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The herpetofauna of drained Lake Karla (Thessaly, Greece): distribution and threats

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Abstract. The distribution of herpetofauna in large parts of mainland Greece has not been studied extensively. This study covers a poorly-known herpetological area in Thessaly Region - Lake Karla's Plain. We conducted 59 field surveys during 12 consecutive years (2008–2019) and recorded a total of 26 herpetofauna species: 4 anuran amphibians and 22 reptiles (5 tortoises and terrapins, 7 lizards and 10 snakes). Our study brings updates regarding the presence, distribution and the main threats for the herpetofauna of Lake Karla's Plain, with 17 species being recorded here for the first time, including an alien freshwater turtle, *Trachemys scripta*.

Keywords. Amphibians, Mapping, Reptiles, Restored wetland, Roadkill, Threats

Introduction

Knowledge of species' distribution contributes to a better understanding of their ecology, systematics, and biogeography, especially in poorly-studied areas (Zachos and Habel, 2011; Jelić et al., 2013; Tomović et al., 2014). Without precise faunistic data, proper strategic management cannot be planned, nor can priorities be set (Jelić et al., 2013). For the effective protection of an area and the species it hosts, distribution patterns must be well understood (Margules et al., 2002).

Most amphibians and reptiles are difficult to detect in their environment, therefore presence-absence data contribute to filling knowledge gaps regarding their distribution. Individual size, specific behaviour, activity patterns, and camouflage may pose difficulties when assessing species diversity in a short time within an area (Kéry, 2002; Mazerolle et al., 2007). Amphibian and reptile imperfect detection is proven given continuous discoveries of new species worldwide every year, in areas where these species were not previously known (Sanches et al., 2020; Biakzuala et al., 2021; Fukuyama et al, 2021; Maier and Cadar, 2021).

The herpetological surveys in mainland Greece are limited in contrast to the extensively studied insular areas of Greece. Species presence in broad areas is mainly based on scarce, single records scattered around the mainland. Therefore, accurate species distributions are unknown and many areas remain poorly studied (Valakos et al., 2008; Pafilis, 2010), such as Lake Karla's Plain. Lake Karla's Basin covers an area of 1663 km², about 600 km² of which are lowland plain (Fig. 1A) and before its drainage, in 1962, occupied most of the eastern part of Thessaly Plain (Fig. 1B). The lake area

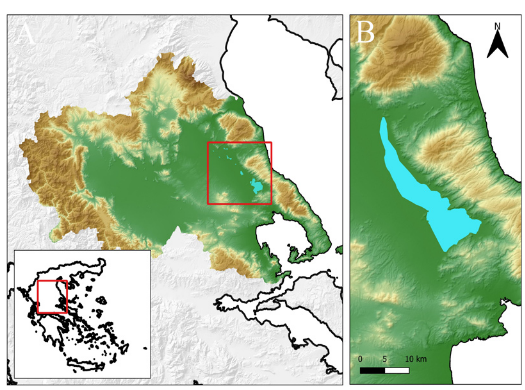

Figure 1. (A) Geographic location of Lake Karla's Plain in the eastern part of Thessaly Region (Greece) with main hydrography and topography of the region. (B) The maximum surface of Lake Karla before its drainage in the 1960s.

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fluctuated from 40 to 180 km^2 due to the very gentle land slope and the inflow–outflow balance (Fig. 1A, 1B). It was one of the most important wetlands in Greece, which provided significant water storage and recharge to groundwater (Loukas et al., 2007; Sidiropoulos et al., 2012). Moreover, the presence of threatened bird species and their large populations made it equally important for wildlife (Christopoulos, 2009).

Today the southernmost location of the former Lake Karla has been partially restored and re-filling started in 2009 using pumping stations and supply channels. Further north in Lake Karla's Plain there are 13 scattered small reservoirs, single or grouped: Kalamaki (2 reservoirs), Kastri (1 reservoir), Niamata (2), Glafki (2), Platykampos (1), Omorfochori (1), Eleftherio (2), Dimitra (2), and one small artificial wetland adjacent to the NW part of the restored lake, which cover a total area of 8 km^2 (Fig. 2).

Lake Karla's Plain, similarly to Thessaly Plain, is mostly used for agriculture and livestock farming. Agricultural activities include cultivation of arable crops (mainly cotton, cereals, maize and alfalfa) or trees (mainly almond and olive trees) and grasing in pastures and meadows (Loukas et al., 2007; Mellios et al., 2015). The low hills –former lake islets– in the plain (Chatzimisiotiki Magoula, Sifritzali, Petra), the foothills of the mountains Chalkodonio, Megavouni and Mavrovouni, the flooded areas around lakeshore, the wet meadows, the extensive road network (including asphalt and dirt roads), the supply channels, the numerous irrigation and drainage channels, the rivers, the streams and many settlements complete the wider area's landscape.

Much of Lake Karla's Plain is currently included within the Natura 2000 network. The "Reservoirs of Former Lake Karla, GR1430007" and "Area of Thessaly Plain, GR1420011" were designated as Special Protected Areas (SPA) in 2010 and 2008 respectively, while "Karla – Mavrovouni – Kefalovryso Velestinou – Neochori, GR1420004" was designated as Site of Community Importance (SCI) in 2006 and later on in 2011, as Special Area of Conservation (SAC) (Fig. 2). Furthermore, the SPAs are also Important Bird Areas (IBAs) for many bird species (Christopoulos, 2009; Catsadorakis, 2019).

There are only few published opportunistic records regarding 10 species of herpetofauna from Lake Karla (Chondropoulos, 1989; Gordinho, 2009; Sofianidou, 2012). Our study aims to update and improve the current knowledge regarding the distribution and threats to herpetofauna from Lake Karla's Plain, by presenting the results of field surveys conducted during 2008–2019 in this area.

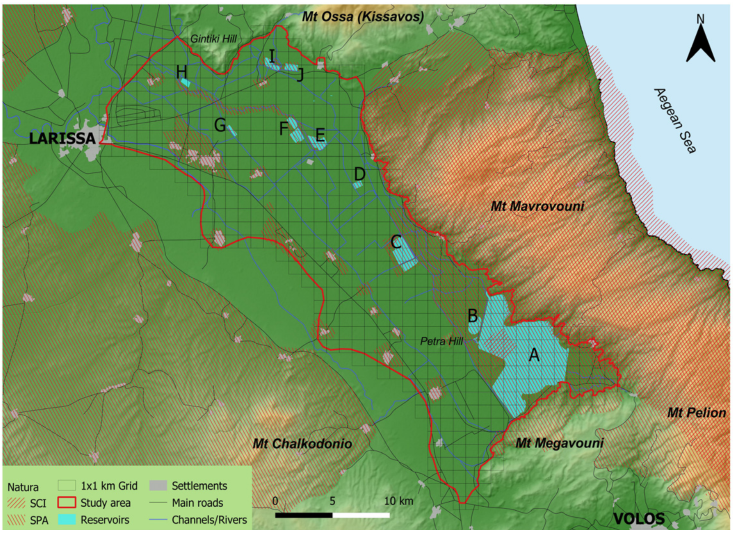

Figure 2. Map of the study area (outlined in red) with surrounding mountains and eastern parts of Thessaly Plain. Details of the reservoir names are given: A = Lake Karla; B = artificial wetland; C = Kalamaki Reservoirs; D = Kastri Reservoir; E = Niamata Reservoirs; F = Glafki Reservoirs; G = Platykampos Reservoir; H = Omorfochori Reservoir; I = Eleftherio Reservoirs; J = Dimitra Reservoirs.

Materials and Methods

Study area. Lake Karla's Plain is located in the eastern part of Thessaly Region (39.49931°N, 22.77837°E), Magnesia and Larisa provinces (Fig. 1A) and covers approximately 480 km^2 (Fig. 2). It includes the restored Lake Karla (38 km^2), 13 reservoirs (6.86 km^2 in total), a small artificial wetland (1.14 km^2), low hills and short part of the foothills of the adjacent mountains (4 km^2 in total), the supply channels and 30 settlements (21 km^2 in total). Most of the plain (80%) is used for extensive agriculture with a variety of annual crops, fallow lands, meadows and irrigation and drainage channel network (Fig. 3). The altitude ranges from 42 to 80 m elevation in the plain, and from 70 to 120 m elevation in the small hills. The natural vegetation is dominated mainly by freshwater aquatic plants or reedbeds and sclerophyllous shrubs or phrygana, in water bodies and hilly areas respectively. The total human population of this area is approximately 15,000 people, much of which are farmers (National Statistical Service of Greece, 2011). The climate is Mediterranean, with hot and dry summers and cold and wet winters (Sidiropoulos et al., 2011; Gkoutis, 2013).

Fieldwork. The fieldwork covered approximately 275 km^2 of the study area and focused more systematically around 10 locations (Table 1): Lake Karla, the reservoirs and artificial wetland, the adjacent mountain foothills and channels; agricultural areas and settlements were visited less frequently compared to wetlands. Roadkills and opportunistic single observations during short visits also contributed to the data collection. The presence data was collected during 22 surveys (lasting 4–12 hours per day) and 37 short visits (lasting 1–2 hours per day), during 2008–2019, comprising a total of 137 days of field work. Most of the surveys took place during January, March, April, May, June and July. Details regarding the dates and sampling effort are summarised in Table 1.

We performed visual encounter surveys during daytime or/and at night time in all habitat types within the study area. We performed the surveys along line transects in random routes and also actively searched for animals by exploring refugia, for example by turning over stones, tree trunks or other objects and extensively searching in the vegetation. We actively searched for possible breeding sites of amphibians in various types of waterbodies using dip nets and playbacks of recorded mating calls. We also recorded information about threats and habitats for all species encountered.

Mapping. Presence data were recorded in the field using a mobile app (Google Maps) with high accuracy, in WGS84 coordinate system. Later on, we manually entered the data in Google Earth on a laptop. All field and literature (Chondropoulos, 1989; Gordinho, 2009; Sofianidou, 2012) records were geo-referenced into HGRS87 coordinate system, checked and visualised with QGIS v. 3.12.1. We applied a grid comprising 575 individual 1x1 km cells on the study area. Then we performed the classification choice to produce a species richness map in QGIS. We further created grid maps for each species to visualise their distribution and calculate the portion of occupied grid cells within the total grid.

Results

We collected a total of 1313 presence records of 26 species during fieldwork in the study area (Table 2; Fig. 4). The number of records per species are summarised in Table 3. Taking into account both literature references and our own results, a total of 27 herpetofauna species, comprising 5 anurans amphibians and 22 reptiles (5 chelonians, 7 sauria and 10 ophidia) were recorded in Lake Karla's Plain between 1979–2019 (Table 3) (Chondropoulos, 1989; Gordinho, 2009; Sofianidou, 2012). The species that we didn't find during our surveys is *Pelobates balcanicus*.

Presence data from both our field surveys and literature covers 275 grid cells of a total of 572 (48%). The highest number of species recorded within a single cell was 15 (Fig. 5). In most grid cells (83.6%) 1–5 species were observed, while 6–10 species were recorded in 15.6% of the occupied grid cells. More than 10 species were found in only two grid cells (Fig. 5).

Species accounts. Bufo bufo *(Linnaeus, 1758) – Common toad*.— The Common toad can be found throughout mainland Greece from sea level to high altitudes and in some islands (Valakos et al., 2008). We documented the presence of this species for the first time in Karla's area. Only three records, all roadkills of adult individuals, were found in the eastern part of the study area, in three distinct grid cells (Fig. 7). The low number of records may be due to the lack of field work during favourable weather conditions. The species could be more common in the study area and especially localised on its eastern side, at the Mavrovouni foothills and in the tree crops where the records come from.

Bufotes viridis *(Laurenti, 1768) – Green toad (Fig. 6A)*.— The Green toad is a common nocturnal amphibian in the study area, with 79 records (5.95% of the data)

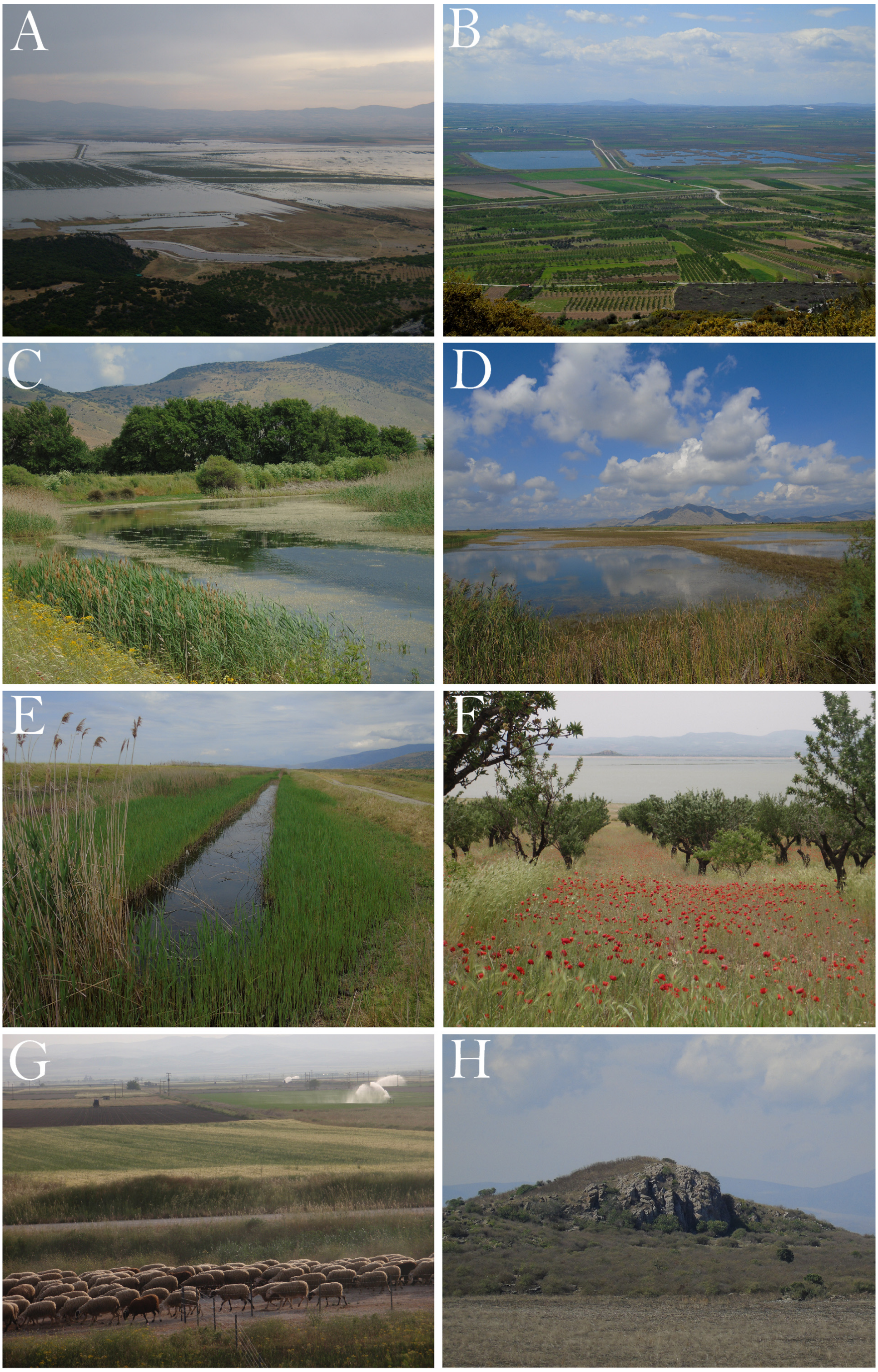

Figure 3. Main habitats in Lake Karla's Plain. (A) View from Mavrovouni Mountain of Lake Karla during the first year of its refilling; 20 June 2009. (B) Kalamaki Reservoirs and adjacent agricultural land with arable and tree crops; 11 April 2019. (C) Eleftherio Reservoir with aquatic vegetation, 10 May 2015. (D) Platykampos Reservoir with the Gintiki Hill on the background, 27 September 2015. (E) A drainage channel with reeds *Phragmites australis* in agricultural area close to Kalamaki Village, 9 May 2015. (F) Crop of almond-trees on the eastern bank of the Lake Karla, 8 May 2010. (G) Agricultural land and livestock at SW side of the Lake Karla, close to Rizomylos Village, 8 May 2010. (H) Shrubland on Chatzimisiotiki Magoula Hill -an ex-islet of the old Lake Karla-, 24 September 2015. Photos by Apostolos Christopoulos.

Table 1. Detailed information regarding the sampling effort and locations of the herpetological surveys performed during this study in Lake Karla's Plain. The 10 locations are denoted by numbers, as follows: A = Lake Karla; B = artificial wetland; C = Kalamaki Reservoirs; D = Kastri Reservoir; E = Niamata Reservoirs; F = Glafki Reservoirs; G = Platykampos Reservoir; H = Omorfochori Reservoir; I = Eleftherio Reservoirs; J = Dimitra Reservoirs. Participants are noted with their initials as follows: AC = Apostolos Christopoulos; TZ= Thanos Zafeiriou; LG = Luís de Oliveira Gordinho; AP = Apostolis Petrikis; GS = Giorgos Satasis; NP = Nikos Papadimas; TG = Thomas Georgoulas; KV = Konstantinos Vlachopoulos; TT = Theofanis Theofanopoulos; MM = Maria Makri; DK = Dionysis Kapatos. Bold fonts correspond to names of the authors of this paper.

Date of survey	Total days	Locations	Participants
8 February 2008	1	A	**AC**
29 February 2008	1	A	**AC**
14–15 March 2008	2	A, C	**AC**
29–30 March 2008	2	A, I, J	**AC**
25 May 2008	1	A	**AC**
7–8 June 2008	2	A, C	**AC**
25 January 2009	1	A, C	**AC**, TZ
12 March 2009	1	A	**AC**, TZ
4–24 May 2009	21	A, C, D, E, I, J	**AC**
13 June 2009	1	A	**AC**, LG
20–21 June 2009	2	A, F, I, J	**AC**, LG
5–6 January 2010	2	A, I, J	**AC**
8–9 May 2010	2	A, C, F	**AC**
4 August 2010	1	A	**AC**, AP, GS
24–25 September 2010	2	A	**AC**, GS
8–9 January 2011	2	A, C, E, I, J	**AC**, GS
1–4 June 2011	4	A, C, E, F, I, J	**AC**, GS
28 April 2012	1	C	**AC**, TZ
19 May 2012	1	F	**AC**, TZ
27 May 2012	1	A, C, E	**AC**
15 June 2012	1	A	**AC**
27 March 2013	1	G, I, J	**AC**, NP, TG
23 April 2013	1	H	**AC**, NP, TG
19 May 2013	1	C, E, F	**AC**, AP
3 July 2013	1	A	**AC**, NP, TG
12 July 2013	1	A	**AC**, NP, TG
20 October 2013	1	A	**AC**, NP, TG
26 November 2013	1	G	**AC**, NP, TG
30 January 2014	1	A, C	**AC**, NP, TG
16 March 2014	1	E, F, G	**AC**, NP, TG
10 May 2014	1	A, H	**AC**, NP, TG
20 June 2014	1	A, C	**AC**, NP, TG
21 November 2014	1	C, E	**AC**, AP
11 January 2015	1	A, C	**AC**, TZ
1 March 2015	1	E	**AC**, AP, TZ
22 March 2015	1	E	**AC**, AP
26 April 2015	1	E, F	**AC**, TZ
9–10 May 2015	2	A, C, E, I, J	**AC**, TZ
21 May 2015	1	E, F	**AC**, TZ, **KV**
13–23 June 2015	11	A, E	**AC**, TZ, NP, TG
11–12 July 2015	2	A, C, H	**AC**, TZ
23 August 2015	1	A, C	**AC**, **KV**, AP, TZ
24–27 September 2015	4	A, C, I, J, D, E, G	**AC**, AP
4–5 October 2015	2	A, I	**AC**, **KV**
21 November 2015	1	A	**AC**, **KV**

Table 1. Continued.

Date of survey	Total days	Locations	Participants
17–18 January 2016	2	A, C, E	**AC**, **KV**
8–17 May 2016	10	A, B, C, E, F, G, I	**AC**, **KV**, TT
8–15 June 2016	8	A, B, C, E	**AC**, **KV**, TT
12–15 July 2016	4	A, B	**AC**, **KV**
6 August 2016	1	A	**AC**, **KV**
23–26 August 2016	4	A, B	**AC**, **KV**
28 September 2016	1	A	**AC**, **KV**
24 October 2016	1	A	**AC**, **KV**
14–18 January 2017	5	A, E	**AC**, **KV**, MM
23 May 2017	1	A, B	**AC**, **KV**, MM
1 April 2018	1	A, B	**AC**, **KV**, MM, AP
21 September 2018	1	A, B	**AC**, **KV**
11 April 2019	1	A, B, C, D, I	**AC**, DK
1–5 July 2019	5	A, B, C	**AC**, **KV**
Total days of field work	137		

in 53 grid cells (9.26% of entire grid; Fig. 7). The species was previously observed by Gordinho (2009). Most records concern single individuals observed during night time across the roads and roadkills (Fig. 11B). Most observations were made in the eastern part of the study area, along the Mavrovouni foothills, in sclerophyllous shrub vegetation and tree crops. The Green toad was also observed in settlements, around reservoirs and channels in agricultural areas. 85% of the species' records were collected during the first half of spring, when toads exhibit the greatest mobility due to migrations towards water bodies for breeding. This species is distributed throughout mainland Greece and in many islands of the Aegean and Ionian Seas (Valakos et al., 2008).

Hyla arborea *(Linnaeus, 1758) – European tree frog*.— The occurrence of the European tree frog in Greece extends in most of the mainland and in some islands, except extreme eastern parts of the country, where it is replaced by the Oriental tree frog, *Hyla orientalis* (Valakos et al., 2008; Stöck et al., 2012). In the wider region of Karla, we collected ten presence records (0.75%) of European tree frog, in ten different grid cells (1.74%; Fig. 7). There is no prior record for this species in the Karla area. The species was observed in

Table 2. Total number of amphibian and reptile records per month during 2008–2019, resulting from the field surveys at Lake Karla's Plain.

Month	Year												
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	**Total**
January		5	5	5			4	3	1	1			24
February	6												6
March	40	13				7	24	16					100
April					17	4		16			31	80	148
May	11	183	52		39	30	29	62	72	34		1	513
June	22	38		69	9		30	45	70				283
July						24		22	27			10	83
August			18					10	20				48
September			15				1	43	2		10		71
October						7		9	4				20
November						5	9	3					17
December													0
Total	79	239	90	74	65	77	97	229	196	35	41	91	1313

Table 3. Checklist of amphibians and reptiles recorded at Lake Karla's Plain during field surveys, along with literature mentions (Chondropoulos, 1989; Gordinho, 2009; Sofianidou, 2012). The number of records (from fieldwork surveys) and number of grid cells (from fieldwork and literature) are provided, along with the Annexes of Council Directive 92/43/EEC and the IUCN Categories corresponding to each species.

Species	Literature	Our study	Rec.	Grid cells	92/43/EEC	IUCN
AMPHIBIA (5)						
Anura						
Bufonidae						
Bufo bufo		+	3	3		LC
Bufotes viridis	+	+	78	53	IV	LC
Hylidae						
Hyla arborea		+	10	10	IV	LC
Pelobatidae						
Pelobates balcanicus	+				IV	LC
Ranidae						
Pelophylax kurtmuelleri	+	+	385	151	V	LC
REPTILIA (22)						
Testudines						
Emydidae						
Emys orbicularis		+	62	37	II, IV	NT
Trachemys scripta		+	1	1		LC
Geoemydidae						
Mauremys rivulata		+	164	76	II, IV	LC
Testudinidae						
Testudo hermanni	+	+	12	15	II, IV	NT
Testudo marginata	+	+	4	6	II, IV	LC
Squamata						
Anguidae						
Pseudopus apodus	+	+	72	58	IV	LC
Gekkonidae						
Hemidactylus turcicus		+	20	18		LC
Mediodactylus kotschyi		+	25	19	IV	LC
Lacertidae						
Lacerta trilineata	+	+	102	77	IV	LC
Podarcis tauricus		+	1	1	IV	LC
Podarcis muralis		+	4	2	IV	LC
Scincidae						
Ablepharus kitaibelii		+	4	4	IV	LC
Boidae						
Eryx jaculus		+	1	1	IV	LC
Colubridae						
Dolichophis caspius	+	+	56	49	IV	LC
Elaphe quatuorlineata		+	31	30	II, IV	NT
Platyceps najadum		+	2	2	IV	LC
Telescopus fallax	+	+	1	2	IV	LC
Zamenis situla		+	14	12	II, IV	LC
Natrix natrix		+	147	101		LC
Natrix tessellata		+	64	47	IV	LC
Psammophiidae						
Malpolon insignitus	+	+	44	38		LC
Viperidae						
Vipera ammodytes		+	6	6	IV	LC
Total	10	26	1313			

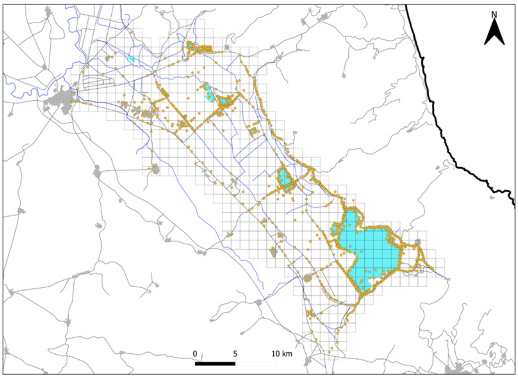

Figure 4. Amphibian and reptile presence records collected from the field during the present study (yellow dots) and literature records (grey dots) at Lake Karla's Plain.

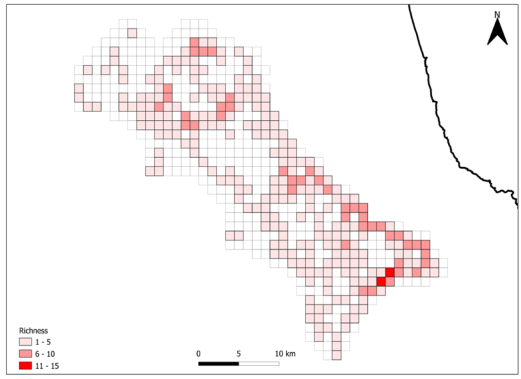

Figure 5. Amphibian and reptile species richness map of Lake Karla Plain. The legend depicts the classes of species richness.

permanent water bodies with dense aquatic vegetation, like irrigation or supply channels and reservoirs. The European tree frog may be occurring in most of the study area, in suitable habitats; more visits to record their vocalisations during the breeding season are needed.

Pelobates balcanicus *(Karaman, 1928) – Balkan spadefoot*.— The Balkan spadefoot has a single record without details in the literature, from the former Lake Karla area, mentioned as *Pelobates syriacus* (Sofianidou, 2012) - but see Dufresnes et al. (2019) for the current name of the taxon (*P. balcanicus*) who's distribution area includes the area of Lake Karla. Although our surveys took place at the right time and habitat, with the right weather conditions, we have not found the species. Further specialised searching in the area is considered necessary. In Greece the species is distributed in the eastern parts of the mainland, along the Aegean Sea shores, western Macedonia, Peloponnese and Euboea Island (Dufresnes et al., 2019).

Pelophylax kurtmuelleri *(Gayda, 1940) – Balkan frog (Fig. 6B)*.— The Balkan frog is the most common amphibian species in the plain, with 385 records (29.1%), in 151 grid cells (26.4%; Fig. 7). In total, we counted approximately 6000 individuals in high densities (groups of 30–100 individuals were common in many locations). It was found in all permanent and seasonal water bodies, especially channels, temporary ponds, reservoirs and Lake Karla. The species was previously recorded in the study area by Gordinho (2009). In Greece it occurs in most of the mainland (except Thrace) and in many islands of the Aegean and Ionian Seas (Valakos et al., 2008).

Emys orbicularis *(Linnaeus, 1758) – European pond turtle (Fig. 6D)*.— The European pond turtle was common with 62 records (4.67%) but with a limited distribution, in 37 grid cells (6.46%; Fig. 8), compared to the Western Caspian turtle which is found at most types of water bodies of the Karla plain. Most of our European pond turtle observations were restricted in reservoirs and surrounding channels, while few single individuals were found in channels far from reservoirs. This is the first report of the species from the study area. It was common to observe groups of 5–10 individuals, rarely more, mainly in reservoirs; a group of 25 individuals was the largest recorded (Niamata Reservoir, 2018). The total count of European pond turtle in the study area was 338 individuals. In most cases this species was found to coexist with the Western Caspian turtle. The European pond turtle is distributed throughout mainland Greece and some islands (Valakos et al., 2008). During the field work some individuals were recorded as traffic victims in various locations.

Trachemys scripta *(Schoepff, 1792) – Pond slider*.— We report the presence of this species for the first time in the study area, with only one record of two adult individuals observed in a channel between the artificial wetland and Lake Karla in 2018. The same location is also inhabited by *Mauremys rivulata*. It is unknown how the pond slider appeared in the area. Most likely, the species arrived from the Pineios River via the extensive channel network that communicates with Lake Karla.

Figure 6. Some of the amphibians and reptiles from Lake Karla's Plain. (A) *Bufotes viridis* close to Plasia (Neochori) Village, 11 April 2019. (B) *Pelophylax kurtmuelleri*, Eleftherio Reservoirs, 10 May 2015. (C) *Testudo marginata* on the limits of the restored Lake Karla with Mavrovouni Mountain foothills, 9 May 2015. (D) *Emys orbicularis*, Niamata Reservoirs, 1 April 2018. (E) *Mauremys rivulata*, Niamata Reservoirs, 1 April 2018. (F) *Mediodactylus kotschyi*, Armenio Village, 27 May 2014. (G) *Lacerta trilineata*, Dimitra Reservoirs, 10 May 2015. (H) *Elaphe quatuorlineata*, restored Lake Karla, 11 July 2015. (I) *Zamenis situla*, restored Lake Karla, 8 May, 2009. (J) Juvenile *Natrix tessellata*, restored Lake Karla, 1 April 2018. (K) *Eryx jaculus*, close to Mavrovouni Mountain foothills, 17 May 2016. (L) *Vipera ammodytes*, on the limits of the restored Lake Karla with Mavrovouni Mountain foothills, 6 May 2009. Photos by Apostolos Christopoulos.

Pineios River maintains a small pond slider population (pers. obs. of the first author) in the area of Larissa city. This species has been introduced in many areas of Greece, and its reproduction has been confirmed in several locations (Bruekers et al., 2006; Zenetos et al., 2009; Adamopoulou and Legakis, 2016; Tzoras et al., 2018).

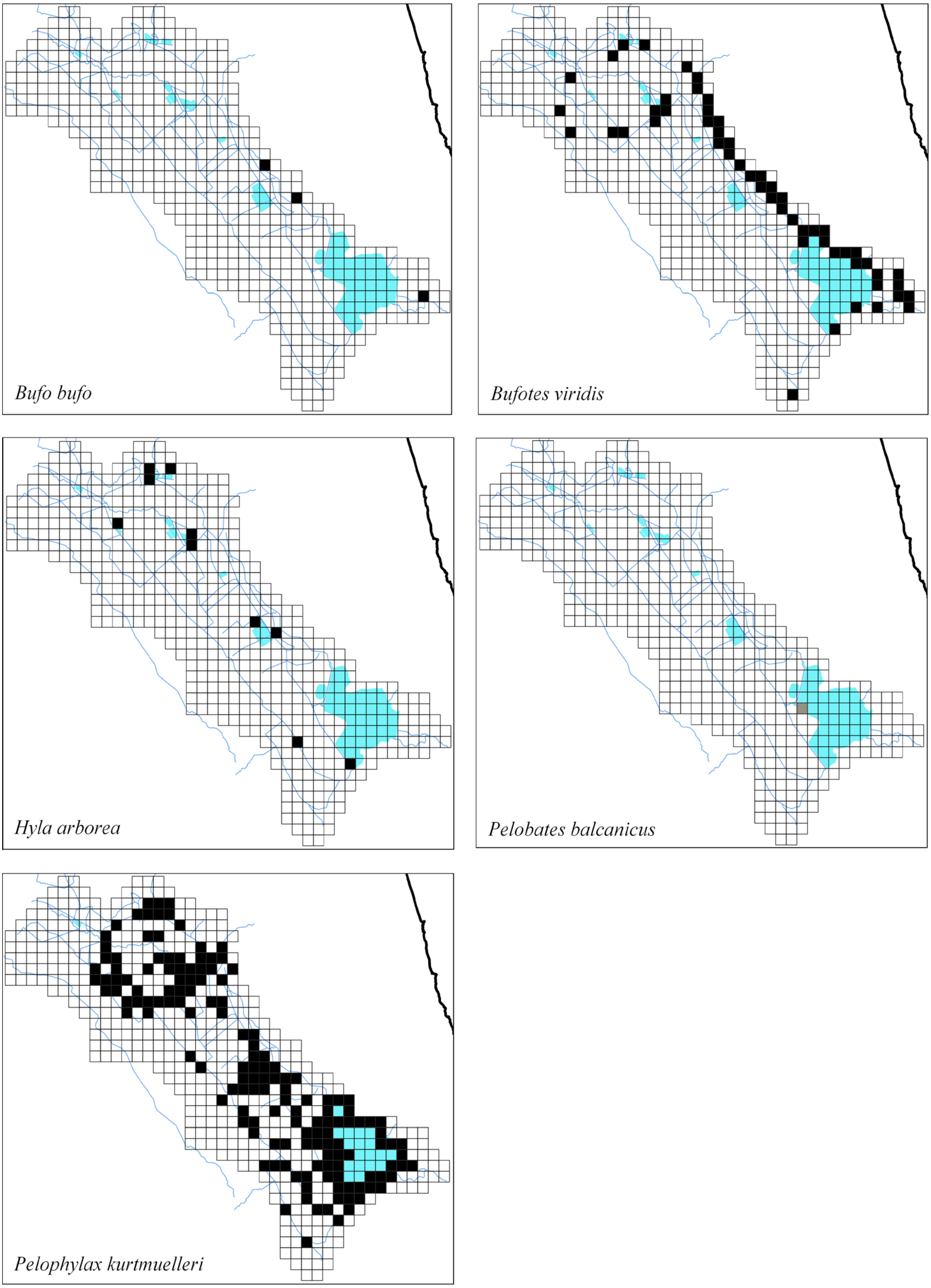

Figure 7. Distribution maps with 1x1 km grid cells of 5 amphibian species in Lake Karla's Plain. Black squares indicate our fieldwork records, grey squares indicate literature records.

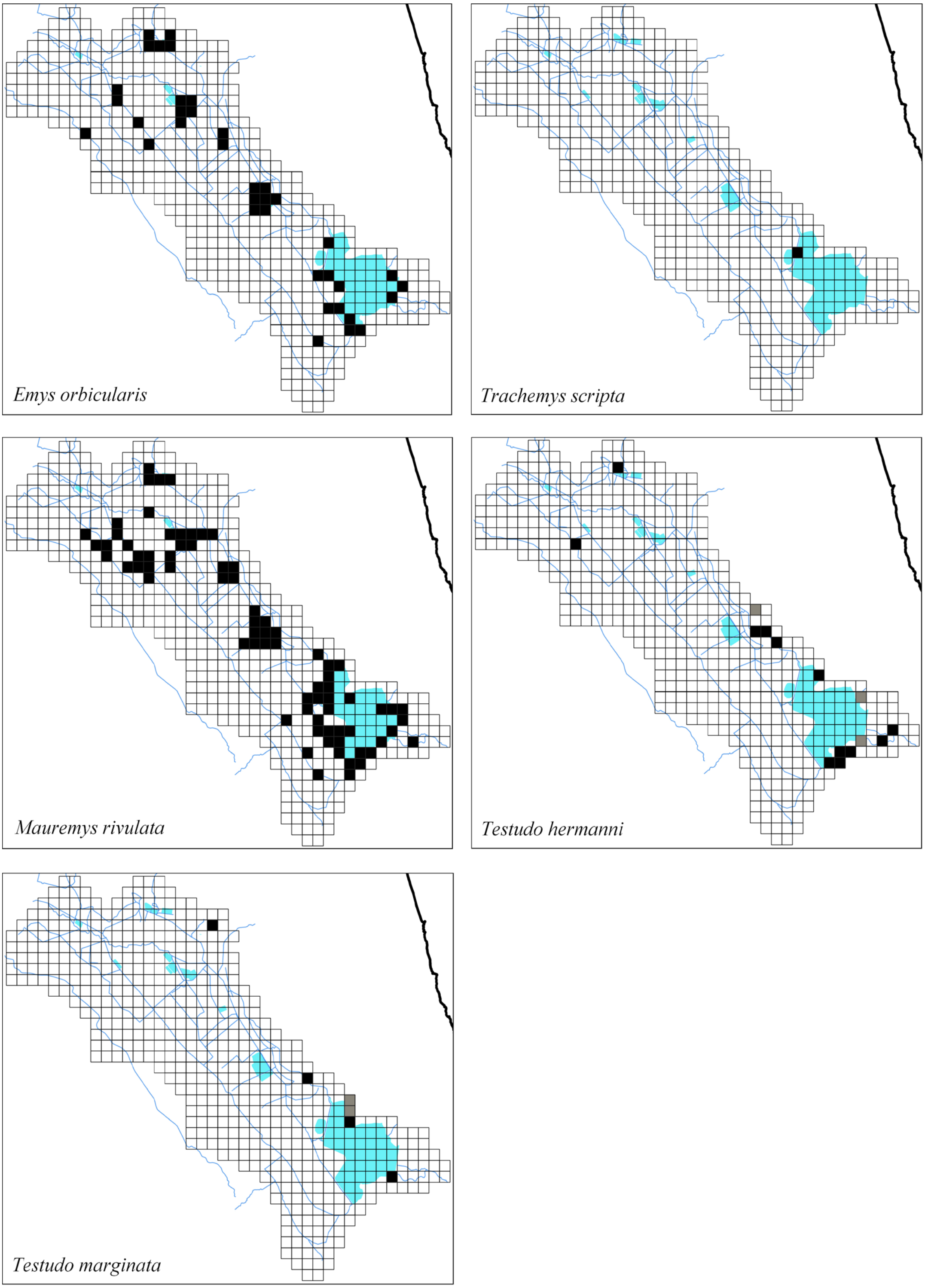

Figure 8. Distribution maps with 1x1 km grid cells of 5 chelonian species in Lake Karla's Plain. Black squares indicate our fieldwork records, grey squares indicate literature records.

Mauremys rivulata *(Valenciennes, 1833) – Western Caspian turtle (Fig. 6E)*.— The Western caspian turtle is the most common turtle of the study area, with 164 records (12.35%), in 76 grid cells (13.2%; Fig. 8). Locally, high densities (e.g., 15–42 individuals) of this turtle were observed. A total of 1330 individuals were counted in almost all permanent water bodies, especially in reservoirs and all types of channels. It was even found in channels used for illegal discharging of livestock and agricultural effluents. We also recorded roadkills of this species on the main roads. Although the species is currently common in the area, it has not been previously reported. It is distributed throughout mainland Greece and in many islands (Valakos et al., 2008).

Testudo hermanni *(Gmelin, 1789) – Hermann's tortoise*.— The Hermann's tortoise is a relatively common tortoise species, with 16 records (1.2%) and 15 occupied grid cells (2.62%; Fig. 8), including the literature mentions. The species was previously observed by Gordinho (2009). Most observations were located in the SE part of the study area, close to the mountains' foothills and in agricultural land; it seems to prefer shrubby and herbaceous vegetation as well as tree crops. This species is distributed throughout mainland Greece and in few islands (Valakos et al., 2008).

Testudo marginata *(Schoepff, 1792) – Marginated tortoise (Fig. 6C)*.— This Greek endemic tortoise was recorded seven times (0.53%) in six grid cells (1.05%; Fig. 8). It was first reported in Karla's plain by Gordinho (2009). Most observations were restricted to the eastern part of study area, close to Mavrovouni Mountain foothills, mainly in scrublands and near tree crops. The natural distribution of Marginated tortoise extends from central Macedonia southwards to the Peloponnese, including some islands (Valakos et al., 2008).

Pseudopus apodus *(Pallas, 1775) – European glass lizard*.— The European glass lizard was the second most recorded and widespread lizard species, with 73 records (5.5%) in 58 grid cells (10.14%; Fig. 9). The species was present in big densities along the foothills of mountains Mavrovouni and Megavouni, both in scrublands and in tree crops. Furthermore, plenty of sparse observations were made in the rest of the study area, in agricultural ecosystems and herbaceous meadows. Road traffic was baneful for this legless lizard as 56% of the field records came from roadkills (Fig. 11C). The first report of European glass lizard from the study area was made by Gordinho (2009). This species is distributed throughout mainland Greece and several islands (Valakos et al., 2008; Balogova et al., 2019).

Hemidactylus turcicus *(Linnaeus, 1758) – Turkish gecko*.— The Turkish gecko was observed in 18 grid cells (3.14%; Fig. 9) with a total of 20 records (1.51%) collected almost exclusively during nighttime. The species was recorded exclusively in human settlements, most often in residential buildings like houses or other buildings, close to lights, lurking for flying insects. The species has not been previously reported in the study area and it is probably present in most settlements. In Greece it is distributed throughout the mainland and in most of the islands (Valakos et al., 2008).

Mediodactylus kotschyi *(Steindachner, 1870) – Kotschy's gecko (Fig. 6F)*.— Kotschy's gecko is a relatively common lizard species in the study area with 25 records (1.88%), found in 19 grid cells (3.32%; Fig. 9) with a total of 50 sighted individuals. In the study area the species seems to be related with human environments, similarly to the Turkish gecko; almost all observations were made in 13 settlements, in uninhabited old buildings. This is the first report of Kotschy's gecko in the Lake Karla's plain. In Greece the species is distributed throughout the mainland and in a large number of islands and islets (Valakos et al., 2008).

Lacerta trilineata *(Bedriaga, 1886) – Balkan green lizard (Fig. 6G)*.— The Balkan green lizard is the most common lizard, with 103 records (7.77%) and presence in 77 grid cells (13.46%; Fig. 9). The species was observed in a wide variety of habitats; it was frequent around aquatic ecosystems with dense vegetation, in human environments, in agricultural areas and around mountains' foothills and hills with every type of vegetation. Gordinho (2009) was the first to mention this species from Karla area. The Balkan green lizard is distributed throughout mainland Greece and in many islands (Valakos et al., 2008).

Podarcis tauricus *(Pallas, 1814) – Crimean wall lizard*.— We found only one adult individual of the Crimean wall lizard in 2014, in an agricultural area at the northern part of the study area, close to River Asmaki. This is the first record of the species in Lake Karla's plain. The Crimean wall lizard is distributed throughout mainland Greece (Valakos et al., 2008), and

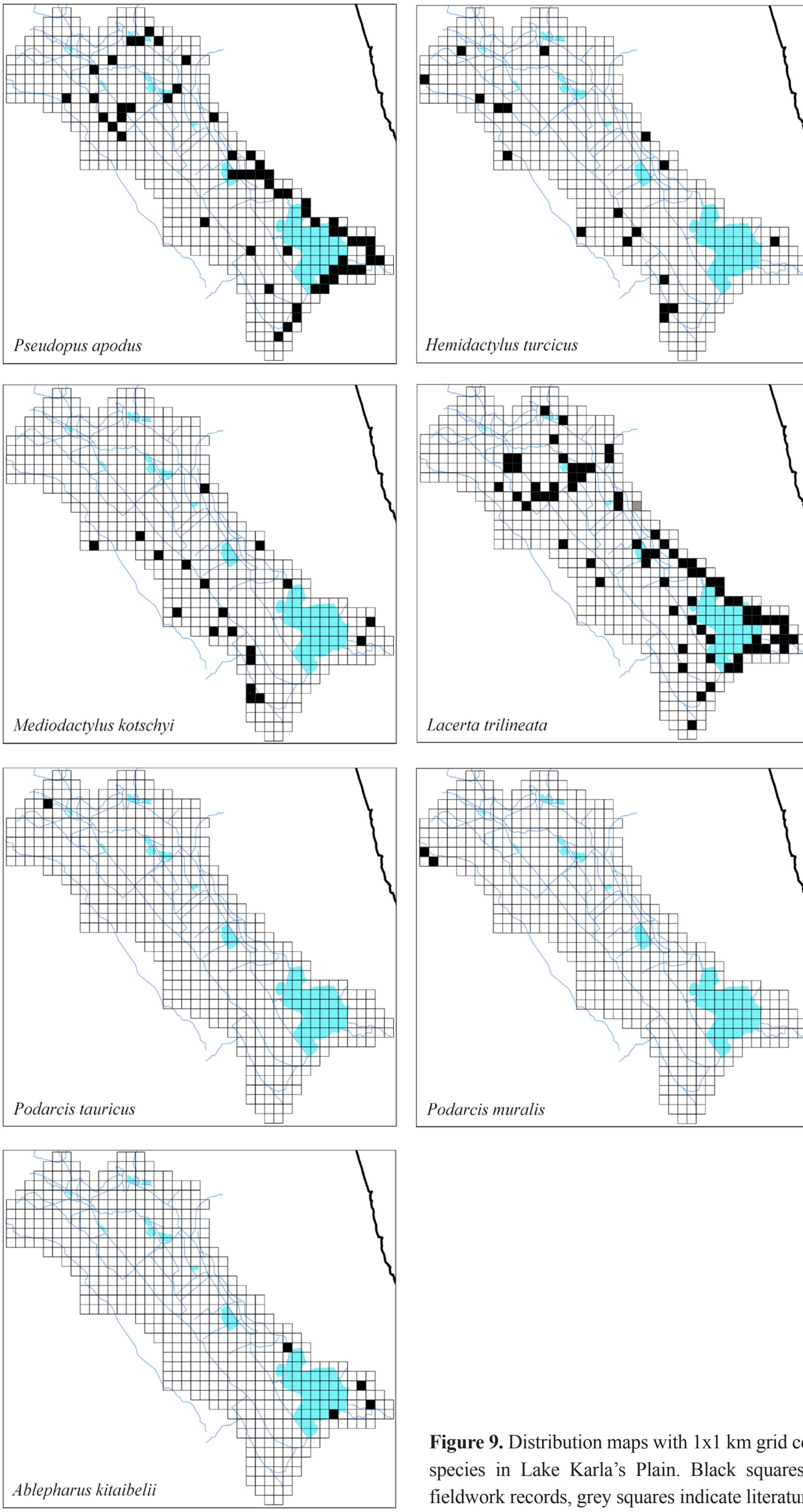

Figure 9. Distribution maps with 1x1 km grid cells of 7 lizard species in Lake Karla's Plain. Black squares indicate our fieldwork records, grey squares indicate literature records.

according to Psonis et al. (2017) its range extends east of the Pindos Mountain range.

Podarcis muralis *(Laurenti, 1768) – Common wall lizard*.— The Common wall lizard was recorded four times in two adjacent grid cells (Fig. 9), in different years. A total of five adult individuals have been observed in the eastern suburbs of Larissa city in a residential area. This is the first record of the species in the study area. This wall lizard is common at Mavrovouni Mountain which borders with the eastern side of the plain (pers. obs. of the first author). This species is distributed throughout a large part of the Greek mainland (Valakos et al., 2008).

Ablepharus kitaibelii *(Bibron and Bory, 1833) – Snake-eyed skink*.— We report the presence of the Snake-eyed skink for the first time in the study area. We collected only four records (0.3%) of the Snake-eyed skink, located in four grid cells (0.7%; Fig. 9). The records were restricted to the surrounding area of Lake Karla, in agricultural locations (almond tree crops and meadows) and in an artificial coniferous grove. This species is distributed throughout mainland Greece and in a considerable number of islands (Valakos et al., 2008).

Eryx jaculus *(Linnaeus, 1758) – Javelin sand boa (Fig. 6K)*.— We report for the first time the presence of the Javelin sand boa; we found only one adult, basking on a dirt road in a scrubby area at the northern part of Lake Karla, near Mavrovouni Mountain foothills, in 2016. The species can be found in most of mainland Greece, Euboea Island and many other Greek islands (Valakos et al., 2008, Christopoulos et al., 2019). The Javelin sand boa spends most of its life underground or in burrows and is hard to detect because of its cryptic lifestyle. The elusive nature of this species may account for the rarity of encounters.

Dolichophis caspius *(Gmelin, 1789) – Caspian whipsnake*.— The Caspian whipsnake was the third most common and widespread snake species, with 57 records (4.3%) in 49 grid cells (8.56%; Fig. 10). The species was found in a variety of habitats, mainly in agricultural and human environments as well as in scrublands of Mavrovouni and Megavouni foothills and in meadows around the reservoirs. 67% of the records came from roadkills. This species was previously mentioned in the study area by Gordinho (2009). The species is distributed in a large part of mainland and insular Greece, except Peloponnese (Valakos et al., 2008).

Elaphe quatuorlineata *(Bonnaterre, 1790) – Western four-lined snake (Fig. 6H)*.— The Western four-lined snake was the fifth recorded snake species, with 31 observations (2.33% of the data) in 30 grid cells (5.24% of entire grid; Fig. 10). 64.5% of the records were roadkills (Fig. 11D). The species was mostly found in locations with high humidity, like reservoirs and agricultural lands that include irrigation and drainage channels with reedbeds, shrubs or trees, as well as pastures, meadows and tree crops. Many records come from settlements. Our mention is the first of the species from the plain of Lake Karla. Distribution of the species in Greece includes the entire mainland (except Thrace), Peloponnese and many islands (Euboea, Ionian Sea Islands, Sporades and Cyclades Islands) (Valakos et al., 2008).

Platyceps najadum *(Eichwald, 1831) – Dahl's whip snake*.— The Dahl's whip snake was recorded only in two grid cells (Fig. 10) in 2008 and 2011. The two records concern two adults in areas with almond tree crops. Although it is a common species throughout mainland Greece and in many islands (Valakos et al., 2008), this is the first record of the Dahl's whip snake from the plain of Karla. It is possible that the species will have a wider distribution in the study area and in more habitat types.

Telescopus fallax *(Fleischmann, 1831) – European cat snake*.— We found only one individual, close to the record from Chondropoulos (1989). These two records were located in the southern part of the plain of Karla (Fig. 10) in rocky scrubby area of the Megavouni foothills and in a suburban environment. The species has a wide distribution throughout mainland Greece and in a large number of islands (Valakos et al., 2008).

Zamenis situla *(Linnaeus, 1758) – Leopard snake (Fig. 6I)*.— The Leopard snake was not previously recorded in the study area, but we found that it is a relatively common snake, with 14 records (1.05%) detected in 12 grid cells (2.09%; Fig. 10). All records were located in the eastern and southern parts of the study area, close to the foothills of Mavrovouni and Megavouni Mountains. We found this species in rocky or stony habitats, with sclerophyllous shrubs, tree crops and meadows. We

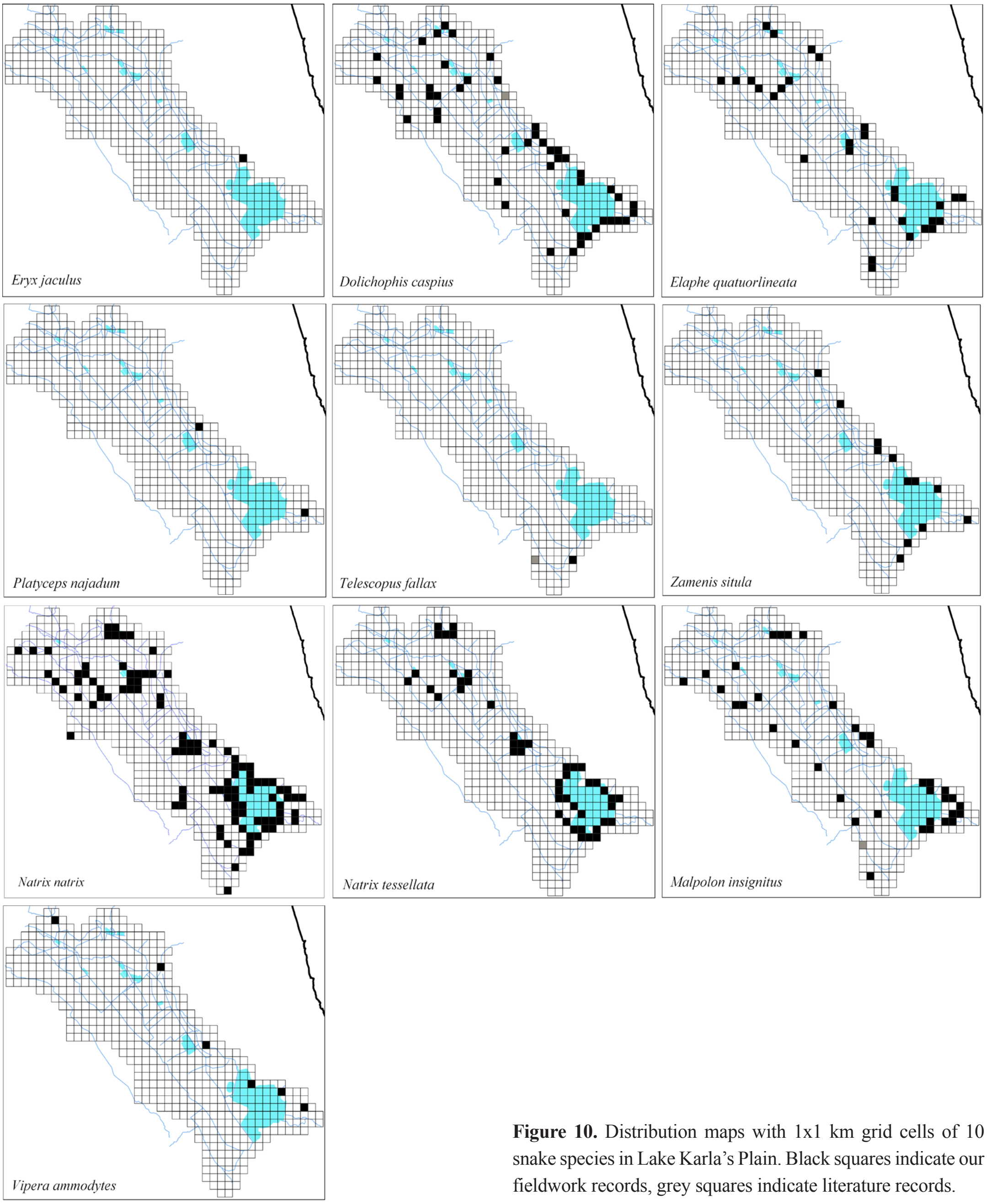

Figure 10. Distribution maps with 1x1 km grid cells of 10 snake species in Lake Karla's Plain. Black squares indicate our fieldwork records, grey squares indicate literature records.

recorded eight adults as roadkills. The distribution of the Leopard snake in Greece extends throughout the mainland and in several islands (Valakos et al., 2008).

Natrix natrix *(Linnaeus, 1758) – Grass snake.*— We report the presence of this species for the first time in the study area. The Grass snake is the most common and extensively distributed snake species in the plain of Lake Karla with 147 records (11.0%) in 101 grid cells (17.65 %; Fig. 10). The species is a frequent traffic victim with 50% of its records concerning roadkills. We found this species in a wide variety of habitats, both in aquatic and in terrestrial ecosystems. Most observations were located in water bodies; the species is very common around reservoirs, Lake Karla and all type of channels in agricultural areas. A significant number of individuals were also detected in less humid locations such as tree crops with stony substrate, dry meadows and rocky hills with phrygana or sclerophyllous vegetation. The species is extended throughout the mainland Greece and in many islands (Valakos et al., 2008).

Natrix tessellata *(Laurenti, 1768) – Dice snake (Fig. 6J)*.— We report the presence of this species for the first time in the study area. The field surveys resulted in a total of 64 records (4.82%) in 47 grid cells (8.21%; Fig. 10) in the study area. Although the Dice snake was the second most common snake species, its distribution was more restricted than its congeneric Grass snake. This is due to the species' preference for aquatic ecosystems; all individuals were mainly detected in and around reservoirs and Lake Karla and less in irrigation and drainage channels. 47% of the records came from roadkills. The species is distributed throughout mainland Greece and in some islands (Valakos et al., 2008).

Malpolon insignitus *(Geoffroy Saint-Hilaire, 1827)*.— Eastern Montpellier snake. — The Eastern Montpellier snake was a common and widespread snake species in the area of Karla, with 45 records (3.4%) which fall in 38 grid cells (6.64%; Fig. 10). Roadkilled specimens amount to 70% of the records for this species. The species was detected in various habitats throughout the plain of Karla, except for locations with high humidity. We recorded this species mostly in agricultural environments (both in arable and tree crops) or scrublands, as well as in meadows or in and around of settlements. The first observation of Eastern Montpellier snake in the study area was made close to Rizomylos Village, by Chondropoulos (1989). The species is spread throughout mainland Greece and in many islands (Valakos et al., 2008).

Vipera ammodytes *(Linnaeus, 1758) – Nose-horned viper (Fig. 6L)*.— We report the Nose-horned viper for the first time in the study area, from six grid cells (1.04% of entire grid; Fig. 10). Five individuals were observed close to Mavrovouni Mountain foothills in stony and rocky areas with shrubs or tree crops and a single adult was found in agricultural land at SW foothills of Gintiki Hill. It is noteworthy that the biggest individual we found measured approx. 90 cm in total length. According to Valakos et al. (2008), this is the maximum total length that the species can reach in Greece, usually measuring under 65 cm. In other Balkan areas the maximum total length was found in Bulgaria and measured 87 cm in *V. a. montadoni* subspecies (Stojanov et al., 2011). The nose-horned viper is distributed throughout mainland Greece and in some islands (Valakos et al., 2008).

Discussion

General. We recorded 17 species of amphibians and reptiles for the first time in Lake Karla's Plain. Ten other species were already recorded during previous studies (Chondropoulos, 1989; Gordinho, 2009; Sofianidou, 2012), of which we were able to confirm the presence of nine of them. The only species that was not found during fieldwork was the Balkan spadefoot *Pelobates balcanicus*, which was found by Sofianidou in 1993, in the southern part of the study area. Thus, we provide an updated checklist of herpetofauna from Lake Karla's Plain, with 26 (potentially 27) species, along with details regarding their distribution and threats. The most frequently observed species were *Pelophylax kurtmuelleri*, *Mauremys rivulata*, *Natrix natrix* and *Lacerta trilineata*, with 385, 164, 147 and 102 records respectively. These species are also the most widespread in Lake Karla's Plain. The highest densities were observed in *Pelophylax kurtmuelleri*, *Mauremys rivulata*, *Emys orbicularis* and *Bufotes viridis*. This pattern can be explained by the availability of extensive water bodies in the area: lakes, reservoirs, marshes, seasonal ponds and channels, but also reflects a sampling bias, since most of the field work was concentrated around wetlands.

The highest species richness was found around Lake Karla, the reservoirs and at the limits of study area with Mavrovouni foothills, which confirms the high value for biodiversity of these spots. These less disturbed areas act as islets for wildlife, providing a mosaic of habitats with natural vegetation, in contrast to the extensive monotonous agricultural land around them.

Due to its geographical location, in the central part of Greece, it was expected that Lake Karla's Plain harboured common species that are distributed in most of the mainland (within the limits of their distribution), when suitable habitats were available. Despite this, we didn't find all the expected species, such as *Lissotriton graecus*, *Anguis graeca*, *Podarcis erhardii*, *Hierophis gemonensis*, *Zamenis longissimus*, *Xerotyphlops vermicularis*. To investigate the presence of these species, as well as for filling distribution gaps of already recorded species, localised and targeted samplings should be done.

Threats and management issues. Due to the drying of Lake Karla in the 60's, the distribution patterns of many species may have changed; aquatic species (frogs, pond turtles, *Natrix* spp.) have lost much of their original habitat, while terrestrial species (lizards, most of snakes, *Testudo* spp.) have spread to the newly-formed habitats, previously occupied by the lake. The aquatic species today are located in the restored part of the former Lake Karla, reservoirs, seasonal water bodies, irrigation and drainage channels. In turn, the conversion of the former lake into arable land, may have further confined the terrestrial species to more natural areas that were preserved around agricultural fields.

During our visits over the last decade, we have identified small-scale habitat degradation. The mechanical removal of accumulated sediments and aquatic plant remnants from the irrigation and drainage canals or the burning of reeds (Fig. 11A) pose an immediate risk of injurying or killing amphibians and reptiles within these habitats. In addition, these activities degrade their habitats. Another threat comes from the illegal dumping of farming wastes, debris, and garbage, especially near or in surface waters.

The main water supply for Karla's Lake comes from Pineios River and the runoffs from the adjacent basin to flow in (Laspidou et al., 2017). Smaller amounts of water are added from the surrounding agricultural drainage channels and from the rain. Lake Karla's Plain is characterised by intense agricultural activity (Oikonomou et al., 2012; Laspidou et al., 2017), which led to the pollution (e.g., with agrochemicals, fertilisers and livestock manure) of the lake and its enrichment with nutrients (Oikonomou et al., 2012; Sidiropoulos et al., 2012). In addition, other factors such as the low water level and the high summer temperatures, seem to contribute to the eutrophication of the lake, which is affected by frequent cyanobacterial blooms (Oikonomou et al., 2010, 2012; Sidiropoulos et al., 2012; Papadimitriou et al., 2013, 2018). These toxic blooms led in turn to mass mortalities in fish (i.e., *Cyprinus carpio*) and birds (i.e., *Pelecanus crispus*) in 2010 and 2016 respectively (Oikonomou et al., 2012; Papadimitriou et al., 2018). Significant negative effects of cyanobacterial toxicity, as mortality, neurological impairments, neurodegeneration, vacuolisation of central nervous tissues, development of lesions within brain tissues, vacuolar myelinopathy, effects on amphibian metamorphosis, inhibition of serine/threonine protein phosphatases-1 and -2A, have been identified in both amphibians and reptiles (Fischer and Dietrich, 2000; Mackey and Boone, 2009; Mercurio et al., 2014; Maerz et al., 2019). Although no effects have been observed on herpetofauna until now in the study area, these blooming phenomena could become a threat for amphibians and aquatic reptiles if eutrophication control measures are not taken (such as maintaining a high water level). We are not aware of cases of toxicity and wildlife killing in the small scattered reservoirs or other surface waters, an encouraging fact for aquatic herpetofauna and general biodiversity of the area.

Out of a total of 1313 records, 325 represent roadkills (~25%), suggesting that the extensive road network in Lake Karla's Plain poses a threat for the persistence of local herpetofauna. The area is surrounded by main country roads and an Old Highway, while several settlements are connected by secondary roads. In addition, the wider agricultural area is crossed by hundreds of kilometres of dirt roads. We encountered roadkills (1–46 per survey; $\bar{x} = 6.3$) of amphibians and reptiles both on the asphalt and on tracks (Fig. 11B–D) during most of our field surveys (88%). Most roadkills were snakes (203 records), followed by lizards (55 records), amphibians (49 records) and pond turtles (18 records). A total of 14 herpetofauna species were found as traffic victims, but the species with more than 50% roadkill records of their total records were *Bufo bufo*, *Pseudopus apodus* (Fig. 11C), *Natrix natrix*, *Dolichophis caspius*, *Malpolon insignitus*, *Elaphe quatuorlineata* (Fig. 11D), and *Zamenis situla*. In amphibians we noted mass seasonal road mortality, mainly in early and mid-spring, when breeding takes place and the animals are highly mobile. Further research on road mortality may highlight the problem and suggest management plans to alleviate it.

Road mortality in animals is one of the most obvious effects of the road network (Spellerberg, 1998; van der Ree et al., 2015) and in wild fauna is estimated at thousands to millions of individuals per year (Forman & Alexander, 1998; Hels and Buchwald, 2001). This threat is especially high in amphibians and reptiles since they can use the roads during migrations to or from their breeding habitats, move slowly, or use the roads for thermoregulation; excessive road mortality and reduced habitat connectivity by road network can contribute or lead to population declines (Hels and Buchwald, 2001; Colino-Rabanal and Lizana, 2012; Andrews et al., 2015). Amphibians' and reptiles' roadkills in Greece go unnoticed for the majority of the society and the effects and the extent of the problem are poorly-known, since only few studies focused on this issue (Kypraios-

Figure 11. Threats for amphibians and reptiles from Lake Karla Plain. (A) Burned reedbed in a marsh near the Kalamaki Reservoirs, 15 March 2008. (B) *Bufotes viridis* roadkill between Kastri – Amygdali Villages, 11 April 2019. (C) *Pseudopus apodus* roadkill, Palaeoskala area, 23 May 2017. (D) *Elaphe quatuorlineata* roadkill, southern area of the restored Lake Karla, 23 May 2017. (E) *Zamenis situla* killed by a local man, Rizomylos Village area, 3 June 2011. (F) Two adult *Emys orbicularis* trapped in a fish wire trap, Niamata Reservoirs, 26 April 2015. Photos by Apostolos Christopoulos.

Skrekas, 2016; Kouris, 2020). Our data contributes to raising awareness regarding this threat in Lake Karla's Plain and should be considered as a call for management actions forthwith, especially in those parts of the study area (33% in total) which are included in Natura 2000 network sites.

Another threat we recorded was the deliberate killing of reptiles by local people (Fig. 11E). Snakes and the glass lizard *Pseudopus apodus* were the most common victims, since they are believed to be harmful and dangerous. A practical solution for this threat is to conduct education campaigns or workshops in the area.

Other threats, unintentional trapping and alien species, concern mainly the pond turtles and were recorded in two locations. *Emys orbicularis* and *Mauremys rivulata* individuals were found trapped in fish wire traps in Niamata Reservoirs at nine occasions (Fig. 11F). The presence of the alien species *Trachemys scripta* was recorded in a channel in the northern part of Lake Karla. *T. scripta* is considered a harmful alien species of European Union concern (EU, 2019), and previous research showed that it can have negative effects on native species (Cadi and Joly, 2003; Pérez-Santigosa et al., 2008, Hidalgo-Vila et al., 2009; Standfuss et al., 2016; Demkowska-Kutrzepa et al., 2018). Management actions are required in order to remove this species from natural ecosystems and continue monitoring for its early detection, focusing on the channels that communicate with Pineios River.

Conclusions. Lake Karla's Plain was a herpetologically poorly-known area and this is the first study that specialised on this animal group, updating knowledge regarding its distribution and threats. A total of 27 herpetofauna species, comprising 5 anuran amphibians and 22 reptiles (5 chelonians, 7 sauria and 10 ophidia) were recorded and mapped in Lake Karla's Plain, both from field surveys and previously published literature. In the early 60s, the drainage of Lake Karla radically changed the landscape, creating new conditions for amphibians and reptiles here. The current habitats available for herpetofauna are represented by reservoirs, small marshes, channel networks, agricultural land (annual and tree crops), pastures and meadows, hilly areas, settlements, shrublands and the partially restored Lake Karla with its small artificial wetland. The threats to the herpetofauna here are habitat degradation, pollution, road mortality, alien species, unintentional trapping and deliberate killing. Further research and monitoring of the amphibians and reptiles in the region is required to supplement our knowledge on their distribution, confirm the presence of species not found during this study, provide better insights regarding the threats they face and identify potential management solutions for their conservation.

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