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Short-term effects of wildfire on Canary Islands' endemic lizards

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The Macaronesia bioregion is experiencing an increase in the intensity and magnitude of fires. However, the impact that this new fire regime may have on the endemic fauna and flora of many islands, such as those of the Canary archipelago, is unknown. In this study, we analyzed the short-term response of the Gallot's lizard, *Gallotia galloti,* to a fire that occurred in the northwestern part of La Palma in the summer of 2023. We carried out 189 linear transects in burned and unburned pine forest and summit scrub plots in June, July, and September 2024, hence, about one year after the fire. We observed a total of 333 lizards, and a Generalized Linear Mixed Model did not detect differences in lizard abundances between burned and unburned pine plots. The presence of juvenile lizards in the burned areas evidences the survival of the eggs after the fire. However, we also found a significant reduction of hatchling lizards in burned areas in September 2024, i.e. the second generation hatched after the fire, indicating that short-term postfire habitat can compromise the viability of the populations. These results suggest that the Gallot's lizard can persist in the face of fire in the short term, although postfire harsh conditions could hinder its resilience in the mid-term.

Key words: Canary Islands; lizard; short-term response; wildfire.

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In many regions of the planet, the recent decades have been characterized by an alteration in the natural fire regime (MOREIRA *et al*., 2011; PAUSAS, 2022), namely in the local characteristics of seasonality, frequency, size and intensity of fire. The causes of this trend on a global scale include climate change and, specifically, the increase in temperature, the irregularity of rain events, prolonged periods of drought, and the increased frequency and intensity of heat waves (PARISIEN *et al*., 2023). At a regional scale, socioeconomic factors, such as rural abandonment and the consequent increase in the quantity and continuity of fuel, facilitate the spread of fires (CHERGUI *et al*., 2018). These processes contribute to the occurrence of severe and large fires in areas where they were not common or during atypical periods of the year (SAYEDI *et al*., 2024).

The response of flora and fauna to fire is heterogeneous. Some species are persistent to fire (that is, at least a portion of the individuals in the affected population survive) or respond positively in the short term, favored by increased open spaces. In contrast, other species decline or disappear shortly after the fire, as they require mature, long-unburned ecosystems (VILJUR *et al*., 2022). In regions where fire has been common and recurrent, it has acted as an evolutionary driver, favoring adaptations that improve the response to fire and to the short-term postfire environmental conditions (PAUSAS & PARR, 2018; JONES *et al*., 2023). Plant species with the capacity to resprout after a fire represent good examples of this. This is the case of the Canary Islands' pine (*Pinus canariensis*) and the cork oak (*Quercus suber*). Moreover, some pine species show serotiny, a property by which plants retain seeds in the tree until the flames have passed (PAUSAS & KEELEY, 2014).

The diversity of responses to fire is also evident in some faunal groups (PAUSAS, 2019), including reptiles (SANTOS *et al*., 2025), which require habitats with thermal heterogeneity. Thus, non-tropical reptiles require a complex environmental spatial structure because this allows them to actively select thermal microhabitats during thermoregulation (HUEY, 1982). In the Western Mediterranean, the set of adaptations of reptiles against fire includes the ability to detect fire and flee or hide from the flames (ÁLVAREZ-RUIZ *et al*., 2021). Thus, some Mediterranean reptiles persist to fire in the short term (SANTOS *et al*., 2022), whereas others show population declines (COUTOURIER *et al*., 2014; SANTOS *et al*., 2016; MORENO-RUEDA *et al*., 2019). In general, saxicolous species and species from xeric environments respond positively in the short and medium term (for example, the common gecko or some wall lizards of the genus *Podarcis*; SANTOS *et al*., 2016), while those from mesic and humid environments respond negatively to early postfire ages (SANTOS *et al*., 2025). This disparity in responses, together with changes in the natural fire regime, highlights the risk that fire can pose for the conservation of reptiles not tolerant to this environmental disturbance.

In the Macaronesia bioregion, the resilience of reptiles to fire is unknown, and this is especially relevant in the western islands of the Canary archipelago where fires are frequent, mainly in pine forests. Canary pines resprout from aerial parts after fire

(Fig. 1a). This adaptation, and the finding of charcoal in the sediments prior to the first human settlements (RAVAZZI *et al.*, 2021), provides evidence that fire was a common disturbance in these islands, promoting landscape diversity (i.e. forests of Canary pine combined with open areas; RAVAZZI *et al.*, 2021). Moreover, dendrochronological studies have shown that, until the 1960s, fire events in the last 150 years were recurrent, suggesting a link with human activities (MOLINA-TERRÉN *et al.*, 2016). From 1960 onwards, the alternation of wet and dry years, and a successful implementation of a fire suppression policy, have reduced frequency but favored the occurrence of large and more intense fires (MOLINA-TERRÉN *et al.*, 2016). The two large fires in the summer of 2023 on La Palma and Tenerife (2,925 and 11,923 ha, respectively), align well with this new fire regime in the Canary Islands. Both fires burned mainly pine forest and, above 2,000 m a.s.l., scrub or summit broom, all of them classified as natural habitats of community interest in the Macaronesian region (BARTOLOMÉ *et al.*, 2005).

The genus *Gallotia* (fam. Lacertidae) includes lizard species endemic to the Canary archipelago. *Gallotia* lizards have similar life history traits to some Mediterranean lacertid species (e.g. similar morphology, thermic behavior, reproduction by oviparity, and saxicolous habits), but they also present distinctive traits due to their insular endemicity, such as an omnivorous diet, a high population density, and a low clutch size (DE LOS SANTOS & DE NICOLÁS, 2008). In La Palma, there is a single species of lacertid lizard, *Gallotia galloti* (Oudart, 1839), a very abundant and widely distributed species across the habitats of this island. It prefers open habitats (including clearings within the forest matrix, and agriculture and forest margins) with rock piles, bushes and grasslands. This species predominantly consumes plant material, with an increased proportion of arthropod consumption in the winter (VALIDO & NOGALES, 2003; VALIDO *et al.*, 2003). Indeed, *G. galloti* has been described as a seed disperser and pollinator of certain plants (VALIDO & NOGALES, 1994; RODRÍGUEZ *et al.*, 2008). Due to their omnivorous habits, the response of *G. galloti* populations to fire may depend on the regeneration capacity of the plant species in the area (i.e. seeder and/or resprouter), as well as on the fire persistence and recolonization capacity of the arthropod prey that they consume.

Although the fire that occurred in the summer of 2023 in the northwestern area of La Palma affected the lizard populations, their persistence towards the fire and their short-term viability are unknown. Hence, the main objective of this work was to evaluate the effect of this fire on the populations of *G. galloti* from La Palma. To do so, we performed visual transects in burned and unburned pine forest and summit scrub plots about one year after the fire. The comparison of relative abundances of lizards in burned and unburned plots allowed the identification of short-term negative or positive responses to fire by this endemic lizard from La Palma.

MATERIALS AND METHODS

We designed a total of 63 transects for sampling lizards, 33 of them along sections of trails and unpaved tracks in burned

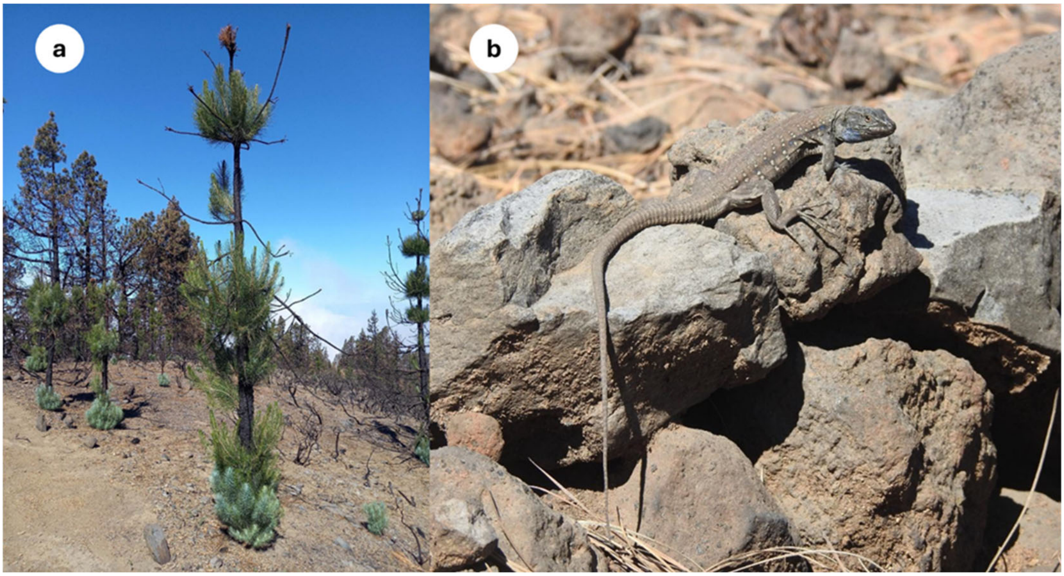

Figure 1: (a) Canary pine resprouting epicormically after La Palma fire (August 2023). (b) Adult male lizard, *Gallotia galloti*, in one of the burned transects on La Palma. Photographs were taken in June and May 2024, respectively.

pine forest and summit scrubland habitats, and 30 transects in similar unburned habitats on the periphery of the burned ones. The 63 transects were surveyed three times over the course of the study, in June, July, and September 2024, and conducted by slowly walking for 15 min along the transect. We recorded the number of lizards, and their age class (hatchling, juvenile or adult) based on a visual estimation of their snout-vent-length (SVL) since adults are larger than 75 mm SVL, whereas juveniles (approximately one-year-old lizards) are smaller than this size. Hatchling lizards were approximately 32-43 mm SVL and had a different dorsal pattern than larger individuals (SALVADOR, 2015). Because hatching occurs by the end of the summer, this lizard category was only recorded in transects performed in September.

The number of lizards observed between burned and unburned areas was compared using a Generalized Linear Mixed Model (GLMM) considering a Poisson residual distribution with log as link function. The model residual distribution complied with the parametric assumptions of kurtosis and skewness. Month (June, July, and September), treatment (burned vs. unburned), habitat type (pine forest vs. summit scrub), and transect type (trail or track) were included as fixed factors. The interaction between treatment and habitat was also analyzed, in order to check if the impact of fire on lizard populations was different between the pine forest and the summit scrub. The observer and the transect code were included as random factors in the model.

Given that the sampling effort was very similar in unburned and burned areas, the total number of juveniles between both treatments was compared by chi-square (χ^2) tests in June and July. In September,

Table 1: Results of the Generalized Linear Mixed Model to analyze whether the abundance of lizards on La Palma differed between the treatments (burned / unburned), habitat types (summit scrub / pine forest), transect types (trail / track), months, and the interaction Treatment * Habitat, almost one year post-fire. Significant effects are shown in bold. Random effects of observer and transect code were included in the model and their effects are not shown in the table. df: degrees of freedom.

Factors	df	χ^2	p
(Intercept)	1	2.18	0.139
Treatment	1	0.83	0.363
Habitat	1	0.09	0.758
Transect	1	5.37	**0.020**
Month	2	12.44	**0.002**
Treatment * Habitat	1	4.08	**0.043**

we performed a similar test only considering new hatchling lizards that were visually identified by their small size (SVL = 32-43 mm; SALVADOR, 2015) and differential color pattern.

RESULTS

We observed a total of 333 lizards, 164 in unburned plots and 169 in burned plots (Fig. 1b). In 54 of the transects, no lizards were observed (30 in burned areas and 24 in unburned areas). The registered maximum number of lizards per transect was 12 in a transect of the burned area. The mean ± standard deviation number of observed lizards did not significantly differ between burned (1.74 ± 2.19 lizards) and unburned (1.82 ± 1.77 lizards; Table 1) treatments. However, there was a significant interaction between habitat type and treatment. Thus, the number of lizards was not affected by fire in the woodlands, but was lower in the burned compared to the unburned scrub plots (Table 1, Fig. 2). There were also significant effects of transect type (trail = 1.44 ± 1.51; track = 2.20 ± 2.40) and month (June = 2.04 ± 1.94; July = 2.00 ± 2.32; September = 1.29 ± 1.60) (Table 1) on the number of lizard observations.

In June and July, we observed 30 juvenile lizards in unburned areas (25.6% of the observed lizards), and 31 in burned areas (22.8%). Due to their size, these individuals were less than one year old, and therefore they hatched from eggs that survived the fire (e.g. protected beneath stones or in the ground). Differences in the number of juveniles between burned and unburned areas in June and July were not significant (χ^2 = 0.28, 1 df, p = 0.6). However, we observed a significantly higher number of hatchling lizards in September (hatched from eggs laid in spring 2024) in unburned (63.8%; n = 30) than in burned plots (18.2%; n = 6) (χ^2 = 16.32, 1 df, $p < 0.001$).

DISCUSSION

Our results indicate that, in the short term, the populations of *G. galloti* on La Palma resisted the fire, with lower lizard abundance observed after the fire only in summit scrub plots. Overall, our results suggest a low mortality due to the 2023 fire. Animal mortality due to fire is still poorly studied in many taxonomic animal groups, although it appears to be elevated after highly severe fires (JOLLY *et al*., 2022). In the short term, the animals' response may be associated with their ability to

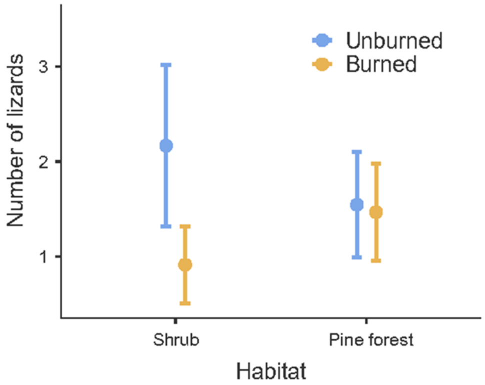

Figure 2: Plot showing the significant interaction found between habitat type and fire treatment on the total number of recorded lizards per transect during the census in La Palma.

move. While many slow-moving animals, such as terrestrial gastropods, survive in refuges within burned areas (SANTOS *et al*., 2009), others, such as open-habitat birds, can easily move to burned areas if the habitat structure is favorable (WATSON *et al*., 2012; PUIG-GIRONÈS *et al*., 2022). Reptiles generally show a limited recolonization capacity, but notable resilience in burned areas (SANTOS *et al*., 2022), although some fire events can result in high lizard mortality rates (GONZÁLEZ-FERNÁNDEZ *et al*., 2024). The presence of less than one-year-old juvenile lizards in the burned areas during June and July suggests that eggs laid before the fire could have survived. The colonization of juveniles from unburned areas peripheral to the fire cannot be ruled out, as it has been seen in small mammals (PUIG -GIRONÈS & PONS, 2023). However, the presence of juveniles in plots far from the fire edge (up to 1.5 km) argues for survival, and not recolonization, to explain their presence one year postfire.

The observed persistence in the face of fire by lizard populations on La Palma has previously been demonstrated in Mediterranean reptiles (SANTOS *et al*., 2016, 2025), particularly, in saxicolous species that often occupy rock accumulations of natural or anthropogenic origin. These low-flammable structures provide refugium to the Canary lizards during fires, as reported for other reptiles in a before-after fire study (SANTOS *et al*., 2016). In fact, *G. galloti* is known to use rocks more frequently than bare ground (VALIDO & NOGALES, 1994), especially for thermoregulation (DÍAZ, 1994). Given the volcanic nature of the study area, rocks were everywhere, although transect selection was not done according to the presence of rocky spots.

Our study only describes the short-term (about one year) response of *G. galloti* to fire. The reduced proportion of hatchlings in the burned areas in September, one year after the fire (i.e. the second generation of lizards hatched after the fire), suggests that the postfire environmental conditions for these omnivorous animals, and specifically the low availability of plant trophic resources (in many places only regrowth of Canary Island pine was observed; Fig. 1a), may have negatively influenced its reproductive success. The absence of plant regeneration in the summit scrub (Fig. 3) may have caused the reduction of the number of lizards in burned compared to unburned summit scrub plots. Most reptile species are capital breeders, that is, they rely on stored fat in the body to reproduce (PRICE, 2017). This is especially important for females, which have the primary energetic cost in reproduction. Long periods of low food availability can prompt female reptiles to modu-

Figure 3: Burned summit scrub in La Palma 10 months after the 2023 fire. Notice the absence of plant regeneration.

late the investment of fat into follicles (Blackburn, 1998), and to finally induce variation in the reproduction output (Santos & Llorente, 2004). This could be the case for females of *G. galloti* in the burned areas from La Palma. The apparent scarcity of plant resources observed in the burned areas poses an uncertain fate for the medium-term viability of these omnivorous lizard populations.

Another interesting result of this study is the presence of *G. galloti* lizards in the pine forest. *A priori* this is an unsuitable habitat for them due to the dense tree cover (Azor *et al*., 2015), low solar radiation at ground level, and reduced herbaceous/shrub plant community. These factors can hinder the thermoregulation of lizards and limit the availability of plant trophic resources. The presence of these reptiles in the pine forest could be explained by the low density of pine trees in some parts of the studied area, and also by the used sampling method, focused on trails and tracks that open the forest matrix, facilitating the access of lizards to new microhabitats where they can bask and find shelter in the stones of the margins (Delgado-García *et al*., 2007). The burned pine forest, especially in areas with a high pre-fire density of trees, could provide a window of opportunities for Canary reptiles, at least during a period in which the vegetation cover is relatively low.

Irl *et al*. (2014) reported that plant species with a postfire germinating strategy increased six years after a forest fire in La Palma, a fact that could increase the available plant items for lizards to eat, and thus favor lizard populations' postfire persistence in burned plots. Accordingly, it is critical to continue monitoring in parallel the postfire dynamics in vegetation recovery and lizard abundance over long periods. This surveillance is crucial to understand how lizard populations develop in a rapidly changing environment and to identify possible challenges in their recovery, anticipating future episodes of high-severity fires. Monitoring is especially important in summit scrubland habitats where intense and large fires can potentially pose at risk the conservation of *G. galloti* populations. In addition, monitoring also allows us to establish and evaluate the effectiveness of conservation practices and adequately manage the habitat to ensure the survival of these species in the future.

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