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Mediodactylus kotschyi in the Peloponnese peninsula, Greece: distribution and habitat

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Abstract. The gecko *Mediodactylus kotschyi* is considered rare in mainland Greece, yet it is very abundant on the Aegean islands. It has been thought to be saxicolous throughout much of its range. In a recent survey on the Peloponnese peninsula, however, we encountered it mainly on trees, and with higher frequency than previously reported. We combined our observations of localities in which we detected this gecko, and places where we failed to detect it, with data about its occurrence from the literature and museum collections. We posited two hypotheses as possible causes for the apparent relative scarcity of *M. kotschyi* in the Peloponnese: that it is associated with low precipitation and that it has an aversion to limestone rock. We predicted that *M. kotschyi* would be more likely to be found in arid places and where limestone is not the dominant type of rock, since it has been reported that this substrate is less suitable for this species. Moreover, we predicted that geckos occurring in limestone regions would be found on trees rather than under rocks. Geckos were indeed found mainly in the more arid parts of the Peloponnese, but not exclusively so. We found no evidence of limestone avoidance. We suggest that, because *M. kotschyi* is better known as being mostly saxicolous over most of its range, and exclusively so on the Greek islands, in the Peloponnese the search for this species has been restricted to a single habitat type, i.e., under rocks and not on trees. It may thus inhabit more localities in the Peloponnese and be more abundant there than has previously been thought.

Keywords. Arboreality, habitat preferences, *Mediodactylus kotschyi*, Peloponnese, rock type.

INTRODUCTION

The genus *Mediodactylus* is predominantly Asian, with only one of 13 species being found in Europe. The Mediterranean thin-toed gecko, *Mediodactylus kotschyi* (Steindachner, 1870) (Reptilia: Gekkonidae), has a discontinuous distribution incorporating southern Italy, through to the Balkans and the Crimean peninsula, to Israel and Iran (Arnold and Ovenden, 2002; Sindaco and Jeremcenko, 2008).

In Greece, *M. kotschy* is ubiquitous and highly abundant on the Sporades, Cyclades, and south Aegean islands as well as around Crete, where its distribution is well documented (e.g., Wettstein, 1937; Beutler and Gruber, 1977; Beutler, 1981; Chondropoulos, 1986), and its diversity is high: 13 subspecies are currently recognized from the Greek islands (Karandinos and Paraschi, 1992; Kasapidis et al., 2005; Uetz and Hošek, 2016). However, it is considered to be rare on the Greek mainland and throughout the Balkans (Stojanov et al., 2011; Tomovic et al., 2014), and is often absent from Peloponnese species checklists (e.g., Werner, 1929; Cyrén, 1935; Bischoff and Bischoff, 1980; Henle, 1989; Pèrez-Mellado et al., 1999).

The Peloponnese peninsula nonetheless forms a major part of *M. kotschyi*'s distribution on mainland Greece

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(Valakos et al., 2008). It has been recorded from several locations (e.g., Monemvasia, the terra typica of *M. k. bibroni*, Beutler and Gruber, 1977; Sparta and Kalamata, Stepánek, 1937), and is thought to be widespread in the western Peloponnese (Valakos et al. 2008). It is nonetheless considered rare, exhibiting a low population density almost everywhere on the Greek mainland (Ajtić, 2014).

M. kotschyi is described as being mainly saxicolous across much of its range, being found under rocks and stone piles, on dry stone walls and even on the external walls of houses and other buildings (Beutler, 1981 and citations therein; Musters and In den Bosch, 1982; Arnold and Ovenden, 2002; Ajtic 2014). In Greece it is described as preferring dry areas with phrygana (=dwarf shrub steppe) vegetation, although it also inhabits cultivated areas (Beutler, 1981). Phrygana is common on the Aegean islands, but is rare on mainland Greece, and this has been claimed to be the main reason for its rarity on the mainland (Beutler, 1981). In Israel, in contrast, *M. kotschyi* is almost obligatorily arboreal, and its Hebrew name (“שממית עצים” = “tree-gecko”) reflects this (Werner, 1993; Bar and Haimovitch, 2012; and our pers. obs.). In Israel, southern Turkey and Iraq it can be found on some common Mediterranean trees such as oak, olive, fig, almond and carob, as well as on introduced species such as *Eucalyptus* (Weber, 1960; Beutler, 1981; and pers. obs.).

Another major factor thought to influence the distribution of *M. kotschyi* is that of substrate. Like all members of its genus, this species lacks adhesive toe pads (Gamble et al., 2012). Many pad-less saxicolous species are associated with rough rock surfaces (Higham, 2015), such as sandstone (Russell et al., 2007), perhaps because they are able to attain a secure grip on these types of rocks compared to smoother ones. Beutler (1981) suggested that in the Cyclades, where *M. kotschyi* is very abundant, the ground is comprised mainly of slate, granite, mica, marble and volcanic rocks. However, the main rock type on the Greek mainland is limestone, which according to Beutler is less suitable for *M. kotschyi*. Consequently, he has claimed that the only mainland region where *M. kotschyi* is abundant is in the Taygetos mountain range south of Sparta, where the dominant rock types are shale and sandstone (Beutler, 1981).

The range of precipitation for Mediterranean vegetation is ~250-800 mm, the lower limit of which corresponds to phrygana vegetation (Aschmann, 1973), which covers the Peloponnese peninsula’s coastline from south to east (Mavromatis, 1978). We hypothesized that, because *M. kotschyi* is thought to be strongly associated with sparse phrygana, it would be more common in the eastern Peloponnese, where the climate is drier due to the rain shadow cast by the central mountains (Kotini-Zabaka, 1983; Bringsoe, 1985). We further hypothesized that *M. kotschyi* would be rare in areas where the main type of rock is limestone (Beutler, 1981), and that in wet regions, and where limestone predominates, it would be more likely to occur on trees than among rocks.

MATERIAL AND METHODS

To test our predictions we constructed a presence and absence distribution map of *M. kotschyi*, incorporating 68 locations from across the entire Peloponnese. Sixteen of these observations (eight presences and eight absences, Table 1a, b) are derived from fieldwork we conducted in June and October 2015, including two locations from which the gecko had been previously reported (Maragou et al., 2015) as well as six new localities in both phrygana habitats and tree groves. The remaining 52 locations were sourced from publications, museum records and localities surveyed independently by KS (Table 2).

We searched for *M. kotschyi* by turning over rocks and visually scanning tree trunks during daylight hours (*M. kotschyi* is mostly diurnal, active during all but the hottest hours of the day, Beutler, 1981; Valakos et al., 2008; Baier et al., 2009; and pers. obs.). In each locality two to four people searched for geckos for at least 30 minutes. Weather conditions were favourable for *M. kotschyi* activity throughout. If no individuals were observed in a locality we considered it to be absent, although we acknowledge that false absences are a possibility.

We recorded the habitat and type of substrate on which the individuals were found. We recorded GPS coordinates of all locations surveyed, for both presence and absence of *M. kotschyi,* and assembled them on a map using ArcGIS (ESRI, 2011). Most literature-based locations (Table 2) are provided only as verbal descriptions (usually the name of a town). We digitized the coordinates of these using Google Maps (2015).

To determine whether a connection exists between the distribution of *M. kotschyi* and aridity, we assigned mean annual precipitation data (from Worldclim, Hijmans et al., 2005) to sampled localities (presence and absence, Tables 1, 2). We also recorded rock type for all such locations using geological maps (Higgins and Higgins, 1996) in order to test for substrate preferences. We performed statistical tests of rock type associations only for the presence locations for which substrate data were specified. We used χ^2 tests for goodness of fit to compare observations from wet and arid regions, Student’s t tests were applied to test for a connection between substrate type and precipitation, and to compare climatic conditions at sites with and without geckos. We used Fisher’s exact test to search for a connection between rock type and preferred substrate. All analyses were carried out using R version 3.0.1 (R Development Core Team, 2013).

RESULTS

During our 2015 survey we encountered geckos in eight locations but failed to encounter them in the remaining eight (Table 1). Most records of *M. kotschyi*

Table 1. Presence (a) and absence (b) of *Mediodactylus kotschyi* at sites surveyed during our field work in June and October 2015 in the Peloponnese. Data on substrate and rock type, annual precipitation (mm) and GPS coordinates were combined with the data presented in Table 2 for map construction.

a. presence

Location	Habitat searched	Substrate	Rock type	Annual precipitation (mm)	No. individuals caught (rocks/ trees)	Latitude	Longitude
North west of Neapolis, Malea Peninsula, Laconia	Sparse phrygana with carob trees and eucalypt logs	On carob and olive trees, and eucalypt logs	Limestone	564	(2/7)	36.5631N	23.0040E
Neapolis, Malea Peninsula, Laconia	Olive grove	On olive and carob trees and on a building's wall	Alluvium	548	(2/4)	36.5339N	23.0421E
North west of Neapoli, Malea Peninsula, Laconia	Dense phrygana	Under a rock	Limestone	585	(1/0)	36.5690N	22.9890E
Gefira, near Monemvasia, Malea Peninsula, Laconia	Dense phrygana with carob trees	Under rocks and on carob trees	Limestone	543	(3/2)	36.6867N	23.0368E
North west of Monemvasia, Malea Peninsula, Laconia	Eucalypt, almond and carob grove	On eucalypt, almond and carob trees	Phyillites	572	(0/17)	36.7291N	22.9802E
North east of Geraki, Laconia	Phrygana with carob trees bordering an olive grove	On carob and olive trees	Alluvium	688	(0/5)	36.999N	22.722E
Kato Vervena, Arcadia	Olive grove	On olive trees	Alluvium	600	(0/5)	37.4396N	22.7370E
Kalogria, south west of Patras, Achaea	Eucalypt and pine forest	Under rock piles and on eucalypt trees	Alluvium	766	(4/2)	38.13N	21.37E

b. absence

Location	Habitat searched	Rock type	Annual precipitation (mm)	Latitude	Longitude
Lagokili, Mani Peninsula	Olive grove (both on trees and under rocks)	Limestone- marble	707	36.6502N	22.4017E
South of Platsa, Mani Peninsula, Messenia	Stone piles	Limestone- marble	752	36.800N	22.318E
Kardamyli, Mani Peninsula	Eucalypt grove (trees only)	Neogene sediments	719	36.891N	22.233E
West of Prosilio, Mani Peninsula	Phrygana (rocks only)	Limestone	770	36.9134N	22.2240E
South east of Agii Anargiri, Laconia	Phrygana (rocks only)	Neogene sediments	676	37.0160N	22.6360E
South west of Kosmas, Laconia	Stream bed (rocks only)	Limestone- marble	849	37.0800N	22.7200E
East of Kalogria, Achaea	Phrygana (rocks only)	Limestone	793	38.1605N	21.3847E
Trochalia, Malea Peninsula, Laconia	Eucalypt grove (trees only)	Alluvium	546	36.6535N	23.0241E

are from the central and eastern parts of the peninsula (Fig. 1). The 800 mm isohyet divides the Peloponnese into roughly equal areas (above 800 mm: 10,134.45 km^2; below 800 mm: 11,113.96 km^2), and thus the null expectation would be for 10:11 number of observations from arid and wet regions. Nevertheless, most records of presence (77%, 46 out of 60, Table 1 a) are from where annual mean precipitation is lower than 800 mm (χ^2 goodness of fit test, χ^2 = 14.21, n = 60, P = 0.0002). Fourteen locations where presence has been recorded are from regions

Table 2. Locations, substrate and rock type, annual precipitation (mm), sources of data, and estimated GPS coordinates (longitude and latitude in decimal degrees) used for map construction.

Location name	Substrate	Rock type	Annual prec. (mm)	Latitude	Longitude	Source
Lachos, Mani Peninsula	Unspecified	Limestone-marble	688	36.48N	22.37E	Valakos et al. 2008
Kokkala, Mani Peninsula	Unspecified	Limestone-marble	651	36.52N	22.47E	Valakos et al. 2008
Kato Kastania, Malea Peninsula, Laconia	Phrygana with many rocks	Limestone	596	36.52N	23.11E	Bringsoe 1985
Ano Kastania, Malea Peninsula, Laconia	Unspecified	Phyllites	606	36.537N	23.102E	Valakos et al. 2008
Lira, Malea Peninsula, Laconia	Unspecified	Phyllites	637	36.640N	22.964E	Valakos et al. 2008
Loutsa, Mani peninsula	Unspecified	Limestone-marble	711	36.643N	22.474E	Valakos et al. 2008
Monemvasia, Malea Peninsula, Laconia	Unspecified	Limestone	546	36.69N	23.05E	Beutler and Gruber 1977
South of Agios Ioannis, Malea Peninsula, Laconia	Unspecified	Limestone	557	36.726N	23.007E	Valakos et al. 2008
5 km north of Monemvasia, Malea Peninsula, Laconia	Building	Limestone	549	36.73N	23.02E	Bringsoe 1985
Methoni, Messenia	Unspecified	Alluvium	742	36.82N	21.704E	Valakos et al. 2008
Kastania, Kariofouni and Driopi area, Laconia	Area with stone walls	Limestone-marble	762	36.84N	22.35E	Bauer 2004; Valakos et al. 2008
Between Saidona and Kastane, Mani Peninsula	Unspecified	Limestone-marble	797	36.87N	22.29E	Bringsoe 1985; Valakos et al. 2008
Lakkos, Mani Peninsula	On trees in forest	Neogene sediments	768	36.893N	22.259E	Pers. obs. Kostas Sagonas 2014
Exochori (Taygetos), Mani Peninsula	Unspecified	Neogene sediments	768	36.90N	22.26E	Werner 1937; Valakos et al. 2008
Mandina near Kampos, Mani Peninsula	Unspecified	Flysch	781	36.93N	22.20E	Naturhistorisches Museum Wien
Kalamata, Messenia	Unspecified	Alluvium	762	37.04N	22.11E	Stepánek 1937; Valakos et al. 2008
2 km south of Gargalianoi, Messenia	On the ground in open field	Peridotite and serpentinite	813	37.049N	21.634E	Pers. obs. Kostas Sagonas 2014
Mystras, Laconia	Unspecified	Limestone- marble	776	37.06N	22.37E	Beutler and Gruber 1977; Stepánek 1937; Valakos et al. 2008
10 km west of Sparta, Laconia	Unspecified	Limestone-marble	913	37.064N	22.305E	Valakos et al. 2008
Pyrgos, Elis	Near stone terraces	Neogene sediments	839	37.07N	21.69E	Bringsoe 1985
Sparta, Laconia	Unspecified	Alluvium	712	37.071N	22.430E	Valakos et al. 2008
5 km north east of Kosmas, Arcadia	Eggs under a flat rock	Limestone	715	37.12N	22.78E	Bringsoe 1985
Rouzaki, Messenia	On trees in forest	Neogene sediments	790	37.236N	21.662E	Pers. obs. Kostas Sagonas 2014
Agii Asomatoi, Arkadia	Under stones in maquis	Flysch	671	37.332N	22.699E	Pers. obs. Kostas Sagonas 2014
Tegea, Arcadia	Unspecified	Alluvium	798	37.45N	22.41E	Naturhistorisches Museum Wien
Didima, Corinthia	Unspecified	Limestone	527	37.461N	23.171E	Valakos et al. 2008
Tripoli, Arcadia	Unspecified	Limestone	807	37.507N	22.371E	Valakos et al. 2008
1 km south west of Mainalo, Arkadia	Under stones in maquis	Limestone	836	37.529N	22.299E	Pers. obs. Kostas Sagonas 2014
Methanon, Malea Peninsula, Laconia	Unspecified	Volcanic rocks	452	37.58N	23.39E	Naturhistorisches Museum Wien

Location name	Substrate	Rock type	Annual prec. (mm)	Latitude	Longitude	Source
Tiryntha, Argolis Peninsula	Unspecified	Alluvium	583	37.59N	22.80E	Beutler and Gruber 1977; Valakos et al. 2008
Argos, Argolis Peninsula	Unspecified	Alluvium	603	37.632N	22.732E	Valakos et al. 2008
Palea Epidavros, Argolis Peninsula	Unspecified	Alluvium	502	37.635N	23.153E	Valakos et al. 2008
Epidavros, Argolis Peninsula	Unspecified	Limestone	560	37.65N	23.14E	Beutler and Gruber 1977
Archea Olympia, Elis	Under stones in phrygana	Alluvium	781	37.651N	21.618E	Pers. obs. Kostas Sagonas 2014
Inachos, Corinthia	Unspecified	Alluvium	603	37.659N	22.750E	Valakos et al. 2008
Nea Epidavros, Argolis Peninsula	Unspecified	Peridotite and serpentinite	555	37.675N	23.126E	Valakos et al. 2008
Nea Epidavros, Corinthia	Under stones in phrygana	Peridotite and serpentinite	538	37.675N	23.134E	Pers. obs. Kostas Sagonas 2014
Levidi, Arcadia	Unspecified	Limestone	873	37.68N	22.29E	Beutler and Gruber 1977; Valakos et al. 2008
Kamenitsa, Laconia	Unspecified	Limestone	833	37.72N	22.19E	Bringsoe 1985; Valakos et al. 2008
Tropaia, Arcadia	Unspecified	Limestone	864	37.730N	21.954E	Valakos et al. 2008
3 km north east of Sofiko, Corinthia	Stone terrace	Limestone	639	37.81N	23.08E	Bringsoe 1985
9 km east of Lampeia, Archaia Olympia	4 eggs under a flat rock	Limestone	927	37.85N	21.91E	Bringsoe 1985
Ano Tripotama, Achaea	Unspecified	Limestone	887	37.857N	21.912E	Valakos et al. 2008
Archea Korinthos, Achaea	Unspecified	Neogene and Pleistocene sediments	587	37.903N	22.882E	Valakos et al. 2008
Korinthos, Achaea	Unspecified	Neogene and Pleistocene sediments	566	37.936N	22.927E	Valakos et al. 2008
Feneos, Corinthia	On walls	Alluvium	835	37.950N	22.325E	Koppitz 2013
Kokkoni, Achaea	Unspecified	Alluvium	600	37.966N	22.779E	Valakos et al. 2008
2.5 km east of Karia, Corinthia	On a wall in phrygana	Alluvium	607	38.009N	22.442E	Pers. obs. Kostas Sagonas 2014
4 km south west of Kalavrita, Achaea	Unspecified	Limestone	883	38.010N	22.079E	Valakos et al. 2008
2 km south of Kalavrita, Achaea	Unspecified	Neogene sediments	865	38.018N	22.102E	Valakos et al. 2008
Mega Spilaio, Achaea	Unspecified	Neogene sediments	848	38.08N	22.17E	Stepánek 1937
Trapeza, Achaea	On a wall	Neogene sediments	728	38.172N	22.229E	Pers. obs. Kostas Sagonas 2014

with > 800 mm precipitation annually (Fig. 1), although only seven of these are from areas with > 850 mm precipitation annually.

In seven of the eight locations (Table 1a) in which we encountered the species in our 2015 fieldwork we found geckos on trees (in three of them exclusively on trees), and in five locations we encountered them under rocks (in one exclusively under rocks). Absence from both microhabitats was also recorded (Table 1b).

Thirty-two percent of gecko localities in the Peloponnese are located in regions where limestone is the dominant rock type (combined data from Tables 1a and 2). We found no connection between rock type and arboreality (Fisher's exact test, two on trees and nine under rocks in limestone habitats, seven on trees and 11 under rocks in other rock types, $P = 0.41$), or between habitat type (rocks or trees) and precipitation (trees: 649 ± 35 mm, rocks: 692.1 ± 28 mm; t-test assuming unequal variances, $t = 2.1$, $n = 29$, $P = 0.34$).

Twenty five percent of our absence findings were in localities in which limestone is the dominant rock type (although we did not try to identify the type of the rocks under which we searched for geckos), and all of them were for locations in which we searched for geckos under

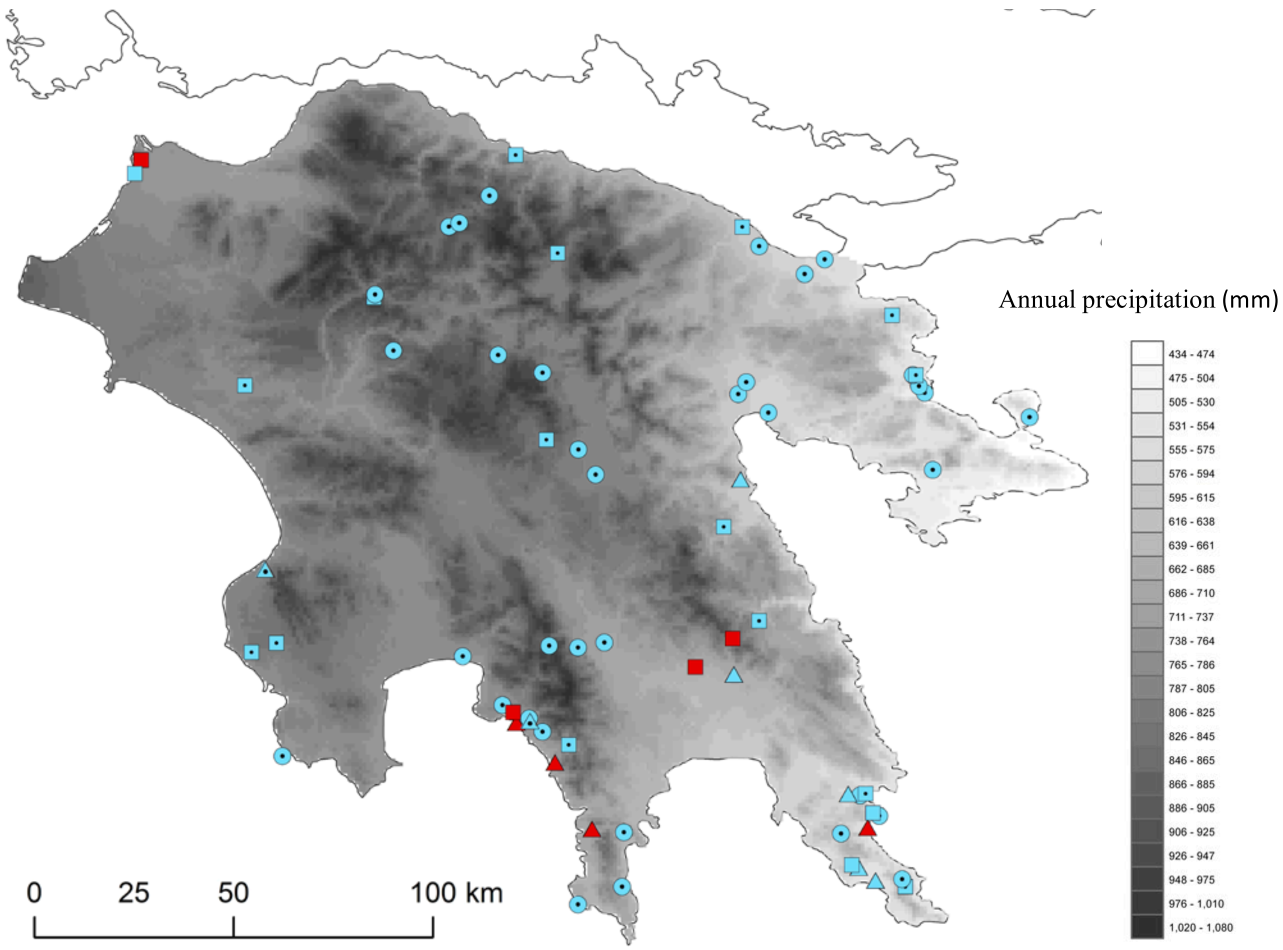

Fig. 1. Presence and absence localities derived from the literature and our field observations plotted on an annual mean temperature map of the Peloponnese (adopted from Worldclim, Hijmans et al. 2005). Squares (☐) designate specimens found among rocks; triangles (Δ) designate specimens found on trees; circles (o) designate specimens for which substrate was not specified; dots inside the symbols (•) represent published, museum and observational data (otherwise: our data); Blue: presence; Red: absence.

rocks (Table 1b). Precipitation was not significantly greater in localities where geckos were not present (Table 1b) than where they were encountered (Table 1a; presence: 690 ± 23 mm, absence: 727 ± 32 mm; t-test assuming unequal variances, $t = 2.13$, $n = 33$, $P = 0.38$).

DISCUSSION

Our hypotheses were only partially supported. Geckos were indeed more common in the more arid areas of the Peloponnese. However, we did not find evidence of limestone avoidance. The high frequency of occurrence of *M. kotschyi* on trees in the Peloponnese contrasts with that on the Greek islands. During fieldwork in the Cyclades (once or twice from 2013 to 2015; e.g., Slavenko et al., 2015) we observed *M. kotschyi* on a tree trunk only twice (on Ano Koufonisi, in May 2013, and on Kimolos Island, in May 2015, Fig. 2). All our other observations (~ 800, from 40 islands) of this species were on and under rocks, in stone piles, on dry stone walls and on low building walls, under various objects of refuse and in abandoned stone shelters (see also Arnold and Ovenden, 2002; Beutler, 1981; Musters and In den Bosch, 1982 and citations therein). During our 2015 survey in the Peloponnese, most specimens (81%) were found on trees, especially on almond, olive and eucalypts (Table 1a). In only three locations were specimens found under rocks (Table 1a), despite searching localities with apparently suitable phrygana habitats.

Because our sole criterion for establishing absence was that we did not find the species following a search under what we considered to be suitable conditions for *M. kotschyi*, we are well aware that some absences may

Fig. 2. *Mediodactylus kotschyi* on the bark of a tree on Kimolos Island, 34.79 N, 24.58 E, 7 May 2015. Photographed by SM.

very well be false-absences. This can only be supported (or refuted), however, by future surveys. That said, we have no reason to believe that reported absences are more likely for either the tree or for the rock microhabitat, or for different geographic locations, and thus false absences are unlikely to alter our conclusions.

Werner (1993) described *M. kotschyi* as being a "paradoxical" species. He contended that, in Israel and Iraq, it lives mainly on large tree trunks with exfoliating bark, such as carob, eucalypts and oak (Werner, 1993), even though it lacks the characteristic adhesive toe pads of other arboreal geckos (Gamble et al., 2012). *M. kotschyi* is nonetheless superbly camouflaged against the background pattern of tree trunks (Werner, 1993; Baier et al., 2009; Bar and Haimovitch, 2012; see also Fig. 2), making it hard to dismiss the idea that it is well adapted to living on trees as well as on rocks.

According to the most comprehensive phylogenies available (Pyron and Burbrink, 2014), the closest relatives of *M. kotschyi* are the arboreal *Mediodactylus sagittifer* and the saxicolous *Mediodactylus heteropholis* and *Mediodactylus heterocercus* (*M. kotschyi* is sister to a clade containing all three). More distantly-related allies (Pyron and Burbrink, 2014) include members of the mostly saxicolous and terrestrial genera *Tenuidactylus* and *Cyrtopodion* (note that *Tenuidactylus caspius* is described as arboreal, saxicolous and terrestrial, Rogner 1997), and the mostly terrestrial *Bunopus*, *Agamura* and *Crossobamon*. The ancestral state of *M. kotschyi* is thus most likely terrestrial or saxicolous although an arboreal ancestor cannot be ruled out. The fact that *M. kotschyi* is saxicolous over most of its distribution may imply that this species was originally saxicolous and later adapted to inhabit trees too.

Current data on the occurrence of this species in the Peloponnese (Tables 1 and 2) do not suggest a strong preference of *M. kotschyi* for a specific type of substrate, and we did not detect an aversion to limestone. The thin-toed gecko does occur in places where the mean annual precipitation is greater than 850 mm, although it is probably scarce in such regions. It is certainly not obligatorily associated with phrygana, in contrast to what was previously suggested (Beutler, 1981). Our findings, along with our observations of this species on trees, lead us to suggest that *M. kotschyi* is highly flexible and adaptable in its habitat preference, which may have contributed to its successful establishment and broad range.

Our observations indicate that *M. kotschyi* is relatively abundant on trees in the Peloponnese, whereas it is extremely abundant and conspicuous on and under rocks and on stone walls in the Cyclades. This might have led to the general misconception that it is purely saxicolous. Although it is certainly much more abundant on islands (as many lizards are, Novosolov et al., 2013), we suggest that *M. kotschyi* is more common in the Peloponnese than has previously been considered, because it was formerly sought mostly on and under rocks.

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