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# One site, three species, three stories: syntopy of geckoes *Euleptes europaea* (Gené, 1839), *Hemidactylus turcicus* (Linnaeus, 1758), *Tarentola mauritanica* (Linnaeus, 1758) in a coastal area of southern Tuscany (central Italy)

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**Abstract.** Ecological aspects of syntopic geckoes were rarely addressed in the Mediterranean basin. We reported basic information on habitat use, and activity patterns of three species found in syntopy in Cala Violina site (divided in three subareas), a highly touristic beach located in southern Tuscany, central Italy, during 2009-2010. The most abundant species at first capture is *Hemidactylus turcicus* (94 individuals), while *Tarentola mauritanica* and *Euleptes europaea* are less represented (28 animals in both cases). Total captures and recaptures were 175. Sex ratio did not differ from 1:1 in all the species, nor sexes of adults did differ in size. Ambient temperatures did not differ in *T. mauritanica* and *E. europaea*, while were different in *H. turcicus*. Despite the humidity of capture sites did not vary among species, we recorded the highest number of *E. europaea* at 95% and *H. turcicus* at 62% humidity. Wind influenced negatively *T. mauritanica* and *H. turcicus* presence, not on *E. europaea*. Higher observation rate took place between 21:00 and 22:00. After 23:00, only *Euleptes* was active. Height from the ground was different only in *H. turcicus*. General Linear Models showed that interaction substrate-height at capture was important for *Euleptes*, not for the other two species. Along the area, *E. europaea* was more concentrated in the northern patch, while *T. mauritanica* and *H. turcicus* distributed more homogeneously. We suggest limitation of human presence for conservation purposes.

**Keywords.** Syntopy, geckoes, *Tarentola*, *Hemidactylus*, *Euleptes*, central Italy.

## INTRODUCTION

The study of the ecology of the Italian reptile species is particularly advanced for some groups, especially for tortoises (e.g., Chelazzi and Carlà, 1986; Rugiero and Luiselli, 2006), pond turtles (e.g., Rovero and Chelazzi, 1996; Lebboroni and Chelazzi, 1998; Zuffi et al., 2004, 2007), as well as for snakes (e.g., Luiselli et al., 1996; Zuffi, 2008; Zuffi et al. 2009; Scali et al., 2011) and lizards (e.g., Perez-Mellado and Corti, 1993; Sacchi et al., 2007; Salvidio and Oneto, 2008; Bombi et al., 2009; Zuffi et al., 2011, 2012).

Most information about Italian lacertilia *sensu lato* has been provided in Atlases and Distributive Maps (Vanni and Nistri 2006; Corti et al., 2011), despite quite anecdotal and descriptive. On the contrary, complete and scrutinized data concern phylogeographic and taxonomic features (Harris et al., 1998; Oliverio et al., 1998; Gamble et al., 2008), and, partially, ecological-behavioural features (Vervust et al., 2007; Biaggini et al., 2009; Marsili et al., 2009; Sacchi et al., 2015; Scali et al., 2016). However, research considering comparative aspects in different reptile species are relatively limited (i.e., Capula, Luiselli and

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Rugiero, 1993; Capula and Luiselli, 1994; Carvalho Jr et al., 2008; Gordon et al., 2010; Maura et al., 2011; Simbula et al., 2019) and further studies are strongly needed.

There are four gecko species in Italy (Corti et al., 2011): *Tarentola mauritanica* and *Hemidactylus turcicus,* distributed in most of the Mediterranean coastal environments, and *Euleptes europaea* and *Mediodactylus kotschyi* more localised, in western Mediterranean Italy and in south-eastern Italy (Apulia), respectively. Although the distribution of *Tarentola*, *Hemidactylus* and *Euleptes* is to some extent overlapped in north-western Italy, namely in coastal Tuscany (Vanni and Nistri, 2006), the only site where the three species actually occur in sympatry and in syntopy is in Southern Tuscany, in the municipality of Scarlino, province of Grosseto (Radi, 2013). On average, available data on *Euleptes europaea* refer to a few sites only in Liguria (Tinetto, Tino, Genoa), Sardinia (Sassari, Gallura) and Tuscany (Castiglione della Pescaia and the Tuscan Archipelago) and regard morphology and population dynamics (Salvidio and Delaugerre, 2003; Salvidio and Oneto, 2008; Salvidio et al., 2011, for a review). Ecological data on *Hemidactylus turcicus* and *Tarentola mauritanica* of Italy are quite descriptive (Capula and Luiselli, 1994; Luiselli and Capizzi, 1999; Aprea et al., 2011; Zuffi et al., 2011) with the exception of a few studies on sympatric geckoes in Italy and Croatia (Lisicic et al., 2012; Simbula et al., 2019). Our research, as far as we are aware, is likely the first one aimed at comparing three Gekkota species in sympatry and syntopy, and analysing and comparing biometrical features, population structure and ecology patterns in a quite unique zoogeographic context.

## MATERIAL AND METHODS

### *Study area*

Study area is in Cala Violina, municipality of Scarlino (province of Grosseto), which is a highly frequented touristic place during summer. This area extends for 1000 × 300 m and falls within the "Monte d'Alma" 108 SIR (Sito di Interesse Regionale, Regional Interest Site; IT51A0008), and pSIC (Sito di Interesse Comunitario, EU Interest Site; Natura 2000 IT51A0008) and the A.N.P.I.L. "Costiere di Scarlino" (Area Naturale Protetta di Interesse Locale, Protected Natural Area of Local Interest) (42.856850°N, 10.774386°E) (Fig. 1). We have focused the field activity on the maximum area extension, which is about 670 m long sector; the area is characterized by a central sandy part. Proceeding towards the far ends of the promontories, that are quite high and boulder-like, the sandy part gradually changes into coarse soiled sandstone cliffs. Going down from the shore to the Mediterranean scrub it is possible to find dissolved bedrock and sandstone slopes, transitional environments in which geckoes live. Climate is Mediterranean, with average rainfall of 600-800 mm during winter, and average temperatures of 14 °C (Selvi and Stefanini, 2005). Specifically, in Follonica, the closest meteorological station to the study area, average rainfall and temperatures are 655.2 mm and 15.7 °C respectively (Barazzuoli et al., 1993).


**Fig. 1.** Satellite picture (source: Google Earth) of Follonica Gulf delimited by Piombino promontory (LI) to the North, and by Punta Ala promontory (GR) to the South. Cala Violina is pointed by a white pin.

### *Sampling and measurements*

Sampling was carried out with censuses during two annual sessions, in 2009, from 23rd July to 22nd November and in 2010, from 07th April to 30th August. We did 20 sampling days in 2009 (18 out of 20 during the night) and 22 in 2010 (20 out of 22 during the night) for 42 sampling days. Each sampling lasted five hours on average for a total of 210 hours of field night sampling. Sampling occurred from 20:00 to 02:00 solar hour to avoid touristic disturbance and to match species' activity. The area is naturally divided in three sectors T1, North, ca 220 m long T2, central, ca 70 m long, and T3 south, ca 350 m long, by two forest tracks (the first 24 m wide, the second 4 m wide) loading to the beach from the forest, for a total of 670 m transect length (Fig. 2). We have considered the three sectors as a unique survey area.

We captured geckoes by hand, or with a noose on a long stick, and placed in cotton sacks before data recording. At each capture, we registered solar time, substrate type (sandstone, loose ground, boulders, sand, vegetation), ambient temperature, humidity (thermo-

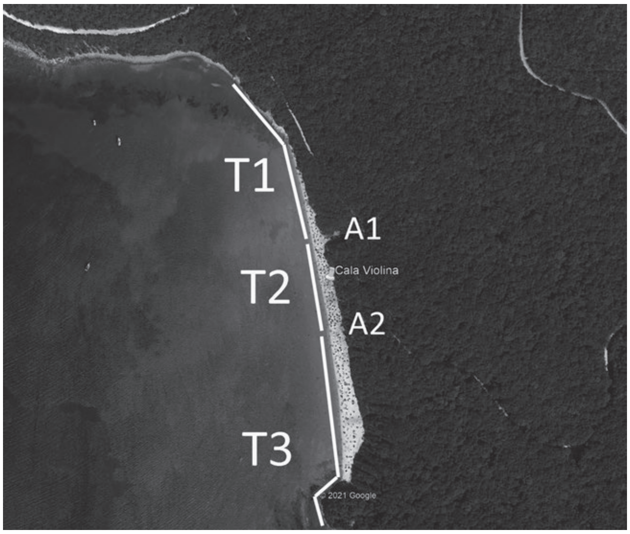


**Fig. 2.** Satellite image (Google Earth) of Cala Violina. White lines show three transects (T1, T2, T3), A1 and A2 indicate access to the beach.

hygrometer HANNA, HI9565, precision 0.1 °C, 0.1% humidity), wind (with the empirical Beaufort scale), animal position (height from the ground, distance from transect starting point). Morphological data were snout to vent length, tail length, head length, width and height, eye diameter, distance between eye and nostril, internarial distance, interorbital distance. We also determined size and sex class, as described in full by Atzori et al. (2007). We therefore considered males and females, juveniles (medium size, unsexable) and new-borns (very small size, unsexable). Geckoes were marked with acrylic water pens for short term recognition and with a cut of coded sub-digital scales (see Atzori et al., 2007) for a long-term recognition. We did not apply sub-digital marking to the new-borns of all the three species due to their markedly small size, and to the adults of the European leaf-toad gecko, due to the extremely reduced size of lamellae and very thin fingers. We assessed female reproductive status by manual palpation and, in some cases, using a direct light placed on the female vent, to detect eggs for transparency. In the whole period, we captured 175 geckoes: 110 *Hemidactylus*, 34 *Euleptes* and 31 *Tarentola*. We excluded recaptures and visual encounters from this research. We therefore analyzed 159 unique gecko records, 100 of which were *Hemidactylus* (59 in 2009, 41 in 2010), 31 were *Euleptes* (21 in 2009, 10 in 2010), and 28 *Tarentola* (14 in 2009, 14 in 2010). We defined three age classes: males, females, and juveniles. We considered juveniles and new-borns together as juvenile category. We tested sex-ratio differences within and among species using a log-linear model (with binomial distribution). We tested differences in size and biometry (all variables were normally distributed, Kolmogorov-Smirnov test, $P > 0.05$) with a General Linear Model (multivariate GLM, with species and sex as fixed factors and their interaction). We applied this analysis only to the adults.

Given all environmental variables, we used a multivariate GLM to test if species do differ in some way between years and among them. In addition, to describe ecological relationships among gecko species, we applied a Principal Component Analysis (Varimax Procedure, eigenvalue $\geq 1$, rotated matrix), to all environmental variables and two biometrical features (SVL, body mass), extracting the most correlated variables within each main component. Therefore, we were able to describe the components driving the average ecology of the three species of geckos. To analyse the spatial distribution of captured and observed geckoes, we normalized the three subsectors, creating a unique transect. We also considered the width of the two tracks used to reach the beach: 26 and 4 metres, respectively.

Temperature, humidity, wind presence and hourly distribution of captures were not normally distributed, and we therefore considered them in GLM and PCA analyses. We carried out univariate and multivariate analyses with SPSS 20.0 release.

## RESULTS

We sampled 31 *Euleptes* (17 males, eight females and six juveniles), 100 *Hemidactylus* (35 males, 36 females and 29 juveniles, and 28 *Tarentola* (nine males, seven females and 12 juveniles). Sex ratio of adults (juveniles were excluded) did not differ from 1:1 in each of the three species (Wald test = 0.785, df = 1, $P = 0.376$).

The three species are markedly different for all considered biometric features (Table 1). *Euleptes* is the smallest, *Hemidactylus* is intermediate and *Tarentola* the largest (all with P values < 0.0001, but inter-nasal $P = 0.015$). They do not show sexual difference (P values from 0.093 for head width to 0.663 for SVL) nor sex × species interaction (P values from 0.130 for head width to 0.695 for inter-orbital). All statistics are reported in Supplementary Table 1.

Ecological variables recorded at each gecko capture (Table 2) showed differences in most cases: multivariate GLM showed a marked difference between 2009 and 2010 for wind ($F_{2,131} = 5.807$, $P = 0.017$) and humidity ($F_{2,131} = 36.593$, $P < 0.0001$). Species differed in site position ($F_{2,131} = 4.011$, $P = 0.020$), height from the ground ($F_{2,131} = 11.670$, $P < 0.0001$) and hour of capture ($F_{2,131} =$

**Table 1.** Average in mm and grams ± 1 SD of selected variables for each gecko species.

| Variable | *Taxon* | Average | SD |
|---|---|---|---|
| Head length | *Euleptes* | 10.230 | 0.312 |
| | *Hemidactylus* | 13.996 | 0.173 |
| | *Tarentola* | 16.419 | 0.367 |
| Head width | *Euleptes* | 6.809 | 0.191 |
| | *Hemidactylus* | 9.251 | 0.106 |
| | *Tarentola* | 11.767 | 0.224 |
| Head height | *Euleptes* | 3.471 | 0.126 |
| | *Hemidactylus* | 5.561 | 0.070 |
| | *Tarentola* | 6.965 | 0.149 |
| Eye diameter | *Euleptes* | 2.036 | 0.059 |
| | *Hemidactylus* | 2.701 | 0.033 |
| | *Tarentola* | 3.012 | 0.069 |
| Nostril eye | *Euleptes* | 2.795 | 0.087 |
| | *Hemidactylus* | 3.695 | 0.048 |
| | *Tarentola* | 5.010 | 0.102 |
| Inter-nasal | *Euleptes* | 1.735 | 0.052 |
| | *Hemidactylus* | 1.863 | 0.029 |
| | *Tarentola* | 1.964 | 0.061 |
| Inter-orbital | *Euleptes* | 4.567 | 0.132 |
| | *Hemidactylus* | 4.702 | 0.073 |
| | *Tarentola* | 6.630 | 0.155 |
| bmass | *Euleptes* | 1.292 | 0.235 |
| | *Hemidactylus* | 3.152 | 0.130 |
| | *Tarentola* | 5.208 | 0.276 |
| SVL | *Euleptes* | 38.939 | 1.086 |
| | *Hemidactylus* | 50.534 | 0.601 |
| | *Tarentola* | 55.377 | 1.276 |

8.587, $P < 0.0001$). Year × species interaction was significant only for humidity ($F_{2,131} = 3.781$, $P < 0.025$).

PCA (sampling adequacy = 0.551; sphericity Bartlett test = 424.286, $P < 0.0001$) extracted four main components, explaining about 68% of total variance (Table 3). The rotated matrix showed the first component describing species and body size, the second describing period, site position, ground type and height from the ground, the third describing wind and humidity, the fourth describing temperature and ground type (Table 4). The distribution of the three species of geckos according to four components are shown in figures 3-5. Figure 3 shows that smaller geckoes, as *Euleptes* and smaller *Hemidactylus* and *Tarentola*, tend to be distributed to the northern part of the study area. Figure 4 shows that *Euleptes* is associated to low or no wind but with high humidity, while the other two species are more associated to a relative absence of humidity. Figure 5 shows that

**Table 2.** Variability of ecological variables recorded at gecko capture. Wind in m/sec, umidity in %, site position and Hmslm in m, Hour as in hours (solar time).

| Variable | Species | Average ± SD | Sample |
|---|---|---|---|
| Wind | *Euleptes* | 0.28 ± 0.45 | 29 |
| | *Hemidactylus* | 0.22 ± 0.45 | 77 |
| | *Tarentola* | 0.16 ± 0.37 | 25 |
| Umidity | *Euleptes* | 77.38 ± 17.70 | 29 |
| | *Hemidactylus* | 69.66 ± 18.17 | 77 |
| | *Tarentola* | 72.20 ± 20.60 | 25 |
| Site position | *Euleptes* | 157.21 ± 45.14 | 29 |
| | *Hemidactylus* | 119.65 ± 69.67 | 77 |
| | *Tarentola* | 119.24 ± 60.10 | 25 |
| Hmslm | *Euleptes* | 2.74 ± 1.15 | 29 |
| | *Hemidactylus* | 1.61 ± 1.04 | 77 |
| | *Tarentola* | 1.72 ± 1.05 | 25 |
| Hour | *Euleptes* | 17:55 ± 08:13 | 29 |
| | *Hemidactylus* | 21:22 ± 00:32 | 77 |
| | *Tarentola* | 21:14 ± 00:17 | 25 |

**Table 3.** First four principal components explaining about 68% of total variance.

| Component | Eigenvalues | | | Weights of rotated factors | | |
|---|---|---|---|---|---|---|
| | total | % variance | % cumulated | total | % variance | % cumulated |
| 1 | 2.653 | 26.533 | 26.533 | 2.405 | 24.048 | 24.048 |
| 2 | 1.687 | 16.873 | 43.407 | 1.705 | 17.053 | 41.101 |
| 3 | 1.359 | 13.592 | 56.999 | 1.377 | 13.767 | 54.868 |
| 4 | 1.105 | 11.052 | 68.051 | 1.318 | 13.183 | 68.051 |

**Table 4.** Rotated component matrix and main contribution of each variable (in **bold**) to each component.

| Variable | Component | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| species | **0.679** | 0.157 | 0.074 | -0.270 |
| month | -0.202 | **0.622** | 0.206 | -0.008 |
| wind | -0.179 | 0.365 | **-0.771** | -0.087 |
| T° | 0.124 | -0.041 | -0.032 | **0.853** |
| umidity | -0.225 | 0.264 | **0.817** | -0.187 |
| siteposition | -0.228 | **-0.717** | 0.208 | -0.099 |
| ground | -0.026 | **0.518** | -0.073 | **0.586** |
| hmslm | -,484 | **-0.548** | 0.077 | 0.078 |
| bmass | **0.898** | -0.022 | -0.049 | 0.199 |
| SVL | **0.844** | -0.076 | -0.089 | 0.276 |

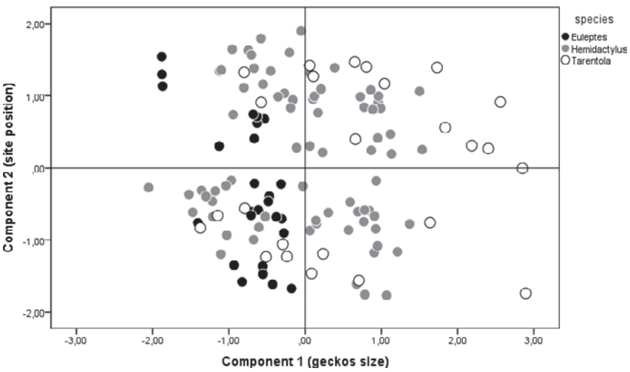


**Fig. 3.** Geckos distribution along the Component 1-Component 2 relationship.

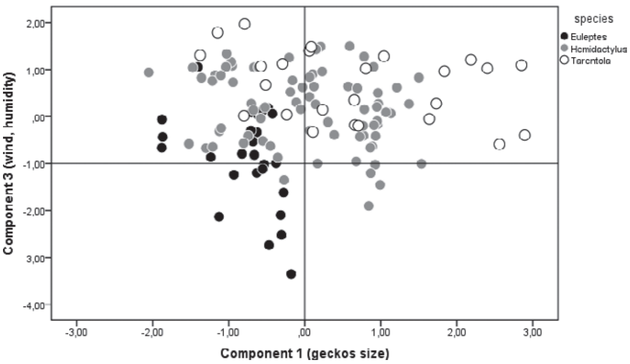


**Fig. 4.** Geckos distribution along the Component 1-Component 3 relationship.

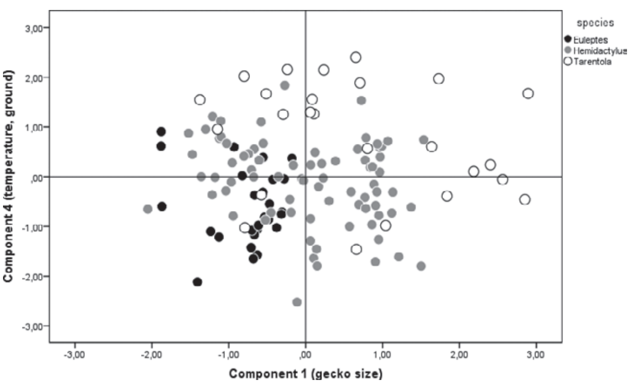


**Fig. 5.** Geckos distribution along the Component 1-Component 4 relationship.

*Euleptes* and *Hemidactylus* are active at lower temperatures and on similar substrate ground than *Tarentola*.

Multiple histograms show the occurrence of captures of the three species along the normalized transect (670 m long). Red bars indicate and delimitate the accesses to Cala Violina (Fig. 6).

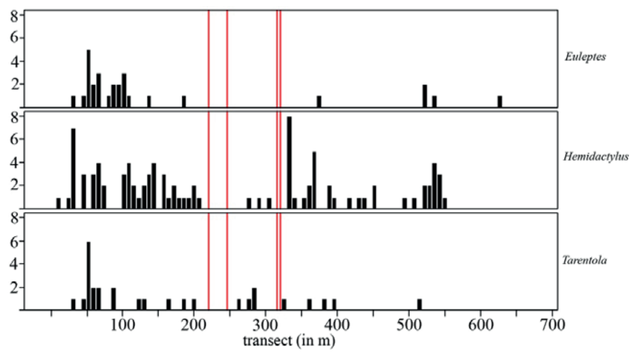


**Fig. 6.** Capture frequency distribution of target species in the study area. Red lines represent the borders of forest tracks to the beach.

All the species showed a different distribution, *Tarentola* and *Hemidactylus* were quite homogeneous, while *Euleptes* was more concentrated in the first patch of the area (transect 1). Spatial distribution was not normal (Kolmogorov Smirnov Z = 2.149, $P < 0.001$), and the observed differences in spatial distribution were significant ($P = 0.007$).

## DISCUSSION

The gecko community in this area shows a sex-ratio not differing from the expected 1:1, for all the species considered. Average body size of the leaf-toad gecko and of the Turkish gecko falls within the range of the species in Italy (Corti et al., 2011), while the Moorish gecko results smaller in size with respect to available data (Tuscany: Atzori et al., 2007). In our studied sample, we did not find any significant sexual difference within each species. This matter may occur in some other populations of *Euleptes* (Delaugerre, 1985), likely due to the biotic capacity of the site (Salvidio et al., 2011). *Hemidactylus* males generally present much larger heads than the females, while size is similar for the two sexes (Corti et al., 2011). In *Tarentola*, sexual dimorphism is significantly marked for some features: larger eye diameter and bigger head in males (more voluminous head than equal sized females) and, same SVL, lighter body mass in females (Zuffi et al., 2011). In our study area, the difference between males and females may be underestimated because the number of the two sexes of juvenile age, or as young adults, probably does not present yet the strongly different sexual dimorphism when considering adults. Interestingly, as pointed out by Simbula et al. (2019) where diurnal vs nocturnal *Tarentola* were considered, sexual dimorphism was not significant, a similar matter as occurred in our population. Furthermore, nocturnal individuals attained a smaller body size than diurnal ones (Simbula et al., 2019), suggesting an analogous pattern also in our sample. Body size did differ for almost all parameters among the species.

We have recorded, on average, a different association of species as regards site position, height from the ground and hour of observation. Between the two years humidity and wind were different, with a significant interaction among species and year for humidity only.

To date, ecology studies on these three species of geckoes are relatively scarce, covering trophic ecology (Capula and Luiselli, 1994; Luiselli and Capizzi, 1999; Hòdar et al., 2006), or underlining competition for spatial niches in sympatric populations of *Hemidactylus* and *Tarentola* in Croatia (Lisicic et al., 2012), and on lizard and geckoes' community in central Italy (Simbula et al., 2019). Overall, our research is among the very few field works on species assemblages and, actually, it is the first work on comparative ecology of these three species of geckoes in condition of syntopy.

*Tarentola* seems to prevail in the northern portion of the area, while *Hemidactylus* is more common in the northern and southern portion, as supported by GLM and Chi square analyses. According to our data, wind and humidity had more effects on *Tarentola* and on *Hemidactylus* respectively (Table 2), the species are differently distributed in the area (e.g., site position) and placed at different heights from the ground, *Euleptes* being relatively higher than the other two species, with a different hour distribution of observation. However, in accordance with data and analyses, the three species seem to occupy and frequent the area not in a markedly different way. PCA results showed a different distribution of age classes (as size component) relatively to the site position especially for *Hemidactylus* and *Tarentola* (Fig. 3) and a relatively importance of wind, humidity, temperature and ground type for geckoes observation (Figures 4-5). The whole scenario is in accordance with previous ecological observations (see for instance Delaugerre, 1984; Simbula et al., 2019).

The similar occurrence of species along the transect despite the slight, significant, differences among them in many ecological parameters, resembles the pattern found and underlined by Simbula et al. (2019). Specifically, the "The observed overlap in spatial resource use was higher than expected by chance, thus showing a shared resource use instead of a partitioning pattern" (Simbula et al., 2019).

For what we know so far, Cala Violina is the only syntopy area for *Euleptes europaea*, *Hemidactylus turcicus* and *Tarentola mauritanica,* and it arises a pivotal importance for the conservation of the three species. On average, we must stress that human presence in this area, as a marked touristic presence for most of the geckoes active season, is on one side undoubtedly a risk for the three species. On the other side, according to recorded data, it is not possible yet to assert if studied populations of the three species have suffered numerical losses because of direct anthropic actions (killings, capture, and removal) or indirect (alteration or damage to habitat, increment of tourism), because there are not yet studies underlining the risk factors. Locally, arsons, inappropriate woodcutting and touristic impacts are the strongest risk factors in the study area. The touristic activity on the seaside probably plays a negative role on daily activity of *Tarentola mauritanica*. In fact, the study area is characterised by intensive daily seaside activity in the spring-summer seasons (from June to September). Cala Violina is featured in S.I.R. (Site of Regional Interest) 108 "Monte d'Alma" (IT51A0008), in homonym pS.I.C. (cod. nature 2000 IT51A0008), and in A.N.P.I.L. (Area Naturale Protetta di Interesse Locale, "Protected Natural Area of Local Interest") "Costiere di Scarlino", but the actual presence of *Euleptes europaea* justifies the opportunity to propose the realization of a Biotope. The "Rete Ecologica Regionale" (Ecological Regional Network), together with the "Piano Territoriale di Coordinamento" (PTC, "Territorial Coordinational Plan) applicable in the Grosseto Province, represent two essential instruments enforcing the importance of environmental connectivity and natural resources protection. Biotopes, in fact, are an innovative aspect in the field of planning management, to define further restrictions congruent to the latest acts of territory planning. In a conservation and management planning for this area, priority should be given to intervention finalized to protect slopes and cliffs in which these geckoes live and spent most of their life history traits. Protective intervention for slopes and cliffs is desirable to avoid further human disturbance, and particularly to avoid damages to natural fissures and crevices (abandon of garbage and other objects in fissures, destruction of portions of loose soil by sun beds, chairs and other), likely used for egg deposition, and surely for daily hideaway. These protective measures could be made up by wood barriers adequately distant from sides (0.5 – 1 m), which do not consist of a landscape obstacle, and with explicative posters making visitors aware of the site peculiarities, fauna richness and of all the protection measures. Besides, it would be appropriate to evaluate through a dedicated study how much touristic impact influences these geckoes and other herpetofauna activity in the area, and to limit, if necessary, the daily access to Cala Violina with a maximum number of people per day (a maximum of 700/day since the last year; P. Biagini pers. comm). Measure of human disturbance on a lizard community has been recently carried out in Spain on a population of wall lizard (*Podarcis muralis*), in a strongly touristic area (Amo, Lopez and Martin, 2006), where the authors pointed out that tourism had harmful effects on physical condition and relations host-parasite in this reptile. Therefore, it would be desirable to verify the actual situation in Cala Violina, because of this and other studies (e.g., Attum et al., 2006; French et al., 2008).

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## SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found at <http://www-9.unipv.it/webshi/appendix/index.html> manuscript number 11547

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