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RESEARCH ARTICLE

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Do ditch-side electric fences improve the breeding productivity of ground-nesting waders?

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Abstract

1. Insufficient reproduction as a consequence of predation on eggs and chicks is a major determinant of population decline in ground-nesting birds, including waders. For many populations, there is an urgent need to maintain breeding populations at key sites, and conservation practitioners need to find viable management solutions to reduce predation.
2. One tool available to the practitioner is fences that exclude key predators from areas containing breeding birds. Temporary electric fencing is an increasingly popular predator exclusion intervention, but such fences have costs associated with purchase and the time needed to erect and maintain them. Their effectiveness and optimal application are also frequently questioned.
3. We evaluate the use of temporary ditch-side four-strand electric fences in lowland grasslands in two countries, The Netherlands and England, in areas containing high densities of breeding waders.
4. In both countries and in all years, godwit and lapwing nest survival was significantly higher within areas enclosed by ditch-side electric fences. Brood survival, assessed for godwits in The Netherlands, was also higher within fenced areas in all years. This demonstrates that using temporary electric fences to enclose ground-nesting birds can be an effective tool for improving breeding productivity.
5. In our study, closely managed electric fences were effective at excluding red foxes *Vulpes vulpes*, but not avian and other mammalian predators. The positive effect that electric fencing had on nest and brood survival therefore likely results from a reduction in the total number of visits by mammalian predators, and especially visits by foxes.
6. Although it requires a substantial time investment throughout the period of use, our temporary electric fence design provides flexibility compared to other fence designs when it comes to enclosing different areas within a season and between

years, as the targets for protection change or as land and flood management dictate. This conservation intervention can help buy the time required to develop and implement longer term solutions for application at larger scales.

KEYWORDS
brood survival, chick survival, nest survival, predation, predator management

1 | INTRODUCTION

Insufficient reproductive productivity is a major determinant of population decline in ground-nesting birds (Roodbergen et al., 2012). Birds breeding in agricultural grassland and meadow habitats are especially affected, and across Europe many breeding waders show population declines over the past 40 years that are partly attributable to low productivity (e.g. Plard et al., 2020; Robinson et al., 2014), such that 10 wader species are listed as being globally vulnerable, threatened or near threatened by the IUCN Red List (IUCN, 2019). The decline in wader productivity is largely driven by factors relating to agricultural intensification and climate change (Kentie et al., 2018; Kleijn et al., 2010). These factors directly and indirectly reduce nest and chick survival by altering the frequency and timing of agricultural cropping, mowing and grazing which increases nest and chick destruction by machinery and livestock (e.g. Donald et al., 2001; Kentie et al., 2015; Kruk et al., 1997), and reduces the availability of habitat and food resources for chicks (Schekkerman & Beintema, 2007; Schekkerman et al., 2009).

In the absence of trampling, flooding and other causes of direct nest destruction (Beintema & Muskens, 1987), a further cause of reduced productivity of ground-nesting birds is increased predation pressure (Baines, 1990; Roos et al., 2018). Conservation interventions are implemented at large scale to counter the negative effects of agricultural activities, for example maintaining optimal habitat within protected areas and through agri-environment schemes in Europe (MacDonald & Bolton, 2008; Roos et al., 2018), but these efforts are frequently negated by high levels of nest predation (Franks et al., 2018). Causes of increased predation pressure could be manifold and act on multiple scales, and are usually context-specific (Evans, 2004). The suite of nest predators includes many mammals and birds, posing a risk for nests night and day. Nest and chick predators in Europe are primarily mammals, including badger *Meles meles*, stoat *Mustela erminea*, polecat *Mustela putorius*, American mink *Mustela vison*, wild boar *Sus scrofa*, racoon dog *Nyctereutes procyonoides* and red fox *Vulpes vulpes*, and to a lesser extent birds, including carrion crow *Corvus corone*, marsh harrier *Circus aeruginosus*, blue heron *Ardea cinerea* and buzzard *Buteo buteo* (Madden et al., 2015; Mori et al., 2021; Nordström et al., 2003; Roos et al., 2018; Salewski & Schmidt, 2020; Salewski et al., 2019; Teunissen et al., 2008). High densities and expanding distributions of predators, predation-compromised conservation efforts, high levels of philopatry of breeding waders (Kruk et al., 1998; Thompson & Hale, 1989; Thompson et al., 1994) and limited suitable habitat all constrain the ability of waders to relocate to alternative areas with a lower predation risk. In the face of rapidly declining grassland breeding bird populations, there is an urgent need in the short term to maintain breeding populations at key sites, to buy the time required to develop and implement longer term solutions (MacDonald & Bolton, 2008).

Predator management options available include culling, removal and relocation, conditioned food aversion and diversionary feeding (Jackson, 2001; Kubasiewicz et al., 2016; Laidlaw et al., 2021; Smart & Amar, 2018; Smith et al., 2010). Predator exclusion using electric fences placed around individual nests and key breeding areas is another method which can improve nest and chick survival (Smith et al., 2011; White & Hirons, 2019). Electric fences can be a barrier to large mammalian predators such as badgers, raccoon dogs and foxes, thereby reducing nest predation within fenced areas (Malpas et al., 2013; Poole & McKillop, 2002). Temporary electric fencing is an increasingly popular intervention for grassland habitats in Europe (Homberger et al., 2017; Rickenbach et al., 2011). However, electric fencing has high costs associated with the required capital investment and the resources needed to erect and maintain fences. Their effectiveness and optimal application are also frequently questioned (Malpas et al., 2013; Poole & McKillop, 2002), highlighting the need for further evaluation of application of this management option to better inform the practitioner.

In this study, we evaluate the use of temporary ditch-side electric fences in lowland grasslands containing high densities of breeding waders from work conducted in The Netherlands and England. We hypothesized there would be fewer predators and higher productivity of breeding waders inside fenced areas compared to outside these areas. To test this, we monitored whether predators entered fenced areas using trail cameras and by searching for tracks and scats. At the same time, we collected data on nest and brood survival of northern lapwing *Vanellus vanellus*, hereafter 'lapwing', and black-tailed godwit *Limosa limosa*, hereafter 'godwit', both inside and outside the fenced areas. We also share our applied experiences of electric fences to make recommendations for their implementation.

2 | MATERIALS AND METHODS

2.1 | Study areas

The Haanmeer (52.55°N, 5.26°W) is a ~200-ha grassland in south-west Friesland, The Netherlands (Figure 1). The Haanmeer consists of fields that are broadly maintained under two different management schemes: (i) intensively managed grassland monocultures for dairy production (69 ha) and (ii) herb-rich meadows managed for breeding birds

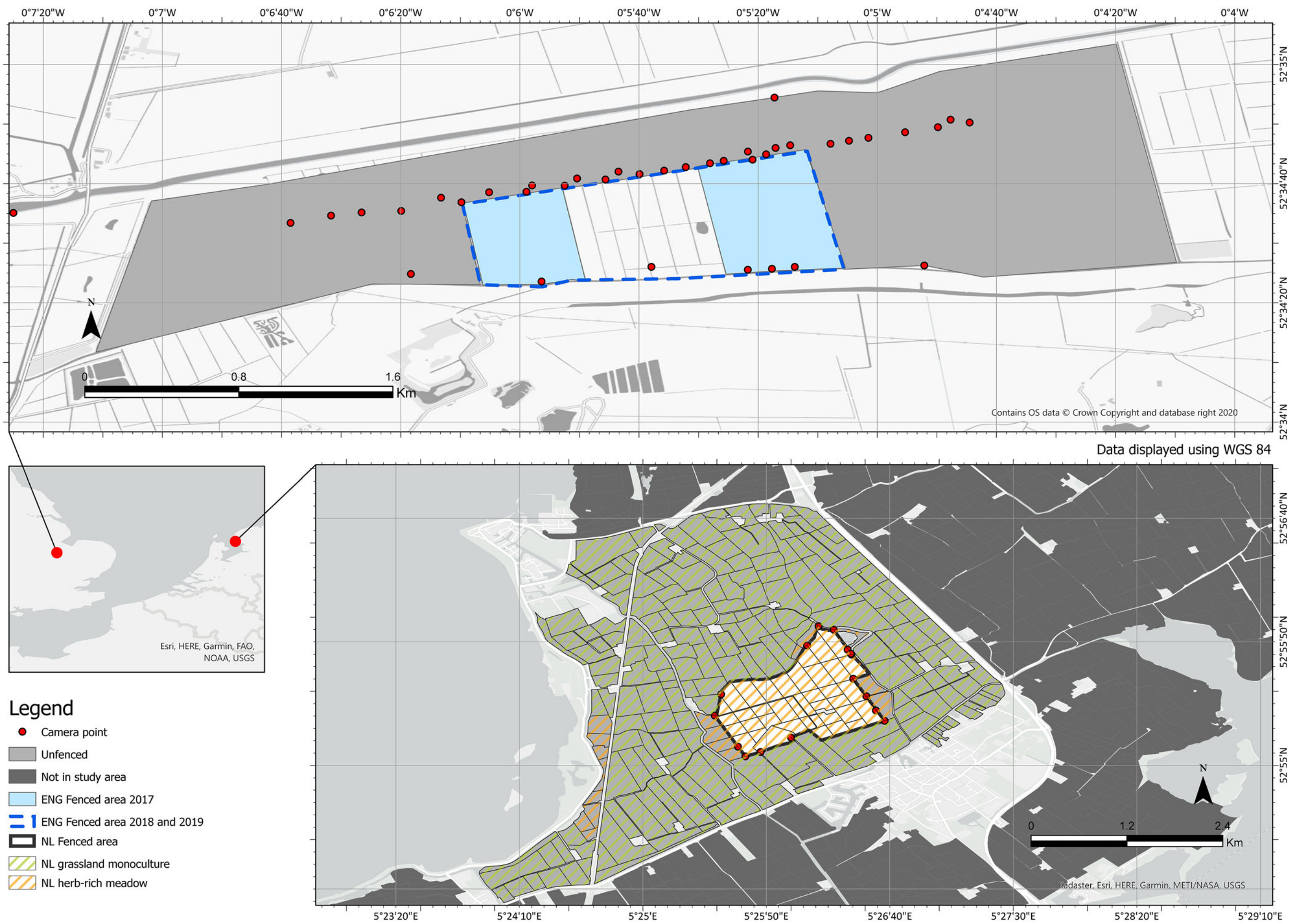

FIGURE 1 Map of the study areas in England (top) and The Netherlands (bottom). The map shows the location of the fenced and unfenced areas as well as the location of the motion-sensor trail cameras. Also shown for The Netherlands is the habitat type for each field in the study

(130 ha). The latter section is one of southwest Friesland's last remaining areas with high densities of breeding godwits (Howison et al., 2018). Also included in the study was 734 ha of the grassland that surrounds the Haanmeer, of which the majority is intensively managed monoculture (717 ha) with scattered herb-rich meadows (17 ha; Figure 1). In total, the entire study site in The Netherlands was 933 ha.

The Nene Washes (52.34°N, 0.05°W) is a 1400-ha flood storage reservoir in East Anglia, England, UK (Figure 1). It is one of five breeding locations for godwits in the United Kingdom and holds ~85% of the UK population (Verhoeven et al., 2021). The washes are used during peak river flows to divert water from the River Nene onto surrounding fields for temporary storage. Our study site consisted of the 308-ha Low Wash, a section of the Nene Washes with a high density of breeding waders, which includes 260 ha that are managed specifically for breeding waders and other wetland birds (Figure 1). Surrounding the Nene Washes is arable land that typically has no breeding waders except when the washes are flooded in the breeding season (Ratcliffe et al., 2005).

At both sites, the area managed for breeding birds is grazed and mown from early summer, avoiding fields with nesting waders to minimize trampling and mechanical destruction of nests and chicks. High water levels and shallow pools are maintained throughout the breeding season. At both sites, consecutive years of poor nest survival, in the absence of substantial nest flooding and subsequent desertion, were the result of increased predation pressure (Verhoeven et al., 2021; MV personal observation). Evidence from nest and trail cameras, and mammal tracks and scats, suggested that most nests were predated by mammals and in particular by red foxes. For this reason, electric fences in the ditch-sides of fields were deployed to exclude foxes and other mammalian predators from the wader breeding area in The Netherlands (2017–2018) and in England (2017–2019).

2.2 | Ditch-side electric fencing

We used ditch-side electric fences because they are temporary and relatively cheap, quick and simple to erect compared to permanent fencing (electric or otherwise). This means we could erect them after any floodwater had receded and before breeding began, and could adjust them as needed to changes in water level during the breeding season. At both sites, the electric fence consisted of four polywire strands. Fences were placed on or near the inside bank of wide

FIGURE 2 In situ fencing showing: (a) power unit and power source used in England, (b) four-strand fence with gate barrier, (c) field gate with additional non-electric wire barrier and (d) trimming vegetation under wires

ditches surrounding the study areas and were angled outward over the water at an angle of approximately 20° (Figure 2a–d). The bottom strand was suspended <10 cm from ground/water level and the other strands were consecutively 10–15 cm higher. Therefore, to enter the fenced area, mammals had to swim across the ditch and touch the wires while wet and grounded, since they were unable to jump the outward-facing fence directly from the water. At both sites, there were 'bridges', dams or gated entrances across ditches to allow human access. To prevent mammals entering fenced fields via these bridges, we erected customized barrier gates either by using metal wire to close off gaps between the rails of existing gates or by constructing new gates with eight wires spaced 10–15 cm apart up to about 1.5 m high (Figure 2b,c). On top of barrier gates, there were angled extensions facing outward, constructed of mesh or wires, with the aim of preventing mammals from jumping and climbing over the barrier (Figure 2c).

In The Netherlands, the circumference of the fence was 4.9 km, enclosing 107 ha of the Haanmeer's herb-rich meadows (Figure 1). This fence was powered by two energizers connected to a 220-V mains electricity supply (one energizer per two strands). Each energizer was earthed with three iron rods placed >20 m from the energizers and >1 m deep into the ground. This earth connection was checked periodically, and the fence voltage checked and maintained daily. This fence voltage had an average of ~4 kV (range 2.3–5.8 kV) and declined over time (Appendix S1). In England, the circumference of the fence was ~3.5 km enclosing 62 ha of wader breeding habitat, in two separate blocks in 2017 and a single block in 2018 and 2019 (Figure 1), and focused on the core godwit nesting area. This fence was powered by three solar/battery-powered energizers earthed with one iron rod, 0.3 m from the energizers and 1 m deep. Earth and voltage were checked one to two times per week in the first part of the season, later increasing to daily checks as vegetation growth increasingly impacted fence voltage. On average, this fence had a voltage of ~9.4 kV.

We provide a detailed overview of fence specifications and maintenance for both sites in Appendix S1.

2.3 | Predator monitoring

At both sites, we used motion-sensor trail cameras (HyperFire HC600 from Reconyx, Wisconsin, USA) to assess the presence/absence of nocturnal predators. We also made daily daytime visits during which we looked for mammal tracks and scats. In The Netherlands, we placed 16 trail cameras, one at each bridge into the fenced area (Figure 1). These cameras were placed on the inside of the fence and photographed mammals that had just entered and those exiting the fenced area via a bridge. These cameras were placed before the fences were erected to provide before and after observations (placed 25 February 2017 and 2 February 2018).

In England, we placed 12 trail cameras that remained in the same location for 10 days before relocation, such that the cameras recorded at 38 different locations in total (Figure 1). Most camera locations were at field entrances, and all were on the outside of the fenced area. Images from these camera locations therefore could not be used to determine whether predators successfully entered the fenced area. However, at any given time, one to two cameras were placed at field edges on the inside of the fenced area. In addition, bespoke miniature nest cameras (Bolton, Butcher, et al., 2007) were placed at a subset of active nests to identify nest predators and determine whether foxes had breached the fence. At both sites, lethal fox control was undertaken annually in early spring, which additionally provided evidence of fox presence during the breeding season.

2.4 | Breeding wader monitoring

In The Netherlands, godwit nests were monitored during 2013–2018 and lapwing nests in 2017 and 2018. The entire 933-ha study area was searched for new nests at least weekly both inside the fence (107 ha of herb-rich meadows) and outside the fence (786 ha of grassland monoculture plus 40 ha of herb-rich meadows; Figure 1). Nests were either marked with a short stick or not marked at all. Although sticks are sometimes thought to provide cues to predators, our experience is that the sticks we place do not affect nest survival; this aligns with other studies demonstrating there is no effect on marked lapwing and godwit nests (Salewski & Schmidt, 2020; Zámečník et al., 2018). To determine the lay date of nests found in the laying phase, we assumed that godwits lay one egg per day (Cramp & Simmons, 1983). For nests that were not found in the laying phase but had a known hatch date, we back-calculated the lay date by subtracting 26 days (the combined average laying and incubation period; Verhoeven et al., 2020). For nests that were not found in the laying phase and did not have a hatch date due to predation or abandonment, we estimated the lay date by subtracting the incubation stage (identified using the flotation method, following Liebezeit et al., 2007) from the date the nest was found. Found nests were visited once a week to check their status (active, failed or hatched). However, a subset of godwit nests was visited more than once in the last week of incubation, due to attempts to capture an incubating adult in that period. In total, nests that hatched were visited four to five times during the nesting season.

In England, lapwing and godwit nests were monitored on the 308-ha Low Wash during 2015–2019. We followed the same nest protocols as in The Netherlands, both inside (62 ha) and outside (246 ha) the electric fencing (Figure 1). In England, we also placed an iButton temperature logger (1-wire thermochron DS1921; Maxim Integrated Products Ltd, CA, USA) in each nest by gluing the logger to a nail, camouflaging it with tape and anchoring the nail in the middle of the nest. These loggers recorded nest temperature every 10 min, enabling a precise determination of the day and time of nest predation or abandonment, versus the less precise method of using weekly nest checks to identify a window during which nest failure occurred. We determined lay date in the same way as in The Netherlands, except that we used nomograms (see Green, 1984) instead of the flotation method to identify incubation stage. These two methods are known to yield comparable results (e.g. Green, 1984).

At both sites, we monitored godwit broods inside and outside of fenced areas by finding and following adults marked with unique combinations of colour rings throughout the chick stage. If a colour-marked adult had been linked to a nest and showed continuous chick guiding behaviour for a 25-day period after hatching, then we considered the brood to have fledged. The fieldwork in The Netherlands was done under license numbers 6350A and AVD105002017823 following the Dutch Animal Welfare Act Articles 9 and 11. In England, licences to disturb and handle birds were granted by Natural England in line with the UK Wildlife and Countryside Act 1981.

2.5 | Statistical analysis

2.5.1 | Annual nest survival estimates

Since it is likely that successful and unsuccessful nests have unequal probabilities of being found (Mayfield, 1961; Verhoeven et al., 2020), we used nest survival models in program MARK (White & Burnham, 1999) through the RMark (Laake, 2013) interface to estimate daily

TABLE 1 The number and fate of nests included in models used to estimate daily survival rates of nests in years before (≤2016) and after fencing (≥2017). Years with electric fences in italics. Results in Table 2

		Fenced area		Unfenced area	
Country	Year	Failed	Hatched	Failed	Hatched
Netherlands (godwits only)	2013	19	63	30	40
	2014	59	65	55	36
	2015	107	52	36	44
	2016	82	12	118	5
	2017	*39*	*32*	*39*	*8*
	2018	*11*	*60*	*16*	*6*
England (godwits and lapwing)	2015	–	–	34	30
	2016	–	–	38	44
	2017	*9*	*23*	*19*	*18*
	2018	*11*	*18*	*18*	*22*
	2019	*16*	*16*	*20*	*11*

survival rates of nests in years before and after fencing was used. In all cases, we selected the model with the lowest AICc value (Akaike Information Criterion is AIC with a correction for small sample size) and without uninformative parameters as the best model (Arnold, 2010; Burnham & Anderson, 2002). When calculating the estimated hatching probability of nests ('nesting success'), we used the daily survival rates from the best model and assumed that nests had to survive for 25 days in order to hatch (Verhoeven et al., 2020). We then used the Delta method to derive an estimate of hatching variance (Ver Hoef, 2012).

In The Netherlands, a grouping variable 'fence' indicated whether nests were in a field that was subsequently fenced or remained unfenced. As a result, there are two nest survival estimates (fenced and unfenced) for each year of the study, even though no part of the study area was fenced in 2013–2016. We took this approach because in The Netherlands, fencing was confounded with habitat differences; the fenced area consisted of 107 ha of continuous herb-rich meadows, whereas the unfenced area consisted of 786 ha of grassland monoculture and only 40 ha of scattered herb-rich meadows (Figure 1). Generating two nest survival estimates enabled us to compare nest survival between and within these two areas both in unfenced years (2013–2016) and in fenced years (2017–2018). Thus, we could distinguish between a positive effect of the fence versus a positive effect of the underlying habitat differences by (1) observing the difference in nest survival rates between 'subsequently fenced' and 'remained unfenced' areas in years before fencing (2013–2016), and (2) observing the more pronounced difference in nest survival in those areas during years with a fence (2017–2018; see Section 3). This analysis included only godwits since lapwing were not followed during years before fencing in The Netherlands (Table 1).

In England, during years before fencing (2015–2016), the 'fence' grouping variable contained a single value 'outside/no fence' (Table 1) and therefore yielded only one estimate for those years. One estimate was sufficient because all nests were in herb-rich meadows on the 308-ha Low Wash (Figure 1). We included 'species' as a two-level factor in the model to explore whether there were species-specific differences in nest survival. We found no such differences (Table 2b). Given that finding, and the fact that our data set was balanced in terms of the proportion of godwits and lapwing inside and outside of fenced areas (see Table S1), we did not include species as a factor in the other models, to prioritize seemingly more important factors and avoid overfitting the models.

2.5.2 | Daily nest survival estimates

For a more detailed look at nest survival dynamics between fenced and unfenced areas within the same years, we used secondary RMark analyses to estimate daily nest survival rates in the years of fencing. We included linear and quadratic seasonal trends and added nest age and year to account for their potential effects (Dinsmore et al., 2002; Weiser, 2021). This analysis also allowed us to expand our sample size in The Netherlands by including lapwings, which in The Netherlands were followed only during the two years with a fence, though we did not include species as a factor for the same reasons described in the previous analysis. The lay date of a nest determines when during the nesting season that nest is active, where nesting season is defined as the period from the initiation of the first nest to the termination of the last nest; including linear and quadratic seasonal trends therefore enabled us to explore whether nest survival probabilities differed between different days of the nesting season (Dinsmore et al., 2002). Nest age, which is the number of days since a given nest was initiated, is included in nest survival models because older nests usually have higher survival than younger nests (Weiser, 2021). We also evaluated two models that included the interaction term fence × date to determine whether the slope across the season was different inside compared to outside the fence, and fence × year to determine whether the effect of fencing differed annually. We selected the model with the lowest AICc value (where AICc is AIC with a correction for small sample size) and without uninformative parameters as the best model (Burnham & Anderson, 2002; Arnold, 2010).

2.5.3 | Annual brood survival analysis

We also explored annual differences in brood survival inside and outside of fencing with a binomial GLM that had 'fence' as a two-level factor. A GLM was sufficient here because there was no difference in encounter probability between broods, since only known nests that hatched are included. Furthermore, the fate of all broods (fledged/failed) is known, and brood survival therefore follows a binomial distribution. We could only perform this analysis for The Netherlands because broods in England moved in and out of the fenced area, preventing us from categorizing broods as belonging to either the inside or outside grouping. In The Netherlands, two godwit broods that hatched close to the fenced area in 2018 moved inside the fencing

TABLE 2 Models evaluating factors influencing nest survival inside and outside of electric fences for (a) godwits in The Netherlands and (b) lapwing and godwits in England. The best models are shown in bold and the parameter estimates of these models are presented in Figure 3

Model	*k*	LogL	AICc	ΔAICc	Weight
(a) The Netherlands					
Fence × Year	**12**	**−1537.94**	**3099.91**	**0.00**	**0.999**
Fence + Year	7	−1553.72	3121.46	21.55	0.001
Year	6	−1568.30	3148.61	48.70	0
Fence	2	−1647.67	3299.35	199.44	0
Constant	1	−1673.76	3349.53	249.62	0
(b) England					
Fence + Year	**6**	**−684.37**	**1380.76**	**0.00**	**0.56**
Fence + Year + Species	7	−684.37	1382.76	2.00	0.21
Fence	2	−689.62	1383.25	2.49	0.16
Fence + Species	3	−689.57	1385.16	4.40	0.06
Fence × Year	10	−684.32	1388.69	7.93	0.01
Constant	1	−695.47	1392.95	12.19	0.00
Species	2	−695.24	1394.47	13.71	0.00
Year	5	−693.32	1396.66	15.90	0.00

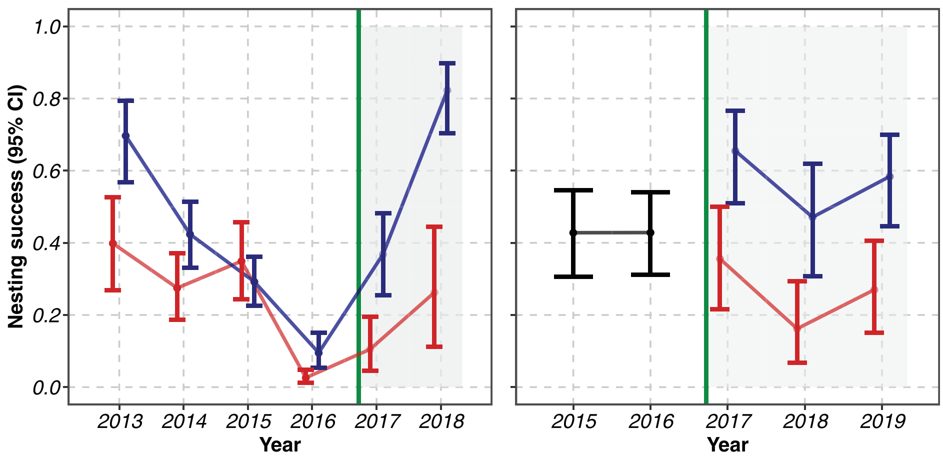

FIGURE 3 Annual variability in nesting success inside (blue) and outside (red) of fenced areas before and after fencing (green line) in (a) The Netherlands (left, godwits only) and (b) England (right, lapwing and godwits). The error bars show the 95% confidence intervals

within 2 days of hatching and fledged there, and were categorized in the fenced group.

3 | RESULTS

3.1 | Fencing

Each year, it took between 4 and 39 person days to construct the fences at each of the two study sites. This period varied depending on fence length and on the effects of spring flooding, which sometimes necessitated reshaping of ditches. In addition to construction time, a further 2 h per day was needed to keep fence wires free of vegetation. We encountered some difficulties in constructing and maintaining the fences; we describe these, along with recommended solutions, in the Supporting Appendix. The main problems were that the fence was (1) occasionally flooded after heavy rainfall, (2) not properly closed by visitors and (3) gradually reduced in voltage as it became overgrown by vegetation. In The Netherlands, the entire fence was checked each morning and all issues found were fixed the same day, such that every evening the fence was fully functional. This maintenance included frequent mowing of vegetation at the base of the fence and moving the fence up and down in the ditch side to adjust to changing water levels. In England, the fence was checked and maintained less regularly and was occasionally not functional. Most notably, in 2018, the fence was inoperable for 45 days due to heavy and prolonged flooding. During this

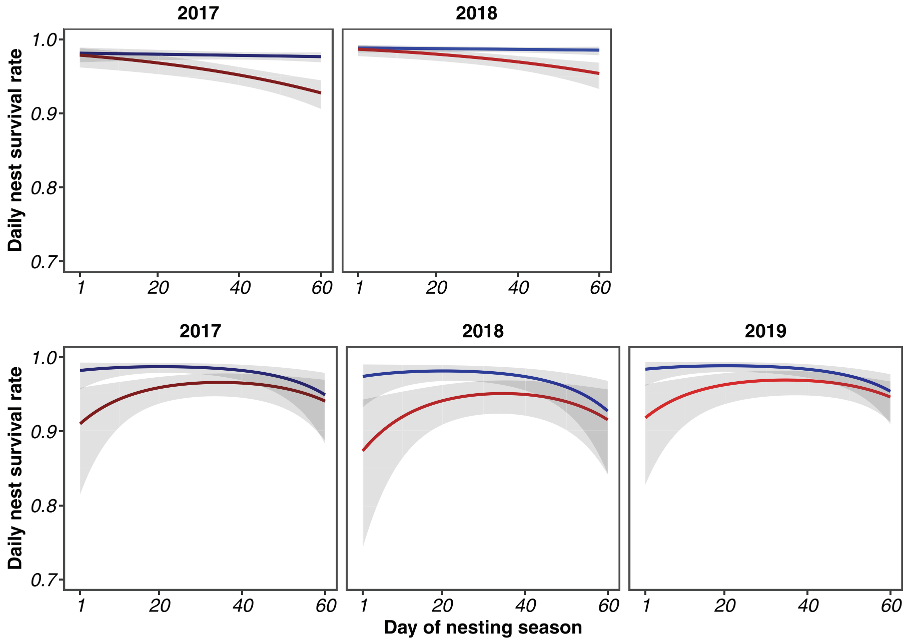

FIGURE 4 Daily survival rates of lapwing and godwit nests inside (blue) and outside (red) of fenced areas in (a) The Netherlands (top) and (b) England (bottom). The grey error margins show the 95% confidence interval

period, a fox was photographed inside the fence and we simultaneously observed high levels of nest predation.

3.2 | Predators

During 2017–2018 in The Netherlands, in the early part of the season before the fence was installed, the following species were recorded at night: badger, beech marten *Martes foina*, brown rat *Rattus norvegicus*, domestic cat *Felis catus*, red fox, polecat, stoat and weasel. Each of these species is a known predator of wader nests. After fencing was completed, all these species were recorded inside and outside of the fenced area *except* for foxes, which were not recorded inside the fence using any method (cameras, tracks or scat). Similarly, in England, a wide range of predators were recorded at night both inside and outside of the area that would be fenced later in the season; these included badger, otter, fox, stoat and weasel. After fencing was completed, all these species were recorded inside of the fence *except* for fox in 2019; foxes were observed both inside and outside of the fence in 2017 and 2018, but only outside the fence in 2019. Even though foxes were observed inside of the fence in England in 2017 and 2018, the fox activity rate—measured as the number of fox observations per minute of night-time trail camera recording—was significantly lower in the fenced area (N. Zielonka, J. Smart & H. Jones unpublished data).

3.3 | Nest survival

In 2016 (before fencing), nest survival in The Netherlands was low: only 17 of 217 godwit nests survived to hatching. In contrast, in the subsequent 2 years (after fencing), nest survival increased both inside and outside of the fenced area but was significantly higher within the fenced area (Figure 3a; Table 2a). This shows that fencing resulted in an additive positive effect on nest survival, in addition to the annual variability in nest survival. Furthermore, nest survival decreased seasonally and at a significantly higher rate outside of the fenced area, with the difference in nest survival probability between nests inside and outside the fence becoming 1.5–2 times larger over the breeding season (Figure 4a; Table 3a). The results for England showed the same pattern, with nests within the fence showing significantly higher survival (Figure 3b; Table 2b) and a declining seasonal trend in nest survival (Figure 4b; Table 3b).

3.4 | Brood survival

In The Netherlands in 2016, no broods fledged any young across the Haanmeer study area. After part of the area was fenced, brood survival was higher inside the fenced area compared to outside in both 2017 (0.17 vs. 0) and 2018 (0.63 vs. 0.33). These differences were not statistically significant (2017: $\chi^2 = 1.73$, d.f. = 1, $p = 0.19$; 2018: $\chi^2 = 1.91$, d.f. = 1, $p = 0.17$), but we attribute the lack of significance to the low sample size of broods outside the fenced area (five and six broods in 2017 and 2018, respectively). This idea is supported by data from 2014, which had a larger sample (26 broods) from the unfenced area and for which we did find a significant difference in brood survival between the fenced and unfenced areas (0.35 vs. 0.11, $\chi^2 = 8.39$, d.f. = 1, $p = 0.004$). These combined data—with brood survival at 0 in the unfenced area and higher in the fenced area in 2017, and with the largest observed difference between the fenced and unfenced areas occurring in

TABLE 3 Models evaluating nest survival of lapwing and godwit inside and outside electric fences for (a) The Netherlands and (b) England, between years, across the season and with nest age. The best models are shown in bold and the parameter estimates of these models are presented in Figure 4

Model	*k*	LogL	AICc	ΔAICc	Weight
(a) The Netherlands					
Fence × Date + Year + NestAge	**6**	**−522.92**	**1057.86**	**0.00**	**0.60**
Fence × Date^2 + Year + NestAge	7	−522.75	1059.51	1.65	0.26
Fence + Year + Date + NestAge	5	−525.75	1061.51	3.65	0.10
Fence × Year + Date + NestAge	6	−525.59	1063.19	5.33	0.04
Fence + Year + Date	4	−530.01	1068.02	10.16	0
Fence	2	−540.53	1085.06	27.20	0
Year	2	−546.78	1097.57	39.71	0
Date^2	3	−547.99	1101.97	44.11	0
Date	2	−549.03	1102.07	44.21	0
NestAge	2	−554.41	1112.83	54.97	0
Constant	1	−555.71	1113.42	55.56	0
(b) England					
Fence × Date^2 + Year + NestAge	**8**	**−365.09**	**746.23**	**0.00**	**0.83**
Fence × Date + Year + NestAge	7	−368.21	750.46	4.23	0.10
Fence + Year + Date + NestAge	6	−369.74	751.51	5.28	0.06
Fence × Year + Date + NestAge	8	−369.69	755.43	9.20	0.01
Fence	2	−376.99	757.98	11.75	0
Fence + Year + Date	5	−374.57	759.17	12.94	0
NestAge	2	−383.02	770.05	23.82	0
Date^2	3	−382.79	771.60	25.37	0
Date	2	−384.10	772.21	25.98	0
Year	3	−383.66	773.32	27.09	0
Constant	1	−385.81	773.61	27.38	0

2018—suggest the fence had an additive effect in addition to the annual variability in brood survival (Figure 5).

4 | DISCUSSION

In *both* countries and in all years, godwit and lapwing nest survival was substantially higher within areas enclosed by ditch-side electric fences. Brood survival, assessed for godwits in The Netherlands, was also higher within fenced areas in all years. We therefore demonstrate that a four-strand temporary electric fence enclosing ground-nesting birds can be an effective tool for improving breeding productivity. In our study, *well-maintained* electric fences were effective at excluding foxes, but not avian and other mammalian predators. The positive effect of electric fencing on nest and brood survival therefore likely results from a reduction in the total number of visiting foxes within the area. Reducing fox access alone was enough to significantly increase nest survival and increase brood survival, despite predation by other predators. Interestingly, observed annual variability in wader nest survival did not differ inside and outside of fenced areas, indicating that annual differences in wader nest survival are not solely related to differences in fox presence.

In The Netherlands, nest survival and successful fledging of broods was higher both inside and outside of the fence in 2017 and 2018. In most years, including prior to fencing, nest survival was higher in the area that was eventually fenced; we attribute this to the absence of mowing activities in the fenced area, in contrast to the intensively farmed agriculture habitat outside the fenced area (see Kentie et al., 2015). But, importantly, nest survival was significantly higher inside the fenced area in years when it was fenced. In 2017 and 2018, brood survival in The Netherlands was also higher inside the fence compared to outside, although the sample size of nests outside the fence that survived to hatching was small. Combined with the clear positive effect of fencing shown in England, where habitat variability was not a factor, these data show that fencing has an additive positive effect on nest and brood survival of ground-nesting waders.

Annual variability in nest survival showed the same trend inside and outside of fenced areas, with years of low or high survival inside fences mirrored outside fences. This indicates that in both countries, factors other than fox presence also impact wader nest survival variably across

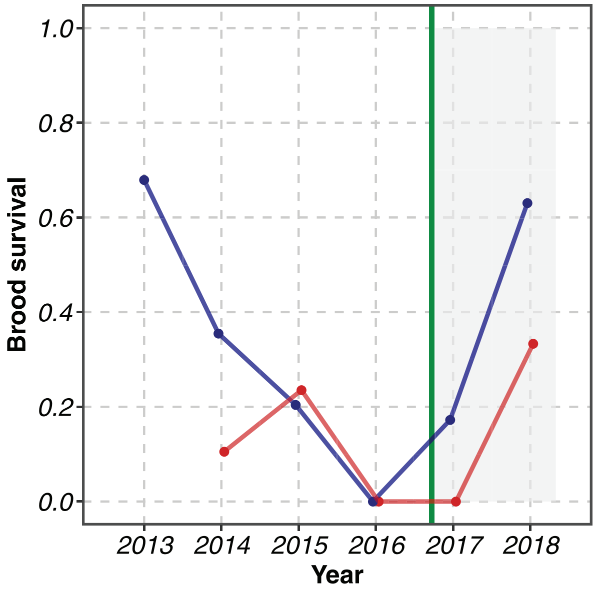

FIGURE 5 Godwit brood survival inside (blue) and outside (red) of fenced areas before and after fencing (green line) in The Netherlands. Brood survival is the proportion of broods that fledged out of all nests that hatched and to which a colour-marked adult was linked during the nesting phase

years. We suggest that factors regulating predator populations and their behaviour are at least partly responsible for the observed annual variation in nest survival; such factors could include annual variation in the abundance of voles or other prey species (Laidlaw et al., 2019; Wymenga et al., 2021), or related elements such as varying local abundance of different predator species, changes to predator behaviour, prey behaviour and vegetation structure as a result of flooding, and so on (Laidlaw et al., 2015). Despite the differential role played by other factors each year, fences still resulted in significantly higher wader nest survival.

Predation pressure on ground-nesting birds is high at both the egg and chick stage, so fencing can improve productivity if used throughout both stages (Teunissen et al., 2008). For precocial birds such as waders, this includes the time that young are flightless and dependent on parents for protection. Our results showed a clear seasonal decline in nest survival in both countries, with this seasonal decline steeper in unfenced areas. We expect this to be due at least in part to seasonally increasing demands of offspring among the predator community, with the fence acting as a buffer for the nests inside the fence. In The Netherlands, the steeper decline in the unfenced area may also have been influenced by a seasonal increase in agricultural activities such as mowing.

Our spatially and temporally replicated study provides further evidence of the effectiveness of electric fencing for protecting ground-nesting birds. Nest survival improved significantly with the protection of fencing, and we also provide some evidence for increased chick survival, which supports the findings of studies deploying other electric fence designs (Rickenbach et al., 2011; Smith et al., 2011; Malpas et al., 2013). Although they require substantial time investment over the entire period of use, temporary electric fences cost one third the amount required for more permanent fence designs (see White & Hirons, 2019 for a price comparison). Temporary electric fences also provide flexibility, since they can be deployed in different areas between years as the targets for protection change or as land and flood management dictate.

Broods stayed inside the larger fenced area in The Netherlands (107 ha) but moved out of the smaller fenced area in England (67 ha). We therefore recommend fencing as large an area as possible in high-quality habitats containing breeding waders, in an effort to (1) protect more nests and especially chicks, (2) minimize the amount of high-quality breeding habitat left exposed outside the fence, thereby (3) limiting the effect of a potential increase in predation pressure outside the fence, and (4) increase cost-effectiveness, since the cost of fencing material per meter decreases as fence length increases (see White & Hirons, 2019). However, we also caution against making a fenced area *too* large: for fencing to be functional, it must be well-maintained along its entire length.

Our study clearly illustrates that temporary ditch-side electric fencing in lowland grasslands can be a successful conservation intervention for improving wader productivity. While electric fencing reduces only fox predation, we show that this can nonetheless be sufficient to make a significant difference to survival rates. Currently, we believe this positive effect of fencing is mostly due to reducing access to nests for foxes, the most prevalent nest predator (MacDonald & Bolton, 2008; Teunissen et al., 2008; Salewski et al., 2019). Fox predation can be even further reduced by other effective predator management tools such as trapping, culling and conditioned food aversion (Bolton, Tyler, et al., 2007; Fletcher et al., 2010; Tobajas et al., 2020). Until there is a better understanding of what drives predator pressure on ground-nesting birds, and how to manage predators at a landscape scale in areas where breeding waders are concentrated in discrete patches of suitable habitat, electric fences provide a viable solution to increase wader productivity and buy the time required to find new solutions.

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AUTHOR CONTRIBUTIONS

MAV, JS, AHJL, PS, CR, MDB and TPiersma conceived and designed the research. MAV, AHJL, TPringle, JS, WK, MW and ADM collected data. MAV analysed the data. MAV, MDB and JS wrote the manuscript and all remaining authors made contributions to it.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data available from the Dryad Digital Repository: https://doi.org/10.5061/dryad.k6djh9w8f (Verhoeven et al., 2022).

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REFERENCES

Arnold, T. W. (2010). Uninformative parameters and model selection using Akaike's Information Criterion. *The Journal of Wildlife Management*, *74*, 1175–1178. https://doi.org/10.1111/j.1937-2817.2010.tb01236.x

Baines, D. (1990). The roles of predation, food and agricultural practice in determining the breeding success of the Lapwing (*Vanellus vanellus*) on upland grasslands. *Journal of Animal Ecology*, *59*, 915–929. https://doi.org/10.2307/5022

Beintema, A. J., & Muskens, G. J. D. M. (1987). Nesting success of birds breeding in Dutch agricultural grasslands. *Journal of Applied Ecology*, *24*, 743–758. https://doi.org/10.2307/2403978

Bolton, M., Butcher, N., Sharpe, F., Stevens, D., & Fisher, G. (2007). Remote monitoring of nests using digital camera technology. *Journal of Field Ornithology*, *78*, 213–220. https://doi.org/10.1111/j.1557-9263.2007.00104.x

Bolton, M., Tyler, G., Smith, K., & Bamford, R. (2007). The impact of predator control on lapwing *Vanellus vanellus* breeding success on wet grassland nature reserves. *Journal of Applied Ecology*, *44*, 534–544. https://doi.org/10.1111/j.1365-2664.2007.01288.x

Burnham, K. P., & Anderson, D. R. (2002). *Model selection and multimodel inference: A practical information-theoretic approach* (2nd ed.). Springer Science & Business Media.

Dinsmore, S. J., White, G. C., & Knopf, F. L. (2002). Advanced techniques for modeling avian nest survival. *Ecology*, *83*, 3476–3488. https://doi.org/10.1890/0012-9658(2002)083%5b3476:ATFMAN%5d2.0.CO;2

Donald, P. F., Green, R. E., & Heath, M. F. (2001). Agricultural intensification and the collapse of Europe's farmland bird populations. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *268*, 25–29. https://doi.org/10.1098/rspb.2000.1325

Cramp, S., & Simmons, K. E. L. (1983). *The birds of the Western Palearctic* (Vol. III). Oxford University Press.

Evans, K. L. (2004). The potential for interactions between predation and habitat change to cause population declines of farmland birds. *Ibis*, *146*, 1–13. https://doi.org/10.1111/j.1474-919X.2004.00231.x

Fletcher, K., Aebischer, N. J., Baines, D., Foster, R., & Hoodless, A. N. (2010). Changes in breeding success and abundance of ground-nesting moorland birds in relation to the experimental deployment of legal predator control. *Journal of Applied Ecology*, *47*, 263–272. https://doi.org/10.1111/j.1365-2664.2010.01793.x

Franks, S. E., Roodbergen, M., Teunissen, W., Carrington Cotton, A., & Pearce-Higgins, J. W. (2018). Evaluating the effectiveness of conservation measures for European grassland-breeding waders. *Ecology and Evolution*, *8*, 10555–10568. https://doi.org/10.1002/ece3.4532

Green, R. (1984). Nomograms for estimating the stage of incubation of wader eggs in the field. *Wader Study Group Bull*, *42*, 36–39.

Homberger, B., Duplain, J., Jenny, M., & Jenni, L. (2017). Agri-environmental schemes and active nest protection can increase hatching success of a reintroduced farmland bird species. *Landscape and Urban Planning*, *161*, 44–51. https://doi.org/10.1016/j.landurbplan.2017.01.001

Howison, R. A., Piersma, T., Kentie, R., Hooijmeijer, J. C. E. W., & Olff, H. (2018). Quantifying landscape-level land-use intensity patterns through radar-based remote sensing. *Journal of Applied Ecology*, *55*, 1276–1287. https://doi.org/10.1111/1365-2664.13077

IUCN. (2019). *The IUCN red list of threatened species: Version 2019-1*. Author.

Jackson, D. B. (2001). Experimental removal of introduced hedgehogs improves wader nest success in the Western Isles, Scotland. *Journal of Applied Ecology*, *38*, 802–812. https://doi.org/10.1046/j.1365-2664.2001.00632.x

Kentie, R., Both, C., Hooijmeijer, J. C. E. W., & Piersma, T. (2015). Management of modern agricultural landscapes increases nest predation rates in Black-tailed Godwits *Limosa limosa*. *Ibis*, *157*, 614–625. https://doi.org/10.1111/ibi.12273

Kentie, R., Coulson, T., Hooijmeijer, J. C. E. W., Howison, R. A., Loonstra, A. H. J., Verhoeven, M. A., Both, C., & Piersma, T. (2018). Warming springs and habitat alteration interact to impact timing of breeding and population dynamics in a migratory bird. *Global Change Biology*, *24*, 5292–5303. https://doi.org/10.1111/gcb.14406

Kleijn, D., Schekkerman, H., Dimmers, W. J., Van Kats, R. J. M., Melman, D., & Teunissen, W. A. (2010). Adverse effects of agricultural intensification and climate change on breeding habitat quality of Black-tailed Godwits *Limosa l. limosa* in the Netherlands. *Ibis*, *152*, 475–486. https://doi.org/10.1111/j.1474-919X.2010.01025.x

Kruk, M., Noordervliet, M., & Keurs, W. (1997). Survival of black-tailed godwit chicks *Limosa limosa* in intensively exploited grassland areas in The Netherlands. *Biological Conservation*, *80*, 127–133. https://doi.org/10.1016/S0006-3207(96)00131-0

Kruk, M., Noordervliet, M. A. W., & Keurs, W. J. T. (1998). Natal philopatry in the Black-tailed Godwit *Limosa limosa L.* and its possible implications for conservation. *Ringing & Migration*, *19*, 13–16.

Kubasiewicz, L. M., Bunnefeld, N., Tulloch, A. I. T., Quine, C. P., & Park, K. J. (2016). Diversionary feeding: An effective management strategy for conservation conflict? *Biodiversity and Conservation*, *25*, 1–22. https://doi.org/10.1007/s10531-015-1026-1

Laake, J. (2013). *RMark: An R interface for analysis of capture-recapture data with MARK, AFSC processed report 2013-01*. Alaska Fisheries Science Center, National Marine Fisheries Service.

Laidlaw, R., Smart, J., Ewing, H., Franks, S. E., Belting, H., Donaldson, L., Hilton, G., Hiscock, N., Hoodless, A., Hughes, B., Jarrett, N., Kentie, R., Kleyheeg, E., Lee, R., Roodbergen, M., Scott, D., Short, M., Syroechkovskiy, E., Teunissen, W., … Gill, J. (2021). Predator management for breeding waders: A review of current evidence and priority knowledge gaps. *Wader Study*, *128*, 44–55. https://doi.org/10.18194/ws.00220

Laidlaw, R. A., Smart, J., Smart, M. A., & Gill, J. A. (2015). The influence of landscape features on nest predation rates of grassland-breeding waders. *Ibis*, *157*, 700–712. https://doi.org/10.1111/ibi.12293

Laidlaw, R. A., Smart, J., Smart, M. A., Bodey, T. W., Coledale, T., & Gill, J. A. (2019). Foxes, voles, and waders: Drivers of predator activity in wet grassland landscapes. *Avian Conservation and Ecology*, *14*, 4. https://doi.org/10.5751/ACE-01414-140204

Liebezeit, J. R., Smith, P. A., Lanctot, R. B., Schekkerman, H., Tulp, I., Kendall, S. J., Tracy, D. M., Rodrigues, R. J., Meltofte, H., Robinson, J. A., Gratto-Trevor, C., Mccaffery, B. J., Morse, J., & Zack, S. W. (2007). Assessing the development of shorebird eggs using the flotation method: Species-specific and generalized regression models. *The Condor*, *109*, 32–47. https://doi.org/10.1093/condor/109.1.32

MacDonald, M. A., & Bolton, M. (2008). Predation on wader nests in Europe. *Ibis*, *150*, 54–73. https://doi.org/10.1111/j.1474-919X.2008.00869.x

Madden, C. F., Arroyo, B., & Amar, A. (2015). A review of the impacts of corvids on bird productivity and abundance. *Ibis*, *157*, 1–16. https://doi.org/10.1111/ibi.12223

Malpas, L. R., Kennerley, R. J., Hirons, G. J. M., Sheldon, R. D., Ausden, M., Gilbert, J. C., & Smart, J. (2013). The use of predator-exclusion fencing as a management tool improves the breeding success of waders on lowland wet grassland. *Journal for Nature Conservation*, *21*, 37–47. https://doi.org/10.1016/j.jnc.2012.09.002

Mayfield, H. (1961). Nesting success calculated from exposure. *Wilson Bulletin*, *73*, 255–261.

Mori, E., Lazzeri, L., Ferretti, F., Gordigiani, L., & Rubolini, D. (2021). The wild boar *Sus scrofa* as a threat to ground-nesting bird species: An artificial nest experiment. *Journal of Zoology*, *314*, 311–320. https://doi.org/10.1111/jzo.12887

Nordström, M., Högmander, J., Nummelin, J., Laine, J., Laanetu, N., & Korpimäki, E. (2003). Effects of feral mink removal on seabirds, waders and passerines on small islands in the Baltic Sea. *Biological Conservation*, *109*, 359–368. https://doi.org/10.1016/S0006-3207(02)00162-3

Plard, F., Bruns, H. A., Cimiotti, D. V., Helmecke, A., Hötker, H., Jeromin, H., Roodbergen, M., Schekkerman, H., Teunissen, W., van der Jeugd, H., & Schaub, M. (2020). Low productivity and unsuitable management drive the decline of central European lapwing populations. *Animal Conservation*, *23*, 286–296. https://doi.org/10.1111/acv.12540

Poole, D. W., & McKillop, I. G. (2002). Effectiveness of two types of electric fence for excluding the Red Fox (*Vulpes vulpes*). *Mammal Review*, *32*, 51–57. https://doi.org/10.1046/j.1365-2907.2002.00095.x

Ratcliffe, N., Schmitt, S., & Whiffin, M. (2005). Sink or swim? Viability of a black-tailed godwit population in relation to flooding. *Journal of Applied Ecology*, *42*, 834–843. https://doi.org/10.1111/j.1365-2664.2005.01076.x

Rickenbach, O., Gruebler, M. U., Schaub, M., Koller, A., Naef-Daenzer, B., & Schifferli, L. (2011). Exclusion of ground predators improves Northern Lapwing *Vanellus vanellus* chick survival. *Ibis*, *153*, 531–542. https://doi.org/10.1111/j.1474-919X.2011.01136.x

Robinson, R. A., Morrison, C. A., & Baillie, S. R. (2014). Integrating demographic data: Towards a framework for monitoring wildlife populations at large spatial scales. *Methods in Ecology and Evolution*, *5*, 1361–1372. https://doi.org/10.1111/2041-210X.12204

Roodbergen, M., van der Werf, B., & Hötker, H. (2012). Revealing the contributions of reproduction and survival to the Europe-wide decline in meadow birds: Review and meta-analysis. *Journal of Ornithology*, *153*, 53–74. https://doi.org/10.1007/s10336-011-0733-y

Roos, S., Smart, J., Gibbons, D. W., & Wilson, J. D. (2018). A review of predation as a limiting factor for bird populations in mesopredator-rich landscapes: A case study of the UK. *Biological Reviews*, *93*, 1915–1937. https://doi.org/10.1111/brv.12426

Salewski, V., Evers, A., & Schmidt, L. (2019). Wildkameras ermitteln Verlustursachenvon Gelegen der Uferschnepfe (*Limosa limosa*). *Natur und Landschaft*, *94*, 59–65.

Salewski, V., & Schmidt, L. (2020). Nest cameras do not affect nest survival in a meadow-nesting shorebird. *Bird Conservation International*, https://doi.org/10.1017/S0959270920000659

Schekkerman, H., & Beintema, A. J. (2007). Abundance of invertebrates and foraging success of Black-Tailed Godwit *Limosa limosa* chicks in relation to agricultural grassland management. *Ardea*, *95*, 39–54. https://doi.org/10.5253/078.095.0105

Schekkerman, H., Teunissen, W., & Oosterveld, E. (2009). Mortality of Black-tailed Godwit *Limosa limosa* and Northern Lapwing *Vanellus vanellus* chicks in wet grasslands: Influence of predation and agriculture. *Journal of Ornithology*, *150*, 133. https://doi.org/10.1007/s10336-008-0328-4

Smart, J., & Amar, A. (2018). Diversionary feeding as a means of reducing raptor predation at seabird breeding colonies. *Journal for Nature Conservation*, *46*, 48–55. https://doi.org/10.1016/j.jnc.2018.09.003

Smith, R. K., Pullin, A. S., Stewart, G. B., & Sutherland, W. J. (2010). Effectiveness of predator removal for enhancing bird populations. *Conservation Biology*, *24*, 820–829. https://doi.org/10.1111/j.1523-1739.2009.01421.x

Smith, R. K., Pullin, A. S., Stewart, G. B., & Sutherland, W. J. (2011). Is nest predator exclusion an effective strategy for enhancing bird populations? *Biological Conservation*, *144*, 1–10. https://doi.org/10.1016/j.biocon.2010.05.008

Teunissen, W., Schekkerman, H., Willems, F., & Majoor, F. (2008). Identifying predators of eggs and chicks of Lapwing *Vanellus vanellus* and Black-tailed Godwit *Limosa limosa* in the Netherlands and the importance of predation on wader reproductive output. *Ibis*, *150*, 74–85. https://doi.org/10.1111/j.1474-919X.2008.00861.x

Thompson, P. S., & Hale, W. G. (1989). Breeding site fidelity and natal philopatry in the Redshank *Tringa totanus*. *Ibis*, *131*, 214–224. https://doi.org/10.1111/j.1474-919X.1989.tb02764.x

Thompson, P. S., Baines, D., Coulson, J. C., & Longrigg, G. (1994). Age at first breeding, philopatry and breeding site-fidelity in the Lapwing *Vanellus vanellus*. *Ibis*, *136*, 474–484. https://doi.org/10.1111/j.1474-919X.1994.tb01124.x

Tobajas, J., Descalzo, E., Mateo, R., & Ferreras, P. (2020). Reducing nest predation of ground-nesting birds through conditioned food aversion. *Biological Conservation*, *242*, 108405. https://doi.org/10.1016/j.biocon.2020.108405

Ver Hoef, J. M. (2012). Who invented the delta method? *The American Statistician*, *66*, 124–127. https://doi.org/10.1080/00031305.2012.687494

Verhoeven, M. A., Loonstra, A. H. J., McBride, A. D., Torres, P. M., Kaspersma, W., Hooijmeijer, J. C. E. W., van der Velde, E., Both, C., Senner, N. R., & Piersma, T. (2020). Geolocators lead to better measures of timing and renesting in Black-tailed Godwits and reveal the bias of traditional observation methods. *Journal of Avian Biology*, *51*, e02259. https://doi.org/10.1111/jav.02259

Verhoeven, M. A., Smart, J., Kitchin, C., Schmit, S., Whiffin, M., Burgess, M. D., & Ratcliffe, N. (2021). The recent population decline of Black-tailed Godwits in the United Kingdom. *Wader Study*, *128*, 65–76. https://doi.org/10.18194/ws.00216

Verhoeven, M. A., Loonstra, A. H. J., Pringle, T., Kaspersma, W., Whiffin, M., McBride, A. D., Sjoerdsma, P., Roodhart, C., Burgess, M. D., Piersma, T., & Smart, J. (2022). Data from: Do ditch-side electrical fences improve the breeding productivity of ground-nesting waders? *Dryad Digital Repository*, https://doi.org/10.5061/dryad.k6djh9w8f

Weiser, E. L. (2021). Fully accounting for nest age reduces bias when quantifying nest survival. *Ornithological Applications*, *123*, duab030. https://doi.org/10.1093/ornithapp/duab030

White, G., & Hirons, G. J. M. (2019). *Guidance on the use of predator exclusion fences to reduce mammalian predation on ground-nestling birds on RSPB reserves*. RSPB.

White, G. C., & Burnham, K. P. (1999). Program MARK: Survival estimation from populations of marked animals. *Bird Study*, *46*, 120–139. https://doi.org/10.1080/00063659909477239

Wymenga, E., Beemster, N., Bos, D., Bekkema, M., & van der Zee, E. (2021). Recurring outbreaks of common vole (*Microtus arvalis*) in grasslands in the low-lying parts of the Netherlands. *Lutra*, *64*, 81–101.

Zámečník, V., Kubelka, V., & Šálek, M. (2018). Visible marking of wader nests to avoid damage by farmers does not increase nest predation. *Bird Conservation International*, *28*, 293–301. https://doi.org/10.1017/S0959270916000617

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