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Contribution to the Batrachofauna of Serbia: Distribution and Diversity of Amphibians in Kosovo and Metohija Province

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Abstract: This study provides the first comprehensive review of the amphibian distribution and diversity patterns in the Kosovo and Metohija Province, Serbia. Unpublished observations were combined with published records and museum data to produce updated and detailed distribution maps of individual species. Our results show that the diversity of amphibians is very high, with 14 species inhabiting the Kosovo and Metohija Province. The most widespread species inhabiting around 40% of Kosovo and Metohija Province are *Salamandra salamandra*, *Bombina variegata* and *Pelophylax esculentus* complex. Rare species are *Bufo bufo*, *Rana graeca, Rana temporaria* and *Triturus macedonicus* (found at 10-20% of studied area), while *Salamandra atra* has extremely limited distribution (less than 5% of studied area). Based on updated distribution maps, we conclude that the distribution of many amphibian species may still be underestimated and further studies are necessary, especially for the Metohija area. Maintaining up-to-date and realistic geographical distribution maps of individual species is crucial for assessing and updating the conservation status of species and populations. Data presented in this study are crucial for the ultimate goal: protection of unique and sensitive amphibian species of the Kosovo and Metohija Province.

Key words: batrachofauna, Anura, Caudata, frogs, newts

Introduction

At the global level, amphibians are one the most endangered groups of vertebrates today, with 32.5% of them being endangered species and 43% of them declining in numbers (Stuart et al. 2004). Trend in amphibian's population decline has accelerated in the last few decades. The leading causes of populations decline are loss and fragmentation of habitats, climate change, infectious diseases like chytridiomycosis, ranavirus disease, saprolegniosis and *Ribeiroia* sp. infection, as well as introduction of invasive species (Daszak et al. 2003, Cushman 2006, Fisher et al. 2009, Gray et al. 2009, Leuenberger et al. 2014). The species with limited distribution are especially vulnerable and endangered (Wake & Vredenburg 2008). Taking into consideration the above-mentioned, it is necessary to take appropriate measures urgently as they should reduce or stop the further decline in amphibian species around the

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world. The first and essential step towards appropriate biodiversity conservation is a precise knowledge of the spatial distribution of all amphibian species at both local and regional levels. Precise distribution maps will help to identify priority areas for their conservation and management (Margules et al. 2002). Regarding this, faunistic studies are becoming very important today as the good knowledge of the taxon distribution is not important only for the protection of biodiversity but it is also essential basis for ecological, evolutionary and systematic research (Jetz et al. 2011).

With 33 autochthonous species of amphibians (9 of them endemic), the Balkan Peninsula has been recognised as one of the hotspots of biodiversity in Europe (Džukić & Kalezić 2004). With 21 autochthonous species, Serbia is one of the Balkan countries with the highest diversity of amphibians in the Balkans after Bulgaria and Greece (Tzankov et al. 2016, Valakos et al. 2008). Serbia is very important for the diversity of amphibians not only in the Balkan Peninsula but for the whole Europe, not just because of (1) the presence of a large number of species, but also because (2) this area is inhabited by some relict species (Džukić et al. 2005), (3) as many as 15 species distribution ranges end here, (4) its the centre of the origin of some species (Sotiropoulos et al. 2007, Ivanović et al. 2012) and cases of paedomorphosis in newts are found (Džukić et al. 2016). The territory of Kosovo and Metohija is inhabited by 14 species of amphibians (Vukov et al. 2013), representing 2/3 of the total number of species in Serbia. This diversity is very high, considering that the region represents only an eighth part of the territory of Serbia.

The number of published studies on the distribution and diversity of amphibians in Kosovo and Metohia is extremely low. The first such study was published in the second half of the 20th century (Pasuljević 1966) and shows the distribution of *Rana temporaria* in the territory of Metohija. The same author two years later (Pasuljević 1968) published the first study of the diversity of the fauna of the amphibians of Kosovo and Metohija, giving a short list of the localities where amphibians were found. In addition, two more papers were published about amphibian fauna (Krizmanić 1997, 1998) but they were focused on really small area of Kosovo and Metohija. Until the emergence of a comprehensive faunistic study of amphibians in Serbia (Vukov et al. 2013), these four studies were the only ones that presented some information about diversity of amphibians in this province of the Republic of Serbia. Although Vukov et al. (2013) have shown in their study the distribution ranges of species of amphibians in Serbia (including Kosovo and Metohija), they have not given information about precise localities or UTM coordinates but only actual and potential contour areas. The only study showing more precise occurrences of some caudate amphibian species at Kosovo and Metohija is that by Džukić et al. (2016).

Despite the fact that in the last several years the dynamics of publishing faunistic data for amphibians from the territory of Kosovo and Metohija has increased, a large number of data is still unpublished or published without discrete geospatial data presented (Vukov et al. 2013), both for anurans and salamanders. Therefore, the main goal of our study is to integrate published and unpublished data and to present amphibian species occurrences at a 10 x 10 km resolution for the territory of Kosovo and Metohija.

Materials and Methods

Study area

Kosovo and Metohija is a province of the Republic of Serbia (Fig. 1) with the area of 10,887 km^2 and range of altitudes between 297 m to 2656 m. It is comprised of two geomorphological and biogeographical entities (Marković 1970) – Kosovo, a plateau of a consistent relative height in eastern part of province, and Metohija – a hilly area surrounded by high mountains at west and south (Bačević et al. 2017). Climate is continental, with cold winters and hot and humid summers. The climate of Metohija is specific, with high precipitation during summers as a consequence of Adriatic Sea proximity and influence of Mediterranean climate. The average annual temperature is 10.3 ^{o}C while average annual rainfall is 686.84 mm (Bačević et al. 2017).

Methods

In order to provide batrachological distribution and diversity patterns of Kosovo and Metohija Province, we combined distributional data from the literature (see Supplementary Materials) with unpublished data from several sources: (1) field trip records of herpetologists, Dr Georg Džukić and Dr Gojko Pasuljević, (2) the Herpetological Collection of the University of Priština, Faculty of Science and Mathematics, and (3) original data of the present authors. The identification of species was done according to the standard herpetological literature (Schneider et al. 1984, Günter et al. 1991, Pagano & Joly 1999, Lode & Pagano 2000, Arnold & Ovenden 2002, Krizmanić 2008) using the newest taxonomy and nomenclature (Speybroeck et al. 2016).

All available records were mapped in the 10 x 10 km UTM (Universal Transverse Mercator) geographic coordinate grid system with separation of new (unpublished), old-confirmed and old-unconfirmed records for each amphibian species. The green frogs distributional data was not presented at the species level but as the *Pelophylax esculentus* complex. Even all new findings of the green frogs in the studied area were classified as *Pelophylax ridibundus* according to their morphology and mating calls (Zaks et al. 2008), many literature finding of green frogs from the studied area were identified as the *Pelophylax esculentus* complex as they coming from the old wet (70% ethanol) collection where morphological identification can be inaccurate (Pagano & Joly 1999). Chorotypes of amphibian species were identified according to the classification of Vigna Taglianti et al. (1999).

Fig. 1. Map of the Republic of Serbia with study area – the Kosovo and Metohija Province (grey).

Results

In total, 628 georeferenced amphibian species occurrences were collected for Kosovo and Metohija Province (Table 1), with 306 records from published literature sources and 322 (51.2%) new unpublished data records.

The lowest number of records (8) was collected for the alpine salamander (*Salamandra atra*), and the highest (114) for the green frog complex (*Pelophylax esculentus* complex). High number of records was collected for the fire salamander (*Salamandra salamandra*) and the yellow-bellied toad (*Bombina variegata*), while low number was collected for the smooth newt (*Lissotriton vulgaris*) and the European tree frog (*Hyla arborea*) (Table 1). The highest number of new unpublished records was collected for the following species: *Bufo bufo*, *Pelophylax esculentus* complex, *Rana graeca* and *Rana temporaria.* The only species with just published data and no new data was the alpine salamander *Salamandra atra* (Table 1).

The most widespread species that inhabit around 40% of Kosovo and Metohija Province are

Table 1. List of amphibian species in the Kosovo and Metohija province with their number of records, UTM squares and chorotype classification.

Species	Total records	Published records	Unpublished records	N of UMTs	Chorotype
Bombina variegata	89	45	44	49	Southern-European
Bufo bufo	54	15	39	26	Eastern-Mediterranean
Bufotes viridis	40	20	20	22	Turano-European
Hyla arborea	23	16	7	14	Turano-European
Ichthyosaura alpestris	28	17	11	15	European
Lissotriton vulgaris	20	12	8	15	European
Pelophylax esculentus complex	114	30	84	49	Eurasian
Rana dalmatina	34	18	16	21	Southern-European
Rana graeca	43	20	23	25	Southern-European
Rana temporaria	30	11	19	13	European
Salamandra atra	8	8	0	4	Southern-European
Salamandra salamandra	99	52	47	50	Southern-European
Triturus macedonicus	46	42	4	25	Southern-European
Total	628	306	322	328	

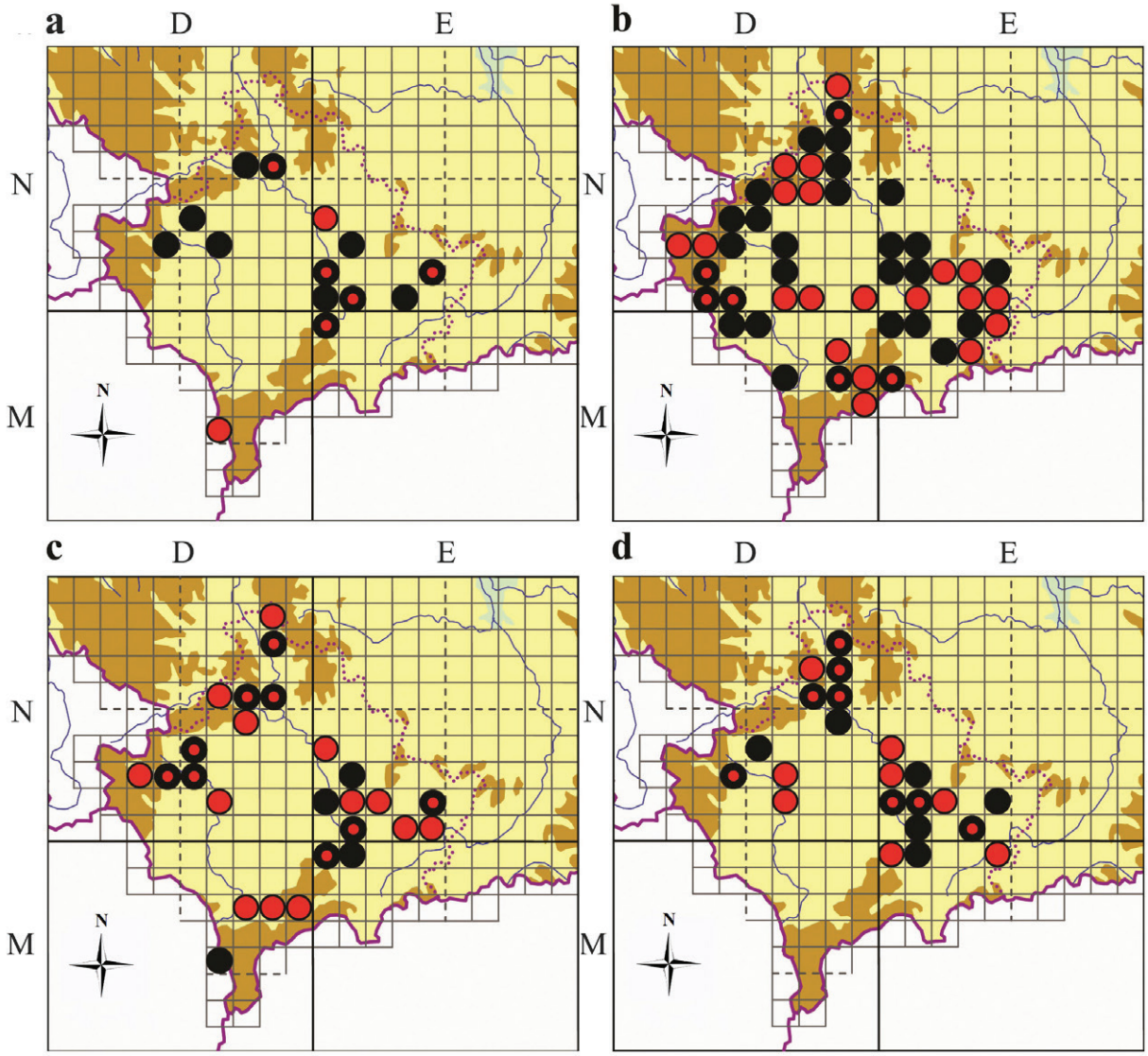

Fig. 2. Distribution maps of *Hyla arborea* (a), *Bombina variegata* (b), *Bufo bufo* (c) and *Bufotes viridis* (d) in the Kosovo and Metohija Province (National grid UTM 10 × 10 km Reference). Red dots = new (unpublished) records, red-black dots = confirmed old literature records, black dots = unconfirmed old literature records.

S. salamandra, *B. variegata* and *P. esculentus* complex. Rare species are *B. bufo*, *R. graeca, R. temporaria* and *T. macedonicus* (found at 10-20% of studied area), while *S. atra* has extremely limited distribution (less than 5% of studied area) (Figs. 2-4). The most of amphibian species were found between 500–1000 m altitude, with exception of *R. temporaria, I. alpestris* and *S. atra*, which were found above 2000 m (Table S1). First two high altitude species have fragmented distribution while *S. atra* has very restricted distribution (Fig. 5). Zoogeographic analysis showed that amphibians of the Kosovo and Metohija Province were classified into five chorotypes (Table 1). The most dominant chorotypes were the southern-European with six species, while the rarest was eastern-European with just one species. According to literature (Szabolcs et al. 2017), *Pelophylax esculentus* complex was classified as distinct chorotype, Eurasian.

Discussion

This paper presents the distribution of amphibians inhabiting the area of the Kosovo and Metohija Province based on combined literature and unpublished data. Taking into account that the surface of the territory of this province is only 10887 km^2, we can say that with 14 species, the diversity of amphibians is very high. For example, the same number of amphibian species inhabits 2.5 times larger area of the Republic of North Macedonia (Uhrin et al. 2016).

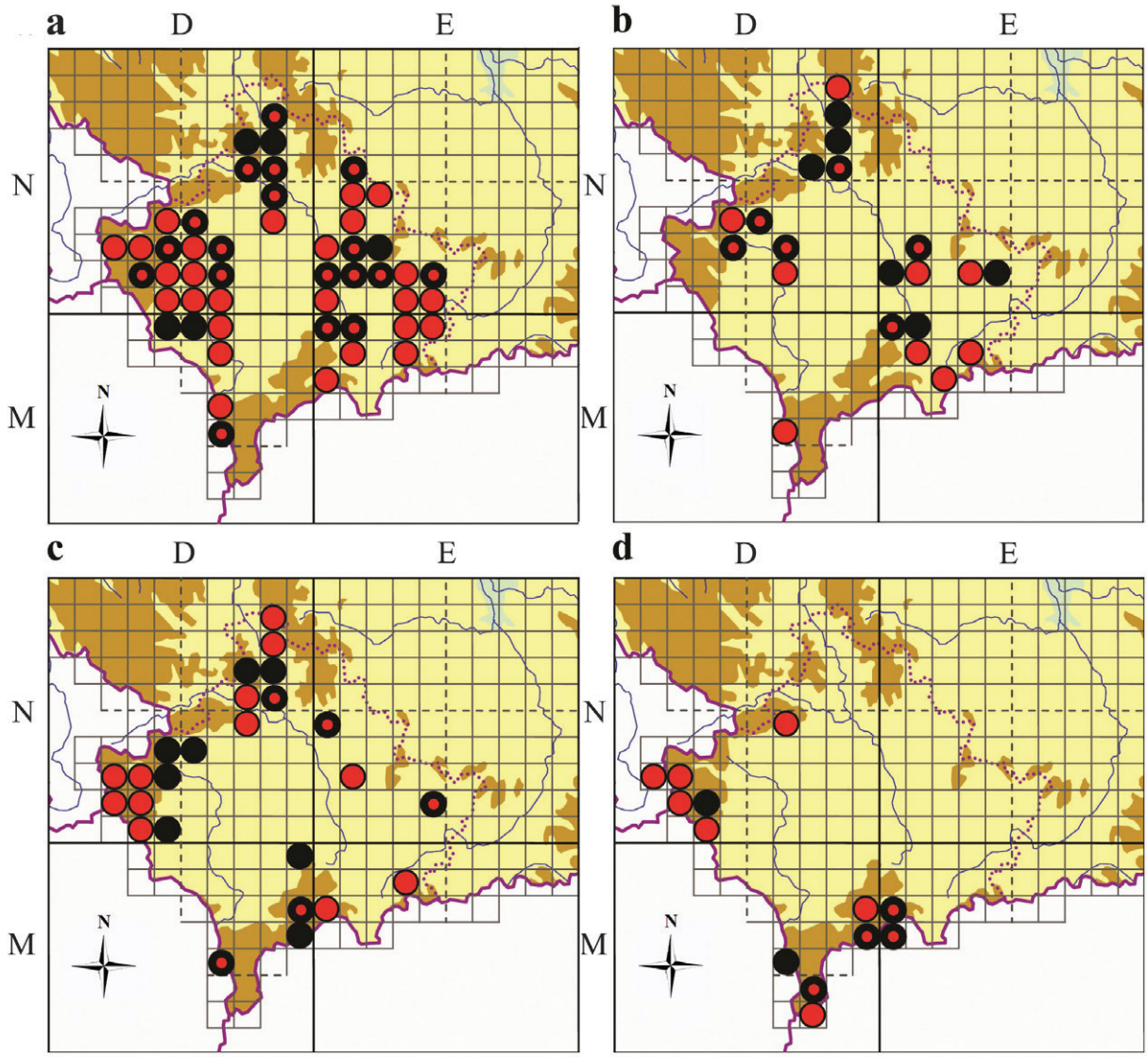

Fig. 3. Distribution maps of *Pelophyllax esculentus* complex (a), *Rana dalmatina* (b), *Rana graeca* (c) and *Rana temporaria* (d) in the Kosovo and Metohija Province (National grid UTM 10 × 10 km Reference). Red dots = new (unpublished) records, red-black dots = confirmed old literature records, black dots = unconfirmed old literature records.

The species richness of the Kosovo and Metohija Province is undoubtedly the result of environmental heterogeneity with favourable abiotic and biotic conditions for amphibians. The environmental heterogeneity is expressed through the wide range of altitudes accompanied by high variation of the land cover, vegetation, soil and climate. Amphibians inhabit a wide variety of habitats, with most species living within terrestrial, fossorial, arboreal or freshwater aquatic ecosystems but they always return to the water to breed. Therefore, knowing that the range of altitudes in Kosovo and Metohia exceeds 2000 m (average altitude is about 800 m), there is a well-developed river network and 83% of the Kosovo and Metohija territory has a humid and extremely humid climate (Bačević et al. 2017), it is clear that the existing amphibian diversity is a direct consequence of orographic and climatic characteristics.

The largest number of recorded data (114) was for the taxon *P. esculentus* complex. Out of the three species in this complex (*P. ridibundus*, *P. lessonae* and *P.* kl. *esculentus*), the presence of *P. ridibundus* has been confirmed by field studies of the present authors. For the pool frog, *P. lessonae*, southern distribution limits are the Sava and Danube rivers, thus the presence of this species is highly unlikely for the Kosovo and Metohija region. The presence of edible frog (*P.* kl. *esculentus*) has been confirmed by allozyme markers in the close vicinity of Kosovo and Metohija (Krizmanić & Ivanović 2010) but further studies are necessary to confirm existence of this species in Kosovo

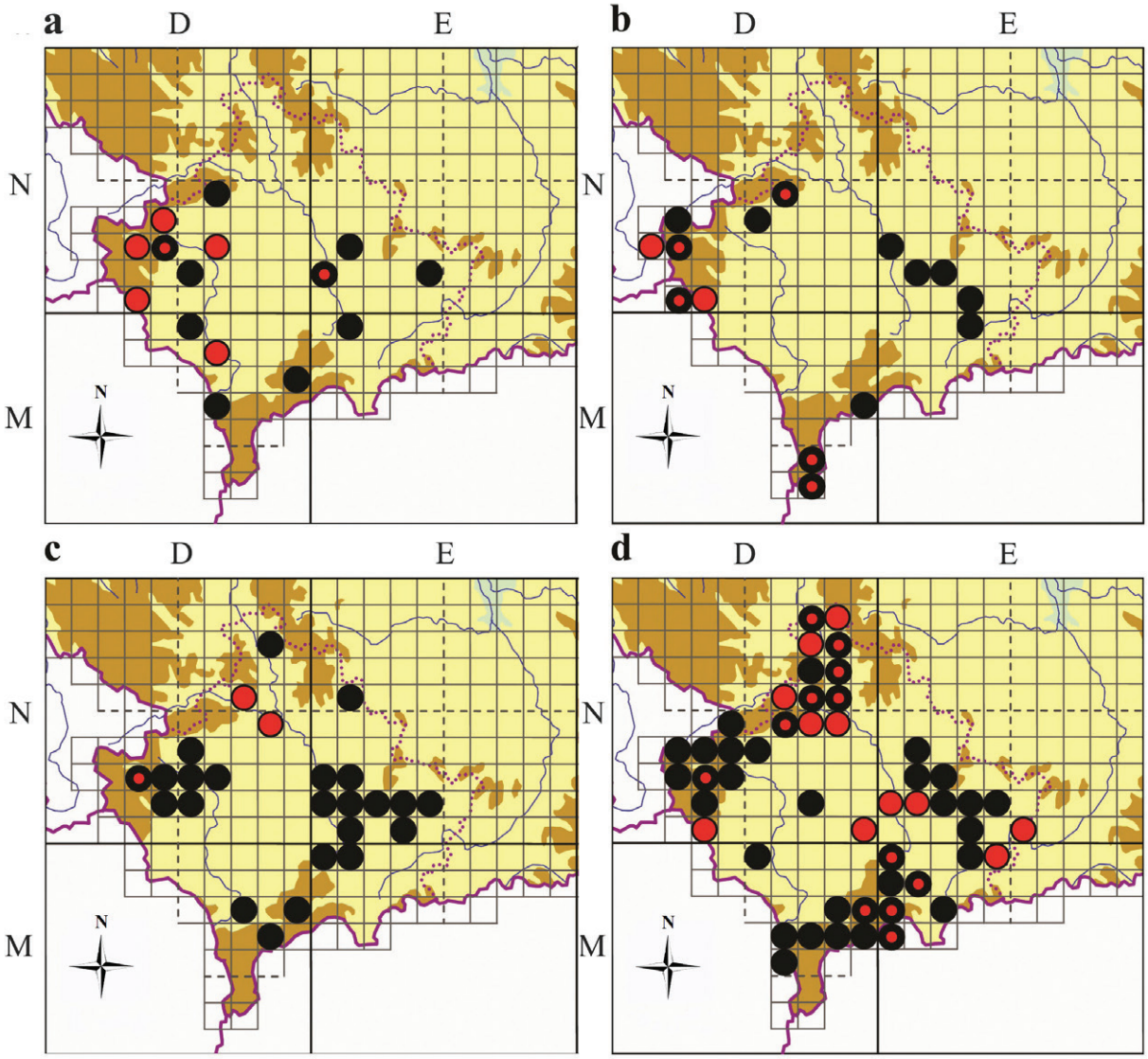

Fig. 4. Distribution maps of *Lissotriton vulgaris* (a), *Ichthyosaura alpestris* (b), *Triturus macedonicus* (c) and *Salamandra salamandra* (d) in the Kosovo and Metohija Province (National grid UTM 10 × 10 km Reference). Red dots = new (unpublished) records, red-black dots = confirmed old literature records, black dots = unconfirmed old literature records.

and Metohija region. Though the low probability of presence of populations of *P. lessonae* in this region, the hybrid species *P.* kl. *esculentus* can be present without its parental species (*P. ridibundus* and *P. lessonae*) in so-called all-hybrid populations (Dubey et al. 2019). A large number of findings of green frogs are not surprising due to several causes. Green frogs inhabit aquatic habitats throughout the year, daily active and easily identified on the basis of their advertisement calls (Arnold & Ovenden 2002). In addition, they are well adaptable to various freshwater habitats and survive even in contaminated waters (Bucci et al. 2000). Due to rapid development, they are also well adapted to breed in temporary ponds. The negative effect of the fish presence in their habitats is almost negligible in comparison to other amphibian species, and they disperse easily by crossing large distances using different aquatic habitats, expanding their distribution (Ficetola & De Bernardi 2004).

A large number of recorded data exist for *Salamandra salamandra* and *Bombina variegata* (99 and 89, respectively). The large number of findings of *B. variegata* is not surprising as they are easy to be visually noticed due to the specific abdominal coloration, activity throughout the day and frequent intercourse in temporary ponds even on the road (Hartel 2008). Similar results for this species have been obtained in some other Balkan countries (Cogălniceanu et al. 2013, Szabolcs et al. 2017). On the other hand, such a large number of findings of *S. salamandra* are unexpected. Although it is

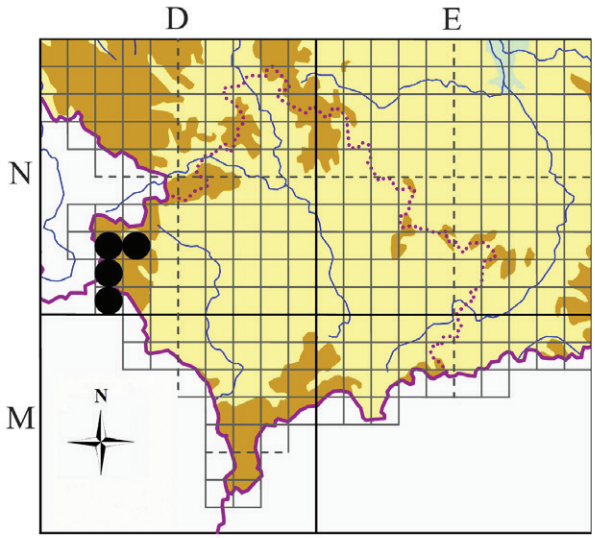

Fig. 5. Distribution maps of *Salamandra atra* in The Kosovo and Metohija Province (National grid UTM 10 × 10 km Reference). Black dots = old literature records.

easy to be observed due to aposematic coloration, this species is active mostly during the night when it is rainy or humid, and easy to find only during the breeding period when it is often found near water. This species is widespread throughout Serbia (Džukić et al. 2016) but the most important reason for the large number of findings of *S. salamandra* on the territory of the Kosovo and Metohija is the in-depth study of this species in the region (Labus et al. 2012, 2013).

The *Pelophylax esculentus* complex, *Bombina variegata* and *Salamandra salamandra* are species with the largest number of findings and also the largest spatial distribution in Kosovo and Metohija. They inhabit more than 1/3 of the territory of the province. The rarest amphibian species in Kosovo and Metohija, according the number of findings and spatial distribution, is *Salamandra atra*. The distribution range of this species is extremely small (around 3% of the Kosovo and Metohija territory) and located on a hardly accessible terrain at an altitude of 1980–2300 m (Table S1) (Labus & Krizmanić 2015). Small number of findings (the last one before more than 20 years) is a result of the inaccessibility of the terrain and the specific life history of this species. This species is critically endangered for Serbia as it inhabits extremely small area not exceeding c. 580 km^2 (Labus & Krizmanić 2015).

The inability to carry out scientific research due to security reasons in the last 20 years, primarily in Metohija and in some areas of Kosovo, has led to lack of detailed distribution schemes of amphibian species for the whole Kosovo and Metohija Province. The consequence of this is the presence of areas in distribution maps without amphibian species, even for those places that have appropriate habitats for amphibians. These “holes” in distribution maps exist for Metohija but, for some species such as *Hyla arborea*, *Lissotriton vulgaris* and *Rana graeca*, the lack of data is obvious even for Kosovo. Inadequate study of some areas in the Kosovo and Metohija, apart from security reasons, is due to the complex configuration of the terrain, especially the Šar Planina Mountains and Prokletije as well as the lack of material conditions and people. Bearing this in mind, one should not be surprised why the largest number of new data (especially those after the year 2000) originates from the northern and the smaller part of the eastern part of Kosovo and Metohija.

However, regardless of certain shortcomings, we believe that our study provides a very important insight into the distribution of amphibians in the territory of the Kosovo and Metohija Province. This is the first detailed study of the distribution and diversity of amphibian fauna in this area after 50 years. It is a foundation for some future studies of amphibian fauna of Kosovo and Metohija, which will contribute to better understanding of their distribution not only in this area but also in the territory of Serbia and the Balkans. In this regard, focus of future studies should be on distribution gaps that will confirm if they are just consequence of insufficient field research or an actual absence of species. Also, special attention should be given to the distribution and condition of the populations of *Salamandra atra* due to its current conservation status.

One of the most important values of this study is that it provides occurrence data essential for more systematic and evidence-based conservation approaches for highly endangered amphibian species. Occurrence data are important for making robust conservation management decisions provided by predictions of species occurrences derived from environmental suitability models that combine biological records with spatial environmental data. Additional faunistic studies are necessary in order to protect unique and sensitive amphibian populations of the Kosovo and Metohija Province.

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Supplementary Data

Table S1. Information on localities of amphibians in Kosovo and Metohija Province, Serbia – http://www.acta-zoologica-bulgarica.eu/002329sd

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