

The effect of landscape fragmentation and habitat variables on nest predation of artificial ground nest in the Bohemian Forest

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Abstract

Nest predation risk of ground nests in relation to habitat fragmentation patterns and microhabitat features was studied in the Bohemian Forest (Czech Republic) during the years 2005 and 2008. We used artificial nests to assess the validity of the edge effect hypothesis on nest predation and for determination other factors influencing predation rate. We placed nests along the edge and interior of forest patches located in highly fragmented agricultural land and closed forest landscape to find out if predation on artificial nests in forest patches was influenced by surrounding landscape type. More than half (52%) out of total 317 artificial clutches was destroyed. The predation rate was similar for edge and interior areas and among two habitat types, suggesting that nests of endangered ground nesting species, such as the hazel grouse (*Bonasa bonasia*), are not exposed to increased predation risk in habitat edges in studied area. The positive correlation was found between the nest predation and visibility of the nest. Based on egg remnants found in destroyed nests, we suppose that the main egg predators were mammals – martens (*Martes* spp.), red fox (*Vulpes vulpes*), and wild boar (*Sus scrofa*).

Key words: artificial nest predation, *Bonasa bonasia*, edge effect, habitat fragmentation, hazel grouse, Šumava Mts.

INTRODUCTION

Avian nest loss in forested environments may be attributed to numerous factors and nests predation is believed to be the most significant of them (GATES & GYSEL 1978, BAINES 1991, HANSKI et al. 1996, KURKI et al. 1997, CAIZERGUES & ELLISON 2000, SANIGA 2002). Analysis of nest predation and habitat characteristics relationship affecting predator abundance and behavior provides useful information for future management to stop declining population trends in many avian species. Habitat fragmentation, which leads to increasing amount of habitat edges, belongs to one of the most important environmental factors affecting the occurrence of predators and subsequent growing predation rate. Edges may alter the distribution, abundance, and behavior of organisms, which has been termed “the edge effect” (MURCIA 1995).

Fragmentation of habitat creates spatial variations in predation risk of forest birds with a tendency to higher losses near edges than inside homogenous areas of habitat (GATES & GYSEL 1978, CHASKO & GATES 1982, ANDRÉN & ANGELSTAM 1988, ANDRÉN 1992, BAYNE & HOB-

SON 1997, FENSKE-CRAWFORD & NIEMI 1997, SUN et al. 2003, SANIGA 2002, BATÁRY & BÁLDI 2004) and often also for increasing predation risk with decreasing patch size (ANDRÉN & ANGELSTAM 1988, MOLLER 1988). Predators can be attracted by a higher and more diverse food supply in the forest edges (GATES & GYSEL 1978, CHASKO & GATES 1982, CHALFOUN et al. 2002) or use habitat edges as travel corridors, thus increasing predation pressure there (VICKERY et al. 1992). Similarly, forest margins along roadsides may be considered as edges or travel corridors for some predators (BEST 1986).

Despite this theoretical reasoning, the generality of the edge effect hypothesis has been debated. Many contradictory results exist, particularly in forested landscapes, where no edge effect has been often recorded (ANGELSTAM 1986, RATTI & REESE 1988, YAHNER et al. 1989, STORCH 1991, NOUR et al. 1993, RODEWALD 2002). These conflicting results may be explained partly by the mediation of edge effects by other landscape characteristics that finally may determine local edge effects (ROBINSON et al. 1995, DONOVAN et al. 1997, MORSE & ROBINSON 1999), such as extent of landscape fragmentation (ROBINSON et al. 1995, DONOVAN et al. 1997, HARTLEY & HUNTER 1998, ZANNETE & JENKINS 2000, TEWKSBURY et al. 2006), patch size (PATON 1994), and in particular the types of surrounding matrix (ANDRÉN 1992, ABERG et al. 1995, ASKINS 1995, FRIESEN et al. 1995, BAYNE & HOBSON 1997, FIENSKE-CRAWFORD & NIEMI 1997, BATÁRY & BÁLDI 2004, TEWKSBURY et al. 2006). Nest predation on habitat edges increases with increasing contrast of productivity between neighbouring habitats (ANGELSTAM 1986, LAHTI 2001). Understanding of large-scale patterns of nest predation may help identify and protect species vulnerable to changes in habitat composition and to habitat fragmentation, such as ground nesting galliforme birds.

Currently is hazel grouse (*Bonasa bonasia*) the only species from protected tetraonid birds in the Bohemian Forest that is not directly endangered (ČERVENÝ et al. 2000). Nevertheless, increased fragmentation of contiguous forest in this area may change the distribution and composition of their populations because of their habitat destruction. The quantity and quality of available breeding habitat is crucial factor influencing population density. Hazel grouse as a habitat specialist, non-migratory bird with low dispersal ability, is very sensitive to fragmentation of suitable habitat (SWENSON 1995, ABERG et al. 1995, 2000, SAARI et al. 1998, KLAUS & SEWITZ 2000). It is widely agreed that forestry management plays crucial role in the decline of European tetraonid birds in general (STORCH 2000, 2007, MIETTINEN et al. 2008, but see SIRKIÄ et al. 2010).

Because of the difficulties with searching of hazel grouse nests, we based our studies on an artificial nest experiment. Artificial nests commonly have been used to test relationships between nest predation and potentially influential factors (ANGELSTAM 1986, RATTI & REESE 1988, STORAAS 1988, WILLEBRAND & MARCSTRÖM 1988, YAHNER & VOYTKO 1989, DONOVAN et al. 1997, KING et al. 1999, RANGEN et al. 2000, ZANNETE & JENKINS 2000, ZANNETE 2002). By using artificial nests, we can determine local predator composition, but reflect only relative, no absolute predation (WILLEBRAND & MARCSTRÖM 1988, KING et al. 1999, ZANNETE 2002).

Although the major part of the Bohemian Forest is protected as national park or protected landscape area, there is permanent risk of continuing fragmentation of dominating mountain spruce forests caused by bark beetle gradation and subsequent logging. Current forest management in the Bohemian Forest, therefore, leads to potential threats of previously stable population of tetraonid birds in general.

From reasons mentioned above, we have been focused on determination whether forest fragmentation and composition belongs to the important variables influencing nest predation of artificial ground nests resembling natural galliform bird nests. Outputs of such analysis would be undoubtedly helpful for species management in both national parks as well as unprotected fragmented forest landscape.

The main goals of our study were: (i) to assess the validity of “edge effect hypothesis on nest predation” in one of the largest forest area in Central Europe, the Bohemian Forest; (ii) to determine the effect of increased forest fragmentation on nest predation by comparison nests in forest landscape type and agriculture landscape type; and (iii) to find out if nest characteristic (visibility, character of biotope around nest) affect predation rate.

MATERIAL AND METHODS

Study area

The field work took place in the Bohemian Forest (Šumava in Czech), in the southern part of the Czech Republic, during spring 2005 and 2008. The vegetation of the upper part of the Bohemian Forest is dominated mainly by Norway spruce (*Picea abies*), either as a natural species forming mountain spruce forests (montane *Calamagrostis* spruce forest or bog spruce forest) or as a planted species in managed forests. Dominating trees species in the valleys and around waterlogged areas are alder (*Alnus glutinosa*), willow (*Salix* spp.), birch (*Betula pendula*), pine (*Pinus sylvestris*), and hazel (*Corylus avellana*). The area is a mosaic of small patches of different forest types and succession stages. Large scale forest fragmentation by meadows and clear cuts is widely presented mainly in lower parts.

In 2005, we made an experiment in the western part of the Bohemian Forest. The study area of 60 km² was situated between the villages of Srní and Jiříčná (49°4′–49°12′N, 13°27′–13°26′E, 580–1125 m a.s.l.; Fig. 1). To determine the effect of forest fragmentation on nest predation, two different landscape types were chosen for the experiment (Fig. 2). Southern part of study area (in the Šumava National Park) represents a forest dominated landscape with sparsely scattered meadows often overgrown by forest succession (Fig. 2A). Of this area 87% is covered by forest and edge density is 50 m per ha. Northern submountain part is represented by highly fragmented landscape – mosaic of forest patches within agricultural land (Fig. 2B). This area is covered by forest only on 37% and edge density is 143 m per ha. Both areas had approximately equal size (30 ha). The altitude was between 600–1125 m a.s.l. in the southern part and between 580–850 m a.s.l. in the northern submountain part. This study area provides ideal opportunity for comparison predation pressure in naturally patchy and human-fragmented landscape. Altogether 232 nests were exposed to predation in 2005.

The second experiment in 2008 was carried out throughout all area of the Bohemian Forest (Fig. 1) in different types of biotopes. Several variables were measured and calculated in order to determine if predation on artificial nests is influenced also by forest stand type and vegetation structure or other factors. We measured the visibility of the nests (vertical view in %), distance to the tracks and vegetation characteristic in a radius of 25 m (tree species diversity, surface vegetation coverage, type of the forest). Seven study sites were selected in order to cover all main habitat types of hazel grouse occurrence in the Bohemian Forest. In total 85 nests was involved in experiment in 2008.

Artificial nests and identification of potential predators

Artificial nests were constructed by digging small ground depressions laid out with small amounts of dry plant material. Three quail eggs were inserted in each nest. The size and colour of quail eggs resembled hazel grouse eggs. One of the eggs was filled with bee wax for predator identification and was fixed with a string to prevent egg loss by carrying away by the predator. Every nest location was marked with a short piece of flagging tape for easier rediscovering. To evaluate the generality of the edge effect on nest predation, we placed 232 nests in 2005, with half nests placed 5 m from the habitat boundary and a half 100 m

from habitat edge (habitat interior). Nests were placed at a distance of 150 m from each other (ŠÁLEK et al. 2004, SVOBODOVÁ et al. 2007) to minimize the probability of being discovered during a systematic searching by a predator. Both years the eggs were placed during the first week of June, when the most of the hazel grouse hens in Czech Republic start incubating (HUDEC & ŠTASTNÝ 2005). Every year, all nests were deployed during 3 following days. Rubber boots and gloves were used with the aim of eliminating human scent. Each nest was checked only once after a 23 days exposure period, which also coincides with the mean length of the species incubation period (GLUTZ VON BLOTZHEIM et al. 1973). At the end, eggs or eggs fragments were removed. The visibility of the nest was measured from an above vertical view (according to SVOBODOVÁ et al. 2004, 2007, ŠÁLEK et al. 2004).

A nest was considered to be depredated when at least one of three installed eggs was damaged, removed from the nest, or completely missing. Nests predators were identified from indirect evidence based on tooth or beak marks remaining on the wax eggs, from droppings, feathers, and tracks found around nest. Since it was difficult to separate mammalian predators, all were lumped together except in those cases when clear evidence was available

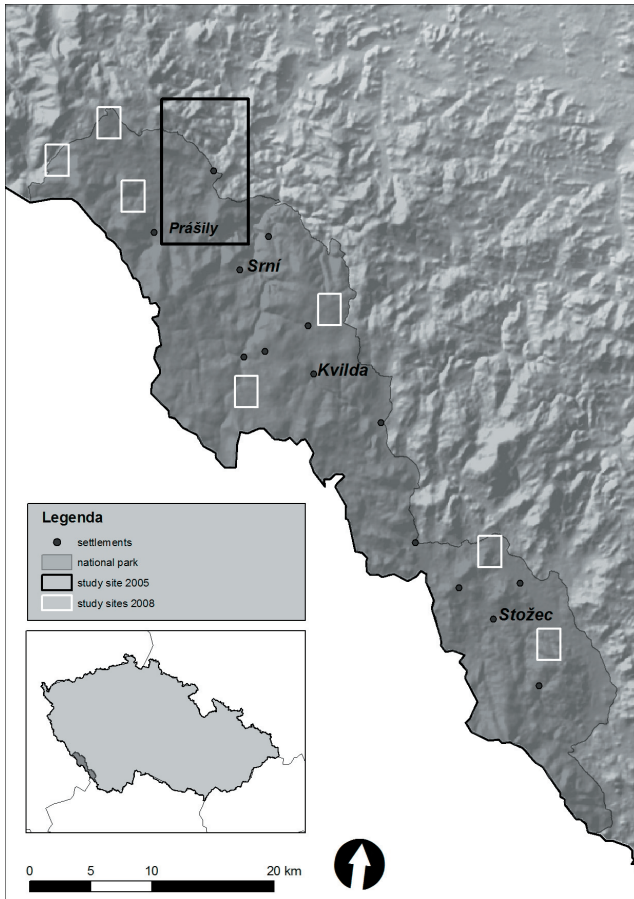


Fig. 1. The study areas in the Bohemian Forest in 2005 and 2008.

(tracks, clear tooth marks). In two cases we also used the camera traps as an alternative method for predator identification (MARINI & MELO 1998). The camera was installed during all exposing time of nest to know, what happened on the nest.

Wax-filled eggs were often damaged by rodents from the side of string insertion. These eggs were included in the analysis, but classified as not predated. Rodents cannot be considered as predators of quail eggs, because of the relatively strong quail's eggshell (HASKELL 1995).

Potential hazel grouse egg predators in study area were corvid birds, particularly European jay (*Garrulus glandarius*), crow (*Corvus corone*), and common raven (*Corvus corax*). Among mammals, it could be red fox (*Vulpes vulpes*), pine marten (*Martes martes*), stone marten (*M. foina*), small mustelids (*Mustela erminea*, *M. nivalis*), wild boar (*Sus scrofa*), and European badger (*Meles meles*). Foxes are very abundant species in all types of biotopes from the lowest elevations of the study area up to the top parts (shooting average in the foothills is 0.92 ind.km² and up 0.27 ind.km² in the upper parts; ANDĚRA & ČERVENÝ 1994).

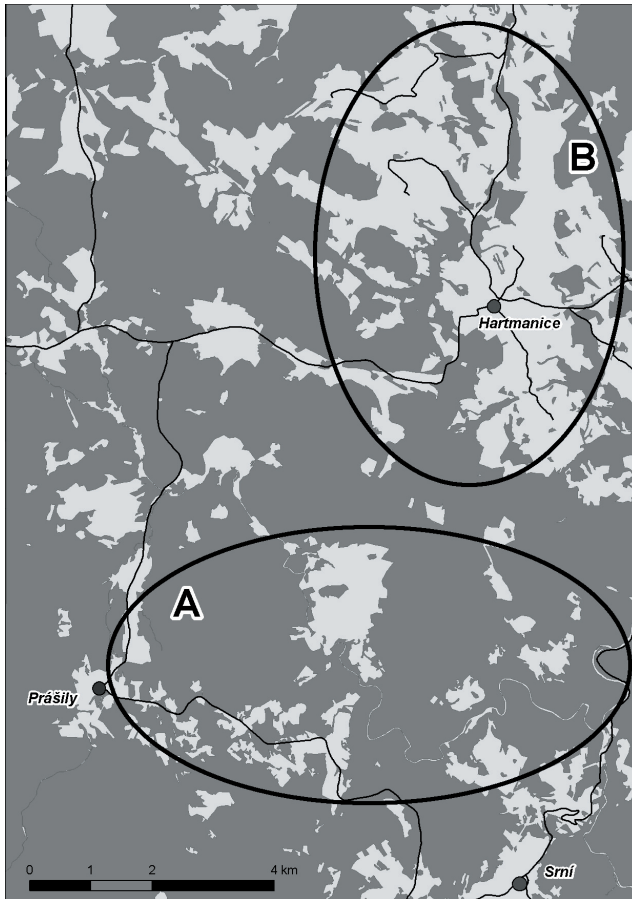


Fig. 2. The study area with two different zones (grey colour indicates forest) in 2005: A – forest dominated landscape, B – highly fragmented landscape.

Data analysis

The first experiment held in 2005 was designed using digital data on land cover (ZABAGED 2009) in GIS (ArcGIS 9.2. ESRI). Proportion of forest was calculated on basis of ZABAGED 2009 database. Various measures of forest fragmentation were calculated for both parts of study area using V-LATE (Vector-Based Landscape Analysis Tools for ArcGIS 9), but only forest edge density was used for further analysis. Artificial nests were distributed according to results of analysis of forest fragmentation in pair test design.

Most of the habitat variables during the experiment in 2008 were obtained by field work (nests visibility and vegetation characteristics), only distance to the forest tracks and roads was calculated using GIS. The analysed environmental variables included: distance to forest/non-forest edge (EDG); distance to paths and forest tracks (PATH); nest visibility (VIS); total share of spruce individuals (SPRUCE); tree species diversity (DIV); and surface cover (SURF).

To evaluate factors affecting nest predation probabilities, we used generalized linear models that assumed binomial distribution of dependent variable (logit link function; CRAWLEY et al. 2007). Nest fate (0-surviving, 1-predated) was treated as binary dependent variable in these models. Best models were selected using backward elimination of non-significant terms, starting with interactions. The significance of a particular term in models was based on the change in deviance between the full and reduced/null models, distributed as χ^2 with degrees of freedom equal to the difference in the degrees of freedom between the models with and without the term in question. Presented are the best supported models, i.e., models with all terms significant. All calculations were done using R 2.8.1 for Windows (R DEVELOPMENT CORE TEAM 2009).

RESULTS

The predation rate on artificial nests was monitored on a sample of 317 nests during 2005 and 2008. The fate of all nests represents Table 1. Our results indicate that the main predator of artificial nests in the study areas were mammals. Red foxes and martens were responsible for depredation of most of the nests from mammals. This was also supported by pictures from triggered cameras. Foxes or martens were captured by 4 camera traps used on 4 different nests.

Results of the model evaluating the effect of nest position in relation to habitat edge (forest edge, forest interior) and habitat type (fragmented vs. forest dominated landscape) and interaction between habitat type and nest position indicated that nest predation events were randomly distributed (Tables 2 and 3). The model indicated that patterns are similar in fragmented and unfragmented landscapes (effect of edge: landscape type interaction: $\chi^2 = 0.019$, $P = 0.89$, $\Delta Df = 1$). Predation rates did not significantly differ between edge and interior sites (edge effect: $\chi^2 = 0.017$, $P = 0.89$, $\Delta Df = 1$). No differences in predation rate were also observed between nests in highly fragmented landscape and forest dominated landscape ($\chi^2 = 0.011$, $P = 0.74$, $\Delta Df = 1$; Fig. 3).

In 2008, we evaluated factors affecting nest predation in forest interiors at a finer scale. The results indicated that nest visibility was a sole predictor of nest fate (null model vs. final model: $\chi^2 = 11.06$, $P < 0.001$, $\Delta Df = 1$, slope: 0.026 ± 0.008 , Fig. 4). In addition to nest visibility, data suggested marginally nonsignificant effect of the proportion of spruce around the nest (effect of spruce in addition to nest visibility: $\chi^2 = 3.31$, $P = 0.07$, $\Delta Df = 1$, slope: 0.017 ± 0.009), when density of spruce is positively correlated with predation rate. Other monitored characteristics (Table 4) did not statistically influenced predation rate (all $P > 0.1$) and did not enter the final model.

Table 1. The fate of the artificial nests in 2005 and 2008.

Year	Total number of artificial nests	Predated (% of total)	Predated by mammals (% of predated)
2005	232	103 (44%)	93 (90%)
2008	85	62 (73%)	49 (79%)
Total	317	165	142

Table 2. The fate of the artificial nests in 2005 in forest dominated landscape (comparing between edge and interior areas).

Nest position	Total number of artificial nests	Predated (% of total)	Predated by mammals (% of predated)
Edge	60	26 (43%)	23 (88%)
Interior	60	26 (43%)	24 (92%)
All	120	52	47

Table 3. The fate of the artificial nests in 2005 in highly fragmented landscape (comparing between edge and interior areas).

Nest position	Total number of artificial nests	Predated (% of total)	Predated by mammals (% of predated)
Edge	56	20 (36%)	19 (95%)
Interior	56	31 (55%)	27 (87%)
All	112	51	46

Table 4. Monitored characteristic and their influence of predation rate in 2008. EDG – distance to forest/non-forest edge, PATH – distance to paths and forest tracks, VIS – nest visibility, SPRUCE – total share of spruce individuals, DIV – tree species diversity, SURF – surface cover; Df – degrees of freedom, AIC – akaike information criterion, LRT – likely ratio test , P – probability level.

Environmental variable	Df	Deviance	AIC	LRT	P
EDG	1	68.276	82.276	0.6554	0.418
PATH	1	67.623	81.623	0.0021	0.963
VIS	1	79.372	93.372	11.751	0.001
SPRUCE	1	70.861	84.861	3.2406	0.072
DIV	1	68.370	82.370	0.7496	0.387
SURF	1	67.639	81.639	0.0185	0.892

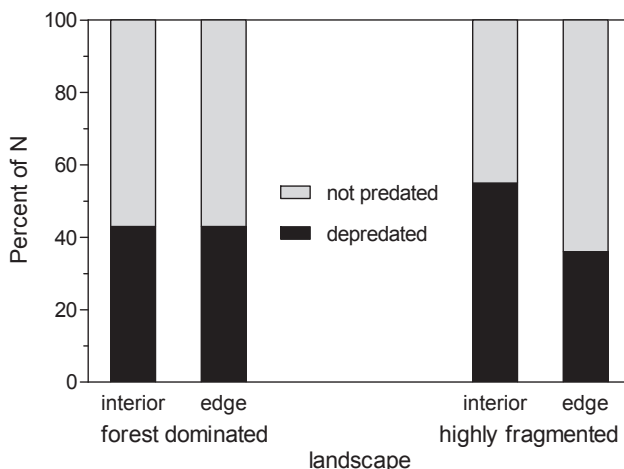


Fig. 3. Nests predation in 2005. Comparison of predation rate between nests in forest dominated landscape (N = 120) and highly fragmented landscape (N = 112).

DISCUSSION

Using artificial nests we assessed nest predation rates in different types of habitat and landscape matrix in areas of hazel grouse distribution. We expected that nest predation rate tends to increase along edges of forest patches, as found in many previous studies (GATES & GYSEL 1978, CHASKO & GATES 1982, STORAAS & WEGGE 1987, ANDRÉN & ANGELSTAM 1988, ANDRÉN 1992, PATON 1994, BAYNE & HOBSON 1997, FENSKE-CRAWFORD & NIEMI 1997, SANIGA 2002, BATÁRY & BÁLDI 2004). Negative influence of such ecotones on nest predation rate is mainly explained by increasing diversity and abundance of generalist predators along edges, attracted to edges by higher diversity and supply of food (BAINE & HOBSON 1997). However, we cannot support the hypothesis of negative edge effect on nest predation based on our data. We found that the same predation pressure acts near habitat edges and on forest patches interior. Results of our study correspond with findings of ANGELSTAM (1986), RATTI & REESE (1988), YAHNER et al. (1989), NOUR et al. (1993), LAHTI (2001), RODEWALD (2002), and SVOBODOVÁ et al. (2004). These results could be explained by the same prey and/or predator densities along edges as in non-fragmented habitats. Predators can also be habitat specialists and do not move between habitats and cross edges, or are equally abundant in both habitats and do not show any directional movement and concentration along edges. There are also some alternative hypotheses to explain heterogeneity in nest predation along edges. Different results can originate from many individual factors such as different productivity of the adjacent habitats (ANGELSTAM 1986, BAYNE & HOBSON 1997, DONOVAN et al. 1997, HARTLEY & HUNTER 1998). Higher predation rate in the surroundings of edges is often detected in highly fragmented forest/farmland mosaic, where a steep gradient in primary productivity across the edge is detected (ANGELSTAM 1986, BAYNE & HOBSON 1997, DONOVAN et al. 1997, BATÁRY & BÁLDI 2004). High nest predation near edges in agriculture landscape can be attributed to increasing number of predator community adapted to human settlement, attracted there to higher food supply, which penetrate the perimeter of forest patches from the surrounding field matrix (GATES & GYSEL 1978, ANDRÉN et al. 1985, WILCOVE 1985, ANDRÉN 1995, KURKI et al. 1997).

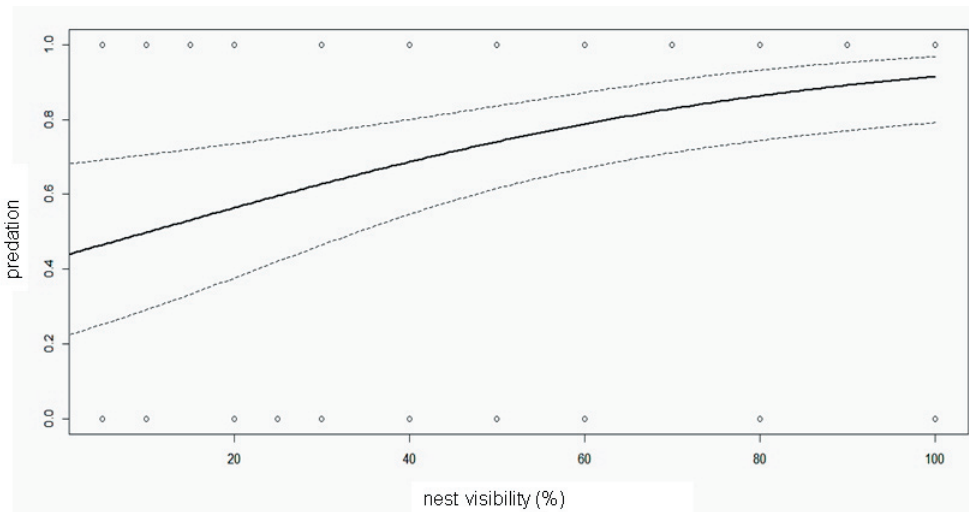


Fig. 4. Predicted probability of a nest being destroyed by predation as a function of nest visibility. Dashed lines denote to 95% confidence intervals.

We also found out the same predation rate in forest dominated landscape as in highly fragmented farmland landscape, what corresponded with other studies on artificial nests of NOUR et al. (1993), ANDRÉN (1995), or BATÁRY & BÁLDI (2004). The degree of landscape fragmentation in our study area so did not significantly influence the total predation rate. In the forest dominated landscape, where open area covered 13%, was almost same predation rate as in highly fragmented landscape, where open area was on 63% of the surface.

In contrast with our findings, some studies found that the loss rate of artificial nests was positively related to the degree of fragmentation of forest habitat (ANDRÉN et al. 1985, YAHNER & SCOTT 1988). ANDRÉN et al. (1985) detected highest predation in the areas where more than 50% of surface was open area, what explained by higher density of generalist predators, such as corvids. Negative influence of landscape fragmentation can be detected also on declining proportion of grouse hens with a brood and brood size (KURKI et al. 2000). Equal predation rate within whole the study can be explained by similar population densities of medium-sized mammalian predator species, mainly foxes and martens.

Red fox and marten are therefore considered as main potential predators of nests of the hazel grouse. High population density and widespread distribution together with analysis of depredated nests and pictures from camera traps support such conclusion. Moreover, preferred habitat of both species includes forest edges and open spaces, as well. Their occurrence is widely recorded throughout the entire Bohemian Forest, both in foothills and higher part of mountains (ANDĚRA & ČERVENÝ 1994) and the occurrence is driven mainly by actual feed resources (ŠÁLEK et al. 2010). Although rodents are the most frequently represented animals in the diet of red fox in the Bohemian Forest (HARTOVÁ-NENTVICOVÁ et al. 2010), small and medium size birds provide considerable ratio, too. Martens show similar feed composition as well – the most common prey are small mammals and birds.

We assume that the most important factor influencing nest predation is predator density – red fox and marten in the case of the Bohemian Forest – compared to other environmental variables. Few other studies allow a comparison between the abundance of predator species and the relative importance of these species as predators on ground nesting birds' nests (LOMAN & GÖRANSSON 1978, MÜLLER 1984, ANGELSTAM 1986). These studies suggest that individuals of the different predator species are equally efficient at finding nests. One possible explanation is that the contribution of eggs to their diet is very low compared with their food requirements (ANGELSTAM et al. 1984). If and when a nest is robbed that can be only random event.

In our study predation was affected mostly by nest concealment and the vegetation structure around the nest. In general, artificial and natural nests, which are more concealed and in areas of vegetation with greater structural complexity, are less likely to be destroyed (YAHNER & SCOTT 1988, BAYNE et al. 1997). The tendency to higher nest predation in coniferous (spruce) forest than in deciduous or mixed forest associated with sparsely undergrowth vegetation and consequent higher visibility of the nest what leads to easier finding by predators. Contrary to initial expectations, more visible nests were predated in most cases by mammals, not by birds that are orienting visually. Again, it is possible to be explained by high population density of mammal predators in the study area, where discovery of the nest by browsing fox or marten would be just a coincidence.

The predation pressure on artificial nests usually differs from real nests (WILLEBRAND & MARCSTROM 1988, KING et al. 1999, ZANNET 2002), so it should not be used to measure actual rates of nest predation, but may be valuable for trends in rates of predation. The predation rate can significantly differ because of a lack of parental defense, what can lead to higher predation rates on artificial nests (KING et al. 1999). The natural nests camouflaged and in some cases defended by the incubating female are mostly robbed by mammalian

predators, which are probably attracted by the scent of the sitting hen by her trails because she usually walks off the nest (WILLEBRAND & MARCSTRÖM 1988, RANGEN et al. 2000), whereas uncovered artificial nests are often destroyed by avian predator (ANGELSTAM 1986, STORAAS 1988, WILLEBRAND & MARCSTRÖM 1988, RANGEN et al. 2000).

In contrast with this view, the most (90% and 79% from depredated nests in 2005 and 2008 respectively) of our artificial nests were robbed by mammals regardless of the rates cover the nests. Also in other studies, which are similarly methodically focused and held in different landscape types in the Czech Republic, the most of the artificial nests were robbed by mammals – 64% (SVOBODOVÁ et al. 2004) and 65 % (ŠÁLEK et al. 2004). We found almost the same main predators (pine marten, stone marten, red fox) as other studies from similar habitats (BERGMANN et al. 1982, SANIGA 2002, SVOBODOVÁ et al. 2004, ŠÁLEK et al. 2004).

Many corvids are considered as generalist predators and are often associated with open areas and edges (ANDRÉN et al. 1985, ANGELSTAM et al. 1985, ANDRÉN 1992), whereas mammals are often responsible for the most of nest predation in large closed forest areas and away from the forest edges (NOUR et al. 1993). We did not find any relationship between species of predator and nest location and rate of landscape fragmentation. It is possible, that more fragmented landscape in the Bohemian Forest foothills still includes large enough or well interconnected forest patches, therefore there is no significant difference in predators' abundance within both studied landscape types.

We determined total predation rate in each year 44% and 73%, which corresponded with the most of the similar study. ŠÁLEK et al. (2004) from the area of the Krušné Hory Mts. found, that increased predation rate on artificial nests from 34% to 76% was corresponded to a significant decrease in small mammal (rodents) numbers in this area. Several other studies from different landscape types have reported diverse rates of nest predation – NOUR et al. (1993) in Belgium presents 76% predated nests; study from Bavarian Alps shows 64% (STORCH 1991); DELONG et al. (1995) in large field experiment from the USA presents 71% of robbed nests; or FENSKE-CRAWFORD & NIEMI (1997) describe predation ratio as much as 85%. Similar results present SANIGA (2002) in study held in central Slovakia – predation rate of real hazel grouse's nests differ from 57 to 85% depending on rodent population cycle.

One of the main factors affecting the predation rate could be also density of small mammals as an alternative prey of potential grouse predators. The alternative prey hypothesis suggests that non-specialised predators may switch from their primary prey to secondary (alternative) prey when the former is scarce and may then cause changes in its numbers (LACK 1954, ANGELSTAM et al. 1984, MOSS & WATSON 2001). The results of SANIGA (2002) on real nests of hazel grouse or ŠÁLEK et al. (2004) on artificial nests support the alternative prey hypothesis. We can not claim with certainty that difference in predation rate between the years is due to small mammals cycles, because their densities did not been monitor and nests were placed slightly differently every year.

CONCLUSIONS

Predation events on simulated nests were similarly distributed throughout study area. Predation rate was almost the same for edge and interior areas; therefore it was supposed that edge effect on nest predation was unimportant in affecting local ground nesting galliform birds populations. Moreover, our results did not find any differences in predation rate depending on the landscape type. Depredation was almost similar in forest and agricultural landscape. Total ratio of depredated nests either in forest or agricultural landscape was relatively high; therefore, considerable regulative effect of predation on population level has to be taken into account.

As hazel grouse is very sensitive to habitat disturbances, special management should be supported in areas of occurrence of this species. Higher predation rate was recorded on more visible nests, so ground vegetation and shrubs seems to be essential component of habitat, which provides better chances for hiding of individuals and nests as well. The management should include semi-natural restoration of mixed forest and regulation of ungulates to support regeneration of ground vegetation. Negative influence of high densities of red deer causing the loss of beech and pioneer trees are detected mainly in the higher parts of the Bohemian Forest. The old forest practice to clean spruce plantation of pioneer trees like willow, birch, or aspen is still common there, even in the national park.

Although the population of hazel grouse in the Bohemian Forest is almost largest in Central Europe, it is still vulnerable to negative effect of forestry mainly driven by wind storm disturbances and consequent bark beetle gradation (e.g. clear cuts) and development of tourist infrastructure (e.g. construction of tracks and bike trails). In the context of the current management of the Šumava National Park and surrounding Protected Landscape Area, appropriate management of this NATURA 2000 species is urgently needed, otherwise the future for hazel grouse is indeed no longer safe there.

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