Journal of Pollination Ecology, 16(15), 2015, pp108-111

— Short Communication —

THE FORGOTTEN POLLINATORS – FIRST FIELD EVIDENCE FOR NECTAR-FEEDING BY PRIMARILY INSECTIVOROUS ELEPHANT-SHREWS

Petra Wester*

Institute of Sensory Ecology, Heinrich-Heine-University, Universitätsstr. 1, 40225 Düsseldorf, Germany

Abstract—Pollination of plants by non-flying mammals, such as mice (Rodentia), is a rarely observed phenomenon. Previously, elephant-shrews (Macroscelidea), small African mammals looking similar to mice, but not being related to them, were believed to be purely insectivorous and occasional flower visits of elephant-shrews in captivity were interpreted as a by-product of the search for insects. Only recently it was demonstrated that under lab conditions elephant-shrews regularly lick nectar from flowers. However, field observations of flower-visiting elephant-shrews and their role as pollinators were completely missing. Here I present the first evidence for flower visits and nectar consumption for elephant-shrews in the field. With video camcorders and infrared lights I recorded Cape rock elephant-shrews (*Elephantulus edwardii*) beside Namaqua rock mice (*Micaelamys namaquensis*) visiting flowers of the Pagoda lily (*Whiteheadia bifolia*, Asparagaceae) under natural conditions in the Namaqualand of South Africa. With their long tongues, the elephant-shrews visited the flowers non-destructively, definitely licking nectar, but not eating insects. The footage clearly shows that the elephant-shrews' fur around their long noses touches the pollen-sacs and the stigmas of the flowers and that the animals' fur is being dusted with pollen. As the elephant-shrews visited several flowers of different plants, it is obvious that they transfer pollen between the plants. This observation contributes to the knowledge about the behaviour of these representatives of a unique clade of small African mammals – especially in their natural habitat. With their behavioural and anatomical uniqueness, it is not unlikely that elephant-shrews even play a role as selective force driving floral evolution.

Keywords: Elephant-shrews, Macroscelidea, field evidence, nectar consumption, pollination, Whiteheadia bifolia, Asparagaceae

INTRODUCTION

Pollination of flowers by non-flying mammals is one of the most recently discovered interactions between animals and plants. This unusual and understudied phenomenon mainly includes marsupials, primates as well as rodents (Buchmann & Nabhan 1996; Carthew & Goldingay 1997; Wester et al. 2009). Especially in South Africa, in the recent years, several studies accumulated evidence that mice (order Rodentia) regularly pollinate flowers and that specific plants are adapted to pollination by these animals (Wiens & Rourke 1978; Johnson et al. 2001; Wester et al. 2009; Johnson & Pauw 2014). Until recently, elephant-shrews, small African mammals looking similar to mice, but belonging to a separate order (Macroscelidea, within the superorder Afrotheria), were often believed to be purely insectivorous (Perrin 1997). From occasional flower visits of elephant-shrews in captivity, in which the animals never lapped nectar from the nectar reservoir of the *Protea* (Proteaceae) flowers presented to them (Wiens et al. 1983), it was presumed that the animals fed on insects when visiting flowers (Fleming & Nicolson 2002, 2003). However, knowledge built up that also plant material, such as leaves, fruits and seeds, is eaten by elephant-shrews (van Deventer & Nel 2006). Only recently, nectar-feeding by elephant-shrews was shown through laboratory experiments for *Whiteheadia bifolia* (syn. *Massonia bifolia*, Asparagaceae, previously in Hyacinthaceae, *Elephantulus edwardii*, Wester 2010), a plant that was previously described to be pollinated by mice (Wester et al. 2009), *Cytinus visseri* (Cytinaceae; *E. brachyrhynchus*, Johnson et al. 2011) and *Hyobanche atropurpurea* (Orobanchaceae; *E. edwardii*, Wester 2011). From these studies, it was only inferred that flower visits take place in the field, because the scats and the fur around the snouts of elephant-shrews captured near the plants carried pollen of the corresponding flowers (Wester 2010, 2011; Johnson et al. 2011; see also Wiens et al. 1983). However, field observations of flower-visiting elephant-shrews and their role as pollinators were completely missing.

As it was known that elephant-shrews visited *W. bifolia* flowers in the lab (Wester 2010), this plant was chosen for observations in the field. In order to test under natural conditions whether elephant-shrews visit flowers for nectar or for preying on insects, *W. bifolia* plants were monitored with the help of video camcorders and infrared light sources in the Namaqualand of South Africa.

MATERIALS AND METHODS

Observations were carried out on the farm Pendoornhoek (S 30°11.672' E 18°00.385', elevation 1085

Received 24 April 2015, accepted 15 July 2015
*Corresponding author: Westerpetra3@gmail.com

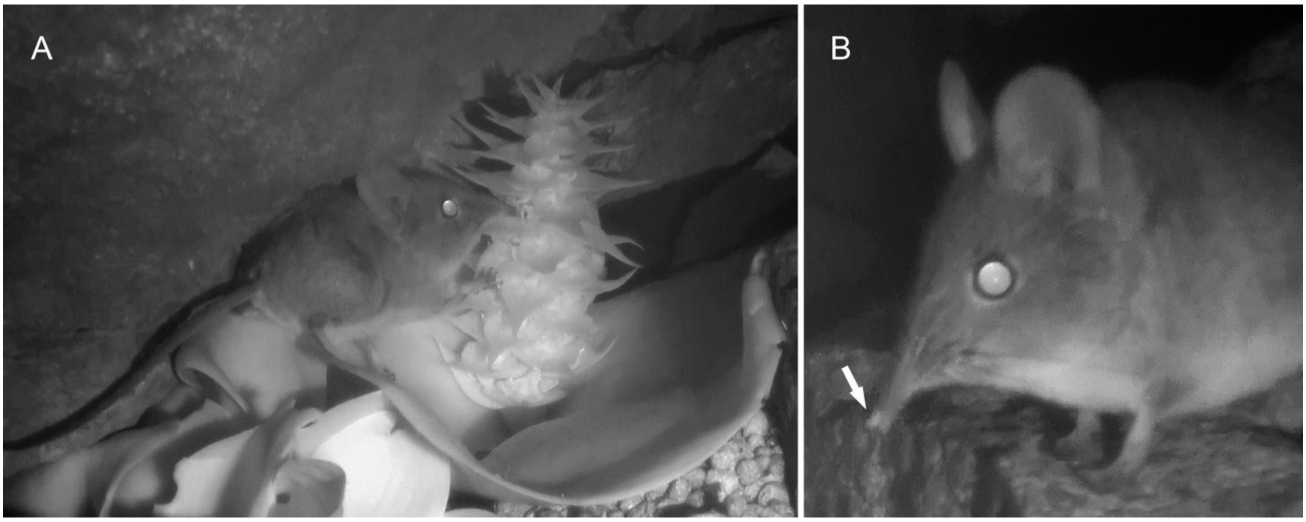

FIGURE 1. First field observation of elephant-shrews as pollinators. (A) A Cape rock elephant-shrew (*Elephantulus edwardii*, Macroscelididae) licks nectar from flowers of the Pagoda Lily (*Whiteheadia bifolia*, Asparagaceae) growing in rock crevices in the Namaqualand of South Africa. (B) The elephant-shrew has pollen (see arrow) on its nose after a flower visit. Both still images are from infrared video footage.

m), 7 km east of Kamieskroon in the Kamiesberg mountain range (western Northern Cape of South Africa), where *Whiteheadia bifolia* grows scattered in shady rock crevices. Six *W. bifolia* plants (one to two at a time per camera) with about 5 to 10 open, nectar-containing flowers per plant, were observed for potential visitors at different places. The observations were carried out with four video camcorders (Sony HDR-XR550) with additional self-made infrared light sources (using one to three 1 Ampère SMD LEDs emitting 940 nm light) using 12V/18Ah lead-acid batteries as power source. The camcorders and light sources were positioned about 70-100 cm away from the plants and running non-stop (5.5 to 13 hours). No motion or heat sensor for automatic triggering was used to avoid data loss due to mis-triggering or shutter lag. The plants were observed from 22nd to 31st August 2014 for 72 hours in total (about 22 hours during the day and 50 hours at night) over 5 days and nights between 01:00 pm and 07:30 am. The licking frequency (in-and-out flicking of tongue) could be determined in detail only for the elephant-shrews, but not for rodents, as the movement of the elephant-shrews' long tongue was clearly visible.

RESULTS

Cape rock elephant-shrews (*Elephantulus edwardii*, Macroscelididae) keenly visited the flowers of the six observed individuals of the Pagoda lily (*Whiteheadia bifolia*; Fig. 1A, Appendix I). The visits took place during all of the five days/nights between 6:45 pm and 3:45 am, mainly at late sunset and during early evening. Altogether 30 flower visits during 7 foraging bouts (sequence of flower visits) were observed. A foraging bout lasted 1.3 to 27.0 seconds (15.6 seconds on average) and included 1 to 8 flower visits (4 visits on average). With two exceptions, the flowers were visited only once. A flower visit lasted 0.5 to 7.5 seconds (3 seconds on average). With their long tongues the elephant-shrews licked the viscous nectar that is located between the ovary and the six stamens (Fig. 1A, Appendix I). Licking by the elephant-shrews led the inflorescences to slightly wobble. The elephant-shrews licked 2 to 28 times (9.4 times on average) per flower visit with a licking frequency mostly about 5 Hz (up to about 8 Hz). When visiting a flower and licking nectar, the animals' long and flexible nose was between the stamens and the style, and touched the pollen-sacs and the stigmas of the flowers (Fig. 1A, Appendix I). Thereby, they were dusted with pollen on their nose (mostly the distal half; Fig. 1B). As far as it was noticeable in at least three of the foraging bouts, the elephant-shrews already had pollen on their nose before they visited the flowers (Appendix I). During almost all of the foraging bouts it was clearly visible that the animals accumulated more and more pollen on the fur around their noses in the process of visiting the flowers. Sometimes the elephant-shrews only briefly sniffed at a flower, but did not visit it (probably due to lacking of nectar). The elephant-shrews visited the flowers non-destructively, not consuming pollen or insects directly and they did not eat floral parts. Depending on the size of the inflorescence and the position of the flowers, the animals sometimes stood upright on their hind legs, sometimes additionally leaning on the long bracts with one or two of their forepaws to reach the upper flowers (Fig. 1A, Appendix I).

Namaqua rock mice (*Micaelamys namaquensis*, formerly *Aethomys namaquensis*, Muridae) visited several *W. bifolia* flowers of 4 different individual plants exclusively in the dark (between 7:00 pm and 06:40 am during two nights). Altogether 50 flower visits (length: 0.3 to 17.0 seconds, 4.2 seconds on average) during 10 foraging bouts (length: 7.2 to 50.0 seconds, 27.2 seconds on average) could be observed. A foraging bout included one to nine flower visits (5.5 on average). With six exceptions, the flowers were visited only once. The mice mostly licked nectar like the elephant-shrews, accumulating pollen on the fur around their snout, touching the pollen-sacs (Appendix II). However, at least in two foraging bouts, the mice nibbled at the flowers. At least one time it was visible on the footage that the mice ate the pollen-sacs of a relatively young flower (just opening)

(Appendix III). It is very likely that during these two foraging bouts the mice were feeding on the pollen-sacs of the young flowers visited as the animals were chewing after the flower visits. One time, a large bract was eaten in between the flower visits. Licking frequency of the mice was similar to that of the elephant-shrews, however, not clearly measurable as the tongue was mostly hidden by the head or snout. During the flower visits the mice mostly stood upright on their hind legs and leaned on the long bracts (one time on the stamens) with their forepaws (one time additionally with one hindpaw), causing the inflorescences to slightly wobble.

No other visitors were observed except one ant that was crawling on a bract during one video sequence. An elephant-shrew, that was lapping nectar at the same plant, did not prey on the insect.

DISCUSSION

The present study clearly shows at the example of *Whiteheadia bifolia* that elephant-shrews visit flowers non-destructively for nectar in their natural habitat. While licking nectar, the elephant-shrews touched the pollen-sacs and stigmas and were dusted with pollen on the fur of their long noses. As the elephant-shrews visited several flowers of different plants, they certainly play a role in transferring pollen between the plants. Although elephant-shrews are primarily insectivorous (Perrin 1997; Skinner & Chimimba 2005), one elephant-shrew preferred nectar over an ant crawling on the same plant.

Beside elephant-shrews, mice were also observed to visit the flowers of *Whiteheadia bifolia*. Whereas nectar drinking mice already were directly observed and photographed in the field (*Micaelamys namaquensis* at *W. bifolia*, Wester et al. 2009), video-graphed with motion activated camera traps (Striped field mouse, *Rhabdomys pumilio* at *Protea foliosa*; Melidonis & Peter 2015) or video-graphed with camcorders in combination with surveillance systems based on body heat and motion-sensing (unidentified rodent at *Liparia parva*, Fabaceae; Letten & Midgley 2009), the present study provides the first field evidence for flower visits and nectar consumption by elephant-shrews. Furthermore, this study gives meaning to former laboratory experiments showing that elephant-shrews visit flowers for nectar, and pollen found on animals captured near flowering plants (Wester 2010, 2011). Since pollen evidence provides no information about the specific behaviour of the animals at the plants, for instance, whether they eat pollen on purpose, remove pollen of their fur via grooming, touch the stigmata and cause pollination, or eat or destroy flowers. The importance of elephant-shrews for pollination of specific plants becomes only apparent via or in combination with direct field observations.

In most plants with direct or indirect evidence for pollination by elephant-shrews, mice have also been found to play a role as pollinators (*W. bifolia*: Wester et al. 2009; Wester 2010; this study; *Protea* spp.: Wiens et al. 1983; *Cytinus visseri*: Johnson et al. 2011). Both animal groups are keen on nectar, and their facial and cranial morphology fits to the floral structure of these plants. As they touch the reproductive organs of the flowers, they are capable of pollen transport in the fur around their snout, enabling pollen transfer between the plants (Fleming & Nicolson 2002; Wester et al. 2009; Wester 2010; this study). The behaviour in both small mammal groups is very similar except that mice can act destructively on flowers. Whereas *M. namaquensis* never ate or damaged flowers of *W. bifolia* in the Cederberg study (Wester et al. 2009, for other plant species see Wiens et al. 1983; Kleizen et al. 2008; Biccard & Midgley 2009), in the present study the mice sometimes fed on floral parts. Similar behaviour was found for instance in *R. pumilio*, that did not act destructively at flowers as observed by Johnson et al. (2011), but sometimes or often did so in other studies (Wiens et al. 1983; Biccard & Midgley 2009; Melidonis & Peter 2015). As destructive behaviour of *M. namaquensis* occurred only rarely in the present study and mostly legitimate flower visits took place, the species is interpreted as a successful pollinator of *W. bifolia*. Elephant-shrews have never been observed performing destructive behaviour at flowers (*W. bifolia* & other species; Wiens et al. 1983; Wester 2010, 2011; Johnson et al. 2011; this study).

Elephant-shrews and mice that are known as pollinators are omnivorous, primarily insectivorous or feed also on plant material other than nectar and pollen (Skinner & Chimimba 2005), thus they are not dependent on flowers that are temporarily restricted. In contrast, small mammal-pollinated plants depend on their pollinators and show characters that have likely evolved as adaptations to these pollinating animals (e.g. geoflory, visual inconspicuousness, bowl-shaped, robust flowers with easily accessible nectar and specific smell; see also Wiens et al. 1983; Wester et al. 2009; Wester 2010; Johnson & Pauw 2014).

With the first field evidence for flower visits and nectar consumption by elephant-shrews, the present study contributes to the knowledge about the behaviour of these remarkable representatives of a unique clade of small African mammals – notably in their natural environment. Given their behavioural and anatomical peculiarities, it is not unlikely that these (almost) forgotten pollinators even play a role as a unique selective force driving floral evolution. Future studies have to show how effective elephant-shrews are as pollinators.

ACKNOWLEDGEMENTS

I thank Lita Cole (Kamieskroon) for locality information, Ria and Koos Beukes (Pendoornhoek) for locality information and the permission to work on their property, Hanneline Smit-Robinson (BirdLife South Africa) for elephant-shrew identification advice, Klaus Lunau (Heinrich-Heine-University Düsseldorf) for providing camcorders and the Northern Cape Department of Tourism, Environment and Conservation for the necessary permits (FAUNA 1210/2014, FLORA 084/2013).

APPENDICES

Additional supporting information may be found in the online version of this article:

APPENDIX I. With its long tongue *Elephantulus edwardii* licks nectar from *Whiteheadia bifolia* flowers, getting dusted with pollen on its nose. Infrared video.

APPENDIX II. *Micaelamys namaquensis* licking nectar from *Whiteheadia bifolia* flowers, getting dusted with pollen on its nose. Infrared video.

APPENDIX III. *Micaelamys namaquensis* feeding on pollen-sacs of *Whiteheadia bifolia* flowers. Infrared video.

REFERENCES

Biccard A, Midgley JJ (2009) Rodent pollination in *Protea nana*. South African Journal of Botany 75:720-725.

Buchmann SL, Nabhan GP (1997) The forgotten pollinators. Island Press, Washington.

Carthew SM, Goldingay RL (1997) Non-flying mammals as pollinators. Trends in Ecology and Evolution 12:104-108.

Fleming PA, Nicolson SW (2002) How important is the relationship between *Protea humiflora* (Proteaceae) and its non-flying mammal pollinators? Oecologia 132:361-368.

Fleming PA, Nicolson SW (2003) Arthropod fauna of mammal-pollinated *Protea humiflora*: ants as an attractant for insectivore pollinators? African Entomology 11:9-14.

Johnson CM, Pauw A (2014) Adaptation for rodent pollination in *Leucospermum arenarium* (Proteaceae) despite rapid pollen loss during grooming. Annals of Botany 113:931-938.

Johnson SD, Burgoyne PM, Harder LD, Dötterl S (2011) Mammal pollinators lured by the scent of a parasitic plant. Proceedings of the Royal Society B-Biological Sciences 278:2303-2310.

Johnson SD, Pauw A, Midgley J (2001) Rodent pollination in the African lily *Massonia depressa* (Hyacinthaceae). American Journal of Botany 88:1768-1773.

Kleizen C, Midgley JJ, Johnson SD (2008) Pollination systems of *Colchicum* (Colchicaceae) in southern Africa: evidence for rodent-pollination. Annals of Botany 102:747-755.

Letten AD, Midgley JJ (2009) Rodent pollination in the Cape legume *Liparia parva*. Austral Ecology 34:233-236.

Melidonis CA, Peter CI (2015) Diurnal pollination, primarily by a single species of rodent, documented in *Protea foliosa* using modified camera traps. South African Journal of Botany 97:9-15.

Perrin M (1997) Cape rock elephant shrew, *Elephantulus edwardii*. In: Mills G, Hes L (eds) The Complete book of Southern African mammals. Struik Winchester, Cape Town, p. 66.

Skinner JD, Chimimba CT (2005) The mammals of the Southern African subregion. 3rd ed. Cambridge University Press, Cambridge.

van Deventer M, Nel JAJ (2006) Habitat, food, and small mammal community structure in Namaqualand. Koedoe 49:99-109.

Wester P (2010) Sticky snack for sengis: the Cape rock elephant-shrew, *Elephantulus edwardii* (Macroscelidea) as a pollinator of the Pagoda lily, *Whiteheadia bifolia* (Hyacinthaceae). Naturwissenschaften 97:1107-1112.

Wester P (2011) Nectar feeding by the Cape rock elephant-shrew *Elephantulus edwardii* (Macroscelidea) - a primarily insectivore pollinates the parasite *Hyobanche atropurpurea* (Orobanchaceae). Flora 206:997-1001.

Wester P, Stanway R, Pauw A (2009) Mice pollinate the Pagoda Lily, *Whiteheadia bifolia* (Hyacinthaceae) - first field observations with photographic documentation of rodent pollination in South Africa. South African Journal of Botany 75:713-719.

Wiens D, Rourke JP (1978) Rodent pollination in southern African *Protea* species. Nature 276:71-73.

Wiens D, Rourke J, Casper B, Rickart E, Lapine T, Peterson C, Channing A (1983) Nonflying mammal pollination of southern African Proteas: a non-coevolved system. Annals of the Missouri Botanical Garden 70:1-31.