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Vegetation and Forest Complexity Analysis of the Caucasian Grouse (*Lyrurus mlokosiewiczii*) Habitats in the Lesser Caucasus Mountain

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Abstract: Species composition can vary among different types of habitat and is defined by the dependency of species on resources. The positive relationship between species composition and forest functions is of increasing interest to researchers. In this study, we focused on the species composition and structural complexity index (SCI) of the Caucasian grouse (*Lyrurus mlokosiewiczii*) habitat, which is an indicator species in mountain forest habitats in the Arasbaran biosphere reserve, Iran. Data were collected from the previously identified presence and pseudo-absence locations of this species. A total of 18 sample plots were surveyed systematically randomly in each area with 800 m distance from each other (36 sample plots in total). The main parameters were type of species, diameter and height of trees, shrubs and regeneration, and number and diameter of coarse woody debris. Overstorey tree species richness per ha differed in the pseudo-absence and presence locations, with 16 and 20 species, respectively. The Caucasian grouse was observed in the site with trees smaller than 10 cm DBH and a balanced density of trees smaller than 5 cm DBH. Overall, the SCI was higher in the presence location than in the pseudo-absence location with no significant difference ($t = 1.491$, p -value = 0.154). The heterogeneity of the stand structure in grouse habitats was high. The area where the Caucasian grouse was present was characterized by high numbers of dead trees and also high log volume. Maintaining a heterogenous forest structure is important for protecting this species. Conservation of fruit trees that are fed on by the grouse is also recommended.

Keywords: Arasbaran biosphere reserve; species richness; structural complexity index; Iran; understorey species



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1. Introduction

Species diversity influences the quality of life in forests, and maintenance of such diversity is one of the most important tasks of forest management. A high degree of species diversity enhances ecological service provision by a large number of species. The characteristics of stand structure can influence species diversity and habitat structure of many species of birds and mammals [1–4]. Structural complexity is a measure of some attributes of forest stands and the relative value of each of these attributes [5]. Given that the contribution of each structural attribute to forest complexity may vary consistently across stands [5], forest structural complexity can vary among different types of habitat [6].

Determining the structural complexity of forest ecosystems is challenging and several measures have been used to quantify aspects of structural complexity that focus on tree-based attributes, such as tree size differentiation, diversity of diameter at the breast height (DBH) classes, species richness, number of strata, and other attributes related to tree and

stand [7–9]. Structural complexity necessarily involves the interactions between a number of different variables, and quantitative comparisons between stands may require complex multivariate analysis. In response to this problem, a variety of means have been devised to describe structural complexity by a single index, thereby facilitating comparisons between stands [5,10,11]. Structural complexity is assumed to positively affect several ecosystem functions and services provided by forests [12], including species diversity, resistance, and resilience [6]. In terms of forest management, modern silviculture has focused on structural complexity [1,13], defined as the way in which species depend on resources [11]. The heterogeneity of forest stand structure has a significant impact on tree-related microhabitats in forest ecosystems and enhances species richness [14].

The positive relationship between structural complexity and forest functions is of increasing interest to researchers. Some researchers have focused on the structural complexity and forest structure by applying different indices to different forest ecosystems throughout the world [10,13,15,16]. The description of forest structure represents an important step in the process of understanding forest dynamics, forest ecosystem processes and the associated services [17,18]. Forest structure is the result of natural processes and human disturbances and it determines the distribution of micro-climatic conditions, the availability of resources and the formation of habitat niches and thus, directly or indirectly, the biological diversity within forest communities [18]. Intensive human interventions, including fire, logging, fuelwood harvesting, and animal husbandry can potentially degrade the composition and availability of structural attributes in forests [6]. These types of interventions can alter the density of the understory, volume of coarse woody debris and the density of dead trees [19]. The loss of these forest attributes affects birds that depend on these key structural habitat attributes for their survival [5,6,20]. Coarse woody debris has been positively associated with avian diversity and abundance [6]. Standing coarse woody debris (i.e., dead trees) is an essential resource for many species of birds, especially birds that use the dead trees for breeding, perching, foraging, communicating, and roosting [21,22]. In standing coarse woody debris is usually excavated and used for cavity-nesting by a variety of species [23]. For example, Acosta-Jamett and Simonetti (2004) reported that coarse woody debris is an essential habitat for different species in loblolly pine forests in central Chile [24]. The value of coarse woody debris as bird habitat has also been documented by many other researchers [23,25–27].

In this research, we focus on the species composition in the overstory and understory layers in the habitat of the Caucasian grouse (*Lyrurus mlkosiewiczzi*), considered an indicator species in lesser Caucasus mountain. The Caucasian grouse (CG), a forest bird species, was selected for determining different forest structural characteristics, as different response patterns can be expected in relation to the habitat requirements of the species, which will affect reserve designation. Our hypothesis is that this species is mostly found in the forest habitat with low species diversity and high complexity in forest structure. To test our hypotheses, we compared structural complexity, as well as key habitat structures, in forest areas previously identified as presence and pseudo-absence locations of the species. The study findings are expected to contribute to objectifying the debate around the effects of strict forest protection on mountain forest biodiversity, and to facilitate systematic reserve selection processes.

2. Materials and Methods

2.1. Study Area

A part of lesser Caucasus Mountain called Arasbaran region is located in the northwestern part of Iran. This region covers mountains, high alpine meadows, semi-arid steppes, rangelands, forests, rivers, and springs. This research was conducted in the Arasbaran deciduous forests in the northwest of Iran, in the Caucasus Iranian highlands, at the border of Armenia and Azerbaijan. Since 1976, UNESCO has designated 72,460 ha of land in this area as a biosphere reserve, the Arasbaran biosphere reserve (Figure 1). The Arasbaran biosphere reserve provides habitat for more than 200 species of birds, notably

the CG, grey partridge, black francolin, and common pheasant, as well as 29 species of reptiles, 48 species of mammals, notably wild goat, wild boar, brown bear, wolf, lynx, leopard, and 17 species of fish [28]. Arasbaran is also inhabited by several nomadic tribes, who mainly live in the buffer and transition zones. The minimum and maximum elevations in the study area are 450 m and 2700 m above sea level, respectively. The grouse occurs in upland habitats above 1800 m asl, mostly at forest edges and along the upper altitudinal timberline [28]. The forest tree species typically include oak (*Quercus macranthera*), oriental hornbeam (*Carpinus orientalis*), and maple (*Acer campestre*), which occur in different proportions across the different elevations. The habitat of the species has been manipulated by human disturbance, forest management, and strict protection and also by nomadic tribes in recent years. The Capercaillie, another species of grouse, strongly benefitted from forest-overexploitation in the second half of the 19th century and is now being negatively affected by the change from rotation forestry to selective cutting, which is associated with increasing canopy closure, lack of clearings, and forest structural homogenization at the landscape scale [15]. A similar trend has been observed in the present study area. The core zone contains four villages with a total population of 120 people, with 59 villages (total population: 4345) in the buffer zone and 16 villages (total population: 3446) in the transition zone [29]. The main subsistence activities of these communities are agriculture, gardening, bee and honey production, and livestock production [30,31]. Several nomadic groups also live in the reserve and seasonally inhabit the core zone [32]. The grouse thus occurs within a human-occupied landscape in the Arasbaran region, with rural communities who make use of locally-occurring natural resources living relatively close to surviving grouse populations, and thus potentially possessing local ecological knowledge about grouse population status, distribution, trends, and threats [33].

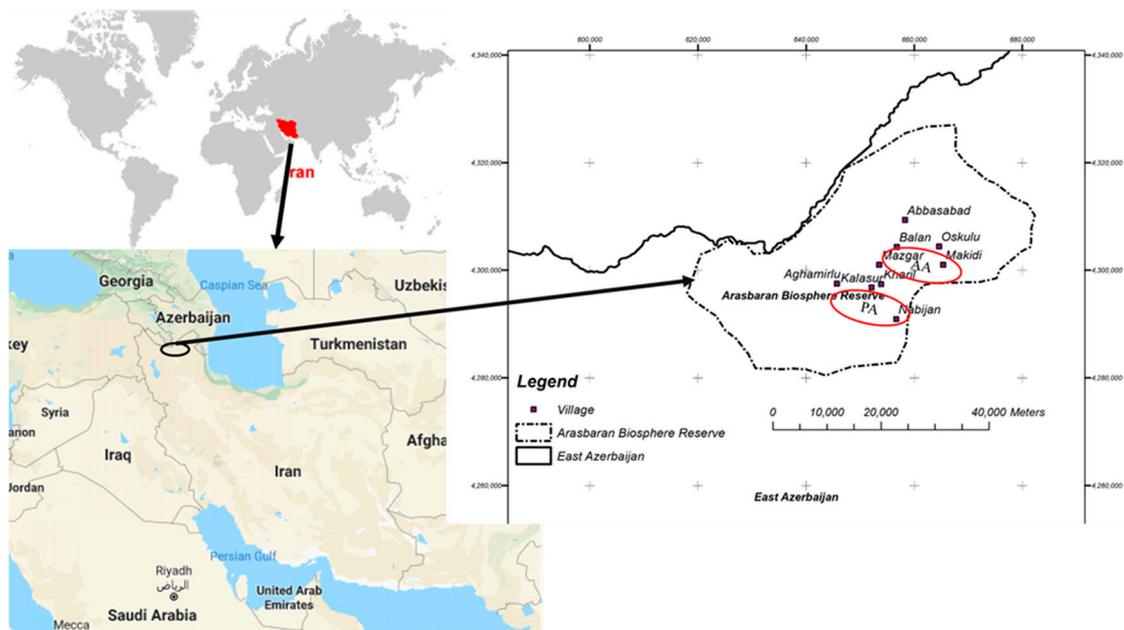


Figure 1. Map of the study area showing the presence and pseudo-absence areas of the Caucasian grouse in the Arasbaran Biosphere Reserve, NW Iran. PA—Presence area, AA—Absence/Pseudo-absence area.

2.2. Species Description

The species is known to occur in an area ranging from the Black Sea to the Caspian Sea in the Caucasus Mountains in Russia, Georgia, Armenia, and Azerbaijan in the north and east, over the lesser Caucasus in northeastern Turkey in the west to northwestern Iran in the south [34]. The CG is a sedentary species, breeding close to deciduous broadleaved forest in the lesser Caucasus Mountains timberline. All areas where the species occurs

in NW Iran are protected and designated as the Arasbaran biosphere reserve. The forest habitats are typically dominated by *Q. macranthera*. The population and distribution of this species have been declining over the last few decades [34,35]. It is one of the grouse species with small distribution and highly fragmented range; it is poorly studied because of its small range, difficulty of access to its remote, high mountain habitat, and its relatively small population size as well as political unrest and poor economies throughout much of its range [36]. In recent years, surveys and population studies have been initiated in Georgia, Turkey, and Azerbaijan. Current population estimates assume 40,000–50,000 birds in Georgia, 25,000–30,000 in Russia, 7500 in Turkey, 1500–3500 in Azerbaijan, 300 in Armenia, and 100 in Iran, resulting in an estimated total population of 80,000–90,000 birds. Habitat loss and deterioration, particularly from intensive grazing of subalpine meadows, are likely to be the major threats [36]. The main reason for habitat loss is mining by Sungun copper mine in this area [37].

2.3. Data Collection and Analysis

In the first step, we selected forest locations where the CG was known to be present and pseudo-absence. Our absence data are based on so-called pseudo-absences. Following Muller et al. (2009), pseudo-absences are not to be treated as a sample of sites with true absences, but as a sample of all sites potentially suitable. Nevertheless, pseudo-absence records along with presence records have been widely used and proved to be a reliable surrogate for true presence/absence data [38]. Data on species presence and pseudo-absence were supplied by ornithologists, foresters, hunters, and local people, i.e., nomadic tribes [15]. The presence and pseudo-absence locations of the species were identified using library studies and field surveys. We established the past and present known distribution of the Caucasian grouse using data from all existing published field surveys, periodic population monitoring by the Department of Environment, and unpublished reports and interviews by ornithologists, foresters, previous hunters, and local people. We then conducted fieldwork within all of the villages situated close to the known locations of surviving grouse populations (Kalasur, Kharil, and Nabijan), or to the locations of grouse populations known to have been extirpated within living memory (Abbasabad, Aghamirlu, Balan, Makidi, Mazgar, and Oskulu) [33]. The distribution areas of the CG on the village maps made by the forest, rangelands, and watershed organization were identified. In each site, we selected randomly systematic 18 rectangular sample plots from a total of 36 sample plots. The sample plots were laid on a grid over the presence and pseudo-absence locations of CG distribution. Each plot had 800 m distance from each other. The sample plots had one hectare area with dimensions 100 m × 100 m and in total, we surveyed plots covering a total area of 36 ha with 18 ha for each site.

2.3.1. Forest Structure

In each sample plot, the species name and diameter at breast height (DBH) of all trees and shrubs were recorded. The DBH was measured with a tree caliper and the height of the trees, with a Suunto clinometer. Tree height is defined as the distance between the base and the top of a standing tree [39]. Trees larger than 1.3 m height as large trees were classified into six size DBH classes; <5 cm, 5–10 cm, 10–15 cm, 15–20 cm, 20–25 cm, and >25 cm. Tree height was classified at 1-m intervals for ten classes; >1.3–2 m, 2–3 m, 3–4 m, 4–5 m, . . . , and >10 m. The number of understory seedlings (<1.3 m in height) was counted in each plot and used to calculate understory density per hectare in each stand [1]. Plot basal area (BA) was calculated as the sum of the radius (at breast height) of all tree stems. The proportion of the respective species was calculated as the ratio between the species BA and the total BA of the stand [40].

The mean values and standard deviations of tree DBH and height were calculated for each sample plot. The relative frequency of three important species was calculated in each plot (Table 1).

The decay class of the snags, logs, and stumps was divided into four classes:

- DC1: recently dead trees with intact tops and the majority of fine branching present, the structure is round, leaves and bark present, cambium is still fresh, wood solid, wood color is original, more than 75% of wood still intact and a good part of the bark was still intact, twigs and leaves attached;
- DC2: 25%–50% of wood beginning to be soft and bark only partially convert; lacked fine twigs and leaves.
- DC3: 75% of the tree trunk has decayed, the bark is totally degraded.
- DC4, trees with broken tops and few or no coarse branches, heartwood decayed soft, leaves absent, bark often absent, wood color is original to faded, and all of the log on the ground, more than 75% of wood has decayed [41–43] (Table 1).

Table 1. Description of attribute studied in the presence and pseudo-absence locations.

Attribute	Index	Description & Reference
Tree diameter	Tree DBH	Tree DBH generally increases with stand age.
	Tree size diversity (TSD)	Shannon–Weiner Index was used to summarize DBH distribution in a single measure called TSD (H'), where $H' = -\sum(p_i \ln p_i)$ and p_i is the proportion of trees in the i th DBH class. The 10–15 DBH class was considered a reference DBH class [44].
	Diameter distribution	The DBH distribution indicates something about the stand structure. Stands with a reverse J distribution are indicative of uneven-aged stands [45]. Also, it is as an attribute of forest structure is the complexity of comparing distributions from different stands [10].
Tree height	Height of overstorey	The simplest attribute associated with height is the height of the overstorey. This attribute may be indicative of successional stage, the number of strata or stand biomass. The overstorey tree layer included all trees with a DBH ≥ 10 cm [46].
Stand basal area		Stand basal area is directly related to mean DBH. It is also indicative of stand volume and biomass.
Tree species	Species richness	The number of species per sample plot [16,47]
	Relative frequency of three high frequency species	The ratio between the frequency of a species and the sum of all species frequencies [47,48]
Understorey vegetation	Shrub height	The understorey tree layer included all trees with a DBH < 10 cm and ≥ 1.3 m in height [46].
	Understorey richness	Species richness was estimated in each sample plot and per ha. Understorey species richness due to the increased interspecific competition may lead to reducing resource availability [46].
Deadwood	Number, basal area and volume of dead trees (by decay classes)	Dead standing and fallen trees are considered key structural elements. In natural forests, a wide variety of dead wood forms correspond to the continuity of wood decomposition, ranging from dead branches still attached to tree crowns, standing dead trees to rotting logs [49]. Number, BA, and volume of dead trees were classified in 4 classes.

2.3.2. Structural Complexity Index

All indices were calculated accurately and used to determine the structural complexity index (SCI). For indexes showing high kurtosis (< 2), logarithm and square-root transformations were used to improve the distribution of the values. The presence of significant numbers of outliers and data larger than the average causes the curve to be drawn upwards and create elongation. Regression analysis through quartiles was then performed to rescale each of the twelve selected stand-structural indices to a score ranging from 0 to 10. Scores of 2.5, 5, 7.5, and 10 were set to the quartile midpoints corresponding to the 12.5, 37.5, 62.5, and 87.5 percentiles of the raw data distribution [5,9]. A maximum score of 10 was attributed to the 87.5 percentile, while the equation was constrained so that the minimum score was

0. The SCI was obtained by adding all 12 rescaled values, with 0 being the minimum and 120 being the maximum additive value. Thus, the total value of a stand with high structural complexity would be closer to 120, while the total value of a less structurally complex stand would be closer to 0 [5,9].

The Gini coefficient was used to analyze the degree of regularity of size structures. This index enables comparison of the DBH structures of different stands. It is obtained from the area between the 45° line and the Lorenz curve, which in turn was derived by plotting the cumulative basal area proportions of trees per hectare against the cumulative proportions of the number of trees per hectare, after ranking the DBH data in ascending order. As the values range from 0 to 1, the Gini coefficient is easy to interpret. It has a minimum value when all of the trees are of equal size [50,51]. We tested for significant differences by means of the paired sample t-test. All analyses were performed using the software package R 2.14.1 and SPSS win 19.

3. Results

The species observed in the pseudo-absence and presence locations were shown in Table 2. Overstorey tree species was different in the pseudo-absence (16 species per ha) and presence (20 species per ha) locations with the similar species number in all study sites ($t = -2.70$, p -value = 0.015) (Table 3). Understorey species richness differed in the pseudo-absence (16) and presence (17) locations ($t = -0.270$, p -value = 0.015). The most abundant species in the presence area was *Ribes biberestentii*.

Table 2. The overstorey and understorey species observed in the pseudo-absence and presence locations of Caucasian grouse.

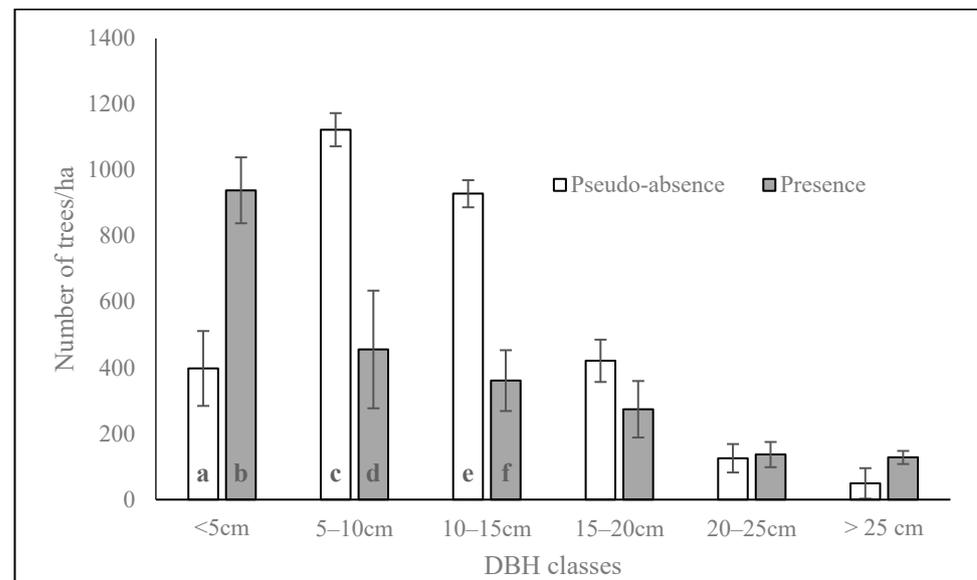
Species Name	Overstorey		Understorey	
	Pseudo-Absence	Presence	Pseudo-Absence	Presence
<i>A. campestre</i>	Yes	Yes	Yes	Yes
<i>A. hyrcanum</i>	No	Yes	Yes	Yes
<i>Berberis densiflora</i>	Yes	Yes	Yes	Yes
<i>C. orientalis</i>	Yes	Yes	Yes	Yes
<i>Cerasus avium</i>	Yes	No	No	No
<i>Cornus sanguinea</i>	Yes	Yes	Yes	Yes
<i>Cotoneaster integerrimus</i>	No	Yes	Yes	Yes
<i>Crataegus meyeri</i>	Yes	Yes	Yes	No
<i>Euonymus</i> sp.	Yes	No	Yes	No
<i>Fraxinus excelsiour</i>	No	Yes	No	No
<i>Juglans regia</i>	Yes	No	No	No
<i>Juniperus communis</i>	Yes	Yes	Yes	Yes
<i>Juniperus excelsa</i>	Yes	No	No	No
<i>Lonicera caucasica</i>	Yes	Yes	Yes	Yes
<i>Malus orientalis</i>	Yes	Yes	Yes	Yes
<i>Mespilus</i> sp.	Yes	No	Yes	No
<i>Prunus spinosa</i>	Yes	Yes	Yes	Yes
<i>Pyrus</i> sp.	Yes	Yes	No	Yes
<i>Q. macranthera</i>	Yes	Yes	Yes	Yes
<i>R. biberestentii</i>	No	Yes	No	Yes
<i>Rosa canina</i>	Yes	Yes	Yes	Yes
<i>Rubus</i> sp.	No	Yes	No	No
<i>Sorbus aucuparia</i>	Yes	Yes	No	Yes
<i>Sorbus graeca</i>	Yes	Yes	No	Yes
<i>Viburnum lantana</i>	Yes	Yes	Yes	Yes

Table 3. Mean values and SD (n = 36) for a selection of structural attributes in the pseudo-absence and presence locations of the Caucasian grouse.

Indices	Pseudo-Absence (Mean \pm sd) (Ranges)	Presence (mean \pm sd) (RangeS)	t-Value	p-Value
1 Mean DBH (cm)	11.1 \pm 5.5 (8–19.3)	12.7 \pm 8.2 (7.6–18.3)	−0.04	0.971
2 Tree size diversity (TSD)	0.34 (0.17–0.55)	0.2 (0.06–0.41)	3.69	0.002
3 Horizontal variation in DBH (CV, %)	39 (23–58)	59 (44–83)	−6.01	0.0001
4 Maximum DBH (cm)	73 (22–73)	60 (22–60)	−0.98	0.340
5 Gini coefficient	0.985 (0.95–1)	0.983 (0.97–0.99)	0.613	0.548
6 Frequency of stems/ha (<5 cm) (number/ha)	53 (15–697)	485 (158–1269)	−4.01	0.001
7 Height of overstorey (m)	6.2 \pm 3.1 (4.9–11)	4.3 \pm 1.9 (3.6–7.6)	3.46	0.003
8 Height class richness (number)	10 (7–10)	10 (4–10)	3.49	0.003
9 Species richness per ha (number of species/ha)	16 (6–28)	20 (16–26)	−2.70	0.015
10 Understorey stem/ha (number/ha)	67 (0–138)	499 (22–639)	−4.63	0.0001
11 Number of dead trees/ha (number/ha)	432 (8–516)	104 (82–1240)	−5.05	0.0001
12 Log volume (cubic meter per ha)	7.2 (0–11.2)	0.7 (0–28.4)	−3.66	0.002
13 SCI	64.1 (50–75)	68.6 (51.6–82.6)	1.491	0.154

DBH—diameter at the breast height, TSD—tree size diversity, SCI—structural complexity index

The frequency of overstorey trees in the different DBH classes differed between the areas with pseudo-absence and presence of the CG (Figure 2). The number of trees was higher in the pseudo-absence location than in the presence location. In the pseudo-absence location, most of the trees corresponded to DBH class 5–10 (1122 stems/ha), while the frequency of trees in the <5 class was relatively high (938 stems/ha) in the presence location. Differences between pseudo-absence and presence location were observed for all size classes. Large differences were observed in DBH class 5–10 cm (1122:455 stems/ha). Although for DBH classes <5 cm, 5–10 cm, and 10–15 cm was observed a significantly difference between pseudo-absence and presence locations at 0.001%. While for DBH classes 15–20 cm, 20–25 cm, and >25 cm was not found a significant difference.

**Figure 2.** Mean density (\pm SE) of overstorey trees in the different DBH classes in the CG pseudo-absence and presence locations (alphabetic items show a significant difference between two groups.).

The number of understorey trees in all height classes was greater in the presence location than in the pseudo-absence location ($t = -3.908$, p -value = 0.001) (Figure 3). A significantly difference was also observed in DBH classes between pseudo-absence and presence locations ($t = -4.081$, p -value = 0.001). The frequency of understorey trees of

all three DBH classes was higher in the presence location than in the pseudo-absence location. This difference was relatively large for height class 50–100 cm (69:325) and DBH class 2.5–5 cm (71:383).

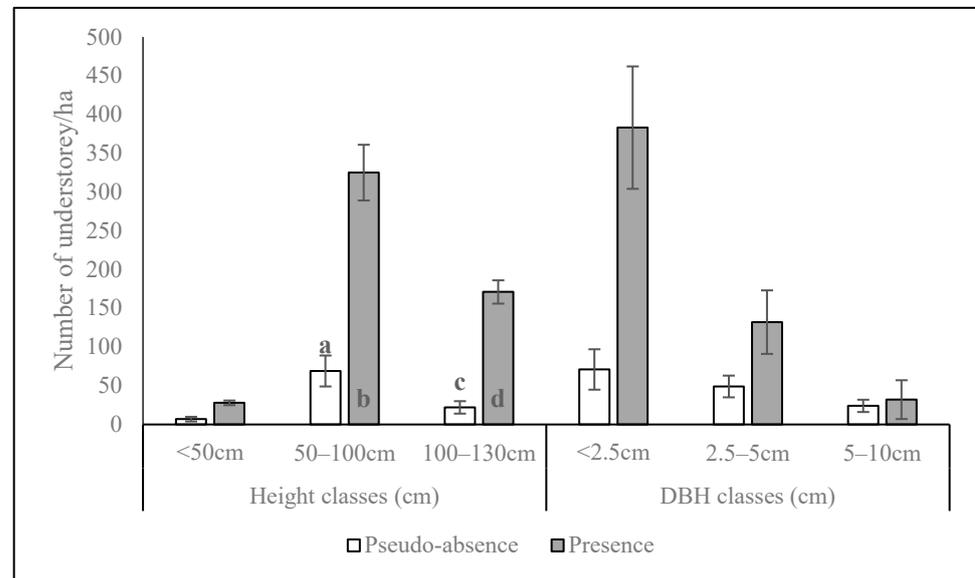


Figure 3. Mean density (\pm SE) of understorey trees in the different height and DBH classes in the pseudo-absence and presence locations (alphabetic items show a significant difference between two groups.).

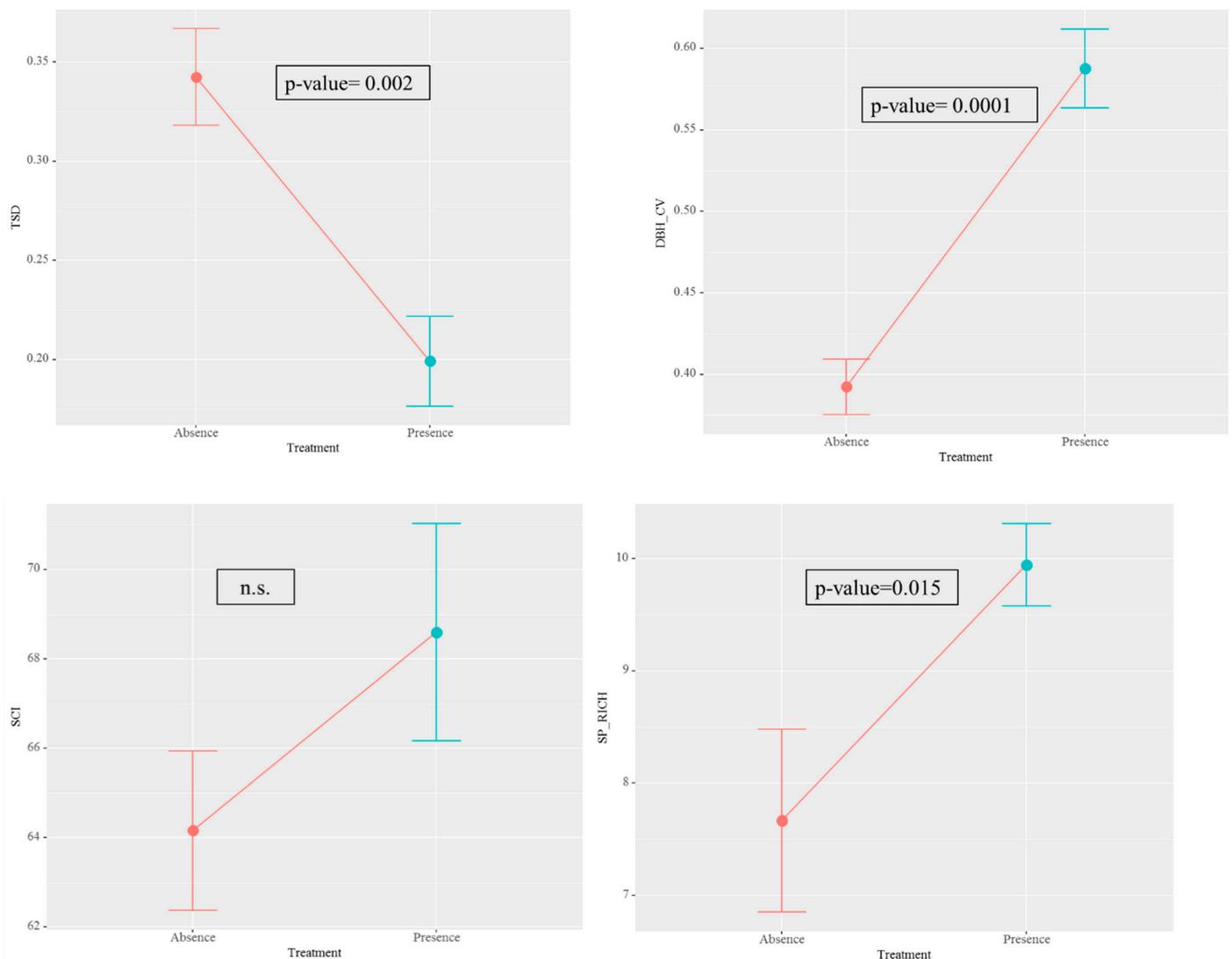
The mean DBH was lower in the pseudo-absence location than in the presence location. The values of some other attributes such as horizontal variation in DBH, maximum DBH, frequency of stems smaller than 5 cm and understorey stems per ha were lower than in the presence location (Table 3). By contrast, the values of other characteristics such as TSD, height of overstorey, height class richness, species richness, density of dead trees and log volume were higher in the presence location than in the pseudo-absence location. Compare mean of selected structural attributes in the pseudo-absence and presence locations of the CG showed that there were a significant difference ($p < 0.05$) in all variables except DBH and maximum DBH of sample plots between the pseudo-absence and presence locations. TSD index showed that frequency of stems in DBH class 10–15 had significant difference between the pseudo-absence and presence locations.

To provide an objective starting point for combining core attributes in an index framework, the core attributes were rescaled as scores from 0 to 10 by using equations that modelled attribute scores as a function of the raw attribute data (Table 4). The equations were constrained so that the rescaled score was always between 0 and 10. This approach led to very little loss of information in the rescaling process.

The TSD provides an estimate of the ratio of trees in the DBH class 10–15 cm as a reference DBH class for all trees in the sample plots. The TSD values were higher in the pseudo-absence location than in the presence location, although the difference was not significant (Figure 4). The CV of DBH indicated a significant difference between the two locations. According to the CV of DBH, the variation in DBH in the presence location was higher than in the pseudo-absence location and the structure was more heterogeneous. However, in the pseudo-absence location, the DBH of trees was similar, with a low CV of DBH. In total, the SCI was higher in the presence location than in the pseudo-absence location ($t = 1.491$, p -value = 0.154). Grouse habitats had higher SCI values. The species richness differed significantly between the two regions with higher value for the presence locations (Figure 4).

Table 4. Regression equations used to assign a score to the quantitative values of indices on a scale of 0–10.

Index	Regression Equation	R ²	Mean of Rescaled Value	
1	Mean of DBH (cm)	Score = $-3.15 + X \times 0.777$	0.903	6.2
2	Tree size diversity (TSD)	Score = $-0.67 + X \times 23.806$	0.934	5.7
3	Horizontal variation in DBH (CV)	Score = $1.47 + X \times 0.267$	0.995	1.6
4	Maximum DBH (cm)	Score = $-1.43 + X \times 0.246$	0.981	6.3
5	Gini coefficient	Score = $-381.22 + X \times 0.393.6$	0.936	6.6
6	Frequency of smaller than 5 cm	Score = $2.838 + X \cdot 0.008$	0.988	6.3
7	Height of overstorey (m)	Score = $-2.844 + X \times 1.47$	0.928	5.9
8	Height class richness	Score = $-8.745 + X \times 1.84$	0.978	2.7
9	Species richness	Score = $-0.968 + X \times 0.839$	0.897	6.4
10	Understorey stem/ha	Score = $4 + X \times 0.017$	0.851	6.06
11	Number of dead trees (n)	Score = $3.258 + X \times 0.012$	0.843	6.2
12	Log volume	Score = $4.79 + X \times 0.432$	0.843	6.2

**Figure 4.** Differences in some attributes in two pseudo-absence and presence locations of the Caucasian grouse (n.s.—non-significant).

4. Discussion

Forests provide habitats for diverse wildlife and grouse species. The dependency of species on resources varies with the habitat location as a combined variable in forest structural complexity. This research focused on forest structural complexity in the locations where the CG was absent and present. The present study analyzed data on the stand structure that provides vital information about the presence of the CG and habitat suitability, with the aim of developing effective conservation programs and plans. Determination of forest structural complexity (SCI) in the pseudo-absence locations by patterning from the presence area is a key for preservation of most of this species' habitat throughout the Arasbaran biosphere reserve. The estimated and computed indices for the presence locations can be implemented in the pseudo-absence locations. If the cause of disappearing was related to the characteristics of silvicultural indices such as height, DBH, crown cover, density, etc., it can help to appearance of this species by managing some indices for example height, DBH, density of understory and overstorey per ha, etc. through silvicultural practices.

Overstorey tree species richness was lower in the pseudo-absence location (16 species) than in the presence location (20 species). Natural and artificial threats can lead to strong dependence of the species on the presence locations. In other areas, with the complex structure of oak and a high degree of competitiveness, fruit trees on which the CG feeds are eliminated, thus limiting the presence of this species [15,36].

The SCI values were higher in the CG presence location than in the pseudo-absence location. Grouse habitats had a higher SCI value. This finding coincides with those of [15], who reported that the Capercaillie is negatively affected by the results of selective cutting, such as increasing canopy closure, lack of clearings and homogenization of forest structure.

The number of understory trees differed significantly between the two types of location. The presence location had a dense understory, which the CG prefers. Similar findings have been reported for the Capercaillie [52]. A well-developed understory with deciduous species is essential for ensuring optimal availability of food for the CG. Understorey vegetation can also provide for cover for grouse chicks during the snow-free season and help to protect them from natural and artificial threats such as predators and game hunters [38,53]. This is consistent with our findings of high-density understory in early-stage succession forests.

The importance of coarse woody debris in the diversity and abundance of bird species has been emphasized by many researchers [23–25]. Birds depend on coarse woody debris for different uses. A positive relationship between coarse woody debris and avian diversity and abundance has been reported [22], which is in line with our findings that the presence of the CG was associated with a high number of dead trees and high logs volume. The CG nests on the ground and below shrubs, and the presence coarse woody debris in the understory and on the ground may hinder nesting.

5. Conclusions

This study focused on the difference between the areas where the CG is present and absent in the Arasbaran biosphere reserve in Iran through the application of an index (SCI). The study findings showed that the SCI values were higher in the presence location than in the pseudo-absence location. Some light-demanding plant species such as *R. biebersteinii*, *R. canina*, *S. aucuparia*, and *Viburnum lantana* identified in the presence area provide food for the bird species in the form of fruit during the summer and buds and catkins during the winter. Therefore, we suggest that silviculture management should increase the density of fruit-bearing species as food sources for the CG. We also confirmed that dense understory vegetation helps to protect the CG from different artificial threats and natural predation. Many researchers emphasized that the presence of coarse woody debris increases the presence of bird species. Also, we found similar results with higher amounts of coarse woody debris in the areas where this bird species was present, as local residents collect the woody debris as firewood. We thus recommend increasing forest structural complexity by saving coarse woody debris in the CG habitat. However, the

effects of human disturbance on forest structure and the CG population requires further study. Maintaining a heterogeneous forest structure is important to help protect this species. We also recommend that fruit trees on which this species feeds should be preserved in the forest structure. Future studies should address the long-term effects of natural and artificial disturbances on forest structure and biodiversity.

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