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Alterations in the reptilian fauna of Serbia: Introduction of exotic and anthropogenic range expansion of native species

Veränderungen in der Reptilienfauna von Serbien: Einschleppung exotischer und anthropogene Arealerweiterung einheimischer Arten

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KURZFASSUNG

Diese Studie beschreibt Fälle von Einschleppungen exotischer Arten und Arealerweiterungen heimischer Arten in Serbien. Die vier wichtigsten Arten sind die eingeführte *Trachemys scripta elegans*, und die einheimischen Arten *Testudo hermanni*, *Mediodactylus kotschyi* und *Podarcis muralis* mit Ihren Arealerweiterungen. *Trachemys scripta elegans* sollte als ein besonderer Fall gelten, da durch sie mehrere negative Auswirkungen auf lokale Ökosisteme bekannt wurden. Gelegentliche Freisetzungen von zwei ausländischen (*Pelodiscus* sp. und *Hemidactylus turcicus*) und zwei einheischen Arten (*Podarcis tauricus* und *Vipera ammodytes*) wurden auch aufgeführt. Am häufigsten konnten Einschleppungen in den städtischen Einzugsgebieten von Belgrad und Novi Sad dokumentiert werden. Zunahmen bei Verkehr, globalem Handel und Frachtsendungen, sowie eine große Anzahl von privaten Haltern exotischer Tiere machen die großen Stadtgebiete anfällig für absichtliche oder unabsichtliche Einschleppungen von Amphibien und Reptilien. Zunehmende anthropogene Veränderungen der Lebensräume durch Urbanisierung können Korridore für die Arealerweiterung heimischer Arten entstehen lassen.

ABSTRACT

This study describes cases of introductions of exotic species and range expansion of native species in Serbia. The four most important introductions are the alien, invasive *Trachemys scripta elegans* and native *Testudo hermanni*, *Mediodactylus kotschyi* and *Podarcis muralis* which expanded their ranges. *Trachemys scripta elegans* should be of special concern, since introductions of this species can have numerous negative effects on local ecosystems. Incidental introductions were documented for two alien (*Pelodiscus* sp. and *Hemidactylus turcicus*) and two native species (*Podarcis tauricus* and *Vipera ammodytes*). The greatest number of introductions is concentrated around urban areas, especially around the cities of Belgrade and Novi Sad. Increased traffic, trading and cargo shipment, as well as a large number of people who keep exotic animals as pets, make large urban areas susceptible to accidental and deliberate introductions of amphibians and reptiles. On the other hand, anthropogenic alteration and degradation of habitats, along with increased urbanization, can provide corridors for the range expansion of native species.

KEY WORDS

Reptilia; distribution, chorology, ecology, exotic species, native species, anthropogenic range expansion, invasive species, Serbia

INTRODUCTION

Various human activities, such as global-scale transportation and environmental changes, as well as pet trade and herpetoculture, can lead to the introduction of exotic, potentially invasive amphibian and reptile species (KRAUS 2009a, 2009b; KROFEL 2009; PUPIŅŠ & PUPIŅA 2011; SCHULTE et al. 2012). Also, anthropogenic habitat modification or degradation can lead to range expansions of native species or previously established populations of introduced species (BAUWENS et al. 1986; SMITH & ENGEMAN 2004; MESHAKA et al. 2005, 2006; AJTIĆ 2009; GHERGHEL et al.

2009). Intentional and unintentional introduction of exotic species is considered a serious risk for global biodiversity (Butchart et al. 2010), since it leads to a "biological homogenization of our planet" (IUCN 2012).

Globally there are 678 amphibian and reptile species that are documented as introduced outside of their native range by human activity, and at least 322 species established alien populations in more than 1,060 cases (Kraus 2009a, 2009b).

The importance of introduction pathways and success varies temporally and geographically. The greatest number of introductions occurred in North America and Europe, with various impacts and consequences. Small islands have proven to be the most vulnerable to introductions (Kraus 2009a, 2009b; Bomford et al. 2009; Reed & Kraus 2010).

Species of amphibians and reptiles can be introduced into new areas deliberately or accidentally. In general, there are several predominant ways of species introduction: unintentional (via cargo shipment and nursery trade) or intentional (via pet trade, for biocontrol use, for food or for "esthetic enjoyment" (Kraus 2009a, 2009b). It has been pointed out that unintentional anthropogenic dispersal played a major role in the spreading of some reptile species around the Mediterranean region, especially on the islands, during historical times (Harris et al. 2004; Podnar et al. 2004; Kasapidis et al. 2005). Intentional introductions were dominant from 1850 to 1960, however, pet trade has still remained the most important introduction pathway, due to escapes and deliberate releases. Many popular species have been introduced repeatedly (Bringsøe 2006; Kraus 2009a, 2009b; Willson et al. 2011).

Exotic amphibian and reptile species establish populations by achieving reproductive success (Cadi et al. 2004; Pérez-Santigosa et al. 2008; Willson et al. 2011). Most introduced species are not harmful to the local ecosystems, and some can even be beneficial (National Invasive Species Council 2008). However, exotic species can have a great negative impact on the local environment and these species are considered invasive. In general, an invasive species is defined as "an exotic species whose introduction does or is likely to cause economic or environmental harm or harm to human health" (National Invasive Species Council 2008). Although a few species of invasive amphibians and reptiles gained considerable scientific and popular account due to the recognition of threats originating from these species, real or potential negative impacts of the majority of introduced amphibian and reptile species are still poorly understood (Reed & Kraus 2010).

To date, the published data concerning exotic reptile species introduced into the republic of Serbia, as well as anthropogenic enhancement of the spreading of native species, is very scarce. Moreover, the status of some species was assessed only recently but was not monitored across times (Džukić et al. 2008; Ajtić 2009; Lazarević et al. 2012; Ljubisavljević et al. 2013).

The aim of this paper is (1) to provide a checklist of anthropogenic dispersals in the Serbian herpetofauna, both for introduced exotic species and for native species which expanded their ranges, and (2) to assess possible ecological risks to local herpetofauna.

MATERIALS AND METHODS

The dataset for this study was collected using published literature data, the authors' unpublished records, specimens deposited in the Herpetological collection of the Institute for Biological Research "Siniša Stanković" in Belgrade and the Aquarium of the Faculty of Science in Kragujevac, field observations, and data available on field herpetology websites. The localities dataset includes site names, coordinates and elevations. The maps were created using DivaGis 7.5. software (Hijmans et al. 2001).

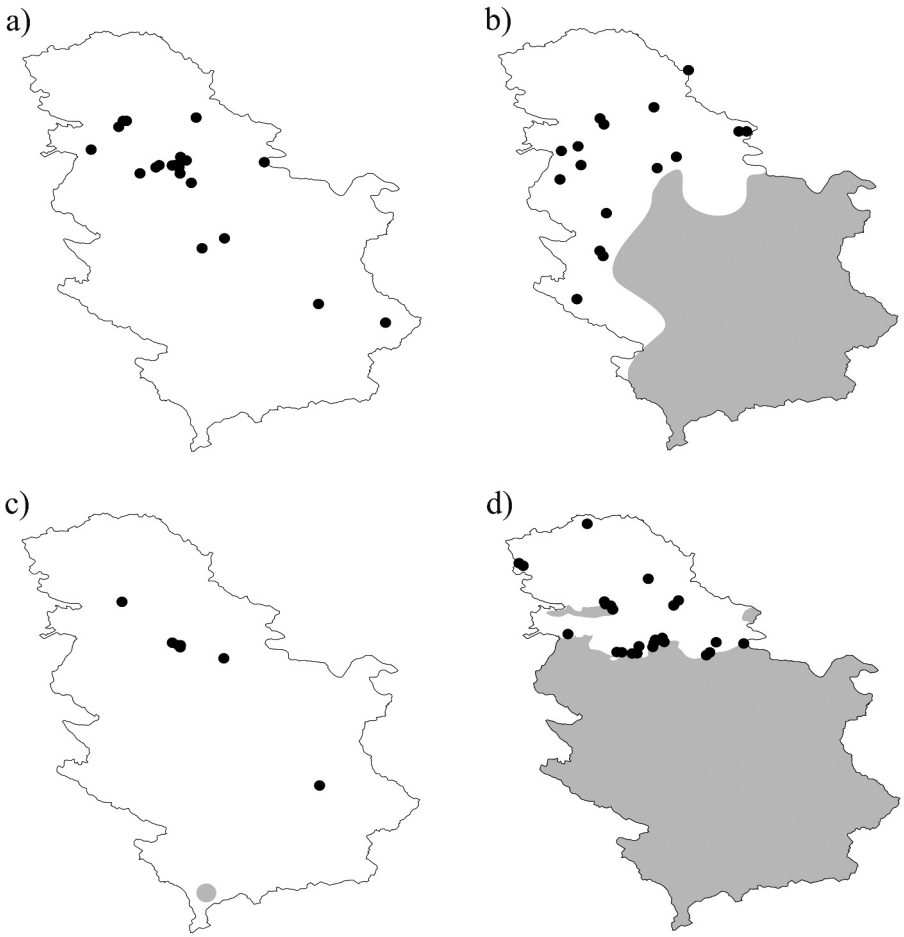

Fig. 1: Records for the four most important introduced reptile species in Serbia. Introductions according to data from the literature(solid circles), native species' ranges (gray areas). a) *Trachemys scripta elegans* (Wied-Neuwied, 1839); b) *Testudo hermanni* (Gmelin, 1789); c) *Mediodactylus kotschyi* (Steindachner, 1870); d) *Podarcis muralis* (Laurenti, 1768). For the native species, native ranges were given according to Ljubisavljević et al. (2011, 2013) for *T. hermanni*; Ajtić & Tomović (2001) for *M. kotschyi*, or according to our assumption that native, non-synanthropic populations of *P. muralis* should be absent from the natural habitats in the Pannonian plain north of the rivers Sava and Danube.

Abb. 1: Nachweise für die vier wichtigsten, eingeschleppten Reptilienarten in Serbien. Beobachtungen von Einschleppungen nach Angaben in der Literatur (gefüllte Kreise) sowie das angestammte Verbreitunggebiet der einheimischen Arten (graue Bereiche). a) *Trachemys scripta elegans* (Wied-Neuwied, 1839); b) *Testudo hermanni* (Gmelin, 1789); c) *Mediodactylus kotschyi* (Steindachner, 1870); d) *Podarcis muralis* (Laurenti, 1768). Die Verbreitung der einheimischen Arten wurde nach folgenden Literaturnangaben dargestellt: Ljubisavljević et al. (2011, 2013) für *T. hermanni*; Ajtić & Tomović (2001) für *M. kotschyi*, und entsprechend unserer Annahme, daß lokale Populationen von *P. muralis*, die nicht als Kulturfolger gelten, in den natürlichen Lebensräumen der Pannonischen Tiefebene nördlich von Save und Donau fehlen.

Table 1: Records of *Trachemys scripta elegans* (Wied-Neuwied, 1839) in Serbia. Obs - confirmed observation from the field (with voucher specimen or photo); Web - Website record.

Tab. 1: Nachweise von *Trachemys scripta elegans* (Wied-Neuwied, 1839) in Serbien. Obs - bestätigte Feldbeobachtung (Belegexemplar oder Foto); Web - Der Nachweis ist auf der Website veröffentlicht.

Locality/ Untersuchungsort	Alt (m)/ Höhe (m)	Coordinates/ Koordinaten	Type/ Typ	Reference/ Referenz	Informant, Collector/ Gewährsperson, Sammler
Bela Crkva - v. Banatska Palanka - Jaruga	66	44°49N 21°20E	Obs	Unpublished	G. Džukić
Belgrade - "Ada Safari" fishing resort	74	44°47N 20°24E	Obs	Unpublished	A. Urošević
Belgrade - Ada Ciganlija bayou	72	44°47N 20°25E	Obs	Unpublished	A. Simović
Belgrade - Ada Ciganlija lake	72	44°47N 20°23E	Obs	Unpublished	A. Simović
Belgrade - Košutnjak	82	44°46N 20°26E	Web	Baley & Jablonsky 2006-2014	N. Preradović
Belgrade - Novi Beograd	67	44°47N 20°22E	Web	Baley & Jablonsky 2006-2014	K. Lazić
Belgrade - Novi Beograd, block 71	66	44°47N 20°21E	Obs	Unpublished	M. Andjelković
Belgrade – Pančevački rit	71	44°50N 20°31E	Obs	Unpublished	W. Becker, Z. Franolić
Belgrade - v. Borča, Sebeš canal	70	44°52N 20°28E	Obs	Unpublished	M. Andjelković
Belgrade - Pariguz lake	138	44°42N 20°27E	Obs	Unpublished	A. Simović, A. Marković
Belgrade – Trešnja lake	241	44°36N 20°34E	Obs	Unpublished	W. Becker, Z. Franolić
Belgrade – Trešnja lake	241	44°36N 20°34E	Obs	Unpublished	T. Vukov et al.
Knić - Gružansko lake	290	43°55N 20°41E	Obs	Unpublished	A. Simović
Kragujevac – Bubanj lake	175	44°01N 20°55E	Obs	Unpublished	G. Džukić
mt. Fruška Gora – Popovica lake	303	45°11N 19°49E	Obs	Unpublished	S. Rajkov, D. Savić
Niš - St. Pantelejmon church	217	43°20N 21°54E	Obs	Unpublished	V. Žikić
Novi Sad - City	80	45°15N 19°51E	Web	Baley & Jablonsky 2006-2014	N. Preradović
Novi Sad - City - Danube park	81	45°15N 19°51E	Obs	Unpublished	A. Simović
Novi Sad - Petrovaradin	77	45°15N 19°53E	Obs	Unpublished	M. Grahovac
Pećinci - v. Kupinovo - Obedska bara	69	44°42N 20°02E	Obs	Unpublished	G. Džukić
Pirot - city pool	368	43°08N 22°36E	Obs	Unpublished	A. Simović
Sremska Mitrovica - Zasavica bog	73	44°57N 19°31E	Obs	Unpublished	R. Ajtić
Surčin - v. Bečmen - Galovica canal	72	44°46N 20°13E	Obs	Unpublished	A. Simović
Surčin - v. Bečmen - lakes	74	44°46N 20°12E	Obs	Unpublished	R. Ajtić
Surčin - v. Bečmen - Tvrđenjava lake	72	44°47N 20°14E	Obs	Unpublished	A. Simović
Zrenjanin - v. Tomaševac - water gate	69	45°17N 20°37E	Obs	Unpublished	A. Simović

RESULTS AND DISCUSSION

Trachemys scripta elegans (Wied-Neuwied, 1839) – Invasive

The Red-eared Slider is distinguished from the indigenous European Pond Terrapin *Emys orbicularis* (Linnaeus, 1758), by yellow stripes across the head and a prominent red patch behind the eye (Ernst et al. 1994; Arnold & Ovenden 2002; Bringsøe 2006). The native range of *T. scripta elegans* comprises eastern and central parts of the United States of America, namely the Mississippi River watershed (Arnold & Ovenden 2002; Bringsøe 2006).

The Red-eared Slider is very popular species in pet trade, and it is among the 100 most dangerous invasive species, according to Scalera (2006). Dumping of adult animals into the wild by careless owners is still considered the only effective spreading pathway for this species (Bringsøe 2006; Scalera 2006). Introductions are concentrated in urbanized areas (Scalera 2006), and there is a positive correlation between population density of *T. scripta elegans* and concentration of human settlements (Arvy & Servan 1996). In Europe, this turtle is reported in almost every country (Scalera 2006), among others Germany (Kordges et al. 1989; Ernst et al. 1994), Spain (Da Silva & Blasco 1995; Bringsøe 2001; Pleguezuelos et al. 2004), France (Arvy & Servan 1996; Cadi et al. 2004), Italy (Luiselli et al. 1997; Ferry & Soccini 2003), Great Britain (Beltz 2002), Denmark, Russia, Finland, Lithuania, Poland, Sweden (Bringsøe 2006), Austria, Belgium, Bulgaria, Croatia, Czech Republic, Greece, Hungary, the Netherlands, Portugal, Romania, Slovakia (Scalera 2006); Latvia (Pupiņš & Pupiņa 2007), Slovenia (Krofel et al. 2009), and Serbia (Scalera 2006; Džukić et al. 2008; Lazarević et al. 2012). The introduced Red-eared Sliders can survive most of the west European winters, with extended periods of temperatures as low as -10 °C (Cady & Joly 2004).

There are published records about introduced populations of this species in Serbia (Džukić et al. 2008; Lazarević et al. 2012), and numerous unpublished field records (Table 1, Fig. 1a). Introductions are concentrated around the cities of Belgrade and Novi Sad, mostly in urban and suburban areas. The Red-eared Sliders are present in ponds, canals and small artificial lakes. In some cases, especially in small scenic lakes in urban parks, introduction of multiple specimens could have happened deliberately, due to the "decorative" value of the Red-eared Sliders. These populations can be large, as the one in the Novi Sad city park. Populations in the central and eastern parts of Serbia were found almost exclusively in lakes that are popular fishing spots and weekend resorts. Various canals and ponds in the lowland province of Vojvodina have proven to be popular spots for dumping unwanted pet turtles. The Red-eared Slider is often seen together with native European Pond Turtles competing for basking spots. Red-eared Sliders can start their seasonal activity very early in the spring, even in mid-February, before *E. orbicularis*. In some cases of mixed populations, the exotic turtles considerably outnumber native turtles (Simović, personal observation). Of special concern are populations introduced in the important protected reservations of the Zasavica bog and the Obedska swamp.

There are some important ecological concerns about *T. scripta elegans* introduction in Serbia. The Red-eared Slider has numerous competitive advantages over the native freshwater turtle, *E. orbicularis*, which is registered as an endangered species (Appendix II of the Bern convention) and is strictly protected in Serbia ("Official Gazette of the Republic of Serbia" No. 5/2010). The Red-eared Slider has a larger adult body size, higher fecundity and lower age at maturity (Arvy & Servan 1998). In addition, in its native range, the Red-eared Slider often lives in syntopy with other turtles (up to six species); this enhances its competitive behavior and potentials (Gibbons 1990).

Freshwater turtles can compete for food, and egg laying or basking sites. The Red-eared Slider can displace the European Pond Terrapin from the native species' preferred basking sites. Prolonged presence of the alien species was observed to lead to

reduced fitness of native turtles (Cady & Joly 2003, 2004).

As an omnivore, the Red-eared Slider consumes a variety of aquatic plants and animals (Ernst et al. 1994; Prévot-Julliard et al. 2007). It is known to exert a considerable predatory pressure on native amphibian larvae (Polo-Cavia et al. 2010).

Another important concern about the Red-eared Slider is that it is a known vector of pathogenic strains of *Salmonella* and *Arizona* bacteria. These strains can potentially spread among the native turtles and other wildlife, with disastrous results. The salmonellosis can also be transmitted to humans through captive animals (Bringsøe 2006; Scalera 2006). Because of the risks they pose to human health, the Red-eared Slider trade was severely restricted in the USA since 1975. This led to closing many commercial breeding turtle farms. However, export to other parts of the world continues. Millions of juvenile Red-eared Slider were exported to Europe before 1997, when the EU implemented a ban on the import of *T. scripta elegans* via Council Regulation (EC) No. 338/97 on the Protection of Species of Wild Fauna and Flora by Regulating Trade (Bringsøe 2006). After the ban, certain "substitute" species and subspecies have become widely available in pet trade (Bringsøe 2006). Despite legal regulations concerning prohibited trade and import ("Official Gazette of the Republic of Serbia" No. 99/2009), Red-eared Sliders are still widely available in pet stores in Serbia.

Testudo hermanni (Gmelin, 1789) – Native, often translocated within and beyond its native range

Hermann's Tortoise was an important commercial species harvested for consumption, pet trade and traditional medicinal purposes (Schlaepfer et al. 2005). From the former Yugoslavia alone, during a continuous 41 year period, 2,615 metric tons of tortoises (*T. hermanni* as well as *T. graeca* Linnaeus, 1758) were exported to 19 countries, mostly Italy, Belgium, Luxembourg, Germany and Great Britain (Ljubisavljević et al. 2011).

Hermann's Tortoise is still illegally collected from nature and sold/kept, both within and outside Serbia (Kecse-Nagy et al. 2006).

There are some reports of *T. hermanni* outside its native range that can be explained by escaped pet animals (Bertolero et al. 2011). Anthropogenic translocations were recorded in Bosnia and Herzegovina and Montenegro (Ljubisavljević et al. 2013). The total Slovenian population of *T. hermanni* was considered to be of exotic origin (Sajović 1913; Tome 1996; Mršić 1997; Krofel et al. 2009). However, the populations near the Adriatic coast are most likely native (Fritz et al. 2006; Bertolero et al. 2011; Ljubisavljević et al. 2013).

In Serbia, 16 extralimital records of *T. hermanni* were reported from the regions north and west of the native range (Ljubisavljević et al. 2013) (Table 2, Fig. 1b). These findings comprise all confirmed cases of introductions, including expert observations without material evidence (voucher specimens, shells, shell fragments or photos). In the case of the village Potočanje near the town of Užice (western Serbia), local people confirmed that the tortoise found was most likely one of the few that had been brought from Montenegro and escaped. The most drastic example of anthropogenic translocation was the release of more than 10 tons of tortoises near Zrenjanin (Banat region) during the early 1970s. The anonymous carrier simply dumped the whole shipment because the retailer and exporter could not agree on a price (Džukić, unpublished). Consequently, over 30,000 tortoises from this single shipment had been introduced north of their natural range, into inadequate habitat, and subsequently perished. Unfortunately, dumping tortoises, due to disagreements about price and demand during the 1970s and 80s, was a common practice that was often disastrous for the captured animals (Džukić, unpublished).

Hermann's Tortoise is listed as a near-threatened species by the IUCN (van Dijk et al. 2004). Major threats for this species are habitat loss, pollution, urbanization and tourism, wildfires, collection for pet trade and road mortality (Stubbs

Table 2: Records of *Testudo hermanni* (GMELIN, 1789). Obs: confirmed observation from the field (voucher specimen or photo); Lit - published literature data.
Tab. 2: Nachweise von *Testudo hermanni* (GMELIN, 1789). Obs - bestätigte Feldbeobachtung (Belegexemplar oder Foto); Lit - publizierte Literaturdaten.

Locality/ Untersuchungsort	Alt (m)/ Höhe (m)	Coordinates/ Koordinaten	Type/ Typ	Reference/ Referenz	Informant,Collector/ Gewährsperson, Sammler
Belgrade - Miljakovac	193	44°44N 20°28E	Lit	DŽUKIĆ 1972	G. DŽUKIĆ
Cer - Široka ravan	492	44°37N 19°27E	Lit	LJUBISAVLJEVIĆ et al. 2013	M. RADOVANOVIĆ
Nova Crnja - v. Radojevo	81	45°45N 20°48E	Lit	LJUBISAVLJEVIĆ et al. 2013	G. DŽUKIĆ
Novi Sad - City	81	45°15N 19°52E	Lit	LJUBISAVLJEVIĆ et al. 2013	G. DŽUKIĆ
Pančevo - v. Vojlovica	77	44°51N 20°40E	Lit	LJUBISAVLJEVIĆ et al. 2013	G. DŽUKIĆ
Prijepolje - v. Kolovrat	488	43°21N 19°37E	Obs	Unpublished	A. SIMOVIĆ
Šabac - v. Majur	80	44°46N 19°40E	Lit	PAVLETIĆ 1964	J. PAVLETIĆ
Sremska Mitrovica - Jalija	77	44°58N 19°38E	Lit	LJUBISAVLJEVIĆ et al. 2013	G. DŽUKIĆ
Sremska Mitrovica - Zasavica	80	44°55N 19°28E	Lit	LJUBISAVLJEVIĆ et al. 2013	G. DŽUKIĆ
Sremski Karlovci - Stražilovo	270	45°10N 19°55E	Obs	Unpublished	I. KRIZMANIĆ
Užice - v. Lazovina	520	43°52N 19°52E	Lit	LJUBISAVLJEVIĆ et al. 2013	G. DŽUKIĆ
Užice - v. Potočanje	387	43°49N 19°54E	Obs	Unpublished	A. SIMOVIĆ
Valjevo - v. Beloševac	173	44°16N 19°56E	Lit	LJUBISAVLJEVIĆ et al. 2013	G. DŽUKIĆ
Vršac - city park	100	45°07N 21°19E	Lit	LJUBISAVLJEVIĆ et al. 2013	G. DŽUKIĆ
Vršac - v. Mesić	199	45°07N 21°24E	Lit	LJUBISAVLJEVIĆ et al. 2013	G. DŽUKIĆ
Zrenjanin	80	45°22N 20°26E	Lit	LJUBISAVLJEVIĆ et al. 2013	G. DŽUKIĆ

Table 3: Records of *Mediodactylus kotschyi* (STEINDACHNER, 1870). Obs - confirmed observation from the field (with voucher specimen or photo); Lit - published literature data. Coll - Specimen deposited in the Herpetological collection of the Institute for Biological Research "Siniša Stanković", Belgrade; Web - Website record.

Tab. 3: Nachweise von *Mediodactylus kotschyi* (STEINDACHNER, 1870). Obs - bestätigte Feldbeobachtung (Belegexemplar oder Foto); Lit - publizierte Literaturdaten; Coll - Exemplar ist in der herpetologischen Sammlung des Instituts für Biologische Forschung „Siniša Stanković" hinterlegt; Web - Der Nachweis ist auf der Website publiziert.

Locality/ Untersuchungsort	Alt (m)/ Höhe (m)	Coordinates/ Koordinaten	Type/ Typ	Reference/ Referenz	Informant,Collector/ Gewährsperson, Sammler
Belgrade - Stari Grad, Pajsijeva st.	111	44°48N 20°27E	Coll	Unpublished	A. ĆETKOVIĆ
Belgrade - Vračar	122	44°47N 20°28E	Web	BALEY & JABLONSKY 2006-2014	D. ĆOSO
Belgrade - Vračar, Kneginje Zorke st.	140	44°48N 20°28E	Obs	Unpublished	A. SIMOVIĆ
Belgrade - Zemun	93	44°50N 20°23E	Obs	Unpublished	A. SIMOVIĆ, J. ILIĆ
Niš - centre, warehouse	196	43°19N 21°55E	Lit	AJTIĆ 2009	R. AJTIĆ
Novi Sad - City - centre	82	45°15N 19°51E	Lit	AJTIĆ 2009	R. AJTIĆ
Novi Sad - City - centre	82	45°15N 19°51E	Web	BALEY & JABLONSKY 2006- 2014	N. PRERADOVIĆ
Smederevo - Fortress, southern wall	71	44°40N 20°55E	Obs	Unpublished	A. UROŠEVIĆ

1989; Willemsen 1995). This species was particularly overharvested in Serbia, legally and illegally (Ljubisavljević et al. 2011). The present scattered distribution of *T. hermanni* in Serbia can be interpreted as a result of local extinctions due to overharvesting and habitat alteration (Ljubisavljević et al. 2013). Anthropogenic translocations of this species sometimes lead to the establishment of new populations, as was the case in inland Slovenia (Krofel et al. 2009; Ljubisavljević et al. 2013). However, translocation is more often disastrous for tortoises because they escape, or are dumped, into completely unsuitable habitats. Additionally, there is concern that released pet tortoises can lead to uncontrolled gene flow ("genetic pollution") weakening native populations, or spread of diseases (van Dijk et al. 2004).

Mediodactylus kotschyi
(Steindachner, 1870) –
Native, expanding its range

The population of Kotschy's Gecko discovered in Prizren (Metohija, Serbia) in 1993 (Ajtić & Tomović 2001) is considered native, in acceptable agreement with the distribution patterns of *M. kotschyi* and other Mediterranean reptiles in Albania, Serbia and FYR of Macedonia (Haxhiu 1998; Ajtić & Tomović 2001; Ajtić 2004). However, the Prizren population is isolated from the rest of the species range (with large parts of Albania and Metohija being data deficient), its origin needs further consideration, including genetic analysis, because it could have also been introduced in historical times, e.g., via trading routes (Ajtić & Tomović 2001; Ajtić 2009; Böhme et al. 2009a). Native range boundaries of this species are largely explained by the natural spreading pathways along the Adriatic Sea coast and the Vardar and Drim River valleys (Haxhiu 1998; Ajtić & Tomović 2001; Ajtić 2009). This species is associated with dry, rocky places and Mediterranean climate. In the northern parts of its range, this gecko inhabits places with sub-Mediterranean or even continental climate, and is often associated with human settlements. It is nocturnal but regularly active by day, especially in the cooler parts of the year (Arnold & Ovenden 2002; Ajtić 2009).

Mediterranean geckos are well known colonizers. For example, many populations of the genera *Tarentola* and *Hemidactylus* are considered to be of anthropogenic origin: in the southern USA (Flower 1933; Davis 1974; Conant & Collins 1998), on Madeira Island (Jesus et al. 2002), in Spain, Portugal, Italy, Menorca, Crete and Tunisia (Harris et al. 2004), and on the Comoro Islands (Rocha et al. 2005). Anthropogenic dispersal could also be an important factor in distribution of Kotschy's Gecko on the Aegean Islands (Kasapidis et al. 2005). It is also considered introduced in southeastern Italy (Böhme et al. 2009a). There are two documented cases of deliberate introductions of *M. kotschyi* in Hungary by amateur herpetologists (in the cities of Siófok and Budapest), and in both cases, small but viable and reproducing colonies established (Farkas et al. 1999).

There are several populations of Kotschy's Gecko discovered in Serbia that were presumably introduced (Table 3, Fig. 1c). The population of Kotschy's Gecko recently discovered in Novi Sad (the capital of the Vojvodina province – Bačka region) is of anthropogenic origin, and well established, hence the introduction presumably occurred a relatively long time ago (Ajtić 2009). Introduced populations were also recorded in the towns of Belgrade (capital city: Šumadija region) and Niš (eastern Serbia) (Ajtić 2009). The established population in Belgrade was confirmed by field observations in different parts of the city (Table 3). In Niš, there is only one reported sighting of Kotschy's Gecko, in a local coffee warehouse, but it lacks expert confirmation. In the town of Smederevo (region Pomoravlje: Table 3), the population inhabiting sections of the southern wall of the medieval fortress has constantly been observed from 2010 to 2014 (Urošević, unpublished). During that time, individuals of all age classes were detected, usually in the evening or at night, and even in the afternoon in the shaded places. Animals in this population are apparently able to survive winters and to reproduce. They can start their seasonal activity as early as

March 15, if the weather conditions are favorable.

Important trading routes passed through the Balkans for centuries, and many Serbian cities including Novi Sad, Belgrade, Smederevo, Niš and Prizren were (and still are) important trading posts. The populations of Kotschy's Gecko in these towns could have originated by animals that had been brought accidentally with cargo shipments from the southern and eastern Balkans (AJTIĆ 2009). However, the first finding of Kotschy's Gecko in Novi Sad was reported in 2006 (N. RISTIĆ and J. HUSARIK, unpublished). The hypothesis of early introduction proposed by AJTIĆ (2009) cannot explain the fact that well established urban populations of partially diurnal geckos in Novi Sad and Belgrade were not noticed earlier. FARKAS et al. (1999) showed that once introduced this species can quickly establish breeding colonies; therefore relatively recent (10-15 years ago) simultaneous introduction into large urban centers is not unlikely.

There are no known negative impacts which *M. kotschyi* can have on native ecosystems. It can share the habitat with other species of gecko, as well as lacertid lizards (ARNOLD & OVENDEN 2002; AJTIĆ 2009). Kotschy's Gecko tends to be associated with human dwellings in the northwestern parts of its natural range; the populations in Skopje (FYR of Macedonia) and Prizren (Metohia region) are localized in urban and suburban areas (ARNOLD & OVENDEN 2002; AJTIĆ & TOMOVIĆ 2001; AJTIĆ 2009). The populations introduced to Hungary managed to establish and reproduce, but there was no further spreading (FARKAS et al. 1999). The populations in Novi Sad, Belgrade and Smederevo are apparently restricted to urban and suburban areas and do not spread to nearby natural habitats.

Podarcis muralis (LAURENTI, 1768) – Native, possibly expanding its range

In the north, the species' range reaches France, southern Belgium and the southernmost Netherlands, south-western Germany, southern and eastern Austria, Slovakia, Hungary and Romania. The southern range limits are located in central Spain, southern Italy and the southern Balkans. Most literature records consider this species to be native in the whole territory of Serbia, due to favorable climate and its north-eastern border lying in Romania, Hungary and Slovakia (RADOVANOVIĆ 1951; ARNOLD & OVENDEN 2002; SCHULTE et al. 2012).

The Common Wall Lizard usually requires sunny, rocky habitats; these are mostly absent in the flat, moist lowlands of the Pannonian plain north of the Sava and Danube Rivers (except on the Fruška gora and Vršački breg mountains). Accordingly, there is a gap in its distribution north of the Sava and Danube Rivers (Vojvodina province: Bačka, Srem and Banat regions) (GUILLAUME 2004). This species is also absent in lowland parts of Hungary, Croatia and Romania, which also belong to the Pannonian plain (GUILLAUME 2004; SCHULTE et al. 2012). In the Hungarian parts of the Pannonian plain, *P. muralis* occurs only in habitats with rocks, bare soil and scrub (HERCZEG et al. 2007). However, it is absent from the arid, sandy steppe areas of Deliblato sands (Serbia, Banat region) (HAM et al. 1981), which remained largely unchanged by agricultural activities, unlike the rest of the Pannonian plain in Serbia. On the other hand, *P. muralis* is very opportunistic and adaptable, and occurs in urban and suburban areas more often than any other small lacertid (ARNOLD & OVENDEN 2002); it was even described as hemerophilous or synanthropic "Kulturfolger" (GRUSCHWITZ & BÖHME 1986). The Common Wall Lizard is also an effective colonizer, especially of habitats modified by human activity. Introduced populations of *P. muralis* were documented in Romania (COVACIU-MARCOV et al. 2006; STRUGARIU et al. 2008; GHERGHEL et al. 2009), Germany, Austria, Switzerland, France, Belgium, the Netherlands and Croatia (SCHULTE et al. 2012), Great Britain (SMITH 1951; STAFFORD 1989; MICHAELIDES et al. 2012) and even in the USA (BROWN et al. 1995). It was shown that *P. muralis* can use gravel railroad beds as corridors for range expansion, as these artificial habitats offer shelter and quick thermal adjustment (COVACIU-MARCOV et al. 2006; STRUGARIU et al. 2008; GHERGHEL et al. 2009; SCHULTE et al. 2013a).

Table 4: Records of *Podarcis muralis* (Laurenti, 1768). Lit - published literature data; Obs - confirmed observation from the field (voucher specimen or photo).
Tab. 4: Nachweise von *Podarcis. muralis* (Laurenti, 1768). Lit - publizierte Literaturdaten; Obs - bestätigte Feldbeobachtung (Belegexemplar oder Foto).

Locality/ Untersuchungsort	Alt (m)/ Höhe (m)	Coordinates/ Koordinaten	Type/ Typ	Reference/ Referenz	Informant, Collector/ Gewährsperson, Sammler
Apatin - Poluostrvo 1	78	45°40N 18°57E	Lit	Perić & Stanković 2005	R. Perić, M. Stanković
Apatin - Staklara	82	45°39N 18°59E	Lit	Perić & Stanković 2005	R. Perić, M. Stanković
Bela Crkva - v. Banatska Palanka - Sapaja	69	44°49N 21°20E	Obs	Unpublished	G. Džukić, M. Marković
Belgrade - Novi Beograd - Bežanija	90	44°49N 20°22E	Lit	Pavletić 1964	J. Pavletić
Belgrade - Novi Beograd - Block 45	80	44°47N 20°22E	Obs	Unpublished	A. Urošević
Belgrade - v. Borča, Šebeš canal	70	44°52N 20°28E	Obs	Unpublished	M. Anđelković
Belgrade - v. Krnjača, embankment	71	44°50N 20°29E	Obs	Unpublished	M. Anđelković
Belgrade - Zemun	94	44°50N 20°23E	Lit	Pavletić 1964	J. Pavletić
Deliblato sands - v. Deliblato	92	44°50N 21°02E	Obs	Unpublished	A. Simović
Kovin - Kovin bridge	71	44°42N 20°57E	Obs	Unpublished	A. Urošević
Kovin - Marina	69	44°43N 20°58E	Obs	Unpublished	A. Urošević
Novi Sad - City - kej	77	45°14N 19°51E	Obs	Unpublished	A. Simović
Novi Sad - Petrovaradin - fortress	90	45°15N 19°51E	Obs	Unpublished	A. Simović
Pećinci - v. Obrež - Obedska Bara, hotel	76	44°44N 19°59E	Obs	Unpublished	A. Simović
Pećinci - v. Obrež - road to v. Kupinovo	70	44°44N 20°02E	Obs	Unpublished	A. Simović
Sremska Mitrovica - Zasavica bog	78	44°55N 19°28E	Obs	Unpublished	A. Simović
Sremski Karlovci - Krstuševine	149	45°11N 19°56E	Obs	Unpublished	L. Tomović
Sremski Karlovci - Zanoš	153	45°12N 19°54E	Obs	Unpublished	A. Simović
Subotica - Railway station	108	46°05N 19°40E	Obs	Unpublished	I. Hulo
Subotica – Senčanski put	108	46°05N 19°40E	Obs	Unpublished	A. Urošević
Surčin - v. Bečmen - lakes	76	44°47N 20°13E	Obs	Unpublished	A. Simović
Surčin - v. Boljevci	72	44°43N 20°12E	Obs	Unpublished	A. Simović
Surčin - v. Boljevci - Crni Lug	71	44°43N 20°09E	Obs	Unpublished	A. Simović
Surčin - v. Progar - Bojčinska forest	73	44°43N 20°09E	Obs	Unpublished	A. Simović
Zrenjanin - v. Melenci - graveyard	78	45°31N 20°19E	Obs	Unpublished	L. Tomović
Zrenjanin - v. Orlovat - bridge	72	45°14N 20°35E	Obs	Unpublished	A. Simović
Zrenjanin - v. Tomaševac - water gate	71	45°17N 20°38E	Obs	Unpublished	A. Simović

All populations of *P. muralis* in the Serbian lowlands north of Sava and Danube Rivers (Vojvodina province) are concentrated in urban and rural areas, or otherwise modified habitats, often only on the northern banks of the above-mentioned rivers (Table 4, Fig. 1d). Exceptions are the populations on the Fruška gora and Vršački breg mountains, which are found in unmodified habitats. It is therefore assumed that this species was introduced by human activity (often brought accidentally with building materials), or expanded its range via bridges, railroad beds and river embankments. Introductions could have happened in historical times. Building materials for Roman, Hungarian or Turkish settlements and fortresses in the Pannonian plain were often brought from quarries south of the Danube River. Later, these populations could have expanded via stony or concrete river and canal embankments, road shoulders and railroad beds. Recent phylogeographic studies, which considered a few native populations from Serbia, assigned them to the Central Balkan clade (SALVI et al. 2012; SCHULTE et al. 2012). A more detailed phylogeographic analysis is needed, which should include a greater number of possibly introduced populations north of Sava and Danube Rivers, as well as native populations from Serbia and surrounding countries, to correctly assess the origin of these populations. Until then, the assumptions about *P. muralis* being introduced in the Vojvodina province remain tentative.

There are some major concerns about anthropogenic translocations of *P. muralis.* This highly adaptable and opportunistic species can have a strong competitive advantage over native lacertid lizard species; e.g., in northern parts of Serbia (Vojvodina province), lowland populations of *Lacerta agilis* (LINNAEUS, 1758) and *Podarcis tauricus* (PALLAS, 1814) might be at risk as cases of competitive displacement have been noted (SCHULTE et al. 2008, 2012). Native populations of *P. muralis* are also at risk of being "genetically swamped" by introduced lineages (SCHULTE et al. 2008, 2012, 2013b). For instance, in areas colonized by different lineages (MICHAELIDES et al. 2012; SCHULTE et al. 2012), hybridization

Table 5: Records of *Pelodiscus* sp., *Hemidactylus turcicus* (LINNAEUS, 1758), *Podarcis tauricus* (PALLAS, 1814) (introduced population) and *Vipera ammodytes* (LINNAEUS, 1758) (incidental findings). Obs - confirmed observation from the field (with voucher specimen or photo); Unc - Unconfirmed field observation; Lit - published literature data; Coll - Specimen deposited in the Aquarium of the Faculty of Science in Kragujevac.

Tab. 5: Nachweise von *Pelodiscus* sp., *Hemidactylus turcicus* (LINNAEUS, 1758), *Podarcis tauricus* (PALLAS, 1814) (eingeführte Population) und *Vipera ammodytes* (LINNAEUS, 1758) (Zufallsfunde). Obs - bestätigte Feldbeobachtung (Belegexemplar oder Foto); Unc - Unbestätigte Feldbeobachtung. Lit - Literaturdaten; Coll - Exemplar ist im Aquarium der Naturwissenschaftlichen Fakultät in Kragujevac hinterlegt.

Species/ Art	Locality/ Untersuchungsort	Alt (m)/ Höhe (m)	Coordinates/ Koordinaten	Type/ Typ	Reference/ Referenz	Informant, Collector/ Gewährsperson, Sammler
Pelodiscus sp.	Apatin – Danube, near the town	80	45°39N 18°57E	Coll	Unpublished	V. SIMIĆ, G. DŽUKIĆ
Pelodiscus sp.	Belgrade – Danube, near the city	70	44°49N 20°27E	Unc	Unpublished	T. VUKOV
Hemidactylus turcicus	Bačka Palanka - Čelarevo	83	45°16N 19°31E	Obs	Unpublished	A. STAJFER
Podarcis tauricus	Kovin - Kovin bridge - embankment	71	44°42N 20°57E	Obs	Unpublished	A. UROŠEVIĆ
Vipera ammodytes	Apatin - v. Prigrevica - Sveti Ivan	84	45°40N 19°04E	Lit	DŽUKIĆ et al. 2005	Đ. MIRIĆ
Vipera ammodytes	Novi Sad - City - Štrand	74	45°14N 19°50E	Lit	DŽUKIĆ et al. 2005	I. KRIZMANIĆ
Vipera ammodytes	Sremski Karlovci	91	45°11N 19°56E	Lit	DŽUKIĆ et al. 2005	W. BECKER

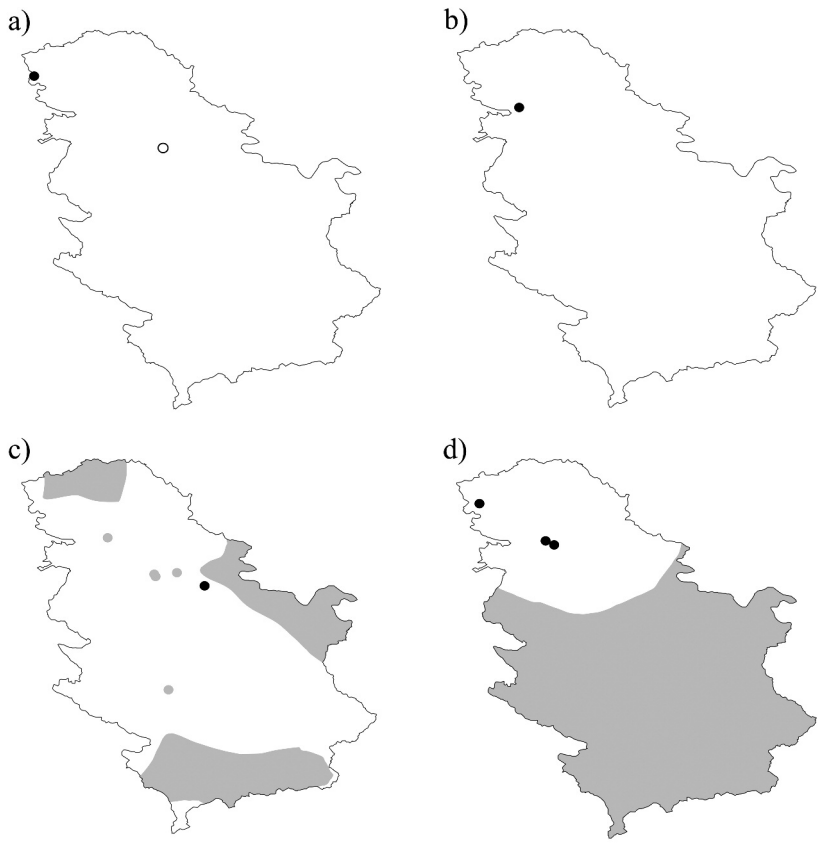

Fig. 2: Records of four more reptile species studied in Serbia; confirmed and unconfirmed introductions and anthropogenic range extensions of native species. Solid circles – confirmed introductions; empty circles – unconfirmed introductions; gray areas – native species' range. a) *Pelodiscus* sp.; b) *Hemidactylus turcicus* (Linnaeus, 1758); c) *Podarcis tauricus* (Pallas, 1814); d) *Vipera ammodytes* (Linnaeus, 1758). For the native species, known native ranges were given according to Böhme et al. (2009b), modified according to Méhely (1903), Karaman (1939), Radovanović (1951, 1964), Džukić (1974) and Ham et al. (1981) for *P. tauricus* and Agasyan et al. (2009) and Jelić et al (2013) for *V. ammodytes.*

Abb. 2: Nachweise für vier weitere untersuchte Reptilienarten in Serbien; bestätigte und unbestätigte Einschleppungen und anthropogene Ausbreitung der einheimischen Arten. Gefüllte Kreise – bestätigte Einschleppungen; leere Kreise - unbestätigte Einschleppungen; graue Bereiche - angestammte Verbreitung einheimischer Arten. a) *Pelodiscus* sp.; b) *Hemidactylus turcicus* (Linnaeus, 1758); c) *Podarcis tauricus* (Pallas, 1814); d) *Vipera ammodytes* (Linnaeus, 1758). Das Verbreitungsgebiet der einheimischen Arten wurde gemäß folgender Literaturangaben dargestellt: Böhme et al. (2009b), modifiziert nach Méhely (1903), Karaman (1939), Radovanović (1951, 1964), Džukić (1974) und Ham et al. (1981) für *P. tauricus*, Agasyan et al. (2009) und Jelić et al (2013) für *V. ammodytes.*

between distinct lineages may, in the long term, affect establishment success and viability of the introduced populations (Michaelides et al. 2012).

Miscellaneous introductions of single specimens and incidental findings

Chinese softshell turtles, *Pelodiscus* spp., are medium-sized carnivorous turtles. They were formerly known as a single species, *Pelodiscus sinensis* (Wiegmann 1835) until recent research showed that *"P. sinensis*" consists of four distinct species (Fritz et al. 2010; Stuckas & Fritz 2011). Chinese softshell turtles are the only softshell turtle species introduced to Europe (Somma 2013). However, the specific status of imported animals is unknown, and introduction of several species and hybridization may be expected (Fritz et al. 2010; Stuckas & Fritz 2011). According to the literature, Chinese softshell turtles are found in Spain, Germany, Great Britain, France and Latvia (Barbadilo et al. 1999; Kirschey 2000; Lever 2003; Kraus 2009b; Pupiņš & Pupiņa 2011). The recent findings in Slovenia, Croatia and Bosnia and Herzegovina (Brejcha et al. 2014) are the first published findings of these species in the Balkans.

A single specimen of the softshell turtle was caught in the Danube River near the town of Apatin (Džukić, personal communication). It had been kept alive in the Aquarium of the Faculty of Science in Kragujevac from 1999 to 2009, when it died of unknown causes (Simić, personal communication). It is now kept as a preserved specimen. Another expert sighting of the softshell turtle was reported near Belgrade, without voucher specimen or photo (Table 5, Fig. 2a). Considering that *Pelodiscus* spp. are the only softshell turtles introduced in Europe, the findings near Apatin and Belgrade were most likely these species. Chinese softshell turtles are a popular source of food in the traditional Asian cuisine and farm-bred for this purpose in high numbers (Fritz et al. 2010). However, the turtles in Europe originate from the pet trade (Kraus 2009b). Chinese softshell turtles are considered invasive; they are predatory, can negatively impact the local aquatic fauna and could establish viable populations (Somma 2013). Since only two sightings for *Pelodiscus* have been reported (one with voucher specimen), it can be recognized as a potential threat at most. Further findings of these possibly invasive turtles and the possible establishment of local populations in Serbia must systematically be reported and monitored.

The Turkish Gecko, *Hemidactylus turcicus* (Linnaeus, 1758), is a small, nocturnal gecko widespread throughout the Mediterranean basin (Arnold & Ovenden 2002). This adaptable species is common in anthropogenic habitats, including urban zones (Agasyan 2009a). Unintentional introductions of this species have been reported for India and the southern United States of America (Flower 1933; Davis 1974; Conant & Collins 1998), Canary Islands, Cuba, Mexico, Panama and Puerto Rico (Agasyan 2009a).

The Turkish Gecko is not a native in Serbia, and there are no published reports on introduction of this species, although unconfirmed amateur reports exist. A single specimen of *H. turcicus* was photographed by an amateur in Čelarevo near Bačka Palanka (Bačka, Serbia) (Table 5, Fig. 2b) and identified by the first author. The animal was hiding among wooden palettes in the local brewery's warehouse. Those palettes were brought from Montenegro, Greece and Israel, and the animal was most likely introduced from one of the countries.

Although the Turkish Gecko is an adept colonizer, and it's range is expanding (Nelson & Carey 1993; Meshaka et al. 2006), it is often restricted to anthropogenic habitats, and it's spreading to the north is limited by climate (Meshaka et al. 2006). Since only one incidental finding has been confirmed, dispersal of this species in Serbia is unlikely.

The Crimean Wall Lizard *Podarcis tauricus* (Pallas, 1814), has a very fragmented range in Serbia (Méhely 1903; Karaman 1939; Radovanović 1951, 1964; Džukić 1974). Because it is associated with open steppe habitats (Arnold & Ovenden 2002), its present range fragmentation could be explained by habitat loss due to agricultural development (Böhme et al. 2009b). On the other hand, this species could benefit from the anthropogenic habitat alteration. It can colonize suitable habitats of anthropogenic origin, particularly sandy, sparsely vegetated parts of river embankments (Džukić,

personal communication). The present river embankment on the Danube near the town of Kovin (Banat region) was built after 1972 (Džukić et al. 2008). Prior to that, *P. tauricus* had not been detected on that part of the Danube bank. Instead, it was recorded further to the north-east, in the Deliblato sands (Radovanović 1951; Džukić 1974, Džukić, personal communication). The population recently detected on the Danube bank near the Kovin bridge (Banat region) (Table 5, Fig. 2c) is most likely a result of recent migration along the river and canal embankments. However, the population was detected within the species' range (Radovanović 1951; Ham et al. 1981; Chondropoulos 2004; Ljubisavljević et al. 2010). Therefore, the authors did not make further assessments concerning *P. tauricus*.

There are also a few confirmed incidental reports of the Nose-horned Viper *Vipera ammodytes* (Linnaeus, 1758) outside of the species' north-western distribution range in the lowland province of Vojvodina (Radovanović 1951; Arnold & Ovenden 2002; Crnobrnja-Isailović & Haxhiu 2004; Džukić et al. 2005). Individual specimens were found in the village of Prigrevica (near the town of Apatin), Novi Sad city (Bačka region) and in the town of Sremski Karlovci (Srem region) (Džukić et al. 2005) (Table 5, Fig. 2d). Those specimens were likely brought accidentally with building materials (e.g., limestone) or wood. The establishment of local viper populations is unlikely in flat, moist lowlands which lack adequate habitats for this species (Radovanović 1951; Arnold & Ovenden 2002; Agasyan et al. 2009b; Jelić et al. 2013). However, incidental introductions of Europe's most dangerous venomous snake into human habitations in regions from which it is generally absent, is of medical and veterinary significance, and must be reported and strictly monitored (Džukić et al. 2005).

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