ACTA ZOOLOGICA BULGARICA

Acta Zool. Bulg., 75 (3), September 2023: 331-341

*Terrestrial Ecology and Behaviour*
*Research Article*

*Published online 06 July 2023*
*DOI: https://doi.org/10.71424/azb75.3.002717*

# Characteristics of Dens of Brown Bear *Ursus arctos* Linnaeus, 1758 (Carnivora: Ursidae) in Bulgaria

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**Abstract:** The hibernation is a critical period for the survival and reproduction of the brown bear. By this reason, the knowledge of the dens' location and characteristics is crucial for planning management actions to reduce disturbance in these areas. In order to locate bear dens, field trips were conducted in the two subpopulations of the brown bear in Bulgaria, i.e. in Stara Planina Mountain and Rila-Rhodopean massif in the period May – October 2022. Totally, 45 dens were studied. We measured the width, length of entrance and depth of the dens and considered the presence and type of bedding in each den. The elevation, aspect, slope, surrounding habitat and distance from roads, settlements and large rivers were analysed. The results showed that all located brown bear dens were in rock cavities, most often in high rocky terrain. Majority of dens were with a southern aspect and situated in forests close to large rivers. In Stara Planina, the dens were at higher altitudes while, in Rhodope Mts, they were at steeper slopes and were significantly closer to roads and settlements. These differences call for different management approaches in the regions of the two subpopulations in order to maximise the conservation efforts in each of them.

**Key words:** den preferences, Brown bear conservation, spatial characterization in GIS

## Introduction

The brown bear *Ursus arctos* Linnaeus, 1758 is among the large carnivorous mammals in Europe, which manages to survive in human-dominated areas. According to Kaczensky et al. (2021), the individuals of the species are spread in a number of European countries, including in Bulgaria as a part of the Eastern Balkan population. The brown bear hibernates in dens as a physiological mechanism to cope with adverse winter conditions (Tietje & Ruff 1980, Schooley et al. 1994). The bear does not feed during denning, relying on accumulated fat reserves in the pre-denning period. Decreasing metabolism and protected hibernation in dens lead to a decrease in physiological functions by about 70 % (Watts & Jonkel 1988, Hellgren 1998, Linnell et al. 2000) and a significant loss of body weight (Kingsley et al. 1983). Hence, the function of the den is to reduce energy loss and provide safety and protection against

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disturbance during winter (Petram et al. 2004, Evans et al. 2016, Faure et al. 2020, Ugarković et al. 2020). Dens also provide the female bears with shelter and protection during birth and the first months after (Seryodkin et al. 2003, Manchi & Swenson 2005, López-Alfaro et al. 2013).

Denning characteristics of brown bears have been described in many studies in its distribution range (Linnel et al. 2000, Manchi & Swenson 2005, Sahlén et al. 2011, Smereka et al. 2017, Eriksen et al. 2018, Mangipane et al. 2018, González-Bernando et al. 2020, Faure et al. 2020). Research showed that bears are very specific in their den selection (Elfström & Swenson 2009, Štofik and Saniga 2012, Sorum et al. 2019, Tammeleht et al. 2020, Faure et al. 2020). Bears can use natural rock cavities, excavations in or under live trees, pits in soil and surface beds for dens (Schoen et al. 1987, Linnell et al. 2000, Seryodkin et al. 2003). According to Linnell et al. (2000), natural cavities are more reused than excavated dens due to their higher structural stability. Factors such as landscape characteristics and climate can also influence the location and time of denning (Evans et al. 2016, Mangipane et al. 2018). Besides, some structural parameters of dens such as total length, tunnel length as well as chamber length and width may vary considerably. This might be due to the landscape characteristics and the properties of the soil in excavated dens as well as brown bear adaptability when choosing natural cavities (González-Bernardo et al. 2020).

The brown bear population in Bulgaria as part of the Eastern Balkan population is one of the largest in Europe, with an estimated population of several hundred individuals (Spassov & Spiridonov 1999, Kaczensky et al. 2012, 2021). However, according to the latest official monitoring data, is in decline (Serbezov & Spassov 2023). It consists of two subpopulations – in Stara Planina Mountain and the Rila-Rhodope massif (Frosch et al. 2014). According to Spassov et al. (1999), the Stara Planina subpopulation was isolated from the Rila-Rhodopean one. However, recent research showed that, despite differences in genotype, there is connectivity between them (Frosch et al. 2014). Todorov et al. (2020) provided some evidence that bears in the Stara Planina use dens most often in the core zone of their home range; however, their characteristics have not been studied. Therefore, the aim of the present work is to study the brown bear den's characteristics in the two subpopulations in Bulgaria and thus to expand the knowledge about the ecology of this species in the Eastern Balkans and Europe. We hypothesised that some characteristics of the dens such as aspect and location in rock cavities would be similar to those found in other parts of the species range. Some differences among the dens in the two subpopulations in Bulgaria due to climatic and topographical features were also expected.

Brown bear protection is a priority for Bulgaria and the European Union, as it is included in Appendix II of the Convention on the Conservation of European Wildlife and Natural Habitats (the Berne Convention) and in Annex II and IV of the Habitat Directive 92/43/EEC. The expanded knowledge of the bear's winter denning is essential for species conservation planning and efforts.

# Materials and Methods

### Study area

The fieldwork was conducted in May – October 2022 in the two brown bear subpopulations in Bulgaria – the Stara Planina Mountain and the Rila-Rhodope massif (Fig. 1 a, b). In the region of Stara Planina Mountain, the study area was in Central Stara Planina as dens were located mainly in the Central Balkan National Park, whose borders coincide with the Nature 2000 site BG0000494. Central Stara Planina covers an area of 536349.3 ha with a mean elevation of 830.52 m (range 165.22–2376.00 m). Large rivers in the area, near which dens falls are Beli Vit, Cherna Reka, Cherni Osam, Beli Osam, Tuzha, Zla Reka, Krajovitsa, Cherna Reka, etc. The main habitats in this study area were broad-leaved forest – predominantly beech forests (*Fagus sylvatica*), mixed forest, land principally occupied by agriculture, with significant areas of natural vegetation, natural grassland, non-irrigated arable land and transitional woodland-shrub. In the Rila-Rhodope massif, the study area was in the Western Rhodopes Mountains, which cover an area of 798277.9 ha and fall within the Nature 2000 site BG0001030. The mean elevation of Western Rhodopes Mts is 1169.04 m (range 228.44–2191.00). The main large rivers in the area are Vacha, Chepelare River, Devinska River, Black River, Malka Arda, Shirokolashka River, Trigrad River, etc. In this study area, coniferous forest covers the largest area, followed by broad-leaved forest, mixed forest, land principally occupied by agriculture, with significant areas of natural vegetation and transitional woodland-shrub. Across the study area, the coniferous belt is well represented with spruce (*Picea abies*), scots pine (*Pinus sylvestris*) and black pine (*Pinus nigra*). At the same time, the beech (*F. sylvatica*) dominates the broad-leaved forests. In height, shrub vegetation and alpine meadows prevail.

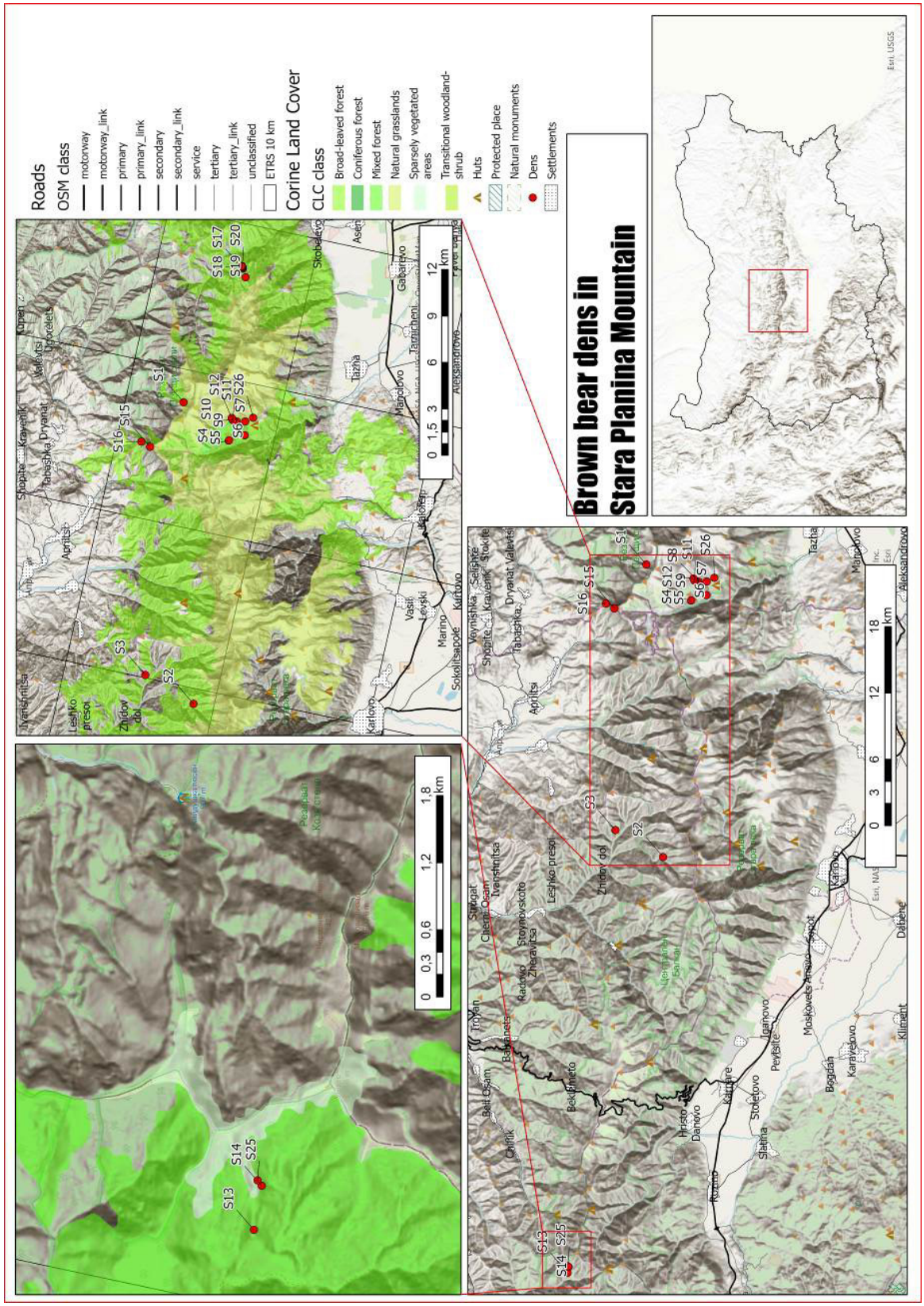


**Fig. 1a.** Brown bear dens in the Stara Planina Mountain. Explanation: The locations of the dens are indicated by codes starting with R1. The roads, CLC classes overlapping with bear dens and settlements are shown. The red rectangles indicate the dens that are presented on the two large-scale maps above.

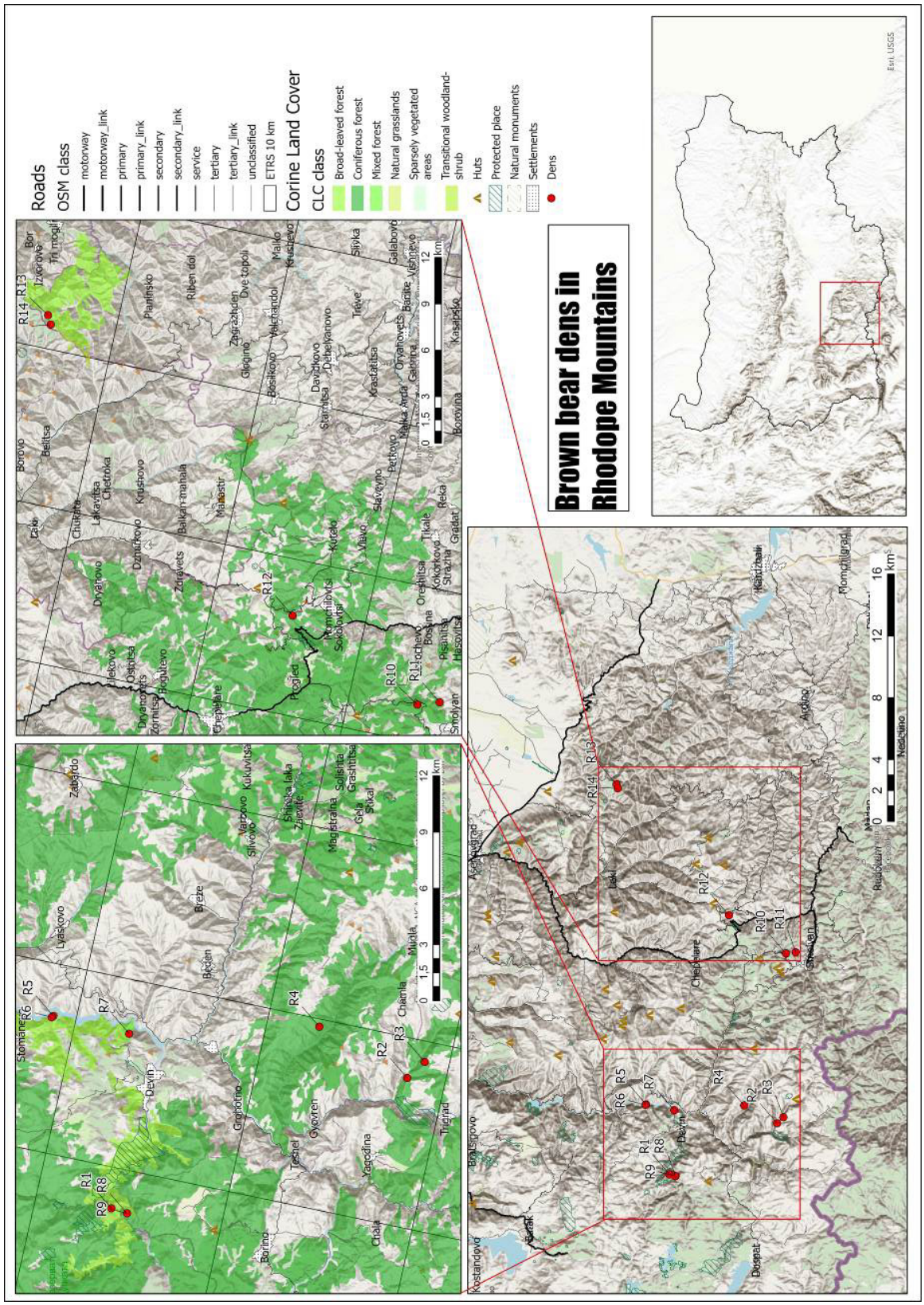


**Fig. 1b.** Brown bear dens in the Rhodope Mountains. Explanation: The locations of the dens are indicated by codes starting with R1. The roads, CLC classes overlapping with bear dens and settlements are shown. The red rectangles indicate the dens that are presented on the two large-scale maps above.

The study areas include the three main types of bear habitats in our mountains defined by the altitude range (MOEW 2018): 1. High mountain areas above 1800 m located above the middle upper limit of the forest, in which isolated forest communities, bare ridges, upper courses of mountain rivers, micro-elevations and depressions of the terrain are found. 2. Areas in the middle of the mountains, 800-1800 m, with a large participation of rocky complexes, massifs and bare terrains combined favourably with predominantly beech forests (*F. sylvatica*). 3. Low mountain areas below 800 m with diverse forest complexes dominated by oak (*Quercus* spp.) formations, often bordering cultivated areas with intensive agriculture and orchards. Both study areas were in the mountainous climatic region and alpine biogeographical region.

**Den variables and GIS analyses**

During the study period, 45 dens were mapped, 30 in the Central Stara Planina and 15 in the Western Rhodope Mts. In both mountains, the dens were located during a detailed search of areas indicated by gamekeepers and rangers as potential den sites as well as a small number were located based on data from GPS-collared animals. The GPS coordinates of each den were taken with Garmin 62s device. The variables width, length of the entrance and depth of the dens were measured on 44 dens with a measuring tape. One den in Rhodope was not accessible during the study period due to the slippery and steep slope. The presence and type of bedding in each den were also recorded. The aspect of the den entrance was determined with a compass. For the GIS analyses, the software packages ArcGIS Pro 3.0 (ESRI) was used. The data layers used for the analyses are presented in Table 1.

The following variables were characterised via GIS analyses: elevation, slope, habitat based on CORINE Land Cover (CLC) 2018, road and settlement distance, and distance to large rivers. The slope was generated in ArcGIS Pro 3.0 with Slope tool extract values to points tool was applied to obtain the slope values for each point, which was associated with the bear's den. CORINE Land Cover data were used to analyze the surrounding habitat around every den location. The Open Street Map (OSM) Roads were classified according to OSM classes, but the following were excluded from the analysis and visualization – path, pedestrian, residential, steps, track, track_grade1 to 5, trunk; trunk_link, unknown. Distances to roads, rivers and settlements were generated with Euclidean distance in a raster file and then the distance values were extracted to each den location. Only distance to rivers and not all water bodies was analysed because they are defined as one of the main landscape variables for a bear's choice of den site (PETRAM et al. 2004). Using the Maximum Bounding Geometry tool, two borders (one for each mountain) around dens locations were created. A 2000 m buffer around the border areas was applied to estimate the anthropogenic pressure near the dens. The size of the buffer corresponds with the minimal size of the core areas of the bears in Bulgaria (Todorov et al. 2020). Thus, the buffer area covered 89122.24 ha in Stara Planina and 179128 ha in Rhodope. Finally, we utilised the defined buffer area for calculating the number of settlements and their total area.

**Statistical analysis**

One-way analysis of variance (one-way ANOVA) was used to determine statistically significant differences in dens characteristics between the two studied regions – width, height, depth, slope and elevation as well as in the variables distance to road, settlements and rivers. The variables were tested for normal distribution using the Kolmogorov-Smirnov test. Statistically significant differences were considered at $p < 0.05$. Statistical analyses were aided by Daniel's XL Toolbox add-in for Excel, version 7.3.2. (Kraus 2014).

# Results

All dens found in the two studied areas were settled in natural cavities in or under rocks as well as between large boulders. There was only one case in the Stara Planina where the soil was dug up to expand a cavity located at the base of a rock. Some of the dens were used in the current year or the year before our visit based on the condition of the bedding. Other dens showed no signs of recent use but reported by the locals to have been used by bears in the late years.

In Stara Planina, the dens were located mainly in broad-leaved forests (Fig. 2). Only here dens were in natural grassland vegetation and sparsely vegetated areas, which are typical for the ridge of the mountain. In the Rhodope region, the dens were found mostly in broad-leaved and coniferous forests and less in mixed forests (Fig. 2).

When comparing the depth of the dens in the two subpopulations, we found that dens in Stara Planina were statistically significantly deeper than in Rhodope Mts (ANOVA: $F_{1, 42} = 4.99$, $p = 0.03$, Table 2). At the same time, statistically significant differences between the dens' width and height in

**Table 1.** Data sources for GIS analyses.

| Data | Source |
|---|---|
| Roads; Huts | Open Street Map Data Extracts https://download.geofabrik.de/ |
| CORINE Land Cover 2018 (CLC) | Copernicus Land Monitoring Service https://land.copernicus.eu/pan-european/CORINE-land-cover |
| ETRS 10 km grid | European Environmental Agency https://www.eea.europa.eu/data-and-maps/data/eea-reference-grids-2 |
| Lakes; Rivers; Settlements | The study on integrated water management in the Republic of Bulgaria – created for the Ministry of Environment and Water by the Japan International Cooperation Agency (JICA). No longer available online |
| Digital Elevation Model (DEM 25 m resolution) | Copernicus Land Monitoring Service https://land.copernicus.eu/imagery-in-situ/eu-dem/eu-dem-v1.1 |
| Bulgarian mountains | https://geography.bg/images/dokladi/21.pdf (Ilieva 2016) |

**Table 2.** Mean and standard error of the measured parameters of the dens. The minimum and maximum values are given in parentheses. Statistically significant values of F in the one-way analysis of variance ANOVA are marked with *.

| Location | Width, cm | Height, cm | Depth, cm |
|---|---|---|---|
| Stara Planina (n = 30) | 102.10±17.09 (30-560) | 99.63±9.81 (33-300) | 487.33±27.13 (220-800) |
| Rhodope Mts (n = 14) | 140.07±22.24 (44-300) | 95.50±12.02 (37-200) | 367.14±53.49 (130-750) |
| $F_{1, 42}$ | $F_{width} = 1.68$, $p = 0.20$ | $F_{height} = 0.14$, $p = 0.71$ | $F_{depth} = 4.99$, $*p = 0.03$ |

**Table 3.** Mean and standard error of the parameters extracted from GIS – elevation, slope, distance to road, settlement, and river. The minimum and maximum values are given in parentheses. Statistically significant values of F in the one-way analysis of variance ANOVA are marked with *.

| Location | Elevation, m | Slope, ° | Distance to road, m | Distance to settlement, m | Distance to river, m |
|---|---|---|---|---|---|
| Stara Planina n = 26 | 1400.77±38.98 (1055-1775) | 24.42±1.44 (9,34-37,01) | 5165.47±255.48 (2332.38-6835.20) | 6164.61±301.98 (2761.24-8652.58) | 1116±13.79 (361-2816) |
| Rhodope Mts n = 14 | 1227.50±70.78 (755-1630) | 30.27±1.97 (20.11-46.34) | 1941.64±323.27 (282.84-4049.69) | 3097.16±401.25 (1357.64-5576.36) | 922±267.30 (100-3312) |
| $F_{1, 38}$ | $F_{elevation} = 5.46$ $*p = 0.02$ | $F_{slope} = 5.76$ $*p = 0.02$ | $F_{road} = 58.49$ $*p = 0.00$ | $F_{settlement} = 36.73$ $*p = 0.00$ | $F_{river} = 0.15$ $p = 0.69$ |

the two subpopulations were not established.

The den with the highest elevation was located in Stara Planina at 1775 m a. s. l., and the one with the lowest elevation was in Rhodope Mts at 755 m a. s. l. (Table 3). In general, the dens in the region of Stara Planina were found to be at statistically significantly higher elevations than those in Rhodope Mts (ANOVA: $F_{1, 38} = 5.46$, p = 0.02). All dens in both study areas fall in the areas in the middle of the mountains (from 800 to 1800 m). In Central Stara Planina, dens S12, S11, S10, S9 and S8 were close to the high mountain areas, which are located east of Golyam Kademlia peak (2275 m). In Western Rhodope Mts, there were no dens that fall in the immediate vicinity of high mountain areas but dens R6, R5 and R7 were located in low mountain areas, more precisely on the eastern shore of the Tsankov Kamak Reservoir.

Regarding the slope, the dens in Rhodope Mts were situated on statistically significant steeper slopes than those in Stara Planina (ANOVA: $F_{1, 38} = 5.76$, p = 0.02). The maximum slope value of a den in Rhodope Mts was 46.34° (Table 3).

The average road distance from bear dens was 4056.5 m. In Rhodope Mts, all dens' locations were statistically significantly closer to roads than in Stara Planina (ANOVA: $F_{1, 38} = 58.46$, p = 0.00, Table 3). The distance of the nearest den to a main road was 282 m (Table 3). Moreover, in Rhodope Mts., the dens were significantly closer to settlements compared to those in the region of Stara Planina (ANOVA: $F_{1, 38} = 36.73$, p = 0.00, Table 3). All located dens were close to large rivers, with an average distance of 983 m. The closest one was found only 100 m from a river in Rhodope Mts (Table 3).

The highest percentage of dens in the regions of both subpopulations were south-facing – 23.33 % in the Stara Planina and 26.67 % in the Rhodope Mts (Fig. 3).

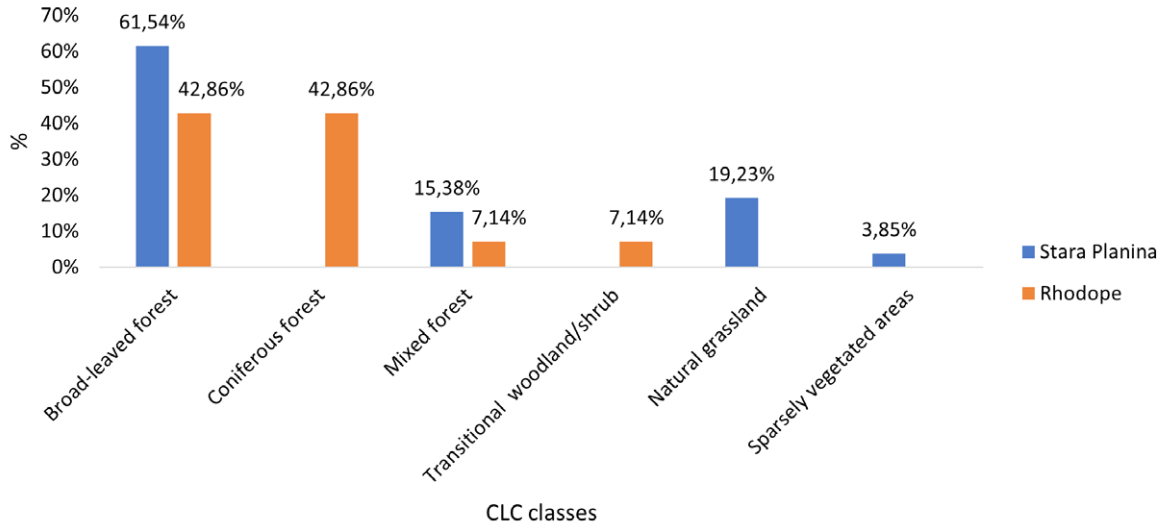


**Fig. 2.** Habitat in which bear dens were located based on CORINE Land Cover.

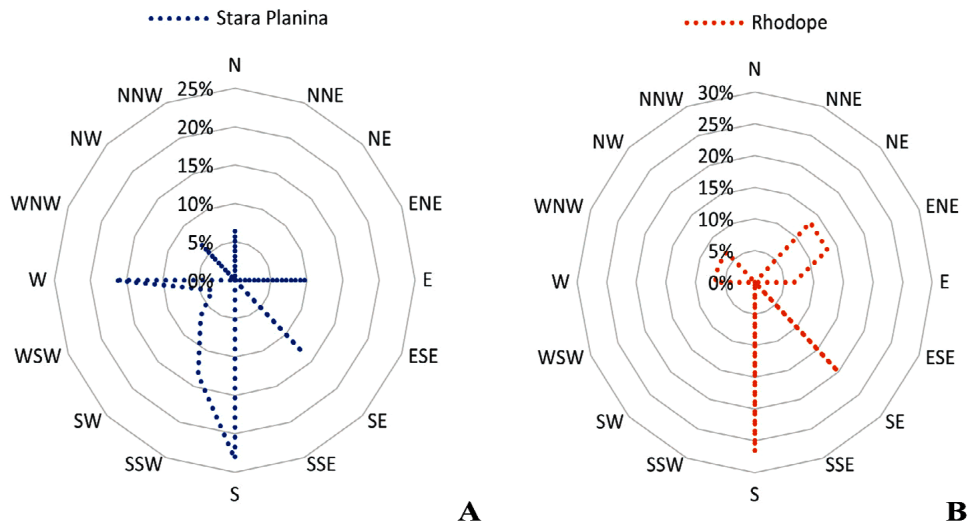


**Fig. 3.** Bear dens' aspect in the regions of Stara Planina (A) and Rhodope Mts (B)

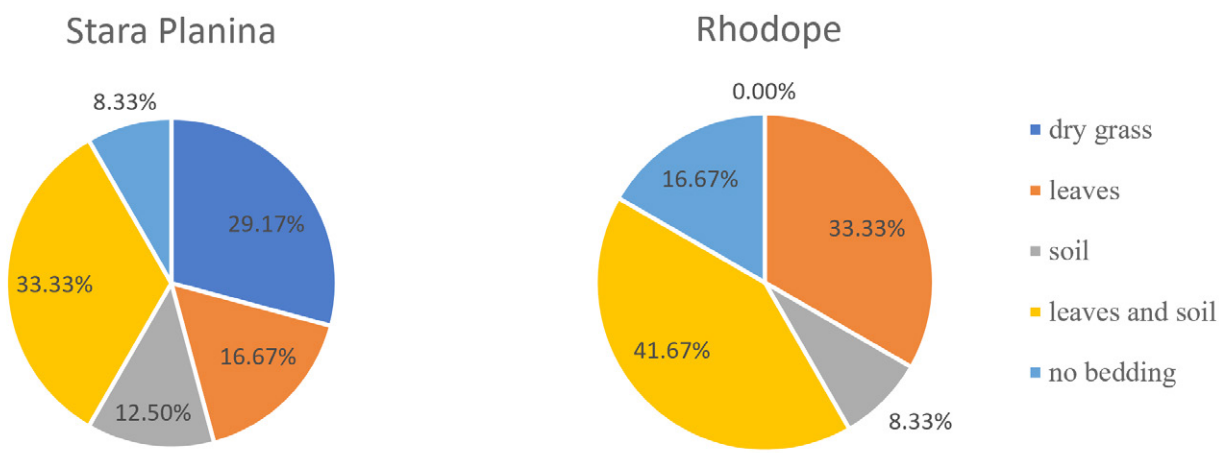


**Fig. 4.** Bedding in the bear dens in the regions of Stara Planina and Rhodope Mts.

**Fig. 5.** Shaped nest in den in Stara Planina.

In both subpopulations, the highest percentage of dens had bedding of leaves and soil (Fig. 4). In Stara Planina, dry grass bedding was found in 29.17 % of the dens and shaped nests were established in only two (Fig. 5). We did not found dens with shaped nests in the Rhodope Mts.

We located 19 settlements in the buffer area around dens in Stara Planina, with a mean distance between settlements of 1905 m. The settlements covered an area of 850.04 ha or 0.95 % of the total area of the buffer.

In the Rhodope Mts buffer area, we found 96 settlements, including three villages without residents and one international resort (Pamporovo). The number of settlements was significantly higher than that in Stara Planina ($\chi 2 = 51.56$, $df = 2$, $p < 0.05$). The settlements in Rhodope Mts occupied 2543 ha or 1.42 % of the buffer area. The mean distance between the settlements here is 1483 m.

# Discussion

In the present study, all dens found were in natural rock cavities. This was also reported by Georgiev (2012) in the Western Rhodope Mts region. This finding was confirmed also by the results of Huber & 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. According to Linnell et al. (2000), the most common den types are those excavated in the ground as well as those located inside natural caves where they occur, especially in southern European and coastal Alaskan areas. Most dens in Velebit Nature Park were also cave dens (Ugarković et al. 2020). Data from North America showed that the use of cave dens could vary widely (Schoen et al. 1987) while, in eastern Russia, brown bears hibernated mainly in root excavation dens (Seryodkin et al. 2003). Unlike our results, the dominant dens in the Scandinavian region were found in anthills, followed by dens dug in the soil (Manchi & Swenson 2005). Analysing the distribution of den locations according to the land cover type, most of them were in forest areas in the current study. Like Pigeon et al. (2014, 2016), we also assume that thick forest cover may better protect the dens from the wind and low temperatures. Our result agreed with Huber & Roth's (1997) study on bear dens in Croatia, where 71 % of dens found were in forests, mainly mixed. In the Northern Dinarides, brown bears preferred dens situated in non-degraded forest ecosystems (Ugarković et al. 2020).

Bedding material in dens contributed to thermal insulation (Craighead & Craighead 1972, McLoughlin et al. 2002, Faure et al. 2020). Thus, it is no surprise that most of the dens located by us had some bedding material. Only in Stara Planina, we found dens with bedding of dry grass, probably due to their location in natural grasslands habitats. In two dens in Stara Planina, nests of dry grass were shaped, probably due to birth preparation. Groff et al. (1998) also describe nest-like beds in bear dens in the region of Trentino, Italy.

Previous studies suggest that bears do not adjust the height of the den entrance, as it is directly proportional to the size of the denning bear (Servheen & Klaver 1983); however, instead, they modify the width (Faure et al. 2020). In our study, we did not find significant differences in the width and height of the dens in the two study areas; however, there were differences in the depth. In the Stara Planina area, the dens were deeper than those in the Rhodope Mts. We assume this may be due to the rock massifs features and the lower average winter temperatures. A den with a greater depth probably protects better from the outside weather conditions and increases the internal thermal insulation. Bears in other parts of their distribution range select high-altitude areas with high amounts of snowfall because deep snow provides better thermal insulation in the den (Vroom et al. 1980, Libal et al. 2012).

In the present study, the dens found in both subpopulations were at an altitude of 755 to 1775 m. Those in the Stara Planina region were located at a significantly higher altitude than those in the Rhodope Mts, probably because the rock massifs in Stara Planina were higher. In comparison, cave dens in the North Dinarides in Croatia were between 900 and 1100 m (Ugarković et al. 2020). The elevation of mountain den locations in Eastern Transylvania (Romania) ranged from 486 to 1607 m, with the altitude of the studied areas in the range 310–1783 m (Faure et al. 2020). The dens in Bulgaria also fall into this range. Besides, González-Bernardo et al. (2020) summarised information from 22 studies and showed that den altitude varies from a minimum average height of 434 m to a maximum of 2696 m.

Numerous studies reveal that bears prefer steeper slopes (McLoughlin et al. 2002, Ciarniello et al. 2005, Elfström et al. 2008, Goldstein, et al. 2010, Libal et al. 2012, Štofík & Saniga 2012, Pigeon et al. 2014, Smereka et al. 2017, Sorum et al. 2019). The tranquillity during hibernation may also be a reason for the registered dens on steeper slopes in the Rhodope Mts. In general, the dens in the Rhodope Mts are closer to settlements and roads, which implies more disturbance. In the region of Eastern Transylvania, the terrain ruggedness is the single most important factor when predicting bear denning habitat (Faure et al. 2020).

In our study, dens were predominantly south-facing. Most cave dens in Croatian Dinarides area were also with a southern aspect (Ugarković et al. 2020). However, other studies found den locations with different aspects: West (Vroom et al. 1980), North (Craighead & Craighead 1972), East (Elfström et al. 2008) and South (Schoen et al. 1987, Groff et al. 1998). According to Faure et al. (2020), the probability of den presence is highest on north- and west-facing slopes, which corresponds to the suggestion by Linnell et al. (2000) that the local stability of snow conditions might influence aspect selection. The influence of other factors is also possible but more research is needed to prove it.

The dens found by us were from 100 to 3312 m from large rivers, with no significant difference between the two subpopulations. This observation was similar to those by Petram et al. (2004) in Slovenia where river valleys were one of the main landscape variables in bear den selection. However, in the current study, we found a statistically significant greater distance of dens to roads and settlements in Stara Planina compared to the Rhodopes probably due to the peculiarities of the regions. The dens in Stara Planina fall mainly within the borders of the Central Balkan National Park, where the only human infrastructures in the vicinity are tourist huts and the human presence is limited mainly to the warm months (May – September). The study area in Western Rhodopes is much more densely populated, with a significantly higher number of settlements. The disturbance in the Rhodope region is considerable, as numerous forestry and gathering activities are taking place. In addition, in the Rhodopes, the major roads are cleared of snow throughout the denning period and most forestry roads are accessible to vehicles throughout winter. A high number of bear damages to livestock and beehives is also traditionally registered in the area – 196 for 2021 and 205 for 2022 (official data of the Regional Inspectorate of Environment and Waters, Smolyan). Despite the high level of disturbance in the Western Rhodope region, the nearest den to a road was found only 282.84 m away. It could be a sign of habituation of the bears there to human disturbance. Faure et al. (2020) stated a similar observation in Romania, where paved roads did not appear to affect den site selection. Petram et al. (2004) and Whiteman et al. (2017) made a similar conclusion for Slovenia and Croatia. According to Linnell et al. (2000),

bears' dens are located more than 1 km from roads. However, this is not always feasible in areas with a dense road network such as the Western Rhodope Mts. Based on the results obtained, it is clear that the brown bear has adapted to human presence but measures can still be planned to reduce disturbance, especially during the hibernation period.

# Conclusions

The obtained results are close to what was found in other regions concerning the den sites preferences of the brown bear: highly rocky terrain, preferably the southern aspect and located in forests close to large rivers. At the same time, differences established between the areas of the two subpopulations imply different management approaches to improve the results of conservation efforts. The timing, scope and intensity of human activities (such as forest exploitation activities and tourist access) should be planned to minimise the disturbance and to preserve the areas with dens.

**Acknowledgements:** This study was funded by the Bulgarian National Science Fund, grant KP-06-H51/8/11.11.2021. We express our gratitude for the support of our colleagues from the National Park Central Balkan, Regional Environment and Water Inspection of Smolyan as well as Mr Vlado Peykov. The authors thank the reviewers for their valuable suggestions, which improved the manuscript.

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Received: 07.04.2023
Accepted: 27.06.2023