 doi:10.20944/preprints202102.0325.v1

Article

Long-term trends of Hazel Grouse (*Tetrastes bonasia)* in the Bohemian Forest (Šumava), Czech Republic, 1972-2019

Siegfried Klaus & Tobias Ludwig

Siegfried Klaus, Lindenhöhe 5, D-07749 Jena and siegi.klaus@gmx.de
Tobias Ludwig, Am Hirtenhaus 4, D-29308 Winsen (Aller), tobilu@web.de

Summary: The long-term dynamics of a central European Hazel Grouse population was investigated in the Bohemian forest (Czech Republic). The fluctuating population was stable for more than 30 years, up to 2006 and then declining. Possible reasons for the decline were increasing forestry (heavy, noisy machines, clear-cutting on large areas, extension of transport lines, and removal of pioneer trees. Disturbance of this shy bird by growing tourist activities and predation were also discussed. Management recommendations to improve the situation for the red-listed umbrella-species embrace the extension of the core zone of the national park, reduction of intensity of forestry in favor of mixed forests with pioneer trees that provide winter food for the species.

Abstract: The population dynamics of Hazel Grouse was studied by presence/ absence recording at stationary sites along fixed routes (110 km) during 1972-2019 in the central part of the Bohemian Forest (Šumava, Czech Republic). The 100-km² study area covered altitudes between 600 m (Rejstejn) and 1,253 m a.s.l., (mount Sokol). Our data base contained indices of Hazel Grouse occupancy: positive sites/ controlled sites for a yearly increasing number of Hazel Grouse occurrence sites (N = 134) for 48 years. We used a loglinear Poisson-regression method to analyze the long-term population trend for Hazel Grouse in the study area. In the period 1972 to 2006 we found a stable Hazel Grouse population ($p = 0.83$). From 2006-2007 to 2019, the population index dropped (-3.8% per year, $p < 0.05$) for the last 13 years. This decline is assumed to be influenced by habitat loss due to succession resulting in older, more open forest stands, by strongly increasing forestry and windstorm "Kyrill" followed by clear cutting, bark-beetle damage, and removal of pioneer trees in spruce plantations, which diminished buds and catkins, the dominant winter food. The influence of disturbance by increasing tourist activities and/or predation is discussed. Our results could help to optimize conservation efforts for Hazel Grouse in the Bohemian Forest.

Keywords: Hazel Grouse; Bohemian Forest; long-term monitoring, population trend, TRIM.

1. Introduction

The Hazel Grouse (*Tetrastes bonasia*) is a cryptically coloured, medium-sized forest bird, adapted to multi-layered and old-growth forests with gaps and spots of dense, young forest succession [1–6]. The IUCN Red List of Threatened Species (IUCN 2006, http://www.redlist.org/) designated the current situation of Hazel Grouse in Europe as „lower risk (near threatened) and the EU Birds Directive (2009/147/EC) listed the Hazel Grouse in Annex I. In National Red Data books of some central and southern European countries the species is recorded as "vulnerable" (e.g. in Czechia,[7]) or "endangered" (e.g. in Germany, [8]), and hunting is forbidden. The European Breeding Bird Atlas-2 documents the large and almost continuous distribution range of the species [9] across the boreal forests with highest occurrence probabilities and abundances in Southern Finland and Russia, where suitable habitats of coniferous and mixed forests prevail throughout large unfragmented areas. There were little areal changes in the core range from Finland through the Baltic States to Belarus and Russia. However, in the more fragmented range

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 16 February 2021 doi:10.20944/preprints202102.0325.v1

in central and western Europe a high number of squares where the species was not confirmed indicate substantial range losses. In France, the Hazel Grouse already vanished from areas outside the Jura Mountains and the Alps before the 1990s. In Switzerland, the species disappeared from the eastern part of the Jura and is only preserved in the less fragmented regions of the western Jura and the Alps [9].

Except for the Alps, the Bohemian Forest is the largest area occupied by Hazel Grouse in Central Europe [10–13]. After World War 2, farmers left this region and forest succession began on abandoned fields and meadows on huge areas. In addition to the natural regeneration of pioneer trees in all suitable habitats, spruce (*Picea abies*) was planted, mostly in small plots forming mosaics with a high density of forest edges throughout the whole region. Before 1950, the density of Hazel Grouse in the spruce -dominated landscape was low. The increase in the amount of young mixed forests was accompanied by a pronounced increase in Hazel Grouse numbers [13–16].

Long-term field studies provide valuable data about animal populations. In practice, this type of data often contains many missing values. Simple comparisons of numbers or occupancy ratios between years may thus yield population and trend estimates that are different from the true population state [17]. In this study, we therefore calculated population trends for Hazel Grouse in the Bohemian Forest applying a loglinear Poisson regression method to the full set of Hazel Grouse sites over a 48-year period. We thus report here on the longest Hazel Grouse monitoring in Central Europe. The aim of our study was 1. to track the dynamics of a formerly expanding Hazel Grouse population in Central Europe by long-term monitoring, 2. to seek possible reasons for the trends, and 3. to provide basic knowledge for conservation [11,18,19]. The influence of weather on the investigated population was published earlier [15] and habitat parameters that explain Hazel Grouse occurrence in the study area were described by Ludwig & Klaus [20].

2. Methods

2.1. Study area

Hazel grouse were monitored during 1972-2019 in the central part (District Klatovy, Czech Republic) of the Bohemian Forest (Šumava in Czech, Bayerischer-Böhmerwald in German). Our 100-km² study area (Figure 1) covered altitudes between 600 m (Rejstejn) and 1,253 m a.s.l., (mount Antigl/Sokol, near Horska Kvilda). The Bohemian Forest is an extensive, 120 km-long mountain range along the border between the Czech Republic, Germany, and Austria. It is one of the geologically oldest mountain ranges in Central Europe.

In 1991, the National Park "Šumava" (Bohemian Forest - 68,064 ha) was founded and 68 % of the control sites became part of this reserve. In contrast to the IUCN rules, timber harvest continued with increasing intensity in the whole study area. The core zone without timber cutting (only 13%, mainly peat bogs), did not match our study area. Only in 2020, after the end of our monitoring period, the core zone was enlarged to 27%, of the national park area. The whole study area is part of the EU-Natura 2000 network (Special protected area). Only 1.47 human inhabitants per 100 ha are living permanently in Šumava national park, but 770,000 visitors were counted in 2008 [21].

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 16 February 2021 doi:10.20944/preprints202102.0325.v1

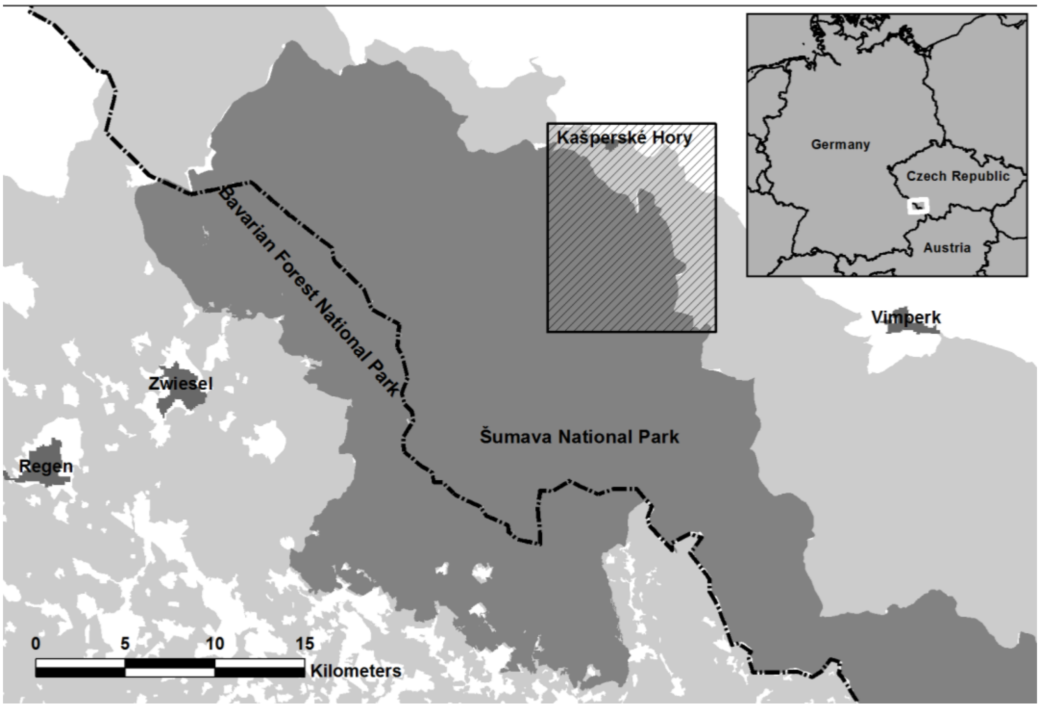

Figure 1. Location of the study area (hatched rectangle) in the central part of the Bohemian Forest, including the small town of Kašperské Hory at its northern edge. Dark-grey areas show national parks Šumava (north of the national border) and Bavarian Forest (south of the national border), light-grey areas indicate Bohemian Forest Landscape Reserves (north of the national border) and Bavarian Forest Nature Park (south of the national border). The white box on the inset map (upper right) depicts the position of the national parks along the German–Czech Republic border.

The spruce-dominated study area includes four main forest types that provide Hazel Grouse habitats. Along an altitudinal gradient, these are valleys with alder (*Alnus glutinosa*) as the dominating deciduous tree (about 600-700 m a.s.l.), lower slopes with birch *(Betula pendula*) and hazel (*Corylus avellana*), as potential winter food (about 700-900 m a.s.l.) , montane mixed forests with spruce, beech (*Fagus sylvatica*) and fir (*Abies alba*) at 900-1100 m a.s.l. and mountain spruce forests where single rowans (*Sorbus aucuparia*), which provide food in winter (above 1100 m a.s.l.).

Potential mammalian predators with impact on Hazel Grouse are Red Fox (*Vulpes vulpes*), Pine Marten (*Martes martes*), Lynx (*Lynx lynx*), Batcher (*Meles meles*), and raptors: Norhtern Goshawk (*Accipiter gentilis*), Sparrow Hawk (*Accipiter nisus*), Eagle Owl (*Bubo bubo*), Ural Owl (*Strix uralensis)*. Wild Boar (*Sus scrofa*), increasing since 1980 may predate on nests and grouse chicks [22].

2.2. Detection of hazel grouse occupancy

Here we use the term "Hazel Grouse site" or "site" instead of "territory", because most of the indications of Hazel Grouse presence were found by indirect evidence and not by territorial activities of the birds responding to play-back of the territorial song. All sites where hazel grouse had been found at least once since 1972 got unique numbers (1-134) and were mapped. An increasing, varying part of the sites (4-14 at the beginning and 23-70 sites since 1981, mean: 41.8 sites/year) were examined yearly (exceptions: 1974, 1977/78, 1993, 2016-18) up to 2019 along fixed routes (in total 110 km, [11,13,20]). The maximum number of visitations per site was 38 years (mean: 12.6 years/ site). Detection of Hazel Grouse included indirect signs (dust-bathing places, droppings, feathers and tracks) and testing the reactions of males to whistling, following the methods described by Wiesner et al. [23] and Swenson [24]. All the positive sites had adequate habitat quality, as indicated by the presence of Hazel Grouse over several years, by habitat descriptions in the literature [2,3,5], and own measurements [11]. The proportion of occupied sites was estimated after the break-up of broods in October. All data on density are indices rather than direct counts. The index of density of occupied sites of a given year was defined as the proportion between the number of occupied sites and the number of sites investigated for the presence of hazel grouse. At every Hazel Grouse site, negative factors (obvious damages caused by forestry resulting from activities in the present year, presence of humans seen during the control of every site , habitat loss by ongoing succession) were recorded simply as presence/absence data during two periods (2007-2011 and 2012-2015 and 2019). All field data were collected by one of the authors (S.K.) without changing the method over the whole period.

2.3. Statistical Methods

Our data base contained investigations of N = 134 Hazel Grouse sites over 48 years (1972–2019). We used R [25] and TRIM (Trends and Indices in Monitoring Data), implemented in the rtrim package [26], to analyze the long-term Hazel Grouse population trend. Using loglinear Poisson regression, the method is capable to estimate the trends of animal populations based on typically incomplete count data as it was the case with our 134 Hazel Grouse sites. Annual and site effects, as well as missing counts, are taken into account to determine annual indices, trends, and their standard errors [17]. In addition, the model considers overdispersion, i.e., the deviation of the variance from the mean of a Poisson distribution, as well as serial autocorrelation, i.e., the time dependence of a count on its predecessors [27]. We deployed TRIMs model type 2, because, in addition to site effects, it also allows linearly changing trends to best describe the increases and decreases in the population. We included binary covariates to test for trend differences inside and outside the national park and between altitudes up to 900 m and above.

For a simple comparison of the mean numbers of monitored sites affected by forestry, tourism, or habitat loss due to succession during two periods of five years each (2007-11 and 2012-15/2019), we applied Welch two-sample t-test, a variant of the paired t-test assuming unequal variances. We also tested visitor numbers (obtained from the administration of Šumava National Park) in four districts as predictors of the index values from our best model using a generalized linear model (GLM).

3. Results

3.1. Population trend

A first model with constant trend was not significantly different from a loglinear Poisson model (Chi-square = 614.6, df = 1575, p = 1.0) and thus achieved a good fit. Over the entire period from 1972 to 2019, the model showed a slight population decrease. The average decrease was 0.6% per year and close to significant ($p = 0.06$). The population may therefore be interpreted as stable over the whole study period (Table 1).

In a next step, we tested for significant trend changes. Stepwise selection of change-points was not possible due to data constraints. Therefore, we sequentially tested all years as potential change points and chose the best model based on lowest Akaikes Information Criterion (AIC) and Wald test for significance of changes in slope. This resulted in an improved version of the model (ΔAIC = 5.56) predicting a stable population until 2006 (p = 0.63) and a population decrease of -3.8% per year ($p < 0.02$) for the last 13 years (Table 1).

Table 1. Coefficients for the model of the Hazel Grouse population with constant trend (second row) and with changing trend (lower two rows) for the Hazel Grouse population. Trend coefficients are given in additive (add) and multiplicative notation (mul) with their standard errors (se). Multiplication of additive coefficients with 100% provides yearly changes for the period. The same is achieved subtracting one from the multiplicative coefficients.

from	upto	add	se_add	mul	se_mul	p	meaning
1972	2019	-0.0061	0.0032	0.9940	0.0032	0.0622	Stable

1972	2006	-0.0008	0.0049	0.9992	0.0049	0.8782	Stable
2006	2019	-0.0376	0.0126	0.9631	0.0121	0.0113	Decrease ($p < 0.05$)

Inclusion of a covariate did neither result in significantly different trends for sites below and above 900 m nor did it for sites within and outside the national park ($p > 0.4$).

The simple occupancy index (proportion occupied/ investigated sites each year) exaggerated the ups and downs of the modelled trend curve (Figure 2). It also tended to overestimate the declining population after the changepoint (2006). However, while the trend index displays change in the population relative to the first year, the occupancy index must be interpreted as the proportion of sites occupied by Hazel Grouse. Our results therefore suggested that Hazel Grouse occupancy in our study area fluctuated between 0.5 and 0.8.

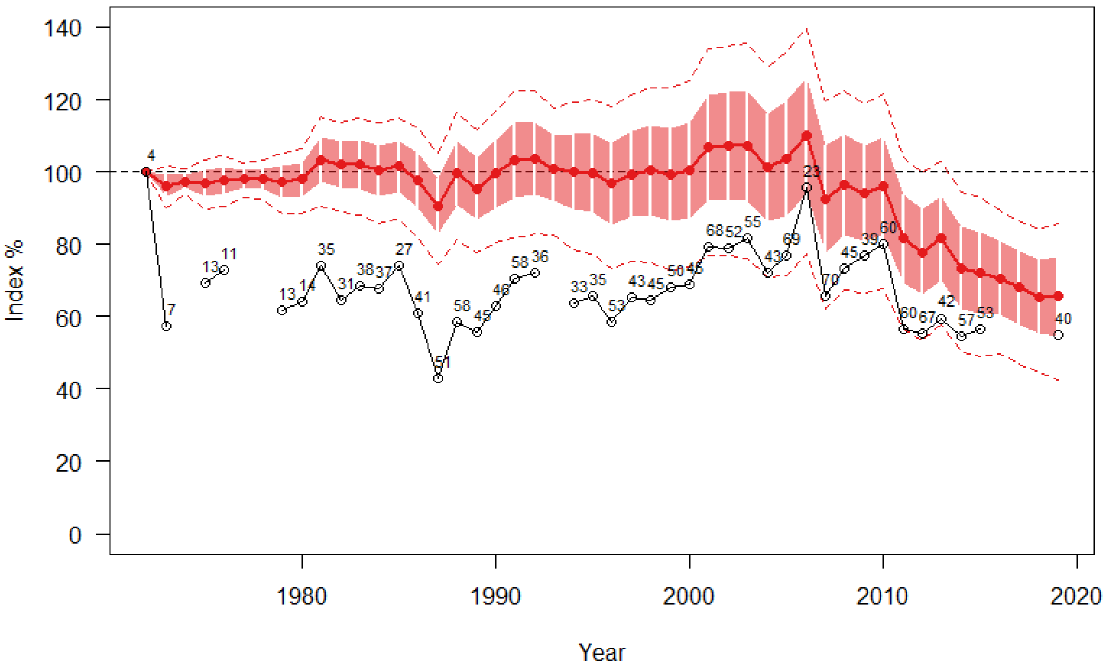

Figure 2. Index curve (bold red line) of the Hazel Grouse population in the Bohemian Forest from 1972 to 2019 (red bar = standard error) and its 95% confidence limits (dashed red lines) based on the best loglinear Poisson-regression model with the year 2006 as a changepoint. 1972 = 100%. Black lines and circles show a simple occupancy index calculated as the proportion between positive sites and controlled sites (lower curve). The number of controlled sites per year is indicated by small numbers (see Methods for details).

3.2. Negative impact of forestry and disturbance by tourism on hazel grouse

Habitat damages by industrial forestry increased from an average of 5.6 monitored sites per year by a factor of 1.3 to 7.4 monitored sites per year (Welch two sample t-test: $t = -1.57$, $df = 7.82$, $p = 0.15$) from 2007-2011 to 2012-15/19. After the strong wind storm „Kyrill“ in 2007, there was also an increase in negative factors in 2007-2011, as compared with the period before. The negative impact of clear cutting and creation of monocultures of spruce was at least partially additive within the two periods because the damaged habitat sites did not recover up to the end of the study period. Therefore, we summed up the negative events for both periods resulting in a combined factor of 2.3.

Disturbance by tourist activities increased by a factor 2.5 from 1.6 sites to 4 sites per year from between the two periods (Welch two sample t-test: $t = -1.98$, $df = 4.97$, $p = 0.10$). The Hazel Grouse trend indices from our best model were negatively linked to increasing visitor numbers in the district "Kašperské Hory" ($p < 0.0001$, $AIC = -41.8$, Figure 3), which includes most of our study area. Visitor numbers within this administrative unit more than doubled during the period 2004-2019 from below 15,000 to more than 30,000 visitors per year (Figure 3).

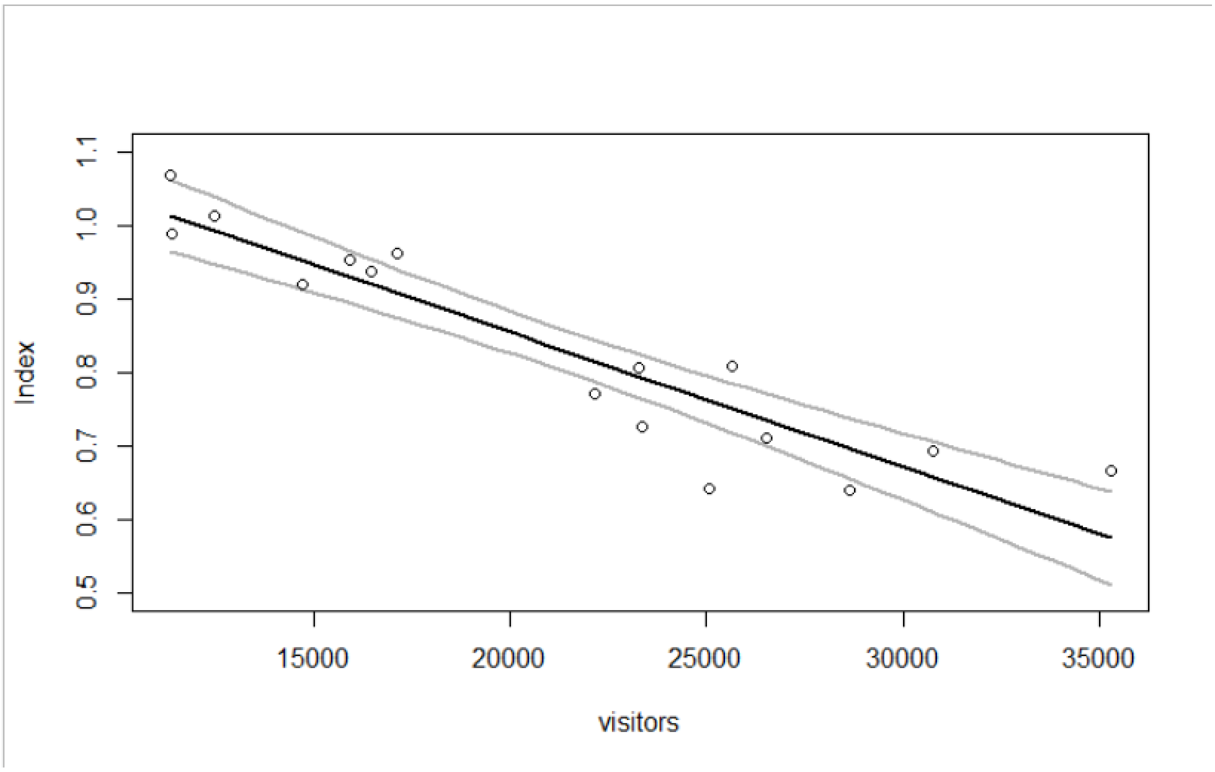

Figure 3. Relationship between the modelled Hazel Grouse index and the number of visitors in district "Kašperské Hory" during the last 16 years (2004-2019). Visitor numbers were provided by the administration of Šumava National Park.

In even-aged plantations, habitat loss in some Hazel Grouse sites was driven by the succession from young to mature forest stands, with reduced cover in mature stands. Habitat loss affected on average 1.6 sites per year during the period 2007-2011 and 3.2 sites during the following five years (Welch two sample t-test: $t = -1.91$, $df = 7.50$, $p = 0.09$). Given that this effect is also cumulative, a 3-fold increase in sites unsuitable to hazel grouse may be considered.

4. Discussion

National park "Šumava" is a special case in Central Europe, because it is a rare example of a stable Hazel Grouse population during 35 years of study as shown by our results and earlier work [15]. Another such example was reported from the Southern French Alps [4,28–30].

Our density index of site occupancy (black line in Figure 2) suggested fluctuations in Hazel Grouse occupancy between 0.5 and 0.8. Most probably these fluctuations reflected both, patterns due to varying site numbers and thus different habitat quality at sites but also turnover in the occupancy of Hazel Grouse territories. Metapopulation dynamics in Hazel Grouse [31]with assessments of colonization and extinction probabilities were beyond the scope of this study. The field data however was well suited to estimate long-term trends. With the applied loglinear Poisson regression, that considers missing values, overdispersion and serial autocorrelation, we are confident that we captured trend estimates that come close to the true overall dynamics of the Hazel Grouse population in the

Bohemian Forest. By using models that make assumptions about the structure of the counts, it was possible not only to obtain better population indices but also to include estimates about their precision. Model fit as assessed by Chi-square test revealed no deviation from the assumed Poisson distribution. Another feature that increased the credibility of our trend estimates was that detection probability was not influenced by different observation skills, because field work was carried out by one of the authors (S.K.).

The modelled index curve in figure 2 shows irregular fluctuations in Hazel Grouse density. However, there is no indication of cyclicity as known from the long-term census data on Hazel Grouse in Russia and Fennoscandia [32–36]. Helle et al. [37] and Ranta et al. [38] reported cyclic fluctuations of grouse populations in Finland with 5-7-year cycle length since 1960. Since the mid-1980s cyclic dynamics have disappeared in all grouse species in most parts of Finland. This resembles the typical situation in central and south of Europe, where cyclicity is less pronounced or even absent (for a review see [39]).

From 2006/2007 to the present, the Hazel Grouse trend and occupancy indices in our study area dropped obviously. This decline (Table 1, Figure 2) could possibly be driven by several factors. In accordance with literature ([2,40] for a review), habitat loss by natural succession, resulting in older and more open forest stands at the one hand, and strongly increasing forestry (pronounced after windstorm "Kyrill" in 2007) on the other hand, probably played the major role. Timber harvest took place in the whole study area over the entire timespan, which might explain that we did not find trend differences between sites inside and outside the national park. Timber harvest by clear cutting for benefit, increased after windstorm "Kyrill" and bark-beetle damage resulted in loss of several territories. In addition, the removal of pioneer trees in spruce plantations, the preferred winter food of Hazel was another negative factor damaging habitat. In parts of the study area, increasing densities of Red Deer *Cervus elaphus* damaging deciduous trees and bilberry *Vaccinium myrtillus*, preferred by Hazel Grouse as ground cover and food year-round had negative impact on habitat quality [41].

There are only few recent studies on Hazel Grouse habitat choice in Central Europe. Based on data from the nearby Bavarian Forest National Park, Müller et al. [42] showed that habitat heterogeneity, stand structure, presence of pioneer trees like mountain ash and willow, root plates of fallen trees, and borderlines are important habitat features for Hazel Grouse. In the northern Carpathians (Southern Poland), the most important factors were the presence of bilberry, gap structure, and the presence of pioneer trees [43]. In the Swiss Alps, Hazel Grouse preferred spruce stands with high portions of tall rowans *Sorbus aucuparia*, forest edges, and dense shrub layers [44]. Our earlier studies in the Bohemian Forest showed that the probability of occupancy by Hazel Grouse for a given habitat site increased with growing tree species richness. Probability of occurrence culminated in young age-class forests between 20 and 40 years. Stands > 50 years old lost habitat quality due to lack of ground cover. In contrast, multi-layered old-growth forests were also used by Hazel Grouse [11]. Ludwig and Klaus [20] found that site occupancy by Hazel Grouse in the Bohemian Forest was high in dense spruce forests characterized by short sighting distances (> 20 m). It increased sharply with small proportions of deciduous trees (5-10%) in conifer-dominated forests. Other elements positively associated with Hazel Grouse site occupancy were the presence of anthills and fallen logs, well developed herb cover, and high bilberry cover. In addition, the Hazel Grouse, as a poor disperser, is sensitive to habitat fragmentation [29,45–47], favored by the recent clear-cutting activities.

Many studies from Fennoscandia presented evidence that predators like Goshawk [48–50] are controlling grouse populations. Also Red Fox and Pine Marten are effective predators on grouse [51,52]. Although predation was outside the aim of our study, indirect evidence from hunting bags [15] indicate that an increase of opportunistic predators and Wild Boar occurred in central Europa during the 1970 to 1990s, when the Hazel Grouse population in the study area was stable. Šťastný et al. [53] documented no increase in Goshawk population during 1973 and 1989 in Czechia. Therefore, the continuous decline since 2006 seems not to be supported by an increase of predator densities, although an increase of predation in more fragmented habitats cannot be excluded. According to

Kauhala and Helle [54] predator numbers also were of minor importance when determining the trends in grouse populations in Finland.

Human disturbance is assumed to have profound negative impacts on the populations of vigilant grouse species [55]. Our data document the rising attractiveness of Šumava National Park to tourists, such as hikers, skiers, and mountain bikers and the increasing disturbance pressure. Increasing visitor numbers from 2004 to 2019 strongly and negatively correlated with the Hazel Grouse trend index in our study area (Figure 3). Though causation cannot be inferred due to simple temporal correlation and a spatial sample size of $N = 1$, high significance of the relationship makes increasing leisure and tourist activities likely to have contributed to the observed negative population trend. To overcome the causation problem at least partially, we tested visitor numbers in three neighboring districts that covered much less of our study area. This resulted in only one district (Březník) also showing a negative relationship with the index values, but at much lower significance ($p < 0.01$). Furthermore, index values were not linked to visitor numbers for the third district "Rokyta" ($p = 0.49$) and were positively linked to those from the fourth district "Poledník" ($p < 0.01$), thus increasing confidence in a causation between visitor numbers and Hazel Grouse trend index.

Effects of climate change on Hazel Grouse was not a topic of our studies. Nevertheless, the increase of bark-beetle damage to spruce plantations was obviously one reason for the fast growth in forest activities. In a long-term perspective, habitats could improve after bark-beetle attack, when pioneer trees in young mixed forests can develop in the openings. The explosion of bark-beetles, resulting in dead wood, natural rejuvenation, and enrichment of structures in Šumava and Bavarian national parks, were reported to favour the increase of both capercaillie *Tetrao urogallus* and Hazel Grouse [18,56].

Conclusions

The long-term dynamics of a central European Hazel Grouse population was investigated. Results could be of use for EU-directed reports on a target- and annex species of the Natura 2000-network. The fluctuating population was stable for more than 30 years, up to 2006. Possible reasons for the decline since 2006 are complex. Increasing impact of industrial forestry (heavy, noisy machines, clear-cutting on large areas, extension of transport lines, frequent thinning operations, removal of pioneer trees), disturbance by growing tourist activities and predation were discussed. Management recommendations include the extension of the core zone of the national park, reduction of intensity of forestry in favor of mixed mountain forests, protection of pioneer trees. The results of this and earlier studies were forwarded to the administration of the Šumava national park, and made public in the form of an open letter from the Galliformes Specialist Group of the SSC/IUCN to the Ministry of Environment of the Czech Republic in order to improve management activities for Hazel Grouse [11,18,19].

Author Contributions: Conceptualization, S.K. and T.L.; field methodology, S.K.; formal analysis, T.L.; investigation, S.K.; data curation, T.L.; writing—original draft preparation, S.K.; writing—review and editing, S.K. and T.L.; project administration, S.K.; All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy reasons and species conservation.

Acknowledgments: We are grateful to the administration of the national park Šumava (Pavel Pečka) for support and for tourist data (Martina Kučerova) during the study period. Our special thanks are due to Margret Klaus for support of the field work, and to Hans-Heiner Bergmann and Jon Swenson for continuous cooperation in hazel grouse research and helpful recommendations for the manuscript. We are grateful to Jukka Jokimäki and three anonymous referees for helpful comments and suggestions.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Scherzinger, W. Rauhfuß-Hühner. *Schr. Natl. Bayer. Wald* 1976, *2*.
2. Bergmann, H.H.; Klaus, S.; Müller, F.; Scherzinger, W.; Swenson, J.E.; Wiesner, J. *Die Haselhühner*; Westarp Wissenschaften: Magdeburg, Germany, 1996; ISBN 3-89432-499-6.
3. Pynnönen, A. Beitrage zur Kenntnis der Lebensweise des Haselhuhns, Tetrastes bonasia (L.). *Riistatiet. Julk. Pap. Game Res.* **1954**, *12*, 1–90.
4. Montadert, M.; Leonard, P. Survival in an expanding hazel grouse Bonasa bonasia population in the southeastern French Alps. *Wildlife Biol.* **2003**, *9*, 357–364, doi:10.2981/wlb.2003.025.
5. Swenson, J.E. The ecology of Hazel Grouse and management of its habitat. *Naturschutzreport* **1995**, *10*, 227–238.
6. Klaus, S.; Bergmann, H.-H. *Auerhühner & Co*; Aula Verlag: Wiebelsheim, 2020; ISBN 978-3-89104-835-1.
7. Šťastný, K.; Bejček, V.; Němec, M. Červený seznam ptáků České republiky. In *Červený seznam ohrožených druhů České republiky. (Red list of Birds, in Czech.)*; Chobot, ., Němec, M., Eds.; Příroda Praha 34, 2017; pp. 107–154.
8. Grüneberg, C.; Bauer, H.-G.; Haupt, H.; Hüppop, O.; Ryslavy, T.; Südbeck, P. Rote Liste der Brutvögel Deutschlands. *Berichte zum Vogelschutz* **2015**, *52*, 19–67.
9. Zbinden, N.; Klaus, S.; Keller, V. Bonasa bonasia -Hazel Grouse. In *European Breeding Bird Atlas 2. Distribution, Abundance and Change*; Keller, V., Herrando, S., Voříšek, P., Franch, M., Kipson, M., Milanesi, P., Martí, D., Anton, M., Klvaňová, A., Kalyakin, M. V., Bauer, H.-G., Foppen, R.P.B., Eds.; European Bird Census Council & Lynx Edicions: Barcelona, 2020; pp. 86–87 ISBN 978-84-16728-38-1.
10. Klaus, S. Effects of forestry on grouse populations: case studies from the Thuringian and Bohemian forests, Central Europe. *Ornis Scand.* **1991**, *22*, 218–223.
11. Klaus, S. Hazel grouse in the Bohemian Forest: Results of a 24-year-long study. *Silva Gabretta* **1996**, *1*, 209–220.
12. Klaus, S.; Martens, J.; Andreev, A.; Sun, Y.H. Bonasa bonasia (Linnaeus, 1758) Haselhuhn. In *Atlas der Verbreitung palaearktischer Vögel*; Martens, J., Eck, S., Sun, Y.-H., Eds.; 20. Jg., Nr. 6, 2003; p. 15.
13. Klaus, S. Hazel Grouse in the Bohemian Forest: Results of a 20-year study. In Proceedings of the Int. Symp. Grouse 6; World Pheasant Association, Reading, UK and Istituto Nationale per la Fauna Selvatica: Ozzano dell'Emilia, Italy, 1995; pp. 27–33.
14. Kučera, L. Verbreitung und Populationsdichte von Auerhuhn (Tetrao urogallus), Birkhuhn (Lyrurus tetrix) und Haselhuhn (Tetrastes bonasia) im westlichen Teil von Šumava (CSSR). *Ornithol. Mitt.* **1975**, *27*, 160–169.
15. Klaus, S. A 33-year Study of Hazel Grouse Bonasa bonasia in the Bohemian Forest, Šumava, Czech Republic: Effects of Weather on Density in Autumn. *Wildlife Biol.* **2007**, *13*, 105–108.
16. Klaus, S.; Ludwig, T. Ökologie, Verhalten und Schutz des Haselhuhns Bonasa bonasia im Böhmerwald (Šumava, Tschechien). In Proceedings of the Symposium Raufußhühner des Landesjagdverbandes Bayern - Bayerischer Jagdverband e.V. und der Bayerischen Akademie für Jagd und Natur; Schriftenreihe des Landesjagdverbandes Bayern e.V., Band 22: Freyung, 2016; pp. 45–54.
17. ter Braak, C.J.F.; van Strien, A.J.; Meijer, R.; Verstrael, T.J. Analysis of monitoring data with many missing values: which method? *Bird Numbers 1992. Distrib. Monit. Ecol. Asp.* **1994**, 663–673.
18. Klaus, S. Forest grouse and wilderness - survival without management impacts. In Proceedings of the Europe's wild heart. Conference Report; Srni/CZ, 2009; pp. 35–37.
19. Klaus, S. Situation of the hazel grouse Tetrastes bonasia in the National Park Šumava and in the Šumava Landscape Reserve – activities of the Galliforme Specialist Group of IUCN. *Grouse News - Newsl. Grouse Spec. Gr.* **2014**, *48*, 7–8.
20. Ludwig, T.; Klaus, S. Habitat selection in the post-breeding period by Hazel Grouse Tetrastes bonasia in the Bohemian Forest. *J. Ornithol.* **2017**, *158*, 101–112, doi:10.1007/s10336-016-1365-z.
21. „Biosphärenreservat Šumava" Available online: https://de.wikipedia.org/w/index.php?title=Biosphärenreservat_Šumava&oldid=207209923 (accessed on Feb 8, 2021).
22. Klaus, S.; Berger, D.; Huhn, J. Capercaillie Tetrao urogallus decline and emissions from the iron industry. *Wildlife Biol.* **1997**, *3*, 131–136, doi:10.2981/wlb.1997.017.
23. Wiesner, J.; Bergmann, H.H.; Klaus, S.; Müller, F. Siedlungsdichte und Habitatstruktur des Haselhuhns (Bonasa bonasia) im Waldgebiet von Bialowieza (Polen). *J. Ornithol.* **1977**, *118*, 1–20, doi:10.1007/BF01647354.
24. Swenson, J.E. Evaluation of a density index for territorial male Hazel Grouse Bonasa bonasia in spring and autumn. *Ornis Fenn.* **1991**, *68*, 57–65.
25. R Core Team *R: A language and environment for statistical computing*; R Foundation for Statistical Computing: Vienna, Austria, 2019;
26. Bogaart, A.P.; Loo, M. Van Der; Pannekoek, J. rtrim: Trends and Indices for Monitoring Data. *R Packag. version* **2016**, *1.0.1*, https://cran.r-project.org/package=rtrim.
27. Pannekoek, J.; Van Strien, A. TRIM 3 Manual (TRends and Indices for Monitoring data). *CBS Stat. Netherlands* **2005**, 58.
28. Montadert, M. *Suivi de la Gelinotte des bois (Bonasa bonasia) dans les Alpes du nord. Suivi 2014 et bilan général 2008–2014*; 2014;
29. Montadert, M.; Klaus, S. Hazel grouse in open landscapes. *Grouse News* **2011**, 13–22.
30. Montadert, M. Fonctionnement démographique et sélection de l'habitat d'une population en phase d'expansion

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 16 February 2021 doi:10.20944/preprints202102.0325.v1

géographique. Cas de la Gelinotte des bois dans les Alpes du Sud, France, Université de Franche-Comté, 2005.
31. Sahlsten, J.; Wickström, F.; Höglund, J. Hazel grouse Bonasa bonasia population dynamics in a fragmented landscape: a metapopulation approach. *Wildlife Biol.* **2010**, *16*, 35–46, doi:10.2981/07-086.
32. Siivonen, L. The Problem of the Short-Term Fluctuations in Numbers of Tetraonids in Europe. *Pap. Game Res.* **1957**, *19*, 1–44.
33. Semenov-Tjan-Shanskij, O.I. Ökologie der Birkhuhnvögel. *Tr. Laplandskogo Gosudarvstveno Zapov.* **1960**, *5*, 1-318 (In Russian, translated into German).
34. Lindström, J.; Ranta, E.; Lindén, H.; Lindstrom, J.; Linden, H. Large-Scale Synchrony in the Dynamics of Capercaillie, Black Grouse and Hazel Grouse Populations in Finland. *Oikos* **1996**, *76*, 221, doi:10.2307/3546193.
35. Lindstrom, J.; Ranta, E.; Linden, M.; Linden, H. Reproductive Output, Population Structure and Cyclic Dynamics in Capercaillie, Black Grouse and Hazel Grouse. *J. Avian Biol.* **1997**, *28*, 1, doi:10.2307/3677087.
36. Helle, P.; Lindén, H. Changes in Finnish grouse populations during the past half-century. *Suom. Riista* **2015**, 56–66.
37. Helle Pekka; Belkin, V.B.L.D.P.I.. J.A. Changes in grouse populations in Finland and Russian Karelia during recent decades. *Suom. Riista* **2003**, *49*, 32–43.
38. Ranta, E.; Helle, P.; Lindén, H. Forty years of grouse monitoring in Finland. *Suom. Riista* **2004**, *50*, 128–136.
39. Remmert, H. *Arctic Animal Ecology*; Springer: Berlin, 1980;
40. Storch, I. *Grouse: Status survey and conservation action plan 2006-2010*; Gland, Switzerland: IUCN and Fordingbridge, UK: World Pheasant Association, 2007; ISBN 978-2-8317-1009-9.
41. Baines, D.; Moss, R.; Dugan, D. Capercaillie breeding success in relation to forest habitat and predator abundance. *J. Appl. Ecol.* **2004**, *41*, 59–71, doi:10.1111/j.1365-2664.2004.00875.x.
42. Müller, D.; Schröder, B.; Müller, J. Modelling habitat selection of the cryptic Hazel Grouse Bonasa bonasia in a montane forest. *J. Ornithol.* **2009**, *150*, 717–732, doi:10.1007/s10336-009-0390-6.
43. Kajtoch, Ł.; Żmihorski, M.; Bonczar, Z. Hazel Grouse occurrence in fragmented forests: Habitat quantity and configuration is more important than quality. *Eur. J. For. Res.* **2012**, *131*, 1783–1795, doi:10.1007/s10342-012-0632-7.
44. Schäublin, S.; Bollmann, K. Winter habitat selection and conservation of Hazel Grouse (Bonasa bonasia) in mountain forests. *J. Ornithol.* **2011**, *152*, 179–192, doi:10.1007/s10336-010-0563-3.
45. Swenson, J.E. Is the hazel grouse a poor disperser? In Proceedings of the 20th Congress of the International Union of Game Biologists; Gödöllö, 1991; pp. 347–352.
46. Åberg, J.; Swenson, J.E.; Angelstam, P. The habitat requirements of hazel grouse (Bonasa bonasia) in managed boreal forest and applicability of forest stand descriptions as a tool to identify suitable patches. *For. Ecol. Manage.* **2003**, *175*, 437–444, doi:10.1016/S0378-1127(02)00144-5.
47. Klaus, S.; Sewitz, A. Ecology and conservation of Hazel grouse Bonasa bonasia in the Bohemian Forest (Šumava, Czech Republic). In Proceedings of the Tetřevovití – Tetraonidae na přelomu tisíciletí. Proceedings of the Intern. Conf. Tetraonids – Tetraonids at the break of the millenium. Ceske Budejovice, Czech Republic; 2000; pp. 138–1446.
48. Lindén, H.; Wikman, M. Goshawk predation on hazel grouse. *Suom. Riista* **1987**, *34*, 96–106.
49. Tornberg, R. Pattern of goshawk Accipiter gentilis predation on four forest grouse species in northern Finland. *Wildlife Biol.* **2001**, *7*, 245–256, doi:10.2981/wlb.2001.029.
50. Tornberg, R.; Lindén, A.; Byholm, P.; Ranta, E.; Valkama, J.; Helle, P.; Lindén, H. Coupling in goshawk and grouse population dynamics in Finland. *Oecologia* **2013**, *171*, 863–872, doi:10.1007/s00442-012-2448-z.
51. Marcstrom, V.; Kenward, R.; Engren, E. The impact of predation on boreal tetraonids during vole cycles: an experimental study. *J. Anim. Ecol.* **1988**, *57*, 859–872.
52. Lindström, E.R.; Andrén, H.; Angelstam, P.; Cederlund, G.; Hörnfeldt, B.; Jäderberg, L.; Lemnell, P.-A.; Martinsson, B.; Sköld, K.; Swenson, J.E. Disease Reveals the Predator: Sarcoptic Mange, Red Fox Predation, and Prey Populations. *Ecology* **1994**, *75*, 1042–1049, doi:10.2307/1939428.
53. Šťastný, K.; Bejček, V.; Hudec, K. *Atlas hnizdniho rozšiřeni ptaku v Česke republice 1985-1989*; Jihlava. (Atlas of breeding birds, in Czech), 1996;
54. Kauhala, K.; Helle, P. The impact of predator abundance on grouse populations in Finland - A study based on wildlife monitoring counts. *Ornis Fenn.* **2002**, *79*, 14–25.
55. Storch, I. Human disturbance of grouse - Why and when? *Wildlife Biol.* **2013**, *19*, 390–403, doi:10.2981/13-006.
56. Kortmann, M.; Heurich, M.; Latifi, H.; Rösner, S.; Seidl, R.; Müller, J.; Thorn, S. Forest structure following natural disturbances and early succession provides habitat for two avian flagship species, capercaillie (Tetrao urogallus) and hazel grouse (Tetrastes bonasia). *Biol. Conserv.* **2018**, *226*, 81–91, doi:10.1016/j.biocon.2018.07.014.