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Handroanthus impetiginosus (BIGNONIACEAE) AS AN IMPORTANT FLORAL RESOURCE FOR SYNANTHROPIC BIRDS IN THE BRAZILIAN SEMIARID

Vitor de Oliveira Lunardi[1,2,3], Érica Emanuela de Medeiros e Silva[2], Saulo Tasso Araújo da Silva[4] & Diana Gonçalves Lunardi[3,4]*

[1] Universidade Federal Rural do Semi-Árido, Departamento de Biociências, Laboratório de Ecologia Evolutiva e Molecular, Av. Francisco Mota 572, CEP 59625-900, Mossoró, RN, Brazil.

[2] Universidade Federal Rural do Semi-Árido, Programa de Pós-Graduação em Ecologia e Conservação, Av. Francisco Mota 572, CEP 59625-900, Mossoró, RN, Brazil.

[3] Universidade Federal Rural do Semi-Árido, Programa de Pós-Graduação em Ambiente, Tecnologia e Sociedade, Av. Francisco Mota 572, CEP 59625-900, Mossoró, RN, Brazil.

[4] Universidade Federal Rural do Semi-Árido, Departamento de Engenharia e Ciências Ambientais, Av. Francisco Mota 572, CEP 59625-900, Mossoró, RN, Brazil.

E-mails: lunardi.vitor@ufersa.edu.br (*corresponding author); ericamanu.ecologia@gmail.com; saulo@ufersa.edu.br; lunardi.diana@ufersa.edu.br

Abstract: *Handroanthus impetiginosus* (Bignoniaceae) is commonly used in urban afforestation in the Brazilian semiarid, and it attracts native urban fauna during the dry season, when the plants are flowering. We conducted focal observations on nine flowering *H. impetiginosus* in an urban area at Brazilian semiarid to record the bird species that used flowers as a food resource and their behavior. We recorded four species of visiting birds at the *H. impetiginosus* flowers: *Eupetomena macroura*, *Chlorostilbon lucidus*, *Icterus pyrrhopterus* and *Tangara sayaca*. Of these, *E. macroura* and *C. lucidus* were observed on illegitimate visits, not contributing to the pollination, and *E. macroura* was the most aggressive species. *Icterus pyrrhopterus* and *T. sayaca* feeding on parts of the flowers or flower buds, generally promoting the flower abscission to access the nectar. The presence of *H. impetiginosus* can support generalist nectarivorous bird species, as *E. macroura*, *C. lucidus* and *I. pyrrhopterus*, and bees, as *Xylocopa* spp. in urban areas, which may contribute to the pollination of other native plant species in reforestation projects in this semiarid region.

Keywords: florivory; illegitimate visit; nectar robbers; synanthropic behavior.

Handroanthus impetiginosus (Mart. ex. DC.) Mattos (Bignoniaceae) is a typical Neotropical tree of dry forests in the Brazilian semiarid, even though its populations are currently in decline due to overexploitation (CNCFlora 2012). It is used in urban afforestation and by recovery projects of degraded areas in northeastern Brazil (Maia 2004). This tree has a reproductive strategy of flowering during the dry season, producing hundreds of pink-colored flowers while losing most leaves. The strategy results in a pink treetop, which makes it especially attractive to visual pollinators, especially bees (Schlindwein *et al.* 2014), which search for nectar and/or pollen along the forest remnants of the Brazilian semiarid.

The Brazilian semiarid region is characterized

in general by a prolonged dry season, with unpredictable and irregular rainfall, high mean temperature over the year, and shallow and crystalline soils (Silva *et al.* 2010). Although this region presents water restriction, it also harbors a considerable diversity of fauna, flora and ecological interactions (Albuquerque *et al.* 2012). Despite the great advance of knowledge on its biodiversity, there are still many gaps for the region, such as about the behavioral and physiological adaptations of its organisms (Albuquerque *et al.* 2012). Between 30.4% and 51.7% of the landscape in the region has been altered by human activities, thus a considerable portion of the biodiversity of the area might have been lost (Leal *et al.* 2005). Particularly, some birds respond positively to urbanization in the region (e.g., Lunardi *et al.* 2013), but identifying which are the factors important for synanthropic species in urban systems is still a challenge (Rodewald & Shustack 2008). Bird pollinators that respond positively to urbanization can play an essential role in the reproduction of many plants and there is great interest in incorporating these species into habitat restoration plans (Menz *et al.* 2011).

In the Brazilian semiarid region, floral nectar of ornithophilous and non-ornithophilous plants contribute significantly to the establishment of hummingbird communities in several natural forest remnants (Machado & Lopes 2004, Machado 2009, Las-Casas *et al.* 2012). Apart from the flower availability, other environmental factors, such as the water restriction and the high temperatures, can potentially influence hummingbirds foraging strategies, time-budget, and physiology (Wolf *et al.* 1975, Gerson *et al.* 2014). Our main objective was to identify if the non-ornithophilous *H. impetiginosus* flowers are important as food resource for synanthropic birds in urban areas of the Brazilian semiarid. Our specific objectives are: (i) to identify the visiting birds at *H. impetiginosus* flowers; (ii) to register the type of access to floral nectar (legitimate or illegitimate visits) or floral consumption (parts of flowers or flower buds); (iii) to record agonistic interactions, and (iv) to investigate if the birds foraging behavior (number of visits and agonistic interactions) vary according to air temperature.

The study was conducted at the Universidade Federal Rural do Semi-árido (UFERSA), Mossoró, Rio Grande do Norte, Brazil (05°12'16"S, 37°19'39"W, Datum SAD84). The campus is located in a wooded urban area with native and exotic plants. According to Köppen, the climate of the study area can be classified as BSh (Alvares *et al.* 2013).

To register the visiting birds, and their behavior, we conducted focal observations (plant focal and animal focal; Altmann 1974) near nine *H. impetiginosus* treetops, during two different flowering periods: November 2013 to January 2014, and October 2014 to January 2015. Focal observations occurred individually for each of the nine analyzed trees during flowering peak. Each focal plant was sampled during an 8 h period, between 06:00 h - 10:00 h (morning) and 14:00 h - 18:00 h (afternoon), totaling 136 h of sampling effort (68 h in the morning and 68 h in the afternoon). Focal animal observations were performed on birds that visited the plant treetops and them flowers. We identified the birds with the help of an 8 × 40 mm Bushnell® binoculars, bird's photographs taken during observations, and identification guides (e.g., Grantsau 1988). Air temperature (°C) was attained from UFERSA's meteorological station.

In this study we adopted the following definitions: (i) visit – continuous period of nectar exploitation in a flower by a bird; (ii) legitimate visits – insertion of a bird's beak in the flower's corolla, possibly contacting the reproductive organs of the plant and taking pollen during a visit (Machado 2009); (iii) illegitimate visits – when a bird pierces the flower at the base of the corolla using its beak during a visit (or using preexisting corolla holes), taking the nectar directly with no contact with the plant's reproductive organs (Machado 2009, Irwin *et al.* 2010); (iii) floral consumption – when a bird consumes flowers parts or flower buds using the mandibles during a visit; and (iv) agonistic interactions – represented by attacks or persecution between visitors (Machado 2009).

We used simple linear regression (Zar 1999) to evaluate the relationship between the total numbers of visits and the average air temperature, and between the total numbers of agonistic interactions and the average air temperature, in each 30 min interval, throughout the study period. The coefficient of determination, r^2, and the F statistic were used to test the significance of the regression (Zar 1999).

We recorded four species of birds visiting *H. impetiginosus* flowers: *Eupetomena macroura*,

Chlorostilbon lucidus (family Trochilidae), *Icterus pyrrhopterus* (family Icteridae) and *Tangara sayaca* (family Thraupidae). All the bird visits registered were illegitimate visits. We recorded 15,764 illegitimate visits performed by the hummingbirds, *C. lucidus* and *E. macroura* (Figure 1a). *Eupetomena macroura* made more illegitimate visits than *C. lucidus* (respectively: N = 13,690; N = 2,074). We not observed the flower abscission immediately after the illegitimate visits of hummingbirds. *Icterus pyrrhopterus* and *T. sayaca* fed on parts of the flower or flower buds of *H. impetiginosus*, generally promoting the flower abscission to access the nectar. A total of 156 floral consumption events (flower or buds tissues) was recorded: 94% performed by *I. pyrrhopterus* (N = 146), and 6% by *T. sayaca* (N = 10) (Figure 1c,d).

The number of illegitimate visits made by the hummingbirds *E. macroura* and *C. lucidus* varied throughout the day (Figure 2). The majority (62%) of illegitimate visits made by *E. macroura* occurred in the morning (N = 8,440) and 38% in the afternoon (N = 5,250), while *C. lucidus* presented an opposite pattern. Only 39% of the illegitimate visits made by *C. lucidus* occurred in the morning (N = 808) and 61% occurred in the afternoon (N = 1,266). The number of illegitimate visits performed by *E. macroura* was higher at milder temperatures, and lower at higher temperatures [simple linear regression equation: number of visits = -75.19*(air temperature) + 3061; coefficient of determination: $r^2 = 0.26$; N = 16; p = 0.04] (Figure 3a). There was not a relationship between foraging activity (number of visits) and air temperature for *C. lucidus* [number of visits = 0.1552*(air temperature) + 125.1; $r^2 < 0.001$; N = 16; p = 0.99] (Figure 3b). All the consumption events performed by *I. pyrrhopterus* were in the morning, and by *T. sayaca*, in the afternoon.

Figure 1. (a) Illegitimate visit on *Handroanthus impetiginosus* (Bignoniaceae) flowers by *Eupetomena macroura* (Apodiformes, Trochilidae); **(b)** Detail of the damage (holes) at the base of the corolla caused by *Xylocopa frontalis* (Hymenoptera, Apidae) in an illegitimate visit; **(c)** Flower parts consumption by *Tangara sayaca* (Passeriformes, Thraupidae); **(d)** Flower bud consumption by *Tangara sayaca*.

We recorded 848 agonistic interactions with the objective of defending floral resource, which included persecution and pecking. Of these, 63% (N = 530) occurred between birds and bees (*Xylocopa frontalis*) and 37% (N = 318), between birds (Figure 4). The main floral visitor that persecuted and peaked the plant visitors was *E. macroura* (N = 840) and its victims were *X. frontalis* (N = 445), other *E. macroura* (N = 313), *C. lucidus* (N = 66), *P. domesticus* (N = 11) and *T. sayaca* (N = 5). *Chlorostilbon lucidus* was recorded persecuting and pecking only other *C. lucidus* (N = 5) and *E. macroura* (N = 3). We found negative relationship between the total number of agonistic interactions and air temperature [number of visits = -10.17*(air temperature) + 351.2; r^2 =0.3, N = 16; p = 0.03], and the agonistic interactions were higher at milder temperatures, and lower at higher temperatures (Figure 3c).

In the studied urban area, *E. macroura* was the bird that benefited the most from the flowering of *H. impetiginosus*, followed by *C. lucidus*, *I. pyrrhopterus* and *T. sayaca*. On the other hand, in a forest remnant of the Brazilian semiarid (Serra do Pará, PE), *C. lucidus* benefited the most from the flowering of *H. impetiginosus*, followed by hummingbirds *Heliomaster squamosus*, *E. macroura* and *Chrysolampis mosquitus* (Las-Casas *et al.* 2012). Therefore, in the Brazilian semiarid, bird communities that visit *H. impetiginosus* may differ in these two environments – forests remnants and urban areas – in terms of species composition and visitation frequency. The higher frequency of records of *E. macroura* in this study may indicate that this species is reaching higher densities in urban areas than in forest remnants (Machado 2009). In addition, this could be evidence of greater foraging opportunities in urban areas due to the reduced competition for resources from other nectarivorous birds – such as *H. squamosus* and *C. mosquitus*, which were absent in the urban study area, but forage in *H. impetiginosus* in forest remnants at Brazilian semiarid (Las-Casas *et al.* 2012).

Also, *E. macroura*, *C. lucidus*, *I. pyrrhopterus* and *T. sayaca* did not realized legitimate visits,

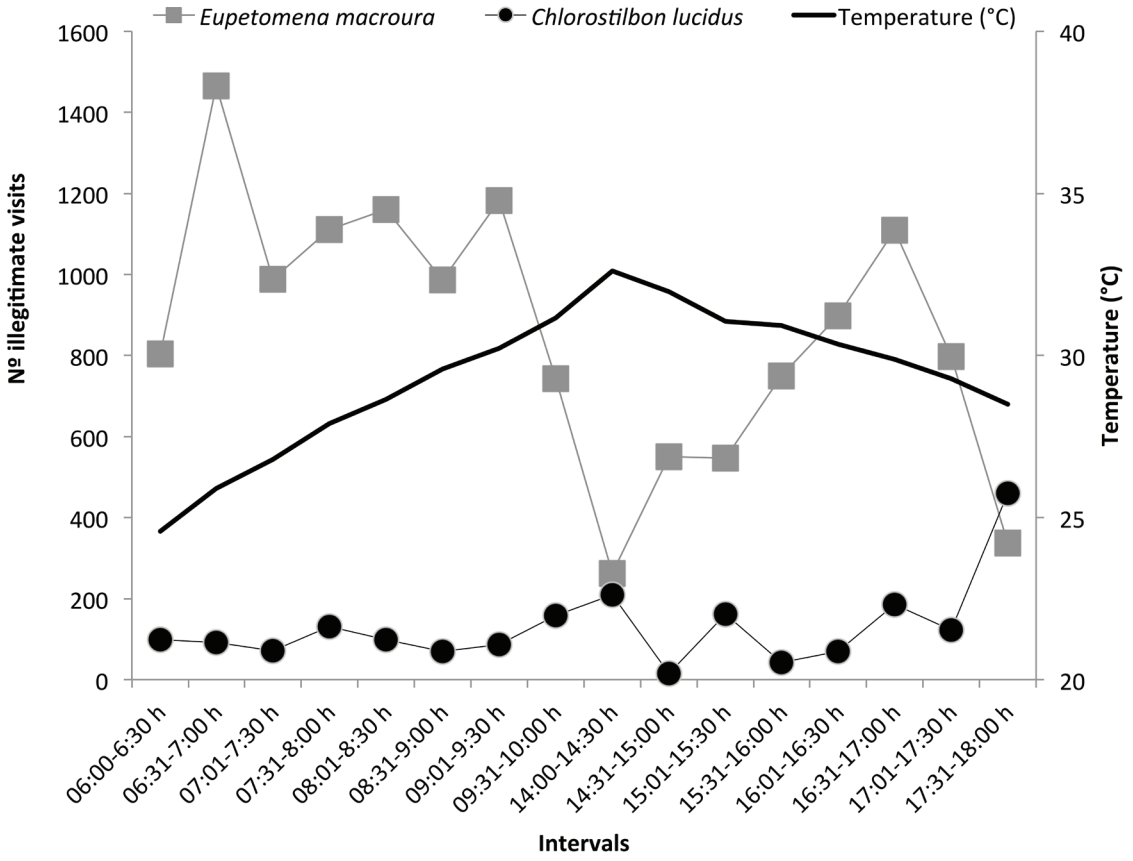

Figure 2. Variation the number of illegitimate visits performed by *Eupetomena macroura* and *Chlorostilbon lucidus* (Apodiformes, Trochilidae) during two focal observation periods (morning = 06:00-10:00 h; afternoon = 14:00-18:00 h) in *Handroanthus impetiginosus* (Bignoniaceae), grouped in intervals of 30 min, as a function of the average air temperature.

and therefore not contribute to pollination of *H. impetiginosus*, behaving invariably as nectar robbers. These four birds are generalist nectar foragers in forest remnants of the Brazilian semiarid, contributing to pollination of ornithophilous, non-ornithophilous plants and/or generalized pollination systems (Machado 2009, Las-Casas *et al.* 2012, Queiroz *et al.* 2016). Although these birds are not contributing to pollination and reproduction of *H. impetiginosus*, this plant must be contributing to the maintenance of nectarivorous-generalist bird populations in urban areas of the Brazilian semiarid. However, urban areas do not have high diversity and richness of plants, common in remaining forests, to maintain many nectarivorous specialist species (e.g., Machado 2009, Las-Casas *et al.* 2012).

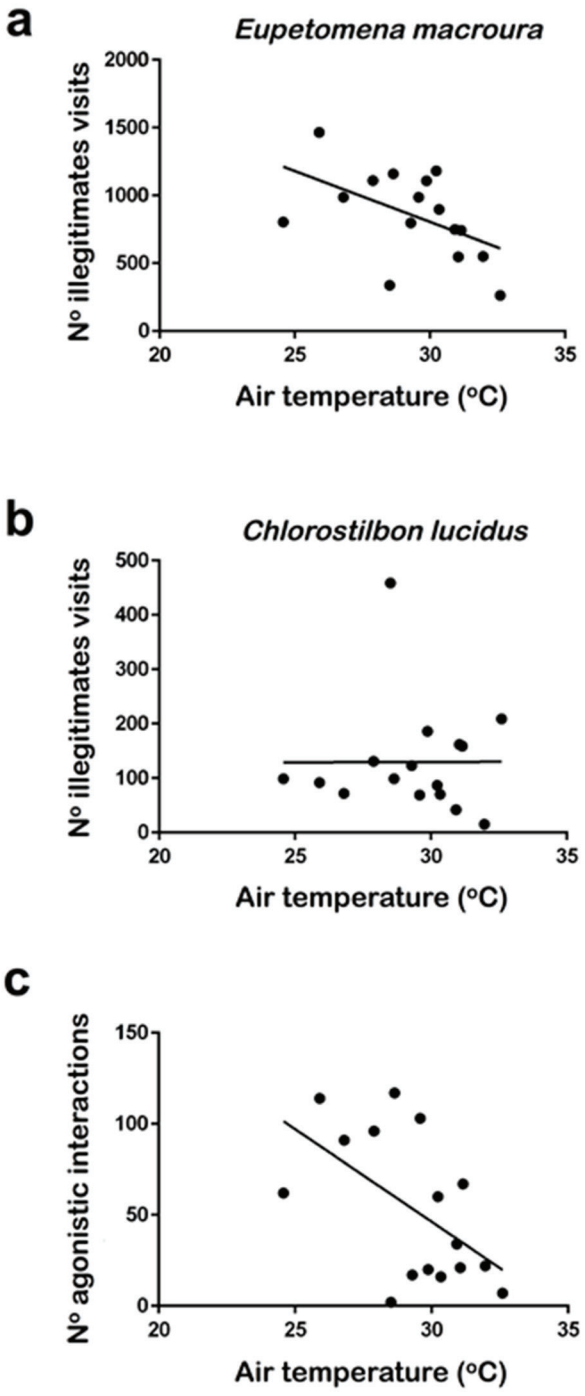

Figure 3. Variation in the number of illegitimate visits performed by *Eupetomena macroura* (a) and *Chlorostilbon lucidus* (b) (Apodiformes, Trochilidae), and variation in the total number of agonistic interactions (c); all as a function of the average air temperature. Linear simple regression lines were presented in the graphs (see text for the statistical test results).

While our data shows that *E. macroura* preferred milder temperatures, which a priori may represent a trade-off between energy gain with feeding and energy expenditure with thermoregulation (Gerson *et al.* 2014), air temperature seems not to determine the foraging activity of *C. lucidus* at *H. impetiginosus*. The properties of nectar (i.e., volume, sugar concentration, and calories) can provide a better explanation of patterns of visits (Wolf *et al.* 1975). From, the total number of illegitimate visits and agonistic encounters, we conclude that *E. macroura* behaved as a dominant bird at *H. impetiginosus* in an urban area, defending these flowering plants as feeding territories. *Chlorostilbon lucidus* rarely behaved as a dominant species, although this species is described as dominant during its visitation in flowers of forest remnants in the Brazilian semiarid (Las-Casas *et al.* 2012).

Icterus pyrrhopterus was not recorded in agonistic encounters possibly because it forages as solitary, such as others *Icterus* spp. (Rocca & Sazima 2010), and as transients, thus not being considered as a territory competitor by hummingbirds *E. macroura* and *C. lucidus* (Queiroz *et al.* 2016). However, we recorded frequent agonistic encounters between *E. macroura* and the bee *X. frontalis*. This bee is considered a nectar robber of H. impetiginosus (Schlindwein *et al.* 2014), and *E. macroura* was frequently recorded using the holes in the flower corollas made by *X. frontalis* in the studied urban area (V. O. Lunardi, personal communication). Thus, in urban areas, *E. macroura* also behaves like a secondary nectar robber (Irwin *et al.* 2010) and it is very likely that *E. macroura* is benefiting from the constant presence of *X. frontalis* in *H. impetiginosus* flowers, because this bee facilitates access to the nectar. The intense nectar robbing by

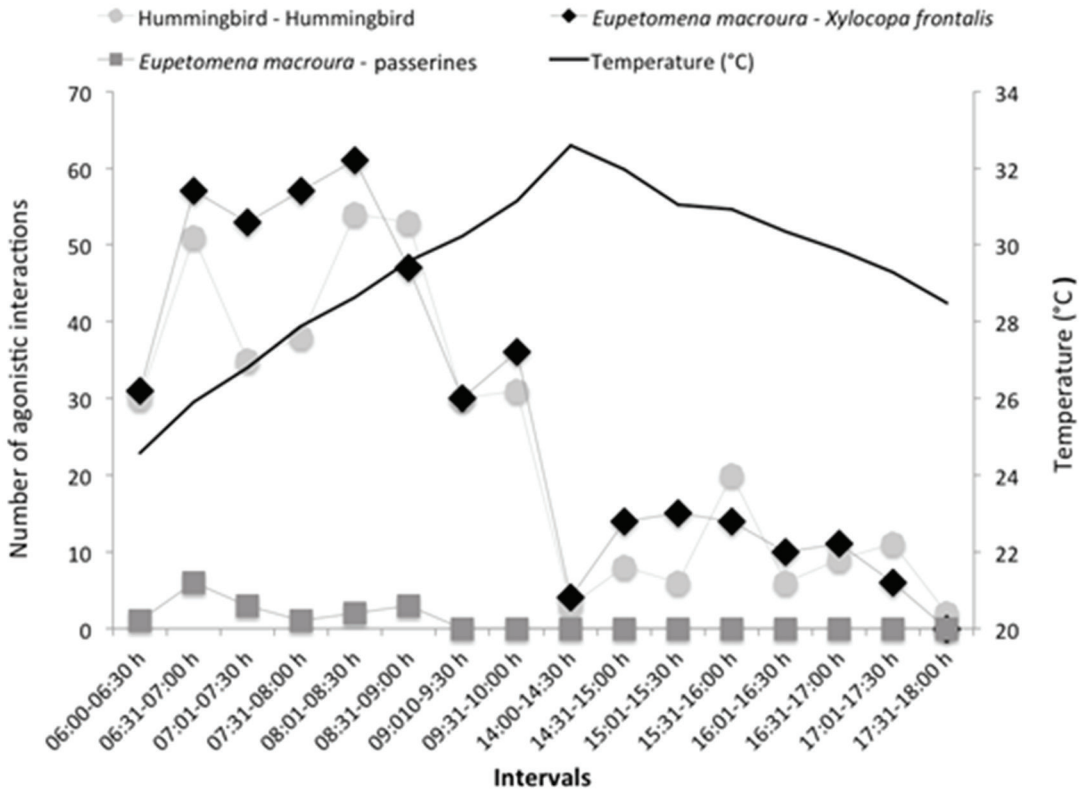

Figure 4. Variation in the number of agonistic interactions between hummingbird vs. hummingbird, *Eupetomena macroura* vs. *Xylocopa frontalis* and *Eupetomena macroura* vs. passerines during two focal observation periods (morning = 06:00-10:00 h; afternoon = 14:00-18:00 h) in *Handroanthus impetiginosus* (Bignoniaceae), grouped in intervals of 30 min, as a function of the average air temperature.

X. frontalis and birds in *H. impetiginosus* in urban areas can reduce the nectar available to legitimate pollinators and, consequently, to seed production (e.g., Castro *et al.* 2008).

The community of visiting birds at *H. impetiginosus* in the studied urban area differed in behavior and species composition when compared to those in a remaining forest in the Brazilian semiarid, Serra do Pará (Las-Casas *et al.* 2012). In the studied urban area, *H. impetiginosus* flowers are important resources for native Brazilian semiarid birds during dry seasons – especially for generalist and synanthropic nectarivorous birds such as *E. macroura*, *C. lucidus* and *I. pyrrhopterus*. *Eupetomena macroura* was the most aggressive species in the defense of *H. impetiginosus* flowers in the studied urban area. Some species exhibited less foraging and aggressive activities in the periods of the day of higher temperature, while other species do not present this pattern. These characteristics and behaviors suggest adaptations of the semiarid hummingbird community to the urban system. Other parameters, as the properties of nectar (e.g., volume, sugar concentration, and calories), should be considered in addition to temperature to provide a better explanation of patterns of bird visits and agonistic encounters in *H. impetiginosus* (Wolf *et al.* 1975, López-Segoviano *et al.* 2018). In a conservation planning framework, we suggest planting of *H. impetiginosus*, both in urban areas and for the recovery of degraded areas, in order to increase the supply of food resources for birds and bees in the Brazilian semiarid during dry seasons. The presence of plant species that support generalist nectarivorous bird species, as *E. macroura*, *C. lucidus* and *I. pyrrhopterus*, and bees, as *Xylocopa* spp. (Schlindwein *et al.* 2014), may contribute to the pollination of other native plant species in urban areas or in reforestation projects in this semiarid region.

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REFERENCES

Albuquerque, U. P., Araujo, E. L., El-Deir, A. C. A., Lima, A. L. A., Souto, A., Bezerra, B. M., Ferraz, E. M. N., Freire, E. M. X., Sampaio, E. V., De-Sa, B., Las-Casas, F. M. G., Moura, G. J. B., Pereira, G. A., Melo, J. G., Ramos, M. A., Rodal, M. J. N., Schiel, N., Lyra-Neves, R. M., Alves, R. R. N., Azevedo-Junior, S. M., Telino-Junior, W. R., & Severi, W. 2012. Caatinga revisited: ecology and conservation of an important seasonal dry forest. The Scientific World Journal, Article ID: 205182. DOI: 10.1100/2012/205182

Altmann, J. 1974. Observational study of behavior: sampling methods. Behaviour, 49(3), 227–267. DOI: 10.1163/156853974X00534

Alvares, C. A., Stape, J. L., Sentelhas, P. C., Moraes, G., Leonardo, J., & Sparovek, G. 2013. Köppen's climate classification map for Brazil. Meteorologische Zeitschrift, 22(6), 711–728. DOI: 10.1127/0941-2948/2013/0507

Castro, S., Silveira, P., & Navarro, L. 2008. Consequences of nectar robbing for the fitness of a threatened plant species. Plant Ecology, 199(2), 201–208. DOI: https://doi.org/10.1007/s11258-008-9424-z

CNCFlora (Centro Nacional de Conservação da Flora). 2012. *Handroanthus impetiginosus* na lista vermelha da flora brasileira, versão 2012.2. Retrieved on June 15, 2017, from http://cncflora.jbrj.gov.br/portal/pt-br/profile/Handroanthus%20impetiginosus

Gerson, A. R., Smith, E. K., Smit, B., McKechnie, A. E., & Wolf, B. O. 2014. The impact of humidity on evaporative cooling in small desert birds exposed to high air temperatures. Physiological and Biochemical Zoology, 87(6), 782–795. DOI: 10.1086/678956

Grantsau, R. 1988. Os beija-flores do Brasil: uma chave de identificação para todas as formas de beija-flores do Brasil. Rio de Janeiro: Expressão e Cultura: p. 233.

Irwin, R. E., Bronstein, J. L., Manson, J. S., & Richardson, L. 2010. Nectar robbing: ecological and evolutionary perspectives. Annual Review of Ecology, Evolution, and Systematics, 41, 271–292. DOI: 10.1146/annurev.ecolsys.110308.120330

Las-Casas, F. M. G., Azevedo Júnior, S. M., & Dias Filho, M. M. 2012. The community of hummingbirds (Aves: Trochilidae) and the assemblage of flowers in a Caatinga vegetation. Brazilian Journal of Biology, 72(1), 21–58. DOI: 10.1590/S1519-69842012000100006

Leal, I. R., Silva, J. M., Tabarelli, M., & Lacher Jr, T. E. 2005. Changing the course of biodiversity conservation in the Caatinga of northeastern Brazil. Conservation Biology, 19(3), 701–706. DOI: 10.1111/j.1523-1739.2005.00703.x

López-Segoviano, G. , Bribiesca, R., & Arizmendi, M. D. 2018. The role of size and dominance in the feeding behaviour of coexisting hummingbirds. Ibis, 160, 283–292. DOI: 10.1111/ibi.12543

Lunardi, V. O., Oliveira-Silva, C. C., Nascimento, L. A., & Lunardi, D. G. 2013. Synanthropic behavior of the Neotropical palm swift *Tachornis squamata* (Apodiformes: Apodidae) in the Brazilian Caatinga. Zoologia, 30(6), 697–700. DOI: 10.1590/S1984-46702013005000012

Machado, C. G. 2009. Beija-flores (Aves: Trochilidae) e seus recursos florais em uma área de caatinga da Chapada Diamantina, Bahia. Revista Brasileira de Zoologia, 26(2), 255–265. DOI: 10.1590/S1984-46702009000200008

Machado, I. C., & Lopes, A. V. 2004. Floral traits and pollination systems in the Caatinga, a Brazilian tropical dry forest. Annals of Botany, 94, 365–376. DOI: 10.1093/aob/mch152

Maia, N. G. 2004. Caatinga: árvores e arbustos e suas utilidades. São Paulo: D & Z Computação Gráfica e Editora: p. 413.

Menz, M. H., Phillips, R. D., Winfree, R., Kremen, C., Aizen, M. A., Johnson, S. D., & Dixon, K. W. 2011. Reconnecting plants and pollinators: challenges in the restoration of pollination mutualisms. Trends in Plant Science, 16(1), 4–12. DOI: 10.1016/j.tplants.2010.09.006

Queiroz, J. A., Quirino, Z. G. M., Lopes, A. V., & Machado, I. C. 2016. Vertebrate mixed pollination system in Encholirium spectabile: a bromeliad pollinated by bats, opossum and hummingbirds in a tropical dry forest. Journal of

Arid Environments, 125, 21–30. DOI: 10.1016/j.jaridenv.2015.09.015

Rocca, M. A., & Sazima, M. 2010. Beyond hummingbird-flowers: the other side of ornithophily in the Neotropics. Oecologia Australis, 14(1), 67–99. DOI: 10.4257/oeco.2010.1401.03

Rodewald, A. D., & Shustack, D. P. 2008. Consumer resource matching in urbanizing landscapes: are synanthropic species over-matching. Ecology, 89(2), 515–521. DOI: 10.1890/07-0358.1

Schlindwein, C., Westerkamp, C., Carvalho, A. T., & Milet-Pinheiro, P. 2014. Visual signalling of nectar-offering flowers and specific morphological traits favour robust bee pollinators in the mass-flowering tree *Handroanthus impetiginosus* (Bignoniaceae). Botanical Journal of the Linnean Society, 176(3), 396–407. DOI: 10.1111/boj.12212

Silva, P. C. G., Moura, M. S. B., Kiill, L. H. P., Brito, L. T. L., Pereira, L. A., Sa, I. B., Correia, R. C., Teixeira, A. H. C., Cunha, T. J. F., & Guimarães Filho, C. 2010. Caracterização do semiárido brasileiro: fatores naturais e humanos. In: I. B. Sa & P. C. G. Silva (Eds.), Semiárido brasileiro: pesquisa, desenvolvimento e inovação. p. 18–48. Petrolina: Embrapa Semiárido.

Wolf, L. L., Hainsworth, F. R., & Gill, F. B. 1975. Foraging efficiencies and time budgets in nectar-feeding birds. Ecology, 56(1), 117–128. DOI: 10.2307/1935304

Zar, J. H. 1999. Biostatistical analysis. New Jersey: Prentice Hall: p. 663.

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