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SHORT COMMUNICATION

Potential role of lava lizards as pollinators across the Galápagos Islands

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Abstract

Lizards have been reported as important pollinators on several oceanic islands. Here we evaluate the potential role of Galápagos lava lizards (*Microlophus* spp.) as pollinators across their radiation. Over 3 years, we sampled pollen transport by 9 lava lizard species on the 10 islands where they are present, including 7 single-island endemics. Overall, only 25 of 296 individuals sampled (8.4%) transported pollen of 10 plant species, the most common being *Prosopis juliflora*, *Exodeconus miersii*, *Sesuvium* sp. and *Cordia leucophlyctis*. At least 8 of these plant species were native, and none were confirmed as introduced to the archipelago. Despite the low overall proportion of individuals carrying pollen, this was observed in 7 of the nine lizard species, and on 8 of the ten main islands (Española, Fernandina, Floreana, Isabela, Marchena, Pinta, Santa Cruz and Santiago), suggesting that this is a widespread interaction. The results reported here support the potential role of lava lizards as pollinators across their radiation, although they may represent a relatively modest contribution when compared with birds and insects. However, we cannot discard that lizards may be ecologically significant for particular plant species and ecosystems given the specific climatic condition and functional diversity of each island.

Key words: flower visitation, *Microlophus* spp., mutualistic interactions, pollination, vertebrate radiation

INTRODUCTION

The Galápagos lava lizards (*Microlophus* spp., Tropiduridae) constitute a remarkable vertebrate radiation that resulted in 10 currently recognized species, of which 8 are single-island endemics (Benavides *et al.* 2009). Of the 10 species, 3 have already been recorded to visit the flowers of 13 plant species on the islands of Pinta, Española and Daphne Major (Werner 1978; Schluter 1984; East 1995). Floral resources, such as pollen and nectar, can be energetically important for lizards when alternative sources of protein, such as arthropods, are scarce (Olesen & Valido 2003; Rodríguez-Rodríguez *et al.* 2013). By feeding on floral resources, lizards can

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transport pollen and act as pollinators (Traveset & Sáez 1997; Gomes *et al.* 2014). The role of lizards as pollen transporters has never been reported across an entire vertebrate radiation. Therefore, we aimed to quantify pollen transport by all lava lizard species, except one which has been recently discovered (*M. barringtonensis* on Santa Fe island), on the main Galápagos Islands. Studies on plant–animal interactions at an archipelago scale (despite being scarce) are essential to identify key ecological links and drivers of functional shifts in insular biodiversity (Traveset *et al.* 2015; Heinen *et al.* 2018; Hervías-Parejo *et al.* 2018).

MATERIALS AND METHODS

Ten Galápagos Islands (Table 1) were visited between 2014 and 2016, from February to May coinciding with the peak flowering time. Sampling was conducted in the arid vegetation zone (approximately 0–300 m a.s.l.) where lizards are common (Tanner & Perry 2007). This zone is the most biodiverse and most plant species have broad distributions across the archipelago (Heleno & Vargas 2015). An area of approximately 1 km^2 was prospected on each island by 2 observers until at least 20 individuals were captured, which usually took 3 to 5 h. Captures were done near flowering species during mid-morning and mid-afternoon, when lizards are most active (Stebbins *et al.* 1967). A total of 296 lizards of both sexes were captured by hand with noose poles and marked with a temporary spot of nail polish (Rosier *et al.* 2011) to avoid resampling the same individual. Each lizard captured was inspected for pollen load by swabbing a single 3-mm^3 cube of glycerine jelly stained with fuchsine on their snouts, neck and forehead (Table 1). The gelatine cube was then placed on a microscope slide, covered, melted by a weak heat source and sealed with clear nail polish. Pollen grains were later identified under a light microscope using a reference collection (Jaramillo & Trigo 2011). Results are expressed as the percentage of samples containing at least 5 pollen grains of any plant species and as the number of pollen grains of each plant species. Fewer than 5 pollen grains of the same species was considered contamination (see Banza *et al.* 2015; da Silva *et al.* 2017).

RESULTS AND DISCUSSION

Overall, 8.4% (n = 25) of the individuals sampled were found to transport more than 5 pollen grains of any plant species (mean = 7.4, median = 2, maximum = 126 pollen grains; n = 296 samples), of which all except 2 individuals transported pollen grains of just 1 species. The proportion of samples with pollen across islands ranged from zero on Pinzón and San Cristóbal to 33% on Pinta. In total, 521 pollen grains of 10 plant species were identified, of which at least 8 are native. Only 11 pollen grains of 2 species morphotypes, *Chamaesyce* and Poaceae spp., could not be classified confidently

Table 1 Number of pollen samples collected from lava lizards (*Microlophus* spp.) on the main Galápagos Islands, from February to May in 2014, 2015 and 2016

Island	Species	*n* samples		% sample with pollen
		Females	Males	
Española	*M. delanonis*	15	15	16.67
Fernandina	*M. albemarlensis*	18	11	3.45
Floreana	*M. grayii*	13	16	3.45
Isabela	*M. albemarlensis*	17	17	2.94
Marchena	*M. habelii*	15	16	16.13
Pinta	*M. pacificus*	11	10	33.33
Pinzón	*M. duncanensis*	25	16	0.00
San Cristóbal	*M. bivittatus*	20	21	0.00
Stanta Cruz	*M. indefatigabilis*	8	12	20.00
Santiago	*M. jabobi*	8	12	5.00
		Total	296	

Samples with fewer than 5 pollen grains of the same species were discarded.

as belonging to native or introduced species, due to the similarity of the pollen grains within these genera. Of the nine lava lizard species, 7 carried pollen on 8 of the 10 islands sampled (Table 2). Pollen of *Prosopis juliflora*, *Exodeconus miersii*, *Sesuvium* sp. and *Cordia leucophlyctis* were the most frequently carried by lizards. During our fieldwork on Pinta we also observed lizards feeding on flowers of species with large pollen grains, namely *Opuntia galapageia* (Fig. 1) and *Ipomea* spp., although we do not know to what extent the pollen of these species can remain attached to the smooth skin of lizards. Size constraints, accessibility and phenological uncoupling shape interaction patterns (Sankamethawee *et al.* 2011) and likely explain why some types of pollen are more frequently carried by lava lizards than others. Phenotypic trait matching in particular deserves attention in future research in the Galápagos as it can be an important driver of plant–pollinator interactions (Biddick & Burns 2018).

Overall, lizards appear to have a relatively modest contribution to pollen transport within the Galápagos flora when compared to birds, the only other class of vertebrate pollen vector in the archipelago (mean = 233, median = 5, maximum = 20.1 pollen grains per individual, 106 plant species dispersed; n = 769 samples [Traveset *et al.* 2015]). Even if the contribution of lizards to pollen transport is quantitatively modest, it might still be ecologically important for some plant species. Therefore, future research should be directed towards evaluating whether pollen transport by lizards results in ef-

Figure 1 The lava lizard *Microlophus pacificus* feeding on pollen and nectar in the flowers of the prickly pear cactus *Opuntia galapageia* on the island of Pinta. Clockwise from upper left: climbing the trunk (photo: MN), nectar feeding (photo: JMO), nectar feeding (photo: RH) and nectar feeding (photo: JMO).

Table 2 Number of pollen grains per plant species transported by lava lizards (*Microlophus* spp.) on the main Galápagos Islands, from February to May in 2014, 2015 and 2016

Island	Pollen species	Family	Origin	n pollen grains	% sample with pollen	
					Females	Males
Española	*Prosopis juliflora*	Mimosaceae	Native	204	1	3
	Sesuvium edmondstonei	Aizoaceae	Native	5	1	0
Fernandina	*Cordia leucophlyctis*	Boraginaceae	Endemic	18	0	1
Floreana	*Sesuvium* sp.	Aizoaceae	Native	5	1	0
Isabela	*Maytenus octogona*	Celastraceae	Native	10	1	0
Marchena	*Cordia leucophlyctis*	Boraginaceae	Native	61	1	4
Pinta	*Chamaesyce* sp.	Euphorbiaceae	Unknown	6	1	0
	Exodeconus miersii	Solanaceae	Native	105	3	1
	Poaceae	Poaceae	Unknown	5	0	1
	cf. *Bursera graveolens*	Burseraceae	Native	6	0	1
Stanta Cruz	*Sesuvium* sp.	Aizoaceae	Native	90	3	1
Santiago	*Heliotropium angiospermum*	Boraginaceae	Native	6	1	0
			Total	521	13	12

During our fieldwork on Pinta we also observed lizards feeding on flowers of *Opuntia galapageia* and *Ipomea* spp.; however, these 2 species were not in the pollen samples.

fective cross-pollination or in floral larceny (i.e. the removal of floral reward without provision of pollination service). At least on some oceanic islands with depauperate pollinator faunas, lizards have been reported to contribute to pollination success (Olesen & Valido 2003; Fuster & Traveset 2019). If effective transfer of pollen onto stigmas results in pollination, *M. habellii* on Marchena and *M. pacificus* on Pinta would act as both pollinators and seed dispersers of *Cordia leucophlyctis* and *Bursera graveolens*, respectively (see Hervías-Parejo *et al.* 2018). In other words, we hypothesize that these lizard species could fit into the concept of double mutualism, similar to that already described between some Galápagos birds and plants (Olesen *et al.* 2018).

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