



# A regional analysis on the amphibian and reptile communities from the Carpathian Mountains and the abiotic factors that shape their distributions and community assemblages

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## Abstract

Understanding how climate and land cover currently shape species distributions and community structure is crucial to inform conservation decisions. Unfortunately, limited information is available for the relative importance of climatic and land use variables in determining the distribution of amphibians and reptiles. Here, we studied amphibian and reptile communities from the Carpathian Mountains, asking (i) to what extent is the distribution of reptiles and amphibians determined by environmental gradients, (ii) does the response to these factors differ between amphibians and reptiles, and (iii) are reptile and amphibian communities at higher altitudes more similar to each other than communities from lower altitudes. We found that forests, pastures, and heterogeneous arable land best explain the composition of the herpetofauna, with mountain communities associated with coniferous forests, and lowland species with mixed or broad-leaved forests and pastures. Our results also suggest that reptiles and amphibians respond idiosyncratically to the influence of climate and land use. Reptiles responded more to land use and less to climate variables compared with amphibians. Of the three amphibian hybrids registered, one (*Bombina*) was associated with heterogeneous arable land. These results have potential implications for future conservation planning, especially in the light of global climate change and changes in land use. Hence, local and regional processes are important in shaping amphibian and reptile communities.

**Keywords** Conservation · Ecological niches · Species distributions · Ordination

## Introduction

Species distribution patterns are determined primarily by abiotic conditions at larger scales and are regulated by biotic interactions at landscape and local scales (Whittaker et al. 2001).

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Gheorghe Romanescu is deceased.

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The distribution of ectothermic organisms such as reptiles and amphibians is largely determined by abiotic conditions (such as climate; Araújo et al. 2006), while biotic interactions are typically considered of secondary importance, although recent evidence suggests otherwise (Anderson 2017; Gherghel et al. 2018; Godsoe et al. 2017). Generally, amphibian and reptile communities differ in their susceptibility to biotic and abiotic environmental factors. Although both taxonomic groups respond primarily to abiotic determinants, reptiles appear to be more strongly influenced by biotic interactions (Cunningham et al. 2015; Gherghel et al. 2018). The structure of amphibian and reptile communities and species richness generally varies along elevation gradients. Most frequently, species richness exhibits a linear decline with increase in elevation, although both mid-elevation peaks and linear increases with elevation have been previously reported (e.g., Chettri et al. 2010). Reptiles and amphibians are considered the most threatened vertebrate groups (Gibbons et al. 2000; Whittaker et al. 2001) and hence, the importance of understanding the factors that shape these assemblages is imperative. Changes in these environmental

factors can lead to a decline in the viability of these species. Diseases, such as chytridiomycosis, have caused regional and mass extinctions of amphibian species (Crawford et al. 2010). In Europe, the presence of predatory fish in ponds that were used by amphibians for reproduction caused changes in species composition and distribution of amphibians at regional scales (Hartel et al. 2007). Habitat loss is the primary cause of reptile decline, and climate change is predicted to drive nearly 20% of lizard species to extinction by the year 2080 (Sinervo et al. 2010). Climate change has already been implicated as a determining factor for widespread decline among snake populations (Reading et al. 2010).

The Carpathian Mountains are considered one of the least disturbed habitats in Europe. These mountainous landscapes are less impacted by anthropogenic activities than the lowland regions of Europe. Furthermore, the Eastern Carpathian Mountains are found at the contact zone between two major European biogeographic regions: Alpine and Continental. The Carpathians are inhabited by both Mediterranean species and species endemic to the Carpathians (Gherghel et al. 2008; Strugariu et al. 2006a, b). The Carpathian region also represents important glacial refugia for many plants (Puscas et al. 2008), mammals (Sommer and Benecke 2005), arthropods (Theissinger et al. 2013), and reptile and amphibian species (e.g., *Rana arvalis* (Babik et al. 2004), *Vipera berus* (Ursenbacher et al. 2006)). Therefore, regional populations exhibit a much higher genetic diversity, and a greater adaptive potential in the face of rapidly shifting selective pressures. These characteristics make the region a natural laboratory for studying reptile and amphibian communities and distribution. Despite what the Carpathians offer, little research has been conducted on the factors shaping their reptile and amphibian communities. The many accounts that do exist occurred in the Eastern Carpathian region (Covaciu-Marcov et al. 2008; Gherghel and Ile 2006; Gherghel et al. 2008; Gherghel et al. 2009; Strugariu et al. 2006a, b), making such analyses possible. Data on variation in community composition from less impacted areas could improve our collective knowledge of reptile and amphibian distribution patterns and relationships with their environment in a European context.

Here we investigate distribution patterns of reptile and amphibian communities from the Eastern Carpathian Mountains and test the following hypotheses: (i) reptile and amphibian distributional patterns are determined along climatic, altitudinal, and land use gradients; (ii) reptiles and amphibians respond differently to these factors; and (iii) reptile and amphibian communities from higher elevations are ecologically more similar than communities inhabiting lower elevations. Finally, because the study area is known to be inhabited by two types of amphibian hybrids (between *Bombina bombina* × *Bombina variegata*, and between *Lissotriton vulgaris* × *Lissotriton montandoni*), we also evaluated whether the presence of hybrids is mediated by the environment.

## Materials and methods

### Study area

The study area is located in the Eastern Carpathian Mountains (Romania), with a surface area greater than 7200 km<sup>2</sup>. Elevations in the study area vary from 140 m ASL in the Siret River meadow to 2100 m ASL in the Călimani Mountains. The landscape is highly heterogeneous, with mountains and valleys as the dominant relief, interspersed with plains, and anthropogenically modified landscapes (such as urban areas, arable land, and manmade lakes). The climate and hydrological regime is strongly influenced by the numerous manmade lakes (such as the Izvorul Muntelui Reservoir) (Cojoc et al. 2015; Gaman and Apostol 2013; Romanescu and Stoleriu 2013; Romanescu et al. 2012). The climatic effects of these lakes have facilitated the presence and migration of some herpetofaunal elements typical of Mediterranean climate into the study area (Gherghel et al. 2009). Finally, the study area comprises the meeting point between two European bioregions: Continental and Alpine; the Continental biogeographical region is among the largest of such regions in Europe, second in size to the Boreal region, and is characterized by continental climates, grasslands, predominantly deciduous forests, and high biodiversity (but low levels of endemism). The Alpine biogeographical region comprises the mountain ranges from the Mediterranean to Siberia and is generally characterized by lower biodiversity and high endemism (European Environment Agency 2002).

### Field study methods and data acquisition

Field collections took place between 2001 and 2007, generally between February and October (Gherghel et al. 2008). Field surveys were primarily based on randomly selected transects of various lengths, covering all types of habitats. Most transects were only visited once. Both diurnal and nocturnal surveys were conducted. In most cases, live animals were directly observed (i.e., without capture) but animals killed by local or vehicular traffic were also accounted for. After completion of the fieldwork, all records (presences) were registered into a geographical informational system (GIS) database. The detailed distribution maps of each species were produced at 5 × 5 km quadrates (see Gherghel et al. (2008) for details). In total, 1004 observations were made from 151 geographic localities. No subsequent efforts have been made to continue mapping the herpetofauna of the region. For the purpose of the current study, we used presence/absence data recorded from Gherghel et al. (2008), at a spatial resolution of 2.5 × 2.5 km, resulting in 212 sampling quadrates. Field investigations revealed the presence of 14 amphibian species and 10 reptile species, as well as three amphibian hybrids (*Lissotriton vulgaris* × *Lissotriton montandoni*, *Bombina bombina* ×

*Bombina variegata*, and the klepton *Pelophylax kl. esculentus*) (Gherghel et al. 2008) (Table 1). Many of these species are of special conservation interest at an international level. For instance, *Lissotriton montandoni* is an Eastern Carpathian endemic and, together with *Triturus cristatus*, *Bombina bombina*, *Bombina variegata*, and *Emys orbicularis*, is legally considered a species of community interest that requires the designation of special conservation areas (Annex II of the E.U. Habitat Directive). Many of the remaining species are also considered species of community interest that requires strict protection (Annex IV of the E.U. Habitat Directive: *Hyla arborea*, *Rana dalmatina*, *Bufo viridis*, *Pelobates fuscus*, *Podarcis muralis*, *Lacerta agilis*, *Lacerta viridis*, *Coronella austriaca*, and *Zamenis longissimus*). Furthermore, although not internationally protected, *Vipera berus* is considered nationally endangered in the Romanian Red Data Book of Vertebrates (Iftime 2005).

## Environmental data

The environmental data used in the current analysis is comprised of three components: climate, land cover, and elevation (Table 1). The baseline (current) climatic data used for running the models had a spatial resolution of 30 arc seconds

(approximately 1 km) and was retrieved from the WorldClim database ([www.worldclim.org](http://www.worldclim.org)). The WorldClim dataset is comprised of 19 bioclimatic variables (see Hijmans et al. (2005) for more details) (Table 2) thought to compute models superior to those generated from monthly temperature and precipitation variables. The Corine Land Cover 2000 database, retrieved from the webpage of the European Environmental Agency ([www.eea.europa.eu](http://www.eea.europa.eu)), was used for land cover data. The dataset is divided into three levels of organization, from very broad (level 1) to very narrow (level 3) land cover classifications. In the present study, we used level 2 except for forests, where we used level 3 classification (broadleaf, coniferous, and mixed forests) (Table 2). The third component of our analysis was altitude, which in our case was represented by the European Digital Elevation Model Version 1, downloaded from the European Environmental Agency ([www.eea.europa.eu](http://www.eea.europa.eu)). In order to minimize the spatial error in the study area, all data was projected to the Romanian national grid system (Stereo 70, Dealul Piscului 1970). The datasets were analyzed in Global Mapper 11 and ArcGIS 10, and resampled to  $2.5 \times 2.5$  km using the nearest neighbor technique that is recommended for large-scale environmental data (see Franklin 2009). Once the species and environmental data had the same spatial resolution, we used the Spatial Join option from ArcGIS 10, and based on spatial

**Table 1** The list of reptile and amphibian species identified in the Eastern Carpathian Mountains

Species	Species abbreviation	Common name	No $2.5 \times 2.5$ km <sup>2</sup>	% of total
<i>Salamandra salamandra</i>	Ss	Fire salamander	101	47.64
<i>Triturus cristatus</i>	Tc	Northern crested newt	132	62.26
<i>Lissotriton vulgaris</i>	Lv	Smooth newt	129	60.85
<i>Lissotriton montandoni</i>	Lm	Montandon's newt	117	55.19
<i>Mesotriton alpestris</i>	Ma	Alpine Newt	129	60.85
<i>Bombina bombina</i>	Bb	Fire-bellied toad	22	10.38
<i>Bombina variegata</i>	Bv	Yellow-bellied toad	192	90.57
<i>Hyla arborea</i>	Ha	Common tree frog	98	46.23
<i>Rana dalmatina</i>	Rd	Agile frog	29	13.68
<i>Rana temporaria</i>	Rt	Common frog	151	71.23
<i>Pelophylax ridibundus</i>	Pr	Marsh frog	126	59.43
<i>Bufo bufo</i>	Bub	Common toad	97	45.75
<i>Bufo viridis</i>	Buv	Green toad	108	50.94
<i>Pelobates fuscus</i>	none	Common spadefoot	8	3.77
<i>Anguis colchica</i>	Ac	Slow worm	66	31.13
<i>Podarcis muralis</i>	Pm	Common wall lizard	9	4.25
<i>Lacerta agilis</i>	La	Sand lizard	148	69.81
<i>Lacerta viridis</i>	none	(Eastern) Green lizard	13	6.13
<i>Zootoca vivipara</i>	Zv	Viviparous lizard	95	44.81
<i>Emys orbicularis</i>	none	European pond terrapin	16	7.55
<i>Coronella austriaca</i>	Ca	Smooth snake	26	12.26
<i>Zamenis longissimus</i>	none	Aesculapian snake	4	1.89
<i>Natrix natrix</i>	Nn	Grass snake	120	56.60
<i>Vipera berus</i>	Vb	Adder	64	30.19

**Table 2** Source, code, and description of the environmental data used in the analysis

Main source and type	Code	Description
WorldClim (climate)	BIO1	Annual mean temperature
	BIO2	Mean diurnal range (mean of monthly (max temp-min temp))
	BIO3	Isothermality (BIO2/BIO7) (*100)
	BIO4	Temperature seasonality (standard deviation *100)
	BIO5	Max temperature of warmest month
	BIO6	Min temperature of coldest month
	BIO7	Temperature annual range (BIO5-BIO6)
	BIO8	Mean temperature of wettest quarter
	BIO9	Mean temperature of driest quarter
	BIO10	Mean temperature of warmest quarter
	BIO11	Mean temperature of coldest quarter
	BIO12	Annual precipitation
	BIO13	Precipitation of wettest month
	BIO14	Precipitation of driest month
	BIO15	Precipitation seasonality (coefficient of variation)
	BIO16	Precipitation of wettest quarter
	BIO17	Precipitation of driest quarter
	BIO18	Precipitation of warmest quarter
	BIO19	Precipitation of coldest quarter
Corine Land Cover 2000 (land cover)	112	Urban fabric
	121	Industrial, commercial, and transport units
	211	Arable land
	222	Permanent crops
	231	Pastures
	242	Heterogeneous arable land
	243	
	311	Broad-leaved forest
	312	Coniferous forest
	313	Mixed forest
	321	Scrub and/or herbaceous vegetation associations
	324	
411	Wetlands	
511	Inland waters	
512		
Digital elevation model	ASL	Altitude (m) above sea level (Baltic Sea)

location, we extracted the environmental value that corresponded to each observation.

### Data analysis

Because simply selecting all variables does not necessarily produce the best possible model, we pared down our variables

by testing for multicollinearity. Pearson correlation indicated a high degree of inter-correlation ( $R > 0.9$ ) between most variables. Therefore, we only utilized the two variables that were the least correlated, weighing additional variables using a stepwise approach during model creation (Table 3).

The amphibian and reptile communities were related to the environment and distribution patterns using detrended correspondence analysis (DCA) and canonical correspondence analysis (CCA). Both methods are eigenvector ordination techniques for studying multivariate gradient analysis. The main difference between the two is that DCA is an indirect ordination technique, while CCA is a direct ordination method. Using CCA is advantageous because it combines the correspondence analysis with multivariate regression, resulting in a special type of multivariate regression (Palmer 1993). During model creation, we chose to down weight the rare species that tend to obscure community patterns due to the large number of undetected occurrences in the dataset (ter Braak and Smilauer 1998; Zimmer et al. 2000). In addition to the DCA, we also added the variables used in the CCA as supplementary variables (Table 2). Finally, in order to test if amphibians and reptiles respond differently to the environment, we used the variance partitioning method (e.g., Borcard et al. 1992) to see how much of the variation is explained by the climate (climate and altitude; using land cover as covariate) land cover (using the climate and altitude as covariate), or jointly explained (climate + altitude + land cover). The statistical significance of the CCA and variance partitioning analysis was completed using Monte Carlo Permutation Test, using 999 replicates. We also used the first two axes of the CCA analysis to explore the species richness biodiversity plots in relation to the ordination space. All analyses were conducted using CANOCO 5.03.

## Results

### Species dominance and richness

The most dominant species in the Eastern Carpathian Mountains were *Bombina variegata* (present in 90.57% of the sampling squares), followed by *Rana temporaria* (71.23%) and *Lacerta agilis* (69.87%) (Table 1). The rarer species from the region are *Zamenis longissimus*, *Pelobates fuscus*, *Podarcis muralis*, *Lacerta viridis*, and *Emys orbicularis*, all reported from less than 10% of the sampling squares (Table 1). Both types of hybrids (*Bombina bombina* × *Bombina variegata* and *Lissotriton vulgaris* × *Lissotriton montandoni*) are uncommon in the area, having been identified in less than 10% of the surveyed grids.

The highest species richness was associated with pastures, broadleaf forests, and their ecotones, while arable land had the lowest overall species richness (Fig. 1). While a greater

**Table 3** CCA forward selection results, variable explain variation, and contribution

Name	Explains (%)	Contribution (%)	pseudo- <i>F</i>	<i>P</i> *	<i>P</i> (adj)
BIO6	21.3	54.5	56.7	0.001	0.016
Heterogeneous arable land	2.5	6.4	6.8	0.001	0.016
BIO13	1.9	5	5.5	0.001	0.016
BIO3	1.6	4.1	4.6	0.001	0.016
Coniferous forest	1.5	4	4.4	0.001	0.016
Pastures	1.5	3.7	4.3	0.001	0.016
BIO15	1.4	3.7	4.3	0.001	0.016
Broad-leaved forest	1.2	3.1	3.7	0.001	0.016

\*As *p* values from stepwise regression are not trustful, we present them only for informative purposes

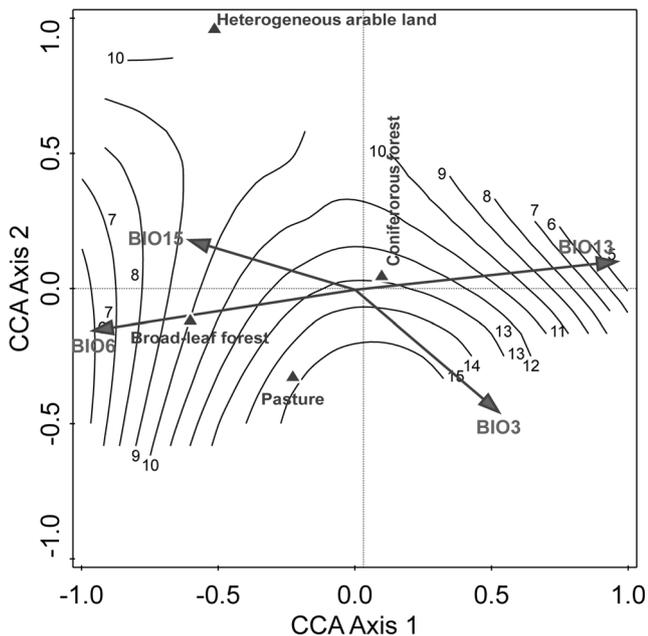
number of species were recorded in the continental biogeographical region (lower elevations) compared with the alpine region (high elevations), the highest species richness was found along the contact zone of the two regions.

**Distribution patterns**

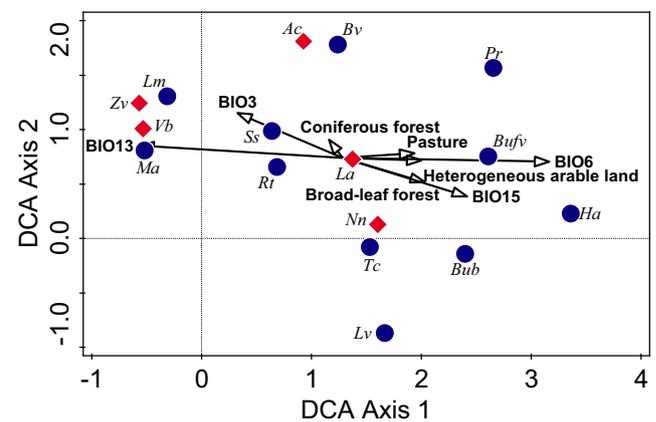
DCA shows that the composition of reptile and amphibian communities follows an altitudinal gradient that underlies other climatic and land cover factors (Fig. 2). The total variation explained by DCA is 1.73, and the supplementary variables used account for 32.9% of the variation. The first two axes explain 38.69% of the variation. The gradient lengths are relatively long on the first axis (2.73) and shorter on the second axis (1.93). Both amphibian and reptile species inhabiting higher elevations (*Lissotriton montandoni*, *Mesotriton*

*montandoni*, *Zootoca vivipara*, and *Vipera berus*) are ecologically similar. We also found that the more common species have wider species response curves than the rare or less common species (Table 1). Mountain species (*Lissotriton montandoni*, *Mesotriton alpestris*, *Zootoca vivipara*, and *Vipera berus*) appear to prefer higher precipitation in the wettest month (BIO13), lower minimum temperatures in the coldest month (BIO6), and coniferous forest. On the other hand, lowland species (*Hyla arborea*, *Bufo viridis*, *Bufo bufo*) tend to prefer higher minimum temperatures in the coldest month (BIO6), lower precipitation in the wettest month (BIO13), and habitats composed of pastures, heterogeneous arable land, and broadleaf forests.

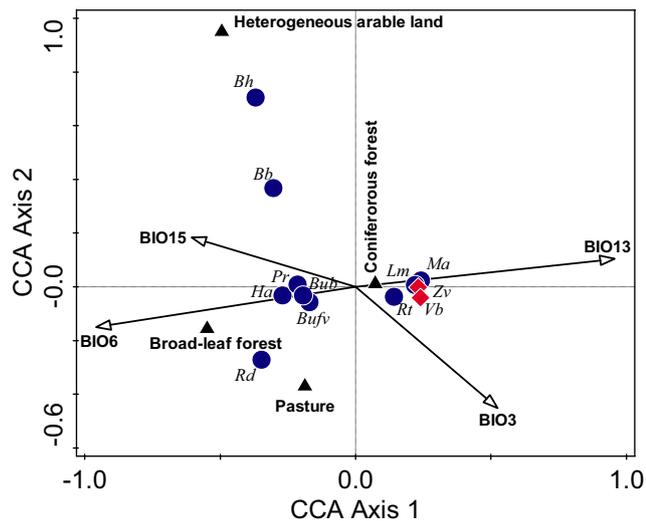
The resulting CCA explained 32.9% of the variation in the dataset and the first two axes explain 26.07% of the variation. The variable that explains the most variation was the minimum temperature in the coldest month (BIO6). This variable alone explained 21.3% of the variation (Table 3). The CCA completed the distribution pattern image given by the DCA and shows similar patterns (Fig. 3). Furthermore, CCA indicated that the presence of *Bombina bombina* × *Bombina variegata* hybrids is explained by heterogeneous arable lands,



**Fig. 1** Species richness along the most significant environmental axes. The isoclines represent species richness in relation to the environmental variables



**Fig. 2** Ordination biplot showing the first two axes of the DCA using supplementary environmental variables. The blue circles correspond to amphibian species and red diamonds correspond to reptile species. Species abbreviation corresponds to the ones described in Table 1



**Fig. 3** Ordination biplot showing the first two axes of the CCA. Blue circles correspond to amphibian species and red diamonds correspond to reptile species. Species abbreviation corresponds to the ones described in Table 1

lower general temperatures (BIO3), and the presence of *Bombina bombina* (which is less common than *Bombina variegata* (Table 2)).

### Variation partitioning on the whole dataset

Both climate and elevation (Monte Carlo test, pseudo- $F$  ratio = 3.3,  $p < 0.001$ ) and land cover (Monte Carlo test, pseudo- $F$  ratio = 3.2,  $p < 0.001$ ) were able to explain amphibian and reptile composition after accounting for the variation partitioning. Moreover, climate and elevation alone was able to explain 44% of the unique variation in the dataset while land cover alone was able to explain 35.6%. The combined effect of climate, elevation, and land cover explained 20.4% of the variation.

### Variation partitioning for amphibians and reptiles separately

For amphibians, the computed partial CCAs were found to be better than random, for both climate and elevation (Monte Carlo test, pseudo- $F$  ratio = 3.6,  $p < 0.001$ ), and land cover (Monte Carlo test, pseudo- $F$  ratio = 3.7,  $p < 0.001$ ). For reptiles, the partial CCA was significant for climate and elevation (Monte Carlo test, pseudo- $F$  ratio = 2.5,  $p < 0.001$ ), and for land cover (Monte Carlo test, pseudo- $F$  ratio = 2,  $p = 0.004$ ). The variation partitioning revealed that amphibians and reptiles are driven by different environmental factors. For amphibians, climate alone was able to explain nearly half of the variation, followed by the land cover with 31.1% of the variation (Fig. 4). For reptiles, however, the variation partitioning demonstrates that land cover is able to explain most of the

variation (47.9%), followed by the climate (31.7%), and the remaining 20.4% consists of the shared effects of climate, land cover, and elevation (Fig. 4).

## Discussion

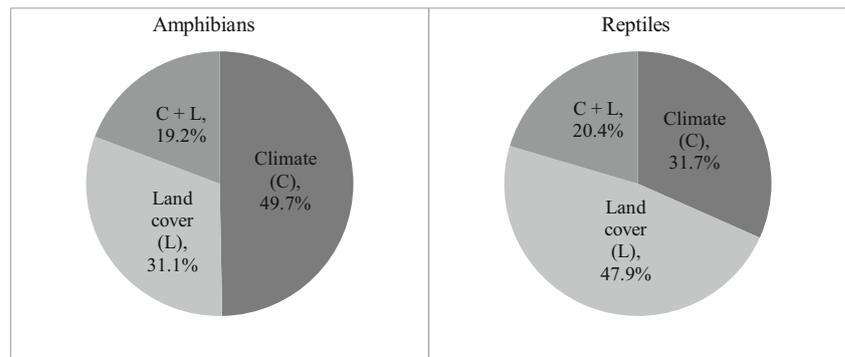
Our data clearly demonstrates a strong relationship between climate/elevation and land cover factors on reptile and amphibian community structure and distribution in the Eastern Carpathian Mountains. We were also able to determine the main members of the reptile and amphibian communities present, and the environmental characteristics that influence them.

### Species dominancy and distribution patterns

Overall, we found higher species richness at the contact zone between the Continental and Alpine bioregions. Along the contact line, an average of 8 to 13 species are present, the number of species decreasing with the distance from the contact zone. From the perspective of elevational distribution patterns, this result indicates a mid-elevation peak in species richness, a pattern that is generally uncharacteristic of amphibians and reptiles (e.g., Chettri et al. 2010). Our results show that typical reptile and amphibian communities from the mountainous region were characterized by *Lissotriton montandoni*, *Mesotriton alpestris*, *Rana temporaria*, *Zootoca vivipara*, and *Vipera berus*, all of which are very cold tolerant species. On the other hand, reptile and amphibian communities from lowland areas were more segregated by their habitat preferences: species like *Pelobates fuscus*, *Hyla arborea*, *Bombina bombina*, *Bufo bufo*, and *Bufo viridis* mostly inhabited areas dominated by agriculture, broad-leaved forests, and warmer temperatures (Figs. 2 and 3). Compared with the montane species, lowland species are more ecologically distant, occupying more diverse and distinct habitat types (Figs. 2 and 3). The probable explanation for this community segregation is the restricted availability of habitat, consequently constraining the ecological diversity of Alpine species. This corroborates the previous findings of studies in the area by (Covaciu-Marcov et al. 2008; Gherghel et al. 2008; Ghiurcă et al. 2009; Ghiurcă et al. 2005; Iftime et al. 2008; Melenciuc et al. 2016; Strugariu 2014; Strugariu et al. 2006ba; Strugariu et al. 2006b).

The distribution of reptiles and amphibians in the Eastern Carpathians was significantly influenced by the climate/elevation and land cover. Since both groups are dependent on their environmental physiological limits to temperature, we found a gradient in species distribution along a temperature/elevation gradient. Climatic factors account for 26.2% of the explained variation. Similar climatic influences on reptile and amphibian communities have been reported by other regional studies, where herpetofaunal communities are

**Fig. 4** Variation partitioning results between two groups of variables (climate/elevation (C), and land cover (L)) for amphibians (left) and reptiles (right)



also distributed along thermal gradients (Sasaki et al. 2005). Moreover, in recent years, climatic conditions have proven to be effective predictors for amphibian and reptile species distributions (Sahlean et al. 2014). Although most studies that attempt to estimate species distributions are at coarse resolutions (e.g., Rodríguez et al. 2005; Sasaki et al. 2005), our study infers that similar patterns can be observed at local or regional scales. Therefore, we can conclude that climatic factors regulate the distribution of amphibian and reptile species and community composition at all levels: landscape, regional, and range scale.

Our results show that land cover was another important factor affecting amphibian and reptile species distributions, acting as a primary determinant of suitable habitat for each species. Indeed, in communities of other organisms, spanning from arthropods to endotherms (mammals), land cover was found to explain more of the variation than climate (Barbaro et al. 2007; Beck and Vun Khen 2007; Davis et al. 2007). In our study, land cover only accounted for 4% of the explained variation.

Our analyses did not reveal relationships between wetlands and the presence of amphibians or aquatic reptile species (e.g., *Emys orbicularis*). However, this result does not exclude the fine-scale ecological relationships between certain amphibian and reptile species and key microhabitat structures. For example, small features such as temporary ponds (often resulting from anthropogenic activity) are key habitats for nearly all amphibians from our study region while stone walls on Southern slopes are essential habitats for certain reptiles (e.g., *Podarcis muralis* (Gherghel et al. 2009)). These fine-scale microhabitat structures were not captured by our data. However, we do offer insights into the coarse, regional habitat types that determine species distributions, and community compositions of amphibians and reptiles. As such, our study is limited by the resolution (i.e., landscape scale vs. microscale) of the land cover database, which can frequently omit differences between certain natural habitats (Divišek et al. 2014). Our analysis found that forests, pastures, and heterogeneous arable land are the best explanations for the composition

of reptiles and amphibians in the Eastern Carpathian Mountains. As expected, the mountain reptile and amphibian communities were associated with coniferous forests, while the lowland species were associated with mixed or broadleaf forests and pastures. The presence of hybrids between *Bombina bombina* × *Bombina variegata* was associated with the presence of heterogeneous arable land and the presence of the least abundant parental species, *B. bombina*. The presence of hybrids between *Lissotriton vulgaris* × *Lissotriton montandoni* was linked to coniferous forests. According to our observations in the area and previously published papers (Gherghel et al. 2012; Gherghel et al. 2008), the morphologically identifiable hybrids occur in areas associated with deforestation events. However, because deforestations are highly dynamic and usually affect local areas of a forest, our model cannot detail the effects of deforestations with the current study design.

In recent years, traditionally managed rural landscapes with moderate anthropogenic impact have been characterized by a generally high value for biodiversity, particularly for amphibians and reptiles (Dorresteijn et al. 2013; Hartel et al. 2013; Hartel et al. 2014; Hartel and von Wehrden 2013; van Halder et al. 2007). Traditional farming practices, characterized by low intensity, low levels of infrastructure development, and high seasonality, produced the majority of optimal quality breeding habitats for amphibians in a well-surveyed central Romanian region (Hartel et al. 2014; Hartel and von Wehrden 2013). In the Eastern Carpathian Mountains, these habitats are typically characterized by localities with low human densities and dominated by pasture or wooded pasture. Moreover, in these traditionally managed habitats, several amphibian species (such as *Bombina variegata*, *Mesotriton alpestris*, or *Lissotriton montandoni*) usually use the flooded pastures or small ponds formed in or near dirt roads for reproduction, resulting in high local densities (Gherghel and Ile 2006; Hartel et al. 2013). Unfortunately, these habitats are difficult to quantify in regional studies, but their importance for species distributions and conservation should not be neglected.

## Differences in variable responses in amphibians vs. reptiles

By analyzing the effects of climate and land cover on reptile and amphibian communities from the Eastern Carpathian Mountains, we found strong, statistically significant associations between each taxonomic group and the environmental parameters. Specifically, we found that climatic factors influence amphibian distributions and communities to a greater extent than reptiles. Reptile distributions, on the other hand, were primarily influenced by land cover. Similar differences between the distribution patterns of amphibians and reptiles were previously described for herpetofaunal communities in Japan (Sasaki et al. 2005) that do not share any of the species reported in our study. This suggests that, at similar scales, the same set of variables are responsible for shaping the distribution patterns of these two taxonomic groups, regardless of geographical location and the exact composition of species. This finding conforms to known thermoregulatory differences between the two groups, as amphibians are thermoconformers and more moisture sensitive than reptiles, while reptiles rely more on behavioral thermoregulation (Zug et al. 2001). Further, similar differences are visible on a much broader scale; an analysis of amphibian and reptile species richness patterns in Europe revealed differential responses to environmental variables, showing that amphibians are more strongly influenced by moisture (Rodríguez et al. 2005). One could suggest, in light of global climate change, that amphibians would receive the brunt of the impact induced by a warming climate. Nevertheless, this does not imply that land cover alterations will impact amphibians less than reptiles, as land cover change and habitat loss are major factors influencing the entire community (Gadsden et al. 2012). Certain habitat and microhabitat features allow herpetofaunal communities to potentially maintain population connectivity and shift their range in response to a changing climate. In the absence of such features, the consequences of climate change are likely to be more severe. Moreover, the persistence of traditionally managed landscapes, which constitute valuable conservation areas for reptiles and amphibians, cannot be predicted due to more complex socio-economical mechanisms (e.g., Hartel et al. 2013, 2014).

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