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The Distribution and Diversity of Reptiles in a Species-Rich Protected Area of Central Italy

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***Abstract*.—Circeo National Park (CNP) is one of the oldest protected areas in Italy. Knowledge of the herpetofauna of CNP is relatively scarce, with the most recent records dating from the 1970s. This gap of knowledge needs to be addressed, considering that this area is one of the last pristine fragments of coastal Mediterranean forest in the Italian Peninsula and potentially hosts high reptile diversity. In this study, we assessed reptile diversity and distribution at the landscape scale, covering all habitats within the park boundary. We performed field surveys during two sampling sessions in 2004–2005 and in 2009–2010, using 127 cells of 1 km^2. We collected 1,471 distribution data points on 16 reptile species. While natural land use categories supported the whole reptile community, urban and agricultural environments hosted about half of the species detected. Reptile distribution was uneven among the natural land categories with 80% of species and all snake species inhabiting the broad-leaved forest category and confirming the expectation of a high herpetological diversity hosted by this last fragment of coastal Mediterranean Forest ecosystem. We discuss the pattern of species distributions in terms of conservation prioritization.**

Key Words.—agricultural landscape; Circeo National Park; conservation; coastal Mediterranean forest; habitat use; urban landscape

Introduction

The Italian Peninsula hosts some of the richest herpetofauna in Europe, both in terms of species diversity (91 total species; 40 amphibians and 51 reptiles) and endemic species (50% amphibians and 17% reptiles; Sindaco et al. 2006). In Mediterranean central Italy, there are some areas that are characterized by unusually high species richness (Vignoli et al. 2013), but that are still relatively understudied (Zerunian 2005). In particular, Circeo National Park (CNP), situated in the southwestern part of Latium, hosts a very rich and diversified fauna (UNESCO - MAB Biosphere Reserves Directory. Biosphere Reserve Information: Circeo. Available from http://www.unesco.org/mabdb/br/brdir/directory/database.asp [Accessed 10 December 2014]), which reflects remarkable habitat diversity despite its relatively small size. While a detailed study is available for amphibians (Cinquegranelli et al. 2015), knowledge on the reptile fauna of CNP remains fairly scarce and incomplete (Bruno 1981, summarized in Carpaneto 1986; Bologna et al. 2000). This gap in ecological knowledge needs to be addressed because CNP potentially hosts high reptile species diversity. This is likely due to the fact that previous faunistic investigations have been carried out either in an opportunistic way (Bruno 1981) or within the framework of a wide-scale study (regional atlas; Bologna et al. 2000). In the latter case, CNP is included in a single 10 × 10 km^2 sampling unit of the Latium Region, which also covers areas outside park boundaries. Thus, the data referring to that sampling unit are limited and may also represent sightings external to the protected area.

We expect that the most common species would have been detected with such an approach, but that elusive and rare species, or those suffering declining trends, may have been overlooked. To overcome this problem, we used a small-scale (i.e., with sampling units of 1 × 1 km^2), systematic (covering the entire area and habitats) survey design to assess the reptile diversity of CNP. This study aims to provide: (1) the first systematic assessment of reptile diversity in CNP; (2) a detailed analysis of the ecological distribution of each species and habitat use at a landscape scale; and (3) conservation and management action recommendations.

Materials and Methods

Study area.—We carried out surveys in Circeo National Park in Latium (Central Italy), (41°25'01" to 41°13'21"N, 12°52'12" to 13°06'11"E). The climate of the region is classified as Mediterranean, with mild-rainy winters and hot summers. The annual average rainfall ranges from 845 to 925 mm with a peak in November. The average temperature of the coldest month (January) is 8° C, and the average for the hottest month (July) is 23.5° C. The average absolute annual minimum temperature is -4.1° C and the maximum is 35.7° C (Blasi 1994).

In CNP, most of the surface (58%) is occupied by forests and semi-natural areas. In particular, forests account for 70% of natural and semi-natural areas and account for about 40% of the park area (Ente Parco Nazionale del Circeo. Piano del Parco Nazionale del Ciceo. Relazione generale. Sabaudia. 2011. Available from http://www.parcocirceo.it/pdf/Relazione%20Tomo%201%20Analisi%20All_Del_CD_43_del_22_12_2011.pdf [Accessed 12 December 2015]). Woods of Turkey Oak (*Quercus cerris*) and Italian Oak (*Quercus frainetto*) represent the largest vegetation type in the park, covering nearly 30% of the total area, followed by woods dominated by Holm Oak (*Quercus ilex*; 8%) and Cork Oak (*Quercus suber*; 2%). Moreover, 15% of the Cork Oak and Italian Oak forests occur as a mosaic interposed with discontinuous urban buildings. The remaining 18% of the natural and semi-natural areas consist mainly of reforestation vegetation, especially coniferous species. The sclerophyll-dominated maquis contains predominantly the scrub Juniperus phoenicea (Ente Parco Nazionale del Circeo 2011, op. cit.). In the natural habitats, the complexity of vegetation structure (habitat complexity *sensu* Mac Arthur and Mac Arthur 1961) mirrors the degree of stratification (i.e., arboreal, shrubby, herbaceous), with Turkey Oak forest > Holm Oak forest > maquis > herbaceous open habitat > dune (Blasi and Spada 1984). The habitat heterogeneity (*sensu* Wiens 1974) describes the alternation of habitat forms along a horizontal gradient. In the study area, the degree of habitat heterogeneity in the natural environments is quantifiable as follows: maquis > Turkey Oak forest > Holm Oak forest > herbaceous open habitat > dune (Blasi and Spada 1984). Agricultural areas cover over 18% of the park, with extensive arable crops predominant. Surface waters cover about 13% of the park and consist primarily of coastal lakes (Fogliano, Monaci, Caprolace, and Paola), with wetlands with reed beds and halophyte vegetation covering about 3% of the park. About 8% of the park is covered by artificial surfaces. In the matrix surrounding CNP, the land-use proportions change radically, with agricultural lands exceeding 56% of the entire area and substantially more artificial surfaces (Ente Parco Nazionale del Circeo 2011, *op. cit*.).

Sampling design.—We performed field surveys during two sampling sessions: 2004–2005 and 2009–2010. We conducted surveys in the spring, summer, and autumn months during the periods of maximum reptile activity. We subdivided the park into 127 cells of 1 km^2 each. For the cells that were only partially within CNP (i.e., the edge cells), we explored only the portion within CNP. Within each cell, we sampled all of the main habitats with a procedure that included opportunistic searching and standardized linear transect surveys that varied in length depending upon the amount of habitat available (Campbell and Christman 1982). To make sure to cover all of the habitats in each cell, we carried out rapid sampling by employing one researcher at a time during daylight hours and without using traps or artificial covers. Although this protocol could underestimate crepuscular and nocturnal species, we assumed that species that may be active during and after sunset in the park were also generally active during the day for thermoregulation or predation activities (e.g., snakes, geckos, terrapins). Overall, we surveyed the entire protected area except for Zannone Island. For this island, we relied on the recent survey by the State Forestry Corp (Zerunian 2005) and later surveys (Sergio Zerunian, pers. comm.) that reported the Italian Wall Lizard (*Podarcis siculus*) as the only reptile species occurring on the island.

We carried out surveys from April to November between 0800 and 1900. The overall field effort was 60 d in 2004–2005 and 50 d in 2009–2010. In addition, we increased the number of records by 5% by including recent observations made by experienced professional herpetologists (recognized based upon publication history and prior work) who had visited the area consistently during the past decade. To provide an updated checklist, we considered only data subsequent to 2004. We identified all of the observed reptiles at the species level using the field guide by Arnold and Ovenden (2002).

We included the GPS position of each reptile record in a database. We plotted records on maps with a 1 × 1 km grid showing the distribution of each species within the park. In each cell, we reported the species presence and abundance category. We considered three abundance categories for most species: 1, 2–5, and 6–10 individuals represented by small, medium, and large markers, respectively. Due to the relatively large number of lizard records, we used different abundance categories for lizard species only: 1–5, 6–50, and 51–100. We used ArcGIS software v. 10.0 for processing the data and for producing the distribution maps. By using environmental data from both sampling sessions and satellite images, we were able to identify land cover categories established by the European Environment Agency (European Environment Agency. Publications: Corine Land Cover. Available from http://www.eea.europa.eu/publications/COR0-landcover [Accessed 10 December 2014]) in the Coordination of Information on the Environment Program (CORINE). We then adjusted our land cover estimations by overlying our observations on a digitized land cover map of the study area supplied by the Regional Administration Office of Latium.

Overall, we recognized 13 land cover categories (3^{rd} CORINE level) within the park boundaries. The CORINE land cover list and nomenclature for the recognized categories are listed in Appendix I. All records of reptile species were thus associated with a given land cover type based on GPS position. We grouped the CORINE levels together into three macro-classes depending on the CORINE category: (1) Urban; (2) Agricultural; and (3) Natural.

Statistical analyses.—To classify species based on their distribution across the different land use categories, we performed a Principal Component Analysis (PCA) on the land cover categories grouped in the three main macro-classes (Urban, Agricultural, and Natural). We classified all reptile species observed in the study area in the multidimensional space by means of a PCA by analyzing their proportional distribution in the various CORINE categories. We considered the variables as significantly correlated to a factor with loading above 0.71 (Tabachnick and Fidell 2001). We assessed habitat selection by means of Compositional Analysis (CA), a method used to categorize animal locations by habitat type and to calculate the proportional use of those habitats (Aebischer et al. 1993). We adopted the approach of CA proposed by Neu et al. (1974) instead of the approach of Aebischer et al. (1993) because we were interested in assessing habitat use at the population level; that is, animals were not uniquely identified and availability was defined at the population level. This technique employs chi-square tests followed by the calculation of confidence intervals for the observed proportion of use within each habitat type with adjusted α for the comparisons of observed and expected values (Bonferroni intervals; Slattery and Alisauskas 2007). Because CA does not allow for zero values, zero values for non-used habitat types were replaced by a value of 0.001% (Aebischer et al. 1993). When one or more habitats have expected values of < 5, we tried to combine similar land-use cover types to obtain greater pooled expected values and to remove the bias inherent in the chi-square test. We considered land cover types as selected or avoided if observed values of proportional habitat use (Bonferroni intervals) were above or below the expected habitat use, respectively (Slattery and Alisauskas 2007). The minimum number of individuals needed for CA is six (Aebischer et al. 1993); thus, for this analysis, only species with adequate number of locations were considered. Due to the small number of observations (≤ 6) for many species, and to depict general patterns, we performed CA on the entire herpetofauna pooled and on three main groups consisting of the following pooled species: lizards (*Lacerta viridis*, *Podarcis muralis*, *Podarcis siculus*), snakes (all snake species), and geckos (the two Gekkonid species found in the area). We used the software Statistica (Statsoft inc., version 8.0) for the PCA analysis and Biotas (Ecological Software Solutions version 2.0) for the CA of habitat use.

Results

Reptile distribution within Circeo National Park.—Overall, we collected 1,471 reptile records, distributed across all 127 cells. We recorded 16 reptile species: two Emydidae, two Gekkonidae, three Lacertidae, one Anguidae, one Scincidae, six Colubridae, and one Viperidae (Table 1). Five species had broad distributions: we detected the Italian Wall Lizard (*P. siculus*) in 52% of the total cells, the Western Green Lizard (*L. bilineata*) in 34.6%, the Common Wall Lizard (*P. muralis*) in 32.3%, the Western Whip Snake (*Hierophis viridiflavus*) in 24.4%, and the Aesculapian Snake (*Zamenis longissimus*) in 11.8%. The geographic pattern of reptile species richness (Fig. 1) revealed two hotspots within the natural areas of the park, one consisting of a small remnant forest fragment close to the wetland of Fogliano Lake, and another in the mesophilic oak woodlands on the northern slope of Circeo promontory. The areas with few or no reptile records in the cells included places occupied by lakes or human-altered environments (primarily roads and residential areas, as well as intensive farming and pastures; see Appendix II).

Reptile distribution across land cover categories.—We detected all of the recorded species in at least two land cover categories (Table 2). After we excluded from the analysis the five most abundant species (as described above), 50% of the remaining species were detected in three CORINE categories. However, we found that eight species had over 50% of their records from a single land cover typology: the Slow Worm (*Anguis fragilis*); the Italian Three-Toed Skink (*Chalcides chalcides*); the Smooth Snake (*Coronella austriaca*); the Four-Lined Snake (*Elaphe quatuorlineata*); the European Pond Turtle (*Emys orbicularis*); the Turkish Gecko (*Hemydactylus turcicus*); *H. viridiflavus*; and the Dice Snake (*Natrix tessellate*). Natural land use categories supported the entire reptile community. By

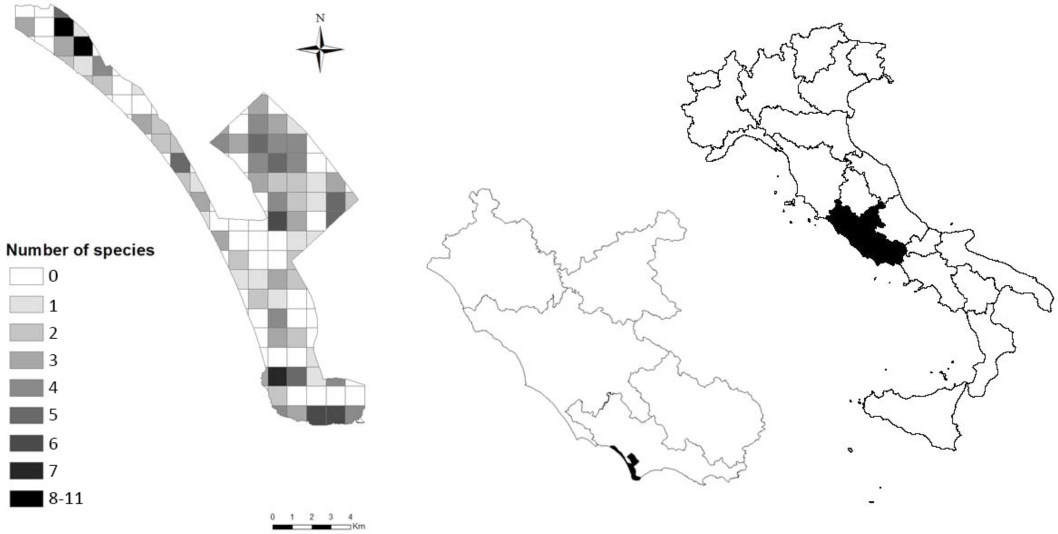

Figure 1. Far left: The distribution of reptile diversity recorded in the Circeo National Park. The number of species detected in each cell ranges from 0 to 11. The study area and its position at regional and national scale are also displayed (center and right, respectively).

contrast, urban and agricultural environments supported about half of the species detected (Table 3). Within the natural habitats (natural land cover macro-class), forest represented the most species-rich habitat followed by wetlands and Mediterranean maquis. Habitats characterized by low stratification and low resource availability such as sandy dune and garigues supported low species richness (Table 4).

The various species showed an overall similar pattern of distribution across the land use categories, with most reptiles associated with natural habitats and few species associated with agricultural categories (Table 5). Exceptions to this pattern were the Moorish Gecko (*Tarentola mauritanica*; mostly found in urban environments) and *C. chalcides* (mostly found in agricultural habitats). In addition, two other species (i.e., the Asp Viper, *Vipera aspis*, and *C. austriaca*) showed a propensity to inhabit rural habitats (Fig. 2).

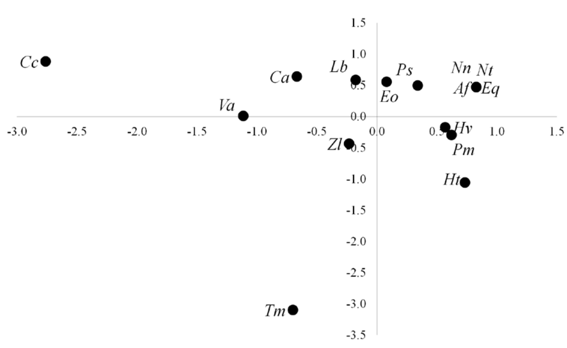

Figure 2. Principal Components Analysis scatterplot showing the distribution of the various species in relation to the proportion of the inhabited land use category group (Urban, Agricultural, and Natural). *Af*: *Anguis fragilis*; *Cc*: *Chalcides chalcides*; *Ca*: *Coronella austriaca*; *Eq*: *Elaphe quatuorlineata*; *Eo*: *Emys orbicularis*; *Ht*: *Hemidactylus turcicus*; *Hv*: *Hierophis viridiflavus*; *Lb*: *Lacerta bilineata*; *Nn*: *Natrix natrix*; *Nt*: *Natrix tessellata*; *Pm*: *Podarcis muralis*; *Ps*: *Podarcis siculus*; *Tm*: *Tarentola mauritanica*; *Va*: *Vipera aspis*; *Zl*: *Zamenis longissimus.*

Habitat selection.—We detected differences in use by species among the considered habitat types with a significant difference in observed use versus expected use ($\chi^2 = 588.92$, df = 8, $P < 0.001$ for all of the following CA comparisons). Overall, natural habitats were used in greater proportion than availability, wetlands in proportion to availability, and agricultural and urbanized habitats in lower proportion than availability (Fig. 3). These general patterns persisted also when data were grouped taxonomically (i.e., lizards, geckos, and snakes). In particular, lizards used artificial, agricultural, and dense forest categories less than expected, whereas they used mixed forest, sclerophyllous, and dune vegetation in higher proportion than availability ($\chi^2 = 566.43$, df = 8, $P < 0.001$). Geckos used urban and agricultural categories following their availability, forests less than availability, and sclerophyllous and dune vegetation more than availability ($\chi^2 = 65.67$, df = 5, $P < 0.001$). Snakes used agricultural areas less than expected, dense forest more than expected, and the remaining categories following their availability ($\chi^2 = 21.07$, df = 7, $P = 0.004$).

Discussion

Reptile diversity and distribution within Circeo National Park.—Our study revealed the presence of 15 autochthonous reptile species inside the park, thus accounting for nearly 30% of the total Italian reptile species (Sindaco et al. 2006) and 78.9% of the species

Table 1. Distribution of 16 reptile species in Circeo National Park, Italy. For each species, we report number (NC) and percentage (%NC) of occupied cells. The abundance category (i.e., the number of individuals per cell) is shown as the absolute number and the percentage (in parentheses). The number of observed individuals (NI) for each species are also reported. For the three most abundant taxa (lacertids), different abundance categories were set and they are listed separately (see Materials and Methods).

					Abundance (n)						
Species	NC	NG	%NC	%NG	1	1–5	2–5	6–50	6–10	51–100	NI
Emys orbicularis (European Pond Turtle)	4		3.1		1 (25)		3 (75)		0		8
Trachemys scripta (Red-eared Slider)	1		0.8		1 (100)		0		0		1
Hemidactylus turcicus (Turkish Gecko)	4		3.1		3 (75)		1 (25)		0		8
Tarentola mauritanica (Moorish Gecko)	8		6.3		4 (50)		2 (25)		2 (25)		23
Anguis fragilis (Slow Worm)	3		2.4		3 (100)		0		0		3
Chalcides chalcides (Italian Three-Toed Skink)	3		2.4		1 (33.3)		2 (66.6)		0		5
Hierophis viridiflavus (Western Whip Snake)	31		24.4		21 (67.7)		8 (25.8)		2 (6.5)		55
Zamenis longissimus (Aesculapian Snake)	15		11.8		11 (73.3)		4 (26.7)		0		24
Elaphe quatuorlineata (Four-Lined Snake)	2		1.6		1 (50)		1 (50)		0		3
Natrix natrix (Grass Snake)	7		5.5		3 (42.9)		3 (42.9)		1 (14.3)		18
Natrix tessellata (Dice Snake)	4		3.1		2 (50)		2 (50)		0		8
Coronella austriaca (Smooth Snake)	3		2.4		2 (66.6)		1 (33.3)		0		4
Vipera aspis (Asp Viper)	4		3.1		3 (75)		1 (25)		0		5
P. muralis (Common Wall Lizard)		41		32.2		23 (56.1)		17 (41.5)		1 (2.4)	343
P. siculus (Italian Wall Lizard)		66		52.0		30 (45.5)		32 (48.5)		4 (6.1)	850
L. bilineata (Western Green Lizard)		44		34.6		40 (90.9)		4 (9.1)		0	113
Total											1,471

recorded in Latium (Bologna et al. 2000). Compared to previous herpetofaunal data for the same area, this study did not detect two species previously reported to be present in CNP: the Southern smooth snake (*Coronella girondica*) and the Hermann's tortoise (*Testudo heermanni*; Bologna et al. 2000). The original data referring to the last sightings for both species in the study area dated back to the 1970s, whereas the very few recent observations of *T. hermanni* from the 1990s likely represent of released captive individuals (Sergio Zerunian pers. comm.). If these species are still present within the park, *C. girondica* could have escaped our detection due to its elusive behavior (Agrimi and Luiselli 1994) coupled with low suitability of southern Latium for the presence of this species (Bombi et al. 2009), which may translate to a very low population density. The same may be true for *T. hermanni*, with low density characterizing most populations in sub-optimal habitats (Cheylan 2001). Alternatively, this latter species may have become locally extinct.

The highest reptile diversity was 11 species in two cells. We did not find any species in 54 cells, mostly located in areas occupied by the four coastal lakes where only shores were sampled (n = 10, representing 19% of the 54 cells without species) or crossed by the main country roads (n = 21, representing 39% of the 54 cells without species). The only non-native species we recorded was a single individual of Red-eared Slider (*Trachemys scripta elegans*). Populations of this non-native turtle should be monitored because experimental

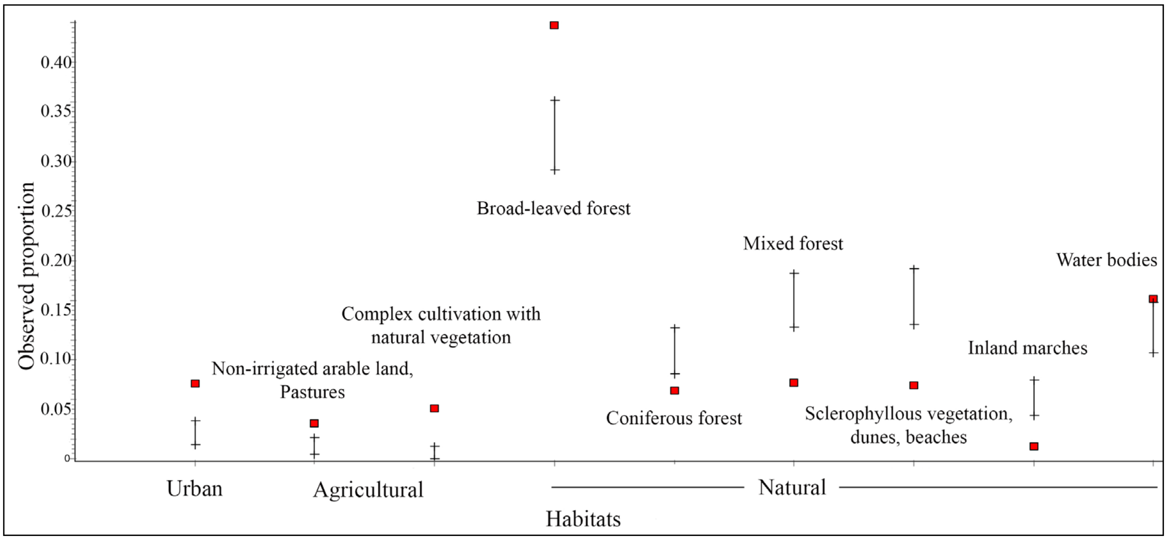

Figure 3. Confidence interval plot obtained by performing Compositional Analysis on the entire herpetofauna recorded in Circeo National Park. Grey squares represent the expected values of habitat use; the bars are the confidence intervals for the observed proportion of use within each habitat type. Some land cover categories were pooled together due to the low amount of records (i.e., when counts were fewer than five).

Table 2. Distribution (in percentage of total observations) of 15 reptile species among 13 CORINE categories (numbers shown under habitat categories). Available = l and use availability (proportion of surface covered by each CORINE category). To give relevance to habitats that are strictly used by each species, values over 50% are presented in bold. See Materials and Methods section and Appendix I for CORINE codes. Abbreviations are *Af* = *Anguis fragilis*; *Cc* = *Chalcides chalcides*; *Ca* = *Coronella austriaca*; *Eq* = *Elaphe quatuorlineata*; *Eo* = *Emys orbicularis*; *Ht* = *Hemidactylus turcicus*; *Hv* = *Hierophis viridiflavus*; *Lb* = *Lacerta bilineata*; *Nn* = *Natrix natrix*; *Nt* = *Natrix tessellata*; *Pm* = *Podarcis muralis*; *Ps* = *Podarcis siculus*; *Tm* = *Tarentola mauritanica*; *Va* = *Vipera aspis*; *Zl* = *Zamenis longissimus,* and *Tc* = total CORINE categories occupied by species.

	CORINE categories													
	Urban	Agricultural						Natural						
	112	211	231	242	243	311	312	313	322	323	331	411	512	Tc
Available	0.087	0.048	0.037	0.068	0.023	0.374	0.057	0.063	0.034	0.082	0.015	0.015	0.098	
Af								66.6				33.3		2
Cc			**60**					20					20	3
Ca			25			**50**							25	3
Eq						33.3	**66.6**							2
Eo		12.5				37.5							**50**	3
Ht	12.5					25				**62.5**				3
Hv	5.5	3.6				**50.9**	10.9	7.3	5.5	9.1		3.6	3.6	9
Lb		8.8	7.1	0.9		21.2	10.6	21.2		8.0	0.9	1.8	19.5	10
Nn						28.3	22.1		19				30.6	4
Nt						37.5							**62.5**	2
Pm	6.4	2.0	0.3	0.3		32.4	5.5	19.0		29.7		0.3	4.1	10
Ps	0.2	7.1	0.6	0.2	0.2	30.8	12.5	14.1	0.2	9.8	0.4	9.2	14.7	13
Tm	32.7	12.3			8.3			8.3		29.9	8.3			6
Va			20			40		40						3
Zl	6.3	12.4		6.1		37.3	12	19.9				6.2		7

Table 3. Pattern of reptile species richness distribution in the three land cover macro-classes. Attendance data were recorded for the total amount of species and for lizard and snake groups.

Species richness	Urban	Agricultural	Natural
Total	6	7	15
Lizards	2	3	3
Snakes	2	4	7

Table 4. Pattern of reptile species richness distribution for five habitats of the natural environment. Species richness was recorded for the total amount of species and for lizard and snake groups.

Species richness	Forest	Garigue	Maquis	Beach	Wetlands
Total	15	3	7	3	11
Lizards	3	1	3	2	2
Snakes	7	2	1	0	4

studies in southeast France indicate that *T. scripta* may compete with *E. orbicularis* for basking sites (Cadi and Joly 2003), affecting its body condition and mortality rate (Cadi and Joly 2004). Nonetheless, there is no evidence that in natural conditions these two species interact in a competitive way (Luiselli et al. 1997). Potential effects of exotic turtles on native herpetofauna (e.g., as predator of amphibians and pathogen transmitter) have been tentatively suggested for Spain (Martínez-Silvestre et al. 2011).

Reptile distribution across land cover categories.— In terms of the urban land use categories, only *T. mauritanica* showed a clear preference for anthropogenic habitats. This may be explained by the propensity of *T. mauritanica* to feed on prey that are attracted to the walls of buildings illuminated by artificial lights (Luiselli and Capizzi 1999). Several cases of lizards taking advantage of night lighting are reported (reviewed by Perry and Fisher 2006 and Perry et al. 2008). Mainly nocturnal species, especially members of the family Gekkonidae, have been reported to be attracted by night-lights, presumably due to the greater quantity of food and the increased predictability of finding prey (Perry et al. 2008). Moreover, there is evidence that artificial lights can also act as heat source, providing supplementary basking sites for lizards during nighttime (Werner 1990).

The occurrence of three reptile species was associated with agricultural land. *Chalcides chalcides* requires open habitats and grasslands (Capizzi et al. 1998), and its preferred habitats in the study area are intensive wheat grass cultivations and meadow grass pastures. *Vipera aspis* and *C. austriaca* are mainly found in rural habitats and forest (Luiselli and Capizzi 1997). These species may benefit from stone walls that delimit fields and pastures as refugia, and from the ecotone strips at the interface between forest and the farmland open habitat as basking sites (Luiselli et al. 1996). Therefore, while agriculture land use is associated with biodiversity deficit at the mesoscale of investigation (i.e., bioregional; Ribeiro et al. 2009), at a finer scale agricultural land use categories might represent exclusive habitats for specialist reptiles and provide suitable environments along the ecotone adjacent to woods for foraging and thermoregulation by forest-dwelling species. In Mediterranean Europe, open habitats or traditional farmland sustained higher reptile species richness than the surrounding scrubland originating from agricultural abandonment (Moreira and Russo 2007). In tropical South America (Mendenhall et al. 2014) and in tropical Africa (Akani et al. 2014a, 2014b), it has been demonstrated that farming landscapes (i.e., coffee plantations and pastures) can support substantial reptile and amphibian biodiversity, albeit different and less dense, compared to the neighboring forest elements in protected areas.

The highest reptile diversity was associated with natural land use categories. Most of the natural land use in our study area is represented by forest and maquis, whereas wetlands and coastal dunes constituted a minor proportion. Among snakes, the most common species we recorded was *H. viridiflavus*, which was detected in 24.4% of cells. By analyzing in detail the species distribution, almost half of all observations fell within the broad-leaved forest category. This preference for a specific land use category differs from what is reported for *H. viridiflavus* in Latium where it is considered a widespread habitat generalist associated with urbanized, agricultural, and natural land use categories (Bologna et al. 2000; Capula et al. 2014). We detected 12 of 15 (80%) reptiles and all of the snake species found in the study in the broad-leaved forest category, demonstrating the importance of Plain Forest of Circeo National Park for snake conservation. The mixed forests (category 313) housed the single record of *A. fragilis*, the highest abundance level for *V. aspis* and *L. bilineata*, the second most abundant for *P. siculus*, and the third for *P. muralis*.

In the sclerophyllous vegetation habitat, the most common species we recorded was *P. muralis*, followed by *P. siculus* and *L. bilineata*. Indeed, the Mediterranean maquis is well known to be a prominent habitat for lizards (see Maura et al., 2011; *L. bilineata*: Di Cerbo and Di Tizio 2008; *P. muralis*: Vignoli et al. 2015a; *P. siculus*: Vignoli et al. 2012). The only snake species recorded in this habitat category was *H. viridiflavus*. The high number of detections for *P. muralis* in this habitat concentrated in areas nearby the promontory of Circeo, where very high temperatures are recorded in summer (Blasi 1994). This could reflect the higher heat tolerance shown by this species in respect to others (Capula et al. 1993; Rugiero 1993). The cells with the highest records of *P. muralis* in sclerophyllous vegetation

Table 5. Factor loadings (Varimax raw) of the Principal Components Analysis (PCA; loadings in bold are >0.700), and eigenvalues resulting from the PCA performed on land cover categories inhabited by reptile species in the study area grouped in Urban, Agriculture, and Natural.

Land Cover Categories	Factor - 1	Factor - 2
Urban	-0.060	-0.984
Agricultural	-0.887	0.062
Natural	0.820	0.264
Explained variance	1.463	1.043
Eigenvalue	1.558	0.948
Cumulative - Eigenvalue	1.558	2.506
% Total - variance	51.938	31.610
Cumulative - %	51.938	83.548

habitat overlap with an area, in the northern slope of the promontory, previously exploited as centuries-old olive plantations and yet widely recolonized by pristine vegetation. A previous study (Graziani et al. 2006) has already highlighted the key role that these plantations play for this species as a suitable site for thermoregulation, sheltering, and feeding activities.

Wetland habitats and their immediate surroundings (water bodies and inland marshes) hosted a species-rich reptile community with a high proportion of sightings for the *E. orbicularis* (50%), and two *Natrix* species, particularly *N. tessellata* (62.5%). These findings are intuitive because all these species spend a significant portion of their life cycle in water or in their immediate surrounding for basking activity (Vignoli et al. 2015b). For the two *Natrix* species, it is well known that freshwaters and wetlands are their preferred foraging habitats, whereas *E. orbicularis* leaves the aquatic habitat only for oviposition (Corti et al. 2011). However, wetlands in the study area have been progressively decreasing in surface and number and the coastal lakes are increasing their salinity concentration due to the seawater intrusion following the reduced freshwater supply from the surrounding channels (Manca et al. 2012). Indeed, the absence of regional water governance, and uncontrolled withdrawals, endanger the coastal natural system (Manca et al. 2012).

Several factors might influence the preference for habitats with a high structural complexity. The presence of trees, bushes, and herbs of different heights creates both vertical stratification (habitat complexity; MacArthur and MacArthur 1961) and horizontal patchiness by a sun-shade gradient (habitat heterogeneity; Wiens 1974). These features should facilitate the availability of different microhabitats and food resources associated with them and the movements between sunlit and shade sites by optimizing movements for basking activity, respectively. Many studies have found that species diversity is related to habitat complexity (MacArthur et al. 1966; Karr 1968; Willson 1974). The reason behind this general hypothesis is explained by the concept that highly complex habitats offer more potential niches than structurally simpler habitats (Klopfer and MacArthur 1960). Potential niches are distributed vertically in complex habitats and both horizontally and vertically in patchy habitats. In this regard, the increasing of both complexity and heterogeneity can increase species diversity (Levins 1968). In our study, the species distribution pattern across the natural land cover categories showed a clear increase in species richness along the increasing complexity and heterogeneity of the habitats. Indeed, the overall reptile species diversity ranged from a minimum of three species in the beach and garigue habitats (minimum vertical stratification and patchiness) up to seven and 15 in the Mediterranean maquis and forest, respectively (maximum vertical stratification and patchiness). The environments surrounding wetlands did not show a consistent complexity but did show high horizontal patchiness because the edge areas around the coastal lakes vary greatly in terms of vegetation type and structure. Indeed, these habitats host a rich reptile community with 11 species.

Habitat selection.—Urbanized areas were negatively selected by most species (except for geckos), and this pattern is expected if we take into account that even for herpetofauna adapted to urban habitat (i.e., those species colonizing green areas within cities), the building matrix is clearly avoided (Vignoli et al. 2009). Geckos represent an exception to this pattern because it is well known that they take advantage from colonizing the building walls in terms of foraging (Luiselli and Capizzi 1999), and tend to avoid closed habitat (dense forests). Agricultural land use categories were less selected than availability by the species, and this is likely due to the low habitat heterogeneity and high disturbance level showed by arable fields. As expected, natural habitats were positively selected by most species. Reptile species inhabit all the natural habitats recorded in the protected area. Among these, the broad leaved forest habitat, representing 65% of the whole forested categories, was the only one less selected than availability. However, we can explain this apparent exception by the fact that most forest-dwelling reptiles (several lizards and snakes) were sampled at the interface between forest and open areas (ecotones) while basking. Although all the forest habitats were sampled at their edges, broad leaved forest is likely to be underrepresented in respect to other forest categories in terms of the sampled edge length due to the large extension of patches (Vignoli et al. 2009).

Conclusions.—The fact that we did not detect two species, *C. girondica* and *T. heermanni*, previously reported to be present in CNP (Bologna et al. 2000), indicate that more surveys (inclusive of specific sampling designs) are needed to assess the occurrence of these elusive species which likely have low-density populations in, or may have been extirpated from, the park. This is particularly true for *C. girondica* because the park has likely low suitability for this species according to Bombi et al. (2009), thus a high extirpation risk may be anticipated. The sites that support high species diversity have important conservation implications. One management recommendation would be to develop a monitoring program for species with localized distributions in the park, such as *N. tessellata* and *E. orbicularis*. This action may indirectly provide information about the health of water bodies in the park.

Because we found that many species occur in isolated habitat patches across the park, conservation programs will need to focus on maintaining the ecological networks between plain forest area and urban and agricultural patches, to permit emigration and immigration between different meta-populations. This is especially true for effectively protecting populations of species with low dispersal ability (i.e., *E. orbicularis*, *C. austriaca*, and *V. aspis*), whereas fewer problems are expected with regard to *H. viridiflavus*, *Z. longissimus*, and the Grass snake *N. natrix* as these taxa are usually able to colonize new areas as well as to inhabit urbanized areas (Sindaco et al. 2006; Corti et al. 2011). Moreover, the increasing salinity concentration in the coastal lakes (Manca et al. 2013) should be monitored and this trend eventually reversed to maintain the quality of freshwaters suitable for aquatic and semi-aquatic species. The pools within the plain forest represent the last remnant natural freshwater habitat suitable for herpetofauna in the park because the few brooks there are largely polluted and for most of them the water does not persist to late spring and summer. The pools are very important habitat for herpetofauna because they potentially host reptiles (e.g., *E. orbicularis* and *Natrix* spp.) and their preferred food (aquatic vegetation, invertebrates, and amphibians; Cinquegranelli et al. 2015), thus maintaining high species diversity. However, as for most small, unstable water basins, the water supply that feeds the pools consists mainly of rainfall, which has undergone dramatic reductions and fluctuations in the last few decades (Alpert et al. 2002, 2008).

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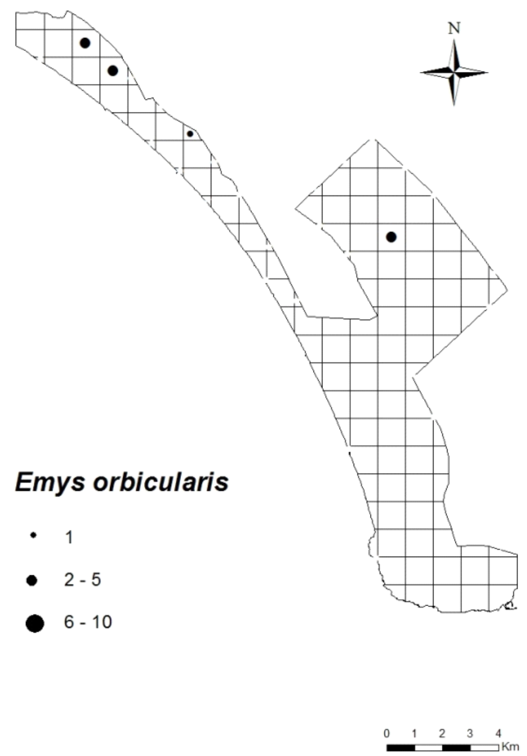
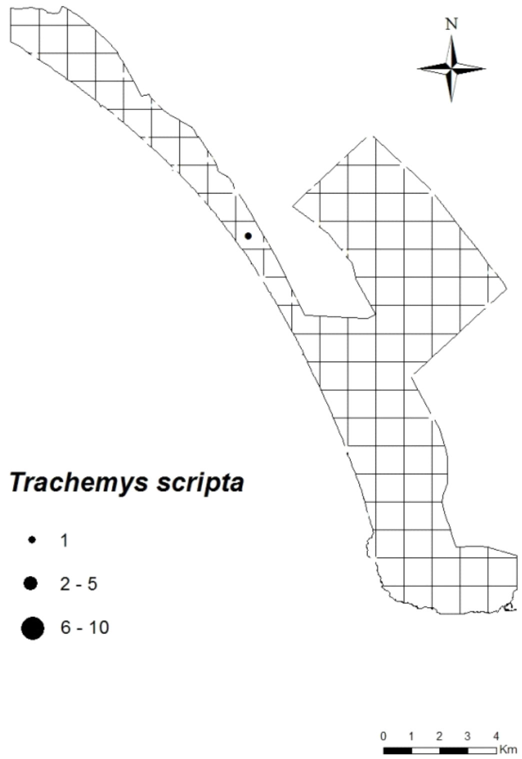
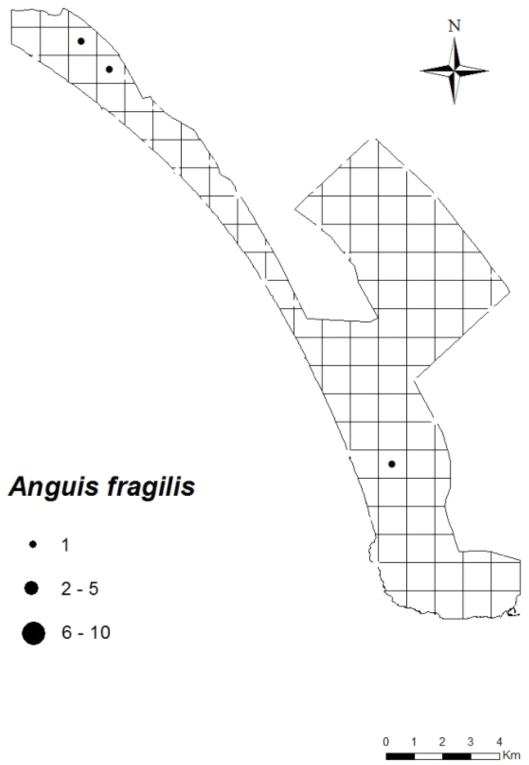
Appendix I. List of the land cover categories within Circeo National Park classified following CORINE nomenclature. We grouped the 13 CORINE levels together into three macro-classes (Group) depending on the CORINE category, namely: Urban, Agricultural, and Natural.

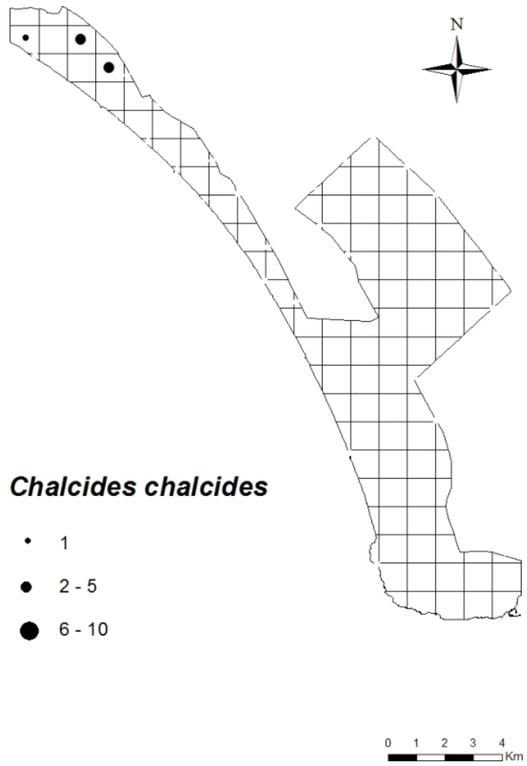
Group	Code	Description	Abb.
Urban	1.1.2.	Discontinuous urban fabric	DUF
Agricultural	2.1.1.	Non-irrigated arable land	NIA
	2.3.1.	Pastures	PAS
	2.4.2.	Complex cultivation	CCU
	2.4.3.	Land principally occupied by agriculture, with significant areas of natural vegetation	ANV
Natural	3.1.1.	Broad-leaved forest	BLF
	3.1.2.	Coniferous forest	COF
	3.1.3.	Mixed forest	MIF
	3.2.2.	Moors and heathland	MOH
	3.2.3.	Sclerophyllous vegetation	SCV
	3.3.1.	Beaches, dunes, and sand plains	BDU
	4.1.1.	Inland marches	INM
	5.1.2.	Water bodies	WBO

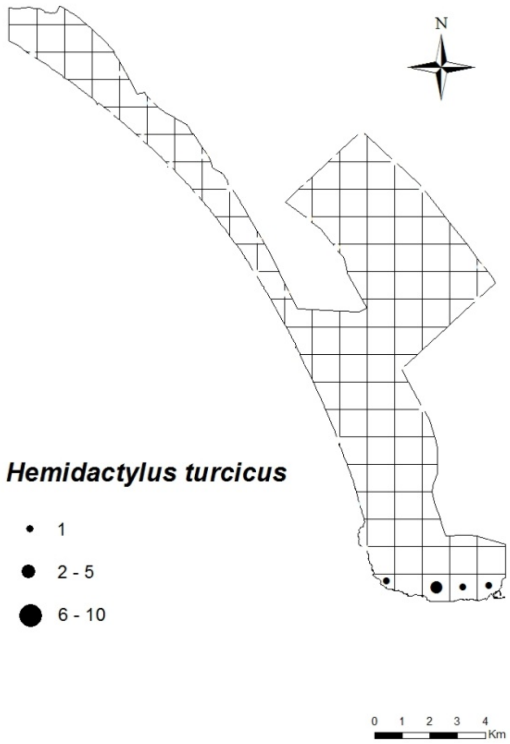
APPENDIX II. Distribution maps of each reptile species recorded in the Circeo National Park. The size of the dots is proportional to the abundance of the species in each occupied cell.







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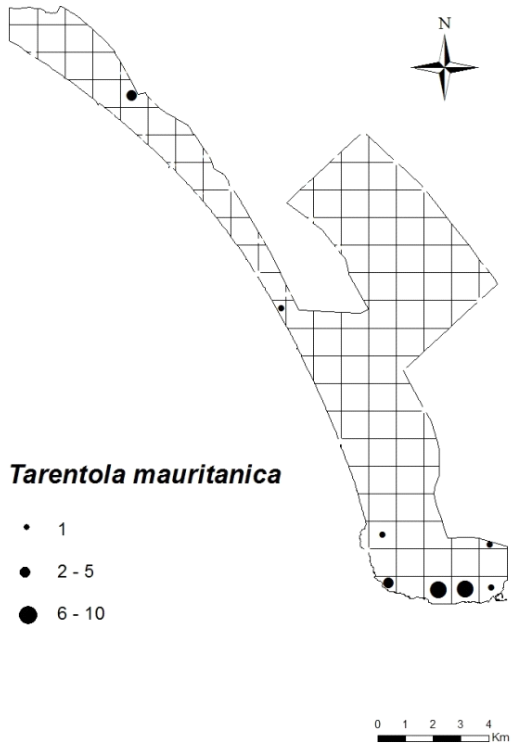
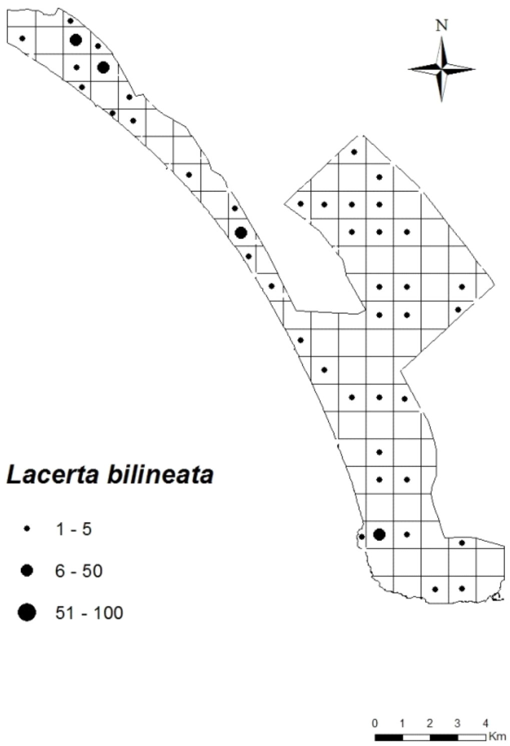
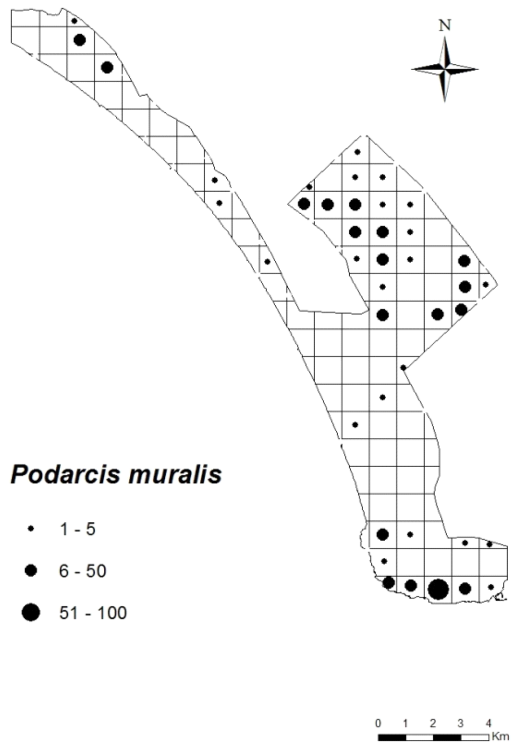
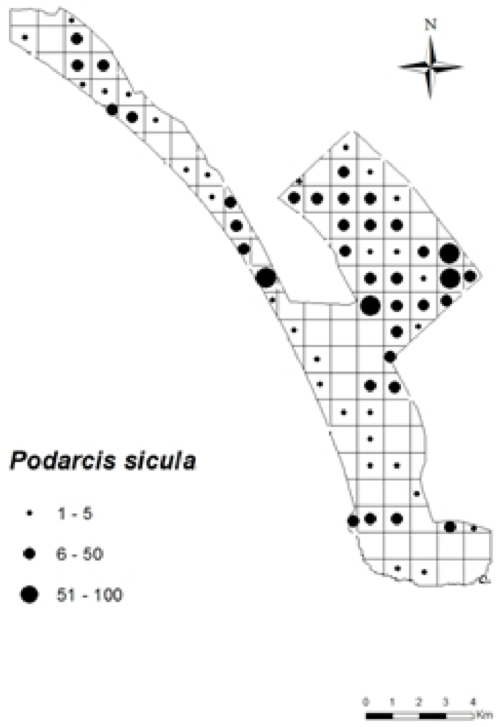
Hemidactylus turcicus
1
2 - 5
6 - 10
0 1 2 3 4
Km


N
Tarentola mauritanica
1
2 - 5
6 - 10
0 1 2 3 4
Km


N
Lacerta bilineata
1 - 5
6 - 50
51 - 100
0 1 2 3 4
Km


N
Podarcis muralis
1 - 5
6 - 50
51 - 100
0 1 2 3 4
Km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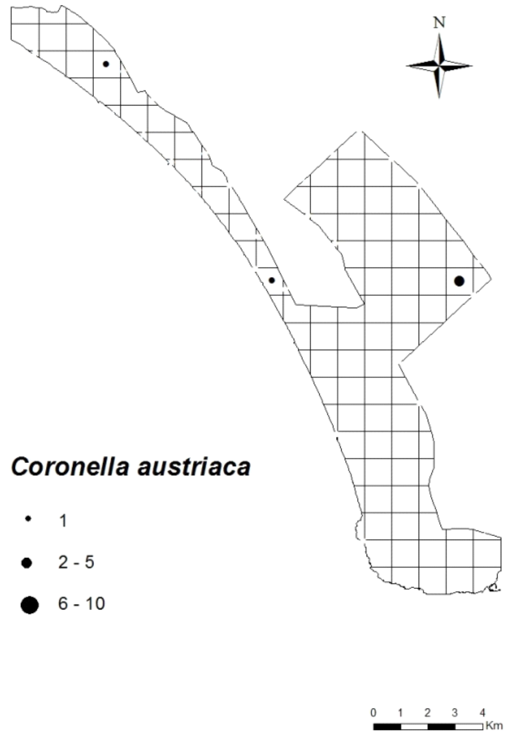
Podarcis sicula
1 - 5
6 - 50
51 - 100
0 1 2 3 4
Km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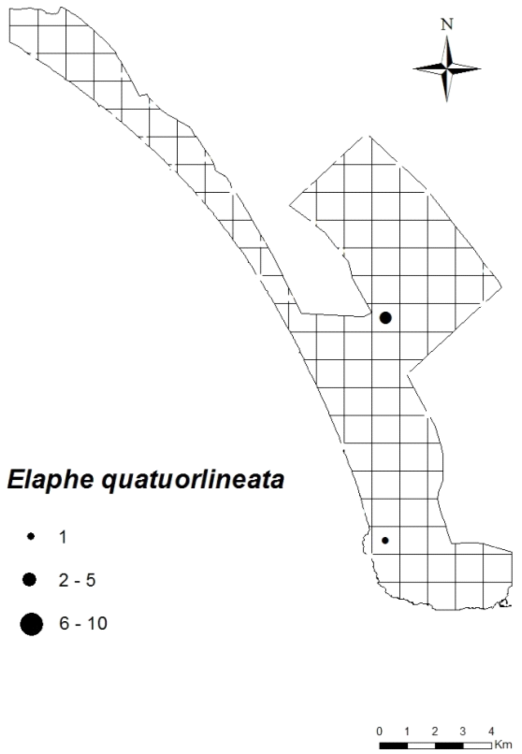
1
2 - 5
6 - 10
0 1 2 3 4
Km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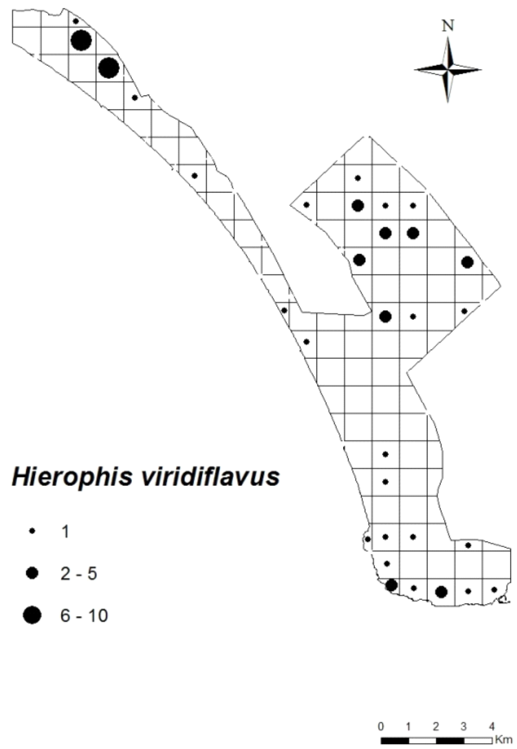
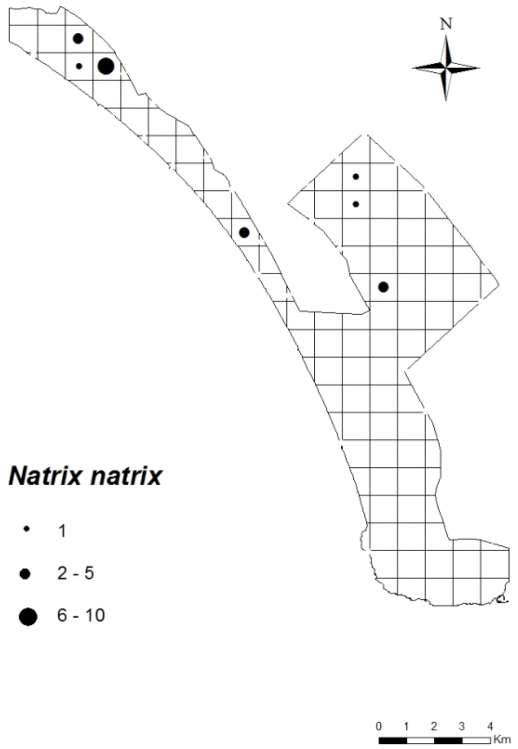
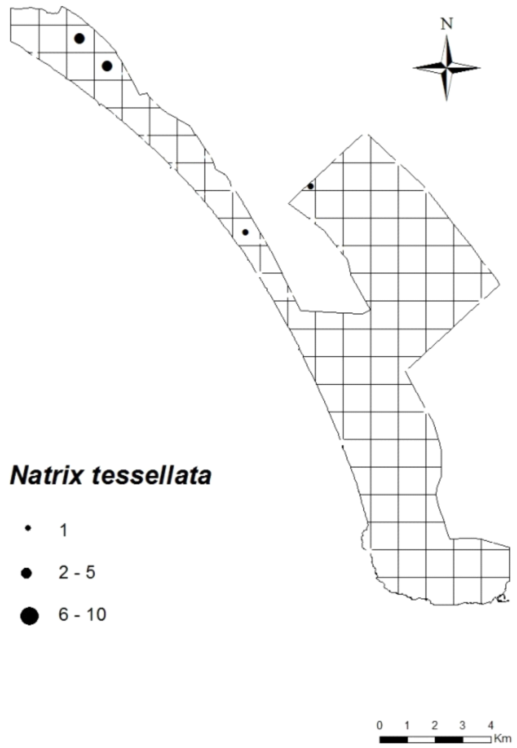
Elaphe quatuorlineata
1
2 - 5
6 - 10
0 1 2 3 4
Km

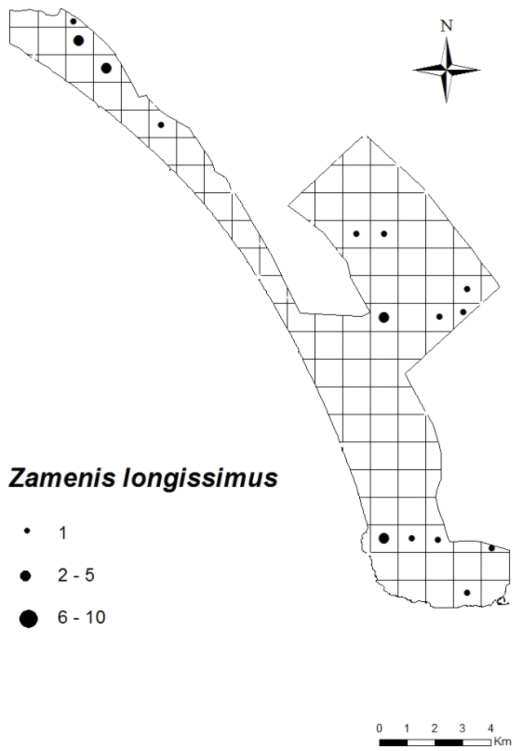

N
Hierophis viridiflavus
1
2 - 5
6 - 10
0 1 2 3 4
Km



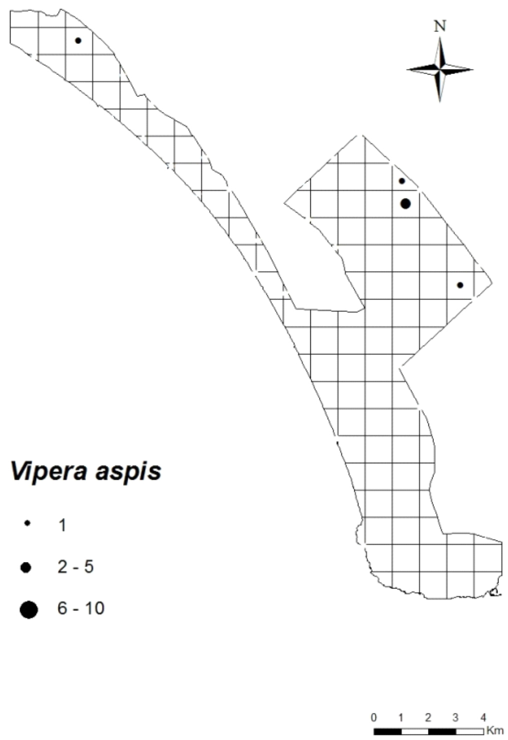
N
Natrix natrix
1
2 - 5
6 - 10
0 1 2 3 4
Km



N
Natrix tessellata
1
2 - 5
6 - 10
0 1 2 3 4
Km



N
Zamenis longissimus
1
2 - 5
6 - 10
0 1 2 3 4
Km



N
Vipera aspis
1
2 - 5
6 - 10
0 1 2 3 4
Km