

The wall (and tree) lizard: surveys and citizen science to improve understanding of arboreal behaviour of Madeiran Wall Lizard *Teira dugesii*

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Abstract. Arboreality can provide lizards with refuge from predators and a resource-rich environment, yet this behaviour is rarely observed in European lacertid species. The Madeiran Wall Lizard *Teira dugesii* is an adaptable species in its native and introduced range, reported to sometimes climb trees and bushes, but this remains largely anecdotal and insufficiently quantified. To better understand such arboreal behaviour, opportunistic and targeted repeated surveys were used to collect data on vegetation climbing by *T. dugesii* in Madeira and were then supplemented and compared with citizen science data extracted for this species across its range. As an additional comparison, the Guadarrama Wall Lizard *Podarcis guadarramae*, which has relatively similar ecology and is also known to sometimes climb trees, was also included with a similar number of citizen science records from the Iberian Peninsula. During field surveys in summer 2022, a total 10% (31 observations) out of the total 312 *T. dugesii* recorded were of individuals climbing trees and flowering shrubs in multiple locations, especially urban parks, but also in natural habitats. Contrary to previous literature reports, many arboreal observations were at substantial heights, of over 10 m in trees, yet the exact reasons for this behaviour and its ecological implications remain unclear. Community science data were abundant (*T. dugesii* 1161 records; *P. guadarramae* 1333 records) and included apparently arboreal records but these were difficult to interpret as height information was missing. Overall, *T. dugesii* appears significantly more arboreal than previously reported or compared to *P. guadarramae*, yet this behaviour remains mostly ignored. Future work could test the drivers and implications for this behaviour in different habitat types and populations.

Keywords. arboreal, scansorial, tree climbing, citizen science

Introduction

Teira dugesii (Milne-Edwards, 1829), formerly *Lacerta dugesii* or *Podarcis dugesii*, is a lacertid lizard species endemic to Madeira and the nearby island groups comprising Porto Santo, Desertas and probably Selvagens. It was accidentally introduced and has established populations on all nine islands in the nearby Azores archipelago, as well as in Lisbon and Porto in mainland Portugal (Malkmus, 2004; Ferreira et al., 2023), and Las Palmas in Gran Canaria, Spain (Silva-Rocha, 2016). On Maderia, despite the diverse habitat and relatively large size (750 km²), due to its volcanic origin and geographic isolation in the Atlantic Ocean (nearly 700 km off the west coast of Africa and 1000 km from mainland Europe), *T. dugesii* is the only native non-flying vertebrate (Brehm et al., 2003). *Teira dugesii*

remains abundant and demonstrates extraordinary plasticity, inhabiting virtually any terrestrial habitat on Madeira, from rocky beaches and coastal semi-arid areas to elevation 1860 m and wet laurel forest, as well as most villages and towns, although with wide differences in density (Arnold and Ovenden, 2002; Malkmus, 1995, 2004; Brown et al., 2023). Abundance appears lowest in dense laurel forest while reaching extreme densities in semi-arid rocky terrain (Malkmus, 2004; Koleska, 2017) and man-made stone walls, with one of the highest estimated densities of any reptile species: average of >7 individuals/m², calculated for small stone wall sections in a single site (Arbuckle and Nichols Arbuckle, 2023).

Similar to some other Iberian or Mediterranean lacertid species, *T. dugesii* is known to sometimes climb vegetation to feed on plant matter, including pollen, nectar, flowers and soft fruit (Beyhl, 1997). It has consequently been heavily persecuted due to perceived damage to grapes in vineyards, especially on Porto Santo (Malkmus, 2004). Although *T. dugesii* mainly eats invertebrates (Sadek, 1981) it can expand its diet in both native and the introduced range to include a broad variety of plant matter but also seabird chicks (Matias et

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al., 2009; Neves et al., 2022). There are several reports that the Madeiran Wall Lizard can climb 2–4 meters on trees (Malkmus, 1995, 2004; Arnold and Ovenden, 2002), presumably in search of basking spots or shelter from predators. This has especially been recorded during January, when most such surveys were carried out. Although several recent papers describe some arboreal observations of Iberian Peninsula lacertids (e.g., Ayres, 2020; Caiero-Dias, 2021), there is no detailed published data on arboreality for the Madeiran Wall Lizard, even though it is anecdotally more likely to display such behaviour. For instance, some *Podarcis gadarramae* were recorded basking 1.5 m high in an olive tree (*Olea europaea*) in an urbanised setting in coastal Spain, possibly to reduce predation risks from feral cats or gulls (Ayres, 2020). Similarly, in grassy areas without rocky outcrops in Portugal, Caiero-Dias (2021) reported observations of several Geniez's Wall Lizards (*Podarcis virescens*) basking below 1 m height on Cork Oak (*Quercus suber*) trunk. Other individuals fled to trees when approached and then climbed to 5–6 m heights if the observer moved closer. In North Africa, the Tunisian form of the *Podarcis hispanicus* species complex was observed climbing Cork Oak or European Chestnut (*Castanea sativa*) trees for basking and feeding or as an escape mechanism in several locations (Kaliontzopoulou et al., 2009). More generally, even though such data often remains unrecorded, several

Podarcis species have been observed at low heights on trees (usually <1 m), with various images available on platforms such as Flickr. However, arboreal behaviour is reportedly rare in species such as *Podarcis muralis* and *Podarcis siculus* (Arnold and Ovenden, 2007).

For *T. dugesii*, the lack of published arboreality data means it is unclear how widespread and frequent this behaviour is. It is equally unclear why arboreality occurs, i.e., whether they climb trees only where terrestrial basking is impeded (e.g., due to ground vegetation shading), only at particular times of the day or mainly during colder months, or if they also forage in the trees. More broadly, it is unknown if this behaviour might play any wider ecological roles, for instance by contributing to seed dispersal or pollination, as shown for several insular lizard species (Olesen and Valido, 2003). This study aimed to explore arboreality in *T. dugesii* using field surveys and citizen science data in order to improve our understanding on this topic.

Materials and Methods

Field data collection. Survey data were collected on Madeira during 12 days in July 2022 using opportunistic transect surveys on foot (total 49 km) at seven locations, which encompass a variety of habitats across the island (Fig. 1). Surveys were performed at similar, normal walking pace, with lizard activity being recorded by visually searching available ground and trees. While

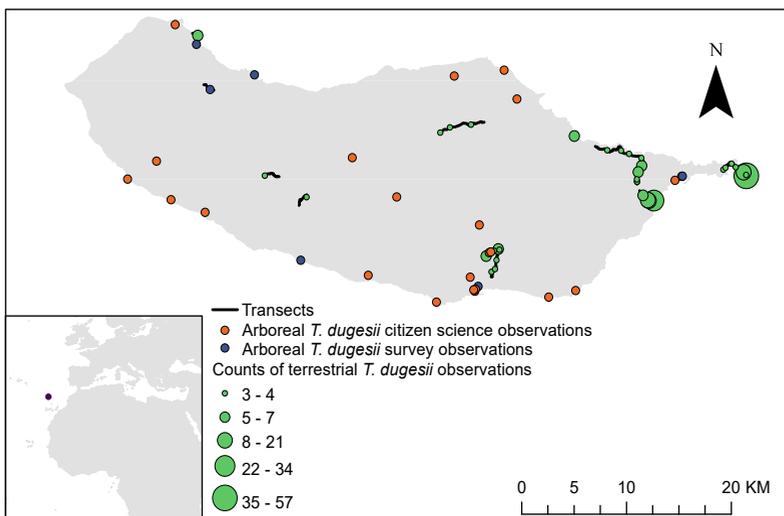


Figure 1. Citizen science, field survey transects and counts of *T. dugesii* on Madeira. Some arboreal and vegetation climbing observations of lizards were in urban parks which were not on transects. Counts of lizards are displayed along the transects where they occur but aggregated in transect sections of under 100 m.

most such areas included footpaths in areas of farmland and forest (26 km, often along small irrigation canals known as levadas), semi-arid natural habitat in coastal landscapes (11 km), laurel forest, pasture and introduced eucalyptus plantations (7 km), they also comprised some urban areas; especially green spaces (e.g., public parks and gardens) in towns and villages (5 km). In towns, such green spaces were also visited outside of transects.

At one site, the Jardim Municipal (8300² m in size) within the capital Funchal, where substantial arboreal activity of *Teira dugesii* was recorded during this study, surveys were supplemented by repeated targeted timed observations of a group of trees using binoculars. These surveys (total of seven 15 min. surveys at 09:00 h, 12:00 h and 19:00 h) were spread across three non-consecutive days. Here, lizards were recorded using several ornamental introduced and native Madeiran trees but the targeted surveys focused mainly on one Macadamia Nut (*Macadamia integrifolia*) and one Australian Umbrella Tree (*Schefflera actinophylla*), plus occasionally a *Ginkgo biloba* and a Nile Tulip or Siala (*Markhamia lutea*) tree. These trees were selected as arboreal lizard activity could be observed using binoculars and a telephoto camera lens both from the ground and from a nearby building. Targeted surveys focused on recording the number of lizards in or near trees, their position height and behaviour (e.g., basking, foraging, emerging from tree cavity). The height of arboreal lizards was estimated using existing markers and angle as well as comparisons with nearby building floors. At all other sites, transects followed footpaths or dirt tracks and took place between 08:00 and 18:00 h. During surveys weather was generally warm (max. 29 °C), sunny, with long cloudy intervals but no significant rainfall.

Citizen science data extraction. To better understand the extent and any seasonal, habitat or spatial trends for arboreal behaviour, the field survey data were supplemented using verifiable citizen science records. On 1 October 2022, “Research Grade” records of *T. dugesii* were extracted from iNaturalist; allowing species verification from photos, location data and the date of observation (Callaghan et al., 2022). iNaturalist records were accessed using taxonomical-only filters (i.e., not geographically restricted) and grid visualization to allow the assessment of each observation that included a photograph. This meant verifying species identification and categorising whether the lizard was in a terrestrial setting (e.g., on the ground, on rocks, etc.), arboreal (i.e. on a vertical tree trunk, fence or on tree branches), or

climbing non-woody vegetation to access flowers. Each record’s location metadata was verified to classify the site (e.g., urbanised area or farmland or natural habitat). Supplementary observation tags and comments were checked for further information, for instance on multiple individuals recorded at the same time or the height of the observation. The specialist amphibian and reptile citizen science observational database HerpMapper was also assessed but as it comprised only six records of *T. dugesii*, including duplicates from iNaturalist, it was discounted. Similarly, the photo repository Flickr was explored by searching photos using the terms “Madeiran lizard”, “lagartixa-da-madeira”, “lagartija de Madeira”, “*Lacerta dugesii*” and “*Teira dugesii*”. Finally, iNaturalist was also assessed for records of tree climbing activity by the Guadarrama Wall Lizard *Podarcis guadarramae*. Identified images were classified using the same criteria to assess if arboreal behaviour is more common for *T. dugesii* compared to *P. guadarramae*. Statistical analysis was carried out in R (R Core Team, 2020) with Strucplot visualisation of the Pearson’s chi-squared test (Meyer et al., 2006).

Results

Field surveys. During opportunistic and targeted visual surveys in urbanised, farmland and natural habitats in July 2022, a total of 335 observations of *Teira dugesii* were collected in multiple transect locations on Madeira (Fig. 1). Most observations concentrated in urbanised (155 records) and coastal semi-arid natural sites (76 individuals), while the rest were in farmland and forest. Individuals were mainly recorded at ground level, typically on rocky substrate, low stone walls and fallen branches on the forest floor. However, 47 observations (14.0%) were of arboreal behaviour including tree climbing, basking on tree trunks high in the trees, using tree cavities or moving on branches in the canopy (Table 1; Figs. 2, 3). In addition, another seven individuals were recorded basking or foraging on tall flower bushes, especially *Hydrangea* sp. (4 lizards) (Fig. 3). Excluding repeated surveys and retaining only the first records, 31 observations (9.9%) were either arboreal or of lizards climbing on vegetation. Surprisingly, arboreal behaviour extended to substantial heights, with nearly half of the *T. dugesii* observations at over 4 m and at least 11 observations at over 10 or even 15 m (Table 1). Most arboreal observations were recorded in green spaces in urban environments (29 out of 31 unique, non-repeated observations) but two were in the protected laurel forest at Fanal, above 1100 m

Table 1. Field survey observations of tree and other vegetation climbing by Madeiran wall lizards. JM: Jardim Municipal.

Observation ID	Site name	Date	Time	Number of lizards	Observation height	Tree/flower species	Behaviour
1	Canical Park	20/07/2022	17:20	1	7 m	Jacaranda tree	Resting
2	Canical Park	20/07/2022	17:20	1	2.5 m	Olive tree	Basking/hiding in tree crevice
3	Funchal JM	22/07/2022	09:00	2	6 m	Nile tulip	Basking/foraging
4	Funchal JM	22/07/2022	09:00	1	3 m	Macadamia nut	Basking/foraging
5	Funchal JM	22/07/2022	12:00	12	2.5–17 m	Macadamia nut	Basking/foraging
6	Funchal JM	22/07/2022	12:00	6	3–9 m	Elephant umbrella tree	Basking/foraging
7	Funchal JM	22/07/2022	12:00	2	3–6 m	Nile tulip	Basking/foraging
8	Funchal JM	22/07/2022	19:00	2	3–7 m	Macadamia nut	Foraging
9	Funchal JM	25/07/2022	09:00	3	1.5–5 m	Elephant umbrella tree	Basking/foraging
10	Funchal JM	25/07/2022	12:00	7	3–17 m	Macadamia nut	Basking/foraging
11	Funchal JM	29/07/2022	09:00	2	2–3 m	Elephant umbrella tree	Basking/foraging
12	Funchal JM	29/07/2022	12:00	1	14 m	Ginkgo	Basking/emerging from tree crevice
13	Funchal JM	29/07/2022	12:00	5	1–9 m	Macadamia nut	Basking/foraging
14	Seixal	28/07/2022	15:30	2	0.4 m	Euphorbia plant	Feeding on pollen
15	Ribera Brava	28/07/2022	10:10	1	0.6 m	Unidentified flower	Feeding on pollen
16	Sao Vicente	28/07/2022	13:20	4	1.3 m	Hydrangea	Basking
17	Fanal Forest	28/07/2022	12:30	2	2.5–3 m	Canary laurel	Basking/hiding in tree crevice
Total				54			

elevation. At least eight *T. dugesii* individuals, including the two at Fanal, were seen exiting or entering small tree cavities, apparently using them as shelter or to look for food.

Behavioural classification was difficult and unclear as individuals appeared to be constantly switching, but most lizard activity in trees seemed to encompass a range of basking, foraging, and resting (Table 1). There appeared to be an overall peak in observations around midday, but numbers were small and did not allow statistical testing: 9 observations in the morning (8–11:30 h); 41 observations during midday (11:30–15:30 h); and four observations in the afternoon (15:30–19:00 h). However, even with the use of binoculars, lizard activity in the canopy was difficult to detect due to their small size and visual obstruction by foliage. As such, lizard numbers and activity at heights of 10 m or more were probably greatly underestimated.

Citizen science data. iNaturalist extracted data produced 1161 *T. dugesii* observations spread between 2013 and 2022, with some observations containing multiple individuals. As expected, most records were from Madeira (709 observations) and fewer from Porto Santo (40), but there were also substantial numbers from the introduced areas in the Azores (312 records), Lisbon (45), and Canary Islands (3). Overall, 29 records (2.5%) were apparently at height including on tree trunks,

branches or wooden fence posts, however two records had incorrect location data (e.g., in the sea) and one was a duplicate and were therefore removed. Notably, one of the records mentioned a total of 40 other unique individuals using the same small tree surrounded by pavement in Funchal, which means the total percentage was actually 6%. Despite this, the height of observations on tree trunks or fences was never specified and in many cases the images suggested that lizards were less than 0.5–1 m from the ground. Numbers are small but overall Madeira had a significantly higher proportion of arboreal observations compared to the observations from Porto Santo, Azores and Lisbon ($\chi^2 = 19.742$; $df = 1$; $p < 0.0001$). Interestingly, none of the *T. dugesii* iNaturalist observations from the Jardim Municipal in Funchal (10 records) were arboreal but in the larger nearby Santa Catarina Park, out of 46 observations, three were on trees and three others were on flowers. Most observations of climbing behaviour were from urban green spaces and gardens (47 observations; 67%), natural habitats (9 observations; 13%) and farmland (4 observations; 5.7%), with 62 out of 70 observations (89%) being on trees.

By comparison, iNaturalist produced 1333 records of *P. gadarramae* in Portugal and Spain, of which only 24 (1.8%) appeared to be on trees, thus, significantly fewer arboreal observations compared to *T. dugesii*



Figure 2. (A) Ten adult *Teira dugesii* at approx. 3–7 m height on Macadamia nut tree and (B) four adult *T. dugesii* at approx. 3.5–8 m height on Australian umbrella tree. Both trees were part of a group of several mature ornamental trees which were used by lizards in Jardim Municipal in Funchal, Madeira. Photos by Silviu Petrovan.

(Fig. 4), but again, height was never specified and from the pictures most such observations appeared to be at under 0.5–1 m.

The searches on the photo repository Flickr revealed 530 images of *T. dugesii*, including at least 35 instances of apparent tree or other vegetation climbing (e.g., mostly on ornamental flowers). However, this dataset was discounted from further analyses as some images lacked location data, some appeared to be separate entries of the same individual, some showed manipulated lizards (hand-caught or attracted with food), some were duplicated from iNaturalist, or showed other lizard species.

Discussion

While tree climbing has been repeatedly mentioned for the Madeiran Wall Lizard, with Malkmus (1995) suggesting they sometimes climb *Castanea*, *Quercus*

and *Ficus* up to 2–4 m in search of basking spots during January, this behaviour appears to have otherwise remained unquantified. The basking hypothesis is similar to the cases of tree climbing by *Podarcis bocagei* in Spain which were suggested to be a consequence of local habitat limitations, specifically the scarcity of terrestrial basking opportunities from overgrowing vegetation (Galan, 2011). While this might have been the case for some of the observations in the citizen science dataset, it was not applicable to the survey sites reported here for *T. dugesii* as exposed sunny ground and low stone walls were available and were in fact used by other individuals during the surveys. Indeed, all iNaturalist records of Madeiran wall lizards in Jardim Municipal in Funchal were on such terrestrial basking sites. Equally, the survey data presented here were collected during one of the hottest parts of the year, in late July, when daily temperatures reached 27–29 °C at

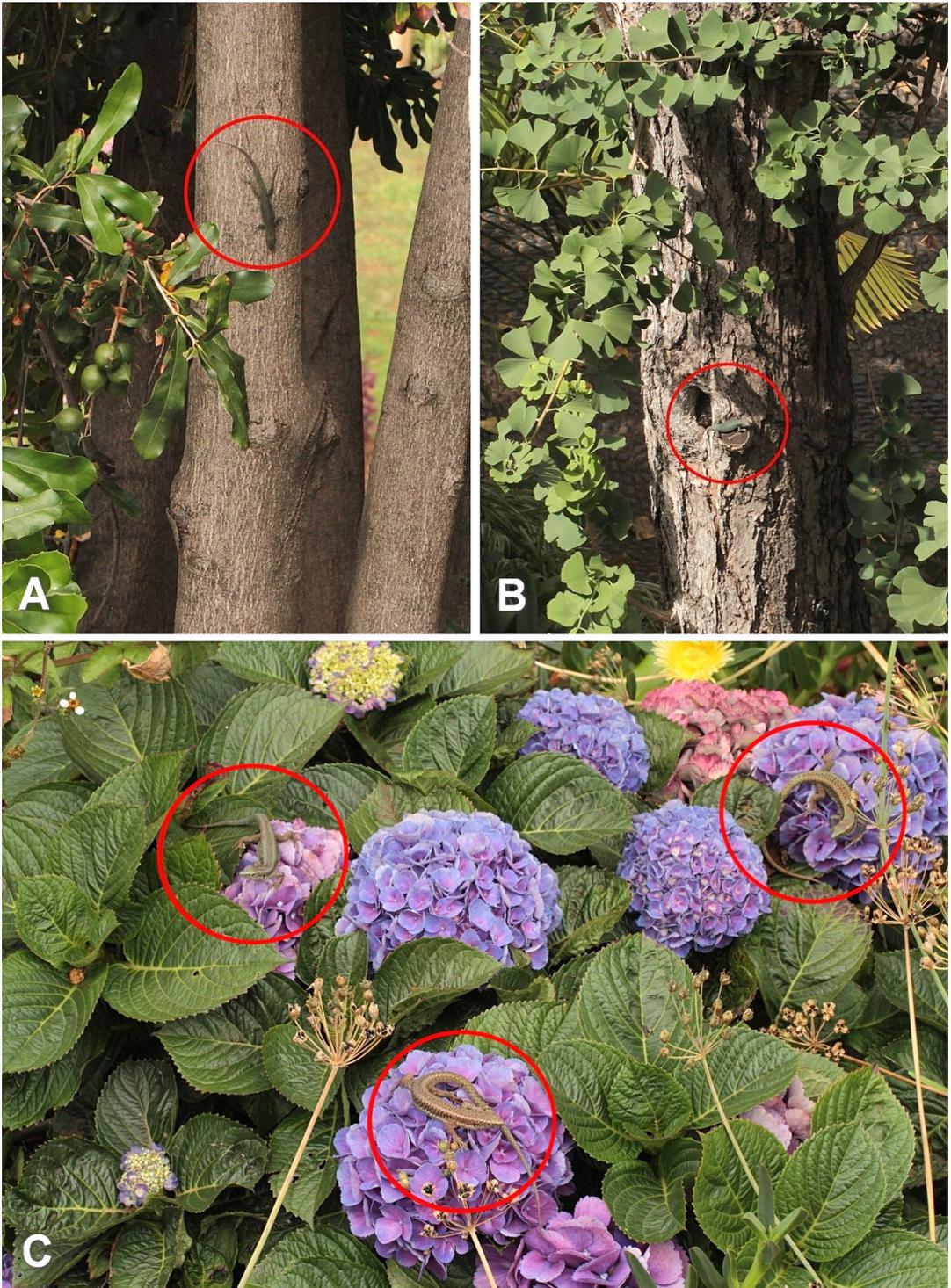


Figure 3. (A) Adult *T. dugesii* moving high in the canopy of a *Macadamia* nut tree in Jardim Municipal, Funchal, at approx. 17 m height; (B) Adult *Teira dugesii* emerging from a *Ginkgo biloba* tree cavity in Jardim Municipal, Funchal, at approx. 14 m height and (C) three adult *T. dugesii* apparently basking on *Hydrangea* bushes in cloudy weather at approx. 1.3 m height in Sao Vicente. Photos by Silviu Petrovan.

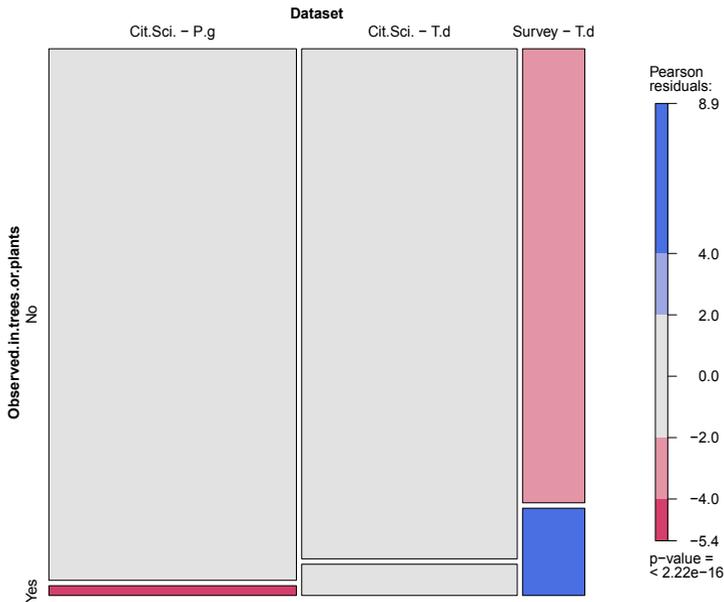


Figure 4. Comparison of arboreal observations in citizen science data for *P. gadarramae* (Cit.Sci. - P.g) with citizen science observations of *T. dugesii* (Cit.Sci. - T.d) and field surveys of *T. dugesii* (Survey - T.d). The red and pink cases indicate that the observed frequencies are smaller than the expected frequencies, whereas the blue cases means that the observed frequencies are larger than the expected frequencies. Pearson’s Chi-squared test (Pearson’s $\chi^2 = 114.57$, $df = 2$, $p < 0.001$).

midday. The need for prolonged basking by *T. dugesii* should have been minimal at this time and consequently, so should the drive to access unusual basking sites on trees. As lizard behaviour was difficult to differentiate for arboreal observations, interpretation is unclear but high lizard activity was also observed in the shaded tree sections in the canopy, suggesting basking was not the primary or sole factor. Most lizards observed in trees appeared to be moving nearly constantly, possibly in search of food. Although none were recorded feeding, this is not surprising given such observations are inherently difficult at distance, at least when focusing on invertebrate prey. However, one of the trees used by the lizards in Jardim Municipal was a Nile Tulip tree which was in bloom at the time of the surveys. The flowers were at the end of thin branches high in the canopy, and thus difficult for lizards to access as a source of pollen or nectar. However, during the surveys it was obvious that flowers were attracting numerous wasps, bumblebees, and flies. It is possible that this invertebrate concentration acted to motivate the lizards to climb high in the canopy, at over 10 m. This could be tested in further surveys by comparing tree climbing activity inside and outside the flowering period for the same trees.

While the citizen science data suggested arboreal behaviour mainly occurs on Madeira, this could be explained by the fact that it is a much larger and ecologically heterogeneous island, ranging from humid subtropical climate in the north to hot and arid in the south and east. In contrast, Porto Santo and the Desertas are mainly flat, smaller islands and almost deprived of vegetation. As the different island populations of *T. dugesii* are isolated and recognised as separate subspecies, it is unknown if tree climbing might be more prevalent on Madeira due to inherited local adaptations or simply a consequence of habitat availability, but this could be investigated using experimental setups with individuals of different geographic origin.

None of the *T. dugesii* citizen science observations from the Jardim Municipal were arboreal, even though numerous people visited the park during surveys and lizard tree climbing was extensive and easy to notice (at least under 5 m in height). This suggests that *T. dugesii* arboreality remains typically ignored and under-recorded in such datasets, likely due to the small size of lizards but also observation bias. Similar tree climbing behaviour was recently demonstrated for common toads (*Bufo bufo*) in Britain using citizen science data from surveys targeting arboreal mammals. Yet, such observations

remain absent in amphibian focused datasets due to survey method bias that excludes arboreal habitats as all UK amphibians are considered terrestrial (Petrovan et al., 2022). If tree-cavity survey data are collected on Madeira for other taxonomical groups, their exploration could include interesting data on *T. dugesii* activity in such habitat micro-niches. Targeted studies could also evaluate tree climbing by *T. dugesii* in different habitat types and seasons to better understand its drivers as well as potential geographic and genetic variation.

The observations collated here suggest a frequent and significantly higher climbing range for *Teira dugesii* compared to other lacertid species in Europe and North Africa, something that raises intriguing anatomical and morphological adaptation questions about this geographically isolated species. However, data collected by community science volunteers in arboreal settings needs to improve and include details such as observation height to be more useful. Second, tree climbing activity might have important ecological consequences in terms of diet, species interactions as well as thermal ecology for this species, which could be studied using novel tools (e.g., metabarcoding for comparisons of diet analysis). As most observations of arboreality were from urban parks, it is possible that such behaviour is driven by efforts of the lizards to avoid disturbance by humans. However, most lizards that were observed on trees in Funchal appeared accustomed to human presence and typically did not react to people walking nearby. Finally, as the Madeiran Wall Lizard has substantially expanded its range due to introductions on other islands or mainland Portugal, there is added value in better understanding its ecology and adaptive capacity in order to better quantify its invasive ecology.

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