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Roads do not increase predation on experimental nests in a highly fragmented forest landscape

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A b s t r a c t . Modern forestry may alter avian reproductive success indirectly through affecting predator-prey interactions. Here we evaluate the influence of road types on nest predation of ground-nesting birds in a highly fragmented forest area interspersed by a dense network of roads and forest paths, with one third of the area covered by a red-deer enclosure. Experimental nests (n = 276) resembling black grouse (*Tetrao tetrix*) nests were proportionally installed along three types of roads discriminated by utility (road type, from frequently used to unused: tarred roads, gravel roads and forest paths) and inside/outside the red-deer enclosure. The nests were placed in couples, with one nest placed close to the road edge and the second placed inside the surrounding forest habitat to assess the "travel line" hypothesis. The "travel line" hypothesis was not supported because there was a similar predation rate among edge and interior nests. Even if predators can be discouraged along busy roads, type of road also did not affect nest predation. Nevertheless, nest predation inside the enclosure was significantly lower than in the surrounding, suggesting that frequent human disturbances in these habitats may have a repellent effect on predators of ground nests.

Key words: artificial nest predation, black grouse, enclosure, red fox *Vulpes vulpes*, traffic, travel line hypothesis

Introduction

Modern forestry has dramatically altered the habitat composition and spatial configuration of forest landscapes in Europe. These changes have a negative effect on birds, both directly through reduction of suitable habitats or indirectly through interspecific interactions like nest predation, a process considered the most serious cause of nesting failure in birds (R i c k l e f s 1969, M a r t i n 1995). Anthropogenic forest fragmentation and the resulting edge effect has been identified as the proximate reason for high nest predation of some birds (e.g., S m a l l & H u n t e r 1988, K u r k i et al. 2000, but see V a n d e r H a e g e n & D e G r a a f 1996). Nests in edge habitats may suffer from higher predation than those in habitat interiors (S t o r a a s & W e g g e 1987, B a y n e & H o b s o n 1997, but see S t o r c h 1991), because some predators are attracted by the more diverse food available along the edges (P r i m a c k 1993, C h a l f o u n et al. 2002), or use edges as travel corridors, which leads to stronger predation (V i c k e r y et al. 1992). Similarly, forest margins along roadsides may be considered as edges or travel corridors for some predators (B e s t 1986, W a r n e r 1994).

Surprisingly, there have been few studies of the effects of road edges on bird populations in forest landscapes (K u i t u n e n et al. 1998, 2003). A few relevant studies from agricultural habitats (e.g., grasslands) have pointed to lower breeding density or reduced nesting success of birds along roads (R e i j n e n et al. 1996, C a m p & B e s t 1994, B r o t o n s & H e r r a n d o 2001). However, an opposite result (higher predation on nests situated far from roads), found in forest habitats in Illinois (M a r i n i et al. 1995), indicates that predators avoid road edges due to the frequent presence of humans in these habitats. There has been no evaluation of the effect of different road types on nesting success in a highly fragmented forest landscape in central Europe.

The main goal of this study was to evaluate the "travel line" hypothesis, which assumes that predators use the margins of forest roads and prey on edge nests more frequently than on nests placed further from the edge. Secondly, we assess the disturbing effect of different road types on nest predation. We supposed a lower predation rate closer to roads with a higher traffic load (B e r g i n et al. 1997) because cautious predators such as the red fox *Vulpes vulpes* (the most common nest predator of ground nests in the study area; S v o b o d o v á et al. 2004) may tend to avoid this habitat. Additionally, since a part of the study area was situated within a red-deer (*Cervus elaphus*) enclosure that is strongly disturbed by regular activities of forest managers and numerous hunters, we tested the hypothesis that nest survival rate inside this enclosure would be higher than in the surrounding, less disturbed area (G e r i n g & B l a i r 1999).

Study Area

The experiment was conducted in the eastern part of the Krušné hory Mts, Czech Republic. The study area of 33 km^2 was situated between the villages of Klíny and Dlouhá Louka (50°38´ – 50°42´ N, 13°33´ – 13°39´ E, 750 – 870 a.s.l.). The landscape consists of three main habitats: young forests (10–30 years; 60% of the total area), open habitats (30%) and mature spruce forest fragments (10%). Young forests are continuously planted on the air-polluted clearcuts created after long-term impact of industrial emissions during the 1970s. However, this reforestation process has not been successful in some areas due to the spread of bushgrass (*Calamagrostis villosa*), causing succession slowdown (S ý k o r a 1983). The forest fragments and clearcuts are highly interspersed with a dense network of interconnected roads and paths due to intensive forest management. Moreover, a red-deer enclosure with many small pasture fields for numerous deer covers one third of our study area.

The dominant potential predators for ground nests in the study area are medium-sized mammals (red fox, pine marten *Martes martes*) while corvids such as crow (*Corvus corone*), raven (*C. corax*) and European jay (*Garrulus glandarius*) were found only rarely (S v o b o d o v á et al. 2004).

Methods

E x p e r i m e n t a l d e s i g n

Given that the predation pressure on artificial nests had been found to be similar among three types of habitats representing different successional stages in the area during a previous study (S v o b o d o v á et al. 2004), the experimental nests in this work were laid only in dominant

young growths. This habitat is considered to be the most important for nesting of black grouse, which is the dominant ground-nesting game bird species in the Krušné hory Mts (Šímová 1996). We installed a total of 300 artificial nests with an even distribution along three road types differing by the level of human disturbance: (1) tarred roads, used most frequently by forest managers and by public transport, (2) gravel roads, employed less frequently by managers and walking tourists or bikers, and (3) unstabilized forest paths, used rarely by managers and occasionally by walking tourists. The nests were placed randomly along both sides of the roads. Following the above pattern, one third of all nests were distributed in the red-deer enclosure.

The nests were laid in couples so that one nest was placed at the edge ("edge nests") while the second nest was placed inside the growth ("interior nests"). The mean distance between the nearest nests was 100 m. The nests were laid close to coniferous tree branches and were left at least 75% visible from an above vertical view.

The edge habitat was defined as a 10 m strip directly adjacent to the rim of the road, and the interior habitat as that at least 50 m from the road (Paton 1994). Before the start of the field experiment, the nest positions were digitalized with the use of GIS software and aerial ortho-photomaps (ArcView GIS 3.2a; Environmental System Research Institute, Redlands, California, USA), to ensure all defined habitat and distance criteria. Then the geographic coordinates of the nests were copied into the GPS to guarantee exact location in the field.

The artificial nests were constructed by digging small ground depressions laid out with small amounts of dry plant material, to mimic natural black grouse nests in general appearance (Glutz von Blotzheim et al. 1981). Each nest was baited with two domestic hen eggs, the size and brown coloration of which resembles grouse eggs.

The experiment was initiated during the second week of June 2003, which corresponds with the black grouse's incubation period in the Czech Republic (Hudec & Šťastný 2005). All nests were deployed during daytime within a period of two days. Rubber boots were used to prevent interference from human scent. Each nest was checked only once after a 21-day exposure according to the length of black grouse incubation period (Glutz von Blotzheim et al. 1981). A nest was considered depredated when at least one of the two installed eggs was damaged, removed from the nest bowl or missing.

Data analysis

The fates of the individual nests (dependent variable) were fitted using a logistic regression in a generalised linear model with a binomial distribution (referred to as GLM_{binom}) where road, enclosure, nest position (edge or interior) and their interactions represented the explanatory variables. The significances of the particular variables were controlled for all other effects, being fitted last in the models (significances based on Type III Sum of Squares, Crawley 2002), non-significant interactions were omitted (all $P > 0.189$). The statistical analyses were performed with S-PLUS for Windows (S-PLUS 1999).

Results

In total, only 276 nests were analysed from the 300 originally baited, because 16 of them could not be relocated and eight were destroyed by factors other than predation (five by forest work, three were trod by animals or human). Total nest predation achieved 76%.

Contrary to the prediction of the "travel line" hypothesis, no difference was found in predation rate between edge (73%) and interior nests (79%; $F_{1,272} = 1.427$, $p = 0.23$). Similarly, nest predation was not either significantly associated with the road type ($F_{2,272} = 2.482$, $p = 0.12$; tar roads 71%, gravel roads 78%, forest path 79%). Only the enclosure had a marginally positive effect on nest survival ($F_{1,272} = 3.892$, $p = 0.051$). Nests positioned outside the enclosure suffered higher predation (79%) than nests within the enclosure (68%; Table 1).

Table 1. Total numbers and numbers of depredated nests in particular habitats under study in the Krušné hory Mts, 2003.

habitat	edge		interior	
	depredated	total	depredated	total
tar road	27	45	38	47
gravel road	37	46	36	48
forest path	34	44	37	46
out enclosure	68	91	79	95
in enclosure	30	44	32	46

Discussion

In general, nests can be expected to be more depredated closer to roads, given that some predators use roads as travel corridors (Van der Zande et al. 1980, Reijnen et al. 1995). However, our data does not support the "travel line hypothesis", because edge and interior nests were depredated with a similar intensity. We therefore conclude that major predators on the study plots, such as fox and martens (Svobodová et al. 2004), used the habitats within the landscape mosaic equally without an obvious preference for line habitats (e.g., Rudnicky & Hunter 1993, Hanski et al. 1996, Carignan & Villard 2002, also Svobodová et al. 2004). It is possible that mammalian predators prefer line habitats as travel corridors particularly in areas with large and continuous forest units (Small & Hunter 1988), while roads become unimportant for them in highly fragmented landscapes such as our study area.

Opposite result, a lower predation rate along roads, was confirmed in fragmented forests in Illinois (Marini et al. 1995) where predators were apparently discouraged by frequent human presence close to roads. This finding is supported by our results since our investigation revealed a lower predation rate inside the enclosure than outside. In the enclosure predators can be disturbed by frequent human activities associated with regular operations there (construction of a haylofts and hides, cultivation of pasture fields, plantations of seedlings). Unfortunately, there are no quantitative estimates of the disrupting effects inside and outside the enclosure, only the fact that all nests destroyed by activities of foresters were positioned inside the enclosure. Alternatively, we might expect lower nest predation in the enclosure as a result of predator control. However, hunting statistics from years 2000–2003 showed that shooting bags of foxes in the enclosure were lower than elsewhere in the Krušné hory Mts (Hunting Associations of the Krušné hory Mts, unpublished data), suggesting that the densities of these predators were lower in the enclosure than outside it. Another possible explanation might be that predators sufficiently exploited available food (small mammals) in pasture fields in the enclosure and therefore their alternative prey (nests) experienced lower failures (Šálek et al. 2004). However,

the results of seven-year study on small mammal communities showed similar densities of small mammals in all parts of the study area or even slightly higher outside the enclosure (V. B e j č e k et al., unpublished data).

In conclusion, habitats close to roads probably did not act as edges in highly fragmented landscape because no increased predation rate has been observed there. In any case, this does not mean that foresters should plan new roads without taking wildlife into account. The effects of roads may vary with species (H e l l e 1983) as well as predation rate in relation to landscape structure (B e r g i n et al. 2000). Nevertheless, areas with frequent human disturbances like enclosures appear to provide a relatively safe nesting habitat for ground-nesting birds, at least in terms of reduced risk of predation.

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