SHORT ARTICLES

NECTAR FEEDING ON AN EXOTIC TREE (*GREVILLEA ROBUSTA*) BY *ALOUATTA CARAYA* AND ITS POSSIBLE ROLE IN FLOWER POLLINATION

Romina Pavé
Silvana M. Peker
Mariana Raño
Carolina Ramírez Orjuela
Gabriel E. Zunino
Martin M. Kowalewski

Introduction

Several species of primates consume nectar and/or pollen (Sussman, 1979; Torres de Assumpção, 1981; Puertas *et al.*, 1992; Peres, 1994; Carthew & Goldingay, 1997; Birkinshaw & Colquhoun, 1998; Passos & Kim, 1999; Riba-Hernández & Stoner, 2005; Marín-Gómez, 2008). Nectar is a high-energy resource and an important food source for mammals living in habitats with marked seasonality (Janson *et al.*, 1981; Garber, 1988; Ferrari & Strier, 1992). Also, mammals including primates can be possible pollinators of different plant species (Kress *et al.*, 1994; Carthew & Goldingay, 1997).

Black and gold howler monkeys, *Alouatta caraya*, are characterized by a folivore-frugivore opportunistic diet (Milton, 1998). This arboreal species inhabits different types of tropical and subtropical forests in NE Argentina, SE Brazil, Paraguay, and Bolivia (Crockett & Eisenberg, 1987; Zunino & Kowalewski, 2008). *Grevillea robusta* (Family Proteaceae) is a tree native to eastern Australia and it has been widely planted in subtropical and tropical environments of Africa, America, and Asia (Harwood, 1992). In Argentina, this species was introduced in the late nineteenth century for construction of furniture (Moscovich *et al.*, 2004). *Grevillea robusta* has hermaphroditic and bright yellow-orange flowers (approximately 23 mm long) grouped into terminal racemes. Fruits are black leathery dehiscent follicles with two seeds. The pollen is deposited onto a cone around the stigma and the nectary secretes yellow nectar that accumulates in a large drop between the style and the perianth segment (McGillivray, 1993; Kalinganire *et al.*, 2000). The species shows both protandry (anthers dehisce prior to stigma receptivity) and a self-incompatibility mechanism (Kalinganire *et al.*, 2000). Therefore, the flowers need pollinators to produce fruits. The species of Proteaceae are not specialized to certain groups of pollinators; they are generalists (Collins & Rebelo, 1987). The clustering of flowers on the ends of branches, brush-type presentation, bright color, and copious nectar production suggest that *G. robusta* is pollinated by diurnal animals, similar to other proteaceous species (Collins & Rebelo, 1987; Kalinganire *et al.*, 2000).

For exotic plants like *G. robusta* in forests in northeast Argentina, pollination success depend on density of plant populations which may affect the attractiveness of enough pollinators, the competition with native vegetation for pollinator attention, and the low number of suitable generalist pollinator species (Stout *et al.*, 2006). However, if generalist native species pollinate introduced plants and these pollinators are abundant, exotic species may be reproductively successful and spread rapidly (Parker, 1997). The aim of this study is to describe the nectar feeding behavior of *Alouatta caraya* on an exotic tree (*Grevillea robusta*, Proteaceae) and suggest the possible role of this primate in flower pollination.

Materials and methods

The study was carried out at San Cayetano (27° 30' S, 58° 41' W), Corrientes Province, Argentina (Rumiz, 1990). The climate is subtropical with an average annual temperature of 21.7° C and an average annual of rainfall of 1,230 mm; the rainfall decreases slightly in the winter (July to August) (Zunino *et al.*, 2007). The site presents a fragmented forest and the vegetation is characterized by dense, semideciduous upland and riparian forests, open lowland forests with palm trees, and grasslands (Zunino *et al.*, 2007). The forest has been heavily modified by logging, the presence of cattle, and burning (Zunino *et al.*, 2007). In addition, there are some individuals of exotic vegetation such as *Citrus* spp, *Grevillea robusta*, *Hovenia dulcis*, and *Melia azedarach*.

Observations were collected on two groups of howlers (Ariscos and Huerta) between 2005 and 2008 during a long-term ecological and behavioral study on *A. caraya* in San Cayetano. We used scan and focal sampling techniques (Altmann, 1974) from sunrise to sunset. During the scan sampling we recorded behaviors and spatial distributions of the whole group every 10 min. During focal sampling we recorded the behavior, height and tree species used, and distance to the nearest individual. We present data from the two sampling techniques but quantitative data on nectar-feeding behavior are based only on scan sampling. We calculated the percentage of feeding records and the rate of nectar-feeding per group per hour. In Table 1 we present the two study groups including study period, date of nectar-feeding, sampling technique, sex-age composition, and flower damage.

Results

The home range size of Ariscos and Huerta groups are 3.78 ha y 6.26 ha respectively. There are two *G. robusta* trees (separated by 80m) within Ariscos's home range, and one within Huerta. Howlers were observed exploiting the flowers of *G. robusta* in spring (October and November). The nectar-feeding records are the following:

- Ariscos group. November 2005 (Table 1). We observed nectar-feeding on one of the two trees within the home range. Nectar-feeding accounted for 6.2% of the 97 scan sampling feeding records (rate: 0.004 records per hour). The whole group consumed nectar and two of them (an adult female and a juvenile male) fed simultaneously on the same tree 1m one from the other. Howlers brought their mouth near to the flowers attached to the inflorescence and licked nectar. They obtained nectar from different inflorescences of the same tree. They did not eat any other part of the flower except the nectar. After each feeding bout, howlers carried abundant yellow pollen on their snouts.
- Ariscos group. October 2007 (Tabla 1). Nectar-feeding accounted for 5.5% of the 165 scan sampling feeding records (rate: 0.24 nectar-feeding records per hour). Two individuals (a subadult male and a juvenile male) consumed nectar and the same tree was visited 2 consecutive days. Howlers fed on nectar in the same way as observed in November 2005. They fed simultaneously on the same tree 3–4 m one from the other.
- Huerta group. October 2007 (Table 1). In October 26, we observed one juvenile male eating one flower of *G. robusta* and drinking rainwater accumulated in the flowers (1h total of focal sampling). On October 27th, the same individual drank rainwater from the flowers. Two juvenile females and the infant were observed drinking rainwater from the flowers at 1m of the juvenile male (1h total of focal sampling). In the two days of focal after drinking the juvenile male carried pollen on its snout.
- Huerta group. October, 2008. During the scan sampling, we observed nectar-feeding by four individuals (Table 1). This accounted for 4% of the 99 scan sampling feeding records (rate: 0.17 nectar-feeding records per hour). One individual obtained nectar from different inflorescences of the same tree and two individuals fed simultaneously on the same tree between 0.5 and 2m of distance. Howlers fed on nectar as was observed in Ariscos group. They did not eat any other part of the flower except the nectar. After feeding bouts, howlers carried abundant yellow pollen on their snouts. During the focal sampling, we only observed the infant feeding on nectar. This infant consumed nectar in three occasions for a total of 21.24h of focal sampling. On one occasion, the infant consumed both nectar and flower parts.

Discussion

This study shows that nectar-feeding was a rare behavior in the feeding repertory of *A. caraya* (the average rate of nectar-feeding was 0.14 records per hour). The nectar is an opportunistic food resource. Only young individuals ate part or all of the flowers together with the nectar. In this regard, Pereira & Fairbanks (1993) show that juveniles spent more time exploring novel objects, including food, in comparison to adult individuals. The rest of the age-classes licked the nectar and did not eat any other part of the flower. Garber (1988) and Riba-Hernández & Stoner (2005) found that adult individuals of *Ateles geoffroyi*, *Saguinus mystax*, and *S. fuscicollis* destroy the flowers of *Symphonia globulifera* (Guttiferae) when they were feeding on nectar. In contrast, studies on *Aotus trivirgatus*, *Ateles paniscus*, *Brachyteles arachnoides*, *Callithrix flaviceps*, *Cebuella pygmaea*, *Cebus albifrons*, *C. apella*, *Eulemur macaco*, *Saguinus fuscicollis*, *S. imperator*, and *Saimiri sciureus* (Janson *et al.*, 1981; Torres de Assumpção, 1981; Ferrari & Strier, 1992; Birkinshaw & Colquhoun, 1998) found that animals did not eat or caused little damage to the flowers when they were feeding on nectar.

Every time howlers visited flowers to feed on nectar they removed pollen with their snouts. They moved between different inflorescences on the same tree, potentially facilitating pollen movement between flowers of the same tree. However, monkeys did not engage in cross-pollination because in Huerta's home range there was just one tree of *G. robusta* and in Ariscos's home range there were two trees but separated by 80m. Nevertheless, we observed effective seed production in the three *G. robusta* trees used by the howlers. Other non-human primates appear to be involved

Table 1. Summary of nectar-feeding records in two groups of *Alouatta caraya* in San Cayetano.

Group	Study period	Days followed	Sampling technique	Date of nectar-feeding	Group composition	Flower damage
Ariscos	Sep 2005-Sep 2006	65	Scan (5 days/month)	Nov 22, 2005	**1 AM, 1 AF, 1 JM**	No
Ariscos	Sep 2007-Feb 2008	18	Scan (3 days/month)	Oct 16-17, 2007	1 AM, 1 AF, **1 SAM**, **1 JM**, 1 I	No
Huerta	Feb-Dec 2007 Jan-Jun 2009	38	Focal	Oct 26-27, 2007	1 AM, 1 SAM, 2 AF, 4 JF, **1 JM**	Yes
Huerta	Sep 2008-Jun 2009	20	Scan (2 days/month), Focal	Oct 14, 2008	2 AM (**1 AM**), 2 AF (**1 AF**), 2 SAF, 2 JF (**1 JF**), 1 JM, **1 I**	Yes

References. **AM:** adult male, **AF:** adult female, **SAM:** subadult male, **SAF:** subadult female, **JM:** juvenile male, **JF:** juvenile female, **I:** infant. Group composition: In bold case, individuals engaged in nectar-feeding.

in pollination, i.e *Aotus lemurinus* (Marín-Gómez, 2008), *B. arachnoides* (Torres de Assumpção, 1981), *C. apella* (Torres de Assumpção, 1981), and *E. macaco* (Birkinshaw & Colquhoun, 1998).

Grevillea robusta has features that can allow its pollination by diurnal vertebrates such as *A. caraya* including a partially fused perianth, brightly colored flowers in terminal racemes, simultaneous flower opening, and abundant nectar and pollen production (Janson *et al*., 1981; Carthew & Goldingay, 1997). In Australia, 28 species of Proteaceae are visited by non-flying mammals for nectar-feeding (Carthew & Goldingay, 1997). Also, in some proteaceous species, large vertebrates as the marsupials are important pollinators (Goldingay *et al*., 1991). In the study area, two species of nectar-feeding bats and at least 320 species of birds have been identified (Zunino & Kowalewski, 2008) and some of them may act as effective pollinators of *G. robusta*. *Grevillea robusta* is not a threat to native biodiversity because it did not become invasive (Mooney & Cleland, 2001). The role of primates and other vertebrates in the maintenance of this plant species remains unclear. Experimental research is needed to evaluate the real importance of *A. caraya* in pollination. Also, further research is critical as exotic species invasions and pollinator ecology are high priority issues in conservation biology.

Acknowledgments

We thank Amparo Perez Rueda, Carlos A. González, Dana Banegas, Freddy Ramírez Pinto, Miguel Blanco, Ramón Martinez, Ramón Romero, for helping us with the field studies. This study was funded by the American Society of Mammalogists, the American Society of Primatologists, Consejo Nacional de Investigaciones Científicas y Técnicas de Argentina, Idea Wild, and the Rufford Small Grants Foundation.

Romina Pavé, Estación Biológica Corrientes- Museo Argentino de Ciencias Naturales, C1405DJR, Buenos Aires, Argentina. E-mail: <rominaepave@yahoo.com.ar>, **Silvana M. Peker** Estación Biológica Corrientes- Museo Argentino de Ciencias Naturales, **Mariana Raño**, Estación Biológica Corrientes- Museo Argentino de Ciencias Naturales, **Carolina Ramírez Orjuela**, Estación Biológica Corrientes- Museo Argentino de Ciencias Naturales and Centro de Ecologia Aplicada del Litoral, Corrientes, Argentina, **Gabriel E. Zunino**, Estación Biológica Corrientes- Museo Argentino de Ciencias Naturales, **Martin M. Kowalewski**, Estación Biológica Corrientes- Museo Argentino de Ciencias Naturales and Department of Anthropology, University of Illinois at Urbana-Champaign, Urbana, Illinois, USA.

References

Altmann, J. 1974. Observational study of behavior: Sampling methods. *Behaviour* 49: 227–267.

Birkinshaw, C. R. and Colquhoun, I. C. 1998. Pollination of *Ravenala madagascariensis* and *Parkia madagascariensis* by *Eulemur macaco* in Madagascar. *Folia Primatol.* 69: 252–259.

Carthew, S. M. and Goldingay, R. L. 1997. Non-flying mammals as pollinators. *TREE* 12(3): 104–108.

Collins, B. G. and Rebelo, T. 1987. Pollination biology of the Proteaceae in Australia and southern Africa. *Aust. J. Ecol.* 12: 387–421.

Crockett, C. M. and Eisenberg, J. F. 1987. Howlers: variations in group size and demography. In: *Primate societies*, B. B Smuts, D. L. Cheney, R. M. Seyfarth, R. W. Wrangham and T. T. Struhsaker (eds.), pp. 54–68. University of Chicago Press, Chicago.

Ferrari, S. F. and Strier, K. B. 1992. Exploitation of *Mabea fistulifera* nectar by marmosets (*Callithrix flaviceps*) and muriquis (*Brachyteles arachnoides*) in South-East Brazil. *J. Trop. Ecol.* 8(3): 225–239.

Garber, P. A. 1988. Foraging decisions during nectar feeding in tamarin monkeys, *Saguinus mystax* and *Saguinus fuscicollis* (Calitrichidae: Primates) in Amazonian Peru. *Biotropica* 20: 100–106.

Goldingay, R. L., Carthew, S. M. and Whelan, R. J. 1991. The importance of non-flying mammals in pollination. *Oikos* 61: 79–87.

Harwood, C. E. 1992. Natural distribution and ecology of *Grevillea robusta*. *Grevillea robusta in Agroforestry and Forestry* (ed. C. E. Harwood) pp. 21–8. International Centre for Research in Agroforestry, Nairobi.

Janson, C., Terborgh, J. and Emmons, L. H. 1981. Non-flying mammals as pollinating agents in the Amazonian forest. *Biotropica* 13(2): 1–6.

Kalinganire, A., Harwood, C. E., Slee, M. and Simons, A. J. 2000. Floral structure, stigma and pollen receptivity in relation to protandry and self-incompatibility in silky oak (*Grevillea robusta* A. Cunn.). *Ann. Bot.* 86: 133–48.

Kress, W. J., Schatz, G. E., Andrianifahanana, M. and Simons Morland, H. 1994. Pollination of *Ravenala madagascariensis* (Strelitziaceae) by lemurs in Madagascar: Evidence for an archaic coevolutionary system?. *Am. J. Bot.* 81(5): 542–551.

Marín-Gómez, O. H. 2008. Consumo de néctar por *Aotus lemurinus* y su rol como posible polinizador de las flores de *Inga edulis* (Fabales: Mimosoideae). *Neotrop. Primates* 15(1): 30–32.

McGillivray, D. J. 1993. *Grevillea. Proteaceae: A Taxonomic Revision*. University Press, Melbourne.

Milton, K. 1998. Physiological ecology of howlers (*Alouatta*): energetic and digestive considerations and comparison with the Colobinae. *Int. J. Primatol.* 19: 513–548.

Mooney, H. A. and Cleland, E. E. 2001. The evolutionary impact of invasive species. *Proc. Natl. Acad. Sci.* 98: 5446–5451.

Moscovich, F., Fassola, H., Crechi, E., Colcombet, L., Lacorte, S., Domecq, C. and Hampel, H. 2004. Silvicultura y manejo de *Grevillea robusta*. 3º Simpósio Latinoamericano sobre Manejo Forestal.

Parker, I. M. 1997. Pollinator limitation of *Cytisus scoparius* (Scotch broom), an invasive exotic shrub. *Ecology* 78: 1457–1470.

Passos, F. C. and Kim, A. C. 1999. Nectar feeding on *Mabea fistuifera* Mart. (Euphorbiaceae) by black lion tamarin, *Leontopithecus chrysopygus* Mikan, 1983 (Callitrichidae), during the dry season in southeastern Brazil. *Mammalia* 63(4): 519–521.

Pereira, M. E. and Fairbanks, L. A. 1993. *Juvenile Primates. Life history, development and behavior*. Oxford University Press, New York.

Peres, C. A. 1994. Primate responses to phenological changes in a Amazonian terra firme forest. *Biotropica* 26(1): 98–112.

Puertas, P., Aquino, R. and Encarnación, F. 1992. Uso de alimentos y competición entre el mono nocturno *Aotus vociferans* y otros mamíferos, Loreto, Perú. *Folia Amazónica* 4(2): 147–156.

Riba-Hernández, P. and Stoner, K. 2005. Massive destruction of *Symphonia globulifera* (Clusiaceae) flowers by Central American spider monkeys (*Ateles geoffroyi*). *Biotropica* 37(2): 274–278.

Rumiz, D. I. 1990. *Alouatta caraya*: Population density and demography in Northern Argentina. *Am. J. Primatol.* 21: 279–294.

Sussman, R. W. 1979. Nectar feeding by prosimians and its evolutionary and ecological implications. In: *Primates ecology: problem-oriented field studies*, R. W. Sussman RW (ed.), pp. 569–577. John Wiley and Sons, New York.

Stout, J. C., Parnell, J. A. N., Arroyo, J. and Crowe, T. P. 2006. Pollination ecology and seed production of *Rhododendron ponticum* in native and exotic habitats. *Biodiv. Conserv.* 15: 755–777.

Torres de Assumpção, C. T. 1981. *Cebus apella* and *Brachyteles arachnoides* (Cebidae) as potencial pollinators of *Mabea fistulifera* (Euphorbiaceae). *J. Mammal.* 62(2): 386–388.

Zunino, G. E., Kowalewski, M. M., Oklander, L. I. and Gonzalez, V. 2007. Habitat fragmentation and population trends of the black and gold howler monkey (*Alouatta caraya*) in a semideciduous forest in northern Argentina. *Am. J. Primatol.* 69: 966–975.

Zunino, G. E. and Kowalewski, M. M. 2008. Primate research and conservation in northern Argentina: the field station Corrientes (Estación Biológica de Usos Múltiples – EBCo). *Trop. Cons. Science* 1(2): 140–150.

YEASTS ISOLATED FROM *ALOUATTA PALLIATA*, *ATELES GEOFFROYI*, *CEBUS CAPUCINUS* AND *SAIMIRI OERSTEDII* (PRIMATES: CEBIDAE)

Norma Gross
Juan Diego Castro
Olga Guerrero
Misael Chinchilla
Ronald Sánchez
Gustavo Gutiérrez-Espeleta

Introduction

In the present study the presence of yeasts on the skin, and in the oral cavity and vagina of *Alouatta palliata* (mantled howler monkey), *Ateles geoffroyi* (black-handed spider monkey), *Cebus capucinus* (white-faced capuchin) and *Saimiri oerstedii* Reinhardt, 1872 (red-backed squirrel monkey) from several sites of Costa Rica was examined. These primates have been characterized with regard to their feeding patterns (Jones, 1983; Happel, 1986) and geographical distribution (Massey, 1987; Lippold, 1988, Rodríguez and Chinchilla, 1996). Also, the bacterial flora as well as the endo- and ectoparasites of Costa Rican primates have been reported (Troyo *et al.*, 2002; Calderón-Arguedas *et al.*, 2004; Gamboa-Coronado *et al.*, 2004; Chinchilla *et al.*, 2005; Chinchilla *et al.*, 2006). The present project is unique in being the first to assess the yeast flora in these Neotropical primates. The yeast *Candida* is a saprophyte in natural products, but has been isolated from the mucosa and skin of humans and animals (Mariat and Droulet, 1996). *Candida* is considered an opportunistic micro-organism that causes disease in hosts with a weakened immune system (Ostrosky-Zeichner, 2003). The most common clinical manifestations of candidiasis are cutaneous, mucocutaneous and invasive infections. In humans, *Candida* infections of the mouth and esophagus are frequently associated with AIDS (de Repentigny *et al.*, 2004). Vulvo-vaginal candidiasis is a common cause of vaginal discharge, soreness, vulvar burning, dysuria and local pruritus. *Candida* may be either a commensal or a pathogen of the vagina, which indicates that changes in the host vaginal defense mechanisms or changes in the vaginal micro-environment are generally necessary for *Candida* to induce pathology or association with clinical symptoms (Sobel, 1997). On the other hand, invasive candidiasis is reported in individuals with prolonged neutropenia such as those receiving treatment for leukemia or solid tumors, or transplantation therapy (García-Ruiz *et al.*, 2004).

The finding of yeast in an individual or in a group of healthy monkeys does not imply that this micro-organism is part of the normal flora of the respective species. It is likely, however, that the isolation of *Candida* in a particular population of monkeys is indicative of colonization, as has been well established for other animals (Mariat and Droulet, 1996). The purpose of the present work was thus to