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# Arboreal Behavior of *Psammodromus algirus* (Squamata: Lacertidae) in Olive Groves

*Ana B. Llorca, Francisco S. Tortosa, and José Guerrero-Casado*[1]

*Departamento de Zoología, Universidad de Córdoba, Edificio Charles Darwin, Campus de Rabanales, Carretera Nacional IV, km 395A, 14071 Córdoba, Spain*
*[1]Corresponding author, e-mail: jose.guerrero@uco.es*

***Abstract***.—**The Large Psammodromus (*Psammodromus algirus*) is a lizard that has flexible antipredator behavior, with a considerable preference for finding shelter in the leaf litter under short scrub, and which rarely uses tree trunks to escape from predators. Nevertheless, few works have studied the microhabitat uses and the antipredator behavior of this species in more simplified landscapes, such as agricultural areas. In this work, we studied the microhabitat use (where they were observed and to where they escaped) of the lizard *Psammodromus algirus* in two types of olive groves located in southern Spain: with herbaceous ground cover and with bare ground. We found a large number of lizards in olive trees, which were their preferred destination after fleeing behavior in both types of olive groves, although the proportion of individuals fleeing towards the trees was greater in plots with bare ground. Moreover, a large proportion of the lizards observed on the ground fled towards the olive trees, suggesting that they actively seek the trees as a place of refuge. These results suggest that the lack of suitable microhabitats proving shelter on the ground forces these terrestrial lizards to use trees, which may allow them to colonize simplified landscapes such as olive groves in which there is no alternative shelter.**

*Key Words*.—agriculture intensification; animal behavior; lizard; predation risk; reptile

## Introduction

Antipredatory behavior in reptiles, such as escaping, hiding in a refuge, or vigilance, have important costs because it reduces the time available for other activities such as basking, foraging, resting, or mating (Amo et al. 2007). That is, there is a trade-off between the benefits of obtaining food and reproduction and the cost associated with the risk of predation (Lima and Dill 1990; Cooper and Frederick 2010; Samia et al. 2016). Prey species, therefore, perceive and evaluate predation risks to select those habitats that have a high availability of both food and refuge from predators (Abrams 2000). It is for these reasons that lizard species modify their escape response depending on the habitat, thus making flexibility in their behavior a key factor (Martín and López 2000).

Reptiles are highly sensitive to modifications made to both landscape and microhabitat (Santos et al. 2014; Carpio et al. 2016; Badiane et al. 2017). Increased agricultural development has greatly modified their natural habitats, thus reducing both food and the availability of shelter, and affecting reptile abundance in different ways (Böhm et al. 2013; Carpio et al. 2021). How increased agricultural development affects the behavior of reptiles, however, has not well studied (but see Biaggini et al. 2009; Ebrahimi and Bull 2015; Simbula et al. 2022).

We studied the microhabitat use and escape behavior of the Large Psammodromus (*Psammodromus algirus*) in olive groves in southern Spain. *Psammodromus algirus* is one of the most common lacertid on the Iberian Peninsula (Salvador 2015), but its ecology in agricultural systems is relatively unknown. Although it can be found in a wide range of habitats, its abundance is affected by the quality and structure of microhabitats, particularly alterations to scrubland. It is most abundant in complex and heterogeneous habitats characterized by a dense cover of short scrub with abundant leaf litter on the ground, and it avoids both open pasture and closed woodland (Díaz et al. 2000; Godinho et al. 2011; Fernandes et al. 2019). This lizard can modify its movement patterns and escape performance depending on the predation risk assessment and the features of its microhabitat (López and Martín 2013). For instance, it can modulate its flight distance, the distance that a predator can approach before it flees, and its escape speed depending on vegetation cover, its perception of a safe refuge, and the probability of escape (Martín and López 1995, 1998, 2000; Amo et al. 2007; López and Martín 2013).

In more natural habitats, this species spends more time basking or foraging on the ground around bushes (Zamora-Camacho et al. 2014), seeking shelter in the leaf litter under scrub, and only occasionally within rock crevices (Martín and López 2000; Salvador 2015). Climbing trees to escape from predators, however, has only rarely been observed in this species. Climbing trees may be an alternative behavior for this species

to elude nearby predators that might not have been detected with sufficient time to be able to employ normal evasive action (Martín and López 2000). At the scale of microhabitats, certain characteristics such as cover or plant richness, the presence of rocks and other refuges, or exposure to the sun, may be important to determine whether an individual changes from having terrestrial behavior to arboreal behavior (Webb and Shine 1998; Kim and Holt 2012; Elzer et al. 2013).

Olive orchards are the most common woody crop on the Iberian Peninsula, and the current area devoted to olive production is of approximately 2.5 million ha (Guerrero-Casado et al. 2022a). The ground in olive orchards is typically free of vegetation and the most common practice to keeping the ground bare all year round is the intensive use of herbicides and ploughing (Carpio et al. 2017; López-Vicente et al. 2021). These conditions, therefore, reduce the shelter on the ground available to *P. algirus*. During the past decade, however, an increasing number of farmers have allowed herbaceous plants to grow around their olive trees to prevent soil erosion, and this may provide shelter and insects as prey for lizards (Rey et al. 2019; Carpio et al. 2019).

In the light of these considerations, we evaluate the microhabitat use made by *P. algirus* populations that live in simplified landscapes in which there is little shelter, as is the case of olive groves. We specifically hypothesize that their arboreal behavior is affected by the amount of bare ground. We predict that we will find lizards in olive trees significantly more often when the ground surface is bare than when it is covered by herbaceous pants.

## Materials and Methods

***Study site and experimental design***.—The study was carried out on six plots in olive groves in the province of Córdoba, southern Spain (Latitude 38.059, Longitude -4.278). The study area has a temperate climate typical of the Mediterranean region, with hot, dry summers and mild, relatively wet winters. The average annual temperature is 18º C and the average annual rainfall is 445 mm (Climate-data.org). The olive groves in this area are classified as mountain olive groves owing to the steep slopes, which make mechanization difficult. The presence of hedges, small patches of natural vegetation, stones, and dry-stone walls at the edges of the crops is relatively common in this area. All plots are formed of old olive trees (> 100 y) with two or three trunks per tree and a low tree density (the spacing between two olive trunks is approximately 10 m). Three olive groves had spontaneous (not sown) herbaceous ground cover between the rows of olive trees, which were mowed in late spring before the dry season (Fig. 1). On the other three plots, herbicides were applied to prevent the growth of herbaceous vegetation, thus keeping the ground bare throughout the year.

***Lizard sampling***.—We collected data in 2021 and 2022 by walking transects done in a zigzag pattern to reduce resightings (Carpio et al. 2015, 2017). We conducted surveys in March, April, and May of each year when the reptiles are most active and coinciding with their breeding season (Guerrero-Casado et al. 2022b). We visited each plot every two weeks during each month, walking transects eight times in 2021 and five times in 2022. We used time as the basis for transect length, and in each visit, each transect was walked for 30 min, and the total sampling effort amounted to 6.5 h of observation in each plot (39 h in total). Considering that the activity of most reptiles depends on the environmental conditions, we only walked transects on sunny days with little wind.

Whenever possible, we recorded the escape behavior for each individual lizard we encountered. We recorded the place in which the lizard was observed. After each detection, we approached the animal by walking toward it and then recorded the place to which it fled. We categorized places from which lizards fled (place of observation) as: (1) rocks or stones; (2) ground, including herbaceous ground cover; and (3) olive trees, including tree trunks and any holes or cavities. We used the same categories for the places to which they escaped and added a fourth category of no escape if the individual did not display any escape behavior.

***Statistical analysis***.—We calculated the absolute and relative frequencies of the number of individuals with

**Figure 1**. The two types of olive groves sampled, with herbaceous cover (upper) and with the bare ground (lower). (Photographed by José-Guerrero-Casado).

respect to the place of observation and that to which they escaped. This was done separately for olive groves with herbaceous ground cover and groves with bare ground. We compared the proportions of the three categories (olives, ground, and rocks) in both types of olive groves using Fisher's Exact Tests ($\alpha = 0.05$). We also made a Sankey diagram to visualize the flows from the place of observation to the place of escape.

## Results

After pooling the data obtained in the two years studied, we found 205 *P. algirus*, of which we found 47 individuals (22.9 %) in olive groves with bare ground and 158 (77.1 %) in olive groves with herbaceous ground cover. Overall, we found 68 individuals (33.2 %) on olive trees, 30 individuals (14.6 %) on rocks, and 107 (52.2 %) on the ground when first spotted. There were no significant differences in the places in which we first found individuals between olive groves with and without herbaceous ground cover (Fisher's Exact Test, $P > 0.05$; Fig. 2).

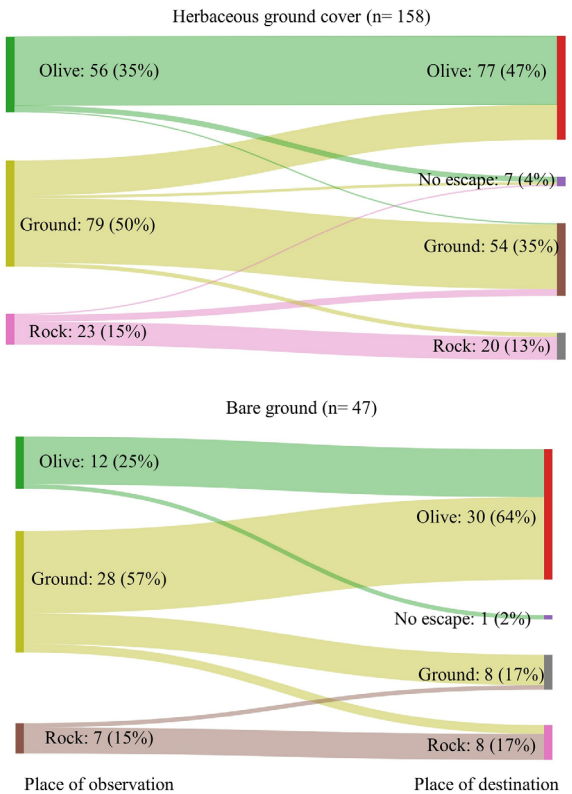


**Figure 2**. Sankey diagram showing the place in which the Large Psammodromus (*Psammodromus algirus*) individuals were observed (left) and where they escaped to (right), for olives groves with herbaceous ground cover (upper) and bare ground (lower). The numbers in brackets indicate the percentage of individuals.

Of the 205 individuals we observed, 107 (52.2 %) escaped toward the olive trees, 62 (30.2 %) toward the ground, and 28 (13.7 %) toward the rocks, while eight individuals (3.9 %) did not attempt to escape (Fig. 2). There were significant differences among the places to which lizards escaped in olive groves with herbaceous ground cover and groves without cover, with a larger proportion of individuals that fled toward the olive trees on plots with the bare ground (Fisher's Exact Test, $P = 0.046$), while a larger proportion of individuals fled toward the ground in olive groves with herbaceous ground cover (Fisher's Exact Test, $P = 0.044$). There were no significant differences between the proportion of individuals that did not escape (Fisher's Exact Test, $P = 0.685$) and those that fled toward the rocks (Fisher's Exact Test, $P = 0.471$) between grove types.

Moreover, most of the lizards observed (91.2 %) on the trunks of olive trees escaped towards holes or cavities in those trees (Fig. 2). Moreover, many individuals (42.1 %) located on the ground also escaped towards the olive trees (Fig. 2). Finally, the lizards observed on the rocks preferred to use those rocks as the place to which to escape (76.7 %).

## Discussion

We found *P. algirus* has developed an arboreal escape strategy that allows this species to colonize olive groves. Previous studies have stated that climbing a tree trunk is an unusual antipredatory strategy for *P. algirus* (Martín and López 1998; 2000) and that only those animals with a high body temperature were able to climb trees (Martín and López 2000); however, we found that a large proportion of individuals use olive tree trunks for both basking and hiding. In this simplified landscape in which the loss of habitat heterogeneity entails a loss of microhabitats for basking, foraging, and seeking shelter, the trunks of old olive trees, with their multiple holes and

**Figure 3**. A male Large Psammodromus (*Psammodromus algirus*) basking on an olive tree trunk, approximately 1.5 m above the ground. (Photographed by José-Guerrero-Casado).

cavities provide a suitable refuge. Indeed, almost half of the individuals observed on the ground fled towards the tree trunks, signifying that they actively seek this resource as a preferred refuge. Biaggini et al. (2009) also showed a clear preference for olive trees as refuges in the case of the lacertid Italian Wall Lizard (*Podarcis sicula*), even if this meant traversing a greater distance.

This arboreal behavior was more marked (in relative terms) in olive groves with bare ground than ground covered by herbaceous plants; however, a larger proportion of lizards that we found were sheltering at ground level on plots in which there was herbaceous vegetation than bare ground, thus suggesting that the lack of herbaceous plant cover may be the reason for the greater use of the trunks of olive trees. Sex, age, body condition, air temperature, and season can also affect escape behavior of lizards (Martín and López 1995; Amo et al. 2007; Iraeta et al. 2010; Zamora-Camacho et al. 2014), and further studies should, therefore, test how these variables influence the arboreal behavior of *P. algirus*. Olive groves with ground cover also harbor a more diverse reptile community than groves with bare ground (Carpio et al. 2017), but in Andalusia, which is the largest olive oil producing region in the world, most olive groves are kept with bare ground (López-Vicente et al. 2021). The use of olive trees may be true of other lizard species in Spain.

In conclusion, our results show that the lizard *P. algirus* greatly depends on the trunks of olive trees to find shelter, particularly in olive groves with bare ground. This arboreal behavior has not been reported previously. This change in the antipredatory response of this species probably allows it to persist in a simplified landscape such as olive groves.

Unfortunately, some old olive trees are being replaced with younger trees (which lack cavities in their trunks) to establish new intensive crop systems (Guerrero-Casado et al. 2021), and this may affect the capacity of *P. algirus* to avoid predation in groves with bare ground and young trees. The use of olive trees by *P. algirus* in new groves would be worth studying.

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**Ana B. Llorca** is a Biologist and is currently studying to obtain a Master's degree in Environmental Management and Biodiversity. She has also been collaborating with the research group in the Department of Zoology at Córdoba University, Spain, for several years. Thanks to this, her knowledge regarding the conservation and behavior of different animal taxa is increasing, and she intends to focus on these areas in the future. (Photographed by Carlos Molina).

**Francisco S. Tortosa** is a Biologist who has been working at Cordoba University, Spain, since 1992. He has been a full Professor in the Zoology Department at Cordoba University since 2017. His research group has been working with different taxa such as birds, mammals, lizards, and insects, focusing on the effect of agriculture methods on farmland biodiversity. His current research interests are focused on woody crops such as olive crops or vineyards, where most of the field work carried out takes place. He also has been studying game species in either forest or agricultural landscapes. (Photographed by José Guerrero).

**José Guerrero-Casado** is a Biologist with a Ph.D. in Natural Resource Management. He is currently working as an Assistant Professor in the Zoology Department at the University of Cordoba, Spain. His research focuses on the effect of agricultural practices on the diversity of vertebrates, and the conservation of wild mammals in human-modified landscapes in both Spain and Ecuador. (Photographed by Ana B. Llorca).