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Habitat use of endemic Balkan rock lizards (*Dinarolacerta* spp.)

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Abstract. *Dinarolacerta mosorensis* and *D. montenegrina* are allopatric and closely related rock lizards endemic to the Dinaric Mountains of the Balkan Peninsula. We analysed their habitat characteristics and relative abundances in the mountains of Montenegro. We found significant differences in structural features of the microhabitat used both between populations of *D. mosorensis* and the two species. *Dinarolacerta mosorensis* was associated with relatively more shaded and damper spots on rocks closer to vegetation and leaf litter, while *D. montenegrina* was found in more open, rocky situations. There were significant differences in relative abundance between the sampling sites. Generally, the studied lizards were more abundant at sites with greater percentage of leaf litter and lower percentages of bare ground and small rocks, despite the lower frequency of available refuges in these places. Our results provide basic information that could assist in the adoption of adequate management practices for protection or restoration of habitat attributes relevant to these vulnerable (*D. mosorensis*) and endemic species.

Key words. Squamata, Lacertidae, habitat preferences, abundance, conservation, Montenegro.

Introduction

Gathering information on species habitat requirements and how changes in environmental patterns influence ecological processes have been regarded as key issues in conservation biology (e.g., Quirt et al. 2006, Blevins & With 2011, Stumpel & van der Werf 2012). Many studies have been performed to research the relationship between species abundance and habitat characteristics in order to predict species responses to natural or human-induced habitat alterations (e.g., Lichstein et al. 2002, Fernández 2005, Amo et al. 2007, Pelegrin et al. 2009). Among these, identifying the factors that influence the spatial distribution of ecologically similar and/or closely related species is especially intriguing (Cardozo et al. 2012, Price-Rees et al. 2013, Bungard et al. 2014).

Being ectotherms, reptiles are considered vulnerable to habitat alteration, because environmental parameters strongly affect their ecological performance (Huey 1991). As a result, they were frequently used as model organisms to study the effects of environmental changes (e.g., Sinervo et al. 2010, Logan et al. 2015). Lizards are particularly suitable for addressing habitat issues because of their high home-range fidelity (Bull & Freake 1999), low dispersal ability (Baguette et al. 2014), and methodological advantages in that they often are very abundant and usually easy to locate and observe (Pianka & Vitt 2003). Studying habitat characteristics in thermally and spatially constrained lizards living at high altitudes is important for improving the conservation measures required in the light of the current progressive climate change and various anthropogenic disturbances (Rubio & Carrascal 1994, Martín-Vallejo et al. 1995, Amo et al. 2007, Arribas 2010, 2013, Monasterio et al. 2010).

Members of the genus *Dinarolacerta* (Arnold et al., 2007) are saxicolous, small-sized lacertid lizards endemic to the Dinaric Mountains in the southwestern parts of the Balkan Peninsula. The genus comprises two species: *Dinarolacerta mosorensis* (Mosor rock lizard) which occurs in the southern parts of Croatia, Bosnia and Herzegovina, and Montenegro, and *D. montenegrina* (Prokletije rock lizard) that is restricted to the Prokletije Mts. along the Montenegrin and Albanian border (Ljubisavljević et al. 2007). Due to the small area of occupancy, a highly fragmented distribution, and a declining extent and quality of its habitat, the Mosor rock lizard has been categorized as a 'Vulnerable' species according to IUCN criteria (Crnobrnja-Isailović et al. 2009). However, there are no detailed studies examining the habitat structure and factors that may influence the abundance of this species.

Literature data provide only rough descriptions of habitat types, indicating that the species is often found on limestone outcrops around mountain springs and lakes in open deciduous, mixed or coniferous forests as well as above the tree line (Džukić 1991, Arnold & Ovenden 2002), preferring more humid habitats than the other Balkan petricolous species (Bischoff 1984, Arnold 1987, Veith, 1991).

The Prokletije rock lizard was formerly considered an isolated population of the Mosor rock lizard at the eastern border of its range (Džukić et al. 1997). It has recently been elevated to the species level, primarily based on molecular evidence (Ljubisavljević et al. 2007), which was subsequently supported by Podnar et al. (2014). However, *D. montenegrina* has basically remained unstudied. It is believed that it occurs in similar habitats as its congener (Ljubisavljević et al. 2007). Based on initial observations, *D. montenegrina* has recently been assessed as 'Least Concern' according to IUCN criteria (Crnobrnja-Isailović & Bowles 2011). Nevertheless, it was postulated as being in need of detailed research, given that nothing was known about its ecology, population trends, and the threats this lizard might be exposed to (Crnobrnja-Isailović & Bowles 2011).

Therefore, the aims of our study were to (i) quantify microhabitat attributes of *Dinarolacerta* lizards and identify any inter- and intraspecific (*D. mosorensis*) differences, and (ii) identify the relative influences of local habitat on the abundance of these species. The results of this study may help to establish baseline information on habitat requirements of *Dinarolacerta* spp. that may be useful as a starting point for creating management and conservation plans for these lizards and their fragile mountain habitats. Namely, Oromediterranean forests of sub-Alpine beech with associations of whitebark pine (*Pinus heldreichii*) on rocky grounds (the most commonly used habitats of *Dinarolacerta* spp., Džukić et al. 1997) are considered to be the most threatened forest-type in Montenegro due to the high degree of human impact (Stevanović et al. 2005).

Materials and methods

Study sites and populations

The study was conducted on three mountains in Montenegro. *Dinarolacerta mosorensis* was studied at two sites on Mt. Prekornica in central Montenegro (Srednja Ponikvica, 1,400 ± 6 m a.s.l., 42.40° N, 19.16° E; Zamršten, 1,585 ± 15 m, 42.41° N, 19.16° E) and one site on Mt. Lovćen in southern Montenegro (Ivanova Korita, 1,222 ± 20 m, 42.22° N, 18.50° E), whereas *D. montenegrina* was studied at one site on Mt. Žijovo (Kastrat, 1,459 ± 10 m, 42.34° N, 19.29° E). All sites lie within the Oromediterranean belt and are characterized by fragmented distributions and the formation of specific preglacial floristic and faunistic elements (Matvejev & Puncer 1989). The main climatic characteristics of this type of landscape are long, very cold, snowy winters, very humid autumns and springs, and hot dry summers with extreme fluctuations between day and night temperatures (Matvejev 1961). Lizards were found on limestone rocky outcrops at all sites. These rocks were surrounded by natural open mixed forests of Subalpine beech (*Fagus sylvatica*) and whitebark pine (*Pinus heldreichii*), except at the study site on Mt. Lovćen, which is framed by planted stands of black pine (*P. nigra*), Scots pine (*P. sylvestris*), Norwegian spruce (*Picea abies*), and European larch (*Larix decidua*). This study site lies within the Lovćen National Park, while other ones are in unprotected areas.

Lizard censuses and habitat characterization

Surveys to assess *Dinarolacerta* spp. habitat characteristics and abundances were performed during June and July of 2014, between 09:00 and 17:00 h CEST, on days with favourable weather conditions (i.e., sunny days with moderate wind speeds) when the lizards were particularly active. The numbers of transects per site and their length were based on the size of the survey area. Multiple transects were at least 15 m apart and regularly distributed across the study area. The size of each surface area sampled, the number of transects, and their total lengths were as follows: Srednja Ponikvica, 0.5 ha, 2 transects, 230 m; Zamršten, 1.5 ha, 3 transects, 545 m; Ivanova Korita, 5.5 ha, 5 transects, 1,600 m; Kastrat, 3.4 ha, 5 transects, 1,345 m. While patrolling these transects slowly, we identified (adult or immature individuals) and counted lizards within a 10 m-wide belt (5 m on each side of the transect line). The visual detectability of lizards is supposed to be high enough to record a maximum number of active individuals. The relative index of abundance was then calculated as the ratio between the lizards observed and the length of each transect. This simple index was previously used in similar studies (Amo et al. 2007, Monasterio et al. 2010), and although it does not provide a measure of the actual density of lizards, it will facilitate between-site comparisons of abundance.

Structural features of the habitat at each study site were quantified at 30 randomly selected sighting spots of lizards, according to method used by Vanhooydonck et al. (2000). Briefly, habitat data were recorded at four spots: the spot where the lizard was first sighted, and the endpoints of three lines at an angle of 120° and 200 cm from the first one. The directions of these lines were determined at random. The point where the lizard was observed initially served as the centre of a circle with a radius of 50 cm, the other three points were each the centre of a 100-cm radius circle (for a schematic representation, see also Bombi et al. 2009). At the place of the first observation of a given lizard, the following habitat variables were recorded: (1) perching rock height, (2) perching rock breadth (the longest side), (3) number of touching neighbouring rocks, (4) distance to the nearest refuge (i.e., a crack large enough to permit a lizard to enter), and (5) distance to the nearest vegetation. In all four circles, we registered the percentage cover at ground level of exposed rocks, grass/herbs, shrubs, trees and leaf litter (6–10), number of refuges (11), number of small rocks (< 25-cm diameter), medium-sized rocks (25–

Table 1. Analysis of variance for habitat variables with 'species', 'locality' and 'ontogenetic stage' as factors. Key to asterisks: *** p < 0.0001, ** p < 0.01, * p < 0.05; ns – not significant.

Variables	Between species		Between localities		Between adults and non-mature individuals	
	F	p	F	p	F	p
Perching rock height	3.95	ns	4.002	*	0.152	ns
Number of touching neighbouring rocks	0.451	ns	5.34	**	0.451	ns
Distance to the nearest refuge	6.027	*	2.12	ns	0.382	ns
Distance to the nearest vegetation	14.07	***	1.417	ns	3.5	ns
Rock cover	20.178	***	10.722	***	3.081	ns
Shrub cover	0.103	ns	9.713	***	0.029	ns
Tree cover	3.892	ns	16.788	***	0.783	ns
Leaf litter	5.484	*	14.529	***	0.027	ns
Number of refuges	16.395	***	11.917	***	7.892	**
Number of small rocks	1.763	ns	14.063	***	0.817	ns
Number of medium-sized rocks	2.389	ns	15.74	***	0.293	ns

100 cm), large rocks (> 100 cm) (12–14), and maximum height of vegetation (15). To reduce the number of variables, analyses were conducted on the mean values of the four circles (variables 6–15) and the values for the central circle only (variables 1–5). All measurements were taken to the nearest 1 cm.

Data analysis

Original data were tested for normality (Shapiro-Wilk W test). As the distributions of data were skewed, they were normalized by ln-transformation. One value from the pair of highly correlated (R > 0.7) habitat variables was excluded from further analyses. Descriptive statistics (mean and one standard error, SE) for habitat variables for each locality and species were calculated. A three-way analysis of variance (ANOVA) was used to check for statistically significant differences in habitat characteristics between the two species, between four sites, and between the two age groups (adult and immature individuals). A principal component analysis (PCA) with varimax-rotated factors was used to reduce all the habitat variables to smaller number of independent components. In order to assess relationships between habitat variables and relative abundance, we correlated values for PC scores for each transect with the relative abundance of lizards for each transect. Likewise, the Pearson's correlation coefficient was calculated by using relative abundances and PC scores for eleven rather than four sites in order to reduce to the risk of committing a Type-II error. Statistical analyses were performed using the software package Statistica 7.0 (StatSoft Inc., www.statsoft.com.), considering p < 0.05 as the level of significance.

Results

Four pairs of variables were highly correlated and therefore one in each pair was excluded from further analyses. Thus, the results are presented for 11 out of 15 recorded habitat variables. The results of a three-way ANOVA with 'species', 'locality' and 'age group' as factors showed significant differences for five habitat variables between species, nine between localities, and only one variable between age groups, out of eleven examined variables (Table 1). Given that adult and immature individuals differ significantly in a single variable, we decided to unite them within each sample to improve our sample size for further analyses.

In comparison to *Dinarolacerta montenegrina, D. mosorensis* was found in places with smaller numbers of refuges, lower percentages of rock cover, but higher percentages of leaf litter. Consequently, *D. mosorensis* individuals were mostly seen at spots farther from the nearest refuge, but considerably closer to the vegetation, compared to *D. montenegrina* (Table 2). A post-hoc Tukey HSD test revealed great variation between localities, with the most pronounced differences existing between microhabitats selected by *D. mosorensis* at Srednja Ponikvica and Zamršten (significant differences in seven out of eleven variables).

The first three principal components accounted for 61.5% of the total variance (Table 3). The number of refuges, number of small rocks, and percentages of rock and leaf litter cover had the highest loadings for the first principal component (PC1), while the percentage of shrub cover was the only variable with a high loading for PC2. The perching rock height and number of touching neighbouring rocks made the greatest contribution to the variance explained by PC3 (Table 3).

The relative abundance of lizards was significantly different between localities (Fisher exact test, p < 0.01). It was highest at Srednja Ponikvica (6.53 lizards per 100 m of transect line, *D. mosorensis*) and lowest at the Ivanova Korita locality (1.82, *D. mosorensis*). Relative abundances of 5.54 and 3.37 individuals were recorded at Kastrat (*D. montenegrina*) and Zamršten (*D. mosorensis*), respectively.

The relative abundance of lizards per transect significantly changed in relation to microhabitat characteristics defined by PC1 (R = -0.64, p < 0.05), but not by PC2 and

Table 2. Descriptive statistics (mean and one standard error – SE) for the habitat variables of *Dinarolacerta mosorensis* and *D. montenegrina.*

	D. mosorensis				*D. montenegrina*
Variables	Ivanova Korita	Srednja Ponikvica	Zamršten	Overall	Kastrat
1. Perching rock height (cm)	26.28±2.63	51.20±8.84	29.06±8.51	33.25±3.60	71.54±15.66
2. Number of touching neighbouring rocks	1.83±0.32	1.93±0.50	4.44±0.89	2.55±0.34	2.71±0.42
3. Distance to the nearest refuge (cm)	13.48±1.69	15.13±1.79	21.69±4.02	16.08±1.46	11.86±1.56
4. Distance to the nearest vegetation (cm)	64.00±14.60	26.80±4.37	46.88±9.13	50.13±7.72	112.39±18.92
5. Rock cover (%)	71.41±3.07	50.87±3.97	55.22±5.21	61.96±2.53	78.48±2.25
6. Shrub cover (%)	1.22±0.90	0.92±0.39	7.61±2.35	2.85±0.84	2.37±0.88
7. Tree cover (%)	0.00±0.00	1.08±0.44	4.45±2.23	1.46±0.64	0.27±0.15
8. Leaf litter (%)	0.08±0.05	4.45±2.18	0.16±0.11	1.19±0.59	0.00±0.00
9. Number of refuges	7.09±0.52	4.45±0.68	9.03±1.11	6.95±0.47	9.42±0.53
10. Number of small rocks	10.16±1.65	5.28±2.03	14.72±1.69	10.16±1.12	10.54±1.04
11. Number medium-sized rocks	3.70±0.40	6.25±0.76	8.23±0.90	5.55±0.43	4.23±0.33

Table 3. Factor loadings for the habitat variables of *Dinarolacerta mosorensis* and *D. montenegrina* on the first three principal components. High factor loadings are indicated in bold.

	PC1	PC2	PC3
Perching rock height	-0.06	0.33	**-0.73**
Number of touching neighbouring rocks	0.29	0.22	**0.71**
Distance to the nearest refuge	0.07	0.6	-0.03
Distance to the nearest vegetation	0.56	0.05	-0.56
Rock cover	**0.68**	-0.42	-0.19
Shrub cover	0.02	**0.78**	-0.17
Tree cover	-0.17	0.58	0.28
Leaf litter	**-0.68**	0.03	-0.05
Number of refuges	**0.79**	0.13	0.24
Number of small rocks	**0.73**	0.14	0.43
Number medium-sized rocks	0.15	0.51	0.57
Explained variance (%)	23.3	18.6	19.6

PC3. This result indicated that *Dinarolacerta* lizards were more abundant at sites with a greater percentage of leaf litter and lower percentages of bareness and small rocks, despite the lower availability of refuges in these places.

Discussion

Our study demonstrates that between-site variation in microhabitat characteristics of *Dinarolacerta mosorensis* is greater than between the two *Dinarolacerta* species. The occupation of generally similar rocky habitats by these two morphologically similar species is not surprising given that ecological and ethological activities of animals are closely associated with morphology (Pianka 1986). Also, thermal challenges in montane environments may cause constraints on the habitat use by lizards and favour interspecific convergence in the characteristics of suitable habitats (Langkilde et al. 2003). However, our results revealed some subtle differences in several features of the habitats occupied by the two rock lizards. Generally speaking, *D. mosorensis* was more related to relatively more shaded and damper spots closer to vegetation and leaf litter, while *D. montenegrina* was found on more open, rocky places.

Rock composition and morphology (rock dimensions, extent of rock cover, number and width of the crevices) are often found to be the most important habitat attributes affecting the occupancy and abundance of saxicolous lizards (e.g., Rubio & Carrascal 1994, Howard & Hailey 1999, Monasterio et al. 2010, Blevins & With 2011, Arribas 2013). For *Dinarolacerta* lizards, proximity to vegetated areas that might affect the thermal properties of the rock, availability of resources (food, water, nesting sites) and provide protection from abiotic extremes in mountain regions, appeared to be more important than the number of available refuges. Retreat-site selection by ectotherms depends on interaction between thermal regimes (Huey 1991, Webb & Shine 1998), social advantages (Stamps & Tanaka 1981), predator avoidance (Downes & Shine 1998), and the structure of the retreat site itself (Croak et al. 2008). Therefore, the number of available refuges per se may be unimportant if they do not meet the specific ecological requirements of the species.

Quirt et al. (2006) found that rock-dwelling lizards carefully choose those retreat sites in cold climates that would afford the best opportunities for achieving and maintaining preferred body temperatures. Our first results indicate that *Dinarolacerta* spp. may be more abundant in spots with medium-sized rocks up to 100 cm in height, which is possibly related to the thermal characteristics of their retreats (comp. Huey 1991). In montane areas, large and thick boulders that offer temperatures of an ectotherm's preferred range at a slower pace (or never) may be used less frequently than warmer rocks of intermediate size. On the other hand, small rocks can become very hot during the day and may thus exceed the tolerated thermal maximum of a species (Huey et al. 1989).

The relative abundance of the studied lizards was lowest on Mt. Lovćen in the population of *D. mosorensis* occurring at the southernmost limit of the species' range. There, the spots occupied by the Mosor rock lizard were characterized by low percentages of leaf litter and tree canopy, indicating somewhat drier conditions with low shade cover. Relatively unshaded conditions may limit activity times and consequently reduce food-capture rates and offspring production (Huey 1991), while lower availability of moisture may affect hatchling phenotypes (Warner & Andrews 2002). Our results are perhaps unsurprising given that relict peripheral populations often exhibit relatively low rates of population increase and low densities (e.g., Berlingd 2005, but see Ljubisavljević et al. 2008), and a previous research has already revealed that the clutch size in the Lovćen population of the Mosor rock lizard was significantly smaller than that from Mt. Prekornica (Ljubisavljević et al. 2007). Moreover, it should be mentioned that the vegetation at the studied site on Mt. Lovćen was originally dominated by Subalpine beech forest. The site is now covered by sparse stands of several conifer species that were planted in the late 1940s to the early 1950s (*Pinus nigra*) and in the late 1970s (*P. sylvestris, P.abies, L. decidua*) (Anonymous 2004). Vegetation conversion does not inevitably have deleterious effects on a lizard population if the microhabitat structure remains similar to the natural macrohabitat (forests) (Amo et al. 2007). However, the lower relative abundance of the Lovćen population compared to other studied populations that inhabit natural mixed forests may indicate negative effects of the modification of the original vegetation on the microhabitat of the Mosor rock lizard.

The results of our study are a first step towards recognizing important habitat components of *Dinarolacerta* lizards that might guide conservation efforts in prioritising the conservation of native forests, efficient control of deforestation, protection of forest remnants, and encouragement of local people to maintain natural rock piles and boulders inside and around forests. Apart from monitoring the Mosor rock lizard population on Mt. Lovćen, further research should also include factors driving habitat selection (such as different aspects of behavioural ecology) and other populations of *Dinarolacerta* spp. across their area of distribution in order to assess population statuses and define conservation priorities.

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