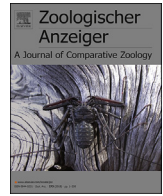




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Research paper

Lizards and the city: A community study of Lacertidae and Gekkonidae from an archaeological park in Rome

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ABSTRACT

The study of animal communities is mainly concerned with how the groupings of species are distributed in nature and the ways in which the members of these communities assemble and interact with each other. Pianka suggested that animals partition environmental resources in three basic ways: temporally, spatially, and trophically. Such differences in activities separate the niches, reduce competition, and presumably allow the coexistence of a variety of species in the communities. The present work compares the spatial, trophic and temporal niches of four reptile species, two geckos (*Tarentola mauritanica* and *Hemidactylus turcicus*) and two lizards (*Podarcis muralis* and *Podarcis siculus*) living in a same roman-age archaeological park situated area inside Rome metropolitan area (central Italy), and sharing the same two-dimensional habitat (the roman aqueduct walls). The results showed an overall overlap among species higher than expected by chance for all considered ecological dimensions except for the spatial resource related to the vertical position on the wall. Surprisingly, despite living in a two-dimension habitat would expect an increase of interspecific interaction rate, no partition was observed between species with the most convergent ecological requirements. Although our hypotheses about lizard communities structuring and interactions in the urban habitat require further investigation, we think that our lizard community is based more on the ecological needs of each species rather than on species' interactions. The observed spatial segregation between diurnal geckos and lizards would not support alone the interaction hypothesis. We speculated that the coexistence of ecologically overlapping species at the study area is allowed by a non-limiting availability of resources (above all food) that would result in the reduction of heterospecific competitive interactions and an overall wide overlap of resource use.

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1. Introduction

An animal ecological niche is a multifactorial concept that can be subdivided into several dimensions (Pianka 1974; Schoener 1974a, 1982). Differences in the ecological and physiological requirements of an individual will determine its position in the different spatial and temporal components of a niche. Therefore, the co-existence of species may result in an overlap in optimal habitat requirements (i.e. spatial niche) and represents one of the most common forms of species interactions (Schoener 1974b). To overcome the potential negative effects of overlapping exploitation of limiting resources, syntopic species may have evolved strategies

that allowed co-existence by partitioning one or more niche dimensions (Vitt & Zani 1998; Chase & Leibold 2003; Grbac & Brnin 2006; De Pinho et al. 2009). Resource partitioning strategies, as a response to past pressures, have been documented in many co-existing, ecologically similar animal species as a general mechanism to mitigate or avoid competition (Chase & Leibold 2003; Luiselli 2006). Indeed, plasticity in resource use may be an important characteristic in the process of co-evolution in sympatric populations and enables flexibility in spatial, trophic or temporal niches, thus allowing successful coexistence (Lisičić et al. 2012).

During the last twenty years, interest in herpetological communities has grown enormously and several meta-analyses have been published (Luiselli 2006, 2008; Vignoli & Luiselli 2012; Vignoli et al. 2017). Even concerning the urban habitats, several datasets on their herpetological communities have been published (Germaine & Wakeling 2001; Jellinek et al. 2004; Perry et al. 2008), including in Mediterranean towns (Luiselli & Capizzi 1999; Rugiero

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& Luiselli 2006, 2007; Vignoli et al. 2009). Urban habitats suitable for herpetofauna are, usually, severely fragmented and present a number of important environmental alterations: natural vegetation is reduced and its structure simplified; food resource availability decrease in variety and is often spatially concentrated; disturbance from humans increases; the community of predators changes and pollution is more frequent with regards to night-time lights, acoustic noise and chemicals. Nevertheless, a few species seem not only to be little affected by the urbanization process, but appear to perceive urban habitats as ecological opportunities, and proliferate and expand their range by showing altered behaviour or life-history strategies in urban areas and thrive (Ditchkoff et al. 2006; Sol et al. 2013). Mortality rates of urban dwelling species may be elevated because of altered predator communities (e.g., dogs and cats) and road killing. On the other hand, habitats with drastic anthropogenic changes might harbour synanthropic generalist species with broad preferences ecologically associated with anthropogenically modified environments and inefficient predators (Tyler et al. 2016). Predation pressures, disturbance intensity, and trophic dynamics in urban areas are indeed complex and may keep populations at lower number than the environmental carry capacity, thus reducing the effect of potential competition due to the exploitation of shared resource.

In this paper we compare the spatial, trophic and temporal niches of four syntopic reptile species similar in size, two geckos (*Tarentola mauritanica*, Linnaeus, 1758, and *Hemidactylus turcicus* Linnaeus, 1758) and two congeneric lizards (*Podarcis muralis*, Laurenti, 1768 and *Podarcis siculus*, Rafinesque, 1810) inhabiting a very simplified urban habitat (bidimensional brick wall) in a roman-age archeological park situated inside Rome metropolitan area (central Italy). For convenience, we will use verbal shorthand and speak of the food, time and spatial niches rather than refer to “the trophic, temporal and spatial dimensions of the niche,” as proposed by Pianka (1973).

In the present paper we address the following questions: i) Are there any overlaps along the three niche dimensions among the study species? ii) If so, is there any resource partitioning among the species in order to allow co-existence? Due to the very simplified habitat structure (i.e. low spatial heterogeneity) shared by the study species, we should expect a lower overlap of resource use by the species on the other main niche dimensions. However, in a same way, the simplified habitat should reduce the prey availability for the species, thus a strong partition of the food spectrum is unlikely. Therefore, we cannot predict how the coexisting species exploit the three main dimension of the ecological niche.

2. Materials and methods

2.1. Study area

Fieldwork was carried out in two contiguous urban green areas, with Roman age monuments, situated in the city of Rome: Tor Fiscale (about 3 ha, 41°51'30.81"N, 12°32'45.74"E) and Acquadotti (150 ha, 41°51'1.29"N, 12°33'26.93"E) parks. These two areas were clearly separated from one another (1.50 km), so that no interchange of individual lizards occurred during the study. The general landscape of the study area was very simplified, with microhabitats useful for the considered reptile species being found only on the walls of the Felice roman aqueduct, which runs through the two parks (Fig. 1).

2.2. Field protocol

All the study areas were surveyed from March to September 2016 both in daylight and nocturnal hours (GMT+1 time). The



Fig. 1. General landscape of the study area, showing the Roman age aqueduct, and the four main habitat. Symbols: Rv = wall with climbing vegetation; Re = exposed wall without climbing vegetation; Rf = walls with some crevices available; F = ruined spots with high abundance of crevices in the wall.

protocol involved to capture the individuals following a transect along the walls of the Felice aqueduct, always starting from Tor Fiscale park (total sampled wall length, 650 m), and continuing for another 800 m inside the Acquadotti park. Sites were revisited over 3 days in each season to ensure that a high proportion of the individuals were sampled. The animals were caught by noose during daylight and by hand during night hours. For each sampling activity we registered date, time, weather conditions and air temperature, whereas for each collected animal we recorded species, sex, snout-vent length (SVL), weight (W), height above ground at first sight and microhabitat. After being caught, lizards were placed in plastic boxes, each individual was marked by means of non-toxic marker pen of different colours for short time identification, while digital photographs of ventral and dorsal sides were taken for long-time identification by examining the number and position of scales (Sacchi et al. 2010). We were able to individually identify most of the lizards and geckos just by using the pen marking due to the high frequency of sampling that prevent moulting events to fade the colour marker. When we caught a non-marked individual we used the photographic database to assess if it was a new or already captured individual. Once they produced faeces for food niche assessment, they were released. No specimen was killed during this study.

We subdivided wall height into six ranges (0–0.5, 0.5–1, 1–1.50, 1.50–2, 2–2.50, 2.50–3 m) and selected four micro-habitat types (MH) along the bidimensional space of the aqueduct walls (Fig. 1):

- Rv = wall with climbing vegetation
- Re = exposed wall without climbing vegetation
- Rf = walls with some crevices available
- F = ruined spots with high abundance of crevices in the wall.

We then counted all the individuals sighted in each height range and microhabitat type, respectively. Lizard individuals that were

sighted at the border between two microhabitat types were not considered in the counts.

We analysed faecal pellets preserved in ethanol (70%) with a binocular microscope, and the food remains were identified to the lowest taxon possible.

As for the temporal niche, the sampling period was divided into three seasons, according to the daily temperature recorded: “Spring” (March, April, May), “Summer” (June and July), and “Late summer” (August and September). Since the nocturnal samplings started on the beginning of June when air temperature was warm enough to allow animals to be active at night, for nocturnal species (*H. turcicus* and *T. mauritanica*) the time category “Spring” could not be taken in consideration. Sampling activity did not start in the morning before 11:00 a.m. when the aqueduct wall surface started to be exposed to the sun. Thus, each sampling day was divided into three time ranges during daylight, namely morning (11:00 a.m.–2:00 p.m.), daytime (2:00–5:00 p.m.), afternoon (5:00–8:00 p.m.). At night hours we used only two time ranges, namely evening (8:00–11 p.m.) and night (11 p.m.–2:00 a.m.). We counted all the individuals observed in activity in each season and daytime range, respectively.

2.3. Statistical analysis

Only adult individuals were considered in the analyses. Regarding *T. mauritanica*, we never recorded any individual that was caught by night also by daytime and vice versa. Thus, apparently these individuals belonged to two different “demes”, thus forcing us to examine separately their data.

In order to determinate the individual animal's fitness, we calculated the Body Condition Index (BCI), as the residual of the log-mass on log-SVL regression line, separately for each sex.

Feeding strategy was determined by the graphical technique developed by Costello (1990), modified by Amundsen et al. (1996). In the Amundsen plot, frequency of occurrence of each food item is plotted against its prey-specific abundance (P_i), the percentage a prey taxon comprises of all prey items in only those predators in which the actual prey occurs (Amundsen et al. 1996). Due to the impossibility to evaluate the volumetric abundance of the prey for their state of preservation in the stools, we considered only the numerical data to describe the food spectrum.

Seasonal phenology (time niche) was analysed by means of Log-Linear analysis in order to determine if there is a statistically significant relationship among all the other variables (species, microhabitats, wall heights and diel time ranges). This method allows analysing any number of variables in a multi-way contingency table by generating all possible models of interacting terms. The main goal of log-linear analysis is to find the smallest model that better fits the data (Streiner & Lin 1998; Brzezińska 2013). We arranged the dataset by grouping environmental variables in comprehensive range values. For diurnal individuals we considered two time ranges, Time1 (11:00 a.m.–2:00 p.m.) and Time2 (2:00–8:00 p.m.), and four wall height ranges: H1 = 0–0.5, H2 = 0.5–1, H3 = 1–1.50, H4 = 1.50–3; for nocturnal individuals two height ranges: H1 (0–0.5 m) and H2 (0.5–3 m). All the analyses were done by using Statistica software (version 8.0; Statsoft) with alpha set at 0.05.

For all species and all the three niche dimensions (trophic, temporal, and spatial) we calculated the niche breadth by Levins' standardized index (B_a) (Levins 1968; Hurlbert 1978) and the niche overlap (O_{jk}) using the symmetric equation of Pianka (1986). Moreover, the analysis of ecological niche overlap was performed both on diurnal and nocturnal species separately. For the calculations of niche breadth and overlap, we used the proportion of individuals spotted in each niche range/category. The degree of niche overlap was estimated by comparing observed O_{jk} values to an

appropriate null model by using the software Ecosim (version 7; <http://www.garyentsminger.com/ecosim>; Gotelli & Entsminger 2001). We built null models by using Monte Carlo simulations of each considered ecological niche dimension by applying two different randomization algorithms: RA2 (zero structure of the matrix retained) and RA3 (amount of specialization for each species retained) (Lawlor 1980). Both algorithms have been demonstrated to be suitable for uncover structure in heterotherm vertebrate communities (Luiselli 2008; Vignoli & Luiselli 2012; Vignoli et al. 2017).

3. Results

3.1. Sample sizes and body sizes

During our study, we examined 141 lizards, 88 *P. muralis* (SVL: mean = 63.01 mm, SD = 6.09 mm), 53 *P. siculus* (SVL: mean = 69.05 mm, SD = 9.33 mm) and 269 geckos, 100 *Hemidactylus turcicus* (SVL: mean = 51.36 mm, SD = 1.315 mm), 169 *T. mauritanica* (SVL: mean = 59 mm, SD = 1.387 mm). All *H. turcicus* were found after sunset, 81 *T. mauritanica* individuals were caught at night while 88 were diurnal. As mentioned above, no *T. mauritanica* individual collected in diurnal samplings was recaptured at night and vice versa, so the two *T. mauritanica* distinct groups showed clear temporal segregation. We recaptured within the same time periods at least one time, 9 *P. muralis*, 2 *P. siculus*, 32 *T. mauritanica* (23 diurnal individuals and 9 nocturnal ones), and only 1 *H. turcicus*. Interestingly, diurnal and nocturnal *T. mauritanica* individuals differed for body length with the former being bigger than the latter with no intersexual difference (TIME: mean SVL diurnal = 66.09 mm; mean SVL nocturnal = 51.36 mm; $F_{1,155} = 34.424$, $p < 0.001$; SEX: $F_{1,155} = 0.588$, $p = 0.448$; SEX*TIME: $F_{1,155} = 1.567$, $p = 0.212$). Moreover, diurnal *T. mauritanica* individuals (both males and females) were in better body condition than nocturnal counterparts, (TIME: $F = 4.799$, $p = 0.030$; SEX: $F_{1,155} = 15.565$, $p < 0.001$; SEX*TIME: $F_{1,155} = 0.155$, $p = 0.694$) (Appendix 1).

3.2. Food habits

Overall, we detected 10 different prey groups in the guts of the four lizard species (Table 1). In all the study species, the predominant taxon in terms of numerical frequency was Coleoptera. A certain degree of specialization towards Dermaptera, Lepidoptera and Scorpionidae was detected in *P. siculus* and towards Hymenoptera and Hemiptera in *P. muralis*. Diurnal *T. mauritanica* fed frequently upon Aranea and Hemiptera, whereas those caught at night showed a specialization to Hymenoptera and to a lesser degree to Dermaptera. *Hemidactylus turcicus* consumed mostly on Aranea and Hymenoptera (Appendix 1).

3.3. Seasonal phenology

All the three diurnal species tended to be more abundant during Spring time, whereas the peak of observation for the nocturnal geckos was in Summer time even if no statistical difference were found between seasons. During Spring, two species were observed mainly during daytime (*P. muralis*: 60%, and *T. mauritanica*: 54%). In Summer, *P. siculus* was detected mainly in daytime (66%), and *T. mauritanica* was spotted more frequently during morning and daytime (46%). Concerning Late summer, *P. muralis* (100% of observations) and *P. siculus* (76%) were preponderant at daytime. No preferences were detected in *T. mauritanica*.

About the nocturnal species, *T. mauritanica* (68%) was observed mainly at evening time during Summer. Instead, in the Late

Table 1

Diet composition of the four species. Prey composition is presented as numeric abundance and percentage. *T. mauritanica* individuals were analyzed separately based on their phenology (diurnal vs. nocturnal).

Preyed taxa	<i>P. sicula</i>		<i>P. muralis</i>		<i>T. mauritanica</i> (diurnal)		<i>T. mauritanica</i> (nocturnal)		<i>H. turcicus</i>	
	n	%	n	%	n	%	n	%	n	%
Coleoptera	63	65.6	49	56.9	34	31.7	15	20.8	14	32.5
Diptera	1	1.04	3	3.4	3	28	4	5.5	–	–
Hymenoptera	13	13.5	13	15.1	11	10.2	29	40.2	18	41.8
Hemiptera	11	11.4	2	2.3	29	27	16	22.2	–	–
Aranea	8	8.3	7	8.3	16	14.9	2	2	6	13.9
Scorpiones	–	–	8	9.3	5	4.6	–	–	–	–
Dermoptera	–	–	2	2.3	6	5.6	6	8.3	4	9.3
Lepidoptera	–	–	1	1.1	2	1.8	–	–	1	2.3
Acarina	–	–	1	1.1	–	–	–	–	–	–
Orthoptera	–	–	–	–	1	–0.9	–	–	–	–
Total	96		86		107		72		43	

summer season, both species were more above-ground active at evening time (*T. mauritanica*: 76%; *H. turcicus*: 88%).

3.4. Microhabitat use

After retaining only the models that contain species identity as the factor (Appendix 1), it appeared that the individuals of all species were not evenly distributed among habitats, height and time of the day (Table 2). Lizards and geckos showed clear preference towards specific heights and habitats at which they were spotted on the aqueduct walls (Fig. 2). Both lizard species were spotted at a maximum height between 0 and 0.50 m, with *P. siculus* evenly observed in *Re* and *Rv* MHs while *P. muralis* predominantly in *Re* MH, instead *T. mauritanica* was frequently observed at 1–1.50 m height range equally in *Rv* and *Rf* MHs. Moreover, we found interspecific differences in the frequencies of individuals observed at different heights in different moments of the day: *T. mauritanica* individuals were more frequently observed during Time1 at higher heights (H3 and H4) and shifted to lower heights at Time2. Lizards always used the lowest height range and they were more frequently observed during Time2 (Fig. 2). Concerning the nocturnal species, only the model that included the interaction between Habitat and Species categories resulted statistically significant (Appendix 1), with *T. mauritanica* occurring at higher frequency in *Re* and *Rv* and *H. turcicus* individuals in *Rv* and *Rf* (Fig. 2).

Table 2

Tests of all marginal and partial associations of diurnal (A) and nocturnal (B) individuals. Only three-way interactions for A models and two-way interactions for B models are considered because higher interaction levels do not increase the overall model fit (Results of Fitting all K-Factor Interactions are available in supplementary materials). Factor codes: 1 = Habitat, 2 = Time, 3 = Wall heights, 4 = Species. Statistically significant association Chi-square tests for interacting terms involving the species factor are highlighted in bold.

Model	Df	Prt. Ass. Chi-sqr.	Prt. Ass. p	Mrg. Ass. Chi-sqr.	Mrg. Ass. p
1	2	25.788	<0.0001	25.788	<0.0001
2	1	14.686	<0.0001	14.686	<0.0001
3	3	21.300	<0.0001	21.300	<0.0001
4	2	76.489	<0.0001	76.489	<0.0001
12	2	1.042	0.594	2.560	0.278
13	6	26.916	<0.001	21.070	0.002
14	4	67.305	<0.0001	63.553	<0.0001
23	3	27.325	<0.0001	31.694	<0.0001
24	2	11.222	0.004	17.685	<0.0001
34	6	38.949	<0.0001	38.049	<0.0001
123	6	3.767	0.710	5.376	0.497
124	4	1.372	0.850	4.127	0.389
134	12	15.882	0.200	17.733	0.124
234	6	25.099	0.0003	28.563	<0.0001

No interspecific difference in wall height range distribution was observed between the nocturnal species, with an overall preference towards between 0 and 0.5 m (Fig. 2).

3.5. Niche breadth

The niche breadth analyses for the three studied dimensions, showed as all the species adopted a generalist strategy, especially *T. mauritanica* during both night and day light. *H. turcicus* showed the widest spatial niche in terms of microhabitat use, and *P. siculus* was the most generalist species along the temporal axis of the niche (Table 3).

3.6. Niche overlap

For the trophic and spatial niches, the observed overlap index values were significantly higher than expected, thus showing a contagious pattern in resource use by species (Table 4). A consistent pattern was found also for the diurnal species along the temporal axis of the ecological niche, with species being active in the same seasonal and daily time ranges. For the nocturnal species, instead, we did not find any assemblage structure with a random use of the resources by species.

4. Discussion

Our results suggest a similarly highly generalist foraging strategy for the two *Podarcis* and for the two gecko species, with Coleoptera species as the most abundant in all the species diet spectrum. We speculate that the preponderance of beetles in all four study species, some of them phylogenetically very distant, could represent a common strategy by consuming the most abundant or energetically rewarding prey, that possibly represents an unlimited food resource and consequently minimizing interspecific competition strength among the four species. The feeble specialisations detected could be led to a different use of the trophic resources influenced probably by spatial and time niche factors, so that all the species can coexist in the same area, as found by Capula et al. (1993), Pérez-Mellado (1998), Bombi & Bologna (2002) and Zuffi & Giannelli (2013). Concerning the diet of *T. mauritanica*, and despite the two demes observed (one diurnal and one nocturnal) are completely separated, it should be remarked that the prey types in the faecal pellet cannot be attributed categorically to the gecko's nocturnal or diurnal activities because the time of ingestion is unknown. In fact, a prey eaten during the day could be expelled with faeces during the night and vice versa, thus creating a bias into the dataset. Anyway, the prey types detected into the

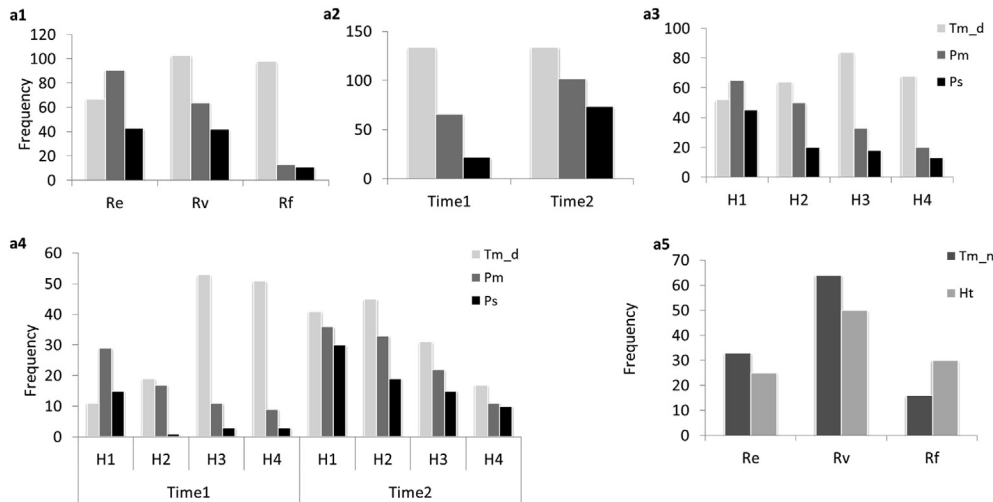


Fig. 2. Log linear analysis: Observed frequency of the diurnal species a1 in the three habitats, a2 in the two time ranges, a3 in the four wall height ranges. a4 interactions among habitats, time ranges and species. a5 frequency of nocturnal species in the three different habitats. Symbols: Re = exposed wall without climbing vegetation; Rv = wall with climbing vegetation; Rf = walls with some crevices available; F = ruined spots with high abundance of crevices in the wall. Time1 = Time2 = . H1: 0–0.5 m, H2: 0.5–1 m, H3: 1–1.50 m, H4: 1.50–3 m; Tm_d = *T. mauritanica* diurnal, Tm_n = *T. mauritanica* nocturnal, Pm = *P. muralis*, Ps = *P. siculus*, Ht = *H. turcicus*.

Table 3

Analysis of niche breadth for the study species along the considered ecological niche dimensions.

Species	Trophic	Spatial (Height)	Spatial (Microhabitat)	Temporal
<i>P. muralis</i>	0.19	0.50	0.42	0.50
<i>P. siculus</i>	0.13	0.46	0.49	0.58
<i>T. mauritanica</i> (diurnal)	0.40	0.69	0.66	0.55
<i>T. mauritanica</i> (nocturnal)	0.30	0.12	0.46	0.99
<i>H. turcicus</i>	0.24	0.06	0.59	0.95

excrements of nocturnal individuals were all typically active during the night, thus suggesting that nocturnal foraging activity is typical of our nocturnally caught gecko sample, the reverse being true for the diurnally caught gecko sample. Moreover, since some individuals were recaptured within the same diel time period, this would suggest persistent diet activity patterns mediated by size or ontogenetic variation in feeding and temporal activity. A long-term capture-mark-recapture study would be of help for discriminating between the two hypotheses. The time of foraging is certainly not an issue for *H. turcicus* and the two *Podarcis* data, since all of these species were exclusively nocturnal and diurnal.

The generalist foraging strategy exhibited by geckos can be appreciated when comparing our data with those of conspecifics studied to date. For example, the diet of *T. mauritanica* in urban areas was found to include mainly flying insects as Diptera and Lepidoptera (Capula & Luiselli 1994; Salvador 1998), with a high use of the “sit-and-wait” foraging strategy near artificial lights.

Table 4

Analyses of ecological niche overlap performed on diurnal and nocturnal species at the study area. We compared the observed (O_{obs}) and expected (O_{sim}) overlap index values (Pianka 1986).

Niche dimension	Phenology	O_{obs}	O_{sim}	RA3 (sig.)	RA2 (sig.)
Trophic	diurnal	0.87	0.30	<0.001	<0.001
	nocturnal	0.86	0.34	0.016	0.023
Spatial (height)	diurnal	0.89	0.64	0.006	0.040
	nocturnal	0.97	0.65	0.018	<0.001
Spatial (micro-habitat)	diurnal	0.87	0.60	0.042	0.048
	nocturnal	0.99	0.70	0.082	0.035
Temporal	diurnal	0.92	0.69	0.052	0.115
	nocturnal	0.99	0.94	0.508	0.106

However, in our study areas, there were no artificial lights available, with the majority of prey living near the ground (our unpublished observations). Thus, in absence of artificial lights allowing the gecko to wait for their prey in ambush, these nocturnal species are forced to adopt a more active foraging strategy in order to catch preys that are randomly arranged in the environment (Hódar et al. 2006). Further studies focusing on the foraging strategies of nocturnal lizard species are needed in the Mediterranean environment.

The observed overlap in spatial resource use was higher than expected by chance, thus showing a shared resource use instead of a partitioning pattern. This would suggest an overall low potential for interspecific competition also along this niche dimension. However, diurnal species in some way segregated spatially along the vertical dimension of the aqueduct walls, with lizards confined in the lowest and *T. mauritanica* observed at intermediate wall heights. Surprisingly, despite living in a two-dimension habitat would expect an increase of interspecific interaction rate, no partition was observed between species with the most convergent ecological requirements (i.e. between lizards and between geckos). In previous studies, spatial partitioning was clearly observed between the two *Podarcis* species, including in urban Rome and in the surroundings, with *P. muralis* being more linked to well-vegetated and shady spots than *P. siculus* (Rugiero & Luiselli, 2006, 2007; Maura et al., 2011). Concerning geckos in urban environment, the two species are widespread and syntopic, but with differential abundance in relation to age of buildings and condition of the walls: *T. mauritanica* was more abundant in ancient ruins and old buildings than *H. turcicus* (Luiselli & Capizzi, 1999).

In our study, as well as in those of Avery (1978) and Capula et al. (1993) the two *Podarcis* lizards showed an almost equal daily and

seasonal activities patterns: *P. muralis* was above-ground active earlier in the morning than *P. siculus* and consequently disappeared earlier at the end of the day. Interestingly, *T. mauritanica* also showed considerable diurnal activity, as previously noted only by few authors. For instance, Frankenberg (1978) described this gecko as a diurnal-nocturnal climber that even during the heat of the day may be seen sunning itself on stone walls or rocks. Moreover Gil et al. (1994) hypothesized that, in this species, the maintenance of fairly high preferred temperatures during the day can be considered as a mechanism to prolong the duration of night-time activity. Intriguingly, the nocturnal and the diurnal “demes” of *T. mauritanica* were clearly distinct in our sample, with the nocturnal individuals being smaller than the diurnal ones. We speculate that probably the diurnal activity is costly for diurnal geckos because on increased predation risks (for instance, the snake *Hierophis viridiflavus*, Lacépède, 1789), which is found at the study areas (our unpublished observations) exclusively with a diurnal activity, and feeds abundantly on lizards (e.g., Capizzi & Luiselli 1996; Luiselli et al. 2012), thus forcing only the largest (and in better body condition) individuals, least prone to being predated upon, to be active above-ground by daytime. This again would suggest ontogenetic variation in diel activity maybe mediated by predators or even by intraspecific aggression already reported for this species.

Concerning the nocturnal geckos, as described in literature (Bustard 1967; Pianka & Pianka 1976) the natural period of nocturnal activity begins shortly after sunset and extends at least until midnight, so that their activity patterns vary seasonally as day length changes, with somewhat later emergence during summer. *H. turcicus*, as it is strictly nocturnal, never emerged before sunset nor extended its activity to early morning sunlight as it is recorded by Frankenberg (1978) and Ibrahim (2007). This pattern may reflect the intolerance of this Mediterranean Gecko to sunlight, probably due to the skin structure (Ibrahim 2007). However, in our sites, *H. turcicus* tended to emerge and retreat earlier during late summer (time band 8:00 p.m.–11 p.m.) than in Frankenberg (1978) and Ibrahim (2007). It is likely that this difference is based on latitude and climate differences among the sites studied. Indeed, both Frankenberg (1978) and Ibrahim (2007) carried out their studies respectively in Sinai Peninsula and Israel, where lower latitude and more temperate climate than our area allow *H. turcicus* to late emerge and early retreat.

In conclusion, though we realize that our hypotheses about lizard communities structuring and interactions in the urban habitat require further investigation, we think that the lizard assemblage investigated is based on the ecological needs of each species rather than by species’ interactions. Unlike our expectations, we found a lower resource partition than by chance for all the three analysed niche dimensions. The observed spatial segregation between diurnal geckos and lizards would not support alone the interaction hypothesis. Alternatively, this community could be not constrained along the food dimensions but mainly by external pressures like predators (e.g. *H. viridiflavus*, domestic dogs and cats) or human disturbance. Indeed, a community top-regulated could explain the poor trophic differences we observed. Further analyses should be needed to define more firmly the segregation or the overlap detected in the use of the resources, especially about the trophic niche. Indeed, the faecal pellet technique used in our study, even if considered a very suitable technique for dietary studies (Capula & Luiselli 1994; Angelici et al. 1997; Perez Mellado et al. 2010), presented the limitation that little detail in prey identification is allowed because only small fragments of prey may be found and identification to species level of these fragments is very difficult. Probably, a more exhaustive taxonomic analysis would have demonstrated a higher segregation for this resource axis.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jcz.2019.08.001>.

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