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Microhabitat characteristics of brown bear den areas

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Abstract

The aim of this study was to determine the microhabitat, relief and forest structure characteristics of brown bear (*Ursus arctos* L.) cave dens and other types of dens in the North Dinarides (Velebit Nature Park) in Croatia. In total, 63 dens were identified, consisting of 89% cave dens and 11% other den types (nest dens 6%, stump dens 3%, trunk dens 2%). In the 20-meter radius around each den, the microhabitat, relief and structural characteristics were recorded, including altitude, slope, exposition, rockiness, forest developmental stage, canopy density, tree height, forest site index, tree basal area, and tree species composition. Based on altitude, the climatic category was determined according to the Köppen climate classification. Most cave dens (62%) were in the temperate climate, at altitudes between 900 and 1,100 m, with a southern exposition and slope class between 30 to 60%. The dens situate in partial canopy density of the third forest site index with tree heights between 16 and 20 m and without forest degradation. Slopes and tree heights were lower ($p < 0.019$) in cave den areas in comparison to other den types.

Keywords: cave dens, microhabitat, forest structure, North Dinarides, Velebit Nature Park

Introduction

The brown bear (*Ursus arctos* L.) is the largest carnivore living in the Croatian Dinarides mountain area, one of the rare habitats having stable populations of brown bears in Europe (Huber et al. 2008). In this high elevation karst area, brown bears live, find food, reproduce, and make their dens.

Reductions of food availability, snow cover, low temperatures and physical conditions are the main reasons determining bears hibernation behaviour (Schooley et al. 1994). The denning characteristics of brown bears have been described in numerous studies (Linnel et al. 2000, Manchi and Swenson 2005, Sahlén et al. 2011, Smereka et al. 2017, Eriksen et al. 2018, Mangipane et al. 2018, Gonzáles-Bernando et al. 2020). However, specific factors such as landscape characteristics and climate can greatly influence the location and time of denning (Evans et al. 2016, Delgado et al. 2018, Mangipane et al. 2018). Dens in the Dinarides area of Croatia are found at high altitudes, on rocky ground with Dinaric beech-fir forests, mesophilic and neutrophilic pure beech forests, pre-alpine beech forests or thermophilic beech forests (Huber and Roth 1997, Ugarković et al. 2014). Brown bears are quite specific regarding den characteristics (Elfström et al. 2008, Elfström and Swenson 2009, Štofik and Saniga 2012, Sorum et al. 2019, Tammeleht et al. 2020, Faure et al. 2020). Dens may be dug into the ground, nest dens made of branches on the ground, dens dug under rocks, rock cavity dens (Manchi and Swenson 2005, Elfström and Swenson 2009), root excavation dens, dens in hollow trees, stumps or logs (Vroom et al. 1980, Ugarković et al. 2014).

The function of the den is to reduce energy loss and provide safety and protection against disturbance during winter (Petram et al. 2004, Evans et al. 2016). The insulation provided by the den ensures the storage or maintenance of energy (Tietje and Ruff 1980). Different types of dens have different insulation characteristics that affect heat loss and fat loss in bears, ultimately affecting homeostasis (Manchi and Swenson 2005). Brown bears are very sensitive to human activities in the areas surrounding their dens, especially if disturbances coincide with the initiation of winter dormancy (Swenson et al. 1997, Linell et al 2000). Therefore, optimal denning areas should provide minimal loss of body temperature and prevent disturbances caused by human activities (Goldstein et al. 2010, Sahlen et al. 2011, Eriksen et al. 2018). The terrain characteristics, ground cover and terrain type will also affect bear preference to certain den areas (Sahlél et al. 2011).

Protection and security provided by microhabitat play a key role in offspring survival, minimising energy loss and den selection (Hellgren and Vaughan 1989). Various studies in the Dinaric region have analysed the density of brown bear populations (Jerina et al. 2003, 2013), population management (Huber at al. 2008), hunting policies (Knott et al. 2013), impact of human activities on the composition and selection of the den (Petram et al. 2004), the quality of habitat for brown bears (Kusak and Huber 1998) and denning ecology (Huber and Roth 1997, Ugarković et al. 2014).

The aim of this study was to evaluate the microhabitat, relief and forest structural characteristics of cave den areas and other types of brown bear dens in the North Dinarides (Velebit Nature Park) in Croatia. While the basic characteristics of denning habitats have been previously described (Whiteman et al. 2017), there is a lack of research concerning the microhabitat characteristics of denning areas, including information on forest trees species and forest stand structure in the area of dens, particularly in areas with different types of dens.

Material and methods

Study area

The field study was conducted in Velebit Nature Park (Figure 1). Mt. Velebit is 145 km long, with an average width of 14 km from the coastal area towards the continental part (30 km in the northern part and 10 km in the southern part). Velebit Nature Park covers an area of approximately 2,270 km^2 with 130 peaks exceeding an altitude of 1,370 m. The Mt. Velebit area belongs to the Central European and Mediterranean vegetation areas. The lower parts of Velebit have an average annual air temperature of 8.4°C and annual precipitation of 1,369 mm, while the highest elevation areas have an average annual air temperature of 3.6°C and precipitation of about 2,000 mm. In the study area, the highest maximum air temperature was 37.0°C and the lowest was 28.9°C.

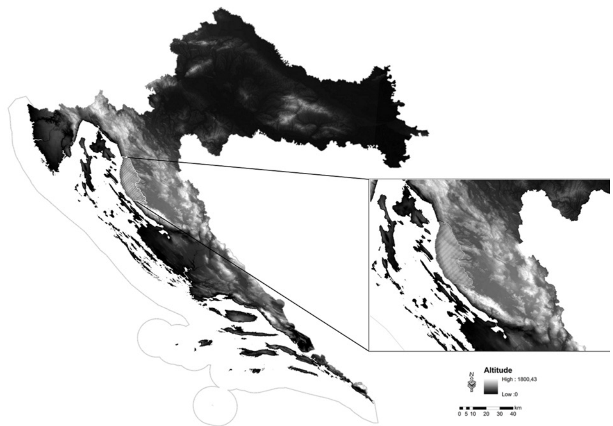

Figure 1. Study area

Large quantities of snowfall are present during the winter period. Maximum snow heights reach up to 300 cm. Snow cover remains on the ground from 70 days at lower altitudes to over 200 days at altitudes above 1500 m a.s.l. (Seletković 2001). The soils in the Velebit area are shallow, rocky and dry, mainly on a limestone geological base of the Middle Triassic and Jurassic ages. From the forest stands on the inland side, the mountain beech forest is found at altitudes of 600 to 900 m, beech forest with fir in the 850 to 1300 m belt, then spruce forest up to 1400 m. Forest vegetation on the coastal side of Mt. Velebit is highly degraded due to the influence of human activities and domestic animals (Španjol and Vukelić 2001), and therefore forest cover area is low. The lower altitudes are dominated by deciduous forests, medium altitudes by mixed forests, higher altitudes by pure coniferous forests and peak areas by mountain pastures (Vukelić 2012).

Den location, microhabitat, and forest structure characteristics

This study was conducted in the period from 2014 to 2018. Hunting maps and chronicles of hunting grounds were analysed to determine potential bear denning areas in forest. According to the Hunting Act of the Republic of Croatia (Hrvatski sabor 2019), a hunting ground is a certain area of land that is a complete natural whole in which there are ecological and other conditions for breeding, protection, hunting and use of game. Management plans and hunting maps are made for each hunting ground. For each hunting ground, it is a legal obligation to keep a hunting chronicle in which all important events in the hunting ground are recorded: animal migrations, the state of forest ecosystems, damage to animals, damage to forests and agricultural crops and others.

Brown bear ecology and population management studies (Huber and Roth 1997, Kusak and Huber 1998, Majnarić 2002, Huber et al. 2008) were reviewed to determine areas providing suitable denning conditions preferred by brown bears for hibernation. The dens were located: a) during a detailed search of a defined area in July and August, b) during a forest inventory of forests in the area, c) by following bear tracks in the spring after leaving den sites. Additionally, some denning sites were reported by gamekeepers and rangers. Paw prints, claw marks and tooth and rubbing marks were used as indicators of active dens (Whiteman et al. 2017).

Data on altitude, terrain slope and exposure were derived from digitized layers of topographic maps 1:25,000, whereas data on the structural characteristics of forests and rockiness were collected from forest management plans. In the 20-meter radius around each den, the microhabitat (relief) and forest structural characteristics were measured (Čavlović and Božić 2008). The den entrance was considered the centre of the plot. Relief characteristics (slope, altitude and exposition) were measured using Suunto Tandem 360 PC/360R DG and Garmin GPS64 devices at the entrance of the den. Dens were classified into one of the two climate classes based on altitude according to the Köppen climate classes, i.e. the temperate climate (class C) up to 1200 m a.s.l., and the continental climate (class D) above 1200 m a.s.l. (Šegota and Filipčić 2003). Rockiness was estimated as a percentage of five subplot surfaces of 1 m^2, in the centre of the plot and 10 m from the centre of the plot on in the cardinal directions described by Cools and De Vos (2016). Canopy density was rated by GRS densitometer using the same five subplots as rockiness determination. The relief elements were categorized for rockiness (0%, 0–2%, 2–5%, 5–15%, 15–40%, 40–80%, >80%) and slope (0–0.2%, 0.2–0.5%, 0.5–1.0%, 1–2%, 2–5%, 5–10%, 10– 15%, 15–30%, 30–60%, 60–100%, >100%) according to Cools and De Vos (2016), for altitude (700–900 m, 900– 1,100 m, 1,100–1,300 m, 1,300–1,500 m, >1,500 m a.s.l.) according to Ugarković et al. (2013) and for exposition (North 316-360° and 0-45°, East 46-135°, South 136-225°, West 226-315°) according to Huber and Roth (1997).

Elements of forest stand structure were grouped into categories for canopy (full, partial, sparse and gaps) and for forest stage (no degradation, degradation) according to the regulations (Hrvatski sabor 2018), for forest site index (I, II, III, IV, V forest site index) according to Pranjić (1966), for tree height according to the height of the trees, i.e. <10 m, 11–25 m, 16–20 m and >21 m (Čavlović and Božić 2008).

Each tree with a diameter at breast height (DBH) larger than 10 cm was measured with Haglof tree calipers (cm), and the height (m) of dominant and co-dominant trees in the experimental plots was measured using digital Vertex IV. This data was used to calculate structural elements including basal area (G) and tree species composition (%). Tree species composition was expressed as the percentage in relation to the overall wood volume of the stand. The local volume model was calculated for each tree species according to the measured heights and parameters of the Schumaher-Hallove function of trees. Forest site index data was obtained based on the average height of dominant trees (Pranjić 1966, Hrvatski sabor 2018). If bedding material was found in the den, its composition was evaluated (broadleaf twigs, conifer twigs, mixed composition).

Statistical analysis

Since no data are available for random points around the dens, this study uses a number of chi-square analyses to test whether den distribution in different habitat and forest structure categories differed from the expected values, i.e. the proportion of available habitat and forest structure in each category. The expected values were calculated based on the known percentage of each class of relief elements and forest structure in the study area. When the expected frequency was less than 5, the categories of microhabitat and forest structure characteristics were combined to fulfil the requirement for the chi-square test. Due to the small sample size of other den types, i.e. not caves ($N = 7$), the comparison of expected and observed distributions was performed by chi-square test only for cave dens ($N = 56$).

The numbers of dens by climate classes C and D was analysed using the Fisher's exact test. The Mann-Whitney U test and Student T test of significance were used for 2-sample comparisons of microhabitat (relief), forest

Table 1. Codes for correlation analyses

Variables	Codes
Den type	Code 1 – cave den, code 2 – other type of dens
Composition of the beds	Code 0 – dens without beds, code 1 – branch, leaves of deciduous species, code 2 – mixed bedding composition, code 3 – coniferous twigs, needles
Climate classes	Code 1 – climate C, code 2 – climate D
Rockiness (%)	Code 1 for 0%, code 2 for 0–2%, code 3 for 2–5%, code 4 for 5–15%, code 5 for 15–40%, code 6 for 40–80%, code 7 for >80%
Altitude (m)	Code 1 for 700–900 m, code 2 for 900–1100 m, code 3 for 1100– 1300 m, code 4 for 1300–1500 m, code 5 for >1500 m
Exposition (°)	Code 1 for 316–360° and 0–45°, code 2 for 46–135°, code 3 for 136–225°, code 4 for 226–315°
Slope (%)	Code 1 for 0–0.2%, code 2 for 0.2–0.5%, code 3 for 0.5–1.0%, code 4 for 1–2%, code 5 for 2–5%, code 6 for 5–10%, code 7 for 10–15%, code 8 for 15–30%, code 9 for 30–60%, code 10 for 60–100%, code 11 for >100%
Forest stage	Code 1 – no degradation, code 2 – degradation
Canopy	Code 1 – full, code 2 – partial, code 3 – sparse, code 4 – gaps
Tree height (m)	Code 1 <10 m, code 2 for 11–25 m, code 3 for 16–20 m, code 4 for >21 m
Forest site index	Code 1 for I, code 2 for II, code 3 for III, code 4 for IV, code 5 for V site index
Composition of the forest	Code 0 – peak areas, mountain pastures, code 1 – deciduous forests, code 2 – mixed forests, code 3 – coniferous forests

structure characteristics and tree species basal area composition of cave dens sites and other den sites.

By correlating relief, climate and structural forest factors, we sought to determine whether there is a significant relationship between these variables and a particular type of den. Non-parametric Kendall's tau correlation was used since the microhabitat (relief) categories, forest structure categories, climate classes and type of dens were in ordinal variables (Table 1).

Correlation coefficients were determined between the composition of beds in the den and the composition of the forest stand in the den vicinity. The codes for the composition of the forest stands were assigned based on the composition of forests from the lowest to the highest altitude of denning, i.e. according to the distribution of vegetation belts on Mt. Velebit (Vukelić 2012).

Data analysis was performed using Statistica 7.1. (StatSoft 2005) and ArcMap 9.2. (ESRI 2009) software packages.

Results

In total, 63 dens were found, comprised of 56 (89%) cave dens and 7 (11%) other den types. Other den types included 4 nest dens (6%), 2 stump dens (3%) and only one trunk den (2%). All dens were in forest ecosystems.

In temperate climate areas, 39 (62%) cave dens were found and 7 (11%) other types of dens, whereas in continental climate areas, 17 cave dens (27%) were found, and no other types of dens found. According to the results of the one-tailed Fisher exact test, the significance was $p = 0.096$.

Figure 2 shows a number of observed and expected cave dens based on the analysed relief factors. There was a significant difference between observed and expected cave dens and altitude categories ($\chi^2 = 107.15$, $df = 3$, $p = 0.000$), different categories of terrain slope ($\chi^2 = 127.39$, $df = 3$, $p = 0.000$) and terrain rock categories ($\chi^2 = 45.49$, $df = 4$, $p = 0.000$).

No differences ($p > 0.05$) were found between observed and expected cave dens and exposure categories ($\chi^2 = 5.00$, $df = 3$, $p = 0.171$) (Figure 2). Cave dens were predominantly ($N = 19$) on terrain with 71–90% rockiness, at altitude range between 900 to 1,100 m ($N = 22$), southern exposure ($N = 19$) and at terrain slope higher than 60% ($N = 22$) (Figure 2).

According to the results of the chi-square test, there was a significant difference in the number of observed and expected caves for tree canopy density ($\chi^2 = 38.82$, $df = 2$, $p = 0.000$), forest site index ($\chi^2 = 35.84$, $df = 3$, $p = 0.000$), and tree height categories ($\chi^2 = 128.21$, $df = 3$, $p = 0.000$). No significant differences were found between observed and expected cave dens for forest degradation stage categories ($\chi^2 = 0.87$, $df = 1$, $p = 0.348$). The largest number of caves was in forests with partial canopy ($N = 23$) and the smallest number of caves was with sparse canopy and gaps ($N = 16$). The largest number of caves was

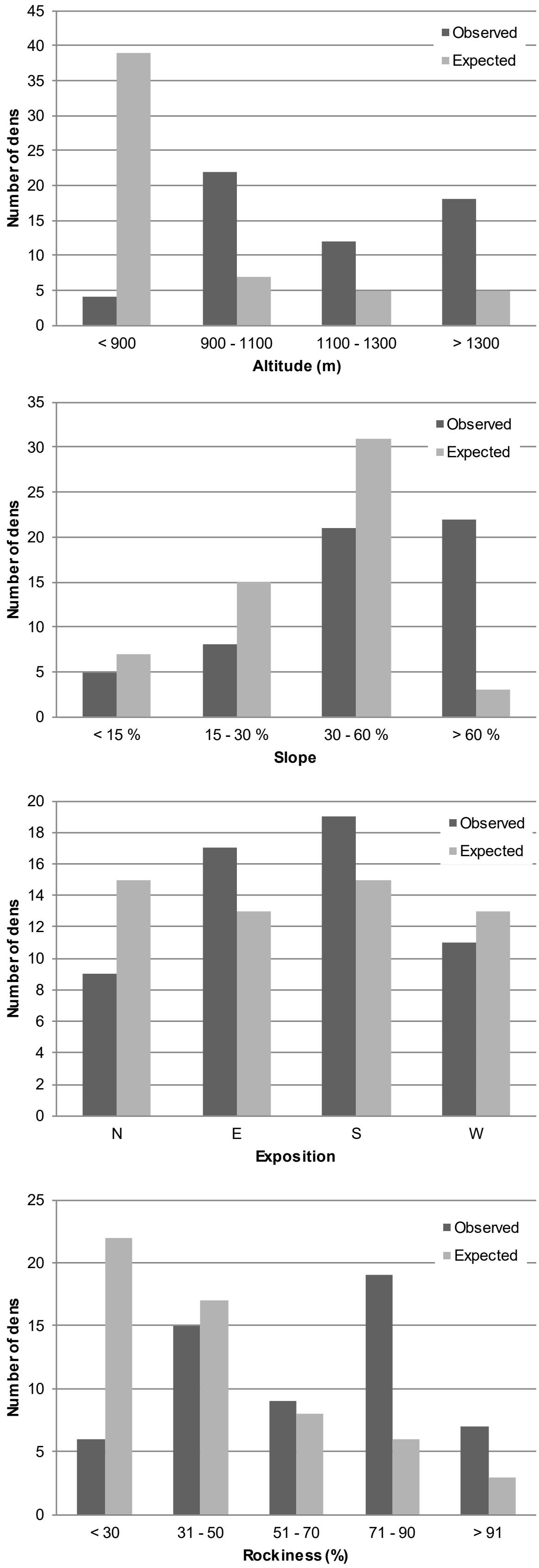

Figure 2. Observed vs. expected number of cave dens according to microhabitat relief characteristics ($N = 56$)

found in the fourth-fifth forest site index ($N = 27$) and no caves were found in the first forest site index. According to tree height categories, the largest number of caves ($N = 23$) was in the 16–20 m height category. The smallest number of caves ($N = 7$) was in the category 11–15 m in height. In total, 49 cave dens were in high-growth or non-degraded stands, and 7 in degraded stands (Figure 3).

Cave dens were found at altitudes from 790 to 1,572 m, while other types of dens were found between 821 and 1,179 m. Exposure of cave dens ranged from 10° to 330°, and for other den types from 90° to 330°. The average exposition of other den types was 241.71° and in cave dens was 168.66°. Terrain slopes in the areas of cave dens were from 1.5% to 143%, and in areas of other den types from 41% to 143%. There was a significant difference in mean values of terrain slopes between the two categories of dens, i.e. 58.80% in cave den areas and 89.71% in other den type areas ($p = 0.022$). Rockiness in cave den areas ranged from 25% to 100%, while in areas of other dens from 10% to 90%. Tree heights in areas of cave dens ranged between 5.00 and 26.00 m, while in areas of other den types ranged between 19.00 and 25.60 m. The average height of trees in other den type areas was 21.55 m and was significantly higher ($p = 0.019$) than the average height of trees in cave den areas, which was 16.85 m (Table 2). The range of basal areas of forest tree species in cave den areas was 0–44.69 m^2/ha, and in areas of other den types was 25.26–36.48 m^2/ha. Percentage of conifer trees in cave dens area was from 0% to 86.38%, and in area of other den types from 17.01% to 66.71%. The percentage of deciduous trees in cave den areas was from 13.62% to 100.00%, and in areas of other den types from 33.29% to 82.99%. According to the results in Table 3, there were no differences ($p > 0.05$) in tree species basal areas between cave den areas and areas with other types of dens ($p = 0.118$). The average basal area of common beech, which was the most common tree species of the studied forest area, was 15.45 m^2/ha in cave den areas and 15.38 m^2/ha for areas with other types of dens. The average basal area of silver fir was 6.20 m^2/ha, and 9.35 m^2/ha in the area of other dens. In the area with other types of dens, hornbeam and sessile oak tree species were not found.

Significant ($p < 0.05$) and weak correlations were found between den type and climate type ($r = -0.21$), slope ($r = 0.23$), tree height ($r = 0.23$), forest site index ($r = -0.28$) and leaf forest composition ($r = -0.22$) (Table 4).

In 35 cave dens (63%), no traces of bedding materials were found. Furthermore, for cave dens where bedding materials were found, there was a positive and significant ($r = 0.27$; $p < 0.05$) correlation between bedding material composition and forest stand composition in cave den sites. Twigs of deciduous species and leaves were more frequently used as bedding material.

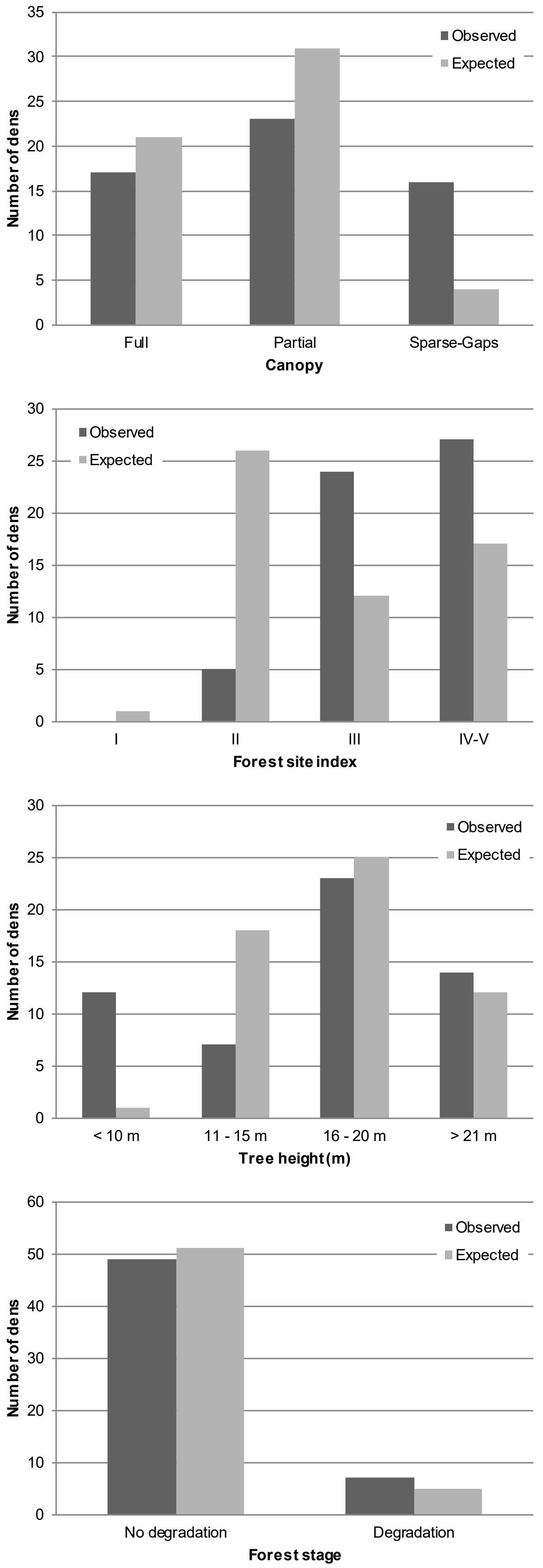

Figure 3. Observed vs. expected number of cave dens according to forest structure characteristics ($N = 56$)

Table 2. Microhabitat (relief) and forest structure characteristics (mean ±std. dev) of cave dens sites (*N* = 56) and other den sites (*N* = 7)

Variable	Cave dens	Other dens	*U* test *Z*	*T* test	*p*-value
Rockiness (%)	73.46 ±19.28	63.57 ±32.36	0.714	-	0.474
Altitude (m)	1110.07 ±208.28	1007.28 ±110.67	-	1.276	0.206
Exposition (°)	168.66 ±90.87	241.71 ±98.99	-	–1.987	0.051
Slope (%)	58.80 ±32.66	89.71 ±34.05	-	–2.350	0.022
Tree height (m)	16.85 ±5.94	21.55 ±2.01	–2.337	-	0.019
Basal area (m²/ha)	21.84 ±12.81	28.50 ±3.78	–1.170	-	0.241
Conifer (%)	26.08 ±24.56	39.61 ±20.69	-	–1.380	0.173
Deciduous forest (%)	73.91 ±24.56	60.38 ±20.69	-	1.380	0.173

Table 3. Comparison of tree species basal area composition (m²/ha) of cave dens sites (*N* = 56) and other dens (*N* = 7)

Den type	Tree species basal area (mean ±SD)						
	Silver fir	Common beech	Common spruce	Sycamore	Sessile oak	Hornbeam	Hophornbeam
Cave	6.20 ±6.81	15.45 ±9.10	1.78 ±4.10	1.06 ±2.03	0.14 ±0.72	0.03 ±0.02	0.81 ±2.67
Others	9.35 ±4.11	15.38 ±4.32	2.22 ±4.71	0.43 ±0.43	-	-	0.01 ±0.03

[a, b] Values marked with different superscript within a column differ significantly ($p < 0.05$); SD – standard deviation

Table 4. Kendall's tau correlations between den types, habitat, relief and forest structural variables (*N* = 63)

Habitat, relief and forest structural variables	Den type
Climate	–0.21*
Rockiness (%)	–0.06
Altitude (m)	–0.11
Exposition (°)	0.06
Slope (%)	0.23*
Forest stage	–0.12
Canopy	–0.05
Tree height (m)	0.23*
Forest site index	–0.28*
Conifer composition (%)	0.03
Leaf forest composition (%)	–0.22*

* significant at $p < 0.05$

Discussion

Forests are preferred denning areas for brown bears (Ugarković et al. 2014, Eriksen et al. 2018) and the continental side of Velebit is well forested (Šprem et al. 2015). Denning in open alpine habitats, compared to forests, provides little shelter (Eriksen et al. 2018) and therefore, vegetation cover is crucial for selecting a denning site. All dens found in Velebit Nature Park were in areas of forest cover. Seryodkin et al. (2018) did not find dens in open areas or dens visible from a great distance in eastern Russia, suggesting that denning areas must have appropriate coverage. Most dens found in Velebit Nature Park area were cave dens. This result confirms the research of Huber and Roth (1997), who stated that cave dens were the most common type of den in Risnjak National Park and Plitvice Lakes National Park in the Northern Dinarides. The presence of certain types of den depends on the ecological and relief features of the terrain.

The percentage of cave dens in North America can vary from 0% to 79% (Schoen et al. 1987), while in eastern Russia, brown bears hibernate mainly in root excavation dens, being only one cave den identified (Seryodkin et al. 2003). The largest numbers of dens in the Scandinavian region were anthill dens, followed by dens dug in the soil (Manchi and Swenson 2005). Soil type is a very important factor in the selection of a denning site in the ground (Schoen et al. 1987). In the Mt. Velebit area, cave dens are prevalent due to the high rockiness of the terrain. In the present study, other types of dens were found less frequently, and no dens were dug into the soil due to the very shallow soil layers in the Mt. Velebit area (Španjol and Vukelić 2001). The type of den most frequently found in an area depends on the terrain rockiness, i.e. on the relief and pedological characteristics, the type of forest community and the forest cover of the area.

In the continental climate area (climate class D), no other type of brown bear den was found, only cave dens. Climate class D, compared to a temperate climate (climate class C), is characterized by large amounts of snowfall, many days with snow, sudden changes in weather, strong winds, low annual air temperatures, high absolute minimum air temperatures, and frequent frost (Šegota and Filipčić 2003).

There was also a negative and significant correlation between brown bear den types and climate class types. This negative correlation corresponds to the absence of non-cave dens in the climate class D area. For this reason, it can be assumed that an area with climate class D is less suitable for denning of brown bears in dens such as ground nests or other types of den. Different types of dens provide different levels of security, protection and insulation for the bear, and bears choose more isolated dens such as caves where possible, as energy losses are reduced (Manchi and Swenson 2005) and disturbances are minimized in such structures (Martorello and Pelton 2003). For this reason, cave dens provide better conditions for hibernation. When large amounts of snowfall cover the cave entrance, a special microclimate is created in the den which is very suitable for bear winter dormancy. Bears are known to select high altitude areas with high amounts of snowfall, because deep snow provides better thermal insulation in the den, and the choice of such habitats reduces energy consumption for thermoregulation during denning (Vroom et al. 1980, Libal et al. 2012).

The average slope for cave dens was 58.80% and for other types of dens 89.71%, and this difference was significant, and corresponds to results reported by Vroom et al. (1980) and Ciarniello et al. (2005). In other types of dens, wintering bears are less protected and more vulnerable to disturbance, so they are more likely to select a den with an entrance that has a greater slope and that is more difficult to access. A significant and positive correlation was found between terrain slope and brown bear den type, confirming that other den types were located at higher slope sites. In the area of Velebit Nature Park, the largest number of caves had a south-facing exposure. According to Vaisfeld and Chestin (1993) and Seryodkin et al. (2018), preference for southern and western exposures is typical of northern regions of the Far East, Russia, Yakutia (Sakha), Volga-Kama regions and the Carpathians (Vaisfeld and Chestin 1993). The heights of trees were significantly lower in the cave den areas on Mt. Velebit. Terrain rockiness determines the depth of the soil (Pernar 2001), and on rocky terrain the soil is shallower, and the tree heights are smaller. Therefore, the forest site index was also lower, as confirmed by a negative weak correlation.

The fewest cave dens were found in degraded forests. Given that degraded forests have a smaller number of trees per unit area and less biomass per unit area (Ugarkovic et al. 2018), they do not provide sufficient shelter for brown bears during hibernation. In degraded forests there is less choice of branches and twigs for making bedding in the den. Huber and Roth (1997) have also found fewer dens in semi-open, degraded broadleaf forests in Risnjak and Plitvice Lakes National Parks in the Dinarides. The correlation of leaf forest composition with the type of dens was weak, indicating that cave dens were more prevalent in deciduous forests and other den types in coniferous silver fir and common spruce forests. Silver firs and common spruce in the Dinaric area, including Mt. Velebit, grow taller than common beech (Matić et al. 1996) and therefore are more suitable for denning in a hollow trunk, stump or root excavation. Silver fir trees are the most damaged forest tree species on Mt. Velebit (Tikvić et al. 2008), so large, individual trees are hollow and suitable for denning. In total, 63% of dens were found without any bedding materials. This result contrasts with the results of Huber and Roth (1997), who reported that only 17% of the dens in the area of Risnjak and Plitvice National Parks were without bedding material. Our results were also in contrast to those reported by Servheen and Claver (1983) and Judd et al. (1986) who found no bedding materials in 27% and 24% of dens. For dens containing bedding materials, an association was confirmed between the bedding material composition and the composition of the forest stand in the vicinity of the den, suggesting that the bear collects materials for the bedding in the immediate vicinity of the den.

One of the components of brown bear population management is the management of denning areas. Forest exploitation can adversely affect brown bear ecology in terms of habitat loss, habitat change, and changing forest structures (especially by cutting large trees that are suitable for denning). Increasing the forest road density also increases access of humans and hunters to den areas (Seryodkin and Pikunov 2002). All these factors contribute to disturbances of brown bears during the winter. Tree cutting in the denning area further increases the small-scale visibility of the area in the short term. When constructing forest roads and skid roads for forest exploitation, cave den areas should be avoided. Preferably, logging intensity in the areas around dens should be less than the regulated by the management plan to preserve the vegetation and maintain visibility around the den. Forest silvicultural practice planned for the winter months in denning areas should be postponed until later (late spring, summer, early autumn). All other actions in the denning area should be considered to protect the needs of bears during the winter, as human activity, microrelief characteristics and land cover influence the selection of the denning area for bears (Martin et al. 2010, Ordiz et al. 2011, Sahlén et al. 2011).

The availability of safe brown bear denning sites is important for the survival of both cubs and adults, as such sites minimize energy loss during winter dormancy (Oli et al. 1997, Hellgren 1998, Sahlén et al. 2011). Miller (1990) found that it is advantageous for brown bears to return to a well-known denning area rather than taking the risk of denning in a new area with similar characteristics, but where the individual has no previous experience. Adult males are known for denning in the same area as in previous years (Manchi and Swenson 2005). For this reason, it is important to preserve, protect and maintain denning areas, with an effort to prevent major changes caused by forest management. It is therefore necessary to monitor these denning habitats for the purpose of identifying changes and, if necessary, implement protective measures.

Conclusions

In Velebit Nature Park in the North Dinarides, brown bears chose cave dens for winter dormancy most often in highly rocky terrain, at altitudes between 900 and 1100 m and in a temperate, mesothermal climate. In the cold climate zone (i.e. continental climate), only cave dens were found. This was confirmed by a weak correlation between den type and climate groups. Most cave dens had a southern exposition and terrain slopes higher than 60%. Brown bears prefer cave dens for denning situated in non-degraded forest ecosystems, with partial canopy density, at the fourth and fifth forest site index with tree heights from 16 to 20 m. Terrain slope and tree height were significantly higher in the area of other den types than in cave den areas. A weak correlation was found between den type, terrain slope and tree height. Considering basal area, no differences were found between the microhabitats with cave dens and other den types. Areas with cave dens were areas with a lower forest site index and more broadleaf forest species. During silvicultural activities and forest exploitation, the timing, scope, and intensity of activities should be planned to minimize the impacts on brown bear ecology and disturbance, and to preserve areas with dens.

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