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Assessment of bird collisions with deer fences in Scottish forests

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Summary

1. Bird collisions along 135 km of deer fences were monitored for 1 year at 27 sites in the Scottish Highlands.
2. The majority (93%) of recorded collisions were by grouse species and at least 16% were fatal (carcasses found).
3. In a trial testing how long carcasses would remain beside fences, 18 out of 20 were not relocated after 1 month.
4. Red grouse *Lagopus lagopus scoticus* collisions were more frequent on fences surrounding pre-thicket plantations, while capercaillie *Tetrao urogallus* collisions were more frequent on fences in native pinewoods.
5. The distribution of collisions differed seasonally. Two-thirds of both red grouse and black grouse *T. tetrix* collisions occurred between February and May, while capercaillie collisions occurred later, with a peak in September.
6. Collisions by capercaillie were positively associated with areas of *Vaccinium* spp., whereas those by black grouse were negatively associated with grass and heather.
7. This study adds weight to previous findings that fences are a frequent cause of mortality in capercaillie.
8. Further work aimed at reducing collision rates is needed, but a policy of deer culling to achieve tree regeneration without deer fencing would be desirable wherever practicable and especially within the range and main native pinewood habitat of capercaillie.

Key-words: grouse, pinewoods, plantations, regeneration, *Vaccinium*.

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Introduction

Bird collisions with high tension electricity wires and cables are well documented for wintering wildfowl (Anderson 1978; Alonso, Alonso & Munoz-Pulido 1994). Similarly, losses of capercaillie *Tetrao urogallus* L., black grouse *T. tetrix* L. and willow ptarmigan *Lagopus lagopus* L. are associated with collisions against electricity transmission wires in Norway (Bevanger 1995), black grouse with cables at Alpine ski resorts (Miquet 1990; Novoa, Hansen & Menoni 1990) and rock ptarmigan *L. mutus* L. with cables at Scottish ski resorts (Watson 1982). Recently, it has been shown that wire mesh and multiple-line wire fences, erected to exclude domestic stock and red deer *Cervus elaphus* L. from young conifer plantations and regenerating native woodlands, kill both black grouse and capercaillie (woodland grouse) in Scotland (Catt *et al.* 1994b).

The capercaillie was reintroduced to Scotland in the 19th century (Lever 1977) following its extinction in the 18th century. After expanding in the late 19th and early 20th centuries (Pennie 1950, 1951), its distribution has become increasingly restricted in the last 20 years (Sharrock 1976; Gibbons, Reid & Chapman 1993). Only 2200 birds (95% confidence intervals 1500–3200) remained in 1992–94 (Catt *et al.* 1994a). Consequently, capercaillie are regarded as being of high conservation concern in the UK (Anon. 1995; Gibbons *et al.* 1996). The study by Catt *et al.* (1994b) in two native pinewoods (Abernethy and Glen Tanar) documented mean collision rates for capercaillie and black grouse of 3·0 and 0·4 collisions per km of deer fence per year, respectively. From 29 capercaillie fitted with radio transmitters, it was estimated that annual mortality from collisions with fences was 32%, while that from all other causes combined was 23%. A comparison of these values with that from an earlier study throughout Scotland (Moss 1987), where overall adult male annual mortality was 34%, of which 16% were due to collisions with fences, suggests that fences are a recent and serious problem to capercaillie.

From the evidence available, in some forests at least, fences would appear to be taking an unacceptable toll on such a restricted population. This study extends the work of Catt *et al.* (1994b) by assessing whether deer fences pose a hazard to capercaillie and other grouse on a wider geographical scale in plantations and native pinewoods in the Highlands of Scotland.

Methods

The incidence of collisions was assessed over a total length of 135 km of deer fence (1·8 m high) distributed over 27 sites in Highland Scotland between April/May 1992 and April/May 1993: Dalnessie (site 1), Tighcreag (2), Craggie Top (3), Craggie Eileag (4), Strathrory (5), Morangie (6), Truderscaig (7), Rimsdale (8), Glenfiddich (9), Blackwater (10), Affric (11), Corrimony (12), Phoc (13), Portclair (14), Ben Tee Laddie (15), Coreich (16), Grudie (17), Strathbran (18), North Hill (19), North Longart (20), Chreag Mhigeachaidh (21), Dell Wood (22), Auchleeks I (23), Auchleeks II (24), Rothiemurchus (25), Glen Tanar (26) and Tomvaich (27). For locations of sites see Fig. 1. Sites were not chosen randomly, but included a range of forest habitats over a large part of the Highlands to assess whether the perceived problem was widespread geographically and between differing grouse habitats. Of the 27 sites, 22 were mixed species plantations in the pre-thicket stage, two were mature Scots pine *Pinus sylvestris* L. plantations (Dell Wood and Tomvaich) (Rose 1979) and two were native pinewoods (Rothiemurchus and Glen Tanar) (Steven & Carlisle 1959). One site (Creag Mhigeachaidh) was on heather moorland adjacent to a native pinewood. All sections of monitored fence were between 4 and 6 km in length, with the exception of Dell Wood (2 km) and Rothiemurchus (8 km).

Fences were searched each month for signs of collisions. One observer systematically searched the ground for feathers or corpses within eye's view (approximately 3 m) on either side of the fence. During the year, 88% of monthly visits were completed. Visits were not made when snow covered the ground and obscured signs of collisions. Under such circumstances, the number of accumulated remains found on the next visit were divided equally between the number of consecutive months when no visits were made. Initially, when remains were found, the species of bird and apparent severity of the collision (slight – only body feathers found; severe – major wing and tail feathers also found; fatal – carcass found) were noted. However, it became apparent that there was no obvious relationship between the number of feathers shed from a bird and whether the collision was fatal or not, with few or no feathers being cast on a number of fatal collisions where a corpse was found. Hence, it was felt that continued division of collisions into the three described classes was meaningless, and thereafter collisions were divided into those that were certainly fatal (carcass present) and others, irrespective of the amount of feathers cast. The collision sites were marked by attaching a numbered metal tag to the fence 0·5 m above the ground. In order to establish whether we underestimated the number of fatal collisions, one red grouse *Lagopus lagopus scoticus* L. carcass and a scattering of feathers was placed beside each of 20 different fences 1 month prior to a second observer checking the fence.

Collision rates (the number of collisions per km of fence per annum) were calculated for each site. When assessing collision rates, data from the first visit (the clear-up round) were excluded as feathers and corpses had accumulated over an unknown period. For an analysis of differences in collision rates between habitats, sites were grouped into one of two habitats: pre-thicket forest (including the moorland site, $n = 23$) or native pinewoods ($n = 4$, including two mature Scots pine plantations). Forests were divided regionally by the Great Glen into western forests (forests 1–8 and 11–20) and eastern forests (forests 9–10 and 21–27) (Fig. 1).

To test if the collision points were randomly distributed, the nearest neighbour distances between collisions were measured for each species. Then, for each species at each site, random points were obtained, equal to the number of collision points, and the nearest neighbour distances were measured. The process was repeated until 1000 nearest neighbour distances had been generated. The distribution of these distances was used to obtain the expected number of nearest neighbour distances if the pattern of collisions was random, and compared against the observed distribution in a chi-square goodness-of-fit test for each species.

In autumn 1993, the fence type (either welded mesh or plain strands of line wire) and habitat and topographical features at collision points were described. Similar descriptions were made at random points, equal to the number of collisions along each fence. Each species was assigned the same number of random points on a given fence as it had incurred collisions. At each collision and random point the woodland was described as pre-thicket, thicket, post-thicket (Rose 1979) or native pinewood. During the habitat descriptions, it was noted that some of the fences were set so far from woodland edges that they were unlikely to have any association with a collision. Therefore, in the analyses of woodland characteristics, only those collision points within an arbitrarily chosen 100 m of forest edges were considered.

At 10 m from the collision point and on each side of the fence, the slope at right angles to the fence was recorded in degrees with a clinometer. The two values

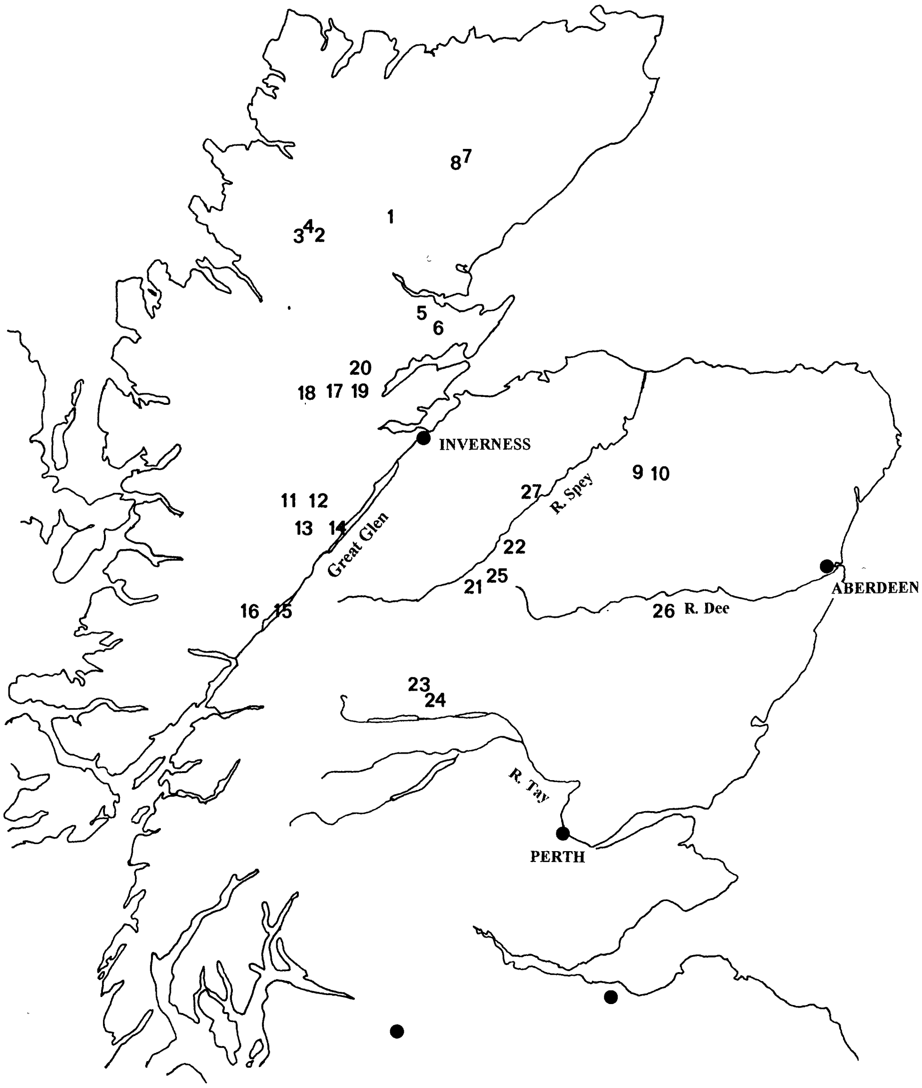

Fig. 1. Location of the 27 fence lines assessed for collisions. For site names see the Methods.

were then averaged. The slope along 20 m of fence was also recorded, the collision point being mid-way along the section. The preference of both capercaillie and black grouse for woodlands with a well-developed ericaceous ground layer, particularly of blaeberry *Vaccinium myrtillus, L.* but also heather *Calluna vulgaris* L., has been well described over several spatial scales (Cayford 1990; Picozzi, Catt & Moss 1992; Storch 1993; Moss & Picozzi 1994; Storch 1995). To assess whether collision sites were linked locally to these preferred foraging areas, the percentage cover of heather, blaeberry, cowberry *V. vitis-idaea* L. and grass was estimated visually on each side of the fence, and within a 10-m radius of each collision point. All trees within 10 m of the collision point on the fence were counted. The distances on each side of the collision point to the nearest tree over 1 m high and over 2 m high, within 45° on either side of a line at right angles to the fence, were measured. The profile of the ground perpendicular to the axis of the fence was scored as a uniform slope across the fence, the ground falling away on both sides of the fence (ridge), or the ground rising on both sides of the fence (hollow).

To test if collision points had habitat or physical features that were different from random points, logistic regression models were fitted for each species, introducing the following factors and variables after the site factor was fitted first: ground slope along the fence, ground slope at right angles to the fence, topography, fence type, woodland type, distance to nearest tree, number of trees and percentage ground cover by heather, *Vaccinium* spp. and grass. The binary-dependent variable was the status of each sample point, i.e. whether it was a collision point (1) or a random point (0). Factors and variables were initially included independently, and then in a step-up procedure, selecting the best univariate model and adding the next best-fitting variable, etc.

Results

BIRD SPECIES AND COLLISION RATES

A total of 281 collisions were recorded from 14 bird species (Table 1). Grouse species comprised 93% of the collisions. Red grouse hit fences most frequently

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Table 1. The total number of bird collisions found on 135 km of deer fence, broken down according to species, and the mean collision rate per km for grouse species. The total includes collisions from the first 'clear-up' visit. Mean collision rates are based on the number of sites (n) where each species was recorded having hit fences and excludes the 'clear-up' visit

		Collision rate per km		
Species	Total collisions	n	Mean	SD
Red grouse	188	21	1·1	1·3
Black grouse	37	12	0·4	0·8
Capercaillie	36	3	1·8	0·1
Wood pigeon	6			
Pheasant	5			
Others*	9			
Total	281			

*Blackbird *Turdus merula*, common gull *Larus canus*, kestrel *Falco tinnunculus*, redwing *Turdus iliacus*, short-eared owl *Asio flammeus*, woodcock *Scolopax rusticola*, fieldfare *Turdus pilaris*, snipe *Gallinago gallinago*, bullfinch *Pyrrhula pyrrhula* (each one collision).

and formed two-thirds of all collisions. Black grouse and capercaillie each comprised 13%. Wood pigeons *Columba palumbus* L. hit fences on six occasions in the autumn when feeding on berries of blaeberry in native pinewoods. Pheasants *Phasianus colchicus* L. collided with a single fence on five occasions. Several of the remains of passerines recorded next to fences may have been killed by raptors that had used the fence posts as perches to pluck them. The percentage of collisions resulting in a corpse being found varied between only 16% and 18% for the three grouse species ($\chi^2_4 = 6{\cdot}8$, NS).

In a trial that assessed whether corpses remained beside fences and were detected a month later, 18 of 20 red grouse corpses could no longer be found and it is presumed they were removed by scavengers. However, evidence of the collision, usually only feathers, was still detected at all but one site. Therefore, it is likely that most collisions were detected if the birds lost feathers, but the proportion of fatal strikes may have been grossly underestimated due to high rates of corpse removal.

Collisions by grouse species were recorded from all but four of the sites. Red grouse collisions were recorded from 21 sites (78%), black grouse 12 sites (44%) and capercaillie three sites (11%). For red grouse, only five sites had collision rates of more than one bird km^{-1} $annum^{-1}$ (maximum 4·4), only one site for black grouse (2·8) and three for capercaillie (maximum 1·8).

Total collision rates combining all three grouse species differed both between habitats ($F_{1,24} = 12{\cdot}39$, $P < 0{\cdot}01$) and between regions ($F_{1,24} = 53{\cdot}12$, $P < 0{\cdot}001$), and together explained 69% of the between-site variation in collision rates. Interaction between habitat, region and species of grouse could not be considered as no fences in native pinewoods were visited west of the Great Glen and only red grouse collisions were regularly encountered on fences surrounding pre-thicket plantations. Red grouse collisions rates, excluding forests with no collisions, were almost seven times higher in forests to the east of the Great Glen ($2{\cdot}7 \pm 0{\cdot}6$ SE km^{-1} $annum^{-1}$) than in forests west of the Great Glen ($0{\cdot}4 \pm 0{\cdot}1\,km^{-1}$ $annum^{-1}$) ($F_{1,17} = 58{\cdot}71$, $P < 0{\cdot}001$).

Red grouse collided with fences at 83% of the pre-thicket forest sites at a rate of 1·2 collisions km^{-1} $annum^{-1}$, but in only one native pinewood site (Table 2). Conversely, capercaillie were not recorded in pre-thicket forests, but hit fences in three of the four post-thicket forests, at a rate of 1·8 collisions km^{-1} $annum^{-1}$. Black grouse collided with fences in a quarter of pre-thicket stands and in half of the post-thicket forests at collision rates of 0·7 and 0·4 km^{-1} $annum^{-1}$, respectively. No significant differences in individual species collision rates between habitats were recorded.

SEASONAL TRENDS IN COLLISION RATES

The collision frequency distribution for each species differed between months; red grouse $\chi^2_{11} = 53{\cdot}10$, $P < 0{\cdot}001$, black grouse $\chi^2_3 = 11{\cdot}00$, $P < 0{\cdot}05$, and capercaillie $\chi^2_5 = 11{\cdot}39$, $P < 0{\cdot}05$ (Fig. 2). Data for black grouse and capercaillie were pooled into 3 and 2 month periods, respectively, to avoid small expected values. There were also seasonal differences between species ($\chi^2_4 = 20{\cdot}72$, $P < 0{\cdot}001$, data pooled for March–June, July–October and November–February). Red grouse collided with fences in every month, but almost two-thirds of all collisions occurred in spring (February–May). The peak month was March, with 21% of collisions. A similar trend was found for black grouse, with three-quarters of collisions taking place between March and July inclusive, with a peak of 24% in April. Only one collision happened in winter (November–February). Capercaillie collisions tended to occur later in the year than the previous two species, with a peak of 26% of collisions in September. In all, 84% of capercaillie collisions occurred between April and September.

COMPARISON OF COLLISION AND RANDOM SITES

The observed distances between nearest collisions showed no significant differences from the expected distributions ($\chi^2_5 = 8{\cdot}2$, $P = 0{\cdot}14$; $\chi^2_2 = 2{\cdot}2$, $P = 0{\cdot}34$; $\chi^2_2 = 1{\cdot}0$, $P = 0{\cdot}62$, for red grouse, black grouse and capercaillie, respectively), showing that there was no evidence of clumping.

Thirty-nine collisions (22%) by red grouse and black grouse were 100 m or more from forest edges. In contrast, 88% of collisions by capercaillie occurred on fences running through forest (between species $\chi^2_4 = 105{\cdot}7$, $P < 0{\cdot}001$). There was no difference in

Table 2. The percentage of forests recording collisions for each grouse species and the mean collision rates (collisions km^{-1} $year^{-1}$) in forests of differing types. Collision rates exclude forests where no collisions were recorded. *Includes one unplanted heather moor

	Pre-thicket plantations (n = 23)*		Native pinewood and mature plantations (n = 4)	
	% of sites with collisions	Collision rate Mean ± SE	% of sites with collisions	Collision rate Mean ± SE
Red grouse	83	1·2 ± 0·3	25	0·5 ± 0·5
Black grouse	26	0·7 ± 0·4	50	0·4 ± 0·1
Capercaillie	0	0	75	1·8 ± 0·1

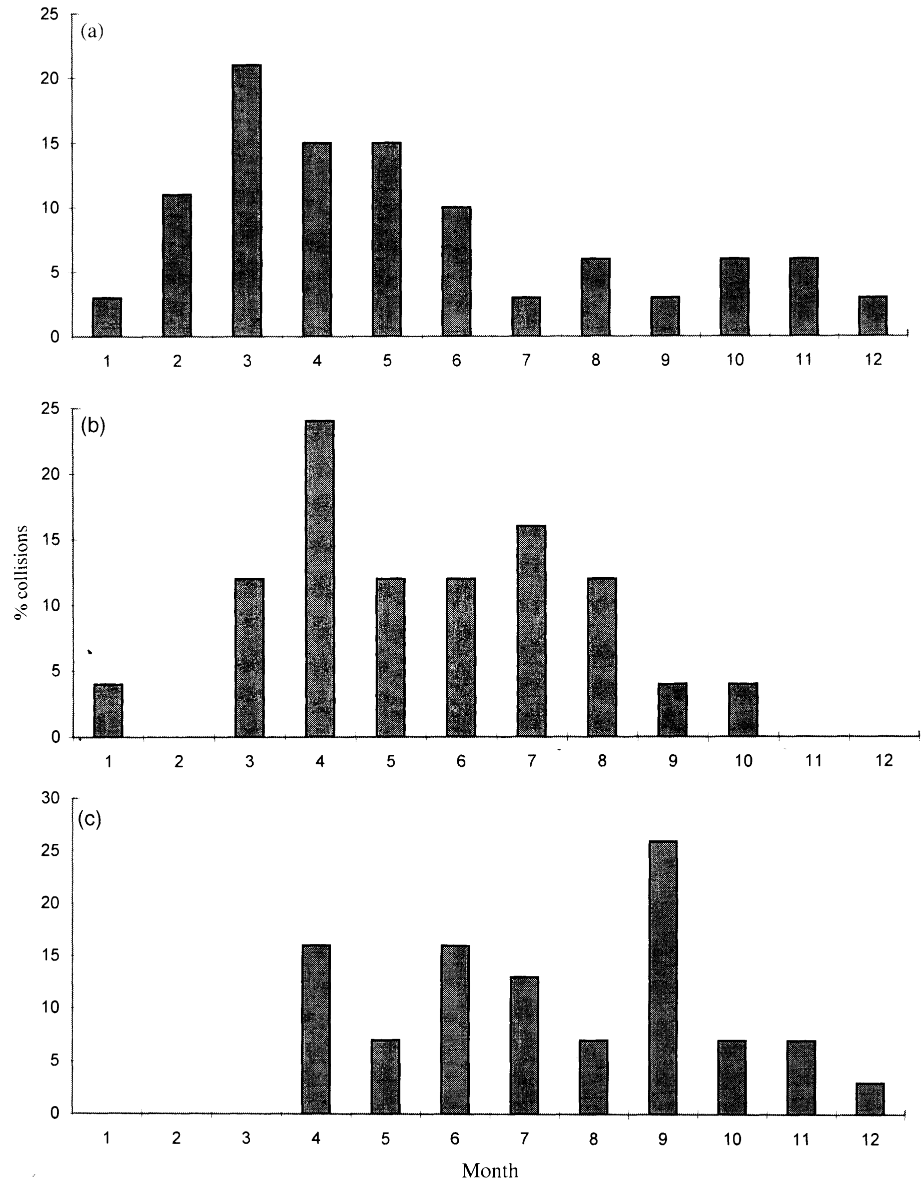

Fig. 2. Seasonal distribution of fence strikes for (a) red grouse (n = 115), (b) black grouse (n = 25) and (c) capercaillie (n = 31). Data have been combined for all sites, but exclude data from the 'clear-up' visit.

fence type, either mesh or strand line wire, between collision and random points.

Although most collisions (97%) occurred on flat or sloping ground, with few on ridges or in hollows, this merely represented the nature of the terrain adjacent to fences and there was no difference between collision and random points in topography. The logistic regression analysis did, however, indicate that the cover of *Vaccinium* was significantly higher at points where capercaillie had collided with a fence than at random points ($t = 2{\cdot}17$, $P < 0{\cdot}05$). No other variable had a significant effect when included in the model together with site and *Vaccinium* cover. An increase of 1 percentage point in the cover of *Vaccinium* resulted in an average increase of 4% for the probability of a point being a collision site rather than a random point. For black grouse, the cover of grass and heather was lower at collision sites than at random sites, both effects being significant when included together in a logistic regression model along with site (grass $t = 2{\cdot}96$, $P < 0{\cdot}01$; heather $t = 2{\cdot}37$, $P < 0{\cdot}05$). No other variable had a significant effect when included in the model together with site, grass and heather cover. An increase of 1 percentage point in the cover of grass resulted in an average decline of 14% in the probability of a point being a collision site rather than a random site. An increase of 1 percentage point in the cover of heather resulted in an average decrease of 10% in the probability of a point being a collision site rather than a random point. No habitat variables accounted for the collision sites by red grouse.

Discussion

This study has shown clearly that gamebirds are the main birds at risk from collisions with deer fences in the Scottish Highlands. The species of grouse most at risk was closely linked to the habitat surrounding the fence. Red grouse hit fences mainly around pre-thicket plantations prior to canopy closure. In contrast, deer fences running through native pinewoods were most hazardous to capercaillie, especially where fences ran through areas of preferred ground vegetation. Black grouse appeared equally at risk in both habitats.

The data presented show that collisions occur over a large geographical area at rates giving cause for concern, and hence are consistent with our suspicions that fences are a widespread and serious mortality agent. The study fences were not selected at random, and consequently the collision rates cannot be multiplied up by km of fence to make regional or national estimates of grouse deaths. Even so, death rates are difficult to assess as corpses can be removed by scavengers (Bevanger 1995; this study), or birds may hit fences, suffer crippling injuries and die up to 2 km from the collision point and hence not be detected (Heijnis 1980). Given these two forms of bias, the proportions of strikes known to be fatal in this study must be viewed as absolute minimum values. Further work in assessing more accurate mortality rates as opposed to collision rates is essential and currently in progress.

Despite not presenting mortality rates along randomly sampled fences, this paper does highlight the extensive nature of the problem and indicates where future management priorities lie (Petty 1995). Fences in native pinewoods present a considerable hazard to capercaillie, with three of the four fences having collision rates of almost two birds km^{-1} $annum^{-1}$. While the lower collision rates for red grouse should not be dismissed, results from this study suggest that fence collisions pose less of a conservation problem for this species, and one that may be largely restricted to the early stages of afforestation, as red grouse is primarily a bird of open moorlands.

Collision rates differed seasonally; most red and black grouse strikes occurred in the spring. This is unusual as bird densities are lowest at this time, but the timing does coincide with peaks in territorial and lekking display and may reflect increased general activity, including aggressive chases between males. In contrast, capercaillie collisions peaked in the autumn, a finding also reported by Catt *et al.* (1994b), which they attributed to young birds dispersing from their natal areas.

Collisions were concentrated within the preferred habitats of each grouse species, but within these habitats only ground vegetation variables significantly explained differences between collision and random sites. Capercaillie collisions were associated with more *Vaccinium*, while those of black grouse with less grass and heather. Unlike the previous study of Catt *et al.* (1994b), there was no direct association between capercaillie collisions and the proximity of the fence to trees, tree density or tree height. However, *Vaccinium* spp. tend to be more abundant where tree densities are higher (Moss & Picozzi 1994). Both studies found a negative association between black grouse collision points and the quantity of heather in the sward.

Low densities of grazing red deer are required for the successful regeneration of native pinewoods (Darling 1947; Beaumont *et al.* 1995). Long-term expansion of native pinewood habitat is considered to be essential for the future health of capercaillie populations, as 'old forest' typified by native pinewoods is believed to be their core habitat (Picozzi *et al.* 1992). Achieving this by fencing to exclude red deer creates a dilemma. In the short term, fences are a considerable hazard. Any benefits of improved ericaceous ground vegetation, which is important for adult woodland grouse, and in the associated invertebrates, important for their chicks, following deer exclusion (Baines, Sage & Baines 1994), may be nullified by increased mortality through collisions.

The ideal solution is to reduce deer densities to levels where regeneration of trees will occur without fencing (Petty 1995). Successful regeneration following increased deer culls has been demonstrated in three Highland native pinewoods: The Black Wood of Rannoch (Innes & Seal 1971), Inshriach and Abernethy Forest (Beaumont *et al.* 1995). Other estates should be strongly encouraged to adopt a similar approach to deer management and woodland regeneration if they value the woodland grouse in their forests. Red deer densities are frequently at 15–20 animals km^{-2} (Clutton-Brock & Albon 1989), and it is only when these are reduced to about six animals km^{-2} that regeneration of Scots pine will start (Holloway 1967).

Despite the argument of Buckland *et al.* (1996) that on most Scottish estates hind numbers can be substantially reduced without incurring a decrease in the number of stags for stalking, we accept that some estates with strong stalking interests will be unable or unwilling to increase deer culls by the necessary amount, and fencing may be the only way to achieve forest regeneration. Where this is the case, fence lines should be sited with extreme care, particularly in areas known to be important for woodland grouse. Fences should not pass through the vicinity of display grounds (leks), preferred feeding areas (*Vaccinium* areas for capercaillie), or along flight lines linking the two. Catt *et al.* (1994b) recommended that new fences should not be sited within 25 m of forest edges, that old fences should be removed as soon as their purpose has been met and that existing problem fences should be marked with heather or coloured netting. Experimental marking trials using bright plastic netting in an attempt to make fences more obvious are being conducted. Initial work has shown that 'marked' fences still kill birds, but their effectiveness in reducing collisions remains to be determined. We recommend that fences in pinewoods and mature pine plantations where capercaillie are known to occur should be monitored for fence strikes and consideration giving to moving or marking sections with regular strikes.

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