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New findings of Kotschy's gecko, *Mediodactylus kotschyi* (Steindachner, 1870) in Serbia, with a particular focus on recently recorded populations in Niš and Sremska Mitrovica

Original Article

Aleksandar Urošević
Institute for Biological Research "Siniša Stanković", National Institute of Republic of Serbia, University of Belgrade, Bulevar Despota Stefana 142, Belgrade, Serbia
aurosevic@ibiss.bg.ac.rs (corresponding author)

Marko Maričić
Institute of Zoology, Faculty of Biology, University of Belgrade, Studentski trg 16, Belgrade, Serbia

Tijana Vučić
Institute of Zoology, Faculty of Biology, University of Belgrade, Studentski trg 16, Belgrade, Serbia

Vladimir Žikić
Faculty of Sciences and Mathematics, University of Niš, Višegradska 33, 18000 Niš, Serbia

Saša S. Stanković
Faculty of Sciences and Mathematics, University of Niš, Višegradska 33, 18000 Niš, Serbia

Mirko Šević
Institute of Zoology, Faculty of Biology, University of Belgrade, Studentski trg 16, Belgrade, Serbia

Marko Anđelković
Institute for Biological Research "Siniša Stanković", National Institute of Republic of Serbia, University of Belgrade, Bulevar Despota Stefana 142, Belgrade, Serbia

Abstract:

Kotschy's gecko (*Mediodactylus kotschyi*) is native to the eastern Mediterranean basin but well known as a successful colonizer. The most probable way of its spreading is cargo and passenger traffic. In Serbia, *M. kotschyi* is assumed native only in Prizren. Anthropogenic introductions were confirmed in Belgrade, Novi Sad, Pančevo and Smederevo. This study aimed to summarize data of *M. kotschyi* findings with reference to recently confirmed population in Niš and newly recorded population in Sremska Mitrovica. These two populations are well-established with multiple pieces of evidence of reproduction. Pholidosis data were collected for several individuals to confirm their specific status. New and previously recorded introduced populations of Kotchy's gecko in Serbia belong to *M. kotschyi bibroni* based on morphology. The introduction was most likely related to railways and further spread in urban zones is expected. It seems that introduced populations do not threaten native ecosystems as these populations are appeared to be highly localized in urban habitats.

Key words:
anthropogenic introduction, colonizing species, distribution, *M. kotschyi bibroni*

Apstrakt:

Novi nalazi Kočijevog gekona, *Mediodactylus kotschyi* (Steindachner, 1870) u Srbiji, sa posebnim fokusom na nedavno zabeležene populacije u Nišu i Sremskoj Mitrovici

Kočijev gekon (*Mediodactylus kotschyi*) se autohtono javlja u basenu istočnog Sredozemlja ali je dobro poznat i kao uspešan kolonizator. Najverovatniji načini njegovog širenja su teretni i putnički saobraćaj. U Srbiji, Kočijev gekon se smatra autohtonim samo na području Prizrena. Antropogene introdukcije potvrđene su u Beogradu, Novom Sadu, Pančevu i Smederevu. Cilj ove studije je da sumira podatke o nalazima *M. kotschyi* sa posebnom pažnjom na nedavno potvrđeno prisustvo populacije u Nišu i novozabeleženu populaciju u Sremskoj Mitrovici. Ove dve populacije su dobro uspostavljene, sa višestrukim dokazima reprodukcije. Podaci o folidozi prikupljeni su za veći broj jedinki da bi se potvrdio njihov status vrste. Nove i prethodno zabeležene populacije Kočijevog gekona u Srbiji prema morfologiji pripadaju *M. kotschyi bibroni* podvrsti. Introdukcije su najverovatnije vezane za železnički saobraćaj i očekivano je dalje širenje ove vrste u urbanim zonama. Pretpostavlja se da introdukovane populacije ne ugrožavaju autohtone ekosisteme jer su po svoj prilici veoma lokalizovane na urbana staništa.

Ključne reči:
antropogena introdukcija, kolonizujuća vrsta, distribucija, *M. kotschyi bibroni*

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Introduction

Lizards, and particularly geckos, are well known as adept colonizers that significantly spread their range via human activity (Flower, 1933; Davis, 1974; Conant & Collins, 1998; Jesus et al., 2002). It was even assumed that many populations of the *Hemidactylus* (Gekkonidae, Squamata) and *Tarentola* (Phyllodactylidae, Squamata) geckos in the Mediterranean basin are of anthropogenic origin (Harris et al., 2004; Kasapidis et al., 2005).

Kotschy's gecko (*Mediodactylus kotschyi* (Steindachner, 1870), Gekkonidae, Squamata) is a small, crepuscular, or nocturnal gecko species

native to the eastern Mediterranean basin (Böhme et al., 2009). Recently, based on nuclear and mitochondrial DNA analysis, it was discovered that it is a species complex consisting of five species – *M. kotschyi* (mainland of Balkan Peninsula, most of Aegean islands, Italy), *M. orientalis* (Levant, Cyprus, southern Anatolia, south-eastern Aegean islands), *M. danilewskii* (Black Sea region, south-western Anatolia and Gavdos island, Greece), *M. bartoni* (Crete and surrounding islets) and *M. oertzeni* (southern Dodecanese Islands) (Kotsakiozi et al., 2018). There are known cases of individuals of *M. kotschyi* species complex introduction outside the native range in Hungary (Farkas et al., 1999), Serbia (Ajtić, 2009; Tomović et al., 2014; Balej & Jablonski, 2015; Urošević, 2016; Urošević et al., 2016, 2019), Romania, Bulgaria (Koynova et al., 2020) and Italy (Mares & Novarni, 2020).

In Serbia, it is assumed native only in Prizren, Metohija (Ajtić & Tomović, 2001), according to the distribution of Mediterranean fauna in Serbia and its neighbouring countries (Haxhiu, 1998; Ajtić & Tomović, 2001; Ajtić, 2004). Other populations that were discovered outside of Metohija are presumed to be introduced during the historical times or, more likely, recently (Ajtić, 2009; Tomović et al., 2014; Balej & Jablonski, 2015; Urošević, 2016; Urošević et al., 2016, 2019). The introductions have been confirmed in Novi Sad (Ajtić, 2009; Balej & Jablonski, 2015;), Belgrade [Vračar (Balej & Jablonski, 2015), Stari Grad – Kneginje Zorke st., Zemun (Urošević et al., 2016)], Smederevo [Smederevo fortress (Urošević, 2016; Urošević et al., 2016)] and Pančevo (Urošević et al., 2019). Finding from Niš has been mentioned in the literature (Ajtić, 2009; Urošević et al., 2016), but it was based only on one reported sighting in a local coffee warehouse, and it has lacked an expert confirmation.

With the recent taxonomic revision of the *M. kotschyi* group (Kotsakiozi et al., 2018), the need to correctly assess the specific status of the introduced populations emerged. Although the molecular analyses are not congruent with most of the described subspecies, the newly described species are very close to the main groups defined by Beutler (1981). Also, Ajtić (2014) showed that discrimination between the main groups (for instance, the mainland *kotschyi* and *danilewskii*) is feasible via morphological characters. Our main assumption was that the introductions occurred by land, from the continental parts of the Balkan Peninsula. Since the geckos could have originated from the Black Sea coast region and therefore belong to the *M. danilewskii* group (D. Jablonski, personal communication) we wanted to assess meristic characters through which we could identify the approximate origin of the colonized geckos, before we conduct the DNA analyses.

The main aim of this study is to provide a comprehensive list of the published and unpublished known findings of the Kotschy's gecko in Serbia, and morphologically assess specific/subspecific status of the populations in Niš (confirmed for the first time) and Sremska Mitrovica (newly discovered), since they are well-established, numerous and with multiple proofs of successful reproduction observed by the authors.

Materials and Methods

The presence of Kotschy's geckos at the studied sites was detected by visual observation or by listening to

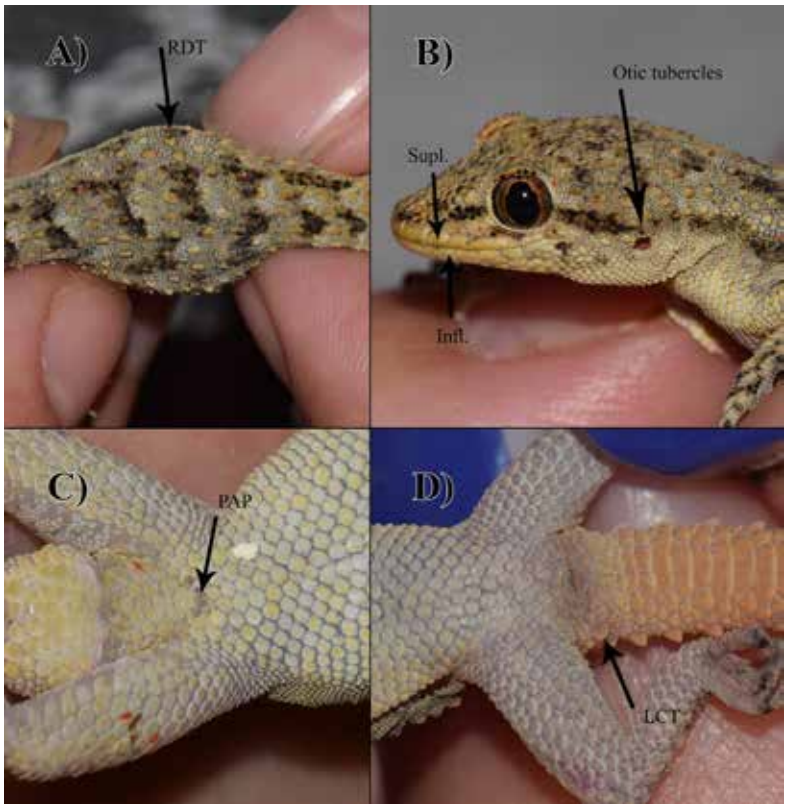

Fig. 1. Meristic data. **A)** RDT – number of rows of dorsal tubercles; **B)** Supl. – number of supralabial tubercles; Infl. – number of infralabial tubercles; Otic tubercles – arrangement, **C)** PAP – number of preanal pores; **D)** LCT – number of lateral caudal tubercles

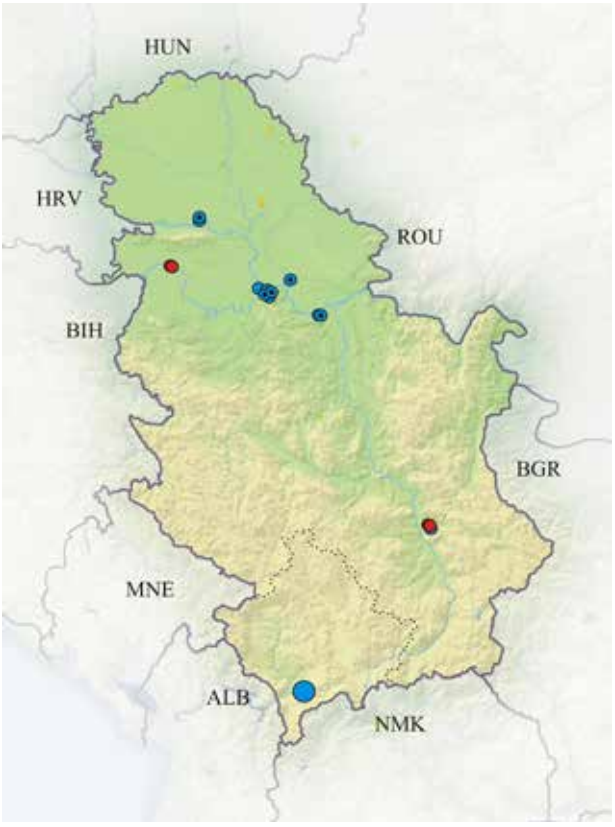

Fig. 2. Map of *M. kotschyi* distribution in Serbia. Empty blue dots represent literature reports, blue dots with black centre represent literature records reconfirmed in the field during the last survey, and red dots denote new distribution records. Population in Prizren, that is considered as native, is presented as a large blue dot

the characteristic "vocalization", usually during the late afternoon or in the evenings, after sunset, during the summer and early autumn of 2020 and 2021. For confirmation, voucher photos of the animals were taken with a digital camera, and the precise locations were georeferenced (via application GPS Measurer – Area, Perimeter, Distance, POI; v. 1.6.6 for Android, EDSA). When possible, the animals were collected by hand to examine pholidosis and take a tail tip as a sample for the subsequent DNA analyses. The detailed pholidosis data was collected for several individuals in Niš and Sremska Mitrovica. Activities such as mating and feeding, as well as presence of juvenile animals or gravid females were also noted if observed.

The pholidosis was compared to the diagnostic characters of the *M. kotschyi* former subspecies (Biserkov et al., 2007; Ajtić, 2009 and references there in) with an emphasis on the former subspecies native to the continental part of the Balkans – *M. k. bibroni* (Beutler & Gruber, 1977), *M. k. skopjensis* (Karaman, 1965), *M. k. rumelicus* (Müller, 1940) and *M. k. danilewskii* (Strauch, 1887), since we assumed that the multiple introductions were most likely via the continental transportation routes. Specific traits that we examined were: 1) layout of the tubercles around the ear opening, 2) shape of the dorsal tubercles, 3) number of rows of the dorsal tubercles (RDT), 4) number of supralabials (Supl.) and infralabials (Infl.), 5) number of the preanal pores (PAP), and 6) number of lateral caudal tubercles (LCT) (**Fig. 1**).

Results

The intensive research re-confirmed the presence of Kotschy's geckos at most of the known locations from the literature (**Fig. 2**, **Supplementary Table 1**). The new findings were reported from the town of Sremska Mitrovica and a few localities in Belgrade, as well as the city of Niš, where the expert confirmation of the introduction was provided for the first time. In Novi Sad, Belgrade, Smederevo and Niš, the findings were often localized to specific walls, buildings, or streets. In those places, the species seems to prefer the walls that are oriented towards the south and/or west, and that receive a lot of insolation during the day. In Sremska Mitrovica, the geckos seem to be frequent throughout the old town centre, probably due to the abundance of old, mutually connected buildings which provide suitable habitats.

The pholidosis characters of the observed individuals in Niš and Sremska Mitrovica are given in **Tab. 1**. All animals had between 11 and 13 rows of dorsal tubercles (most had 12), between 8 and 10 supralabial scales (most having 9), 6 or 7 infralabial scales (most having 7) and 2 or 3 lateral caudal tubercles. All males in the sample had 4 preanal pores. All animals had large, keeled dorsal tubercles and almost all individuals had otic tubercles above and in front of ear opening (only one had above, in front and behind).

In Niš, mating was observed and one gravid female with two visible eggs was caught (**Fig. 3**). In Sremska Mitrovica, three caught animals were subadults. We also observed feeding on arachnids in Niš. Many animals in both populations had regenerated tails, which is a strong indication that they are subject to predation (by wall lizards, feral cats, etc.) or aggressive intraspecific behaviour.

Discussion

Mediterranean geckos are known as successful colonizers and their spread to the north is constrained only by their association with anthropogenic habitats

Table 1. Meristic data for the collected individuals. Abbreviations: **Ind.** – Individual; **RDT** – number of rows of dorsal tubercles; **Supl.** – number of supralabial tubercles; **Infl.** – number of infralabial tubercles; **PAP** – number of preanal pores; **LCT** – number of lateral caudal tubercles; **SDT** – shape of dorsal tubercles; **Subad.** – Subadult.

Locality	Ind.	Sex	RDT	Supl.	Infl.	PAP	LCT	SDT	Otic tubercules	Note
Niš	NI001	M	12	9	7	4	3	Large, keeled	Above and in front	
Niš	NI002	F	12	10	6	/	2	Large, keeled	Above and in front	Gravid
Niš	NI003	M	12	9	7	4	/	Large, keeled	Above and in front	
Niš	NI004	F	11	9	7	/	3	Large, keeled	Above and in front	
Sremska Mitrovica	SM001	F	13	9	7	/	3	Large, keeled	Above and in front	Subad.
Sremska Mitrovica	SM002	F	11	8	6	/	3	Large, keeled	Above and in front	
Sremska Mitrovica	SM003	M	13	9	7	4	3	Large, keeled	Above, in front and behind	
Sremska Mitrovica	SM004	F	12	10	7	/	3	Large, keeled	Above and in front	
Sremska Mitrovica	SM005	F	13	9	7	/	2	Large, keeled	Above and in front	
Sremska Mitrovica	SM006	F	11	8	7	/	2	Large, keeled	Above and in front	Subad.
Sremska Mitrovica	SM007	F	13	9	7	/	2	Large, keeled	Above and in front	Subad.
Sremska Mitrovica	SM008	F	12	8	6	/	2	Large, keeled	Above and in front	
Sremska Mitrovica	SM009	M	12	9	7	4	2	Large, keeled	Above and in front	

and climate (Meshaka et al., 2005). In Serbia, the establishment of Kotschy's geckos in the urban areas is well known and documented (Ajtić, 2009; Tomović et al., 2014; Balej & Jablonski, 2015; Urošević, 2016; Urošević et al., 2016, 2019). By now, only the population in Prizren is considered to be autochthonous (Ajtić & Tomović, 2001). Due to its isolation from the rest of the native range of *M. kotschyi*, it is hypothesized that the Prizren population could also be a result of the historical introduction (Ajtić & Tomović, 2001; Ajtić, 2004, 2009). However, the isolation could be explained by the lack of distribution data from the north Albania and Metohija regions (Haxhiu, 1998), since these areas generally lack systematic faunistic research (Ajtić & Tomović, 2001; Ajtić, 2009; Tomović et al., 2014). The rest of the populations in Serbia are considered to be anthropogenic introductions (Ajtić, 2009; Urošević et al., 2016). Since the discovered population in Novi Sad appeared stable, it was supposed that the introduction took place long ago (Ajtić, 2009). The other populations that were discovered afterwards also seemed well established, albeit localized, and could be detected throughout consecutive years, with most being reconfirmed during the last field surveys. Hypotheses of historical introduction could not explain how well-established populations of partially diurnal geckos were not noticed earlier. The deliberate introductions in Hungary showed that these geckos can establish breeding colonies quickly (Farkas et al., 1999). Urošević et al. (2016) proposed a scenario of

Fig. 3. Evidence of *M. kotschyi* reproduction in the Niš population. **A)** Mating pair; **B)** Gravid female with visible eggs

relatively recent (15–20 years ago), simultaneous introduction into the large urban centres.

Ajtić (2009) assumed that geckos were introduced accidentally throughout the known localities in Serbia, via cargo shipments from south or east. Through the centuries, Balkan Peninsula harboured an important network of trading routes. For instance, *Via Militaris* (later known as "Tsarigrad Road") had been traced in the 1st century AD. Some of the places where gecko populations were confirmed (Prizren, Belgrade, Sremska Mitrovica, Pančevo, Smederevo, and Niš) were the important trading hubs and caravan stations during the Roman and Ottoman empires (Simonović, 2003; Ajtić, 2009; Urošević, 2016; Urošević et al., 2016). Today, these places are well connected by road and railroad networks. Railroads are suggested as an especially probable means of introductions, since most of the known introductions in Serbia are situated up to 1.5 km far from the railroad stations and junctions, and railroad beds can also provide good migratory corridors for reptiles (Gherghel et al., 2009; Urošević et al., 2019). This could also have facilitated the spread of geckos via cargo or passenger traffic (Urošević, 2016). According to the meristic characters interpretable as diagnostic for the subspecies (Biserkov et al., 2007; Ajtić, 2009), geckos from the populations in Niš and Sremska Mitrovica clearly belonged to the former *M. kotschyi bibroni* subspecies, characteristic for the central and southern Balkans – males had four preanal pores, all examined individuals had two or three lateral caudal tubercles, most animals had otic tubercles only above and in front of the ear opening (which rules out *M. kotschyi rumelicus*) and dorsal tubercles were large and strongly keeled. Animals observed in Belgrade, Novi Sad and Smederevo that were photographed also had strongly keeled dorsal tubercles and otic tubercles only above and in front of the ear opening. The number of rows of the dorsal tubercles ruled out the geographically closest subspecies, *M. kotschyi skopjensis*, since it usually has only 10 rows of tubercles, while the animals we observed had between 11 and 13 (most 12) rows, which corresponds with *M. kotschyi bibroni* group (Ajtić, 2009). According to the molecular data, the group *M. kotschyi bibroni*, which inhabits the mainland Balkans, belongs to the *M. kotschyi* species (Kotsakiozi et al., 2018).

Although Kotschy's gecko seems to be spreading in Serbia, there are no known negative effects which it can have on native ecosystems (Urošević et al., 2016). All known introduced populations are localized in the urban zones, sometimes only on specific buildings. In the north of its native range, the species is also almost exclusively associated with human dwellings, in urban or suburban zones (Ajtić & Tomović, 2001; Arnold & Ovenden, 2002; Ajtić, 2009). We expect further spread of Kotschy's gecko predominantly into urban areas, towns and cities that, due to the "heat island effect", provide

adequate thermal conditions for the predominantly Mediterranean species.

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