

# DATA CONCERNING CENTIPEDE FAUNA FROM VÂLCEA COUNTY (ROMANIA) WITH EMPHASIS ON BUILA-VÂNTURARIȚA NATIONAL PARK: DISTRIBUTION AND ECOLOGY

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An overview of the centipede fauna of Vâlcea County (Romania) is given, with particular focus on Buila-Vânturarița National Park (BVNP), emphasizing species ecology and conservation status. Records were extracted from existing literature and a database completed with recently collected specimens. During the field campaign, 14 centipede species were collected and identified representing 5 genera and 4 families. The number of known species in BVNP reaches 16, while for the Vâlcea county is 27. Out of these, four species, *Dicelophylus carniolensis*, *Harpolithobius anodus anodus*, *Lithobius schuleri* and *L. burzenlandicus* are considered endangered in the Carpathian Mountains, while two species are endemic for Romania, *Lithobius decapolitus* and *Harpolithobius triacanthos*. The identified species, grouped by ecological categories, attests to a good natural condition of the protected habitats under study. Data on the know distributional range of the species over some abiotic factors are also given.

**Keywords:** Centipede, ecology, distribution, relics, conservation status, Buila-Vânturarița, Romania.

## INTRODUCTION

A proper comprehension of species distribution is essential to identify diversity patterns (including biodiversity hotspots), species tolerance range for abiotic ecological factors and to plan and evaluate conservation measures (Myers *et al.*, 2000; Booth, 2017). Even more, under the pressure of anthropogenic generated threats (Bowler *et al.*, 2020), as well as climate change, species can shift their ranges (Wiens, 2011; Fernández & Hamilton, 2015; Spence & Tingley, 2020). Therefore, assessing the impact of these threats on various species is a goal for many researchers, calling for high-quality distribution data (Cogălniceanu *et al.*, 2013; El-Gabbas & Dormann, 2018; Ahmad Suhaimi *et al.*, 2021).

Romania can be considered one of the richest countries in Europe, regarding species number both for Myriapoda (Loveland, 2011) and separately for Chilopoda

fauna, the latter with estimated numbers between 112–116 species (Ion, 2016; Baba *et al.*, 2019). However, regional sampling bias, especially towards karstic rich areas of the country, is easy to spot from maps published in national fauna fascicles dedicated to centipedes (Matic, 1966, 1972). Hence, systematic investigations on neglected territories may enhance the knowledge base on centipede species diversity and distribution.

Buila-Vânturarița National Park and also site of community importance (ROSCI0015 Buila-Vânturarița), is the smallest national park in Vâlcea County, Romania (Muntean *et al.*, 2010) with an area of 4186 ha and hosting impressive karstic formations (Goran, 1981). Even so, the many other habitats types in the area, especially forests, were neglected by myriapodologist.

In this paper, we present a detailed account of centipede fauna from Vâlcea County, based on literature data and field-collected specimens. We also wanted to explore how much more can systematic habitat sampling increase the knowledge on species richness in a protected area, investigating various habitats from BVNP. Insights on the ecology, conservation status of identified species, as well as range of some abiotic factors from the national distribution of each species is given.

#### MATERIAL AND METHODS

Vâlcea County is situated in the South-central part of Romania. With an area of 5.765 km<sup>2</sup>, its running waters are drained by the Olt river that flows from the north (in the Southern Carpathians) to the south passing through various landscapes in the Subcarpathians, Piedmont zone and reaching plains (Ploaie & Turnock, 1998).

The mountains area of the county is split by the Olt river in two, Făgăraș Mountains in the east and Parâng into the west and is covered by beech and spruce forest that is replaced by alpine pastures in highest altitudes. From a subdivision of these mountains, named Căpățâna Mountains, stands out the massif mountain of Buila-Vânturarița. The ridge of Buila extends 14 km from SW to NE, having the lowest altitude of about 550 m and reaching up to 1885 m at Vânturarița Mare peak (Lotrean, 2012). The massif consists of limestones structures situated between Bistrița and Olănești river valleys, which dug deep gorges. The geological and hydrological structure of the Buila-Vânturarița massif aided the development of spectacular exokarst formations and an impressive number of endokarst formations (Goran, 1981).

According to the approved management plan, forest habitats occupy over 60% of the park area. In the rest of the area, there are meadows, rocky habitats, alpine *Juniperus* scrubs, riparian zones as well as restricted areas with cultivated or construction areas (Ministerial Order OM 1151/2016 Annex 1).

The zoological material was collected from BVNP during 2016–2018 from five habitat types (beech forest, mixed forest, rocky meadows and riparian). Manual searches, with tweezers, were made from an area of 5 x 5m (under logs, rocks, tree bark) for half an hour by one person. Additionally, centipedes were also collected from 10 soil and litter samples (25 x 25 cm) per collection station. The material is preserved in 70% ethyl alcohol and kept in the first author collection.

For the identification of species the keys from fauna fascicles dedicated to Romanian centipedes (Matic, 1966, 1972) were used. Information obtained from field data were added to a geodatabase where literature species distribution data for Vâlcea County was also collected. Taxonomy is based on papers published by: Negrea (2006), Bonato & Minelli (2014), Ion (2016), and online Chilobase 2.0 (Bonato *et al.*, 2016).

General distribution data for species were updated according to new proposed zoogeographic regions (Holt *et al.*, 2013). For the protection status, we verified the list of the endangered species in the Carpathian mountains (Kukuła *et al.*, 2003) and also *The Red Book of Invertebrates of Romania* [(Ion, 2021, in Murariu & Maican (Coord.), 2021)]. Species were considered endemic for Romania if their distribution is known only from the Romanian territory or there is, at most one distribution point outside the borders and the literature's mention is considered uncertain.

The state of habitats in the BVNP was assessed by analyzing the specific composition according to the ecological category in which the species falls according to a method tested in the Czech Republic (Tuf & Tufová, 2008). The proposed scheme divides all species into three categories taking into account their known habitat requirements. This distinguishes between relict species, generally present in unaffected natural habitats, adaptable species, able to live in both unaffected and slightly affected natural habitats and eurytopic species that are present in various habitats, including those strongly affected and anthropogenic. Following the analysis of several areas and their compositions, Tuf established that in natural habitats with a good state of conservation over 30% of chilopod species are in the category of relicts followed by adaptable species. Affected habitats are predominantly occupied by adaptable species with a low proportion of relict species, while heavily affected, anthropogenic habitats are populated by high percentages of eurytopic species (Tuf & Tufová, 2008).

To explore species ecology, the above-mentioned geodatabase was enriched with climatic data. We used 1 km resolution raster layers from a set of bioclimatic global database WorldClim (Hijmans *et al.*, 2005, 2008). Based on publications that explored the influence of climate on myriapods distribution (Tursman *et al.*, 1994; Marek *et al.*, 2012; Georgopoulou *et al.*, 2016; Cox *et al.*, 2020) we selected

the annual mean temperature (BIO1), mean temperature of the coldest quarter (BIO11) and annual precipitation (BIO12). Also, the elevation, derived from Shuttle Radar Topography Mission (SRTM) data, was taken into consideration from the same source. For each species distribution point these data were extracted in ArcGIS version 10.4 (ArcMap; Environmental Systems Resource Institute, Redlands, California). With these, we explored elevational and bioclimatic distributions over which centipede species present in Vâlcea County were historically detected in Romania compared to the range of the same factors in BVNP. For this we used a web application, PlotsofData, allowing us to visualize data and statistical summaries (Postma & Goedhart, 2019). Species with less than 10 distribution points within Romania were disregarded.

## RESULTS

From the biological material collected in the BVNP area, we identified 14 centipedes representing five genera and four families. The number of known species in BVNP reaches 16 as two species mentioned in the literature were not found. For the whole Vâlcea County, the total count is 27 centipede species (Table 1).

Four of the species collected from BVNP, *Dicellyphilus carniolensis*, *Harpolithobius anodus anodus*, *Lithobius schuleri* and *Lithobius burzenlandicus* are present on the Carpathian list of endangered species (Kukuła *et al.*, 2003). Two other species (*Harpolithobius triacanthos* and *Lithobius decapolitus*) are endemic to Romania and were included in *The Red Book of Invertebrates of Romania* [(Ion, 2021, in Murariu & Maican (Coord.), 2021)].

Concerning ecological category, the species in BVNP are in a percentage of 43% relict species, similar with adaptable species, while eurytopic species make up to 14%. Moreover, relict species seem to be more frequent in forested habitats, especially with beech. The situation is replicated almost similarly for the whole of Vâlcea County.

Only four species seem to have their distribution restricted to Romania and, at most, neighbouring Bulgaria. Almost half of the species from Vâlcea have general West-Palearctic distribution. Several others extend also in the Saharo-Arabian region, while six species can be found in a few other places from Nearctic, Australian or Sino-Japanese bioregions.

Comparing the types of ecosystems investigated, the highest number of species was identified in forested habitats (12 species in beech forests, six in mixed forests and five in coniferous forests), followed by riparian zone (five species) and subalpine meadows.

Table 1

List of centipede species identified from Vâlcea County and Buila Vânturarița National Park with reference to their general distribution, ecological category and protection status.

Species	Distribution	Ecological categories	Protection status and endemity	Literature data		Field data					
				Vâlcea county	On BVNP territory	Beech forest	Mixed forest	Coniferous forest	Rocky meadow	Riparian	
<b>Order Geophilomorpha, Family Dignathodontidae</b>											
1.	<i>Dignathodon microcephalus</i> (Lucas, 1846)	W-PAL SAH-A	R		*						
2.	<i>Henia (Henia) illyrica</i> (Meinert, 1870)	W-PAL	A		*						
<b>Order Geophilomorpha, Family Geophilidae</b>											
3.	<i>Geophilus flavus</i> (De Geer, 1778)	W-PAL NEAR	E		*						
4.	<i>Pachymerium ferrugineum</i> (C.L. Koch, 1835)	PAL NEAR Japan	A		*						
<b>Order Geophilomorpha, Family Linotaeniidae</b>											
5.	<i>Strigamia acuminata</i> (Leach, 1815)	W-PAL SAH-A	E		*						
6.	<i>Strigamia crassipes</i> (Koch, 1835)	W-PAL	A		*		*				
<b>Order Geophilomorpha, Family Mecistocephalidae</b>											
7.	<i>Dicelophylus carniolensis</i> (Koch, 1847)	W-PAL	E	CRL- VU;	*	*	*		*		*

Table 1 (continued)

Species	Distribution	Ecological categories	Protection status and endemity	Literature data		Field data					
				Vâlcea county	On BVNP territory	Beech forest	Mixed forest	Coniferous forest	Rocky meadow	Riparian	
<b>Order Lithobiomorpha, Family Lithobiidae</b>											
8.	<i>Eupolybothrus transylvanicus</i> (Latzel, 1882)	W-PAL	R		*						
9.	<i>Eupolybothrus tridentinus</i> (Fanzago, 1874)	W-PAL	R			*					
10.	<i>Harpolithobius anodus anodus</i> (Latzel, 1880)	W-PAL	R	CRL-EN;				*	*		*
11.	<i>Harpolithobius radui</i> (Matic, 1955)	RO, BG	R		*		*	*			
12.	<i>Harpolithobius triacanthos</i> Matic, 1964	RO	R	END RO; ROM_R B-EN			*	*			*
13.	<i>Lithobius cyrtopus</i> Latzel, 1880	W-PAL	R				*				
14.	<i>Lithobius decapolitus</i> Matic, Negrea & Prunescu, 1962	RO	R	END RO; ROM_R B-EN		*					
15.	<i>Lithobius forficatus</i> (Linnaeus, 1758)	W-PAL SAH-A NEAR	E				*	*	*	*	
16.	<i>Lithobius melanops</i> Newport, 1845	W-PAL NEAR	E		*						

Table 1 (continued)

Species	Distribution	Ecological categories	Protection status and endemity	Literature data		Field data				
				Vâlcea county	On BVNP territory	Beech forest	Mixed forest	Coniferous forest	Rocky meadow	Riparian
17. <i>Lithobius mutabilis</i> L. Koch, 1862	W-PAL	A								*
18. <i>Lithobius muticus</i> C. L. Koch, 1847	W-PAL	A		*		*	*			
19. <i>Lithobius schuleri</i> Verhoeff, 1925	W-PAL	R	CRL-VU;	*		*				
20. <i>Lithobius tenebrosus</i> Meinert, 1872	W-PAL	A	.	*		*				
21. <i>Lithobius (Monotarsobius) crassipes</i> L. Koch, 1862	W-PAL SAH-A NEAR	A		*						
22. <i>Lithobius (Sigibus) burzenlandicus</i> Verhoeff, 1931	W-PAL	R	CRL-VU;		*	*		*		
23. <i>Lithobius (Sigibus) pustulatus</i> Matic, 1964	RO BG	R		*						
<b>Order Scolopendromorpha, Family Cryptopidae</b>										
24. <i>Cryptops croaticus</i> Verhoeff, 1931	W-PAL	A		*						
25. <i>Cryptops hortensis</i> (Donovan, 1810)	W-PAL SAH-A NEAR AUST	A		*		*				

Table 1 (continued)

Species	Distribution	Ecological categories	Protection status and endemity	Literature data		Field data				
				Vâlcea county	On BVNP territory	Beech forest	Mixed forest	Coniferous forest	Rocky meadow	Riparian
26. <i>Cryptops parisi</i> Brolemann, 1920	W-PAL SAH-A	A		*	*	*	*	*		*
<b>Order Scutigermorpha, Family Scutigeridae</b>										
27. <i>Scutigera coleoptrata</i> (Linnaeus, 1758)	W-PAL SAH-A	A		*						

*Abbreviations:* W-PAL: Western Palearctic; SAH-A: Saharo Arabian; NEAR-Nearctic; RO: Romania; BG: Bulgaria; R: relict species (stenotopic species, restricted to natural undisturbed habitats); A: adaptable species (can be found in natural environments, but sometimes also in anthropized or man-made habitats like urban green spaces); E: eurytopic (wide distribution, found equally in natural and highly anthropized habitats like brownfields, often synanthropic); CRL: species included in the Carpathian List of Endangered Species [(Witkowski *et al.*, 2003) (EN-endangered, VU-vulnerable)]; ROM\_RB: species included in *The Red Book of Invertebrates of Romania* (EN-endangered);

\* - marks the presence of species in the area or/and type of habitat.

From the WorldClim raster data, the range of altitude within BVNP falls between 550–1885m, annual mean temperature between 3.1–8.2°C, mean temperature of the coldest quarter -5.2 – -2.1°C and annual precipitation between 688–940 mm, represented as a vertical band over the violin plots in Fig. 1. In the figure, a middle vertical line indicates the median of the data, the horizontal bars indicate the median 95% confidence interval determined by bootstrapping for each species. The jittered dots within the violin plot represent the actual records. The species are ordered according to their median value.

Centipede species from Vâlcea County used a varied elevation range with *Lithobius tenebrosus* and *L. cyrtopus* inhabiting higher elevations (800–1200 m) and *Scutigera coleoptrata*, *Henia illyrica* and *Lithobius crassipes* present in lower elevations (40–220 m). *Lithobius tenebrosus* and *Strigamia acuminata* showed by far the preferences towards higher amounts of annual precipitations (780–800 mm), followed by a tight group of eight centipede species with a median of annual precipitation of around 720–740 mm. *Scutigera coleoptrata* has the lowest annual precipitation distribution, with most of records toward median of 470 mm. Regarding mean temperatures, *Scutigera coleoptrata*, *Eupolybothrus transsylvanicus*,



*Henia illyrica* and *Lithobius crassipes* were frequently recorded in areas with higher mean temperatures (both annual and of the coldest quarter). *Lithobius tenebrosus* and *L. cyrtopus* seems to tolerate lower mean temperatures 8.4–8.9°C (annual) and -4.6 – -4.4°C (in the coldest quarter). Taking into consideration the 95% median confidence interval (95% CI, determined by bootstrapping) (Postma & Goedhart, 2019) we identified three species *Strigamia acuminata*, *Lithobius pustulatus* and *Pachymerium ferrugineum* that have an overlap of their elevational/bioclimatic distribution with the distributions of the same variables within BVNP (for at least two variables), but which have not yet been collected from the park.

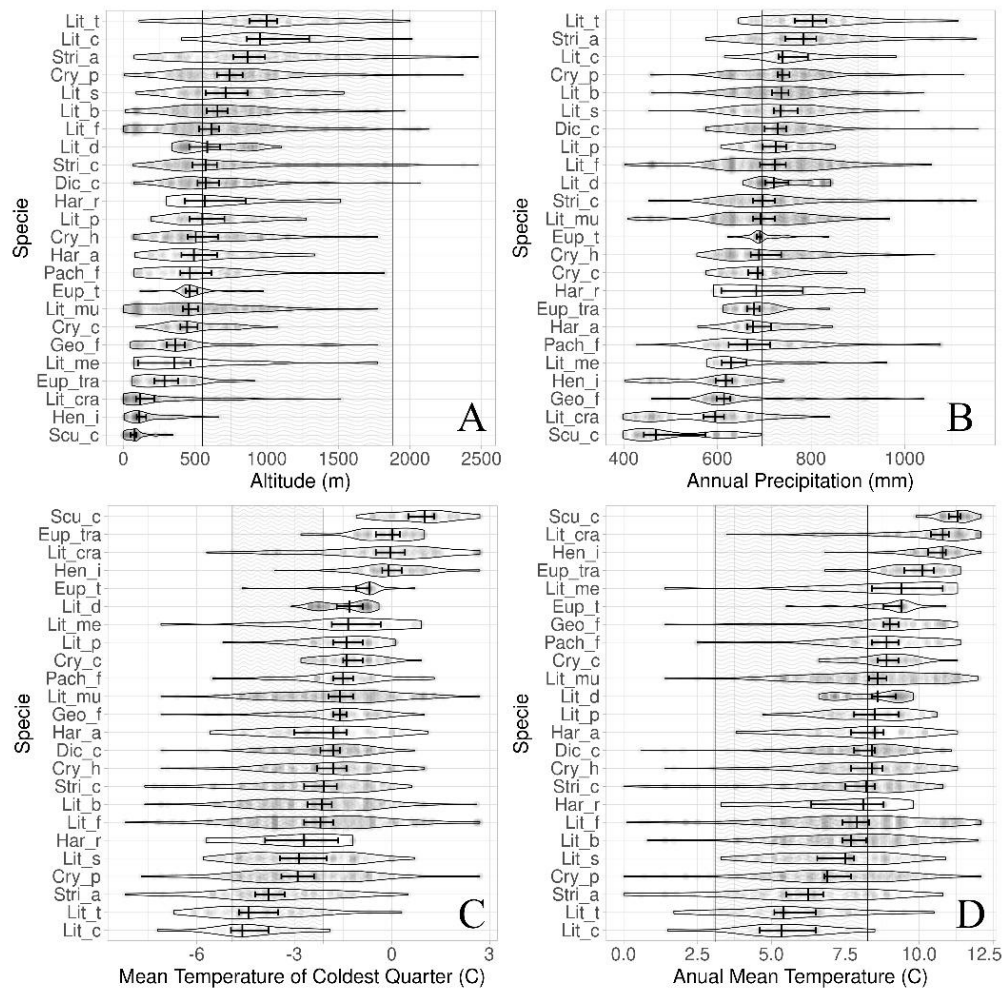


Fig. 1 – Violin plots for the elevational distribution (A), annual precipitation distribution (B), mean temperature of coldest quarter distribution (C), and the annual mean temperature distribution (D), over which species presence points were recorded.

*Abbreviations:* Cry\_c = *Cryptops croaticus*; Cry\_h = *C. hortensis*; Cry\_p = *C. parisi*; Dic\_c = *Dicellogophilus carniolensis*; Eup\_t = *Eupolybothrus tridentinus*; Eup\_tra = *E. transsylvanicus*; Geo\_f = *Geophilus flavus*; Har\_a = *Harpolithobius anodus*; Har\_r = *H. radui*; Hen\_i = *Henia illyrica*; Lit\_b = *Lithobius burzenlandicus*; Lit\_c = *L. cyrtopus*; Lit\_cra = *L. crassipes*; Lit\_d = *L. decapolitus*; Lit\_f = *L. forficatus*; Lit\_me = *L. melanops*; Lit\_mu = *L. muticus*; Lit\_p = *L. pustulatus*; Lit\_s = *L. schuleri*; Lit\_t = *L. tenebrosus*; Pach\_f = *Pachymerium ferrugineum*; Scu\_c = *Scutigera coleoptrata*; Stri\_a = *Strigamia acuminata*; Stri\_c = *S. crassipes*.

## DISCUSSIONS

From the literature review, most of the information about chilopod species in BVNP was from caves or cave entrances. Thus, the species *Cryptops parisi* and *Eupolybothrus tridentinus* (Matic & Negrea, 1966; Negrea, 1994) were collected from the Green Lake cave, located in the western wall of Mount Stogsoare. Other papers (Matic *et al.*, 1962; Matic, 1968) mentioned species collected from the Bat Cave (St. Grigore Decapolitul), namely *Dicellogophilus carniolensis*, *Lithobius burzenlandicus* and the endemic *Lithobius decapolitus*.

Extending the reference area to the northern half of Vâlcea County, where the Park is located, extrapolations were made regarding the probable presence of other eight species of centipedes. Thus, in the first volume of the chilopod fauna (Matic, 1966), among the lithobiomorphs, the species *Harpolithobius radui* and *Lithobius muticus* are mentioned as present in the Călimănești area, the latter being also identified in Olănești. Also, from Călimănești are mentioned two geophilomorphs (*Henia illyrica* and *Geophilus flavus*). In the area of Govora balneoclimateric resort, another geophilomorph species (*Pachymerium ferrugineum*) was collected, while close to Călimănești locality, but on the left shore of Olt river, more precisely on Cozia slope were collected the species *Cryptops croaticus*, *Cryptops parisi* and *Cryptops hortensis* (Matic, 1972). Our field studies confirmed that four of all these species also reside inside of BVNP protected area.

The 16 species found in BVNP and 26 species in Vâlcea County represents 15%, and 25% respectively from the total known number of centipedes in Romania. The threefold increase of species richness in BVNP was expected, as only areas around caves were previously inspected and the protected area holds many habitat types that can offer a wide array of ecological diverse niches for centipedes.

From the species that are mentioned in the Carpathian list of endangered species (Kukuła *et al.*, 2003), *Dicellogophilus carniolensis* is well represented in Romania (Ion, 2016). More important for the conservation strategies of BVNP are the endemic species. *Lithobius decapolitus* is a troglobiont species, endemic to the Southern Carpathians, in an area bounded by the rivers Olt and Cerna rivers. Its presence is recorded in 12 caves (Negrea, 2006), often in large populations, and the cave after which it was named, St. Grigore Decapolitul, is at the eastern limit of the distribution. *Harpolithobius triacanthos* was mentioned in the literature from

Pălteniș (Sibiu County, Romania) (Matic, 1966), so the collection point from BVNP is the second record for the species in the same mountain group. The other two presence points in the country are of uncertain identity (Ilie, 2003; Negrea, 2006).

Concerning habitat quality evaluation, centipedes were proposed as useful bioindicators due to them being common in many habitats and having limited dispersal capabilities (Tuf & Tufová, 2008). A high presence of relict and adaptable species, like in the case of our study in BVNP, suggests a good state of the habitats and protection level. Disturbance factors that affect the centipedes are those that lead to the modification of the specific microhabitat (soil, litter, wood material in various stages of decomposition) or the change of the hydrological regime of the area. Thus, deforestation, change in tree composition, removal of fallen trees, drainage or water abstraction can be seen as potential threats to chilopod species of interest to the park. Management measures must aim at limiting such legal or illegal activities, monitoring the effects and stimulating the natural regeneration of the affected areas.

Our results indicated that species tolerance range for the ecological factors taken into consideration in this study could be a useful indicator of potential distribution into a known area, based on the range of these factors in said area. Hence, from the eight species established from literature as being present near BVNP (northern part of Vâlcea County), all four that were later collected and identified from BVNP (*Harpolithobius radui*, *Lithobius muticus*, *Cryptops parisi*, and *C. hortensis*) have their 95% median confidence interval overlapping the distributions of the same variables within BVNP for at least two variables. Using the same indications, three more species from Vâlcea County could be residing in BVNP, *Strigamia acuminata*, *Lithobius pustulatus* and *Pachymerium ferrugineum* (the distance from BVNP to the closest outside distribution point, from the geodatabase we populated, being between 8–18 km). Most of the Vâlcea species that were not identified also in BVNP, fall well outside the range of factors present in the park (see Fig. 1, *Scutigera coleoptrata*, *Henia illyrica*, *Lithobius crassipes*). An interesting distribution can be observed for the species *Lithobius decapolitus*. While the violin plots for most species are unimodal, *Lithobius decapolitus* showed a bimodal plot for elevation and bioclimatic elements. But *L. decapolitus* is a troglobiont species and Negrea (2006) suspected that it can migrate through deep rock clefts, hence is less influenced by ecological elements from the surface. Moreover, we did not have ecological data from caves, and instead, for distribution points in the geodatabase, we selected cave entrances coordinates. All these might explain the bimodal plots obtained for this species.

Prior research has proven that some centipede species manifest thermal tolerance over a wide range of temperatures, but also using microhabitat and behavioural thermoregulation. However, according to Cox *et al.* (2020), they are also sensitive to extreme temperatures, like the bark centipede, *Scolopocryptops sexspinosus*. The lethal lower measured temperature for wood centipede (*Lithobius forficatus*) was around  $-6^{\circ}\text{C}$ . Therefore, insulated microhabitat use is essential for

this species to survive (Tursman *et al.*, 1994). Similarly, our results regarding mean annual temperatures (Fig. 1 D) evidences a rather wide preferences range (with median values from 5 to 11°C) for different species. Also, the calculated 95% CI of the median for the mean temperature of the coldest quarter for all species distribution do not fall under -5°C. The outliers can be assimilated with variations explained by microhabitat use. Changes in the air temperature and precipitations (also, indirect in soil humidity) might start to threaten some species as reported by Lazorič & Kula (2015) in mountain forest from the Czech Republic, for species *Lithobius crassipes* and *L. tenebrosus*.

### CONCLUSIONS

In brief, based on our study the checklist for BVNP consists of 16 centipede species, while for Vâlcea County is of 27 centipede species.

For the Buila-Vânturarița protected area, the following 11 species are for the first time reported: *Strigamia crassipes*, *Harpolithobius anodus*, *H. radui*, *H. triacanthos*, *Lithobius cyrtopus*, *L. forficatus*, *L. mutabilis*, *L. muticus*, *L. schuleri*, *L. tenebrosus* and *Cryptops hortensis*.

Our findings prove that more systematic surveys could increase the species lists in many areas (some of them being protected) with high potential but surprisingly understudied.

We found BVNP to be a protected area with complex biodiversity in quasi-natural conditions, with a generally good state of the habitats – able to sustain the presence of a high percentage of relict and adaptable centipede species.

Species distribution range for elevation and other ecological factors illustrates that some of them, like extremely cold temperatures, could probably prevent nearby species to colonize BVNP. In future surveys, it could be interesting to monitor if, under climate change, the alpha biodiversity will be modified.

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