Journal of Tropical Ecology (2001) 17:755–761. With 1 figure

SHORT COMMUNICATION

Insular interactions between lizards and flowers: flower visitation by an endemic Mauritian gecko

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(Accepted 16th February 2001)

KEY WORDS: Aloeaceae, Araliaceae, *Gastonia mauritiana*, Geckonidae, lizard pollination, *Lomatophyllum tormentorii*, *Phelsuma ornata ornata*

Lizards mainly eat arthropods, fruit, nectar, pollen and animal scats (Pérez-Mellado & Casas 1997, Whitaker 1987), using their sense of smell and good colour vision while foraging (Vinson & Vinson 1969). Although several papers have contributed to the knowledge on the relationship between lizards and floral resources, this topic is often still regarded as anecdotal. However, a few detailed ecological studies on lizard and flower interactions have been conducted, e.g. in New Zealand and the Balearic Isles (Eifler 1995, Sáez & Traveset 1995, Traveset & Sáez 1997, Whitaker 1987). Pollination by lizards was rendered likely by the following findings: first, Mediterranean lacertid lizards and New Zealand geckos have pollen adhering to their belly, throat and labium; second, they may carry pollen for several hours, and thus also transport pollen some distance away from a pollen donor plant. New Zealand geckos carry pollen up to 72 m away from donors. Good experimental evidence of lizard pollination was produced by Pérez-Mellado & Casas (1997). They showed that an umbellifer species produced less viable seeds if *Podarcis lilfordi* lizards were excluded from flowers.

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https://doi.org/10.1017/S0266467401001560 Published online by Cambridge University Press

Reports on flower visitation and pollination by Indian Ocean day geckos (*Phelsuma*) also exist. *Phelsuma ornata ornata*, for example, may be an important pollinator of several plant species on Round Island 20 km north of Mauritius (Staub 1988) and other cases of *Phelsuma*-flower interactions are known from the Seychelles (Cheke 1984, Murphy & Myers 1996). *Phelsuma* geckos may even be keystone pollinator species in some of their habitats (Jones 1987, Staub 1988, Watson 1992).

Phelsuma (day geckos) is a group of lizards of which 41 species are known. Their geographic range includes mainly islands in the Indian Ocean. Only a few studies have been conducted on the ecology of *Phelsuma* species. Four species and five subspecies of *Phelsuma* live in Mauritius, all being endemic. *Phelsuma ornata ornata* (Gray) (Mauritian ornate day gecko) occurs in hot, dry habitats on most islets off the coast (e.g. Round Island and Ile aux Aigrettes) and on the mainland up to 300 m asl (Vinson 1976). It is diurnal, 10–13 cm long and has a greenish-blue back with red spots and a distinct 'T' on its head. This gecko is associated with flowering plants, probably being attracted by floral nectar and pollen, and flower-visiting insects on which it preys (Staub 1988).

In this paper, we address the questions: is *P. o. ornata* a potential pollinator of endemic plants? and if so, what is the extent of the pollen flow?

The study was conducted on Ile aux Aigrettes (20° 25′00″ S, 57° 43′43″ E), a small coralline island 600 m off the southeast coast of Mauritius, Indian Ocean. This island has an area of 27 ha being partially covered with sand and soil deposits. It became a nature reserve in 1965 and is now an important conservation site serving as a refuge for several endemic species. On the southern part of the island we studied gecko flower visitation of two Mauritian endemic species, *Lomatophyllum tormentorii* Marais (Aloeaceae) and *Gastonia mauritiana* Marais (Araliaceae). The first species is an evergreen rosette plant with succulent leaves and regular flowers borne along a raceme. The flowers are tubular, red and about 2 cm long. They open for approximately one day. The species used to be widespread and abundant in this type of habitat but only four adult individual plants exist on the island today. They flowered from mid-October and until the beginning of November. *Phelsuma ornata* visited the flowers for nectar (Vinson & Vinson 1969). From 27 October to 5 November 1999, 62 h were spent observing a single *Lomatophyllum* plant from 06h00–18h00. The observation hours were evenly distributed throughout the period with a minimum of 3 h in days with low-activity periods of flower visitors. Observations were made from a distance of 2 m behind a mosquito net with a small observation hole to prevent geckos from being distracted by our presence. The plant flowered during the entire period. A foraging bout by a flower-visiting gecko was defined as a visit to the plant, lasting from the time a gecko arrived on the plant and ending once the gecko had left it again, and it might include visits to more than one inflorescence. Numbers of inflorescences and flowers visited were recorded as was the duration of each foraging bout. Sex and age class of the visiting geckos were also noted as well as the type of floral resource exploited (nectar and/or pollen).

Gastonia mauritiana is a tree with xeromorphic leaves. Its open, yellow-green, dish-shaped flowers, being 1 cm in diameter, are aggregated into dense umbellate inflorescences. They are open for one day (n = 12 flowers). Flowering of the population lasted for months due to a staggered flowering among individual trees. *Gastonia* trees were abundant at our study site with a wide range of size classes present. Within a plot of 200 × 150 m, all *Gastonia* trees were counted and mapped. Mean distance between *Gastonia* trees was 20 ± 28.7 m (n = 33). Twenty-one adults and 12 juveniles were examined for geckos. Visits to a *G. mauritiana* tree were observed from the roof of an abandoned house which made it possible to survey about one-fifth of the canopy of a large tree. A total of 43 h of observations were made from 06h00–18h00 from 6–12 November 1999. Observation hours were evenly distributed throughout the period with a minimum of 2 h d^{-1} in low-activity periods. A foraging bout was here defined as a visit to an inflorescence, starting from the time a gecko began feeding and ending once the gecko left the inflorescence. Both flowers and young fruits produced nectar. Numbers of both flowers and young fruits visited and duration of all foraging bouts were recorded. Sex, age class and floral resource type exploited was noted for each visiting gecko. Inflorescences with at least some open flowers were termed flowering while those that had only fruits were termed fruiting. In total, we observed 40 and 249 foraging bouts of *P. ornata* feeding from flowers of *Lomatophyllum* and *Gastonia* respectively. In both species, most geckos only consumed nectar, a few pollen and some both nectar and pollen. Pollen feeding took place in the beginning of a visit. Occasionally, geckos also ate flower-visiting insects, such as ants, bees, flies and butterflies.

On *Lomatophyllum*, foraging took place between 08h47 and 14h46. Eighty per cent of flower-visiting geckos were females and their activity peaked earlier than that of males. Mean length of a foraging bout was 242 s and mean number of flowers visited per min was 0.5 (n = 40 bouts, observation time 161 min).

Age class and sex structure of geckos visiting *Gastonia* are given in Table 1. More than twice as many females as males made floral visits, and 87% of all visitors were adults. Number of foraging bouts made by juveniles and adults of both sexes are given in Table 2. Regardless of age and sex, geckos preferred flowering trees to fruiting ones, and this preference was the same in both sexes and in both age classes (sex: $\chi^2 = 0.075$, $P = 0.78$; age: $\chi^2 = 1.70$, $P = 0.19$).

Table 1. Age and sex structure of gecko population visiting *Gastonia mauritiana*. Figures are number of geckos observed on inflorescences.

	Juveniles	Adults	Undetermined age	Total
Males	20	59	0	79
Females	12	154	2	168
Undetermined Sex	1	0	0	1
Total	33	213	2	248

https://doi.org/10.1017/S0266467401001560 Published online by Cambridge University Press

Table 2. Number of gecko foraging bouts to flowering and fruiting inflorescences of *Gastonia mauritiana*.

	No. of foraging bouts		
	Flowering inflorescences	Fruiting inflorescences	Total
Males	48	31	79
Females	99	69	168
Undetermined sex	0	1	1
Juveniles	21	10	33
Adults	123	90	213
Undetermined age	1	1	2
Total	147	101	248

Females and males visited the same number of flowers and fruits per foraging bout (Females: mean ± SD = 4.2 ± 3.2 visits per bout, range 1–21; males: 3.5 ± 2.2 visits per bout, range 1–13; Mann–Whitney U-test: z = 14.74, P = 0.14). Foraging on *Gastonia* took place between 08h58 and 16h39. Activity of juveniles began in the afternoon and activity of females peaked significantly earlier than that of males (Kolmogorov–Smirnov 2-sample test: maximum difference = 0.286, χ^2 = 15.5, P = 0.036). Mean length of a foraging bout was 46 s.

In both species, standing crop of nectar in flowers was measured using micropipettes. Sugar concentration (as sucrose equivalents) was measured using a Stanley & Bellingham pocket refractometer modified for small volumes of nectar. Flowers were only used once. Nectar from *Lomatophyllum* flowers was extracted between 07h00–13h00. Nectar from *Gastonia* flowers, however, could only be extracted in the early morning and by pooling nectar from several flowers. Later the nectar dried out and turned into a solid sugary layer on top of the ovary or young fruit. Mean standing crop of nectar per *Lomatophyllum* flower was 10.5 ± 7.8 μl (n = 11 flowers, range 1.8–36) and mean sugar concentration of nectar was 21 ± 6.2% (n = 17 flowers, range 14–39%). Mean sugar concentration of nectar from *Gastonia* flowers was 38% (n = 10 samples, each from several flowers; sampling between 07h00 and 08h00) and from young fruits >50% (n = 13 samples, each from several fruits).

Using a stick with an adjustable nylon string noose we caught and released 122 geckos at the *Gastonia* study site. Capture took place between 07h00–10h00 as activity level of geckos was relatively low in the morning, making them easier to catch. Geckos were marked with correction fluid, and by use of different colours and patterns we could distinguish all individuals. We inspected a large area around the release site and particular areas with high densities of geckos to resight marked ones. This resighting, however, was not done in a completely random way. We expected to find a bias towards recording too many short distances. Out of 122 marked geckos, 91 were resighted; 89% of these were observed less than 15 m from their release site (Figure 1). The longest distance recorded for a gecko, marked at 10h00 and resighted the next day at 15h00 was 87 m. It was resighted on another *Gastonia* tree which had just started to flower. Since geckos only were active from 06h00–18h00 this particular gecko had moved with a speed of at least 5 m h^{-1}.

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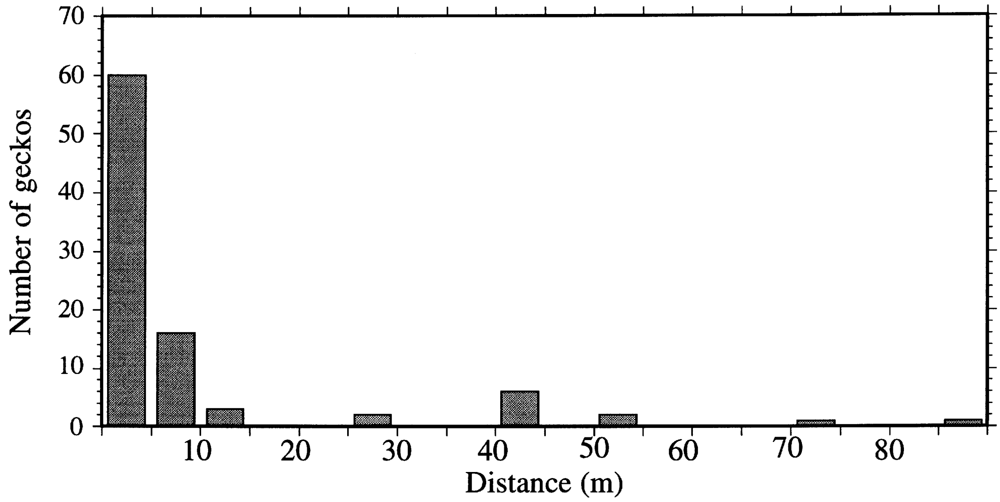

Figure 1. Distribution of mark–resight distances for *Phelsuma ornata*.

To examine geckos for pollen we pressed adhesive transparent tape onto dorsal and ventral sides of snouts of 96 geckos. Tape samples were stuck onto microscopic slides, and later examined for pollen grains. Eighty-six (90%) geckos carried pollen and 48 (55%) of these carried *Gastonia* pollen. Average pollen grain number per smear was 5.0 (n = 86; and one-third of these grains were from *Gastonia*). Eight pollen types were found in the samples. Some of these may belong to the same plant species. However, only about 10 plant species were flowering on the island during the study period (L. I. Eskildsen, unpubl. data). Thus Mauritian geckos may visit the flowers of up to 80% of all plant species in the ecosystem.

Several genera of lizards are known to transport pollen. In a sample of ten *Podarcis lilfordi* lizards, Traveset & Sáez (1997) found an average of 209 *Euphorbia dendroides* pollen grains per animal. In another study of *P. lilfordi* visiting *Crithmum maritimum* all lizards in a sample of 20 had large number of pollen grains adhering to their belly, throat and lips (Pérez-Mellado & Casas 1997). These authors showed that *Crithmum maritimum* produced fewer viable seeds if *Podarcis lilfordi* lizards were excluded from flowers. Smears were also sampled from 15 *Hoplodactylus duvauceli* and 17 *H. pacificus* from New Zealand. Throats had highest pollen density. Twenty-eight of 32 geckoes carried pollen (Whitaker 1987).

Two studies have demonstrated the importance of Mediterranean *Podarcis lilfordi* as a pollinator (Pérez-Mellado & Casas 1997, Traveset & Saéz 1997). However, its importance to outcrossing in plants is less well known. Whitaker (1968) recorded a *Hoplodactylus duvauceli* that moved 73 m during 72 h. Pollen smears from this species show that it can carry pollen for at least 12 h (Whitaker 1987). In our study, *P. ornata* was shown to carry pollen from one day to the next and may move up to 87 m during 29 h. In general, we expect

https://doi.org/10.1017/S0266467401001560 Published online by Cambridge University Press

pollen flow distances to be underestimates. However, our study suggests that *P. ornata* mediates outcrossing in the population of *G. mauritiana* on Ile aux Aigrettes. Outcrossing may, however, be reduced by gecko territorial behaviour. Often marked geckos were resighted up to a week at the same spot and some individual geckos were observed to forage within the canopy of one *G. mauritiana* tree for an entire day. On the other hand, the staggered flowering of *Gastonia* trees could increase pollen flow by inducing geckos to move around in the habitat during the flowering season. This might promote outcrossing.

Besides geckos, *Lomatophyllum* was also visited by birds. We observed the Red Whiskered Bulbul (*Pycnonotus jocosus* (Baker)) as a flower visitor (unpubl. data). On flowers of *Gastonia* we observed several species of arthropods visiting flowers (unpubl. data). Several of these were introduced species (L. I. Eskildsen *et al*. *pers. comm.*).

We conclude that lizards are important flower visitors on several oceanic islands and that flower visitation is widespread among lizards (Pérez-Mellado & Casas 1997, Olsson *et al*. 2000, Staub 1988, Traveset & Saéz 1997, Whitaker 1987). However, we still lack any evidence that they act as selective agents on the floral biology of their food plants.

ACKNOWLEDGEMENTS

We thank E. N. Arnold, E. Dulloo, L. I. Eskildsen, S. Venkatasamy and C. Westerkamp for help and comments in the field and on the manuscript. This study was partly financed by the Faculty of Sciences, University of Aarhus (to D.F.N. and C.K.) and the Danish National Science Research Council and WF-Denmark/Novo Nordisk (to J.M.O.).

LITERATURE CITED

CHEKE, A. S. 1984. Lizards of the Seychelles. Pp. 331–360 in Stoddart, D. R. (ed.). *Biogeography and ecology of the Seychelles*. Dr. W. Junk, The Hague.

EIFLER, D. A. 1995. Patterns of plant visitation by nectar-feeding lizards. *Oecologia* 101:228–233.

JONES, C. G. 1987. The larger land-birds of Mauritius. Pp. 208–300 in Diamond, A. W. (ed.). *Studies of Mascarene island birds*. Cambridge University Press, Cambridge.

MURPHY, T. J. & MYERS, A. A. 1996. The behavioral ecology of *Phelsuma astriata semicarinata* on Arid Island Nature Reserve, Seychelles. *Journal of Herpetology* 30:117–123.

OLSSON, M., SHINE, R. & BA'K-OLSSON, E. 2000. Lizards as a plant's 'hired help': letting pollinators in and seeds out. *Biological Journal of the Linnean Society* 71:191–202.

PÉREZ-MELLADO, V. & CASAS, J. L. 1997. Pollination by a lizard on a Mediterranean Island. *Copeia* 1997:593–595.

SÁEZ, E. & TRAVESET, A. 1995. Fruit and nectar feeding by *Podarcis lilfordi* (Lacertidae) on Cabrera Archipelago (Balearic Islands). *Herpetological Review* 26:121–123.

STAUB, F. 1988. *Fauna of Mauritius and associated flora*. Indian Ocean Press, Rose-Hill, Mauritius.

TRAVESET, A. & SÁEZ, E. 1997. Pollination of *Euphorbia dendroides* by lizards and insects: spatio-temporal variation in patterns of flower visitation. *Oecologia* 111:241–248.

VINSON, J.-M. 1976. The saurian fauna of the Mascarene Islands II. The distribution of *Phelsuma* species in Mauritius. *The Mauritius Institute Bulletin* 8:177–195.

VINSON, J. & VINSON, J.-M. 1969. The saurian fauna of the Mascarene Islands. *The Mauritius Institute Bulletin* 6:203–320.

WATSON, J. 1992. Nesting ecology of the Seychelles kestrel (*Falco araea*) on Make, Seychelles. *Ibis* 134:259–267.
WHITAKER, A. H. 1968. The lizards of the Poor Knights islands, New Zealand. *New Zealand Journal of Science* 11:623–651.
WHITAKER, A. H. 1987. The roles of lizards in New Zealand plant reproductive strategies. *New Zealand Journal of Botany* 25:315–328.

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