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New data on introduced geckos of the *Mediodactylus kotschyi* complex in Hungary

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The emergence of invasive alien species is one of the most significant threats to biological diversity worldwide (IPBES, 2019). Despite efforts, not much is known surrounding the range and biology of adventive species. Many turn invasive, but in the early stages of their establishment escape detection (Crooks and Soulé, 1999), thus curbing effective measures to stop their spread or to evaluate the threat they pose to local ecosystems. Collection of early data on them is, therefore, of paramount importance.

Hungary has been invaded by several non-indigenous species of plants (Csiky et al., 2023) and animals (Haraszthy, 2022). Among reptiles, so far, only a few species have established populations in the country. The Pond Slider (*Trachemys scripta*) poses the most significant threat to the native European Pond Turtle (*Emys orbicularis*) (Weiperth, 2022). The sporadic but lately regular observations of the Snapping Turtle (*Chelydra serpentina*) in Hungary also elicit concern (Babocsay, 2022a). Other non-native turtles captured in Hungary include the Chinese Soft-shelled Turtle (*Pelodyscus sinensis*), the Chinese Pond Turtle (*Mauremys reevesii*), and the False Map Turtle (*Graptemys pseudogeographica*) (Haraszthy, 2022; Szajbert and Weiperth, 2022; Weiperth, 2022), but their successful establishment has not yet been confirmed.

Among squamates, geckos of the *Mediodactylus kotschyi* species complex from the Balkans (see Kotsakiozi et al., 2018) have been reported from four localities within Hungary (Farkas et al., 1999; Babocsay, 2021, 2022b). Outside its native range *M. kotschyi* (or its former subspecies elevated to species level) has been reported from inland Bulgaria (Novi Pazar, Plovdiv, Ruse [possibly extinct], Shumen) (Petkov, 2002; Beshkov and Nanev, 2006; Mollov et al., 2015; Koynova et al., 2017, 2020), Serbia (Belgrad, Leskovac, Niš, Negotin, Novi Sad, Smederevo), Kosovo (Prizren) (Urošević et al., 2016, 2021, 2023), and from Romania (Bucharest) (Gherghel and Tedrow, 2019). The Kotschy's Gecko (*sensu* Kotsakiozi et al., 2018) occurs in the Eastern Mediterranean from the southeastern Italian Peninsula (Apulia and Basilicata) to the south of the Balkan Peninsula (Albania, southern North Macedonia and Greece including the Aegean Islands). About 20 subspecies are recognised (Uetz et al., 2024) to date. Some populations formerly treated as subspecies of *M. kotschyi* have been elevated to the species level (Kotsakiozi et al., 2018): *Mediodactylus bartoni* (Crete and the surrounding smaller islands), *M. danilewskii* (Crimea, southeast Bulgaria, Thrakia, southwest Asia Minor), *M. oertzeni* (Dodekanese, Greece), and *M. orientalis* (Ikaria, Samos, Cyprus, south of Asia Minor, Western Syria, Lebanon, Israel). Especially in the northern parts of their ranges (e.g., Bulgaria, Crimea) these geckos often inhabit buildings (Beshkov and Nanev, 2006; Petrov, 2007; Mollov, 2014; Kukushkin et al., 2019), while elsewhere, especially towards the south, they are often seen in natural habitats, on boulders, stone fences and tree trunks (Werner, 1993; Schwarz et al., 2016; Kukushkin et al., 2019). It seems that the populations beyond the native ranges are established from synanthropic populations living on buildings (Mollov, 2014; Mollov et al., 2015). Geckos of the *Mediodactylus kotschyi* complex were first reported in Hungary by Farkas et al. (1999). Since then, new populations have been found within the country. Using data collected in the field, obtained from Herpterkep (2024), a Hungarian online herpetological mapping platform, from social media platforms, and from inquiries of private residents, I summarise what is known to date about these populations.

Material and Methods

Observation data were obtained from the following

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sources: 1) historical data on previously known populations in the literature; 2) interviews with the herpetoculturists who accidentally or intentionally released geckos and, thus, established the current feral populations; 3) social media platforms and other online sources: Herpterkep – the herpetological mapping platform of the Amphibian and Reptile Conservation Group of MME BirdLife Hungary (ARCG MME) (Herpterkep, 2024), Facebook groups of ARCG MME (2024); and Állathatározó ~ Animal Identifier (2024); and 4) field surveys, and inquiries made of residents in gecko-colonised neighbourhoods. Online sources of geckos were considered confirmed only when vouchered by photograph.

Field surveys were carried out from late April until late September after dusk, between 20.00– 00.00 h in 2023 and 2024 in suitable weather conditions: in warm (<20 ºC) and calm (without wind and rain) nights. In each survey one to four persons participated. Surveyors walked along sidewalks and looked for the geckos or their calls on the building facades. Geckos were visually (using flashlight) and acoustically localised. Only ten surveys yielded geckos. The number of unsuccessful surveys was not recorded, but did not exceed ten. Only approximate temperatures were recorded using online weather applications (idokep.hu), except on one occasion when an infrared thermometer was used. When possible, photos were taken of the observed individuals. Locations were recorded by GPS implemented in smart phone (Samsung A20) and by recording postal addresses.

Specimens collected by residents or herpetoculturists, when died, were deposited in the Vertebrate Collection of the Mátra Museum of the Hungarian Natural History Museum, Gyöngyös (HNHM MM), Hungary. Due to the low number of specimens (voucher specimens and high resolution photographs), morphological analysis into the species identity was not performed.

Results

Historical data, inquiries of herpetoculturists. To date three existing and one eradicated populations of the *Mediodactylus kotschyi* complex have been recorded in Hungary (Appendix 1; Figs 1, 2). Two of them were reported by Farkas et al. (1999): one from a residential house (92/B Budaörsi Road, 11th district of Budapest) and another from a residential house of Balatonszéplak, western Hungary. Most probably, the former population went extinct when the house was demolished in 2012. Some geckos were rescued before the destruction of their habitat, but their fate is unknown. This population was intentionally introduced by a herpetologist and reptile keeper in 1984 or 1985. Four or five founding individuals from either Sandanski (southwest Bulgaria) or Sozopol (on the Bulgarian Black Sea Coast; uncertain recall due to elapsed time since) were released in the stairwell of the building. By the mid-1990s the geckos could be seen regularly, though their number was probably not higher than two dozen. The Balatonszéplak population was also established in 1985 from Sandanski, Bulgaria. The population still exists according to the owner of the house and has spread to one or two neighbouring buildings.

In the early 2000s, Kotschy's Geckos started to pop up in the inner part of the 9th district of Budapest

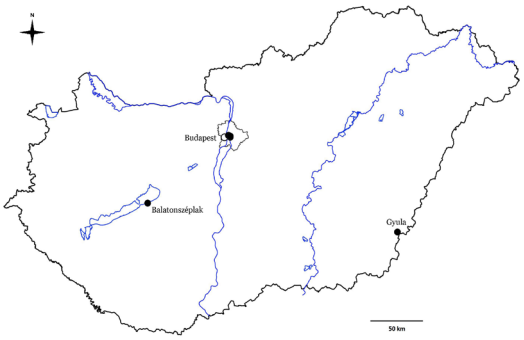

Figure 1. Occurrences of geckos of the *Mediodactylus kotschy* complex in Hungary. Empty dot: extinct population. Solid dots: extant populations.

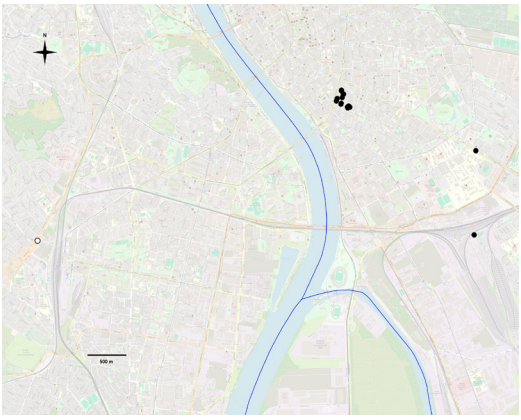

Figure 2. Occurrences of geckos of the *Mediodactylus kotschy* complex in Budapest, the capital of Hungary. Empty dot: extinct population. Solid dots: extant populations.

characterised by old, large, four-five storey buildings. Inquiries revealed that the founders of this population escaped a wall terrarium that fell and broke in 1983 or 1984. According to their keeper, these geckos too were collected in Sandanski, Bulgaria. At that time, just a few houses away, another amateur herpetologist (since passed away) also kept geckos from Sandanski, additional escapees or freed individuals from that stock may have joined the founders. The location of one specimen collected in 2007 was indicated as being "close to Népliget", the outer part of the 9th district. This distance is rather far (over two kilometres) from the above population with no intermediate observations. The specimen was brought in to the Department of Systematics and Ecology of the Eötvös Loránd University, but the identity of the collector and the precise location cannot be retrieved. This locality should be treated as dubious. Another young Kotschy's Gecko was observed in a store house of the Hungarian National Railways in October 2024. This location is 2.5 kilometres away from the population of the inner 9th district, again, with no intermediate observations and separated by a wide rail yard.

A fourth population from a residential house in Gyula, southeast Hungary was reported in 2020 by the owner of the house. The geckos were first observed in 2008. Their origin is unknown. They might have been accidentally introduced by one of the neighbours who runs an international road freight company which also operates in the Balkans.

Data from mapping platforms, social media, field surveys and residents. A total of 14 geckos were observed in the 9th district of Budapest in 2024 and another 22 geckos were reported by residents and by herpetology enthusiasts (in the period between 2020 and 2024) These observations include repeated sights of the same geckos (Appendix 1). Except for the two outlying observations in the outer 9th district all geckos were found within an area of approximately 170 by 200 metres characterised by four-five storey city buildings. Of these, two geckos were reported in herpterkep.hu, and five individuals were reported on the Facebook groups of ARCG MME and Állathatározó (~ Animal Identifier). During our surveys, the temperatures hovered around 30 ºC during the summer. The lowest temperature at which geckos were observed outside was 20 ºC (air) and 22 ºC (wall) on 5 May 2024.

We surveyed the population on a residential house in Gyula, southeast Hungary in the evening of 18 August 2022 and observed ca. 15 individuals (sightings and

Figure 3. Kotschy's Gecko (*Mediodactylus kotschyi*) on an old city building in the 9th district of Budapest (Tompa Street 6). Photograph number: HNHM MM Gy/287. Photo by Gergely Babocsay.

Figure 4. Internal yard of an old city building as habitat of Kotschy's Geckos (*Mediodactylus kotschyi*) in the 9th district of Budapest (Ferenc körút). Photo by Gergely Babocsay.

calls). Flashlight searches yielded an additional two Kotschy's Geckos on the facades of two neighbour buildings, one on each. Exact locations of the residential houses are not given for privacy considerations.

Discussion

I reported here on four established populations of the *Mediodactylus kotschyi* species complex in Hungary, one of which has been extirpated by a real estate development project. Tracing back the origins of the geckos revealed that the Balatonszéplak and the Budapest 9th district populations almost certainly came from stocks collected in the town of Sandanski, southwest Bulgaria. In the early 1980s several amateur herp-enthusiast visited this area, the richest area for Balkan reptiles that could be easily accessed for non-Soviet citizens of the Communist Bloc. Kotschy's Geckos were collected from house facades and were kept as pets. Some, like the geckos in the 9th district escaped accidentally, while others, like the ones in the Budaörsi Road, were intentionally freed as keeping them turned out to be cumbersome. Still others (in Balatonszéplak) were released with the intent to establish a feral population. The two disjunct observations in the outer parts of the 9th district of Budapest are puzzling in terms of their origin. They either indicate the expansion of the inner part of the 9th district population or they represent nascent propagules established by short distance introductions by humans from the inner 9thdistrict, or from somewhere else.

The Budaörsi Road populations came either from Sandanski, southwest Bulgaria or from Sozopol, Coastal Bulgaria. It is unknown whether the rescued geckos from this population survived in captivity or were re-released somewhere in town. Three old houses near the demolished building are still standing, but it is not known whether any geckos survived on them. Tracing the origins of the Gyula, population has so far been unsuccessful. A morphological and genetic study is needed to substantiate their taxonomic and geographical affinity.

Hungary, having a wet continental climate, lies well outside of the natural range of the *M. kotschyi* species complex. Budapest's annual mean temperature (average of 1991-2020) is 9.7 ºC, its January mean temperature is 0.0 ºC, while July's mean temperature is 22.6 ºC (Hungarian Meteorological Service, 2024). In winter, the temperatures can plummet below -10 ºC, making conditions suboptimal for the Mediterranean *M. kotschyi*. However, the heated buildings can provide safe hibernacula and indeed, geckos have been observed inside apartments and in stairwells, where temperatures stay above zero even on cold winter days. Conversely, the warm seasons are warm enough to allow the geckos to be active by night, and to prolong their active season long enough to maintain optimal physical conditions to reproduce. It is unclear how easily these geckos disperse. In case of populations on residential houses, the owners' and our observations confirmed dispersion, but in only over a few houses distance. The Budapest population, however, colonised at least an area of 170 by 200 metres on four-five story buildings attached to each other. This area includes a narrow street which the geckos either crossed on their own, or via objects moved by humans such as furniture. Despite our searches, buildings beyond the above mentioned city block have thus far not yielded any geckos. However, it is difficult to spot the small grey geckos on the old, dark facades of tall city buildings. They often ambush close to gutters or behind air conditioners or other objects. When asked, most residents were completely oblivious to the presence of geckos. This means, that in the future, geckos may be observed beyond the area they have been seen in thus far. The types of buildings that yielded geckos varied. Geckos were equally likely to be found on old buildings with cracked rendered facades or stone cladding, as well as on modern buildings with neat external polystyrene insulation. Most likely, all provide gaps leading into frost-free inner cavities. The ambush heights of the geckos on facades ranged from above two metres up to approximately five metres. Spotting them higher up is hampered by poor visibility. Geckos also entered apartments on the top floors (3rd or 4th), close to the roof. Living on the upper floors may allow geckos to bask in the sun within the internal courtyards of the tall buildings where sunshine rarely reaches the lowest floors.

It is unclear at what temperatures geckos start their activity in spring and finish it in autumn. In Gyula, the geckos appear in April and stop showing up in early October. This indicates a rather short activity season, but it may be possible that they start earlier and continue later into the season but with a more elusive presence. In Bulgaria, *M. kotschyi* was observed being active in mid-January and down to 12 ºC (Mollov et al., 2015), in Crimea *M. danilewskii* was observed below 9 ºC (down to 4.2 ºC) air temperature in winter (Kukushkin, 2006, 2007).

The long-term survival of some of the populations may be ensured by the relatively temperate spaces in the buildings they colonised. The survival of geckos living

in residential buildings is less assured as exemplified by the demise of the Budaörsi Road population. However, populations spreading in downtown Budapest apartment buildings may survive and continue to spread. The geckos of the *M. kotschyi* complex will probably not have a significant impact on the local herpetofauna as competitors, but they may carry parasites unknown to native reptiles (Matyot, 2004). This may negatively affect native reptile populations, especially the urbanised Common Wall Lizard (*Podarcis muralis*).

As our inquiries revealed, the founder geckos in Balatonszéplak and in the inner part of the 9th district of Budapest came from Sandanski, southwest Bulgaria. These geckos therefore belonged to the subspecies *Mediodactylus kotschyi bibroni* (Beutler and Gruber, 1977) (Valakos et al., 2008; Stojanov et al., 2011; Koynova et al., 2020), but see opposing nomenclatural proposal in Kotsakiozi et al. (2018). The geckos from the Budaörsi Road, 11th district, Budapest came either from Sandanski, southwest Bulgaria or Sozopol, eastern Bulgaria. Therefore they could belong either to *M. kotschyi* (Steindachner, 1870) or *M. danilewskii* (Strauch, 1887) (Beshkov and Nanev, 2006; Koynova et al., 2020). The origin and therefore the taxonomic identity of the population in Gyula remain unknown.

It seems that the ability of the geckos to spread is limited, at least in case of populations on residential houses. Geckos on large building complexes spread to all surrounding buildings within a complex, but how much they are inclined to cross streets onto other building complexes is unclear. Our data so far indicates slow colonisation. It is also important to note that contrary to the common speculations in the literature, three out of the four known Hungarian populations of the *M. kotschyi* complex were established – either intentionally or accidentally – by herpetoculturists, rather than as by stowaways in transported goods.

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Appendix 1. Observations of geckos of the *Mediodactylus kotschyi* complex in Hungary. For the still existing residential private houses, for privacy considerations only the coordinates of the geographic centres of their settlements are given.

Date	No.	Age	Locality	Coordinates		Altitude (m)	Air temp. (ºC)	Coll. no. of voucher
2007	1	ad	outer 9th dist., "Népliget"	47.4775N	19.0935E	114	n/a	MM2024.85.1.
27 Sep 2020	1	ad	inner 9th dist.	47.4840N	19.0696E	104	n/a	MM 2024.78.1.
18 Nov 2020	1	juv	inner 9th dist.	47.4843N	19.0701E	104	n/a	
25 May 2023	1	ad	inner 9th dist.	47.4840N	19.0696E	104	n/a	
7 Sep 2023	1	n/a	inner 9th dist.	47.4838N	19.0715E	104	n/a	MM 2023.7.1.
Spring 2024	1	juv	inner 9th dist.	47.4843N	19.0701E	104	n/a	
Spring 2024	1	n/a	inner 9th dist.	47.4843N	19.0701E	104	n/a	
5 May 2024	2	ad, subad.	inner 9th dist.	47.4824N	19.0716E	104	20	
5 May 2024	1	juv	inner 9th dist.	47.4828N	19.0700E	104	20	
13 May 2024	1	ad	inner 9th dist.	47.4834N	19.0694E	104	20	
13 May 2024	call	n/a	inner 9th dist.	47.4823N	19.0712E	104	20	
13 May 2024	1	ad	inner 9th dist.	47.4824N	19.0716E	104	20	
20 Jun 2024	1	ad	inner 9th dist.	47.4828N	19.0701E	104	n/a	
22 Jun 2024	1	ad	inner 9th dist.	47.4825N	19.0714E	104	n/a	
1 Jul 2024	1	ad	inner 9th dist.	47.4839N	19.0705E	104	n/a	
1 Jul 2024	1	ad	inner 9th dist.	47.4839N	19.0705E	104	n/a	
1 Jul 2024	1	ad	inner 9th dist.	47.4824N	19.0716E	104	n/a	
13 Jul 2024	1	ad	inner 9th dist.	47.4831N	19.0693E	104	30	MM Gy/287
13 Jul 2024	2	ad	inner 9th dist.	47.4839N	19.0705E	104	30	
13 Jul 2024	call	n/a	inner 9th dist.	47.4839N	19.0705E	104	30	
16 Jul 2024	1	ad	inner 9th dist.	47.4824N	19.0712E	104	n/a	
22 Jul 2024	1	ad	inner 9th dist.	47.4825N	19.0714E	104	28	
22 Jul 2024	call	n/a	inner 9th dist.	47.4825N	19.0714E	104	28	
31 Jul 2024	1	juv	inner 9th dist.	47.4839N	19.0705E	104	n/a	
8 Aug 2024	1	n/a	inner 9th dist.	47.4839N	19.0705E	104	n/a	
8 Aug 2024	1	n/a	inner 9th dist.	47.4824N	19.0712E	104	n/a	
10 Aug 2024	1	ad	inner 9th dist.	47.4824N	19.0716E	104	28	
22 Aug 2024	1	ad	inner 9th dist.	47.4824N	19.0712E	104	25	
22 Aug 2024	1	ad	inner 9th dist.	47.4843N	19.0701E	104	n/a	MM 2024.90.1.
28 Aug 2024	1	subad.	inner 9th dist.	47.4843N	19.0701E	104	n/a	
1 Sep 2024	1	ad	inner 9th dist.	47.4839N	19.0704E	104	n/a	
1 Sep 2024	2	ad	inner 9th dist.	47.4835N	19.0703E	104	n/a	
22 Oct 2024	1	juv	outer 9th dist., Péceli str.	47.4679N	19.0932E	115	n/a	
1984/85-	extinct popul.		Budaörsi út 92/b, Budapest	47.4672N	19.0173E	125	n/a	
1985-	popul.		Balatonszéplak	46.8973N	18.0055E	107	n/a	
2008-	popul.		Gyula	46.6500N	21.2828E	85	n/a	MM 2024.1.1-2.

Accepted by Francesco Paolo Faraone