Ornis Fennica 97: 53–63. 2020

High tourism activity alters the spatial distribution of Hazel Grouse (*Tetrastes bonasia)* and predation on artificial nests in a high-mountain habitat

Marcin Matysek*, Robert Gwiazda, Filip Zięba, Maciej Klimecki, Radosław Mateja & Piotr Krzan

*M. Matysek, R. Gwiazda, Institute of Nature Conservation, Polish Academy of Sciences, Adama Mickiewicza 33, 31-120 Kraków, Poland. * Correseponding author's e-mail: matysek@iop.krakow.pl*
M. Matysek, F. Zięba, M. Klimecki, R. Mateja, P. Krzan, Tatra National Park, Kuźnice 1, 34-500 Zakopane, Poland

Received 30 September 2019, accepted 22 March 2020

Human presence can significantly reduce habitat availability for wildlife. We investigated the impact of the distance from hiking trails and number of tourists on the number of sites occupied by Hazel Grouse (*Tetrastes bonasia*) and on the predation rate of artificial nests in two forest types (spruce and beech) in the Tatra Mountains (Poland). The study was carried out in the Tatra National Park from 2009 to 2014. Presence of Hazel Grouse males was detected in spring by playing territorial calls of this species from an electronic device. A total of 79 sites occupied by Hazel Grouse were found, and 174 artificial ground nests were monitored. Data on the number of tourists gathered at entry points and at trail crossings in the Tatra National Park were used to estimate levels of tourism activity. Sites occupied by Hazel Grouse were mostly located farther from hiking trails and in places with low tourist numbers. Artificial nests were mainly predated by mammals (85%) in both spruce and beech forests. Predation on artificial nests was higher in areas with smaller numbers of tourists. The frequency of egg predation did not differ between spruce and beech forests. Based on our results, hiking trails and the number of tourists who frequent them are important factors influencing the occurrence and reproduction of ground-breeding birds such as the Hazel Grouse.

1. Introduction

Human presence and activity can significantly impact on wildlife through disturbance and by limiting the use of important resources for animals (Rösner *et al.* 2013). Furthermore, human presence can also increase synanthropization of animals and change their behaviour. In areas where humans are present, access to resources such as food supplies and breeding or roosting sites can be directly restricted (e.g., Vitousek *et al.* 1997, Burger *et al.* 2004, Gill 2007). Outdoor recreation and ecotourism in protected areas can act as potential stressors for wildlife; frequent disturbances can also cause a decline in populations (e.g., Müllner *et al.* 2004). Animals react to approaching humans in a similar way as they do to a predator, i.e., they hide or move away (Beale & Monaghan 2004).

Animals can be disturbed by intensive human activity, resulting in discontinued feeding, changes in daily activities, altered habitat selection or increased stress load (Gander & Ingold 1997, Taylor & Knight 2003, Stankowich 2008, Thiel *et al.* 2008, Pęksa & Ciach 2015). Capercaillie (*Tetrao urogallus*) and mountain hares (*Lepus timidus*) living in areas with frequent recreational activities by humans in winter show changes in physiology and behaviour (Thiel *et al.* 2011, Rehnus *et al.* 2014).

Similarly, the stress levels of chamois (*Rupicapra rupicapra*) increased with the number of visitors and showed peak values in summer, coinciding with the highest number of visitors to the Tatra National Park (Zwijacz-Kozica *et al.* 2013).

The negative effects of recreational activities on populations of ground-nesting bird species and their breeding success have been reported in several studies (e.g., Watson & Moss 2004, Střen *et al.* 2010). Various ecological factors (e.g., habitat structure, landscape fragmentation, availability of prey) influence the predation risk of ground nests. However, for ground-nesting birds, nest predation is a major factor affecting breeding success (e.g., Angelstam 1986, Saniga 2002). Predator densities are often higher in the vicinity of tourist facilities due to the supply of discarded food (Storch & Leidenberger 2003, Watson & Moss 2004). Furthermore, foraging by predators is facilitated by forest roads and hiking trails within large forest tracts (Storch *et al.* 2005, Seibold *et al.* 2013). Grouse are ground nesting birds, which are highly susceptible to human disturbance (Storch 2000, Storch 2007).

As shown by Storch & Leidenberger (2003), large concentrations of tourists, e.g. around hostels, attract crows (*Corvus corone*), which can directly affect the Galliformes colonizing the surrounding forests. For Capercaillie and the Black Grouse (*Tetrao tetrix*), higher concentrations of faecal stress hormone metabolites (corticosterone) were found after disturbance (Arlettaz *et al.* 2007, Thiel *et al.* 2008). There is evidence that an elevated frequency of disturbance affects the habitat use of Capercaillie (e.g., Thiel *et al.* 2008) and may even cause population declines (Brenot *et al.* 1996). So far, the impact of tourism pressure has only been tested for the Capercaillie and the Black Grouse (*Tetrao tetrix*) (e.g., Storch & Leidenberger 2003, Thiel *et al.* 2008, Rupf *et al.* 2011, Rösner *et al.* 2013) and research into the impact of tourist activity on the Hazel Grouse (*Tetrastes bonasia*) is not available.

The Hazel Grouse is an extremely shy bird and hides both in the ground layer and in dense tree cover. This species occurs in both lowlands and mountainous regions across Eurasia inhabiting coniferous and mixed forests (Cramp & Simmons 1980, Johnsgard 1983, Bergmann *et al.* 1996). The Hazel Grouse is a territorial bird with specific habitat and food requirements (e.g., Bergmann *et al.* 1996, Bonczar *et al.* 1998, Swenson 2006, Matysek *et al.* 2018, Matysek *et al.* 2019a). The species maintains a territory throughout the year, staying in one place (e.g., Swenson 1991a, Swenson 1991b, Montadert & Leonard 2006). The European population of Hazel Grouse was estimated at ~1,480,000–2,920,000 pairs (BirdLife International 2018). The number and range of Hazel Grouse populations in most European countries has decreased moderately since 1980 (Swenson & Danielson 1991, Storch 2000, Storch 2007). The population is estimated to be stable in the Polish Carpathian Mountains (Matysek 2016).

The main reason for the decreasing populations of this species elsewhere is thought to be the negative human impact on the structure and species composition of forests, namely the simplification of habitat structure and the fragmentation of forest complexes (Kajtoch *et al.* 2012, Seibold *et al.* 2013). Moreover, disturbance of birds, especially during breeding, by foresters or tourists potentially has a negative impact on reproductive success (Kajtoch *et al.* 2011, Bonczar & Kajtoch 2013).

The aims of this study are to evaluate the impacts of the distance from the hiking trail and number of tourists on (1) the number of sites where Hazel Grouse was present, on (2) the predation rate of artificial nests, and (3) whether forest type affects the proportion of predated nests. We hypothesised that hiking trails (in terms of distance and number of tourists) would negatively affect the number of sites where Hazel Grouse are present. Predation rates on artificial nests might also be negatively related to the distance from the hiking trails (predators can use them for moving and food searching) and the number of tourists (predators avoid greater numbers of tourists).

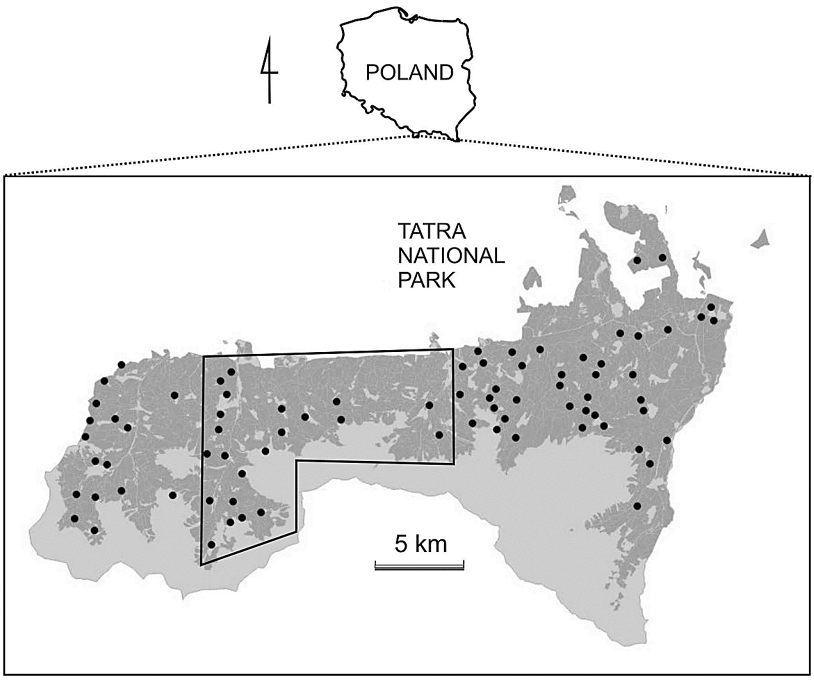

Fig. 1. Location of Tatra National Park, Poland. Forest is marked by dark grey and meadows and rocks by light grey. Sites occupied by the Hazel Grouse are marked by black circles. Artificial nests were located in the area delineated by the polygon.

2. Material and methods

2.1. Study area

The research was conducted in the Polish Tatra Mountains. The study area of 150 km^2 was situated within the Tatra National Park (Tatra NP) (49°15'32.92"N, 19°54'34.61"E, Fig. 1). Forests in the Tatra NP hold 17 tree species, but five of them occur most commonly: Norway spruce (*Picea abies*), fir (*Abies alba*), beech (*Fagus sylvatica*), sycamore (*Acer pseudoplatanus*), rowan (*Sorbus aucuparia*) and mountain pine (*Pinus mugo*). The average age of the main forests stand is about 90 years (data of the Tatra NP Authority). Forests in the Tatra NP cover both a lower (from 950 a.s.l. to 1,250 a.s.l.) and an upper (from 1,250 a.s.l. to 1,550 a.s.l.) mountain zone.

The lower forest mountain zone is mostly (80%) covered by unnatural, planted spruce forests dominated by Norway spruce whilst the rest is covered by natural or semi-natural beech forests dominated by beech, fir, with admixture of sycamore and coniferous forests of Norway spruce and fir. Other tree species (Scots pine (*Pinus silvestris*), European larch (*Larix deciduas*), Poplar (*Populus* sp.), Willow (*Salix* sp.)) occur rarely. In contrast, the upper forest mountain zone is dominated by natural Norway spruce forests and a rare relict of Swiss pine (*Pinus cembra*) forest. Other tree and shrub species can occur depending on the altitude, habitat fertility and stand density.

Over many centuries, mainly upper forests zones have been largely transformed. A key factor contributing to adverse changes in the forest species composition here was intensive forest management in the 19th and 20th centuries, and especially the introduction of spruce in natural habitats occupied by fir and beech. This process resulted in high landscape fragmentation, with the occurrence of preserved patches of old growth forests alternating with open habitats (meadows, pasture fields, clear-cuts) and different-aged young coniferous and mixed stands. In the lower forest mountain zone, spruce monocultures currently account for 80% of the area. These forests are mainly exposed to the adverse effects of abiotic and biotic factors, resulting in considerable dieback. The subsequent mountain pine floor is mainly covered by mountain pine. Above this zone there are the alpine and crag zones (Fabijanowski & Dziewolski 1996). The Tatra Mountains are a UNESCO World Biosphere Reserve and are included in the Natura 2000 network of protected areas in Europe and the

Tatra National Park is habitat for a large number of rare animal species, including three species of forest Galliformes: Capercaillie, Black Grouse and Hazel Grouse (Wilk *et al.* 2016). The breeding population of Hazel Grouse in Tatra NP has been estimated at 80 territories (Matysek 2016). This species is threatened in Poland and Slovakia and is included in the Carpathian list of endangered species (Witkowski *et al.* 2003).

About 3.5 million tourists visit the park every year (data of the Tatra NP Authority, http://tpn.pl/zwiedzaj/turystyka/statystyka). The forests (Hazel Grouse occurs only in this habitat) are crossed by about 100 km of hiking trails, differing in length and intensity of tourist traffic (from a few to 8,000 tourists a day) (data from the Tatra NP Authority, http://tpn.pl/zwiedzaj/turystyka/statystyka). The highest tourist pressure occurs in spring and summer, when up to 40,000 tourists visit the park each day and move along ~270 km of hiking trails (data from the Tatra NP Authority). Most tourism activities (i.e., hiking) are concentrated in the valleys above the hostels, which are located at the upper limit of the forest.

2.2. Tourist pressure

We calculated the monthly numbers of tourists visiting Tatra NP from 2009 to 2014 (data from the Tatra NP Authority, http://tpn.pl/zwiedzaj/turystyka/statystyka). Monitoring was performed all year at all the entrances to the valleys in order to obtain information about the number of tourists throughout the year and in particular valleys. The highest number of tourists visited in August in all years. Detailed daily monitoring of tourist traffic was conducted in the Tatra NP in August 2009 (data from the Tatra NP Authority). Tourist traffic was measured at the entry points to the park, where the tickets were sold and at points where trails cross. Tourist numbers were counted by NP employees and volunteers. In order to accurately determine the number of visitors, tourists entering the park before the opening of the ticket points (5.00–8.00 a.m.) were also counted. Tourists were counted at 1-hour intervals each day, differentiating between individuals, groups and group tours to determine the spatial and temporal distribution of tourist traffic on particular routes. Mean daily tourist number in August was calculated for each hiking trail.

2.3. Bird sites

Hazel Grouse were censused in forests with a total area of 150 km^2. We detected Hazel Grouse individuals twice a year during a peak in the spring call period (April and May) from 2009 to 2013 by using MP3 speakers to play imitations of Hazel Grouse calls throughout the entire forest area. Bird presence was checked every 150–200 m, with pauses spanning a few minutes to lure the Hazel Grouse response calls (Swenson 1991a, Bonczar 2009).

The observer recorded whether the site was occupied by the Hazel Grouse after two minutes of listening and then moved to the next point. Indicators of the occurrence of Hazel Grouse, such as droppings, tracks and other signs, were searched for in April, when the study area was covered by snow. These tracks were helpful in determining the sites when the birds could not be detected otherwise (e.g. along a loud stream or at sites with tourists). The census was mainly performed during the mornings and evenings because a lower response frequency was found during midday, and only in good weather conditions (without heavy rain or snow and strong winds; see also Swenson 1991b).

Occupation was verified for all records of this species at less available sites by additional checking and searching for tracks. Due to the specific life strategies of the Hazel Grouse (hidden in the undergrowth), we did not search for nests nor determine the boundaries of the territories. The recorded sites were mapped in the field and the positions were noted in a GPS Garmin 62. The distance of a site where a Hazel Grouse was present was determined in intervals of up to 100 meters from the point where the bird was found. In total we analyzed 49 hiking trails for the presence of Hazel Grouse.

2.4. Nest predation

Artificial ground nests were placed in the forest in an area 40 km^2 during May–June 2012, 2013 and

2014. This period corresponds with the main breeding season for the three species of forest Tetraonids in the climatic conditions of the study region (Bergmann *et al.* 1996). The location for placing artificial nests was chosen randomly within the study area, but within this location the artificial nests were placed near tree trunks or under hanging branches, according to the preferences of Hazel Grouse (Johnsgard 1983, Bergmann *et al.* 1996).

A total of 174 artificial nests were constructed in the field. The artificial nests were made by digging small ground depressions (ca. 20 cm of diameter and ca. 5 cm of depth) laid out with small amounts of dry plant material (Šálek *et al.* 2004). Each nest was baited with 5 very small (length ~5.4 cm, width ~4.6 cm) and not white, Domestic Hen eggs (*Gallus gallus domesticus*). Prior to being placed in the artificial nests, the eggs were sprayed with the washing water of dead Quail (*Coturnix coturnix*) to give them the smell of a wild Galliformes species. Subsequently, we masked the artificial nest components with undergrowth plant material, mimicking the female's coloration (Richard & Yaherabd 1996, Burke *et al.* 2004, modified).

The nests remained conspicuous, i.e. the eggs were at least 70–80% visible from an above vertical view. The locations of nests were recorded using a GSP device. To avoid leaving traces of scent during this work we used rubber gloves and walked the smallest possible distances in the vicinity of artificial nests (Summers *et al.* 2009, Jones *et al.* 2010). Nests were checked once a week from a distance 2–10 m depending on their visibility (see also Jones *et al.* 2010, Żmihorski *et al.* 2010). In the case of nests with eaten eggs, the experiment was repeated and a replacement nest was constructed in another randomly chosen place, to imitate the repeated breeding attempts of wild birds whose nests are predated.

Each artificial nest was monitored for about 27 days, mimicking the average period of incubation by forest Tetraonids (Johnsgard 1983, Bergmann *et al.* 1996, Kurki *et al.* 2000). Eighty seven artificial nests were monitored using camera traps (Ltl Acorn 5220, lens f = 3.1, infrared-lamp 940 nm, 24 diodes) to identify predator species. Nests were considered to be predated if at least one egg disappeared or had marks indicating a predator's visit (e.g., Martin & Joron 2003, Colombelli-Négrel & Kleindorfer 2009). The mean distance between artificial nests was 650 m (range: 150–2,150 m) to reduce the probability of nearby nests being discovered by a predator searching intensively.

2.5. Statistical analyses

Spatial data were calculated using QGIS 2.12.3 (QGIS 2017), and distances between the nearest artificial nests were measured in a straight line. Spatial autocorrelation of artificial nests was tested by Moran's index (Moran 1950). The Friedman's ANOVA was used to search for differences in the monthly number of tourists visiting Tatra NP among the study years (repeated variable was month) and for differences in number of tourists between months (repeated variable was year). Two Generalized Linear Mixed Model (GLMMs, Binomial distribution, logit link function) with in turn response being (1) site occupied (n = 79) or not occupied (n = 79) by the Hazel Grouse, and (2) artificial nest predated (n = 59) or not predated (n = 115). Random factors were year and identity of the trail. Predictor variables were distance to hiking trails, daily number of tourists, forest type and interaction between distance to hiking trails and daily number of tourists.

A larger number of tourists on the trail causes predators such as martens to seek food further from the trail. Multivariate regression was used to obtain $R2$ values for all predictor variables. Collinearity of predictor variables was checked by calculation of the variance inflation factor (VIF) according to formula $1/(1–R2)$. The predictor variables did not correlate with each other (VIF values: 1.06–1.13). Spatial autocorrelation of the residuals of these models was calculated using Moran's index. For statistical analyses, the software STATISTICA 12 was used (StatSoft 2014). Logistic regressions were visualised using ggplot2 package in R (R Core Team 2018).

3. Results

3.1. Tourist numbers and Hazel Grouse sites

Differences in the numbers of tourists that visited Tatra NP between study years were found during

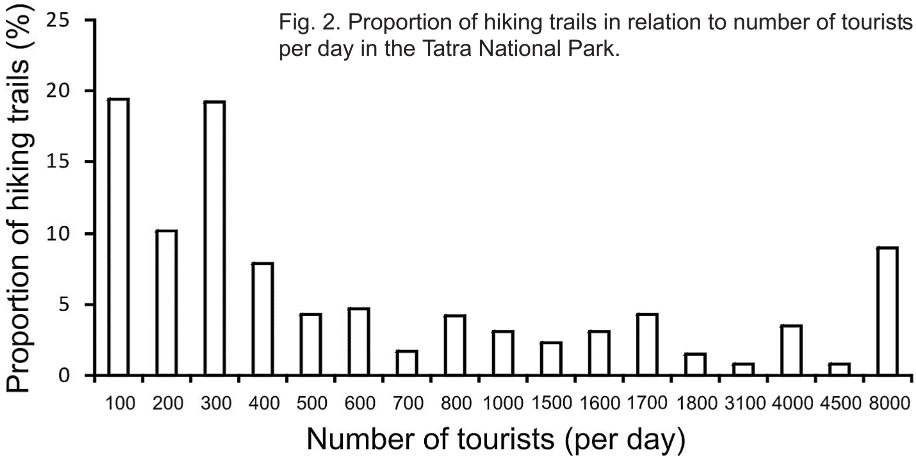

Fig. 2. Proportion of hiking trails in relation to number of tourists per day in the Tatra National Park.

the period of 2009–2014 ($\chi^2 = 12.19$, df = 5, p = 0.03). Moreover, the number of tourists significantly varied between months ($\chi^2 = 62.69$, df = 11, $p < 0.001$) with low values from early November to late April. Hiking trails with 300 tourists per day represented 48% of all trails (Fig. 2). The probability of a site being occupied by a Hazel Grouse increased with increasing distance from the hiking trails and decreasing number of tourists (Table 1; Fig. 3). Spatial autocorrelation of the residuals of the GLMM model was not found (Moran's I = 0.005, $p < 0.59$) and showed that the spatial distribution of Hazel Grouse sites did not appear to be significantly different from random. We found no differences in the occupation of sites by Hazel Grouse between spruce and beech forests (Table 1).

3.2. Nest predation

Altogether 59 (34%) of 174 artificial nests were predated, mostly by mammalian predators and only a few by bird predators. Of the monitored nests (by camera traps) with destroyed eggs, 54% were predated by pine marten (*Martes martes*),

Table 1. Summary of generalized linear mixed models describing components of the site occupied and unoccupied by the Hazel Grouse in the Tatra NP. Significant differences are marked in bold.

Variable	Estimate	Standard error	Wald	p-value
Intercept	**–1.051**	**0.324**	**9.796**	**0.002**
Distance to trail	**0.002**	**0.001**	**9.326**	**0.002**
Number of tourists	**0.002**	**0.001**	**14.624**	**<0.001**
Distance to trail × Number tourists	**–0.001**	**0.001**	**15.414**	**<0.001**
Forest type	0.124	0.115	1.111	0.29

Table 2. Summary of generalized linear mixed models describing components of the predated and unpredated artificial nests in the Tatra NP. Significant differences was marked in bold.

Variable	Estimate	Standard error	Wald	p-value
Intercept	0.253	0.207	1.041	0.31
Distance to trail	0.001	0.001	0.344	0.56
Number of tourists	**0.001**	**0.001**	**4.661**	**0.03**
Distance to trail × Number tourists	–0.001	0.001	3.246	0.07
Forest type	0.027	0.111	0.098	0.75

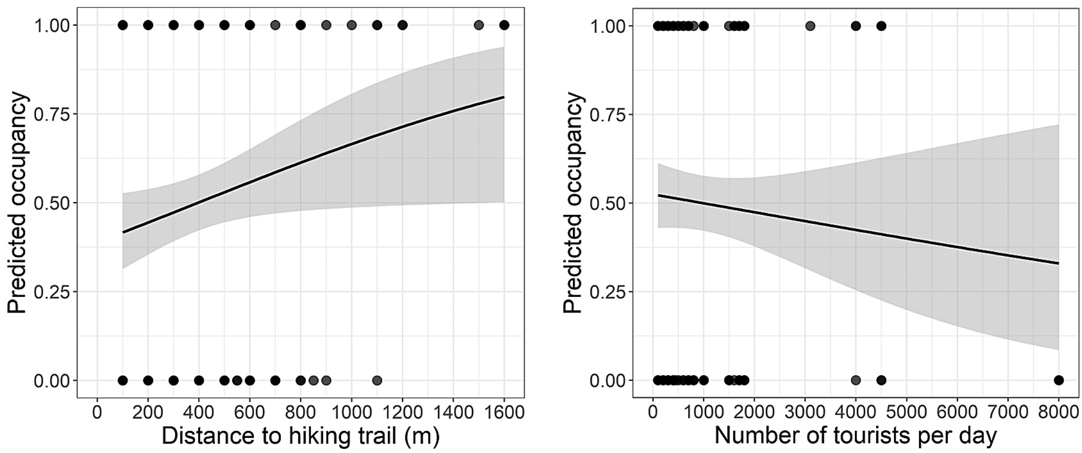

Fig. 3. Logistic regression showing the relationships between sites occupied by Hazel Grouse with (A) distance from hiking trails, and (B) the number of tourists per day on the hiking trails. Regression (solid line) and 95% confidence intervals (grey area).

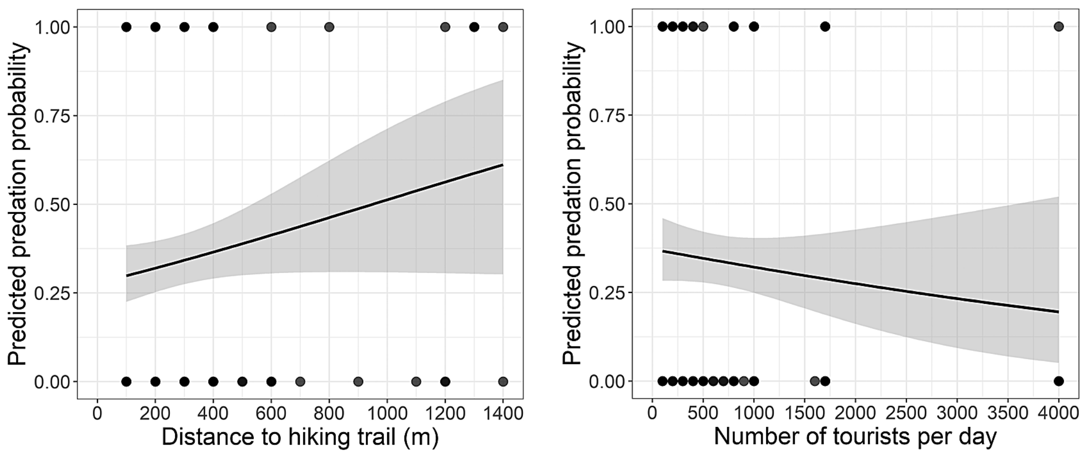

Fig. 4. Logistic regression showing the relationships between predated artificial nests with (A) distance from the hiking trails, and (B) the number of tourists per day on the hiking trails. Regression (solid line) and 95% confidence intervals (grey area).

23% by red fox (*Vulpes vulpes*), 15% by raven (*Corvus corax*), and 8% by brown bear (*Ursus arctos*).

The spatial distribution pattern of predated nests did not differ from random in 2012 (Moran's I = 0.081, $p < 0.40$). However, the spatial distribution of predated nests in 2013 and 2014 was more spatially clustered than would be expected (Moran's I = 0.350, $p < 0.001$; Moran's I = 0.489, $p < 0.03$, respectively). Spatial autocorrelation of the residuals of the GLMM model was not different from random in 2013 and 2014 (Moran's I = 0.051, p = 0.77; Moran's I = 0.135, $p < 0.20$, respectively) but in 2012 the clustered pattern was non-random (Moran's I = 0.451, $p < 0.001$).

We found an influence of the number of tourists on the predation of artificial nests (Table 2). The number of predated nests increased with decreasing number of tourists (Table 2; Fig. 4). Predation on artificial nests did not differ between the two types of forests (Table 2).

4. Discussion

Recreational trails may affect the presence and nesting success of some bird species (Storch &

Leidenberger 2003, Thiel *et al.* 2008, Rupf *et al.* 2011) with human presence creating a "landscape of fear" (Rösner *et al.* 2013). A significant relationship was found in the present study between the number of sites occupied by Hazel Grouse and the distance from hiking trails and the number of tourists in the Tatra NP. Rösner *et al.* (2013) similarly reported a negative impact of recreational activities on the distribution of the Capercaillie in the Bohemian Forest.

Tetraonidae on the ground are exposed to a high risk of predation (Wegge *et al.* 1987). The main predator of the artificial nests in the Tatra NP was the European pine marten, followed by the red fox. Similarly, Bergmann *et al*. (1996) found that red fox and species of mustelids (*Mustela* sp.) were the main predators of Hazel Grouse eggs. In the mountains of Central Slovakia stone marten (*Martes foina*), pine marten, mustelids and red fox (altogether 22%), along with wild boar (*Sus scrofa*) (9%), and brown bear (3%) were the main mammalian egg predators (Saniga 2002).

Predation rate on artificial nests can be related to the population dynamics of small mammals which, in turn, are the main prey of egg/nest predators, according to the Alternative Prey Hypothesis (Begon *et al.* 1990). Small rodents in Tatra NP were observed in large numbers in 2012 (Matysek *et al.* 2019b) and we did not find that predated nests were spatially distributed in this year. Thus the spatial distribution of predated nests in 2013 and 2014 might be explained by more intensive searches for nests and eggs by predators in years of lower numbers of rodents.

In our study, nest predation was related to the number of tourists. In some areas along the Front Range of Colorado (USA), predation rates increased with distance from the trails, and mammals depredated more nests at a greater distance from the trails and appeared to avoid nests near trails (Miller & Hobbs 2000). High tourist pressure may scare potential predators and thereby reduce their hunting area. Research in the Białowieża Primeval Forest (NE Poland) has shown that the European pine marten – being the main predator in the Tatra NP – avoids people and preys in places with less human traffic (Wereszczuk & Zalewski 2015). Pine martens show increased glucocorticoid concentrations in seasons and areas with increasing tourist intensity (Barja *et al.* 2007).

We did not find differences in the predation rate between the two forest types (spruce or beech) in the Tatra NP. Similarly, predation on artificial ground nests (using chicken eggs resembling Capercaillie eggs in size and colour) did not differ between highly fragmented forests in south-eastern Norway and in natural forests in north-western Russia (Wegge *et al.* 2012). However, forest type can affect the predation rate on bird nests (Bayne *et al.* 1997). Seibold *et al.* (2013) showed that the most important driver of predation risk of artificial ground nests can be vegetation, rather than human activity. Increasing vegetation density around a nest reduces predation risk by concealing the nest and by limiting the mobility of foraging predators (e.g., Wilcove 1985, Lahti 2001, Baines *et al.* 2004, Tirpak *et al.* 2006).

The present study showed that not only distance from the hiking trails but also tourist numbers were important factors for the occurrence of the Hazel Grouse. Therefore, Hazel Grouse are likely to benefit from limiting the number of tourists on intensively used hiking trails. Outdoor recreation in protected areas can be a major problem for nature conservation. It can decrease the populations of endangered species for instance (Thiel *et al.* 2008, Pęksa & Ciach 2015). Therefore, in order to efficiently protect ground-nesting birds, tourist traffic on the hiking trails through the main breeding sites should be limited. Also, a lower density of hiking trails is recommended in breeding habitats of great importance for nature conservation.

Acknowledgements. We are grateful for all valuable comments of two anonymous reviewers and the Associate Editor. This work was partly supported by the Institute of Nature Conservation, Polish Academy of Sciences and partly from grant funding for PhD students and young scientists given from the Institute of Botany, Polish Academy of Sciences. Special thanks to Bogusław Binkiewicz, Grzegorz Szewczyk, Zbigniew Bonczar (†) and Tatra National Park, and Jan Krzeptowski-Sabała, Marcin Bukowski for providing data on number of tourists and GIS data. The authors would like to thank Dr. Piotr Skórka from the Institute of Nature Conservation PAS for his assistance in preparing the figures.

Vuoristoalueen turismin vaikutus pyyn esiintymiseen ja keinopesien saalistusasteeseen

Ihmisen läsnäolo, kuten vilkas turismi, voi heikentää elinympäristöjen saatavuutta ja laatua. Tutkimme retkeilyreittien etäisyyden ja matkailijoiden määrän vaikutusta pyyn esiintymiseen ja keinotekoisten pesien (174) saalistusasteeseen kahdessa metsätyypissä (kuusi ja pyökki). Koiraiden määrä selvitettiin soittamalla kutsuääniä keväisin. Pyitä havaittiin 79 alueella. Matkailuaktiivisuuden tasoa arviointiin laskemalla turistien lukumäärät kansallispuiston sisäänkäynneillä ja polkujen ylityskohdissa.

Pyitä esiintyi pääasiassa kauempana retkeilyreiteistä ja paikoissa, joissa turistien lukumäärä on alhainen. Nisäkkäät olivat pääasiallisia (85 %) keinotekoisten pesien hävittäjiä sekä kuusi- että pyökkimetsissä. Keinotekoisten pesien saalistus oli suurempaa alueilla, joilla turisteja oli vähemmän. Munien saalistamistiheys ei eronnut kuusi- ja pyökkimetsien välillä. Tulosten perusteella retkeilyreitit ja niitä usein käyttävien turistien lukumäärä ovat tärkeitä tekijöitä, jotka vaikuttavat maassa pesivien lintujen, kuten pyyn, esiintymiseen ja lisääntymiseen.

References

Angelstam, P. 1986: Predation on ground-nesting birds' nests in relation to predator densities and habitat edge. — Oikos 47: 365–373.

Arlettaz, R., Patthey, P., Baltic, M., Leu, T., Schaub, M., Palme, R. & Jenni-Eiermann, S. 2007: Spreading free-riding snow sports represent a novel serious threat for wildlife. — Proceedings of the Royal Society – Biological Sciences 274: 1219–1224.

Baines, D., Moss, R. & Dugan, D. 2004: Capercaillie breeding success in relation to forest habitat and predator abundance. — Journal of Applied Ecology 41: 59–71.

Barja, I., Silván, G., Rosellini, S., Piñeiro, A., González-Gil, A., Camacho, L. & Illera, J.C. 2007: Stress physiological responses to tourist pressure in a wild population of European pine marten. — Journal of Steroid Biochemistry and Molecular Biochemistry 104: 136–142.

Bayne, E.M., Hobson, K.A. & Fargey, P. 1997: Predation on artificial nests in relation to forest type: contrasting the use of quail and plasticine eggs. — Ecography 20: 233–239.

Beale, C.M. & Monaghan, P. 2004: Human disturbance: people as predation-free predators? — Journal of Applied Ecology 41: 335–343.

Begon, M., Harper, J.L. & Townsend, C.R. 1990: Ecology: individuals, populations and communities. — Blackwell Scientific Publications, Oxford.

Bergmann, H.H., Klaus, S., Müller, F., Scherzinger, W., Swenson, J.E. & Wiesner, J. 1996: Die Haselhühner, *Bonasa bonasia* und *B. sewerzowi*. — Die Neue Brehm-Bücherei, Westrap Wissenschaften, Magdeburg. (In German).

BirdLife International 2018: IUCN Red List for birds. — Downloaded from http://www.birdlife.org on 21/04/2018.

Bonczar, Z. 2009: Hazel Grouse *Bonasa bonasia*. — In Monitoring of breeding birds. Methodological guide concerning species protected by Birds Directive. (ed. Chylarecki, P., Sikora, A. & Cenian, Z.): 287–291. Biblioteka Monitoringu Środowiska, Warszawa. (In Polish).

Bonczar, Z., Borowiec, F. & Swenson, J.E. 1998: Regional variation in the food quality of hazel grouse *Bonasa bonasia* (L.). — Zeszyty Naukowe Akademii Rolniczej w Krakowie. Hodowla i Biologia Zwierząt 33: 75–86. (In Polish with English summary).

Bonczar, Z. & Kajtoch, Ł. 2013: Hazel Grouse *Tetrastes bonasia*. — In Designation and quality evaluation of bird habitats in Natura 2000 Special Protection Areas (ed. Zawadzka, D., Ciach, M., Figarski, T., Kajtoch, Ł. & Rejt, Ł.): 121–125. GDOŚ, Warszawa. (In Polish with English summary).

Brenot, J.F., Catusse, M. & Ménoni, E. 1996: Effets de la station de ski de fond du Plateau de Beille (Aričge) sur une importante population de grand tetras *Tetrao urogallus*. — Alauda 64: 249–260.

Burger, J., Jeitner, C., Clark, K. & Niles, L.J. 2004: The effect of human activities on migrant shorebirds: successful adaptive management. — Environmental Conservation 31: 283–288.

Burke, D.M., Elliott, K., Moore, L., Dunford, W., Nol, E., Phillips, J., Holmes, S. & Freemar, K. 2004: Patterns of nest predation on artificial and natural nests in forests. — Conservation Biology 18: 381–388.

Colombelli-Négrel, D. & Kleindorfer, S. 2009: Nest height, nest concealment, and predator type predict nest predation in superb fairy-wrens (*Malurus cyaneus*). — Ecological Research 24(4): 921–928.

Cramp, S. & Simmons, K.E.L. 1980: The Birds of the Western Palearctic. Vol. II — Oxford University Press, Oxford.

Fabijanowski, J. & Dziewolski, J. 1996: Forests. — In Nature of Tatra National Park (ed. Mirek, Z.): 675–696. Tatrzański Park Narodowy, Kraków-Zakopane. (In Polish)

Gander, H. & Ingold, P. 1997: Reaction of male alpine chamois *Rupicapra r. rupicapra* to hikers, joggers and mountain bikers. — Biological Conservation 79: 107–109.

Gill, J.A. 2007: Approaches to measuring the effects of human disturbance on birds. — Ibis 149: 9–14.

Johnsgard, P. 1983: The grouse of the world. — University of Nebraska Press, Lincoln.

Jones, D.D., Conner, L.M., Warren, R.J. & Ware, G.O. 2010: Effects of a supplemental food sources and density on success of artificial ground nests. — Fish and Wildlife Agencies 64: 56–60.

Kajtoch, Ł., Matysek, M. & Skucha, P. 2011: Forest grouses Tetraonidae of Beskid Wyspowy and Beskid Makowski Mountains and adjacent foothills. — Chrońmy Przyrodę Ojczystą 67(1): 27–38. (In Polish with English summary).

Kajtoch, Ł., Żmihorski, M. & Bonczar, Z. 2012: Hazel Grouse occurrence in fragmented forests: habitat quantity and configuration is more important than quality. — European Journal of Forest Research 131: 1783–1795.

Kurki, S., Kikula, A., Helle, P. & Lindén, H. 2000: Landscape fragmentation and forest composition effects on grouse breeding success in boreal forests. — Ecology 81(7): 1985–1997.

Lahti, D. 2001: The edge effect on nest predation hypothesis after twenty years. — Biological Conservation 99: 365–374.

Martin, J.L. & Joron, M. 2003: Nest predation in forest birds: influence of predator type and predator's habitat quality. — Oikos 102: 641–653.

Matysek, M. 2016: Hazel Grouse *Bonasa bonasia* (2016) — In Birds of Carpathians – state, threats, conservation. (ed. Wilk,T., Bobrek, R., Pępkowska-Król, A., Neubauer, G. & Kosicki, J.Z.): 112–120. Ogólnopolskie Towarzystwo Ochrony Ptaków, Marki. (In Polish with English summary)

Matysek, M., Gwiazda, R. & Bonczar, Z. 2018: Seasonal changes of the Hazel Grouse Tetrastes bonasia habitat requirements in managed mountain forests (Western Carpathians). — Journal of Ornithology 159(1): 115–127.

Matysek, M., Kajtoch, Ł., Gwiazda, R., Binkiewicz, B.& Szewczyk, G. 2019a: Could gaps and diverse topography compensate for habitat deficiency by the forest-dwelling bird Hazel Grouse (*Tetrastes bonasia*)? — Avian Biology Research 12(1): 59–66.

Matysek, M., Zub, K., Gwiazda, R., Zięba, F., Klimecki, M., Mateja, R. & Krzan, P. 2019b: Predation on artificial ground nests in relation to abundance of rodents in two types of forest habitats in the Tatra Mountains (South Poland). — Wildlife Research 46(3): 205–211.

Miller, J.R. & Hobbs, N.T. 2000: Recreational trails, human activity, and nest predation in lowland riparian areas. — Landscape and Urban Planning 50: 227–236.

Montadert, M. & Leonard, P. 2006: Post-juvenile dispersal of Hazel Grouse *Bonasa bonasia* in an expanding population of the southeastern French Alps. — Ibis 148: 1–13.

Moran, P.A.P. 1950: Notes on continuous stochastic phenomena. — Biometrika 37: 17–23.

Müllner, A., Linsenmair, K.E. & Wikelski, M. 2004: Exposure to ecotourism reduces survival and affects stress response in hoatzin chicks (*Opisthocomus hoazin*). — Biological Conservation 118: 549–558.

Pęksa, Ł. & Ciach, M. 2015: Negative effects of mass tourism on high mountain fauna: the case of the Tatra chamois *Rupicapra rupicapra tatrica*. — Oryx 49(3): 500–505.

QGIS 2017: A Free and Open Source Geographic Information System. www.qgis.org/pl/site.

R Core Team. 2018: R: A language and environment for statistical computing. — R Foundation for Statistical Computing, Vienna-Austria, https://www.R-project.org/.

Rehnus, M., Wehrle, M. & Palme, R. 2014: Mountain hares *Lepus timidus* and tourism: stress events and reactions. — Journal of Applied Ecology 51: 6–12.

Richard, H. & Yaherabd, C.G. 1996: Effects of egg type on artificial ground nests. — Wilson Bulletin 108(1): 129–136.

Rösner, S., Mussard-Forster, E., Lorenc, T. & Müller, J. 2013: Recreation shapes a "landscape of fear" for a threatened forest bird species in Central Europe. — Landscape Ecology 29(1): 55–66.

Rupf, R., Wyttenbach, M., Köchli, D., Hediger, M., Lauber, S., Ochsner, P. & Graf, R. 2011: Assessing the spatio-temporal pattern of winter sports activities to minimize disturbance in capercaillie habitats. — Eco. mont 3(2): 23–32.

Saniga, M. 2002: Nest loss and chick mortality in capercaillie (*Tetrao urogallus*) and hazel grouse (*Bonasa bonasia*) in West Carpathians. — Folia Zoologica, 51: 205–214.

Seibold, S., Hempel, A., Piehl, S., Bässler, C., Brandl, R., Rösner, S. & Müller, J. 2013: Forest vegetetion structure has more influence on predation risk of artificial ground nests than human activities. — Basic of Applied Ecology 14(8): 687–693.

Stankowich, T. 2008: Ungulate flight responses to human disturbance: a review and meta-analysis. — Biological Conservation 141: 2159–2173.

StatSoft 2014: STATISTICA (data analysis software system), version 12. www.statsoft.pl.

Storch, I. 2000: Status Survey and Conservation Action Plan 2000–2004. Grouse. WPA/Birdlife/SSC Grouse Specialist Group — IUCN, Gland, Switzerland and Cambridge UK and World Pheasant Association, pp 112.

Storch, I. 2007: Grouse: status survey and conservation action plan 2006–2010. — IUCN and World Pheasant Association, Gland, Switzerland & Cambridge, UK/Fordingbridge, UK.

Storch, I. & Leidenberger, C. 2003: Tourism, mountain huts and distribution of corvids in the Bavarian Alps, Germany. — Wildlife Biology 9: 301–308.

Storch, I., Woitke, E. & Krieger, S. 2005: Landscape-scale Edge Effect in Predation Risk in Forest-farmland Mosaics of Central Europe. — Landscape Ecology 20(8): 927–940.

Střen, O., Wegge, P., Heid, S., Hjeljord, O., Nellemann, C. 2010: The effect of recreational homes on willow ptarmigan (Lagopus lagopus) in a mountain area of Norway. — European Journal of Wildlife Research 56: 789–795.

Summers, R.W., Willi, J. & Salvidige, J. 2009: Capercaillie *Tetrao urogallus* nest loss and attendance at Abernethy Forest, Scotland. — Wildlife Biology 15(3): 319–327.

Swenson, J.E. 1991a: Social organization of Hazel Grouse and ecological factors influencing it. — PhD thesis. University of Alberta, Edmonton.

Swenson, J.E. 1991b: Evaluation of the density index for territorial male from Hazel Grouse *Bonasa bonasia* in spring and autumn. — Ornis Fennica 68: 57–65.

Swenson, J.E. 2006: The importance of alder to Hazel Grouse in Fennoscandian boreal forest: evidence from four levels of scale. — Ecography 16(1): 37–46.

Swenson, J.E. & Danielson, J. 1991: Status and conservation of Hazel Grouse in Europe. — Ornis Scandinavica 22: 297–298.

Šálek, M., Svobodová, J., Bejček, V. & Albrecht, T. 2004: Predation on artificial nests in relation to the numbers of small mammals in the Krušné hory Mts, the Czech Republic. — Folia Zoologica 53: 312–318.

Taylor, A.R. & Knight, R.L. 2003: Wildlife responses to recreation and associated visitor perceptions. — Ecological Applications 13: 951–963.

Thiel, D., Jenni-Eiermann, S., Braunisch, V., Palme, R. & Jenni, L. 2008: Ski tourism affects habitat use and evokes a physiological stress response in capercaillie *Tetrao urogallus*: a new methodological approach. — Journal of Applied Ecology 45: 845–853.

Thiel, D., Jenni-Eiermann, S., Palme, R. & Jenni, L. 2011: Winter tourism increases stress hormone levels in the Capercaillie *Tetrao urogallus*. — Ibis 153:122–133.

Tirpak, J., Giuliano, W., Miller, C., Allen, T.J., Bittner, S., Edwards, J., Friedhof, S., Igo, W.K., Stauffer, D.F. & Norman, G.W. 2006: Ruffed grouse nest success and habitat selection in the central and southern Appalachians. — Journal of Wildlife Management 70: 138–144.

Vitousek, P.M., Mooney, H.A., Lubchenco, J. & Melillo, J.M. 1997: Human domination of Earth's Ecosystems. — Science 277: 494–499.

Watson, A. & Moss, R. 2004: Impacts of ski-development on ptarmigan (*Lagopus mutus*) at Cairn Gorm, Scotland. — Biological Conservation 116: 267–275.

Wegge, P., Ingul, H., Pollen, V.O., Halvorsrud, E., Sivkov, A.V. & Hjeljord, O. 2012: Comparing predation on forest grouse nests by avian and mammalian predators in two contrasting boreal forest landscapes by the use of artificial nests. — Ornis Fennica 89: 145–156.

Wegge, P., Larson, B.B., Gjerde, I., Kastdalen, L., Rolstad, J. & Storaas, T. 1987: Natural mortality and predation of adult Capercaillie in southeast Norway. — In Proceedings of the International Grouse Symposium (ed. Lovel, T. & Hudson, P.): 49–56. IUCN — Grouse Specialist Group, Suffolk, UK.

Wereszczuk, A. & Zalewski, A. 2015: Spatial Niche Segregation of Sympatric Stone Marten and Pine Marten – Avoidance of Competition or Selection of Optimal Habitat? — PloS ONE 10(10), e0139852. doi.org/10.1371/journal.pone.0139852.

Wilcove, D. 1985: Nest predation in forest tracts and the decline of migratory songbirds. — Ecology 66: 1211–1214.

Wilk, T., Bobrek, R., Pępkowska-Król, A., Neubauer, G. & Kosicki, J.Z. 2016: Birds of Carpathians – state, threats, conservation. — Ogólnopolskie Towarzystwo Ochrony Ptaków, Marki. (In Polish with English summary)

Witkowski, Z.J., Król, W. & Solarz, W. 2003: Carpathian List of Endangered Species. — WWF and Institute of Nature Conservation, Polish Academy of Sciences, Vienna-Krakow.

Zwijacz-Kozica, T., Selva, N., Barja, I., Silván, G., Martínez-Fernández, L., Illera, J.C. & Jodłowski, M. 2013: Concentration of fecal cortisol metabolites in chamois in relation to tourists pressure in Tatra National Park (South Poland). — Acta Theriologica 58: 215–222.

Żmihorski, M., Lewtak, J., Brzeziński, M. & Romanowski, J. 2010: Nest survival in a large river valley: an experiment using artificial nests on an island and river bank in Vistula river (Poland). — Polish Journal of Ecology 58: 197–203.