



Natural History of the Neotropical Arboreal Ant, *Odontomachus hastatus*: Nest Sites, Foraging Schedule, and Diet

Authors: Camargo, Rafael X., and Oliveira, Paulo S.

Source: Journal of Insect Science, 12(48) : 1-9

Published By: Entomological Society of America

URL: <https://doi.org/10.1673/031.012.4801>



Natural history of the Neotropical arboreal ant, *Odontomachus hastatus*: Nest sites, foraging schedule, and diet

Rafael X. Camargo^{1,2a} and Paulo S. Oliveira^{1b*}

¹Departamento de Biologia Animal, Universidade Estadual de Campinas, C.P. 6109, 13083-970 Campinas SP, Brazil

²Biology Department, University of Ottawa, 30 Marie Curie, Ottawa ON, K1N 6N5 Canada

Abstract

The ecology of most arboreal ants remains poorly documented because of the difficulty in accessing ant nests and foragers in the forest canopy. This study documents the nesting and foraging ecology of a large (~13 mm total length) arboreal trap-jaw ant, *Odontomachus hastatus* (Fabricius) (Hymenoptera: Formicidae) in a sandy plain forest on Cardoso Island, off the coast of Southeast Brazil. The results showed that *O. hastatus* nested in root clusters of epiphytic bromeliads, most commonly *Vriesea procera* (70% of nest plants). Mature *O. hastatus* colonies include one to several queens and about 500 workers. Foraging by *O. hastatus* is primarily nocturnal year-round, with increased foraging activity during the wet/warm season. The foragers hunt singly in the trees, preying on a variety of canopy-dwelling arthropods, with flies, moths, ants, and spiders accounting for > 60% of the prey captured. Although predators often have impacts on prey populations, the ecological importance of *O. hastatus* remains to be studied.

Keywords: activity rhythms, Atlantic forest, Brazil, bromeliad-nesting ants, canopy-dwelling ants, Formicidae, nocturnal ants, Ponerinae

Correspondence: ^a rafael.x.camargo@gmail.com, ^b psa@unicamp.br, * Corresponding author

Editor: Mario Muscedere was Editor of this paper.

Received: 30 May 2011, **Accepted:** 22 July 2011

Copyright : This is an open access paper. We use the Creative Commons Attribution 3.0 license that permits unrestricted use, provided that the paper is properly attributed.

ISSN: 1536-2442 | Vol. 12, Number 48

Cite this paper as:

Camargo RX, Oliveira PS. 2012. Natural history of the Neotropical arboreal ant, *Odontomachus hastatus*: Nest sites, foraging schedule, and diet. *Journal of Insect Science* 12:48 available online: insectscience.org/12.48

Introduction

Ants are dominant social insects that occur in a wide variety of habitats, and exhibit a vast diversity of nesting and feeding habits (Wheeler 1910). Ant foraging strategies may range from solitary hunting to different levels of cooperative foraging mediated by recruitment behavior among nestmates (Hölldobler and Wilson 1990). The majority of ant species are considered generalists by feeding on a broad range of animal- and plant-derived food items, but numerous species may have specialized diets (Carroll and Janzen 1973; Hölldobler and Wilson 1990). Ants are especially dominant in tropical habitats where they are remarkably diverse both on the ground and on vegetation (Brown 2000). Surprisingly, however, very little is known about the natural history and ecology of most tropical ants. Even for large and conspicuous species there is a general lack of information on their basic ecological features such as nest sites, activity rhythms, foraging substrate, and diet.

Most species in the subfamily Ponerine are regarded as predators because they possess powerful mandibles and are armed with a sting (Hölldobler and Wilson 1990). Ponerine species may have diverse feeding habits and foraging modes, ranging from solitary to group hunting, both on the ground and/or foliage (Peeters and Crewe 1987; Brown 2000). Foraging strategies may consist of active hunting for live prey, scavenging for dead arthropods, gathering of plant and/or insect exudates, pearl bodies, and fleshy fruits and seeds (e.g., Duncan and Crewe 1994; Déjean and Suzzoni 1997; Blüthgen et al. 2003; Oliveira and Freitas 2004; Dutra et al. 2006).

The ponerine genus *Odontomachus* is widely distributed in tropical and warm temperate environments and is especially abundant in the Neotropical region where numerous species may occur from semi-arid environments to rain forests (Brown 2000). *Odontomachus* ants are well-known by their trap-jaws that are used to capture and kill prey (Spagna et al. 2008). Individual foragers usually hunt on a broad variety of invertebrates (e.g., Déjean and Bashingwa 1985; Ehmer and Hölldobler 1995; Raimundo et al. 2009), but may also consume small vertebrates (Facure and Giaretta 2009), plant and insect exudates (Blüthgen et al. 2003; Souza and Francini 2010), and nutrient-rich fleshy fruits (Passos and Oliveira 2002, 2004). Because visual access to arboreal ant foragers in the three dimensional forest canopy is inherently difficult, detailed studies on the foraging ecology of tropical ponerines have focused mostly on ground-dwelling species whose laden workers are easier to follow and their prey identified (but see for instance Dejean and Suzzoni 1997; Djieto-Lordon et al. 2001).

Odontomachus hastatus (Fabricius) (Hymenoptera: Formicidae) is a poorly-studied arboreal species inhabiting tropical rainforests of Central and South America (Brown 1976; Gibernau et al. 2007). In Southeast Brazil, the species is facultatively polygynous and commonly nests among roots of epiphytic bromeliads in coastal sandy forests (Oliveira et al. 2011). This study provides qualitative and quantitative data on the natural history and ecology of *O. hastatus* with emphasis on nest sites, daily and seasonal activity schedules, and diet in a forest reserve on Cardoso Island off the coast of Brazil.

Materials and Methods

Study area

Fieldwork was undertaken from August 1999 to October 2001 in the sandy plain forest of the State Park of Cardoso Island (22500 ha, 0–800 m a.s.l.), located off the coast of São Paulo State, Southeast Brazil (25° 03' S, 47° 53' W). The vegetation presents an open canopy formed by 5–15 m–tall trees growing on poor sandy soil, and abundant terrestrial and epiphytic bromeliads. The climate is characterized by two main seasons: a cool and less rainy period (winter) from April to August (minimum temperature 13 °C, rainfall ~500 mm), and a warm and rainy period (summer) from September to March (maximum 32 °C, rainfall up to 2600 mm) (Funari et al. 1987).

Nest sites

The density of *O. hastatus* colonies in the sandy forest at Cardoso Island was estimated by surveying epiphytic bromeliads within a plot of 13,350 m². Locations of ant-occupied plants were found by following loaded workers attracted to sardine baits distributed on vegetation. 45 epiphytic bromeliads were found hosting *O. hastatus* colonies within root clusters (Figure 1). The plant species used as nest (single or clumped epiphytes) and the height of the nest relative to the ground were recorded for each colony. The size and composition of *O. hastatus* colonies (i.e., number of workers, queens, and presence of brood) was described in the field by collecting 19 entire nest bromeliads and carefully counting the ants living within the root clusters. Additional details on colony demography and colony organization in *O. hastatus* is provided elsewhere (Oliveira et al. 2011).

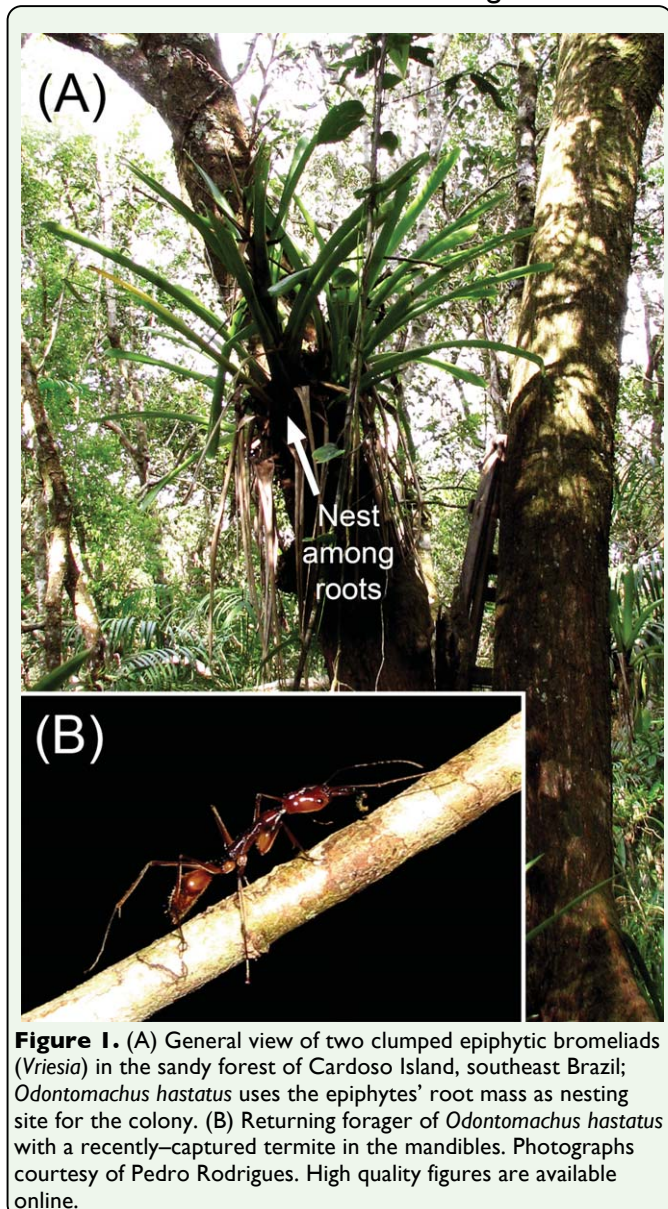


Figure 1. (A) General view of two clumped epiphytic bromeliads (*Vriesia*) in the sandy forest of Cardoso Island, southeast Brazil; *Odontomachus hastatus* uses the epiphytes' root mass as nesting site for the colony. (B) Returning forager of *Odontomachus hastatus* with a recently-captured termite in the mandibles. Photographs courtesy of Pedro Rodrigues. High quality figures are available online.

Activity rhythm and diet

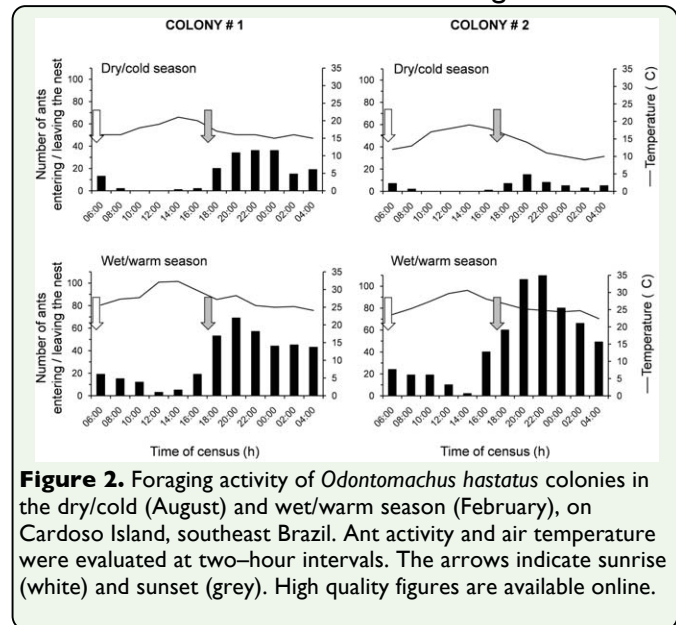
Foraging activity of each of two tagged colonies of *O. hastatus* was evaluated once per season (each colony on a different day) in the dry/cold (August 2000) and wet/warm (February 2001) periods. The activity rhythm of the colonies was monitored by recording all ants entering or exiting the nests during the first 40 min of every two hours for a period of 24 hours. Nocturnal observations were carried out using a flashlight covered with a red filter to reduce disturbance of the ants. Air temperature was recorded simultaneously with ant samplings.

The food items retrieved by *O. hastatus* were surveyed by removing them from the mandibles of returning foragers. Collections were performed in February and March 2001 during the period of greatest foraging activity (from 17:30 to 23:00). The food items taken from foragers were preserved in 70% alcohol and brought to the laboratory for identification. The items were then kept in an oven at 70 °C for 3 hours to determine their dry weights with a Mettler H51Ar analytical balance (Mettler–Toledo International Inc., www.mt.com). In the few cases where the collection of the item was not possible, the identification of the food was included in the survey. To avoid disturbance of ant foragers, no food item was collected during sessions monitoring the daily activity rhythm of ant colonies.

Results

Collected colonies of *O. hastatus* contained 35 to 536 workers (291.2 ± 163.0 workers; $N = 19$ colonies), and approximately half of the colonies had more than one dealated queen (4.0 ± 3.7 queens; range 1–12; $n = 18$ queenright colonies). 45 nests were found in the 13,350 m² sandy forest study plot (density of ~ 33.7 nests/ha). All colonies nested among root clusters of single or clumped epiphytic bromeliads 1.5 to 4.6 m above ground (2.2 ± 1.2 m; $N = 45$) (see Figure 1). The species of Bromeliaceae most frequently used by *O. hastatus* for nesting were *Vriesea procera* (73%; 33/45 nests), followed by *Aechmea* spp. (13%), and *Quesnelia arvensis* and *Vriesea* sp. (7% each). The ants used *V. procera* opportunistically, since this plant species accounted for 80% of the epiphytic bromeliads sampled in the study area (Oliveira et al. 2011).

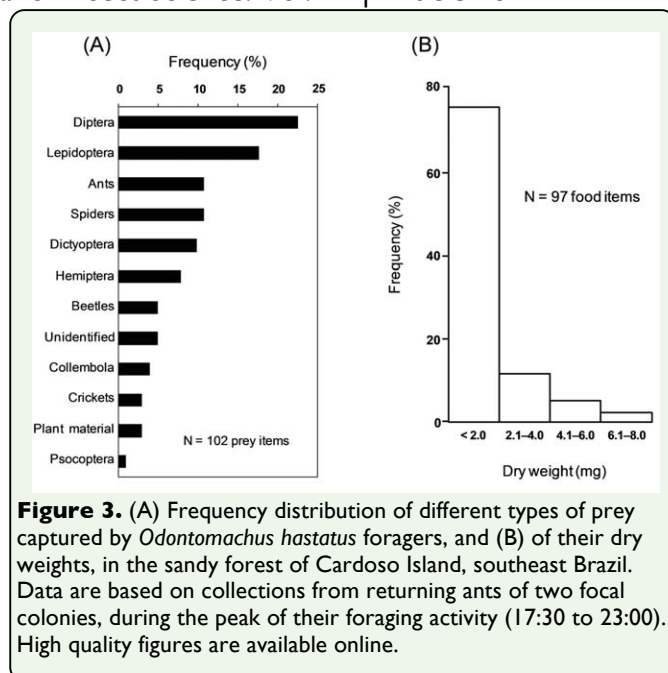
Individual foragers of *O. hastatus* searched for



food usually in the canopy of the tree hosting the nest bromeliad. Hunters frequently used climbing lianas as bridges to go from tree to tree in the forest canopy, or to search for prey on lower plants (Figure 1). *O. hastatus* was never observed searching for food on the ground.

Foraging activity typically begins at dusk around 17:30 and peaks near 20:00 (Figure 2). At sunset, individual foragers depart from nest bromeliads to hunt for prey among foliage. Typically as the first workers return with newly-captured prey, more ants tend to leave the nest. Foraging ceases at dawn between 06:00 and 08:00. The foraging rhythm is predominantly nocturnal throughout the whole year, with a marked increase in the overall worker activity in the wet/warm compared to the dry/cold season (Figure 2).

From a total of 102 food items registered as part of the diet of two colonies of *O. hastatus*, canopy-dwelling arthropods comprised the vast majority of the items retrieved by ant foragers in the study area (Figure 3A). The most representative prey groups were dipterans (adults), lepidopterans (larvae and



adults), ants (workers and winged forms), and spiders, which together accounted for over 60% of the prey captured. *Odontomachus hastatus* is a typical generalist predator, with the vast majority of the prey consisting of organisms captured alive (88% of the identified animal items), most of which of dry weight < 2.0 mg (Figure 3B).

Discussion

Odontomachus species have frequently been documented nesting in both terrestrial and epiphytic bromeliads (e.g., Davidson and Epstein 1989; Dejean and Olmsted 1997; Oliveira et al. 2011), and colonies have been recorded occupying variable parts of their nest plants, including the basket-like leaf structure, the root mass, or spaces between the epiphyte and the host tree (Dejean et al. 1995; Blüthgen et al. 2000; Oliveira et al. 2011). The nesting space used by *O. hastatus* apparently has a strong influence on the size and social structure of the colonies at Cardoso Island, since worker and queen numbers were shown to be positively associated with the diameter of the root mass housing the colony (Oliveira

et al. 2011).

Foraging activity in *O. hastatus* is likely influenced by the photoperiod since the ants leave the nest bromeliads to hunt just after dusk and return before dawn, a daily activity pattern also reported for other arthropods, including ants (Rosengren 1977; Heinrich 1993; Machado et al. 2000; Raimundo et al. 2009). Indeed, arboreal *O. hastatus* remains primarily nocturnal year-round regardless of seasonal fluctuations in temperature, with a marked increase in foraging activity in the wet/warm season. A similar nocturnal rhythm was reported for the ground-dwelling species *O. chelifer* in a forest site in Southeast Brazil (Raimundo et al. 2009). Other ponerines, however, are known to alter their daily activity schedules to follow seasonal fluctuations in temperature and/or humidity (e.g., Déjean and Lachaud 1994; Medeiros and Oliveira 2009). For instance, in arid Australia, *Odontomachus* colonies have been reported to shift crepuscular activity in the spring toward nocturnal activity in the summer due to severe temperatures (Briese and Macauley 1980). Similarly, raids to termite nests by the Neotropical and obligate termitophagous species *Pachycondyla striata* change to the night period during the hot season (Leal and Oliveira 1995).

Seasonal fluctuations in the abundance of insect prey (Wolda 1988) and/or plant-derived resources such as extrafloral nectar, insect honeydew, and fleshy fruits (Rico-Gray and Oliveira 2007) may also affect foraging patterns and/or food preference by ant colonies year-round, and this is usually associated with the presence of larvae in the nest (i.e., Judd 2005). For instance, increased activity and foraging range by bromeliad-nesting *Gnampogenys moelleri* in the

wet/warm season matches the period of increased quantity of brood in the colonies and greater availability of arthropod prey at Cardoso Island (Cogni and Oliveira 2004). Increased activity by *O. hastatus* foragers during the wet/warm season at Cardoso Island also corresponds with greater quantity of brood in the colonies (Oliveira et al. 2011).

Tank bromeliads are reservoirs of arthropod diversity, and some of the preferred prey groups consumed by *O. hastatus* (e.g., flies, ants, spiders) are among the most frequent inhabitants of bromeliad leaf baskets, or in their vicinity (see Richardson 1999; Frank et al. 2004; Gonçalves-Souza et al. 2010). This contrasts with other tropical generalist ground-dwelling *Odontomachus* spp., which hunt preferentially on termites (Fowler 1980; Déjean and Bashingwa 1985; Ehmer and Hölldobler 1995; Raimundo et al. 2009). As opposed to bromeliad-nesting *Gnamptogenys moelleri* that hunts chiefly within the nest plant (Cogni and Oliveira 2004), large *O. hastatus* is a typical generalist predator of canopy-dwelling arthropods that expands its hunting area up to 8 m from the nest plant, also using other epiphytes as foraging terrain (Rodrigues 2009). With the aid of their good vision (Oliveira and Hölldobler 1989) and efficient trap-jaws (Spagna et al. 2008), nocturnal *O. hastatus* hunters are able to capture fast-fleeing prey such as winged-insects (flies, moths, and ants) and spiders. Despite being regarded as mostly carnivorous, *Odontomachus* spp. also consume lipid- and protein-rich fleshy fruits on the ground of tropical forests and savannas (Passos and Oliveira 2002, 2004), as well as extrafloral nectar (Blüthgen et al. 2003) and insect honeydew (Souza and Francini 2010) on foliage. Since it was not possible to accurately follow *O. hastatus* foragers on the forest

canopy at night, it is not known whether the ants consume plant or insect exudates. In the very few cases in which plant matter was brought to the nest (Figure 3), the food item was not identifiable. Although individual foragers of *O. hastatus* typically searched for food and retrieved prey without cooperation, an increase in forager departure as food is brought to the nest by early hunters may suggest an elementary form of recruitment, as noted for other species in this genus (Fowler 1980; Oliveira and Hölldobler 1989; Raimundo et al. 2009).

In conclusion, arboreal *O. hastatus* nests in root clusters of epiphytic bromeliads at Cardoso Island, with *Vriesea procera* accounting for nearly 70% of the nest plants recorded. Mature colonies contain nearly 500 workers and from one to several queens. The ant is primarily nocturnal year-round, with increased foraging activity during the wet/warm season, and a generalist diet consisting of a variety of canopy-dwelling arthropods. This study adds to the knowledge about the natural history and foraging ecology of tropical arboreal ponerines. Several avenues of investigation remain to be explored about the behavioral ecology of *O. hastatus*, most notably the modes of colony foundation, the ecological factors mediating polygyny in this species, the stability of epiphytic nest plants, as well as seasonal variation in diet and foraging range as related to food availability.

Acknowledgements

We are grateful to A.V.L. Freitas, E.P. Barbosa, C.A. Iserhard, and P.P. Rodrigues for helpful suggestions on the manuscript, and V. Fourcassié for help during fieldwork. P.P. Rodrigues and D. Muniz assisted with the illustrations. Ants and bromeliads were

identified by C.R. Brandão and E.R. Pansarin, respectively. We thank the Instituto Florestal de São Paulo and the Parque Estadual da Ilha do Cardoso for logistical support. R.C. was funded by the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP). P.S.O. was supported by grants from FAPESP, the Brazilian Research Council (CNPq), and the Fundo de Apoio ao Ensino, à Pesquisa e à Extensão (FAPEX).

References

- Blüthgen N, Gebauer G, Fiedler K. 2003. Disentangling a rainforest food web using stable isotopes: dietary diversity in a species-rich ant community. *Oecologia* 137: 426-435.
- Blüthgen N, Verhaagh M, Goitía W, Blüthgen N. 2000. Ant nests in tank bromeliads – an example of non-specific interaction. *Insectes Sociaux* 47: 313-316.
- Briese DT, Macauley BJ. 1980. Temporal structure of an ant community in semi-arid Australia. *Australian Journal of Ecology* 5: 121-134.
- Brown WL. 1976. Contribution toward a reclassification of the Formicidae. Part VI. Ponerinae. Tribe Ponerini. Subtribe Odontomachini. Section A. Introduction, subtribal characters, genus *Odontomachus*. *Studia Entomologica* 19: 67-173.
- Brown WL. 2000. Diversity of ants. In: Agosti, D, Majer JD, Alonso LE, Schultz TR, Editors. *Ants: Standard Methods for Measuring and Monitoring Biodiversity*. pp. 45-79. Smithsonian Institution Press.
- Camargo RX. 2002. *Ecologia e comportamento social da formiga arborícola *Odontomachus hastatus* (Hymenoptera: Formicidae: Ponerinae)*. Master's Dissertation, Universidade Estadual de Campinas, Brasil.
- Carroll CR, Janzen DH. 1973. Ecology of foraging by ants. *Annual Review of Ecology and Systematics* 4: 231-257.
- Cogni R, Oliveira PS. 2004. Patterns in foraging and nesting ecology in the neotropical ant *Gnamptogenys moelleri* (Formicidae, Ponerinae). *Insectes Sociaux* 51: 123-130.
- Davidson DW, Epstein WW. 1989. Epiphytic associations with ants. In: Lüttge U, Editor. *Vascular Plants as Epiphytes*. pp. 200-233. Springer.
- Déjean A, Bashingwa EP. 1985. La prédation chez *Odontomachus troglodytes* Santschi (Formicidae-Ponerinae). *Insectes Sociaux* 32: 23-42.
- Déjean A, Lachaud JP. 1994. Ecology and behaviour of the seed-eating ponerinae ant *Brachyponera senaarensis* (Mayr). *Insectes Sociaux* 41: 191-210.
- Dejean A, Olmsted I. 1997. Ecological studies on *Aechmea bracteata* (Swartz) (Bromeliaceae). *Journal of Natural History* 31: 1313-1334.
- Déjean A, Olmsted I, Snelling RR. 1995. Tree-epiphyte-ant relationships in the low inundated forest of Sian Ka'an biosphere reserve, Quintana Roo, México. *Biotropica* 27: 57-70.
- Déjean A, Suzzoni JP. 1997. Surface tension strengths in the service of a ponerine ant: A new kind of nectar transport. *Naturwissenschaften* 84: 76-79.
- Djipto-Lordon C, Orivel J, Déjean A. 2001. Consuming large prey on the spot: the case of the arboreal foraging ponerine ant *Platythyrea modesta* (Hymenoptera, Formicidae). *Insectes Sociaux* 48: 324-326.
- Duncan FD, Crewe RM. 1994. Field study on the foraging characteristics of the ponerinae ant, *Hagensia havilandi* Forel. *Insectes*

Sociaux 41: 85-98.

Dutra HP, Freitas AVL, Oliveira PS. 2006. Dual ant attraction in the Neotropical shrub *Urera baccifera* (Urticaceae): the role of ant visitation to pearl bodies and fruits in herbivore deterrence and leaf longevity. *Functional Ecology* 20: 252-260.

Ehmer B, Hölldobler B. 1995. Foraging behaviour of *Odontomachus bauri* on Barro Colorado Island, Panama. *Psyche* 102: 3-4.

Facure KG, Giaretta AA. 2009. Semi-terrestrial tadpoles as a vertebrate prey of trap-jaw ants (*Odontomachus*, Formicidae). *Herpetology Notes* 2: 63-66.

Fowler HG. 1980. Populations, prey capture and sharing, and foraging of the Paraguayan Ponerinae *Odontomachus chelifer* Latreille. *Journal of Natural History* 14: 79-84.

Frank JH, Sreenivasan S, Benshoff PJ, Deyrup MA, Edwards GB, Halbert SE, Hamon AB, Lowman MD, Mockford EL, Scheffrahn RH, Steck GJ, Thomas MC, Walker TJ, Welbourn WC. 2004. Invertebrate animals extracted from native *Tillandsia* (Bromeliales: Bromeliaceae) in Sarasota County, Florida. *The Florida Entomologist* 87: 176-185.

Funari FL, Struffaldi-De Vuono Y, Salum ST. 1987. Balanço hídrico de duas áreas de Mata Atlântica: Reserva Biológica de Paranapiacaba e Parque Estadual da Ilha do Cardoso (Estado de São Paulo). In: Pereira, MFA, Massei MAS, Editors. *Anais do Congresso da Sociedade Botânica de São Paulo*. pp. 95-101. Sociedade Botânica de São Paulo.

Gibernau M, Orivel J, Delabie JHC, Barabe D, Dejean A. 2007. An asymmetrical

relationship between an arboreal ponerine ant and a trash-basket epiphyte (Araceae). *Biological Journal of the Linnean Society* 91: 341-346.

Gonçalves-Souza T, Brescovit AD, Rossa-Feres DC, Romero GQ. 2010. Bromeliads as biodiversity amplifiers and habitat segregation of spider communities in a neotropical rainforest. *Biotropica* 38: 270-279.

Heinrich B. 1993. *The Hot-Blooded Insects*. Harvard University Press.

Hölldobler B, Wilson EO. 1990. *The Ants*. Harvard University Press.

Judd TM. 2005. The effects of water, season, and colony composition on foraging preferences of *Pheidole ceres* (Hymenoptera: Formicidae). *Journal of Insect Behavior* 18: 781-803.

Leal IR, Oliveira PS. 1995. Behavioral ecology of the neotropical termite-hunting ant *Pachycondyla* (=termitopone) *marginata*: colony founding, group-raiding and migratory patterns. *Behavioral Ecology and Sociobiology* 37: 373-383.

Machado G, Raimundo, RLG, Oliveira PS. 2000. Daily activity schedule, gregariousness, and defensive behaviour in the Neotropical harvestman *Goniosoma longipes* (Opiliones: Gonyleptidae). *Journal of Natural History* 34: 587-596.

Medeiros FNS, Lopes LE, Moutinho PRS, Oliveira PS, Hölldobler B. 1992. Functional polygyny, agonistic interactions and reproductive dominance in the neotropical ant *Odontomachus chelifer* (Hymenoptera, Formicidae, Ponerinae). *Ethology* 91: 134-146.

- Medeiros FNS, Oliveira PS. 2009. Season-dependent foraging patterns: case study of a neotropical forest-dwelling ant (*Pachycondyla striata*; Ponerinae). In: In Jarau S, Hrnir M, editors. *Food Exploitation by Social Insects: Ecological, Behavioral, and Theoretical Approaches*. pp. 81-95. CRC Press.
- Oliveira PS, Camargo RX, Fourcassié V. 2011. Nesting patterns, ecological correlates of polygyny and social organization in the neotropical arboreal ant *Odontomachus hastatus* (Formicidae, Ponerinae). *Insectes Sociaux* 58: 207-217.
- Oliveira PS, Freitas AVL. 2004. Ant-plant-herbivore interactions in the Neotropical cerrado savanna. *Naturwissenschaften* 91: 557-570.
- Oliveira PS, Hölldobler B. 1989. Orientation and communication in the Neotropical ant *Odontomachus bauri* Emery (Hymenoptera, Formicidae, Ponerinae). *Ethology* 83: 154-166.
- Passos L, Oliveira PS. 2002. Ants affect the distribution and performance of *Clusia criuva* seedlings, a primarily bird-dispersed rainforest tree. *Journal of Ecology* 90: 517-528.
- Passos L, Oliveira PS. 2004. Interaction between ants and fruits of *Guapira opposita* (Nyctaginaceae) in a Brazilian sandy plain rainforest: ant effects on seeds and seedlings. *Oecologia* 139: 376-382.
- Peeters C, Crewe R. 1987. Foraging and recruitment in ponerine ants: solitary hunting in the queenless *Ophtalmopone berthoudi* (Hymenoptera: Formicidae). *Psyche* 94: 201-213.
- Raimundo RLG, Freitas AVL, Oliveira PS. 2009. Seasonal patterns in activity rhythm and foraging ecology in the Neotropical forest-dwelling ant, *Odontomachus chelifer* (Formicidae: Ponerinae). *Annals of the Entomological Society of America* 102: 1151-1157.
- Rico-Gray V, Oliveira PS. 2007. *The Ecology and Evolution of Ant-Plant Interactions*. The University of Chicago Press.
- Richardson BA. 1999. The bromeliad microcosm and the assessment of faunal diversity in a neotropical forest. *Biotropica* 31: 321-336.
- Rodrigues PAP. 2009. *Estudo experimental sobre orientação e marcação de ninho na formiga arbórea Odontomachus hastatus* (Formicidae: Ponerinae). Master's Dissertation, Universidade Estadual de Campinas, Brasil.
- Rosengren R. 1977. Foraging strategy of wood ants (*Formica rufa* group), II: nocturnal orientation and diel periodicity. *Acta Zoologica Fennica* 150: 1-30.
- Souza TS, Francini RB. 2010. First record of trophobiotic interaction between a ponerine ant and a cicadelid bug. *Psyche* 2010: 1-4.
- Spagna JC, Vakis AI, Schmidt CA, Patek SN, Tsutsui ND, Suarez AV. 2008. Phylogeny, scaling, and the generation of extreme forces in trap-jaw ants. *Journal of Experimental Biology* 211: 2358-2368.
- Wheeler WM. 1910. *Ants: Their Structure, Development and Behavior*. Columbia University Press.