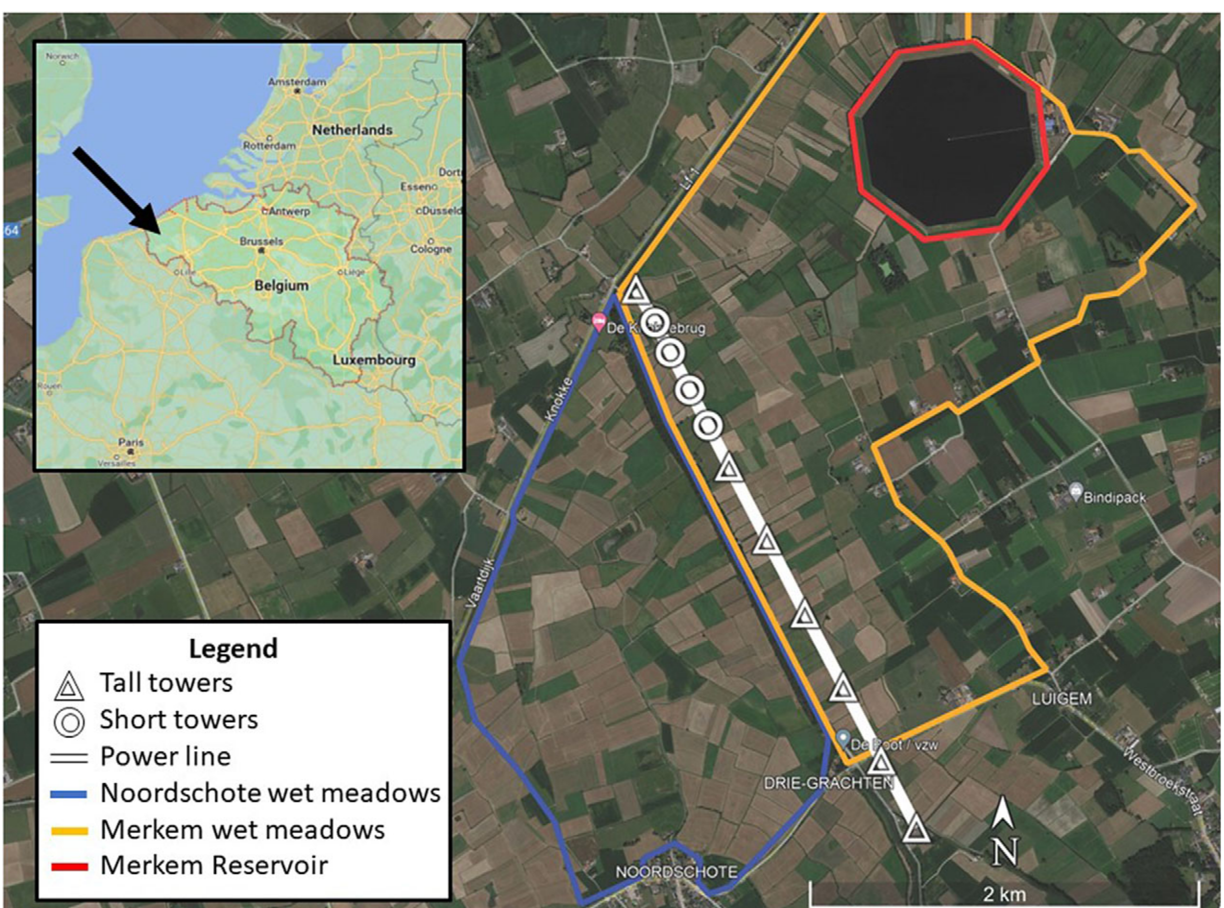

Figure 1. The study included 10 powerline spans in or adjacent to three important avian wintering areas.

Figure 2. The study area included two pylon configurations. A taller configuration with a shield wire supported five spans at the south end, and a shorter configuration without a shield wire supported five spans at the north end. (Photo credit: James F. Dwyer.)

potentially causing collisions. This timing allowed us to avoid semi-annual winter flooding of the Yser River in the survey area, and to search for carcasses before tall summer vegetation blocked detection.

In October 2019, Elia installed 302 line markers at 30-m spacing on each marked wire, with markers offset by 10 m on each of three marked wires in each span. This created a visual effect of 10-m spacing. Elia installed the FF model of FireFly because the FF was an active (moving) device which spun and fluttered in wind, presumably increasing visibility to birds compared with alternative passive line markers that lacked movement. On the southern five spans (supported by tall pylons), Elia installed line markers on the shield wire and on the upper and lower conductors, i.e. all wires accessible from the west. This left the middle conductor unmarked. On the northern five spans (supported by short pylons), where no shield wire was present, Elia installed line markers on all three conductors.

During each survey, at least two volunteers searched for avian carcasses by walking parallel to each other along the transmission line right-of-way, maintaining 10–15-m spacing between surveyors as they searched for carcasses. We attempted to minimise the influence of variation in the number of searchers by ensuring that each survey included at least one ornithological expert with carcass surveying experience and knowledge of the local avifauna. In 2001, we used paper maps and data sheets to record each carcass found. In 2018 and 2021, we used a smartphone app (ObsMapp/iObs; www.waarnemingen.be) to facilitate the collection of real-time spatially accurate data (2001 data were also entered into this portal when available). The app recorded carcass locations together with user data and photographs of each carcass. We subsequently identified the span involved from the location data and used that data to avoid double-counting during subsequent visits. Each time we found a carcass, we recorded the most precise taxonomic level possible given the condition. We also recorded piles of ≥10 feathers within 1 m² following Barrientos et al. (2018). This allowed us to include feather piles likely attributable to post-collision scavenging while omitting feathers likely attributable to moulting or preening (Barrientos et al. 2018).

We considered the effects of line marking across the entire studied line segment by comparing numbers of collisions documented before line marking to numbers of collisions documented after. We also considered the effects of line marking on spans with shield wires (connecting tall pylons to tall pylons) and separately on spans without shield wires (connecting short pylons to short pylons and short pylons to tall pylons) to consider the effects of line marking relative to configuration.

Year effect

Our study design prevented us from comparing collisions on marked and unmarked spans within the same year, creating the potential for a confounding year effect. To address that, we scaled the number of collisions we found to metrics of avian abundance at our study site each year. Each winter, the Research Institute for Nature and Forest (INBO) and Natuurpunt coordinate mid-monthly waterbird counts from October to March throughout northern Belgium (Flanders). During these counts, all waterbirds other than gulls (Laridae) are counted in as many wetlands as possible, creating a long-term georeferenced data set. Flanders' gulls are counted separately with simultaneous counts at as many gull roosts as possible, again creating a long-term georeferenced data set.

To consider a year effect, we calculated quasi-collision rates (hereafter, "collision rates") for waterbirds and gulls, both abundant in our carcass data set, in our study area in 2001, 2018, and 2021 as the number of collisions counted vs the number of birds counted. These are quasi-rates because not all waterbirds and gulls in the area necessarily crossed the study area, and because those that did cross the study area may have crossed multiple times. For waterbirds, we focused particularly on Common Coots *Fulica atra* and Eurasian Teals *Anas crecca* because these species were found during carcass searches in each of our survey years and were abundant in count data. For gulls, we focused on Black-headed Gulls *Chroicocephalus ridibundus*, Common Gulls *Larus canus*, and Herring Gulls *Larus argentatus* because they were present in our collision data and occurred in relatively large numbers (≥100 individuals) in count data. We compared collisions with counts from Merkem IJzerbroeken, Noordschote IJzerbroeken, and the Merkem Reservoir for waterbirds, and Merkem Reservoir for gulls because the line we studied traversed or was adjacent to these areas.

Biases

We considered two types of biases. Carcasses found in our study area due to predation could have increased our estimate of collisions, while carcasses due to collision but not found could have decreased our estimate. To consider predation, we followed Constantini et al. (2016) in excluding carcasses attributable to Peregrine Falcons *Falco peregrinus*, which were known to hunt birds in our study area. The typical prey remains left behind by a Peregrine Falcon were near a pylon rather than mid-span, and had the breastbone and wings connected by the shoulder girdle with all associated muscle consumed (Costantini et al. 2016; Verbelen and Swinnen 2019; Verbelen et al. 2021). Terrestrial scavengers do not leave carcasses in that condition, and Peregrine Falcons generally do not scavenge carcasses, allowing us to clearly distinguish the carcasses of birds depredated by Peregrine Falcons from the carcasses of birds which had collided with the transmission line and were subsequently scavenged.

We considered scavenger bias arising when carcasses were consumed by scavengers more quickly than the sequential surveys occurred, resulting in carcasses which were never found during a survey. We assessed this in March 2021 by setting up three remote cameras along the survey route and placing an avian carcass up to 5 m in front of each camera. Five days later, we downloaded images from each remote camera, changed batteries, and replaced the carcasses. We repeated this every five days from early March to early April, resulting in 21 carcasses deployed. This allowed us to estimate the percentage of carcasses likely to have been present but scavenged between surveys to better estimate the actual number of birds present. The Wildlife Rescue Centre (Ostend, Belgium) donated carcasses for these trials after rehabilitation efforts failed. Presumably, scavengers also removed carcasses during the 2001 and 2018 studies. As we did not quantify scavenging in those surveys, we do not know if rates were comparable to 2021 scavenging rates; 2018 rates were likely similar, but 2001 rates may have differed substantially. For that reason, we used raw numbers in our analyses, and simply noted that they indicate minimum values.

Results

Before line marking, we found 30 carcasses attributable to collision under the study spans in 2001 and 113 in 2018 (Table 1). After line marking, we found six carcasses attributable to collision in 2021. Of the total carcasses found in all three surveys, 57 were waterbirds and 17 were gulls. Collision rates averaged one collision for every 2,519 waterbirds and one collision for every 524 gulls before line marking (Table 2). Collision rates averaged one collision for every 19,292 waterbirds and one collision for at least every 2,596 gulls after line marking. Thus, in 2021, line marking correlated with a collision rate reduction of at least 85% and up to 100%, depending on the pre-treatment year and species group being considered.

The spans we studied were of two different configurations: tall spans with shield wires, and short spans without shield wires. Prior to line marking, 97 collisions (68% in 2001 and 2018 combined) occurred on spans supported by tall pylons with shield wires, and 46 collisions (32% in 2001 and 2018 combined) occurred on spans supported by short pylons without shield wires (Table 3). After line marking, six collisions (100% in 2021) occurred on spans supported by tall pylons, and none (0%) occurred on spans supported by short pylons. Thus, in 2021, FireFly line markers correlated with an observed mortality reduction of at least 73% and up to 100%, depending on the configuration.

Biases

Peregrine Falcons were likely present in the area in 2001 but were not considered as a cause of mortality for the carcasses collected. Presumably some carcasses in 2001 should have been attributed to Peregrine Falcon predation, but because Peregrine Falcons were relatively rare at that time, the biasing factor is likely low. In 2018 and 2021, 23 and 11 carcasses were attributed to Peregrine Falcon predation, respectively (Figure 3), and were removed from the data set to avoid over-counting carcasses attributable to collisions.

We deployed 21 carcasses with remote cameras to quantify carcass persistence. Of these, seven (33%) were removed completely by scavengers and presumably consumed within the five-day deployment window (Appendix 1). This suggests that in addition to the six carcasses we found in 2021, an additional 33% (two carcasses) likely occurred in the study area but were not detected because they were scavenged.

Discussion

After installing line markers, avian collisions declined in our study area, even as avian populations increased. Collisions may even have been eliminated on spans without shield wires, although with only six collisions found in 2021, it may be that through collecting more data over multiple years a collision might be identified eventually. Our findings suggest line markers reduced avian collisions with the transmission line we studied, presumably by increasing the visibility of suspended wires to birds. Our findings suggest FireFly FF line markers or other line markers with similar characteristics may also be effective in reducing bird collisions with transmission lines at

Table 1. Carcasses attributable to powerline collisions found in our study before (2001 and 2018) and after (2021) a 70-kV powerline was marked with FireFly line markers

Species	Scientific name	2001	2018	2021	Total
Black–headed Gull*	*Chroicocephalus ridibundus*	3	3		6
Common Coot*	*Fulica atra*	2	4	2	8
Common Gull*	*Larus canus*	2	5		7
Common Moorhen	*Gallinula chloropus*	2	2		4
Common Pheasant	*Phasianus colchicus*		7		7
Common Redshank	*Tringa totanus*		1		1
Common Snipe	*Gallinago gallinago*		2		2
Common Starling	*Sturnus vulgaris*		7	1	8
Common Wood Pigeon	*Columba palumbus*	3	6	1	10
Eurasian Magpie	*Pica pica*	2			2
Eurasian Sparrowhawk	*Accipiter nisus*		1		1
Eurasian Teal*	*Anas crecca*	3	3	1	7
European Golden Plover	*Pluvialis apricaria*		1		1
Fieldfare	*Turdus pilaris*		4		4
Garganey	*Spatula querquedula*	1			1
Grey Heron	*Ardea cinerea*	2	1		3
Herring Gull*	*Larus argentatus*	1	3		4
Jack Snipe	*Lymnocryptes minimus*		1		1
Mallard	*Anas platyrhynchos*		2		2
Mute Swan	*Cygnus olor*	1			1
Northern Lapwing	*Vanellus vanellus*		18		18
Pink–footed Goose	*Anser brachyrhynchus*		1		1
Redwing	*Turdus iliacus*	1	2		3
Rock Pigeon	*Columba livia*	1		1	2
Ruff	*Calidris pugnax*		1		1
Song Thrush	*Turdus philomelos*		2		2
Tundra Bean Goose	*Anser serrirostris*		1		1
Unidentified bird	Aves species	5	30		35
Unidentified Anseriformes	Anseriformes species	1	4		5
Western Jackdaw	*Coloeus monedula*		1		1
Total		30	113	6	149

*These species were prevalent in collision and abundance data.

Table 2. Waterbird and gull collisions decreased in 2021 after line marking

Group and year	Collisions counted	Birds counted in the area	Collision rate (ratio)	Collision rate (decimal)	Change in 2021 after line marking
Waterbirds*					
2001	12	35,400	1:2,950	0.000339	85% decrease
2018	42	100,600	1:2,395	0.000417	88% decrease
2021	3	57,875	1:19,292	0.000052	—
Gulls*					
2001	6	1,916	1:319	0.003132	100% decrease
2018	11	7,002	1:637	0.001571	100% decrease
2021	0	2,596	<1:2,596	0.000000	—

*Waterbirds considered were Common Coots and Eurasian Teals. Gulls considered were Black-headed Gulls, Common Gulls, and Herring Gulls because these species were prevalent in collision and abundance data.

Table 3. Most carcasses attributable to collision were found prior to line marking. After line marking, all carcasses attributable to collision were found under powerline spans with shield wires connecting tall pylons

Pylon height/ shield wires	Collisions counted			Change in 2021 after line marking
	2001	2018	2021	
Tall/Present	22	75	6	73% (2001) to 92% (2018) decrease
Short/Absent	8	38	0	100% decrease
Total	30	113	6	80% (2001) to 95% (2018) decrease

other sites in Europe, particularly when collisions involve waterbirds and gulls.

Previous research has identified a wide range of effectiveness in using FireFly line markers to reduce avian collisions. Specifically, Yee (2007) identified a 60% reduction in the number of carcasses found under spans marked with FireFly line markers, and Murphy et al. (2009) identified a 50–66% reduction in collisions. More recently, Silero et al. (2011) identified a collision reduction of 87% and found a 40% increase in birds flying above wires marked with FireFly line markers, rather than flying between or below unmarked wires. In meta-analyses considering many types of line markers, Barrientos et al. (2012) found line markers reduced collisions by an average of 78% (range = 55–94%) across 21 mostly peer-reviewed studies. Bernardino et al. (2019) also considered many types of line markers and found line markers reduced collisions by an average of only 50% (95% confidence interval estimate: 40–59%) when additional grey literature was included in their analysis. Given that nonsignificant findings are generally published less frequently, the average effectiveness is likely lower. Our findings of collision mitigation were near the top of the range of effects. We suggest this is because all wires except for the middle conductor were marked on spans supported by tall pylons, and all wires were marked on spans supported by short pylons. Usually, only shield wires are marked. The large effect we documented may also have been attributable, at least in part, to the selection of active FireFly FF line markers which incorporated high-contrast, reflective, glow-in-the-dark, and moving elements intended to make them as visible as possible to birds in flight. This hypothesis remains speculative because studies attempting to compare the effectiveness of various line marker types have generally been inconclusive due to a lack of statistical power (Bernardino et al. 2019). Future research should continue to investigate the merits of high-contrast, reflective, glow-in-the-dark, and moving elements in avian collision mitigation.

The spans where collisions continued after line markers were installed were longer and higher than spans where collisions were not observed, included an unmarked conductor, and were

Figure 3. Examples of avian carcasses found in 2021 attributable to Peregrine Falcon predation in which the breastbone and the wings were connected by the shoulder girdle and all muscle had been consumed. (A) Common Pochard *Aythya ferina*; (B) Common Starling *Sturnus vulgaris*; (C) Common Coot *Fulica atra*; (D) Eurasian Teal *Anas crecca.* (Photo credits: Filip Declerck.)

composed of multiple horizontal planes. This combination of variables makes it impossible to identify the specific mechanism allowing collisions to persist on the marked spans between tall pylons. Perhaps because spans were longer, birds using pylons as cues to increase flight height (Pallett et al. 2022), did not see the nearest pylons when crossing the right-of-way, leading to ongoing, but reduced, collisions. Perhaps because pylons were taller, birds flew higher, but not high enough, and so collided with the shield wire despite the presence of line markers. Although sandwiched between marked wires, it is possible the unmarked conductor was involved in the collisions. This seems unlikely because prior research has demonstrated that most collisions with transmission lines involve shield wires. For example, in early research Scott et al. (1972) found 10 of 10 (100%) observed collisions involved shield wires. Thereafter, Faanes et al. (1987) found 102 of 109 (94%) collisions involved overhead shield wires, and Murphy et al. (2009) found 233 of 321 (73%) collisions involved shield wires. More recently, Dwyer et al. (2019) found 47 of 50 collisions (94%) and Baasch et al. (2022) found 36 of 64 collisions (56%) involved shield wires. Shield wires are approximately half the diameter of conductors, do not generate corona emissions, and are higher than conductors. This makes overhead shield wires more difficult to see than conductors and places them in the flight paths of birds climbing over conductors (Bernardino et al. 2018). Based on the history of observed collisions, it seems likely birds collided with the shield wire on the marked spans in our study, but future research involving nocturnal observations with night vision optics or automated collision detection systems (as in Sporer et al. 2013; Dwyer et al. 2019; Baasch et al. 2022) would be necessary to verify or refute this hypothesis.

Although our findings were positive, two features limited our study. First, we used varying numbers of volunteers to conduct surveys, and second, we only accounted for two types of bias. Intuitively, more volunteers per survey should result in increased detection rates. This would presumably be true if all volunteers were highly qualified and actively engaged throughout their time searching for carcasses. This was likely the case when Demeter et al. (2018) used volunteers to search for avian electrocutions at the bases of power pylons, and Kolnegari et al. (2022) used crowd-sourced reporting to identify avian nesting on power pylons. In practice, sometimes our additional volunteers were neither highly qualified nor actively engaged throughout the day, but were instead accompanying friends or family with those characteristics. We encouraged participation by untrained volunteers because we believe it helped support our long-term conservation goals by encouraging development of a conservation ethic, but their presence did not necessarily increase the detection of carcasses during surveys. Consequently, our analysis does not account for numbers or expertise of volunteers. Future research using volunteers may contribute to avian conservation by quantifying volunteer numbers and expertise.

Future research could also improve the accuracy of overall collision estimates by quantifying crippling bias, detection bias, predator bias (Peregrine Falcons), and scavenging bias during each field season (Dwyer and Mannan 2007; Huso 2011; Ponce et al. 2010). Quantifying crippling bias was not strictly necessary in this study as we can assume that was relatively consistent across survey years. Detection bias could have changed from year to year, however, and scavenging bias almost certainly changed from 2001 to 2021. For that reason, although our results were generally consistent when comparing 2001 to 2021 and 2018 to 2021, a very conservative interpretation might discard the 2001 data, and only consider the comparisons we report from 2018 to 2021. Our separate-year reporting in the Results section facilitates this approach.

Although our study was imperfect, our findings that avian collisions declined substantially following the installation of line markers is encouraging, our quantification of Peregrine Falcon predation is novel, and our findings of different collision rates on tall spans with shield wires compared with short spans without shield wires is important to future conservation and management. We hope lessons learned in our study can be used to improve future avian collision research in Europe.

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Appendix 1.

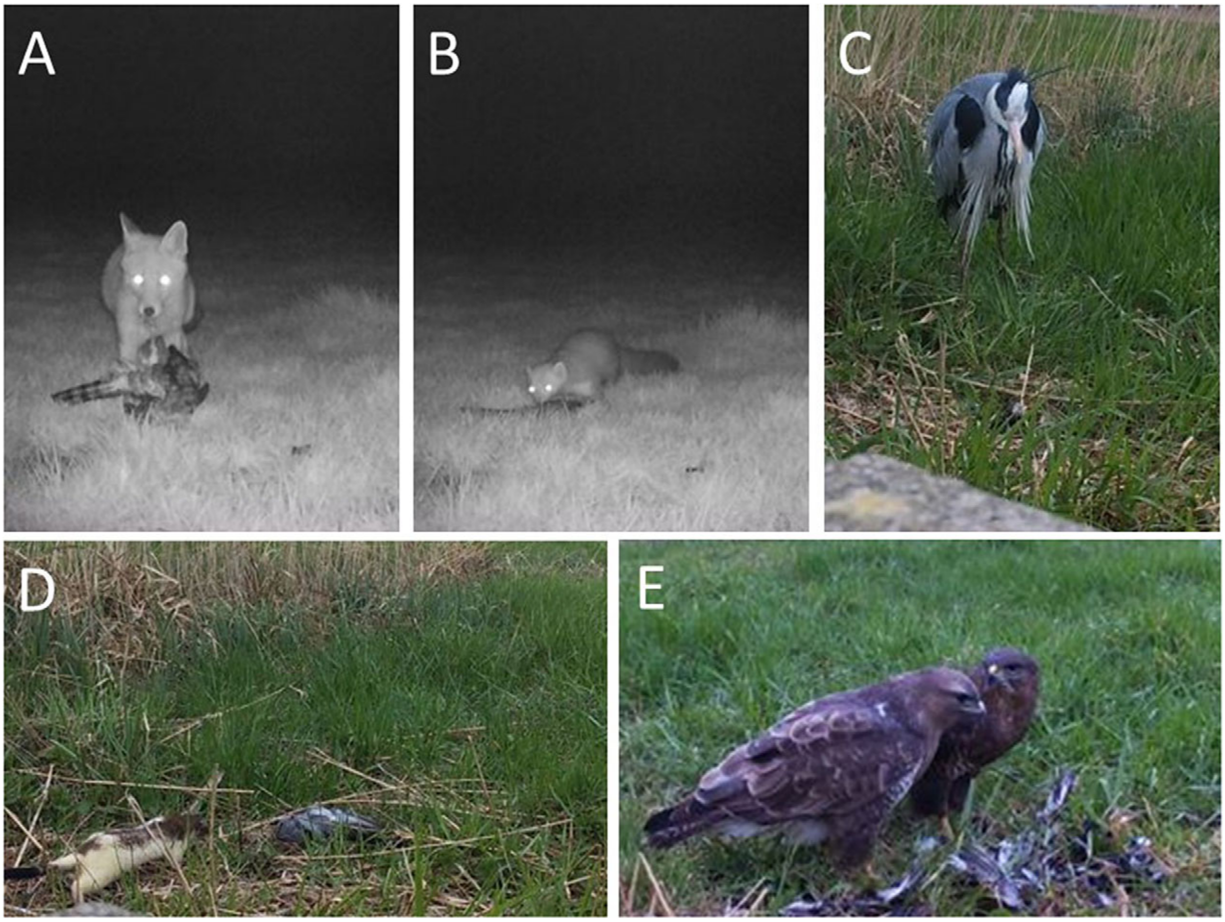

Figure A1. (A) A red fox *Vulpes vulpes* moved but did not consume a Eurasian Sparrowhawk *Accipiter nisus* carcass. (B) A beech marten *Martes foina* investigated but did not consume a Eurasian Sparrowhawk carcass. (C) A Grey Heron *Ardea cinerea* approached but did not contact a European Robin *Erithacus rubecula* carcass. (D) A stoat *Mustela erminea* approached but did not contact a Rock Pigeon *Columba livia* carcass. (E) Two Common Buzzards *Buteo buteo* plucked and consumed a Common Snipe *Gallinago gallinago* carcass. (Photo credits: Natuurpunt remote cameras, March and April 2021.)

Table A1. Of 21 carcasses deployed, 10 were moved or removed by scavengers, and 11 remained in place for the duration of the five-day exposure period

Species	Scientific name	Mass (g)	Deployment date	Outcome
Common Moorhen	*Gallinula chloropus*	322	22 March 2021	intact, same location
Common Snipe	*Gallinago gallinago*	65	7 March 2021	moved and gnawed
Common Snipe	*Gallinago gallinago*	62	12 March 2021	intact, same location
Common Snipe	*Gallinago gallinago*	69	12 March 2021	intact, same location
Common Snipe	*Gallinago gallinago*	62	17 March 2021	no longer present
Common Snipe	*Gallinago gallinago*	72	22 March 2021	no longer present
Common Starling	*Sturnus vulgaris*	56	6 April 2021	no longer present
Eurasian Kestrel	*Falco tinnunculus*	189	27 March 2021	intact, same location
Eurasian Sparrowhawk	*Accipiter nisus*	218	7 March 2021	moved
European Robin	*Erithacus rubecula*	22	12 March 2021	intact, same location
European Robin	*Erithacus rubecula*	12	1 April 2021	intact, same location

(*Continued*)

Table A1. (*Continued*)

Species	Scientific name	Mass (g)	Deployment date	Outcome
European Robin	*Erithacus rubecula*	15	6 April 2021	no longer present
Great Tit	*Parus major*	14	6 April 2021	no longer present
Grey Heron	*Ardea cinerea*	1,189	17 March 2021	intact, same location
House Sparrow	*Passer domesticus*	16	1 April 2021	no longer present
Meadow Pipit	*Anthus pratensis*	11	27 March 2021	no longer present
Rock Pigeon	*Columba livia*	232	17 March 2021	moved and gnawed
Rock Pigeon	*Columba livia*	174	22 March 2021	intact, same location
Rock Pigeon	*Columba livia*	199	27 March 2021	intact, same location
Rock Pigeon	*Columba livia*	230	1 April 2021	intact, same location
Western Jackdaw	*Coloeus monedula*	181	7 March 2021	intact, same location