Patterns of abundance of three reptile species inside the metropolitan area of Rome (Italy)

Francesco Gallozzi

francesco.gallozzi@uniroma1.it

Sapienza University of Rome

Flavio Melchiorri

Sapienza University of Rome

Carlotta Antinucci

Sapienza University of Rome

Riccardo Castiglia

Sapienza University of Rome

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Abstract

Urbanization reshapes natural environments, impacting biodiversity and creating complex ecosystems where some species adapt while others decline. This study examines the abundance and distribution patterns of three reptile species — *Podarcis siculus*, *P. muralis*, and *Tarentola mauritanica* — within the metropolitan area of Rome, Italy. Data were collected from 36 plots representing different level of urbanization, categorized by green area coverage. Results reveal *P. siculus* as the most widespread species, found across all vegetation cover categories, while *P. muralis* and *T. mauritanica* were more frequent in plots with over 50% green area coverage. Vegetation type emerged as a primary factor influencing reptile abundance, with meadow cover positively affecting *Podarcis* species, while bush cover promoted *T. mauritanica* presence. Notably, *P. siculus* abundance increased with the number of garbage bins, suggesting potential exploitation of anthropogenic food resources. Possibly, species interactions also played a role, with *P. siculus* and *P. muralis* exhibiting negative correlations in abundance. The study highlights the importance of maintaining heterogeneous urban green spaces to support reptile biodiversity. These insights contribute to urban ecology and inform strategies to enhance biodiversity in metropolitan landscapes.

INTRODUCTION

Urbanization is a dynamic and ongoing process that reshapes natural habitats, leading to profound effects on biodiversity. This transformation involves habitat loss, fragmentation, and the introduction of exotic species, coupled with changes in resource availability (Garrard et al., 2018). Urban areas are among the fastest growing land-use types across the globe, driven by rapid population growth and economic development (McDonald, 2008). Current projections suggest that by 2050, approximately 68% of the global population will reside in urban and peri-urban areas, intensifying the pressure on natural ecosystems (United Nations, 2018). This expansion converts natural landscapes into impervious surfaces, such as roads, buildings, and industrial zones, which not only fragment habitats but also isolate populations, disrupt ecological networks, and contribute to biodiversity loss (McKinney, 2002; Grimm et al., 2008; Aronson et al., 2014). Moreover, the remnant vegetation, particularly the shrub layer essential for many species' cover and foraging, is drastically reduced and native flora and fauna are increasingly replaced by exotic, often opportunistic, species better suited to withstand urban stressors (McKinney, 2002, 2006).

However, urban environments are not exclusively hostile to wildlife. In certain contexts, they provide novel ecological opportunities. Man-made structures, such as walls, abandoned buildings, and drainage systems, create refuges and microhabitats that some species exploit for shelter and thermoregulation. Additionally, urban areas can offer lower predation pressures, particularly where natural predators are scarce and non-native predators have limited impact, and may present abundant food resources, including anthropogenic waste (McKinney, 2002; Francis & Chadwick, 2013; Parris, 2016). This duality — where cities act as both a threat and an opportunity — shapes urban biodiversity in complex ways.

Although studies on the impact of urbanization on reptiles are not lacking (e.g., Ackley et al. 2015; Hall and Warner 2017; Tiatragul et al. 2017; Gainsbury 2022; Larson et al. 2024), they are fewer in number compared to those conducted on birds and mammals. (Brum et al. 2023). In fact, this group of vertebrates remains scarcely studied when it comes to understanding how specific urban features influence their ability to tolerate city environments (French et al., 2018). While some species adapt and even thrive in urban fragmentation and development, many others are highly susceptible to habitat alterations and landscape modifications, as observed in squamates (Wolf et al., 2013; French et al., 2018). Reptiles, being ectothermic organisms, are particularly sensitive to environmental changes, with temperature playing a critical role in their behaviour, physiology, and overall survival (Kearney et al., 2009). Urban areas often create "urban heat islands", where temperatures are significantly higher than in surrounding rural areas due to heat-retaining materials and reduced vegetation cover (Ackley et al. 2015; Kolbe et al., 2016). This altered microclimate can influence reptile basking behaviours, growth rates, and reproductive success, while also increasing mortality risks due to higher predation rates by domestic animals and road traffic (Simbula et al., 2019). Previous studies have shown that the diversity and abundance of reptile species in urban environments are closely linked to the extent and configuration of green areas, with larger, irregularly shaped patches supporting greater biodiversity (Vignoli et al., 2009; Smolesky and Fitzgerald, 2011; Ackley et al., 2015; Kolbe et al., 2016; Brum et al., 2022). Moreover, microhabitat preferences among species influence their spatial distribution within the cities, reflecting a combination of ecological requirements and interspecific interactions (Capula et al., 1993; Simbula et al., 2019).

Rome (Italy) is among the oldest continuously inhabited cities in the world, with the first urbanization processes dating back to at least the 9th and 5th century BC (Attema et al., 2014; Fulminante, 2014). Rome's municipal territory spans 1285 km^2 and stands out as one of the greenest European urban areas, with more than 60% of its land covered by green spaces, including public gardens and woodlands — half of which are designated as protected areas (Blasi et al., 2001; Celesti Grapow et al., 2006). A significant portion of these green spaces comprises remnants of larger natural habitats that predate urban expansion or originated as estates belonging to the Roman nobility (Celesti Grapow, 1995; Bologna et al., 2003; Vignoli et al., 2009). Moreover, Rome lies inside the Mediterranean basin, a well-known biodiversity hotspot with a unique and diverse herpetofauna (Myers et al., 2000). The present study aims to investigate the influence of environmental factors (natural and anthropogenic) on the abundance and distribution of two lizards and a gecko within Rome's urban landscape. Specifically, this study will test (1) how the presence of urban reptiles is influenced by the green area coverage inside the city, (2) how land cover and urban/landscape factors shape the relative abundance of the target species, and (3) how different reptile species influence the abundance of each other. We expect more generalist species to be less affected by urbanization and by the presence of other potentially competitor species. Moreover, different vegetation types are expected to influence reptile abundance differently, accordingly to each species ecology and needs. By examining these relationships, this research seeks to uncover how urban environments impact reptile communities. Additionally, assessing potential interspecific interactions would be helpful to understand how coexistence and competition might further modulate species distributions inside a city.

MATERIALS AND METHODS

The study area lies entirely inside the metropolitan area of Rome (Italy) and it consists of 36 square plots. We selected 9 areas of 1 km^2 and, for each of them, 4 square plots of 100x100 m were chosen. The four square plots were selected based on their accessibility and the presence of green areas, in order to ensure variability in the proportion of green space relative to built-up areas. The location of the 9 areas and the plots inside them is shown in Fig. 1.

The study focuses on three very common and easy to observe reptile species: the Italian wall lizard (*Podarcis siculus*), the common wall lizard (*P. muralis*), and the Moorish gecko (*Tarentola mauritanica*). The two lizard species are among the two most common reptiles in Italian cities (Corti et al., 2011) but, despite often occurring in sympatry, they show some significant ecological differences: *P. siculus* is usually more generalist and thermophilic, while *P. muralis* tends to occupy shadier and wetter environments but still thrives in urban areas, and it is often found living in wall cavities (Corti et al., 2011; Biaggini et al., 2011). For *T. mauritanica*, recent studies suggested the presence of two divergent diurnal and nocturnal lineages (Fulgione et al., 2019, 2025). In this study (and hereafter), we focused on diurnal geckos only, since the sampling activity took place during daylight and the two *Podarcis* species are exclusively diurnal.

Sampling sessions took place between April and October 2023 with a break from the end of July to September due to the extreme heat resulting in reduced reptile activity. Sampling consisted of time constrained visual sampling (Heyer et al., 1994; Montgomery et al., 2021; Barkmann et al., 2023; Avalos-Hernandez et al., 2024). For each plot, the number of adult individuals for each species was recorded by a single observer in a 30-minute time range. To avoid double counts, a one-way direction was followed along a random path throughout the entire the plot. This was made easier also by architectonic structures such as buildings, walls, etc. that, when present, guided the observers along the sampling path. Each plot was visited four times, walking always in the same direction and following the same path, in different days and times, to guarantee replicates. We aimed to ensure two morning surveys and two afternoon surveys for each plot.

The majority of the individuals observed were basking and therefore fully exposed. Consequently, the presence of urban obstacles (e.g., walls, buildings) did not significantly influence the detectability of reptiles across the different plots. This allowed us to obtain four abundance values for each species in each plot. The highest for each species in each plot was considered as the relative abundance (hereafter abundance) of that given species in that plot (Banville and Bateman, 2012). Urban factors like the number of fountains and garbage cans found in each plot was also recorded during field work, while landscape factors and land cover data were obtained through remote sensing in QGis using the HCMGIS plugin and validated during fieldwork. A detailed description of each variable is provided in Table 1.

Table 1
List of the variables collected for each plot during this study.

Variable	Description
Tree cover	Percentage of the plot area covered by trees.
Bush cover	Percentage of the plot area covered by shrubs (woody plants < 2m, branched at the base).
Meadow cover	Percentage of the plot area covered by meadows, grass and other herbaceous plants.
Number of fountains	Number of water fountains present within the plot.
Impervious soil	Percentage of the plot area covered by impermeable surfaces (e.g., asphalt roads, infrastructure).
Bare soil	Percentage of the plot area covered by unvegetated permeable bare soil (e.g., dirt roads, unpaved parking lots).
Number of garbage cans	Number of medium and large garbage cans present within the plot.
Green area	Percentage of the plot area covered by trees, shrubs, and grass.
Urbanized area	Percentage of the plot area covered by bare soil and impermeable surfaces.
Distance from nearest body of water	Distance in meters from the center of the plot to the nearest body of water.

The obtained dataset composed of species abundance and environmental variables was imported in R (R Core Team, 2021), where all statistical analyses were performed. To test if the percentage of green area had a statistically significant effect on the presence of the three reptile species, a Wilcoxon-Mann-Whitney test was run (function *wilcox.test* of the package *stats*) for all species presence and co-occurrences. Subsequently, a Pearson correlation matrix (package *corrplot*) was built among all the urban, landscape and land cover variables collected inside the 36 plots. When a pair of variables showed $r > 0.75$, one of them was removed and not included in the models. Then, all values, including relative abundance of all the three species, were log-transformed to standardize the dataset. After that, a generalized linear model (function *glm* of the package *stats*) for each species was built adopting a gaussian distribution to understand the relations between the relative abundances of the three studied species, land cover, urban and landscape factors.

RESULTS

In the 36 plots selected within the municipality of Rome, we recorded a total of 1309 sightings of the three target species, divided as follows: 983 of *P. siculus*, 189 of *P. muralis*, 137 of *T. mauritanica*; *P. siculus* was by far the most common species and observed in 32 plots (88.9% of the total plots examined), *T. mauritanica* was recorded in 25 plots (69.4%) and *P. muralis* was sighted in 20 plots (55.6%). Specifically, *P. siculus* was observed in all green area coverage bands, meaning from the most urbanized plots to the more natural ones. On the other hand, *P. muralis* and *T. mauritanica* are more commonly found in plots with green area coverage greater than 50%.

It is also worth noting that in several cases, the co-occurence of multiple species was recorded in the same plot. For example, *P. muralis* and *P. siculus* were identified simultaneously in 19 plots, corresponding to 52.8% of the total; *P. siculus* and *T. mauritanica* in 24 plots (66.7%); *P. muralis* and *T. mauritanica* in 16 plots (44.4%); finally, all three species were observed together in 15 plots (41.67%).

According to the Wilcox-Mann-Whitney test, *P. muralis* is the only species whose presence is significantly positively influenced by the green area coverage ($p < 0.05$). Anyway, the same trend emerged for *P. siculus* and *T. mauritanica* as well, with p-values < 0.1 (Fig. 3). Moreover, the green area coverage seems to have a positive effect on all the types of co-occurrence, with statistically significant relationships (Fig. 3).

According to the Pearson correlation matrix, “green area”, “urban area” and “impervious soil” show $r > 0.75$ with at least one variable (see Supplementary Materials for details). Therefore, they were excluded from the GLMs.

Our models revealed that, although the abundance of all the three species is positively influenced by the tree cover, this relationship is not statistically significant for any of the species. Differently, bush cover seems to have a negative relationship with the abundance of *Podarcis* muralis ($p < 0.05$) and a positive relationship with *T. mauritanica* ($p < 0.05$). The opposite trend is found for meadow cover, with a positive effect on *Podarcis* ssp. abundances ($p < 0.05$ for both species). The percentage of bare soil does not seem to significantly influence the abundance of any of the three reptile species. The results regarding land cover variables are shown in Fig. 4.

Regarding species interactions, the two *Podarcis* lizards have a negative influence on each other abundance ($p < 0.05$), while *T. mauritanica* does not appear to influence or be influenced negatively by the other reptile species included in this study ($p < 0.1$). Results are reported in Fig. 5.

Landscape and urban factors related to water availability (i.e., distance from nearest body of water, number of fountains) does not show any significant influence on the abundance of reptiles. However, there is a positive relationship between the number of garbage cans and the abundance of *P. siculus* ($p < 0.05$). This relationship is not observed for *P. muralis* and *T. mauritanica* (Fig. 6).

DISCUSSION

A few papers investigating reptile community in the city of Rome are already present in literature (Capula et al., 1993; Vignoli et al., 2009; Simbula et al., 2019), some of which even focusing on the three species examined here. However, these previous studies are mainly centred on size and shape of the green areas (Vignoli et al., 2009) or are based on a restricted geographical scale (i.e., a single locality Capula et al., 1993; Simbula et al., 2019). Therefore, this research presents a complementary approach to previous works, focusing on a large area of the Rome metropolitan area that also includes highly urbanized spots. It also incorporates variables not considered in earlier works, such as anthropogenic factors and vegetation types.

According to our data, the presence of the three reptile species in the plots is mainly affected by the percentage of green cover. The co-presence of two or three species is also observed in 52.8% (*P. siculus* and *P. muralis*), 66.7% (*P. siculus* and *T. mauritanica*) and 41.7% (all the three species) of the plots. Again, co-presence of species is enhanced by green cover as plots showing a green area percentage greater than 50% are those where it is easier to find two or three of the studied species. This is likely because the high vegetation cover within the sampled areas allows for the presence of more ecological niches that can be occupied by more taxa, thanks to high environmental heterogeneity (Vignoli et al., 2009; Piccoli et al., 2019; Simbula et al., 2019).

This result was coherent with previous studies, that highlighted how vegetation cover and natural patches size are the main drivers in determining the status of reptile communities in urbanized areas (Vignoli et al., 2009; Mulhall et al. 2022).

Anyway, differently from previous papers in which only parks and other green areas were considered, we included highly urbanized zones, thus providing information about the role of the different components influencing reptile abundance inside a city. Results suggested that the relative abundance is influenced by specific vegetation types and intraspecific interaction. Otherwise, landscape and other urban factor influence minimally the species abundances.

The Italian wall lizard *P. siculus* is the most common reptile species in the metropolitan area of Rome. This species is not found in four plots only, with very diverse values of green area coverage (8.42%, 14.55%, 39.12%, 59.78%). The absence of *P. siculus* in the two plots with low green area coverage (8.42%, 14.55%) can be explained by scarcity of suitable habitat. On the other hand, for the two plots showing higher green area coverage (39.12%, 59.78%), the observed high abundance of *P. muralis* in the same area represents a more likely explanation, since the abundances of these two species have a significant negative relationship with each other. Other significant relationships with the abundance of *P. siculus* are those with the meadow cover and the number of garbage cans, both with a positive effect ($r = 0.78$ and 0.36, respectively). As reported in Capula et al. (1993) and Piccoli et al. (2019), a higher number of individuals of this species are usually observed in grassland areas and open fields. This species' preference for open grassy areas is likely due to its physiological need to maintain a higher body temperature compared to other lacertid species like *P. muralis* (Avery, 1978). Regarding the relationship with garbage cans, to date, no studies directly correlate the abundance of lacertid species with the number of garbage bins, but a similar increase in certain reptile taxa has been observed in relation to the presence of landfills (Plaza & Lambertucci, 2017). Evidently, in the context of the city of Rome, garbage bins fail to keep their contents sealed inside (authors' personal observation). Various factors — such as poor maintenance, insufficient capacity, etc… — lead to waste spilling out and accumulating outside. It is therefore plausible that garbage bins may act as small-scale landfills, having a positive effect on the abundance of *P. siculus* due to the presence of organic material that can either be directly consumed or attract small invertebrates, which can be preyed upon by the species. As a matter of fact, the ability of this species to adapt to a high variety of food and even to exploit anthropogenic resources is a well-documented phenomenon (Mačát et al., 2015; Mo & Mo, 2021; Valerioti & Sperone, 2024).

The other two target species are found in a smaller number of plots, *P. muralis* in 55.6% and *T. mauritanica* in 69.4% of the plots. The common wall lizard *P. muralis* is well known for preferring highly vegetated areas with abundant trees (Biaggini et al., 2011). However, no significant relationship was found between tree abundance and species abundance and this is in contrast also to what has been reported in other studies conducted in non-urban contexts (Romano et al. 2022). In fact, according to our models, the abundance of this species has significant relationships with the bush cover (negative) and meadow cover (positive) and a non-significant relationship with tree cover. The fact that this relationship is not significant, despite the well-known preference of *P. muralis* for habitats with abundant trees (Biaggini et al., 2011), is probably explained by the high abundance of *P. siculus*, an urban-adapted and more generalist species, that may be able to competitively exclude *P. muralis* in anthropic disturbed areas, even with high tree covers. Therefore, the abundance and distribution of this species inside cities can be the results of a combination of interspecific interactions, urban and vegetation factors rather than reflecting just its ecological needs.

The abundance of *T. mauritanica* has a positive statistically significant relationships with bush cover. The result would seem to contrast with the literature, as *T. mauritanica* is considered a highly abundant species near predominantly anthropic structures such as buildings, house walls, etc., or near archaeological sites (Luiselli & Capizzi, 1999; Piccoli et al., 2019; Simbula, 2019). However, further investigation may reveal possible differences in habitat choice between the diurnal subpopulation studied here and the nocturnal one, thus explaining this discrepancy.

This work extending the spatial scale of investigation to the entire metropolitan area of Rome, provided insights into how the studied species adapt to increasingly urbanized habitats. Our findings confirm the central role of different vegetation type in sustaining reptile communities, while also highlighting the importance of species interactions in shaping abundance patterns. Specifically, considering the overall situation, it appears evident that the extent of green areas favors the occurrence of the studied species. However, when looking at relative abundances, tree cover does not significantly influence the three species. In contrast, other types of vegetation (meadows and shrubs) play a positive but species-specific role. Another unanticipated result is that water availability did not affect species abundance, unlike what has been observed in other groups of urban terrestrial mammals (e.g., bats; Ancillotto et al. 2025). This is likely related to the urban context, where impermeable surfaces limit water infiltration while promoting the formation of small water pools that may sustain lizard populations despite the absence of permanent water bodies or fountains. All this knowledge will inform conservation strategies aimed at enhancing urban biodiversity and ensuring the persistence of reptile populations within metropolitan landscapes.

Declarations

Author Contribution

F.G. statistical analysis and manuscript writing; F.M. field work, data preparation, statistical analysis; C.A. field work and data preparation; R.C. conceptualization, field work, funding acquisition and manuscript writing.

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Figures

Figure 1

Location of the nine 1 km^2 areas inside Rome urban area and of the four plots inside each of them.

Figure 2

The three reptile species included in this study: A) *Podarcis siculus*, B) *P. muralis*, C) *Tarentola mauritanica*. Pictures by F. Gallozzi, all rights reserved.

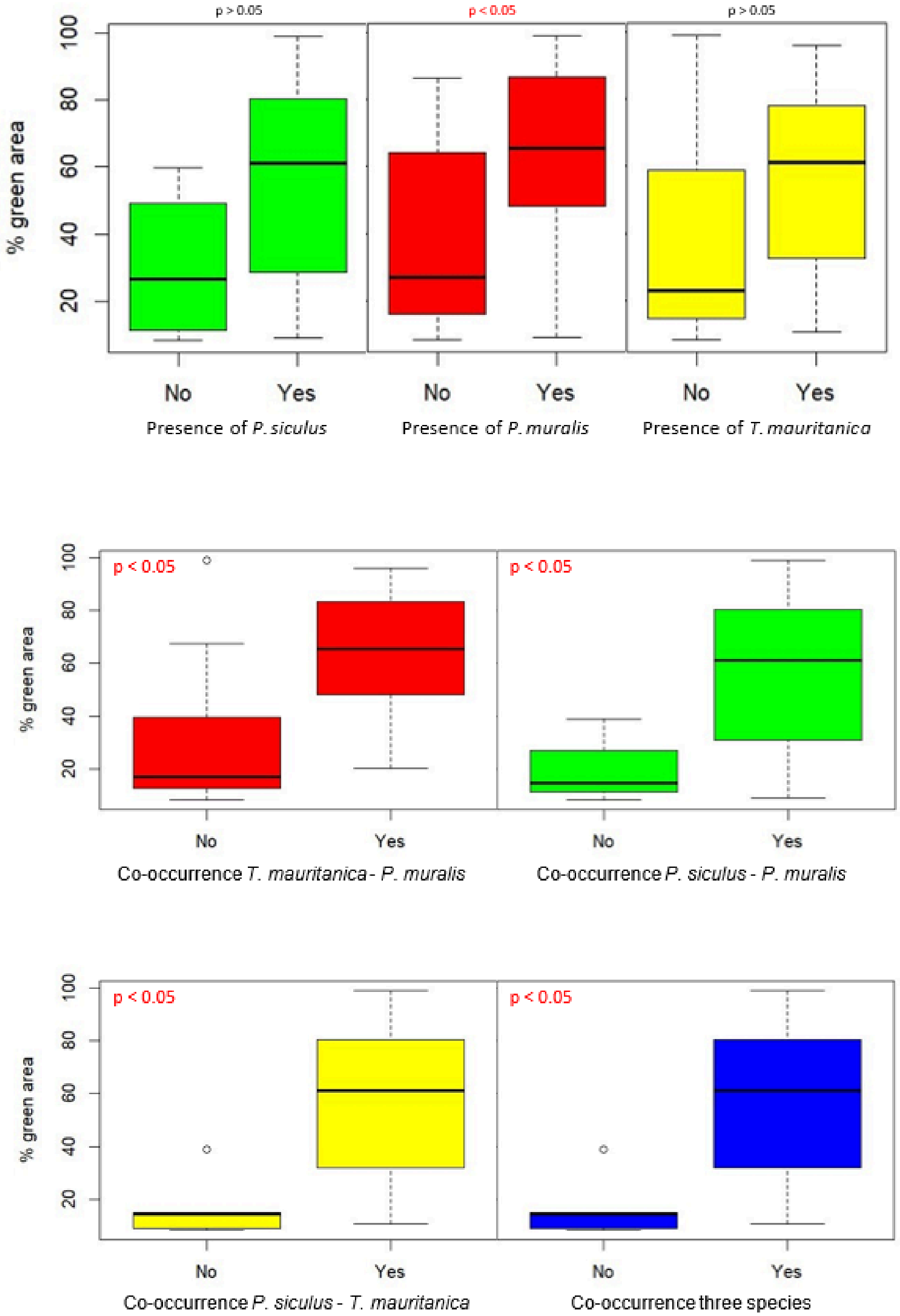

Figure 3

Boxplots representing the variation of green area among the plots in relation to the presence/absence of the three studied species and the co-occurrence of two or more species in the same plot. Significant p-values are in red.

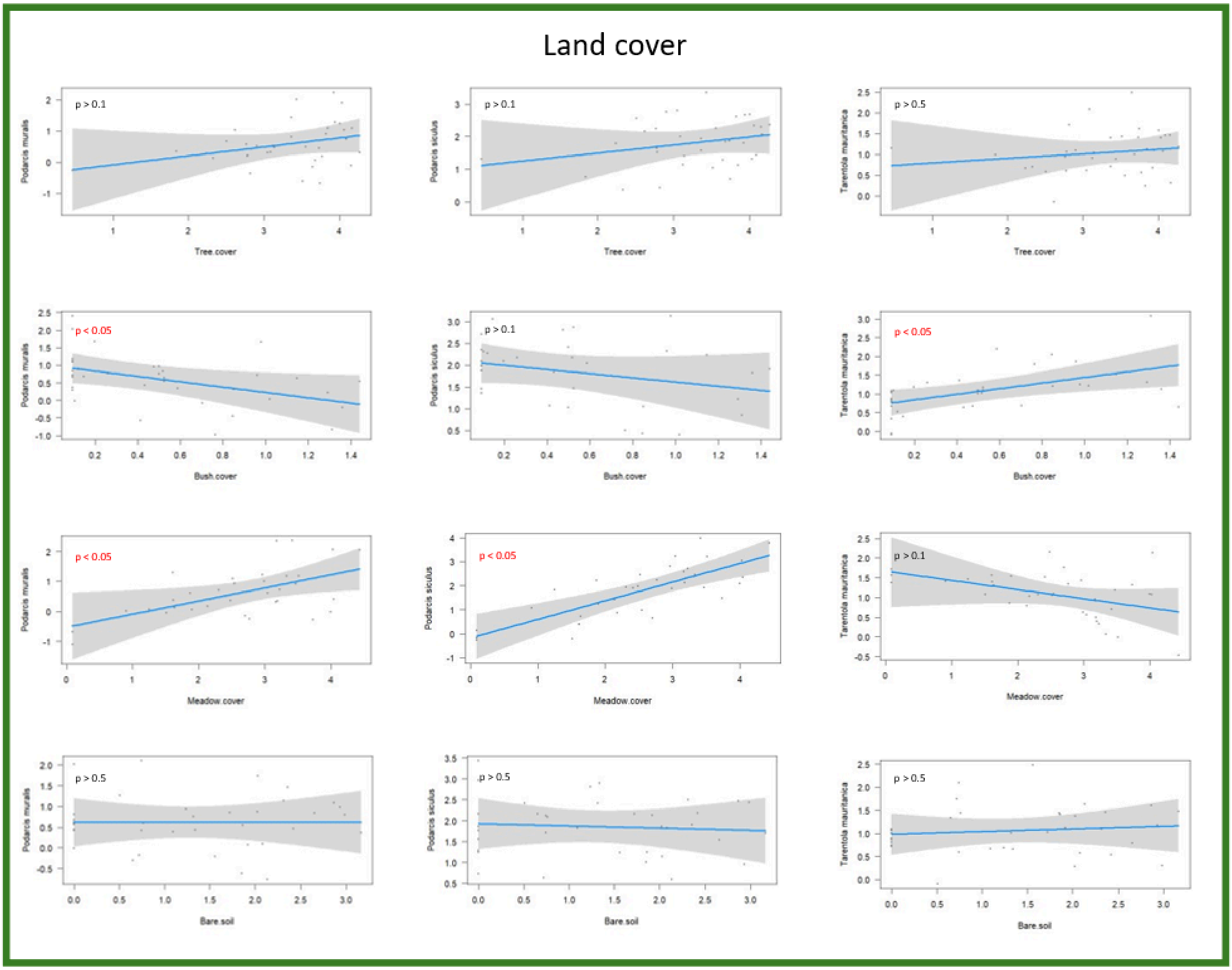

Figure 4

Linear regressions from the GLMs based on land cover data. Each row of graphs represents a different variable (top-down: tree cover, bush cover, meadow cover, bare soil), and each column represents a different species (left-right: *P. muralis*, *P. siculus*, *T. mauritanica*). Significant p-values are in red.

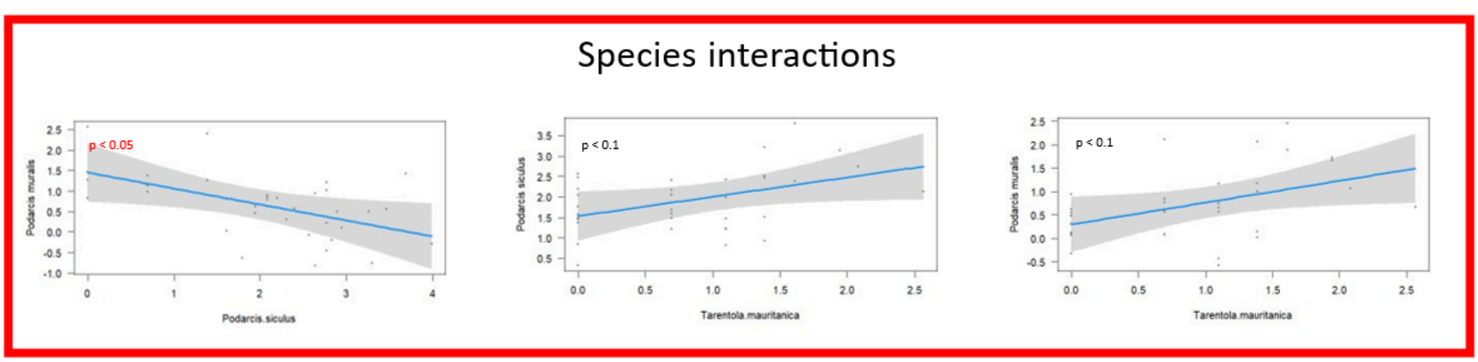

Figure 5

Linear regressions from the GLMs based on interspecific interactions. Left-right: *P. muralis* vs *P. siculus*, *P. siculus* vs *T. mauritanica*, *P. muralis* vs *T. mauritanica*. Significant p-values are in red.

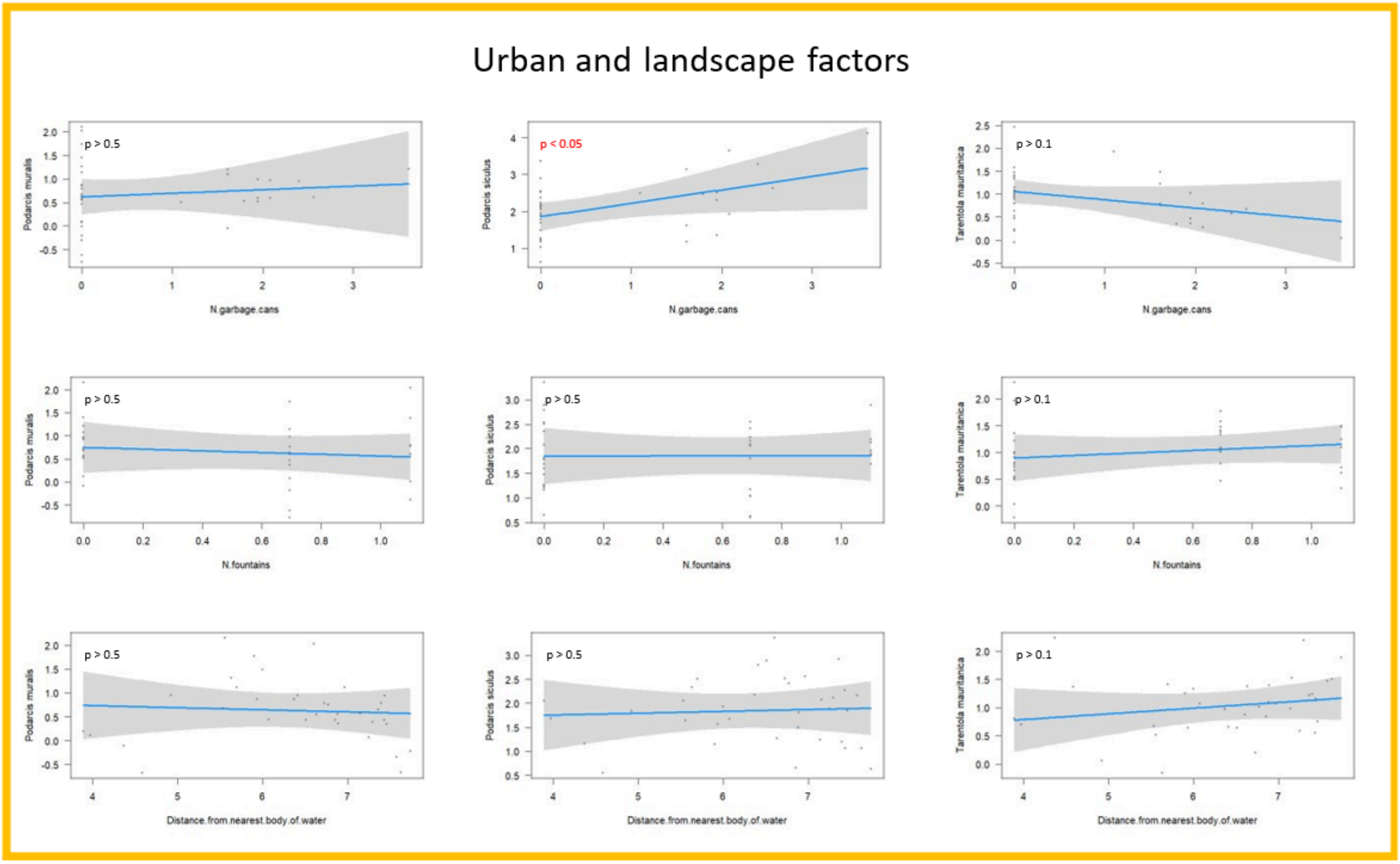

Figure 6

Linear regressions from the GLMs based on urban and landscape factors. Each row of graphs represents a different variable (top-down: number of garbage cans, number of fountains, distance from nearest body of water), and each column represents a different species (left-right: *P. muralis*, *P. siculus*, *T. mauritanica*). Significant p-values are in red.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- rawdata.csv
- correlationmatrix.png