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Construction of a refuge wall with crevices to protect European leaf-toed geckos *Euleptes europaea* and young Turkish geckos *Hemidactylus turcicus* on the Ile du Levant, France

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INTRODUCTION

Faced with the rise in invasive reptile species worldwide and the consequent threats to native species (Dubos et al., 2023), studying the requirements of the most vulnerable animals is crucial for their successful conservation management. Conservation translocations are being used increasingly for reptiles with positive results being reported (Evans et al., 2023) but a lack of understanding of their ecological requirements can lead to problems such as rejection of the release site that results in wandering, exhaustion or predation (Berger et al., 2020; Bradley et al., 2023). Two species of geckos, the European leaf-toed gecko *Euleptes europaea* (Gené, 1839) and the Turkish gecko *Hemidactylus turcicus* (L., 1758), have long been present on the Ile du Levant (Lantz, 1931; Ineich et al., 2019) a Mediterranean island in the Hyeres archipelago lying about 10 km from the south coast of France (43°01' N, 6°27' E). A third species, the Moorish gecko *Tarentola mauritanica* (L., 1758), which is considered to be problematic, has been introduced recently (Deso et al., 2018). In France, including Ile du Levant, these three gecko species are often the subject of translocation plans in response to land development projects. Although *T. mauritanica* is a nationally protected species (Arrêté national de protection du 8 janvier 2021), it is nevertheless considered a potentially invasive species in France (Zdunek, 2022a) and throughout the world (Rato et al., 2023). Its arrival on Mediterranean islands is being monitored (Médail et al., 2013; Deso et al., 2020), as its presence is a threat to native island species (Astruc et al., 2014). The colonisation of natural and man-made environments by *T. mauritanica* on the Ile du Levant has now reached the heart of the island (Deso et al., 2020).

Given the concerns about the potentially significant impacts of *T. Mauritanica* on small threatened species (Renet et al., in press), and the reported extinctions of isolated populations of *E. europaea* (Salvidio & Delaugerre, 2003), we undertook a rapid test of an experimental refuge wall for the two vulnerable gecko species as part of a development and translocation plan. In the case of the leaf-toed gecko, an abundance of deep, narrow crevices is a key factor in the species' survival (Salvidio & Oneto, 2008). Since September 2022, we have been supervising the construction of two 10-metre-long experimental walls with 200 narrow cracks that are conducive to the establishment of adult and juvenile *E. europaea*, as well as juvenile and subadult *H. turcicus*. At the beginning of December 2022, we relocated a total of 10 *E. europaea* into the experimental walls, these are the smaller and more threatened of the two species, to assess the site fidelity of this species and the visits and colonisation by other lizard species.

MATERIALS & METHODS

It is known that *E. europaea* prefers refuges in which it would fit tightly such as narrow cracks in rocks (Salvidio & Oneto, 2008) or tightly packed tree bark (Deso et al., 2023). On the island of Port-Cros it has been reported that *E. europaea* can occupy particularly narrow cracks and interstices, ones to which *H. turcicus* does not have access (Delaugerre, 2003a). Given the depth of the skull of *E. europaea*, we considered that crevices of 0.4–0.7 cm would constitute a comfortable refuge for both young and adult specimens and from which it would be difficult for larger species of lizard to remove them.

To provide such crevices we constructed two walls each 10 m long and 70 cm high on 5–6 September 2022 using breeze blocks (50 x 25 x 20 cm) in three layers (Fig. 1). A numbering system was used to identify the layers (wall 1 A–C, wall 2 D–F) and the crevice positions (1, 2, 3 etc.). The centres of the breeze blocks were hollow and were filled with soil in which plants could grow (Fig. 1C). This plant cover provided additional hiding places for the geckos and food resources from the insects that the plants attracted. The walls were constructed with a south-south-west orientation, the same as the rock faces and low garden walls around the site, which were already heavily colonised by both gecko species. As favourable thermal properties of refuges are crucial for the persistence of populations (Bradley et al., 2023), we took care not only to reproduce an exposure appreciated by both gecko species, with the heat of the day making the walls warm and allowing the geckos to thermoregulate efficiently by thigmothermy during the night (Delaugerre, 1984; Salvidio & Oneto, 2008) but also embedded part of each breeze block, partially covered with soil, in the ground in order to form a barrier to strong thermal amplitudes (Fig. 1A). We inspected

Figure 1. Views of an experimental breeze block wall constructed on an excavated surface with the breeze blocks set apart to give standardised crevices between them, in which *Euleptes europaea* and young *Hemidactylus turcicus* could take refuge, as photographed in - **A.** September 2022, **B.** January 2023, **C.** June 2023

Figure 2. One of ten *Euleptes europae* located to an experimental wall

the area around the refuge wall to eliminate any shelters that might offer refuge to other larger lizards (and geckos) that could potentially be predators.

On 5 December 2022, ten adult *E. europaea* were captured during the demolition of an old asbestos building located 200 m from the experimental walls. The ten specimens were deposited in crevices of the walls (5 individuals in each wall) on the same day (Fig. 2). To monitor the crevices and observe the behaviour of the geckos in the crevices and around the walls, we used an L52 LED lamp and a video trap (Num'Axes Trail Camera PIE 1023) as well as an infrared thermal camera (Leica Calonox View). In total, we made one visit each month from January to December (= 12 visits), which involved a one-hour inspection of the numbered cracks to determine the presence/absence of geckos or other lizards. This protocol of inspecting numbered cracks, one after the other, means that there was no double counting of geckos and also allowed us to see whether the geckos were faithful to particular crevices.

RESULTS

Ageing of the wall

After four months of winter, the scrubland around the walls had regrown with many local plant species, such as strawberry tree *Arbutus unedo*, myrtle *Myrtus communis*, pistachio *Pistacia lentiscus*, thistles, etc. (Fig. 1C). The lower sections of the two walls, which were built on loose soil, had undergone movement and by April 2023 showed five crevices that had spread beyond 0.7 cm (in a localised sector of the wall) and 50 crevices that had closed completely, so that of the 200 original crevices 145 were still available as refuges for *E. europaea*.

Monitoring of geckos

After the transfer of ten *E. europaea* at the beginning of December 2022, although we did not mark or photo-identify the individuals, we observed between four and eleven different adult individuals during 2023 (in approximately the same crevices) and five different juveniles that established themselves from August, September, October, November and December 2023 (Figs. 3 & 4). We noted the arrival of four different adult *H. turcicus* from May and three adult wall lizards *Podarcis muralis*, including a hibernating juvenile, in one of the cracks in December. The presence of other adult and larger lizard species is linked to the enlargement of the spacing of five crevices mentioned above, making it possible for them to be exploited by larger animals. Night-time video surveillance during the night of 21 June in a section of wall where only 0.4–0.7 cm crevices were present enabled us to observe their usage by *E. Europaea* and the prospecting of three adult *H. turcicus* unable to enter these crevices (BHS video, 2024). *Euleptes europaea* showed a certain willingness to retreat into the crevices in the face of repeated visits by

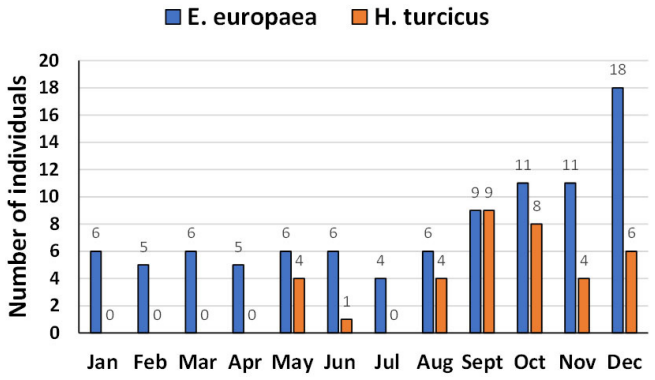

Figure 3. Monthly count of individual *Euleptes europaea* and *Hemidactylus turcicus* in the two experimental walls in 2023

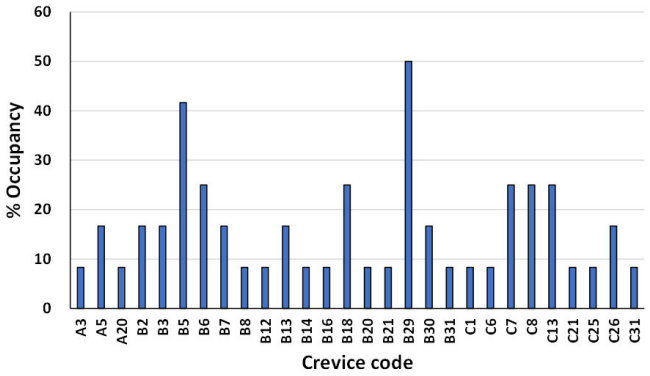

Figure 5. % occupancy by *Euleptes europaea* of the crevices of experimental wall #1 from January to December 2023

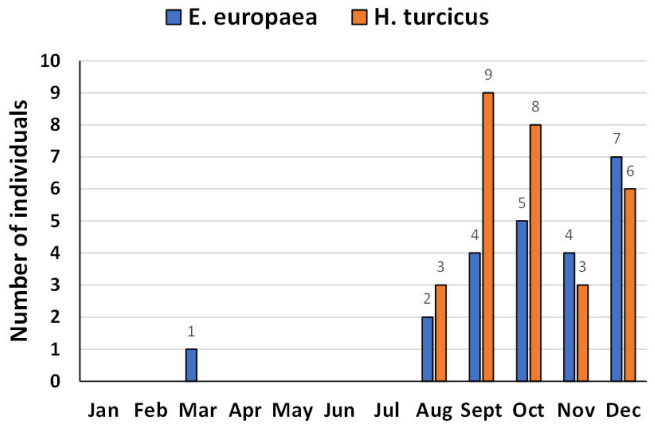

Figure 4. Monthly count of individual juvenile *Euleptes europaea* and *Hemidactylus turcicus* in the two experimental walls in 2023

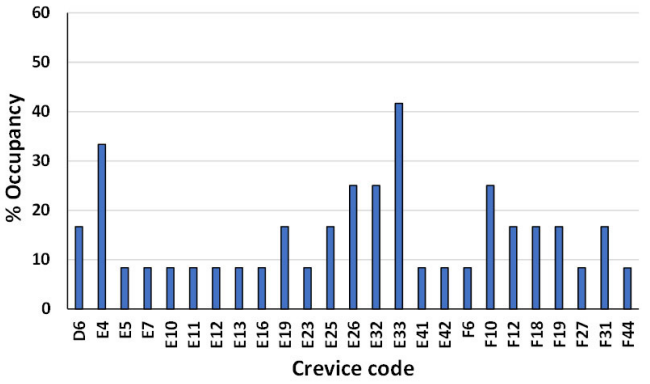

Figure 6. % occupancy by *Euleptes europaea* of the crevices of experimental wall #2 from January to December 2023

adult *H. turcicus*. On several occasions between 22:40 h and 00:30 h, *H. turcicus* attempted to interact by positioning itself around the same crevices but without being able to enter them (BHS video, 2024). Juveniles of both *E. europaea* and *H. turcicus* were observed at the walls mostly in August and September (Fig. 4). Out of 145 crevices considered favourable, 23.5% were occupied by six *E. europaea*. Crevice occupancy rates in the two experimental walls sometimes exceeded 40% (Figs. 5 & 6) and crevice B29 in wall 1 even reached an occupancy rate of 50% for *E. europaea* (Fig. 5).

DISCUSSION

Sympatric lizard species may coexist by adopting different activity patterns and niche partitioning (Luiselli & Capizzi, 1999; Simbula et al., 2018; Radi & Zuffi, 2022; Zdunek, 2022b). In the case of the gecko species of concern in this study, when sharing the same habitat (syntopia), *T. mauritanica* may displace *H. turcicus* towards more vegetated areas (Lisičić et al., 2012) and it is suspected that *E. europaea* will move towards denser forest environments in response to *H. turcicus* (Deso et al., 2023). To facilitate monitoring of *E. europaea*, artificial refuges have already been built on certain Mediterranean islands, such as piles of stones on Port-Cros (Delaugerre, 2003b) and tiles on the island of Grand Rouveau (Cheylan et al., 2018) and the encouraging results of those studies have led to the construction of refuges using tiles and piles of stones on Ile du Levant (pers. comm.). However, it is now known that these refuge structures are easily damaged by wild boar following their arrival on the islands of Hyères (Ballouard et al., 2021), and potentially result in the predation of the geckos when they turn over the piles of stones and tiles. There are already wild boar present on Ile du Levant and we observed wild boar dung close to the walls throughout the year but they remained undamaged so we conclude that the breeze block walls are not vulnerable to wild boar.

Successful measures to manage gecko populations by creating appropriate crevices in solid walls have been implemented in south-east Australia (Webb & Shine, 2000). We have therefore opted for this strategy using a standardised crevice size (0.4–0.7cm) favouring *E. europaea* and also juvenile and subadult *H. turcicus*.

Our translocation of *E. europaea* at the beginning of winter was successful in that most of the geckos took up residence in the refuge walls and over the winter the flora gradually colonised the new habitats providing further cover. During the video capture of 21 June, *E. europaea* showed its eagerness to withdraw into the crevices in the presence of adult *H. turcicus* that attempted to interact by positioning themselves around the same crevices (but without being able to enter them). The nocturnal movements of three adult *H. turcicus* across the ground to the refuge wall, despite the lack of shelter

(caches for large geckos had been removed), indicates the considerable dispersal ability of this species.The number of juvenile *H. turcicus* that found and colonised the refuge walls was greater than that of *E. europaea*, which appears to corroborate this observation (Fig. 4). This avoidance of *H. turcicus* by *E. europaea* suggests limitations to cohabitation between these species that may result in the displacement of *E. europaea* (Lisičić et al., 2012). However, the persistence of adults and juveniles of *E. europaea* for a whole year demonstrates the advantage of a refuge that prevented the intrusion of adult *H. turcicus*. Habitat supplementation and revegetation are important parameters for increasing the densities of protected species (Goldingay & Newell, 2017; Mickael et al., 2018) but also for increasing the chances of successful translocations (Bradley et al., 2023). Here, we tested the effectiveness of a refuge wall to separate two gecko species whose nature of interaction is still uncertain, prior to the arrival of an even more aggressive invader to the site, *Tarentola mauritanica*. Although the walls showed a few points to be corrected, such as the fact that they should be established on a solid base to prevent them from moving over time, the initial results are encouraging for the development of different strategies depending on the life stages of the different gecko species living in syntopia. It is a positive sign that the experimental walls allowed the establishment of 11 *E. europaea* adults (Fig. 3) for a whole year (including one winter), as well as the colonisation of seven juveniles making a total of 18 European leaf-toed gecko with eight individuals in addition to those originally displaced. Some crevices in the two experimental walls reached a high occupancy rate of over 40%, and sometimes as high as 50% over the year. The strong colonisation by young *H. turcicus* (nine juveniles) in September 2023 shows that they also feel the need to exploit shelters that offer them protection at this stage of their lives. Given that adult *H. turcicus* were unable to penetrate the wall crevices and potentially dislodge adult and juvenile *E. europaea* or young *H. turcicus*, it may be assumed that the same crevices would also protect these species from *T. mauritanica*. Our results clearly show the usefulness of this type of structure for *E. europaea*, which showed an increase in the presence of individuals (18). The presence of 11 adults throughout the year, as well as the autumn colonisation and overwintering by juveniles (7), also show the usefulness of this type of refuge for the hibernation of this species.

Despite the presence of juveniles, at this stage we do not know whether the refuge walls may have served as an egg-laying site for *E. europaea* which has the habit of using cracks to lay its eggs (Delaugerre, 2003; Salvidio et al., 2010). This is of particular interest as the availability of egg laying sites is a key factor in the survival of gecko species such as *E. europaea* that lay hard-shelled eggs (Salvidio & Oneto, 2008); it would be useful to pay particular attention to this in further research.

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