

HIGH OCCUPANCY OF EUROPEAN LEAF-TOED GECKO IN TWO ISLAND STANDS OF *EUCALYPTUS* SP.: TREE SELECTION, HABITAT EFFECT, AND SYNTOPY WITH OTHER GECKO SPECIES

GRÉGORY DESO^{1,5}, PAULINE PRIOL², THIERRY REYNIER³, AND JULIEN RENET⁴

¹Association Herpétologique de Provence Alpes Méditerranée, Maison des Associations, 384 Route de Caderousse, 84100 Orange, France

²StatiPop, Scientific Consulting, 54 Place de l'église, 34190 Cazilhac, France

³Reynier Environnement, 12 Montée du Château, 83560 Ginasservis, France

⁴Fauna studium, Scientific Consulting, 25 Avenue du Jabron, 04200 Sisteron, France

⁵Corresponding author; e-mail: ahpam.contact@gmail.com

Abstract.—The conservation of a species is dependent on a comprehensive understanding of its ecology. Considered to live exclusively in rocky environments, the European Leaf-toed Gecko (*Euleptes europaea*) has in fact been observed in the past and more recently in vegetated and wooded habitats in various locations throughout its range. This preference for alternative habitats is likely due to the prehensile tail of this species, a characteristic of geckos with arboreal behavior. To assess the occupancy of trees by *E. europaea* and other two species of geckos, we conducted site-occupancy surveys in 2022 on Levant Island (Hyères, France). We selected two stands of the non-native eucalyptus (*Eucalyptus* sp.) for surveying. One stand was located in an urbanized area, consisting of scattered woodland and clear ground (stand 1), and the other represented a more natural forest with dense ground vegetation (stand 2). We found that *E. europaea* had a high occupancy rate in both stands, with an average probability of 0.57 (95% Confidence Interval [CI] = 0.40-0.72). We also found Mediterranean House Geckos (*Hemidactylus turcicus*) and Moorish Geckos (*Tarentola mauritanica*), which we only detected in stand 1, with average occupancy probabilities of 0.64 (CI = 0.34-0.85) and 0.38 (CI = 0.05-0.88), respectively. Our results suggest that the ecology of *E. europaea* should be re-evaluated and research should be expanded to systematically include vegetated and forest habitats besides rocky areas.

Key Words.—arboreal behavior; *Euleptes europaea*; Ile du Levant; prehensile tail; site occupancy.

INTRODUCTION

Conserving wildlife requires a thorough understanding of life history and ecology of a species to be able to identify suitable management and conservation actions (Soulé and Siberloff 1986). Certain aspects of the ecology of a species, however, may remain unnoticed or obscured due to incomplete knowledge of its biology (Burgman 2005). This applies particularly to cryptic species, which are challenging to detect and therefore the least well understood (de Lima et al. 2011; Martin et al. 2022).

The European Leaf-toed Gecko (*Euleptes europaea*) is a small, cryptic gecko endemic to the western Mediterranean with a primarily insular distribution (Delaugerre 2004). It is the only member of the Sphaerodactylidae family in Europe, while the other species are mainly found in the Americas, Asia, and Africa (<http://www.reptile-database.org>). The species was described from Sardinia in 1839 by Gené (1839). This species is known to have a

prehensile tail (Fitzinger 1843; Boulenger 1885), an uncommon feature in the family Sphaerodactylidae, but characteristic of geckos with arboreal behavior (Linkem et al. 2008; Grismer et al. 2021). The use of this prehensile tail to move through vegetation was discussed by Lataste (1877) and later studied in detail by van Eijsden (1983), who found that the tail of *E. europaea* is used as a climbing organ. Gené (1839) described that the species as occurring mainly under the bark of trees and considered it rare under stones. Knoepffler (1960) specifies that *E. europaea* is common under stones on the island of Bagaud (deforested and arid) and especially present under tree bark on Port-Cros and Le Levant islands of France. According to Bruno (1976), on the island of Montecristo, the species was most often found under the bark of heather (*Erica* sp.) and Holm Oak (*Quercus ilex*). Vanni and Lanza (1978) considered this species a bark-dweller, but with an affinity for rocks. More recently, due to the sparsely wooded nature of the Mediterranean islands and islets where



FIGURE 1. (a) *Eucalyptus* (*Eucalyptus* sp.; centre of image) in stand 1 in an urbanized context. (b) Dense stand of *Eucalyptus* sp. in stand 2 in a semi-natural state, with a high degree of ground vegetation cover.

this species is largely found, it has been considered a rocky habitat species both on islands (Delaugerre 1980; Cheylan 1983; Delaugerre and Cheylan 1992) and on the mainland (Salvidio et al. 2010). The absence of observations of this gecko in some of the tree species surveyed (e.g., Cork Oak, *Quercus suber*) certainly contributed to the impression that the use of woody plants by *E. europaea* was marginal (Delaugerre 1980).

In the last two decades, naturalists have occasionally reported observations of the species in trees and plants, mainly on French and Italian islands (Oneto et al. 2008; Berg and Berg 2010; Salvi et al. 2023). On Giglio Island (Italy), this gecko has been found under the bark of eucalyptus (*Eucalyptus* sp.; Fattorini 2010). Indeed, eucalyptus trees shed a great deal of bark, creating sheltering opportunities on the tree itself (under the bark) and on the ground (in the litter). This shelter is used by many wildlife species (Verdade et al. 2020; Vásquez et al. 2021), including arboreal geckos in Australia (e.g., Marbled Southern Gecko, *Christinus marmoratus*, and Congo Gecko, *Strophurus congoo*) that are closely associated with semi-dry eucalyptus forests (Davis 2006; Vanderduys 2016). These historical and recent records seem to point to gaps in our knowledge of the ecology of *E. europaea* and its morphological adaptation to vegetation. This is an urgent concern as the species is Near Threatened globally according

to the International Union for Conservation of Nature (Cox and Temple 2009) and is in danger of extinction in southeastern France (Marchand et al. 2017).

To assess the occupancy of forest habitat by *E. europaea* and the effect of certain tree characteristics (circumference, autocorrelation, state of the tree), we conducted a site-occupancy study in two stands of *Eucalyptus* sp. on Levant Island off the Mediterranean coast of southeastern France. These two stands presented different physiognomies depending on whether they were part of an urbanized or semi-natural state. We also evaluated the occupancy of two other geckos in the same habitat to determine any differences in occupancy between species based on the context of each location and the tree characteristics.

MATERIAL AND METHODS

Study area.—We carried out the study on Levant Island (43°01'24.5"N, 6°27'29.1"E) in southeastern France (Hyères, Var Department). This island, formed of gneiss and mica schist, is 996 ha in area and is one of the three main islands of the Hyères archipelago along with Porquerolles and Port-Cros (Tanazacq 1966; Médail et al. 2013). The vegetation in the area is primarily composed of tall and impenetrable Maquis, which is dominated in some places by Aleppo Pine (*Pinus halepensis*)

Forest. This plant formation covers most of the area, but there are also several non-native plant species on the island, including stands of *Eucalyptus* sp., probably introduced at the beginning of the last century (Jahandiez 1929). The island is located in a sub-humid thermo-Mediterranean bioclimatic zone (Quézel and Médail 2003).

More than half of the island (the eastern side) is covered by a restricted military area consisting mainly of natural habitats and some technical buildings served by roads and tracks. The rest of the island (the west side) is inhabited by civilians. *Euleptes europaea* and the Mediterranean House Gecko (*Hemidactylus turcicus*) are the two species of geckos historically present on the island (Jahandiez 1929; Lantz 1931). The Moorish Gecko (*Tarentola mauritanica*) has been found on the island since 2010 in the civilian area and since 2019 in the restricted military area (Deso et al. 2018, 2020).

Field data collection.—We selected two eucalyptus stands for site-occupancy surveys. The first stand was located in the urbanized area of the restricted military zone and distributed along tracks, roads, and buildings (Fig. 1). The second stand was also located in the restricted military zone and was located 100 m south of the urbanized area. It was characterized by a compact and continuous forest unit, with dense vegetation on the ground and around the trees (Fig. 1). We randomly selected 68 trees (30 trees were in stand 1 and 38 trees in stand 2). For each tree, we measured the circumference using a decameter. We also noted the state of the trees (alive or dead).

We carried out night surveys (from 2200 to 0100) on the previously selected trees. Each tree was inspected for 2 min using headlamps (500 Lumens). We looked under the bark and on the surface of trees up to 2 m above ground level. When detected, we identified geckos to species. We replicated surveys of the 68 selected trees three times in the summer of 2022: 1 June; 21 June; and 27 June. One observer carried out the survey for the first survey, two observers were present for the second survey, and three for the last survey. We made surveys simultaneously on the same trees when there were several observers. The start of surveys alternated between stands 1 and 2, so as not to always start at the same time in one stand.

Statistical analyses.—We used Mann Whitney U-tests to compare circumferences of trees and the average distance between trees between stands. We modeled survey data using Single-season Occupancy

Models (MacKenzie et al. 2003, 2006). These allowed the estimation of occupation probability, as well as the detection probability of each survey. We tested the following: (1) no effect on the occupancy (.); (2) the effect of the context, either semi-natural or urbanized area; (3) the circumference (circumf); and (4) the state of the tree (state) on the occupancy of each of the three species of geckos on the island. To take into account the spatial non-independence of the data, we created an autocorrelation variable (autocor), considering the presence of a species on trees close to the focal tree (within a 5 m radius). We tested this autocorrelation variable alone and in addition to the other covariates. The numeric circumference covariate was center reduced before analysis. We tested the effect of number of observers (confounded with time) on detection probabilities (t) by comparing with a constant detection (.). Because they were not detected in stand 2, we fitted Single-season Occupancy Models for *H. turcicus* and *T. mauritanica* for the 30 trees of stand 1.

We fitted 16 models for *E. europaea*, and 12 for *H. turcicus* and *T. mauritanica*, and we obtained maximum likelihood estimates using the unmarked package (Fiske et al. 2012) in R Studio version 2022.12.0 (R Core Team 2022). We assessed the goodness-of-fit of the top-ranked models with the parametric bootstrap using Chi-square as a test statistic with 5,000 bootstrap samples. We compared models using the corrected Akaike's Information Criterion (AICc; Burnham and Anderson 2002). We used the entire set of models to draw inferences by computing model-averaged parameter estimates and their unconditional standard errors for the variables appearing in the models with the most support, whereas we model-averaged predictions for the occupancy parameters from each model (Mazerolle 2013). Using co-occurrence models (MacKenzie et al. 2004) was not possible due to insufficient data.

RESULTS

The average tree circumference was 169 cm (range of values 22–550 cm). In stand 1, the average tree circumference was 266 cm (120–550 cm), and in stand 2 it was 92 cm (22–423 cm). The circumferences of stand 1 were significantly larger than those of stand 2 ($U = 92.5$, $n_1 = 30$, $n_2 = 38$, $P < 0.001$). The average distance between trees was 8.3 m and 4.8 m in stand 1 and 2, respectively, with significantly greater distances between trees in stand 1 ($U = 312$, $n_1 = 30$, $n_2 = 38$, $P = 0.002$).

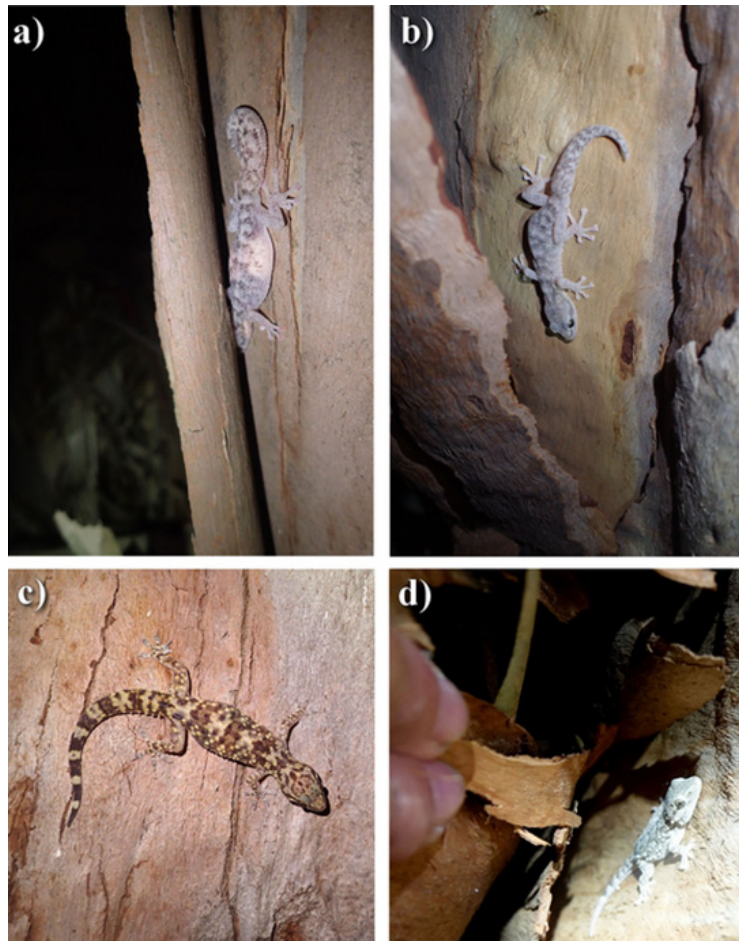


FIGURE 2. (a) A gravid European Leaf-toed Gecko (*Euleptes europaea*) female (an egg is visible on the gecko’s left side) takes refuge under the bark of a eucalyptus (*Eucalyptus* sp.) tree in stand 2. (b) An adult *E. europaea* male in a *Eucalyptus* sp. tree in stand 1 (the urbanized area). (c) An adult Mediterranean House Gecko (*Hemidactylus turcicus*) moving on the surface of a *Eucalyptus* sp. tree (stand 1). (d) A subadult Moorish Gecko (*Tarentola mauritanica*) under the bark of a *Eucalyptus* sp. tree.

We made 78 observations of geckos on the 68 trees surveyed: 49 *E. europaea*, 23 *H. turcicus*, and six *T. mauritanica*. We observed *E. europaea* between 10 and 28 times in the three surveys (Table 1, Fig. 2). We observed *H. turcicus* between six and 11 times during surveys (Table 1, Fig. 2), and *T. mauritanica* between zero and five times (Table 1; Fig. 2). We found geckos in 23 of the 68 trees surveyed. In stand 1 (urbanized area), we detected *E. europaea*

on 14 trees, *H. turcicus* on 15, and *T. mauritanica* on five. Of the 38 trees in stand 2 (the more natural area), we only found *E. europaea*, which we found on half (19) of the trees. The number of trees occupied by only one species varied from one to 32, by two species from one to six, and all three species together occupied only one tree (Table 2).

For *E. europaea*, four models were most supported ($\Delta AICc < 2$), with an Akaike weight of 0.27 for

TABLE 1. Number of observations of individuals of European Leaf-toed Gecko (*Euleptes europaea*), Mediterranean House Gecko (*Hemidactylus turcicus*), and Moorish Gecko (*Tarentola mauritanica*) during the field surveys in urbanized (stand 1) and semi-natural sites (stand 2) on Levant Island, France.

Species	Survey 1		Survey 2		Survey 3		Total observations
	Stand 1	Stand 2	Stand 1	Stand 2	Stand 1	Stand 2	
<i>E. europaea</i>	2	8	11	17	8	3	49
<i>H. turcicus</i>	6	0	11	0	6	0	23
<i>T. mauritanica</i>	0	0	5	0	1	0	6

TABLE 2. Number (n) of eucalyptus trees (*Eucalyptus* sp.) occupied by one, two, or three European Leaf-toed Geckos (*Euleptes europaea*), Mediterranean House Geckos (*Hemidactylus turcicus*), and Moorish Geckos (*Tarentola mauritanica*) in the two forest stands on Levant Island, France. The abbreviation E.e refers to *E. europaea*, H.t refers to *H. turcicus*, and T.m refers to *T. mauritanica*.

One Species		Two Species		Three Species	
Species	n	Species	n	Species	n
<i>E. europaea</i>	32	<i>E.e + H.t</i>	6	<i>E.e + H.t + T.m</i>	1
<i>H. turcicus</i>	6	<i>H.t + T.m</i>	2		
<i>T. mauritanica</i>	1	<i>E.e + T.m</i>	1		

the first, and 0.19, 0.18 and 0.11 for the following three, respectively (Appendix Table 1). These models considered a strong influence of the state or circumference of the tree and/or the spatial autocorrelation on occupancy probability and the influence of the survey session on detection probability. The goodness-of-fit of these models was high (respectively, $P = 0.70$, $\hat{c} = 0.49$; $P = 0.67$, $\hat{c} = 0.49$; $P = 0.69$, $\hat{c} = 0.53$; and $P = 0.75$, $\hat{c} = 0.5$). Although spatial autocorrelation was close to having an effect, no variable we tested had a significant effect on *E. europaea* occupancy (Table 3). We estimated naïve occupancy at 0.57 (95% Confidence Interval [CI] = 0.40–0.72), or 0.40 (CI = 0.22–0.62) when trees within a 5 m radius had no *E. europaea* presence, and 0.69 (CI = 0.46–0.86) when *E. europaea* was detected in trees nearby. Detection probability depended on survey session ($p(t)$ versus $p(\cdot)$) $\Delta AICc = -19.97$ in Appendix Table 1) and was estimated at 0.27 (CI = 0.14–0.44) for the first survey, 0.74 (CI = 0.52–0.89) for the second survey, and 0.29 (CI = 0.16–0.46) for the third survey (average of 0.40; CI = 0.23–0.60).

For *H. turcicus*, one model was most supported ($\Delta AICc < 2$) with an Akaike weight of 0.53 (Appendix Table 2). This model considered an influence of circumference on occupancy probability, but the effect was not significant (model-averaged estimates = 13.79, standard error [SE] = 12.21, 95% unconditional confidence interval = -10.14, 37.72). The goodness-of-fit of this model was good (respectively $P = 0.45$, $\hat{c} = 0.96$). We estimated naïve occupancy probability at 0.64 (CI = 0.34–0.85). We estimated detection probability in urbanized area at 0.64 (CI = 0.34–0.85).

Five models were considered equivalent ($\Delta AICc < 2$) for *T. mauritanica* with a cumulative Akaike weight of 0.80 (0.28 for the first, and 0.17, 0.12, 0.11 and 0.11 for the following four, respectively; Appendix

TABLE 3. Model-averaged parameter estimates and standard error (SE) for European Leaf-toed Gecko (*Euleptes europaea*) occupancy probability (Ψ) on Levant Island, France. Because 95% unconditional confidence intervals (UCI) include 0, none of the parameters tested had a significant effect on occupancy.

Parameter	Estimate	SE	Lower 95% UCI	Upper 95% UCI
Tree state	-1.7508	1.2052	-4.1129	0.6113
Tree circumference	0.5667	0.38299	-0.1836	1.3171
Spatial autocorrelation	1.2604	0.6502	-0.0140	2.5347

Table 3). These models had a fair goodness-of-fit ($P = 0.03$, $\hat{c} = 2.12$; $P = 0.00$, $\hat{c} = 3.32$; $P = 0.10$, $\hat{c} = 1.97$; $P = 0.49$, $\hat{c} = 0.1$ and $P = 0.27$, $\hat{c} = 1.51$). Variables (autocorrelation, tree circumferences or state) had no influence on occupancy probability (model-averaged estimates = 2.17, SE = 7.37, 95% unconditional confidence interval = -12.28, 16.61; model-averaged estimates = 17.81, SE = 45.27, 95% unconditional confidence interval = -70.91, 106.53; model-averaged estimates = 8.42, SE = 74.47, 95% unconditional confidence interval = -154.37, 137.53). The influence of survey session was marginal on detection probability ($p(t)$ versus $p(\cdot)$) $\Delta AICc = -5.55$; Appendix Table 3). We estimated naïve occupancy in urbanized area at 0.38 (CI = 0.05–0.88) and naïve detection probability at 0.17 (CI = 0.03–0.62). Detection probabilities could not be estimated in $p(t)$ models (CI too large) because of lack of data.

DISCUSSION

Our study quantifies for the first time the occupancy probability of *E. europaea* on trees in a forest patch of *Eucalyptus* sp., supporting the idea that this species can be much more arboreal than previously thought. For this species, the effects of tree circumference, tree condition, and context were not significant, indicating that these parameters do not influence its tree occupancy. On the other hand, spatial autocorrelation suggests that the occurrence of conspecifics on nearby trees increases the occupancy of the tree. Indeed, in Australian and African arboreal geckos (e.g., *Christinus marmoratus*, Tree Dtella, *Gehyra versicolor*, and Kenya Dwarf Gecko, *Lygodactylus keniensis*), several factors have been shown to influence tree occupancy, such as the presence of potential predators (Moore et al. 2022), tree size, bark thickness, ground surface area of the forest habitat (Mickael et al. 2018), presence or absence of sap on the trunk (Edwards et al. 2021), and

proximity of trees to an area rich in food resources (Pringle et al. 2010). Considering only the urbanized area, *H. turcicus* occupied most of the trees, most of the time co-occurring with *E. europaea* or alone, and rarely with the non-native *T. mauritanica*. For all three gecko species, these occupancy rates obtained in trees are very likely to be underestimated, as the surveys were only conducted on one type of tree (*Eucalyptus* sp.) and on the lower part of the trees accessible at human height. Other species of Mediterranean trees and shrubs have been reported in the literature as potential habitats for geckos (e.g., *Quercus ilex*, *Pinus halepensis*, *Erica* sp., Common Olive, *Olea europaea*; Canós-Burguete et al. 2023; Salvi et al. 2023), so it would be of interest to survey additional plant species in the future.

Detection probability was a function of the survey session only for *E. europaea*. Contrary to others (Nichols et al. 2000; Costa et al. 2020), we found that the presence of several observers did not greatly increase the detection probability, as the best detection was achieved by two observers, well above those obtained by one (survey one) or three observers (survey three). Average detection probability was much lower for *T. mauritanica*, estimated at 0.17 (from 0.03 to 0.62), potentially due to a lower population density because its presence on the military part of the island is recent (Deso et al. 2020). This lower detection may also be because this shaded forest habitat is less favorable to *T. mauritanica*, which prefers to occupy more open habitats well exposed to sunlight (Salvador 2016). As the number or experience of observers was not higher in survey session two, it seems safe to presume that the differences were due to fluctuations in gecko activity probably influenced by local abiotic conditions. In any case, these findings underscore the importance of conducting multiple surveys when studying reptiles to consider the detection probability of these frequently elusive and uncommon species (Mazerolle et al. 2007). Otherwise, there is a possibility of underestimating their presence and arriving at erroneous conclusions regarding their ecology.

Although our results found that three gecko species used trees in the study site, the exclusive presence of *E. europaea* in stand 2 is revealing. This could indicate that the morphology of this species is most adapted to environments with dense vegetation. Unlike *H. turcicus* and *T. mauritanica*, *E. europaea* has a prehensile tail bearing adhesive pads with sensory capabilities (Griffing et al. 2021) found in many species of arboreal geckos (Bauer 1998; Bauer and Menegon 2006). From an evolutionary point of view,

a tail can act as a fifth limb, facilitating both balance when resting and slow climbing within densely vegetated habitats on the ground and in the upper forest strata (Jusufović et al. 2008). The high vegetation cover observed in stand 2 likely represented a barrier for less well-adapted species. Like other members of the Sphaerodactylidae family (e.g., Natal Pigmy Gecko, *Coleodactylus natalensis*; De Sousa and Freire 2011), *E. europaea* may be a more shade-tolerant species and a passive thermoregulator that is better adapted to the forest environment than *T. mauritanica* or *H. turcicus*.

Even though eucalyptus trees are not native, their bark peels off in long ribbons that provides shelter, egg laying sites, and prey for geckos. Eucalyptus stands characterized by dense ground vegetation could thus be used as refuges by *E. europaea*, allowing the gecko to mitigate the effects of potential competitive interactions with co-occurring species, in particular *T. mauritanica*, which was recently introduced. The latter is a massive gecko known for its strong territoriality and frequent agonistic behavior (Lisičić et al. 2012; Salvador 2016), and it is suspected of having caused the decline of *E. europaea* in a mainland locality (Renet et al. 2024). The arrival of *T. mauritanica* on Levant Island is likely to lead to behavioral responses in the *E. europaea* population: for example, asynchronous activity rates (Luiselli and Capizzi 1999) or the emergence of avoidance strategies such as retreating into specialized habitats (Delaugerre et al. 2019). Lisičić et al. (2012) reported that populations of *T. mauritanica* in Croatia led to spatial segregation, pushing *H. turcicus* into more vegetated habitats. This could certainly affect the native geckos and will have to be evaluated in the future. In a mainland site in southern Tuscany (Italy), Radi and Zuffi (2022) found that the effective spatial segregation between *T. mauritanica*, *H. turcicus*, and *E. europaea* suggested a different rhythm of activity of *E. europaea* compared to the other two. The biotic relationships between these gecko species remain poorly understood and deserve to be studied by setting up a protocol allowing the use of co-occurrence models to assess any competition between these species, particularly in areas newly colonized by *T. mauritanica*.

Future studies are needed to assess in a standardized way gecko occupancy in other tree species such as *Pinus halepensis*, *Quercus ilex*, *Q. suber*, and Tree Heather (*Erica arborea*), which are Mediterranean species widely distributed on Levant Island. It is also imperative to better understand the use of vegetation

by *E. europaea* and how certain forest structures may affect colonization by other gecko species. It will also be essential to compare the occupancy rates of geckos (and individual densities) between rocky habitats and forested habitats. Studying the interactions between these two habitats will lead to a better understanding of habitat use for each species. These insights will certainly provide keys for the conservation of *E. europaea*, which is threatened with extinction in the southeast of France (Marchand et al. 2017).

In conclusion, our study clearly shows the arboreal behavior of *E. europaea*, which corroborates historical observations of early naturalists. Consequently, we advocate a reconsideration of *E. europaea* ecology that broadens its habitat to include vegetated areas and woodland. It appears evident that the distribution of *E. europaea* is biased due to surveys primarily conducted in rocky habitats, highlighting the necessity to broaden our research scope for this species. This argument is reinforced by the recent chance discovery of *E. europaea* in an Aleppo Pine Forest in the Naples area of Italy, about 330 km from the nearest previous continental record of its sighting (Di Nicola et al. 2022).

Acknowledgements.—We would like to warmly thank the staff of the testing site of DGA (the French MoD Procurement Agency), Lucile Objois, Céline Monserat, Patrice Ortola, Charly Gicqueau, Laura Vetter, and Sandrine Perroni, who made this study possible and facilitated the logistics on the study site. We also thank Aloys Crouzet, Stéphanie Cappellano, Paul Simar Bayet, and Tony Genova who offered support and helped us in the field, Aaron Bauer (Villanova University, Pennsylvania, USA) for his useful comments, Cindy Monnet for bibliographic research, and Elise Bradbury for her work in proofreading the English.

LITERATURE CITED

- Bauer, A.M. 1998. Morphology of the adhesive tail tips of carphodactylid geckos (Reptilia: Diplodactylidae). *Journal of Morphology* 235:41–58.
- Bauer, A.M., and M. Menegon. 2006. A new species of prehensile-tailed gecko, *Urocotyledon* (Squamata: Gekkonidae), from the Udzungwa Mountains, Tanzania. *African Journal of Herpetology* 55:13–22.
- Berg, P., and R. Berg. 2010. Herpetologische Eindrücke von der Mittelmeerinsel Ile du Levant, Südfrankreich. *Elaphe* 18:54–61.
- Boulenger, G.A. 1885. Catalogue of the Lizards in the British Museum (Natural History) Geckonidae, Eublepharidae, Uroplatidae, Pygopodidae, Agamidae. Volume 1. Wheldon and Wesley, London, UK.
- Bruno, S. 1976. Note riassuntive sull'Erpetofauna dell'Isola di Montecristo (Arcipelago Toscano, Mare Tirreno). *Biogeographia - Journal of Integrative Biogeography* 5:753–838.
- Burgman, M. 2005. *Risks and Decisions for Conservation and Environmental Management*. Cambridge University Press, Cambridge, UK.
- Burnham, K.P., and D.R. Anderson. 2002. *Model Selection and Multimodel Inference: A Practical Information-theoretic Approach*. Springer, New York, New York, USA.
- Canós-Burguete, M., M. Torrijo-Salesa, F.S. Tortosa, and J. Guerrero-Casado. 2023. Lack of refuge as a bottleneck for reptiles in intensive woody crops. *Amphibia-Reptilia* 44:213–225.
- Cheylan, M. 1983. Statut actuel des Reptiles et Amphibiens de l'archipel des Iles d'Hyères (Var, Sud-est de la France). *Travaux Scientifiques du Parc national de Port Cros* 9:35–51.
- Costa, A., A. Romano, and S. Salvidio. 2020. Reliability of multinomial N-mixture models for estimating abundance of small terrestrial vertebrates. *Biodiversity and Conservation* 29:2951–2965.
- Cox, N.A., and H.J. Temple. 2009. European Red List of Reptiles. Office for Official Publications of the European Communities, Luxembourg.
- Davis, C. 2006. The importance of dead Jarrah (*Eucalyptus marginata*) stags as microhabitat for arboreal lizards (*Cryptoblepharus plagiocephalus* and *Christinus marmoratus*) in rehabilitated bauxite mine-pits and native Jarrah Forest of south-west Western Australia. Honours Thesis, Murdoch University, Murdoch, Australia, 122 p.
- Delaugerre, M. 1980. Sur l'histoire naturelle de *Phyllodactylus europaeus*, Port-Cros; étude d'une population naturelle. *Travaux Scientifiques du Parc national de Port-Cros* 6:147–175.
- Delaugerre, M. 2004. *Phyllodactylus europaeus* Gené, 1839. Pp. 212–213 *In Atlas of Amphibians and Reptiles in Europe*. Gasc, J.P., A. Cabela, J. Crnobrja-Isailovic, D. Dolmen, K. Grossenbacher, P. Haffner, J. Lescure, H. Martens, J.P. Martinez Rica, H. Maurin, M.E. Oliveira, et al. (Eds.). *Societas Europaea Herpetologica and Muséum*

- National d’Histoire Naturelle, (Institut d’Écologie et de Gestion de la Biodiversité /Service du Patrimoine Naturel), Paris, France.
- Delaugerre, M., and M. Cheylan. 1992. Atlas de Répartition des Batraciens et Reptiles de Corse. Ajaccio Parc Naturel Régional de Corse et Ecole Pratique des Hautes Études, Montpellier, France.
- Delaugerre, M.J., R. Sacchi, M. Biaggini, P.L. Cascio, and R. Ouni. 2019. Coping with aliens: how a native gecko manages to persist on Mediterranean islands despite the Black Rat? *Acta Herpetologica* 14:89–100.
- De Lima, R.F., J.P. Bird, and J. Barlow. 2011. Research effort allocation and the conservation of restricted-range island bird species. *Biological Conservation* 144:627–632.
- Deso, G., M.-C. Gomez, P. Priol, F. Capoulade, and R. Duguet. 2018. Premières mentions de la Tarente de Maurétanie *Tarentola mauritanica* (Linnaeus, 1758) et de la Grenouille rieuse *Pelophylax ridibundus* (Pallas, 1771) sur l’île du Levant (îles d’Hyères, Var). *Scientific Reports of Port-Cros National Park* 32:237–240.
- Deso, G., J. Renet, M.-C. Gomez, P. Priol, F. Capoulade, D. Geoffroy, R. Duguet, and C. Rato. 2020. Documenting the introduction of the Moorish Gecko *Tarentola mauritanica* (Linnaeus, 1758) (Squamata: Phyllodactylidae) on the Levant and Port-Cros Islands (Hyères Archipelago, Var department, France). *Herpetology Notes* 13:809–812.
- DeSousa, P.A., and E.M. Freire. 2011. Thermalecology and thermoregulatory behavior of *Coleodactylus natalensis* (Squamata: Sphaerodactylidae), in a fragment of the Atlantic Forest of northeastern, Brazil. *Zoologia (Curitiba)* 28:693–700.
- Di Nicola, M.R., M. Colombo, and F. Russo. 2022. First record of European Leaf-toed Gecko *Euleptes europaea* (Gené, 1839) (Squamata, Sphaerodactylidae) in Campania (Italy). *Rivista del Museo Civico di Scienze Naturali “Enrico Caffi”* 35:79–82.
- Edwards, C., W. Cornwell, and M. Letnic. 2021. Frequent consumption of sap suggests that omnivory is widespread among Australian geckos. *Science of Nature* 108:1–6. <https://doi.org/10.1007/s00114-021-01720-6>.
- Fattorini, S. 2010. Influence of recent geography and paleogeography on the structure of reptile communities in a land-bridge archipelago. *Journal of Herpetology* 44:242–252.
- Fiske, I., J.R.B. Chandler, D. Miller, A.J. Royle, and M. Kery. 2012. Models for data from unmarked animals. R Package Unmarked. <https://rbchan.github.io/unmarked/>.
- Fitzinger, L.J. 1843. *Systema Reptilium*. Volume 1. Braumüller and Seidel, Vienna, Austria.
- Gené, J. 1839. Synopsis Reptilium Sardiniae Indigenorum. *Memorie della Reale Accademia delle Scienze di Torino* 2:257–286.
- Griffing, A.H., T.J. Sanger, L. Epperlein, A.M. Bauer, A. Cobos, T.E. Higham, E. Naylor, and T. Gamble. 2021. And thereby hangs a tail: morphology, developmental patterns and biomechanics of the adhesive tail of Crested Geckos (*Correlophus ciliatus*). *Proceedings of the Royal Society B* 288:1–9. <https://doi.org/10.1098/rspb.2021.0650>.
- Grismer, L.L., P.L. Wood, N.A. Poyarkov, M.D. Le, F. Kraus, I. Agarwal, P.M. Oliver, S.N. Nguyen, T.Q. Nguyen, S. Karunarathna, et al. 2021. Phylogenetic partitioning of the third-largest vertebrate genus in the world, *Cyrtodactylus* Gray, 1827 (Reptilia; Squamata; Gekkonidae) and its relevance to taxonomy and conservation. *Vertebrate Zoology* 71:101–154.
- Jahandiez, E. 1929. Les îles d’Hyères: Monographie des îles d’Or, Presqu’île de Giens, Porquerolles, Port-Cros, île du Levant: Histoire, Description, Géologie, Flore, Faune. Etablissements Rébufa et Rouard, Libraires-éditeurs, France.
- Jusufi, A., D.I. Goldman, S. Revzen, and R.J. Full. 2008. Active tails enhance arboreal acrobatics in geckos. *Proceedings of the National Academy of Sciences* 105:4215–4219.
- Knoepffler, L.P. 1960. Additifs à la faune herpétologique des îles d’Hyères. *Vie et Milieu* 11:331.
- Lantz, L.A. 1931. Note sur la faune herpétologique des îles d’Hyères. *Bulletin de la Société Zoologique de France* 65:420–422.
- Lataste, F. 1877. Sur le *Phyllodactylus europaeus*, Géné, trouvé en France et sur le *Ph. Doriae*, n. sp., de L’île de Tinetto. *Bulletin de la Société Zoologique de France* 2:468–469.
- Linkem, C.W., J.A. McGuire, C.J. Hayden, M.I. Setiadi, D.P. Bickford, and R.M. Brown. 2008. A new species of bent-toe gecko (Gekkonidae: *Cyrtodactylus*) from Sulawesi Island, Eastern Indonesia. *Herpetologica* 64:232–242.
- Lisičić, D., S. Drakulić, A. Herrel, D. Dikić, V. Benković, and Z. Tadić. 2012. Effect of competition on habitat utilization in two temperate climate gecko species. *Ecological Research*

- 27:551–560.
- Luiselli, L., and D. Capizzi. 1999. Ecological distribution of the geckos *Tarentola mauritanica* and *Hemidactylus turcicus* in the urban area of Rome in relation to age of buildings and condition of the walls. *Journal of Herpetology* 33:316–319.
- MacKenzie, D.I., L.L. Bailey, and J.D. Nichols. 2004. Investigating species co-occurrence patterns when species are detected imperfectly. *Journal of Animal Ecology* 73:546–555.
- MacKenzie, D.I., J.D. Nichols, J.E. Hines, M.G. Knutson, and A.D. Franklin. 2003. Estimating site occupancy, colonization and local extinction when a species is detected imperfectly. *Ecology* 84:2200–2207.
- MacKenzie, D.I., J.D. Nichols, J.A. Royle, K.H. Pollock, L.L. Bailey, and J.E. Hines. 2006. *Occupancy Estimation and Modeling: Inferring Patterns and Dynamics of Species Occurrence*. Elsevier, San Diego, California, USA.
- Marchand, M.A., C. Roy, J. Renet, J. Delauge, D. Meyer, and C. Hayot. 2017. Liste rouge régionale des amphibiens et reptiles de Provence-Alpes-Côte d’Azur. Conservatoire d’Espaces Naturels Provence-Alpes-Côte d’Azur, Aix-en-Provence, France. 16 p.
- Martin, M.E., M.S. Delheimer, K.M. Moriarty, D.A. Early, K.A. Hamm, J.N. Pauli, T.L. McDonald, and P.N. Manley. 2022. Conservation of rare and cryptic species: challenges of uncertainty and opportunities for progress. *Conservation Science and Practice* 4:1–11. <https://doi.org/10.1111/csp2.12809>.
- Mazerolle, M.J. 2013. AICcmodavg: model selection and multimodel inference based on (Q)AIC(c). R package version 1.29. <http://CRAN.R-project.org/package=AICcmodavg>.
- Mazerolle, M.J., L.L. Bailey, W.L. Kendall, J.A. Royle, S.J. Converse, and J.D. Nichols. 2007. Making great leaps forward: accounting for detectability in herpetological field studies. *Journal of Herpetology* 41:672–689.
- Médail, F., G. Cheylan, and P. Ponel. 2013. Dynamique des paysages et de la biodiversité terrestres du Parc national de Port-Cros (Var, France): enseignements de cinquante années de gestion conservatoire. *Scientific Reports of Port-Cros National Park* 27:171–262.
- Michael, D.R., D. Florance, M. Crane, W. Blanchard, and D.B. Lindenmayer. 2018. Barking up the right tree: comparative use of arboreal and terrestrial artificial refuges to survey reptiles in temperate eucalypt woodlands. *Wildlife Research* 45:185–192.
- Moore, E., D.G. Nimmo, S. Wassens, and D.R. Michael. 2022. Use of artificial bark covers to investigate the distribution and abundance of arboreal lizards in a floodplain environment. *Australian Journal of Zoology* 69:125–135.
- Nichols, J.D., J.E. Hines, J.R. Sauer, F. Fallon, J. Fallon, and P.J. Heglund. 2000. A double-observer approach for estimating detection probability and abundance from avian point counts. *Auk* 117:393–408.
- Oneto, F., D. Ottonello, and S. Salvidio. 2008. Primi dati sulla biometria di *Euleptes euopaea* (Gené, 1839) dell’isola del Tino (La Spezia, Liguria). *Doriana* 8:1–8.
- Pringle, R.M., D.F. Doak, A.K. Brody, R. Jocqué, and T.M. Palmer. 2010. Spatial pattern enhances ecosystem functioning in an African savanna. *PLoS Biology* 8(5): e1000377 <https://doi.org/10.1371/journal.pbio.1000377>.
- Quézel, P., and F. Médail. 2003. *Ecologie et Biogéographie des Forêts du Bassin Méditerranéen*. Elsevier, Collection “Environnement”, Paris, France.
- Radi, G., and M. Zuffi. 2022. One site, three species, threestories: syntopy of geckoes *Euleptes euopaea* (Gené, 1839), *Hemidactylus turcicus* (Linnaeus, 1758), *Tarentola mauritanica* (Linnaeus, 1758) in a coastal area of southern Tuscany (central Italy). *Acta Herpetologica* 17:187–195.
- R Core Team R. 2022. *A language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Australia. <http://www.R-project.org>.
- Renet, J., T. Dokhelar, and N. Dubos. 2024. One gecko’s pain is another gecko’s gain: is the Moorish Gecko *Tarentola mauritanica* becoming invasive in France? *Herpetological Journal* 34:84–91.
- Salvador, A. 2016. Salamanquesa común - *Tarentola mauritanica*. Pp. 1–17 *In Enciclopedia Virtual de los Vertebrados Españoles*. Salvador, A., A. Marco (Eds.). Museo Nacional de Ciencias Naturales, Madrid. España.
- Salvi, D., E. Berrilli, G. Bruni, M. Garzia, V. Gomes, G. Radi, and M. Delaugerre. 2023. The secret life of a rock-dweller: arboreal acrobatics observed in the European Leaf-toed Gecko *Euleptes euopaea*. *Herpetozoa* 36:135–141.
- Salvidio, S., B. Lanza, and M. Delaugerre. 2010. *Euleptes euopaea* (Gené, 1839). Pp. 258–270

- In Fauna d'Italia, Reptilia*. Corti, C., M. Capula, L. Luiselli, E. Razzetti, and R. Sindaco (Eds.). Edizioni Calderini de Il Sole 24 ORE Editoria Specializzata S.r.l., Bologna, Italia.
- Soulé, M.E., and D. Simberloff. 1986. What do genetics and ecology tell us about the design of nature reserves? *Biological Conservation* 35:19–40.
- Tanazacq, F. 1966. Sur le rapport des gneiss de Bormes et des micaschistes du cap Negre à l'île du Levant (Var). *Bulletin de la Société Géologique de France* 7:5–9.
- Vanderduys, E. 2016. A new species of gecko (Squamata: Diplodactylidae: *Strophurus*) from north Queensland, Australia. *Zootaxa* 4117:341–358.
- Van Eijsden, E.H.T. 1983. Der haftfähige Greifschwanz des Europäischen Blattfingergekkos *Phyllodactylus europaeus* Gené. *Salamandra* 19:1–10.
- Vanni, S., and B. Lanza. 1978. Note di erpetologia della Toscana: Salamandrina, *Rana catesbeiana*, *Rana temporaria*, *Phyllodactylus*, *Coluber*, *Natrix natrix*, *Vipera*. *Natura Milano* 19:42–58.
- Vásquez, C., T.S. Marques, E.F. de Abreu, R. Cioci, C.I. Piña, and L.M. Verdade. 2021. Diversity of small mammals on the early second commercial cycle of Eucalyptus plantations in southeast Brazil. *Forest Ecology and Management* 489(2):119052 <https://doi.org/10.1016/j.foreco.2021.119052>.
- Verdade, L.M., R.A. Moral, A. Calaboni, M.V.S.G. do Amaral, P.S. Martin, L.S. Amorim, C. Gheler-Costa, and C.I. Piña. 2020. Temporal dynamics of small mammals in eucalyptus plantations in southeast Brazil. *Global Ecology and Conservation* 24(1):e01217 <https://doi.org/10.1016/j.gecco.2020.e01217>



GRÉGORY DESO is a Herpetologist who has been active in environmental organizations since 1999 on the Mascarene Islands, where his work has focused on the distribution and ecology of various native and introduced species and their interactions linked to human activity. Grégory now resides in mainland France (Provence Alps Côte d'Azur region) where he founded the non-government organization Association Herpétologique de Provence Alpes Méditerranée, which works toward the protection of amphibians and reptiles. Today, his work concerns all aspects of the continental and island Mediterranean herpetofauna. (Photographed by Valentin Lafond).



PAULINE PRIOL works as Scientific Consultant in Conservation Biology after several years managing conservation programs for endangered species (European Pond Turtle, *Emys orbicularis*, and Western Spadefoot, *Pelobates cultripes*) and two graduate degrees (France and Canada). She is now working between field practitioners, stakeholders, and statisticians that develop methods for population dynamic modeling, to building and evaluating monitoring protocols, estimating demographic parameters, evaluating impacts of perturbations, and evaluating or defining management actions. (Photographed by Julien Renet).



THIERRY REYNIER is a university-trained Ecologist who has been working for over 20 y in environmental consulting. He is involved in the conservation of terrestrial protected species. Thierry specializes in the acoustic analysis of chiropterans. (Photographed by Najate Bouchich).



JULIEN RENET is a French Wildlife Biologist who works as a scientific consultant for Fauna Studium. For over 10 y, Julien has designed, coordinated, and implemented conservation programs for wildlife. His work concerns the general framework of conservation biology, more specifically spatial ecology, population dynamics, biogeography, and assessments of individual marking methods. (Photographed by Cindy Monnet).

APPENDICES

APPENDIX TABLE 1. Sixteen occupancy models based on the second-order Akaike Information Criterion (AICc), showing the distance between each model and the top-ranked model (Δ AICc), Akaike weights (wi), and the number of estimated parameters (K) for European Leaf-toed Geckos (*Euleptes europaea*) in urbanized (stand 1) and semi-natural sites (stand 2) on Levant Island, France, during 2022. The symbol Ψ is the occupancy probability and p is the detection probability.

No.	Models	K	AICc	Δ AICc	Wi
1	$\Psi(\text{circumf}+\text{autocor}) p(t)$	6	204.20	0.00	0.27
2	$\Psi(\text{autocor}) p(t)$	5	204.84	0.64	0.19
3	$\Psi(\text{state}+\text{autocor}) p(t)$	6	204.96	0.76	0.18
4	$\Psi(\text{state}) p(t)$	5	205.97	1.77	0.11
5	$\Psi(.) p(t)$	4	206.55	2.36	0.08
6	$\Psi(\text{Circonf}) p(t)$	5	206.87	2.67	0.07
7	$\Psi(\text{area}+\text{autocor}) p(t)$	6	207.16	2.96	0.06
8	$\Psi(\text{area}) p(t)$	5	208.81	4.61	0.03
9	$\Psi(\text{state}+\text{autocor}) p(.)$	4	220.94	16.74	0.00
10	$\Psi(\text{circumf}+\text{autocor}) p(.)$	4	221.17	16.97	0.00
11	$\Psi(.) p(.)$	3	221.19	16.99	0.00
12	$\Psi(\text{state}) p(.)$	3	222.31	18.12	0.00
13	$\Psi(.) p(.)$	2	223.04	18.84	0.00
14	$\Psi(\text{circumf}) p(.)$	3	223.32	19.12	0.00
15	$\Psi(\text{area}+\text{autocor}) p(.)$	4	223.45	19.25	0.00
16	$\Psi(\text{area}) p(.)$	3	225.16	20.96	0.00

APPENDIX TABLE 2. Twelve occupancy models based on the second-order Akaike Information Criterion (AICc), showing the distance between each model and the top-ranked model (Δ AICc), Akaike weights (wi), and the number of estimated parameters (K) for Mediterranean House Geckos (*Hemidactylus turcicus*) in urbanized (stand 1) and semi-natural sites (stand 2) on Levant Island, France, during 2022. The symbol Ψ is the occupancy probability and p is the detection probability.

No.	Models	K	AICc	Δ AICc	Wi
1	$\Psi(\text{circumf}) p(.)$	3	98.76	0.00	0.53
2	$\Psi(\text{Circonf}) p(t)$	5	101.15	2.39	0.16
3	$\Psi(\text{circumf}+\text{autocor}) p(.)$	4	101.44	2.68	0.14
4	$\Psi(.) p(.)$	2	103.36	4.60	0.05
5	$\Psi(\text{circumf}+\text{autocor}) p(t)$	6	104.30	5.54	0.03
6	$\Psi(.) p(t)$	4	104.84	6.08	0.03
7	$\Psi(\text{state}) p(.)$	3	105.60	6.83	0.02
8	$\Psi(\text{autocor}) p(.)$	3	105.69	6.93	0.02
9	$\Psi(\text{state}) p(t)$	5	107.50	8.74	0.01
10	$\Psi(\text{autocor}) p(t)$	5	107.60	8.84	0.01
11	$\Psi(\text{state}+\text{autocor}) p(.)$	4	108.01	9.25	0.01
12	$\Psi(\text{state}+\text{autocor}) p(t)$	6	110.41	11.65	0.00

APPENDIX TABLE 3. Twelve occupancy models based on the second-order Akaike Information Criterion (AICc), showing the distance between each model and the top-ranked model (ΔAICc), Akaike weights (w_i), and the number of estimated parameters (K) for Moorish Geckos (*Tarentola mauritanica*) in urbanized (stand 1) and semi-natural sites (stand 2) on Levant Island, France, during 2022. The symbol Ψ is the occupancy probability and p is the detection probability.

No.	Models	K	AICc	ΔAICc	W_i
1	$\Psi(\text{autocor}) p(t)$	5	40.66	0.00	0.28
2	$\Psi(.) p(t)$	4	41.64	0.99	0.17
3	$\Psi(\text{circumf}) p(.)$	3	42.31	1.65	0.12
4	$\Psi(\text{circumf}) p(t)$	5	42.52	1.86	0.11
5	$\Psi(\text{state}) p(t)$	5	42.53	1.87	0.11
6	$\Psi(\text{state+autocor}) p(t)$	6	42.78	2.12	0.10
7	$\Psi(\text{circumf+autocor}) p(t)$	6	43.73	3.07	0.06
8	$\Psi(\text{autocor}) p(.)$	3	46.21	5.55	0.02
9	$\Psi(.) p(.)$	2	47.61	6.95	0.01
10	$\Psi(\text{state+autocor}) p(.)$	4	47.85	7.20	0.01
11	$\Psi(\text{state}) p(.)$	3	48.08	7.42	0.01
12	$\Psi(\text{circumf+autocor}) p(.)$	4	48.53	7.87	0.01