

**POLLEN LOAD AND TRANSPORT BY THE INSULAR LIZARD,
PODARCIS LILFORDI (SQUAMATA, LACERTIDAE) IN COASTAL ISLETS
OF MENORCA (BALEARIC ISLANDS, SPAIN)**

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ABSTRACT

An analysis of pollen grains loaded and transported by the Balearic lizard, *Podarcis lilfordi*, at three coastal islets of Menorca (Balearic Islands, Spain) was performed. We studied 228 individual lizards from spring and summer, 1998, recording 323,986 pollen grains belonging to 35 different plant species. As a consequence of its foraging behavior, the Balearic lizard is able to load large quantities of pollen. In Aire Island pollen load was higher in adult females than males. *P. lilfordi* is an important pollen loader of some plant species such as *Pistacia lentiscus*, *Crithmum maritimum*, *Allium ampeloprasum*, *Carlina corymbosa*, and *Pancreatium maritimum*. The role of *P. lilfordi* as the main pollinator has been previously demonstrated only for the sea fern, *C. maritimum*. However, results reported here indicate that the Balearic lizard can play an important role in the reproductive success of other plant species on coastal islets off the main island of Menorca.

INTRODUCTION

The role of lizards in plant pollination has been suggested frequently (Elvers, 1977, 1978; Whitaker, 1987a,b; Sáez and Traveset, 1995). However, it has only recently been demonstrated that the Balearic lizard, *Podarcis lilfordi*, is the pollinator of two plant species. The evidence came from two different locations of the Balearic Islands (Spain) and involved two plant species, *Crithmum maritimum*, an Umbelliferae from Sanitja Island in Menorca (Pérez-Mellado and Casas, 1997) and *Euphorbia dendroides* (Euphorbiaceae), from the archipelago of Cabrera (southeastern Mallorca; Traveset and Sáez, 1997). The components of this pollination syndrome are almost unexplored (Pérez-Mellado and Traveset, 1999).

Pollen load is one of these components, part of the so-called “pollination quality” (Dafni, 1992), even if heavily loaded pollinators are not always the most efficient ones. Several lizard species have been recorded feeding on flowers (Henle, 1984; Whitaker, 1987a,b; Pérez-Mellado, 1989; Beyhl, 1990, 1997; Sáez and Traveset, 1995), but

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relatively little information is available on the pollen load capacity of lizards as potential pollinators. Whitaker (1987a,b) observed pollen loads of gekkonid lizards from New Zealand. Traveset and Sáez (1997) recorded an average of 209 pollen grains of *E. dendroides* on the snouts of three individuals of *P. lilfordi* from Cabrera and observed that pollen grains were more abundant on the ventral part of the snout. Pérez-Mellado and Casas (1997) indicated that 20 lizards from Sanitja Island also loaded large quantities of pollen grains of the sea fern, *C. maritimum*.

Podarcis lilfordi (Günther, 1874) (Squamata, Lacertidae) is an endemic lacertid lizard inhabiting the archipelago of Cabrera and the coastal islets of Mallorca and Menorca (Balearic Islands, Spain). Similar to other species of lacertid lizards from the Mediterranean basin (see Pérez-Mellado and Traveset, 1999 and references therein), its diet includes a large proportion of vegetal matter (Pérez-Mellado, 1989; Pérez-Mellado and Corti, 1993). During spring and summer, Balearic lizards spend a significant proportion of their foraging activity on plants (Pérez-Mellado, 1989; Pérez-Mellado and Casas, 1997), playing an important role as pollinators and seed dispersers (Castilla, 1999).

In this study, we demonstrate the role of *P. lilfordi* as pollen loader and transporter in small islets off the coast of Menorca. We tested for pollen load at three different islets: Sanitja, where lizard pollination was experimentally demonstrated (Pérez-Mellado and Casas, 1997); Aire, where there is wide use of plant material as a food resource (Pérez-Mellado and Corti, 1993; and Rei.

MATERIAL AND METHODS

We studied 228 adult lizards in spring and summer, 1998, from three islets around Menorca: Aire (80 males and 54 females), Rei (30 males and 24 females), and Sanitja (23 males and 17 females, including a sample of 19 individuals in 1994 from this islet, see below; for a detailed description of these islands see Pérez-Mellado, 1989).

For Aire Island, we included samples from April, June, July, and August. Pollen was collected at different hourly intervals (0800 to 1600 for Aire Island, 0700 to 1700 for Rei Island, and 1000 to 1500 for Sanitja Island). Lizards were noosed with a pole. Pollen was removed employing three clear adhesive (Scotch) tape strips on the three body regions sampled. One tape was carefully extended over the back (dorsal sample), from the tip of the head to the base of the tail. A second tape was applied from the neck to the cloaca, over the belly (ventral sample), and the third tape was extended over the throat surface (gular sample), from the neck to the ventral side of the snout. The strips were placed directly onto a microscope slide for identification under an optical microscope (10× and 40×). Lizards were released immediately after sampling. In the case of Sanitja Island, we included an additional sample of 19 individuals checked in August 1994 with only one Scotch tape strip from the cloaca to the end of the back, between the hind legs. Due to these different sampling techniques, we did not combine the samples from Sanitja Island in the comparative analyses.

The limited plant diversity at each islet and a previous study of plant diversity (De la

Torre and Vicedo, unpublished data) simplified pollen identification. Using our sampling technique, no staining of pollen grains was possible. In spite of this, it was possible to identify pollen grains, in several cases to species level (see a similar approach in Feinsinger, 1992).

Data were analyzed using the SPSS package. Logarithmic transformations were used to normalize data when required.

RESULTS

Pollen load is notably different at the three islets under study. At Rei Island, we detected pollen of at least 19 vegetal taxa (Table 1), but in all cases with small pollen quantities ($n = 252$ pollen grains). The most important plant species was *Pistacia lentiscus*, habitually consumed by lizards (Table 1 and Pérez-Mellado et al., unpublished data). In Aire Island we observed a high plant diversity, but pollen numbers were dominated by the sea fern, *Crithmum maritimum* (Table 1). In Sanitja Island, two plant species were important, the sea fern, with a mean pollen load of $\bar{x} = 6730.8 \pm 2146.7$ (SEM) pollen grains per individual lizard (range: 1–60378, including the two samples of 1994 and 1998) and the endemic Liliaceae, *Allium ampeloprasum* (Table 1). Both plant species are part of the normal food of Balearic lizards in Sanitja Island. The case of *A. ampeloprasum* is also interesting because its long thin stalk normally precludes its consumption by lizards, unless the plant is blown or knocked down by wind, etc. In Sanitja, pollen load was only studied in two months, July and August. We found significantly higher pollen load during August (July: $\bar{x} = 373.3 \pm 118.8$, $n = 13$, range: 1–1201; August: $\bar{x} = 10863 \pm 3243.4$, $n = 20$, range: 233–60378; Mann–Whitney test, $U = 6.0$, $p < 0.001$).

Regarding sex differences, pollen load is normally higher in adult females from Aire and Sanitja islands (Table 2), where *C. maritimum* is the dominant plant species. In Aire, these differences are statistically significant at dorsal and gular regions. No difference was detected for Rei Island.

DAILY ACTIVITY OF LIZARDS AND POLLEN LOAD

At Aire Island, we found a significant correlation between hour of the day and quantity of pollen loaded on the ventral ($R = 0.48$, $p < 0.01$, $n = 80$ for males and $R = 0.66$, $p < 0.01$, $n = 54$ for females), gular ($R = 0.46$, $p < 0.01$ for males and $R = 0.55$, $p < 0.01$ for females), and dorsal (excepting, in this case, the sample of males, $R = 0.36$, $p > 0.05$ and $R = 0.63$, $p < 0.01$ for females) regions.

If we analyze total pollen load of *C. maritimum* alone, we obtain similar results ($R = 0.66$, $p < 0.01$, $n = 134$) and significant differences in number of pollen grains loaded during each hourly interval (one-way ANOVA, $F = 5.06$, $p = 0.0003$). The a posteriori Duncan test indicates that differences correspond to the highest values of the interval from 1400 to 1500 hours (GMT). Consequently, pollen load takes place mainly during the first hours of the afternoon. In Sanitja Island, we observed the same significant correlation between hourly interval and pollen load, with the peak load from 1330 to 1430 ($\bar{x} = 11260 \pm 4462.9$ pollen grains, range: 216–60378).

Table 1

Pollen load (counted pollen grains) in *Podarcis lilfordi* from three islets around Menorca (Balearic Islands). The asterisk indicates that the plant species is also consumed by the lizard, according to fecal analyses (Pérez-Mellado et al., unpublished data). The sample of 1994 from Sanitja Island is also included (see text for more details). Small quantities of pollen grains (<10) could have an airborne origin

Plant species	Family	Aire	Sanitja	Rei
<i>Chenopodium murale</i>	Chenopodiaceae	51		
<i>Urtica membranacea</i>	Urticaceae	3		
<i>Capparis inermis</i>	Capparaceae			3
<i>Sedum rubens</i>	Crasulaceae			1
<i>Tamarix africana</i>	Tamaricaceae	1*		
<i>Ononis crispa</i>	Leguminosae	3		
<i>Medicago littoralis</i>	Leguminosae	12*		1
<i>Euphorbia</i> sp.	Euphorbiaceae	22*		2
<i>Anagalis arvensis</i>	Primulaceae	12		
<i>Mesembrianthemum crystallinum</i>	Aizoaceae	3		
<i>Pistacia lentiscus</i>	Anacardiaceae	893*		186*
<i>Erodium</i> sp.	Geraniaceae	78		
<i>Geranium rotundifolium</i>	Geraniaceae	11*		1
<i>Crithmum maritimum</i>	Umbelliferae	96536*	222115*	
<i>Umbelliferae</i> undet.		1		12
<i>Limonium</i> sp.	Plumbaginaceae	14		
<i>Olea europaea</i>	Oleaceae	3		
<i>Solanum nigrum</i>	Solanaceae	*		4*
<i>Veronica hederifolia</i>	Scrophulariaceae			1
<i>Heliotropum</i> sp.	Boraginaceae			1
<i>Ajuga iva</i>	Labiatae	*		3
<i>Lonicera japonica</i>	Caprifoliaceae			1
<i>Ecballium elaterium</i>	Cucurbitaceae			8
<i>Calendula arvensis</i>	Compositae	22		
<i>Carlina corymbosa</i>	Compositae	741*		4
<i>Silybum marianum</i>	Compositae		1	
<i>Senecio</i> sp.	Compositae	2		
<i>Compositae</i> undet.		11	4	
<i>Tamus communis</i>	Dioscoriaceae			1
<i>Poa annua</i>	Poaceae	3		
<i>Allium ampeloprasum</i>	Liliaceae	19*	2899*	2
<i>Asphodelus aestivus</i>	Liliaceae	4*		3
<i>Liliaceae</i> undet.		28		16
<i>Narcissus tazetta</i>	Amaryllidaceae			2
<i>Pancreatium maritimum</i>	Amaryllidaceae	237*	7	

Table 2

Pollen load at each body region (mean number of pollen grains per individual \pm SEM). One-way ANOVA tests indicate differences between male and female pollen load. In this comparison, we excluded the 1994 sample from Sanitja Island (see text for more details)

Body region	Aire		Rei		Sanitja	
	i	i TM i TM	i	i TM i TM	i	i TM i TM
Dorsal	15.6 \pm 3.2	59.44 \pm 19.68 <i>F</i> =5.57, <i>p</i> =0.02	1.53 \pm 0.62	1.87 \pm 0.89 <i>F</i> =0.023, <i>p</i> =0.87	56.5 \pm 17.5	209.3 \pm 88.8 <i>F</i> =3.26, <i>p</i> =0.08
Ventral	118.1 \pm 58.2	719.8 \pm 379.0 <i>F</i> =1.82, <i>p</i> =0.17	1.56 \pm 0.81	3.04 \pm 2.37 <i>F</i> =1.17, <i>p</i> =0.29	158.8 \pm 81.2	136.3 \pm 66.5 <i>F</i> =0.22, <i>p</i> =0.63
Gular	112.0 \pm 66.1	587.3 \pm 233.0 <i>F</i> =5.71, <i>p</i> =0.01	1.10 \pm 0.65	0.25 \pm 0.17 <i>F</i> =1.36, <i>p</i> =0.28	114.3 \pm 43.4	180.1 \pm 67.5 <i>F</i> =2.88, <i>p</i> =0.10

Table 3

Variation of pollen load of *Podarcis lilfordi* adult females from Aire Island. Number of lizards within parenthesis. For each body region, we give the mean \pm SEM and the range. We show the results of monthly comparisons made with a Kruskal–Wallis analysis

Month	Dorsal	Ventral	Gular
April (11)	6.3 \pm 2.1 (0–23)	2.2 \pm 0.8 (0–9)	2.2 \pm 0.9 (0–10)
June (2)	8.0 \pm 6.0 (2–14)	27.5 \pm 22.5 (5–50)	5.5 \pm 0.5 (0–11)
July (10)	6.9 \pm 2.3 (0–25)	4.3 \pm 0.5 (1–7)	8.1 \pm 4.5 (0–48)
August (31)	98 \pm 32.7 (0–645)	1250 \pm 648.2 (0–15921)	1019.2 \pm 390.5 (0–10700)
Total (54)	59.4 \pm 19.6	719.8 \pm 379 (0–15921)	587.3 \pm 233 (0–10700)
Kruskal–Wallis analysis	$\chi^2 = 4.025, p = 0.25$	$\chi^2 = 16.38, p = 0.0009$	$\chi^2 = 14.94, p = 0.002$

SEASONAL EFFECTS

No monthly difference was detected in total pollen load for dorsal (one-way ANOVA of log-transformed data, *F* = 2.41, *p* = 0.07), gular (Kruskal–Wallis analysis, $\chi^2 = 0.81$, *p* = 0.85), and ventral (Kruskal–Wallis analysis, $\chi^2 = 5.79$, *p* = 0.12) samples of the males of Aire Island. Similarly, no differences were found in females for dorsal pollen load (Kruskal–Wallis analysis, $\chi^2 = 4.03$, *p* = 0.26), but we detected highly significant differences between months for ventral ($\chi^2 = 16.39$, *p* = 0.0009) and gular ($\chi^2 = 14.95$, *p* = 0.002) samples. These results are due to the load of *C. maritimum* pollen grains during July and August, the two months of blooming of the sea fern (Table 3).

DISCUSSION

Although Elvers (1977) pointed out that the skin of lacertid lizards is too smooth for effective pollen transport, Balearic lizards (frequent visitors of several plant species at

the three islets under study) are able to load and transport large quantities of pollen grains. In general, there is an enormous variation among individuals in pollen load, as was reported among insect loaders (see, for example, Olesen and Warncke, 1989). Pollen transport was described in other lizard species such as gekkonid lizards from New Zealand by Whitaker (1987b). This author showed that over 60% of the lizards carried pollen grains. In our study, 100% of the random sample of lizards from the three islets carried pollen grains.

The high load is the result of lizard foraging behavior on certain plant species. In the three islets, vegetal matter is an important component of spring, and especially, summer diet (Pérez-Mellado and Corti, 1993). Hence, the intensity of pollen load is the result of the high consumption of some particular plant species such as the sea fern, *C. maritimum*, at Aire and Sanitja islands. The lizards employ a higher proportion of the time budget licking flowers of this Umbelliferae. In doing so, pollen adheres to the ventral parts of the body, the throat, and even the back (Pérez-Mellado and Casas, 1997).

Even if pollen load and transfer by lizards have a positive effect on a plant species, foraging behavior is very variable, from nectaring that leaves intact flowers, as we observed in sea ferns, to direct consumption of the whole flowers, as in the case of *Phillyrea latifolia rodriguezii* on the islet of Addaia Gran (northeastern Menorca), where this foraging behavior also allows considerable pollen load and transport (Pérez-Mellado, unpublished data). In some cases, lizards' foraging behavior apparently does not affect flowers, but nectar depletion by a non-pollinator could affect the energetics of plants and limit their ability to attract other potential pollinators. Thus, foraging on flowers by lizards can have opposite effects for the same plant species (Pérez-Mellado and Traveset, 1999). One of the critical points in pollination biology is the clear distinction between visitors and pollinators (Dafni, 1992). In our study, this distinction was made showing the role of *Podarcis lilfordi* as pollinator (Pérez-Mellado and Casas, 1997).

Our results are reported as counts of total pollen load. This differs from the functional pollen load, that is, the pollen that due to its location on the body may reach the target stigma (Dafni, 1992). This distinction is always difficult, especially in the case of lizards, which, due to their body size, can transfer pollen grains to stigmas from any body surface. In addition, we cannot exclude the possibility that some pollen grains are part of the airborne pollen. But that could be possible only in the case of pollen grains of species recorded in small numbers. Moreover, the significant correlation of pollen load on different body regions is an indirect indication of its origin.

The first hours of the afternoon are the main period of pollen load and plant foraging for the species under study. At least for the sea fern, it is probable that during this period nectar, the most important reward, is more liquid and thus more available to lizards or, alternatively, its production is higher during this period.

We detected a higher pollen load (mainly sea fern) in females from Aire Island, whereas in Sanitja both sexes showed similar pollen load values. Males from Aire were significantly bigger than females, while no sexual dimorphism in body size existed on Sanitja (Table 4). We propose, as a preliminary hypothesis, that these sexual differences in pollen load could be due to the bigger body mass of males from Aire Island, which

Table 4
Sexual dimorphism of adult *Podarcis lilfordi* at three islets of Menorca. Mean snout–vent length (in mm) \pm SEM and range. *F* values of one-way ANOVA analyses

	Aire	Rei	Sanitja
\bar{i} \bar{i}	67.8 \pm 1.11 (49–79)	67.7 \pm 1.13 (53–77.5)	59.5 \pm 2.14 (42.5–68)
\bar{m} \bar{m}	59.3 \pm 1.03 (48–77)	61.3 \pm 1.05 (51–67)	55.7 \pm 1.76 (50.5–60.5)
	<i>F</i> = 16.09 <i>p</i> = 0.0002	<i>F</i> = 16.65 <i>p</i> = 0.0002	<i>F</i> = 1.06 <i>p</i> = 0.31

probably precludes their full access to higher inflorescence of *C. maritimum*. Thus, females seem to be better pollen loaders than males in Aire Island.

An effective pollen carrier not only loads pollen, but also retains it over some distance (Whitaker, 1987b). Future research would be directed to home range sizes of lizards, individual movements, pollen retention times, and its viability. These additional data will provide a more complete picture of the role of Balearic lizards in the reproduction of plant species visited and consumed.

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