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ORIGINAL PAPER

The importance of habitat diversity and plant species richness for hazel grouse occurrence in the mixed mountain forests of the Western Carpathians

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Abstract
Hazel grouse habitat requirements are relatively well known in coniferous forests, and less known in mixed or deciduous forests. We studied habitat differences between sites occupied by hazel grouse *Tetrastes bonasia* and control plots in mixed mountain forests of the Western Carpathians in 2009 and 2010. Hazel grouse presence at sites was determined in April and May. The habitat variables ($n=21$) and the proportion of tree and shrub species ($n=22$) were collected both in sites of hazel grouse presence and control plots within a radius of 100 m. Greater numbers of tree species and greater proportions of deciduous trees (mainly birch *Betula* sp.) were found in sites where hazel grouse was present. Lower canopy cover was an important variable for hazel grouse occurrence, and sites with hazel grouse had a greater proportion of young trees (<40 years). Sites were also characterized by a higher proportion of overgrown glades and dead woods in comparison with control plots. Sites occupied by hazel grouse were characterized by a greater number of tree species in the undergrowth (minimum of five species) in comparison with control plots. GLM models revealed that the most important environmental factors for hazel grouse occurrence in mixed mountain forests were open habitats (overgrown glades), good hiding opportunities (fallen trees and dead woods) and good conditions for foraging (trees cover in undergrowth). Poplar (*Populus* sp.) and willow (*Salix* sp.) were the most important tree species for hazel grouse occurrence. The presence of habitat structures and the vegetations richness provides good shelter or food for the hazel grouse. Extensive forest management should be proposed to increase the number of hazel grouse. Large areas covered by herbs and light-seeded tree species of low economical value for forestry are recommended to support hazel grouse population.

Keywords Environmental factors · Habitat structure · Mixed forests · Site occupancy · Plant species richness · Tetraonidae

Introduction

Preservation of various forest structures is important for the protection of endangered species (Zellweger et al. 2013; Kajtoch et al. 2012, 2016). To be able to preserve relevant structures, it is necessary to know the requirements of these species in different habitats. Forest-dwelling birds are often seriously threatened, particularly in regions where habitat transformation and fragmentation are well advanced (Kajtoch et al. 2012). Forest structure is crucial for the distribution and abundance of many bird species, including hazel grouse *Tetrastes bonasia* (Swenson and Angelstam 1993; Lycke et al. 2011; Storch 2013; Zhang et al. 2013; Kortmann et al. 2018) which is generally considered to be a sedentary forest-specialist (Bergmann et al. 1982; Swenson 1991a; Montadert and Leonard 2006). Hazel grouse prefers large coniferous and mixed forests, but can also inhabit fragmented, smaller forest complexes. This species depends on different habitats and food resources throughout the year and could not survive and reproduce in areas which do not sufficiently provide all resources (Chalfoun and Martin 2007; Aldridge and Boyce 2008; Kajtoch et al. 2016; Matysek

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et al. 2018). The hazel grouse forages on different plants, including trees, shrubs and herbs, as well as invertebrates during the breeding season (Cramp and Simmons 1980). This species also requires certain plant structures to survive different phenological seasons (Ludwig and Klaus 2017; Matysek et al. 2018). Greater proportion of deciduous trees and greater species richness in spring sites of this species was found in comparison with winter sites (Matysek et al. 2018). It is searching for food on the ground in summer and on shrubs and pioneer trees in winter.

Hazel grouse habitat requirements are relatively well known in boreal and mountain ecosystems covered by coniferous forests (Bergmann et al. 1996; Kämpfer-Lauenstein 1997; Åberg et al. 2003; Mathys et al. 2006; Müller et al. 2009; Schäublin and Bollman 2011; Ludwig and Klaus 2017), and less known in mixed or deciduous forests (Wiesner et al. 1977; Rhim 2006; Kajtoch et al. 2012; Matysek et al. 2018, 2019). Habitat preferences differ in detail according to diversity of available sites. Forest structure and composition in Fennoscandia and in the Alps differ strongly from those in the Carpathian foothills where mixed forests have been transformed with numerous overgrowing glades and a high degree of fragmentation.

Hazel grouse is still quite abundant in some areas of Europe (Hagemeijer and Blair 1997; BirdLife International 2004); however, while populations are stable in north, they are decreasing in most Western and Central European countries (Swenson and Danielson 1991; Storch 2000). The species is relatively widely distributed in the Polish Carpathians (predominantly in the mountains) but is less prevalent in the foothills (Kajtoch et al. 2011; Matysek 2016).

Hazel grouse habitat requirements have already been studied in the Carpathians, but only for the lowest (covered by mixed forests) and the highest altitudes (dominated by spruce forests). They were not studied in another forest type at medium altitudes (mainly covered by mixed forests with beech, spruce and fir). The aim of this study was to quantify the habitat requirements of hazel grouse in the mixed forests of the Carpathian Mountains at the medium altitudes. Understanding of habitat variables which are necessary for the occurrence of this species is important in its protection and reintroduction.

Study area

The study was carried out in the eastern part of the Makowski Beskid Mountains (Western Carpathians, southern Poland) (49.48°N,19.51°E). The altitude of the study area is between 450 and 857 meters a.s.l. This area comprises moderately high hills covered by forests and agricultural areas (fields and meadows). Mixed forests with coniferous trees are located mostly on the hilltops and in valleys. Forests with varying proportions of spruce *Picea abies*, fir *Abies alba*, pine *Pinus sylvestris*, beech *Fagus sylvatica*, birch *Betula* sp. and other tree species cover more than 50% of the study area. The forested area consists of a mosaic of woodland patches with overgrown glades. Most forests belong to private owners, with the remainder belonging to the Polish Forestry Services. State forests consist predominantly of beech, fir and spruce, while private forests mainly comprise spruce and fir. The oldest forests contain dying trees and dead woods. These forests occupy ca. 20% of the total forest area. Forest stands tend to be younger in private forests. Juvenile forest communities comprise different species (birch, poplar *Populus* sp., willow *Salix* sp., sycamore *Acer pseudoplatanus*). Pastures, meadows and fields are in many places (Ostafin 2009). Most forest stands are extensively managed (with selective cutting of trees). Villages are located mostly along valleys. Such diversity in forest characteristics provides a large area of habitat heterogeneity.

Methods

Hazel grouse monitoring

Places considered as potential habitats for the hazel grouse were selected based on the analysis of satellite images and topographic maps. The selected places were visited at least twice in each season 2009 and 2010 to find hazel grouse sites. MP3 speakers playing hazel grouse male territorial calls from playback were used to detect potential occurrence of individuals in spring (April and May). The presence of hazel grouse was investigated every 150 m walk along a transect. After 3 min of listening, the observer moved on to the next sampling point (Bonczar 2009). The surveys were performed only in good weather conditions and mainly during mornings and evenings, as Swenson (1991b) found a lower response frequency during midday. The recorded sites were mapped in the field. Additionally, traces of existence such as tracks, feathers, sand bathing places or droppings were noted. In places where such traces were found, hazel grouse was detected playing its calls from playback. We found 19 sites occupied by hazel grouse (where birds answered to imitations of its calls). Control plots were chosen randomly in places where no hazel grouse occurrence was found.

Environmental data

A total of 43 environmental variables (21 of habitat factors and 22 of species composition) were collected in 19 hazel grouse sites and 28 control plots in spring (Table 1). Each studied site and control plot was a circle with a radius of ca. 100 m. Habitat factors were determined by biotic and abiotic variables in the circles (Table 1). Trees and shrubs

Table 1 Environmental variables in sites of Hazel Grouse presence and control sites within 100 m radius used in analysis

Variable	Description	Code
Habitat factors		
Deciduous tree proportion	Proportion of deciduous tree species	Decid
Coniferous tree proportion	Proportion of coniferous tree species	Conif
Stand age < 40 years old	Proportion of tree of this age	Tree < 40
Stand age 40–80 years old	Proportion of tree of this age	Tree 40–80
Stand age 80–120 years old	Proportion of tree of this age	Tree 80–120
Stand age > 120 years old	Proportion of tree of this age	Tree > 120
Richness of trees in canopy	Number of tree species in canopy	Tree rich
Tree cover in canopy (%)	Proportion of stand forest cover	Tree cover
Richness of trees in understory	Number of tree species in understory	Bush rich
Tree cover in understory (%)	Proportion of tree cover in understory	Bush cover
Richness of trees in undergrowth	Number of tree species in undergrowth	Un rich
Tree cover in undergrowth (%)	Proportion of tree cover in undergrowth	Un cover
Grass and herbs richness	Categorical: < 10 species, 10–20 species, > 20 species)	Herbs rich
Grass and herbs cover	Categorical: 0–25%, 25–50%, > 50%	Herbs cover
Glades	Presence/absence	Glades
Clearcuttings	Presence/absence	ClearFell
Fallen trees	Presence/absence	FallTree
Dead woods	Presence/absence	DeadW
Ravines	Presence/absence	Ravin
Streams	Presence/absence	Stream
Unpaved roads	Presence/absence	Unroad
Species composition		
Spruce *Picea albies*	Proportion of this species	Spr
Pine *Pinus sylvestris*	Proportion of this species	Pine
Fir *Abies alba*	Proportion of this species	Fir
Larch *Larix deciduas*	Proportion of this species	Larch
Oak *Querqus* sp.	Proportion of this species	Oak
Beech *Fagus sylvaticus*	Proportion of this species	Beech
Birch *etula pendula*	Proportion of this species	Birch
Hornbeam *Carpinus betulus*	Proportion of this species	Hor
Ash *Fraxinus excelsior*	Proportion of this species	Ash
Sycamore *Acer pseudoplatanus*	Proportion of this species	Syc
Linden *Tilia* sp.	Proportion of this species	Lin
Alder *Alnus* sp.	Proportion of this species	Ald
Poplar *Populus* sp.	Proportion of this species	Pop
Hazel *Corylus* avellana	Proportion of this species	Haz
Willow *Salix* sp.	Proportion of this species	Wil
Elm *Ulmus* sp.	Proportion of this species	Elm
Rowan *Sorbus aucuparia*	Proportion of this species	Row
Viburnum *Viburnum* sp.	Proportion of this species	Vib
Hawthorn *Crataegus* sp.	Proportion of this species	Haw
Wild Cherry *Prunus avium*	Proportion of this species	Wcherry
Bird Cherry *Prunus padus*	Proportion of this species	Bcherry
Beige *Sambucus* sp.	Proportion of this species	Beige

were considered to be an element of undergrowth, understory and canopy depending on the height (up to 0.5 m, 0.5–5 m, more than 5 m, respectively). Also the species composition was determined by the proportion of tree and shrub species in the studied site in a circle with a radius of ca. 100 m (Table 1).

Statistical analyses

Statistical differences of habitat factors between sites where hazel grouse was present and control plots were compared using the Mann–Whitney *U* test. A generalized linear model (GLM) with a binomial distribution was used to assess the importance of environmental variables at sites where hazel grouse was present. To build a multivariate model, it was necessary to reduce the number of variables. 'Deciduous and coniferous tree proportion' was not included in the multivariate model of the habitat factors because proportion of tree and shrub species was analyzed in the model of species composition. Principal Component Analysis was used to check collinearity among the environmental variables (Freckleton 2011). Correlated factors were classified to one group to reduce the number of factors for inclusion in the GLM model. 'Ravines' and 'Streams' were joined as one variable ($r = 0.75$, $p < 0.001$). This variable explained 53.1% of the variance (component 1). 'Stand age' was not included to the multivariate model of the habitat factors because other factors were related to the stand age. We found correlations: between trees < 40 years and richness of trees in undergrowth and richness of trees in understory ($r = 0.65$, $p < 0.001$ and $r = 0.62$, $p < 0.001$, respectively), between trees 40–80 years and tree cover in undergrowth ($r = 0.60$, $p < 0.001$), between trees > 120 years and tree cover in undergrowth ($r = 0.52$, $p < 0.001$), between trees 80–120 years and slope ($r = 0.57$, $p < 0.001$). 'Fallen trees' and 'Dead woods' were joined as one variable because they are ecologically related to each other ($r = 0.53$, $p < 0.001$). This variable explained 77.2% of the variance (component 1). Only tree species which share a minimum of 5% in the studied places were taken to multivariate analysis of the species composition. Linear regression models were used to test the importance of two groups of factors—habitat factors and species composition in forest—for hazel grouse occurrence. Akaike's information criterion (AIC) was used for best model selection (Burnham and Anderson 2004). The resulting models were subsequently ranked in order of increasing AIC; the model with the lowest AIC score and highest weight (w) can be viewed as the most parsimonious as it explains most of the variance with the smallest number of parameters. Following Burnham and Anderson (2004), models with Δ AIC < 2 compared to the model with the lowest AIC were assumed to have high strength of evidence. To determine the significance of particular variables, AIC weights (AIC w) for models containing given variables were used to assess the importance of each independent variable (Burnham and Anderson 2004). The predictor with the highest AIC w was considered to be the most important. Univariate logistic regression modeling was adopted to build curves showing the relationship between number of tree species and hazel grouse presence. A multimodel inference, made by summing AIC weights for models containing given variables, was used to assess the real importance of each independent variable. We used STATISTICA version 10 for the statistical analyses (StatSoft Inc 2014).

Results

We found differences between sites where hazel grouse was present and control plots in the study area (Table 2). The presence of overgrown glades was ninefold higher which was recorded in sites occupied by hazel grouse than in control plots. Higher proportion of dead woods (2.1-fold higher) was found in sites occupied by hazel grouse compared to control plots. Sites where hazel grouse was present were characterized by greater numbers of tree species and deciduous trees compared to control plots. The abundance of poplar, alder *Alnus* sp., willow, birch, wild cherry *Prunus avium*, bird cherry *Prunus padus* and hazel *Corylus* sp. was statistically greater in sites where hazel grouse was present compared to control plots (17.6-fold higher, 14.6-fold higher, 9.4-fold higher, 8.1-fold higher, 12.0-fold higher, 6.4-fold higher, 5.1-fold higher, respectively) (Table 2). Tree species richness and their undergrowth and understory cover were higher in sites where hazel grouse was present than in control plots. Sites occupied by hazel grouse also comprised a greater proportion of young trees aged < 40 years (share of these trees was 2.5-fold higher than in control plots). We identified a greater mean number of tree species in the undergrowth in sites occupied by hazel grouse (5–22 species) in comparison with control plots (2–18 species) ($Z = 4.216$, $p < 0.001$, $n = 47$). Contrary, the control plots were characterized by a higher proportion of coniferous trees and canopy cover. The number of tree species in the undergrowth and understory had a significant impact on the probability of hazel grouse occurrence (Fig. 1a, b). Five tree species in the undergrowth were the minimum at the sites occupied by hazel grouse.

The best model explaining hazel grouse presence included the tree cover in the undergrowth, and the occurrence of glades, fallen trees and dead woods (Table 3). GLM analysis of species composition in the forest indicated that models that included poplar and willow best explained hazel grouse presence (Table 3). The most important environmental factors for hazel grouse occurrence were tree cover in the undergrowth ($\sum$ AIC $w = 0.78$), glades ($\sum$ AIC $w = 0.62$) and fallen trees and dead woods ($\sum$ AIC $w = 0.50$). The proportion of poplar ($\sum$ AIC $w = 0.80$), willow ($\sum$ AIC $w = 0.80$) and spruce ($\sum$ AIC $w = 0.69$) had the greatest importance of the forest composition in predicting hazel grouse presence at sites.

Table 2 Basic statistics describing habitat factors and forest structure in the sites of Hazel Grouse presence and control sites

Variable	Sites		Control		*Z*	*p*	*n*
	Mean	Min–Max	Mean	Min–Max			
Habitat factors							
Deciduous tree proportion	61.5	0–100	32.4	0–100	3.924	< 0.001	47
Coniferous tree proportion	38.5	0–100	67.6	0–100	− 3.924	< 0.001	47
Stand age < 40 years old	45.5	0–100	18.4	0–100	2.699	0.007	47
Stand age 40–80 years old	34.2	0–100	42.7	0–100	− 0.563	0.57	47
Stand age 80–120 years old	12.1	0–40	27.0	0–100	− 0.629	0.53	47
Stand age > 120 years old	8.2	0–50	12.3	0–90	− 0.269	0.79	47
Richness of trees in canopy	**5.6**	**1–10**	3.9	**1–11**	**1.994**	**0.046**	**47**
Tree cover in canopy (%)	**41.3**	**5–80**	**62.1**	**5–100**	**− 2.623**	**0.009**	**47**
Richness of trees in understory	**12.4**	**3–22**	**4.7**	**1–15**	**4.682**	**< 0.001**	**47**
Tree cover in understory (%)	**52.6**	**25–80**	**34.3**	**5–100**	**2.807**	**0.005**	**47**
Richness of trees in undergrowth	**13.4**	**5–22**	**6.8**	**2–18**	**4.216**	**< 0.001**	**47**
Tree cover in undergrowth (%)	**40.8**	**15–80**	**21.1**	**5–70**	**3.772**	**< 0.001**	**47**
Grass and herbs richness	**2.0**	**1–3**	**1.0**	**1–2**	**3.794**	**< 0.001**	**47**
Grass and herbs cover	**2.3**	**1–3**	**1.2**	**1–3**	**3.794**	**< 0.001**	**47**
Glades	**0.6**	0–1	**0.1**	**0–1**	**3.219**	**0.001**	**47**
Clearcuttings	0.4	0–1	0.1	0–1	0.821	0.41	47
Fallen trees	0.6	0–1	0.4	0–1	1.572	0.12	47
Dead woods	**0.6**	**0–1**	**0.3**	**0–1**	**2.081**	**0.04**	**47**
Ravines	0.4	0–1	0.2	0–1	0.975	0.33	47
Streams	0.4	0–1	0.2	0–1	1.181	0.24	47
Unpaved roads	0.8	0–1	0.8	0–1	0.184	0.85	47
Species composition							
Spruce *Picea albies*	23.6	5–70	43.0	5–100	− 1.539	0.12	47
Pine *Pinus sylvestris*	1.7	0–8	0.5	0–7	2.330	0.02	47
Fir *Abies alba*	**18.9**	**2–67**	**36.8**	**0–90**	**− 2.309**	**0.02**	**47**
Larch *Larix deciduas*	0.8	0–8	0.3	0–6	1.420	0.16	47
Oak *Querqus* sp.	0.3	0–2	0		0.890	0.36	47
Beech *Fagus sylvaticus*	7.4	0–23	14.8	0–99	− 0.282	0.78	47
Birch *Betula pendula*	**25.8**	**0–67**	**3.2**	**0–38**	**24.715**	**< 0.001**	**47**
Hornbeam *Carpinus betulus*	0.3	0–2	0		0.890	0.36	47
Ash *Fraxinus excelsior*	0.5	0–3	0.2	0–5	1.327	0.18	47
Sycamore *Acer pseudoplatanus*	3.6	0–12	2.1	1–15	0.790	0.43	47
Linden *Tilia* sp.	0.2	0–1	0		0.890	0.36	47
Alder *Alnus* sp.	**2.0**	**0–12**	**0.1**	**0–2**	**2.959**	**0.003**	**47**
Poplar *Populus* sp.	**3.7**	**0–10**	**0.2**	**0–3**	**4.481**	**< 0.001**	**47**
Hazel *Corylus avellana*	**1.7**	**0–5**	**0.3**	**0–3**	**3.388**	**< 0.001**	**47**
Willow *Salix* sp.	**4.7**	**0–10**	**0.5**	**0–4**	**4.781**	**< 0.001**	**47**
Elm *Ulmus* sp.	0.1	0–1	0		0.293	0.77	47
Rowan *Sorbus aucuparia*	1.9	0–5	0.5	0–2	1.744	0.08	47
Viburnum *Viburnum* sp.	0.2	0–1	0		1.203	0.23	47
Hawthorn *Crataegus* sp.	0.4	0–2	0		1.203	0.23	47
Wild Cherry *Prunus avium*	**0.7**	**0–2**	**0.1**	**0–1**	**2.504**	**0.01**	**47**
Bird Cherry *Prunus padus*	**1.3**	**0–4**	**0.1**	**0–1**	**3.664**	**< 0.001**	**47**
Beige *Sambucus* sp.	0.4	0–2	0		1.507	0.13	47

Significant differences (Mann–Whitney test) between plots were given in bold

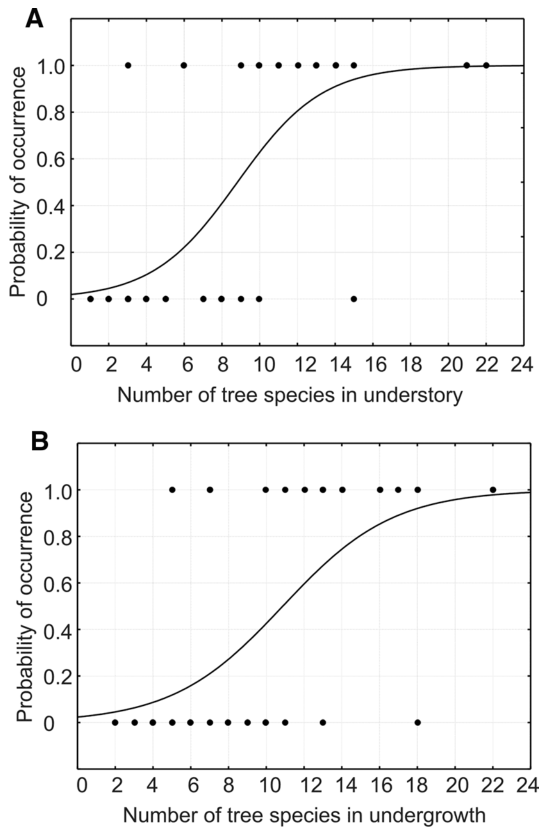

Fig. 1 Logistic regression of the probability of Hazel Grouse occurrence: **a** richness of trees (number of tree species) in understory, **b** richness of trees (number of tree species) in undergrowth

Discussion

Our study showed that sites occupied by hazel grouse were characterized by lower tree cover in the canopy, meaning more light could reach the forest floor and allow the development of the undergrowth and understory. Kortmann et al. (2018) showed that decreasing canopy cover increased the probability of hazel grouse presence in the Bavarian Forest (SE Germany). Moreover, we found the presence of open areas as overgrown glades was an important factor for hazel grouse occurrence in mixed mountain forests, similar as in high-mountain spruce forests (Matysek et al. 2019). Adra et al. (2013) showed that small forest openings are essential for this species in the French Alps. Hazel grouse occupies the early seral stages of forests. Kajtoch et al. (2012) determined the most important factors in the Carpathian Foothills (southern Poland) were the presence of clearings and pioneer trees. Similarly, we found a greater proportion of young trees (<40 years old) in sites of hazel grouse presence. Juvenile tree stages are often accompanied by some pioneer species, and shrubs. Pioneer vegetation in open areas after clearcutting can increase habitat differentiation, provide good shelter and food for hazel grouse (Kajtoch et al. 2012; Matysek et al. 2018). Similar Wiesner et al. (1977) demonstrated the importance of the shrub layer of mixed woodland, particularly in earlier successional stages, for hazel grouse occurrence (east Poland). Conversely, in boreal forest (south central Sweden), hazel grouse occurred in middle-aged (20–69 years) or old (>90 years) stands, but with a greater proportion of deciduous trees and a rich field layer (Åberg et al. 2003). Hazel grouse prefers areas with a better-developed understory.

Table 3 Sets of candidate GLM models (selected 5 the best models) explaining the important factors in sites of Hazel Grouse presence and control plots in the mixed mountain forests

Models	*k*	AIC	Δ	*w*
Habitat factors				
Best models				
Un cover + Glades + FallTreeDeadW	4	63.950	0.000	0.020
Un cover + Herbs cover + Glades + FallTreeDeadW	6	64.153	0.204	0.018
Un cover + Bush rich + Glades	3	64.523	0.573	0.015
Un cover + Bush rich + Glades + FallTreeDeadW	5	64.726	0.776	0.013
Un cover + Glades	2	64.780	0.831	0.013
Species composition				
Best models				
Pop + Wil	2	32.151	0.000	0.023
Pop + Wil + Spr	3	32.491	0.341	0.019
Pop + Wil + Pine	3	32.910	0.759	0.016
Beech + Birch + Pop + Wil + Fir + Spr	6	33.103	0.952	0.014
Beech + Pop + Wil + Spr	4	33.381	1.230	0.012

Akaike's information criterion (AIC), difference between the given model and the most parsimonious model (Δ) and Akaike weight (*w*) are reported for each model. Group of factors were joined "_". Used codes were given in Table 1

We did not find hazel grouse in sites that had lower than five tree species in the undergrowth, and it can be a limit of hazel grouse occurrence in the mixed, mountain forests. In our study, tree cover in the undergrowth and understory and the cover of grass and herbs were greater in sites of the mixed mountain forests where hazel grouse was present. The diversity of vegetation show the importance of glades or other open areas in forest for occurring of hazel grouse. Areas rich in grass and herbs on the forest floor are important for hazel grouse because they provide a rich food base in the undergrowth as well as better possibilities to hide. In the Bohemian Forest (Czech Republic), sites with hazel grouse were positively influenced by higher proportions of herbs but negatively influenced by a higher proportion of grass cover (Ludwig and Klaus 2017; Klaus and Ludwig 2018). Mixed forests with rich understory and undergrowth layers deliver appropriate food supply and living conditions for this species. This species often feeds on the ground; therefore, the greater species richness in the undergrowth is an important component of its occurrence. Mathys et al. (2006) showed that stand structure and shrub and herb coverage were essential habitat variables for hazel grouse occurrence in the Jura mountains (Switzerland). However, Vauhkonen and Imponen (2016) showed the understory, shrub and herb layers were not suitable for habitat mapping of Hazel Grouse in boreal forest in Finland.

Hazel grouse prefers richly structured forest stands with a canopy of tall trees, such as spruce and fir, but that also comprise smaller species such as alder, birch or willow in clearings (Cramp and Simmons 1980; Swenson 1991a; Bergmann et al. 1996; Swenson 2006). GLM models revealed the importance of poplar and willow at sites occupied by hazel grouse in the mixed mountain forests. Seeds and buds of deciduous species are food for hazel grouse, and indeed, higher species richness and proportion of trees giving seeds or fruit in our study were found to be important factors for the hazel grouse occurrence. Moreover, in our study, hazel grouse occurrence was associated with a greater number of tree species in all layers (canopy, understory and undergrowth), and a greater proportion of deciduous trees (mainly birch). Hazel grouse occupied habitats rich in alder (79%), followed by birch and/or hazel (64%) in the Bohemian Forest (Šumava, Czech Republic) (Klaus and Ludwig 2018). Schäublin and Bollman (2011) showed that hazel grouse preferred forests with high proportions of alder and a diverse mosaic of canopy and stand structure in the Swiss Alps. The importance of alder for hazel grouse occurrence in the Fennoscandian boreal forest was confirmed by Swenson (2006). We also found a greater proportion of alder in the sites occupied by hazel grouse presence. The species preferred sites with a dense understory of rowan *Sorbus* sp., willow, beech and spruce in the upper part (1100–1600 m a.s.l.) of the Jura mountains (Switzerland) (Sachot et al. 2003). However, we did not find a greater proportion of rowan in the sites occupied by hazel grouse in the mixed mountain forests. The species requires certain plant species in their diet to survive different phenological seasons (Ludwig and Klaus 2017; Matysek et al. 2018). Generally, hazel grouse consumes flowers and leaves of birch, alder, aspen, willow, linden *Tilia* sp., shoots of herbs and small bushes in spring (Glutz von Blotzheim et al. 1973). Matysek et al. (2018) showed that habitat differentiation plays an important role for hazel grouse in the Carpathian Mountains (southern Poland).

Our study revealed that hazel grouse sites were characterized by a greater presence of fallen trees and dead woods. Similar showed that these structures was positively associated with hazel grouse site occupancy in the Bohemian Forest (Šumava, Czech Republic) (Ludwig and Klaus 2017; Klaus and Ludwig 2018). The environmental structures give the possibility to avoid predators and provides sites for nests (Montadert and Leonard 2004; Seibold et al. 2013).

Heterogeneity of the environment has decreased in most of the Carpathian forests (Kajtoch et al. 2016). Areas where hazel grouse was present were characterized by higher habitat diversity (Matysek et al. 2018). Low habitat heterogeneity and a simplified forest structure decrease the availability of shelter and food for hazel grouse (Matysek et al. 2018). High species richness, including herbs and trees giving seeds or fruit, seems to be important in determining the presence of hazel grouse. Therefore, the presence of such species as willow, birch, alder, hazel and poplar is important for the protection of the hazel grouse. Extensive forest management in forests should be proposed to increase the number of hazel grouse. Natural regeneration of forest after felling should be used more often. For improving the habitat of this species, we recommend to leave areas of vegetation richness. Light-seeded tree species, and admixed tree or bush species of low economical value for forestry, but whose seeds or fruits constitute its food are important for occurrence of hazel grouse. This study broadens our knowledge and allows better understanding the habitat requirements and occurrence of the hazel grouse in another type of forest than in Alps and Scandinavia (dominated by coniferous forests).

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