UNIVERSIDADE FEDERAL DE MATO GROSSO
INSTITUTO DE BIOCIÊNCIAS
CURSO DE DOUTORADO EM ECOLOGIA E CONSERVAÇÃO DA BIODIVERSIDADE

INTERAÇÃO ENTRE AS FORMIGAS PARABIÓTICAS *Camponotus femoratus* (Fabricius, 1804) E *Crematogaster levior* Longino, 2003 COM SUAS EPÍFITAS ASSOCIADAS E INFLUÊNCIA SOBRE A COMPOSIÇÃO DA ASSEMBLEIA DE FORMIGAS DA AMAZÔNIA MERIDIONAL

RICARDO EDUARDO VICENTE

CUIABÁ – MT
2016

UNIVERSIDADE FEDERAL DE MATO GROSSO
INSTITUTO DE BIOCIÊNCIAS
CURSO DE DOUTORADO EM ECOLOGIA E CONSERVAÇÃO DA BIODIVERSIDADE

INTERAÇÃO ENTRE AS FORMIGAS PARABIÓTICAS *Camponotus femoratus* (Fabricius, 1804) E *Crematogaster levior* Longino, 2003 COM SUAS EPÍFITAS ASSOCIADAS E INFLUÊNCIA SOBRE A COMPOSIÇÃO DA ASSEMBLEIA DE FORMIGAS DA AMAZÔNIA MERIDIONAL

RICARDO EDUARDO VICENTE

Tese apresentada ao Curso de Pós-Graduação, do Instituto de Biociências, para obtenção do título de Doutor em Ecologia e Conservação da Biodiversidade.

CUIABÁ – MT
2016

Dados Internacionais de Catalogação na Fonte.

V632i Vicente, Ricardo Eduardo.
Interação entre as formigas parabióticas Camponotus femoratus (Fabricius, 1804) e Crematogaster levior Longino, 2003 com suas epífitas associadas e influência sobre a composição da assembleia de formigas da amazônia meridional / Ricardo Eduardo Vicente. -- 2016
vii, 162 f. : il. color. ; 30 cm.

Orientador: Thiago Junqueira Izzo.
Co-orientador: Wesley Francisco Dáttilo da Cruz.
Tese (doutorado) - Universidade Federal de Mato Grosso, Instituto de Biociências, Programa de Pós-Graduação em Ecologia e Conservação da Biodiversidade, Cuiabá 2016.
Inclui bibliografia.

1. Ecologia. 2. Jardim de formigas. 3. Parabiose. 4. Mutualismo. 5. Dominancia. I. Título.

Ficha catalográfica elaborada automaticamente de acordo com os dados fornecidos pelo(a) autor(a).

ORIENTADOR: DRº THIAGO JUNQUEIRA IZZO

CO-ORIENTADOR: DRº WESLEY FRANCISCO DÁTTILO DA CRUZ

BANCA EXAMINADORA

Prof. Dr. Thiago Junqueira Izzo
Universidade Federal de Mato Grosso
Presidente/orientador

Prof. Dr. Rodrigo dos Santos Machado Feitosa
Universidade Federal do Paraná
Examinador Externo

Profa. Dra. Danielle Strock-Tonon
Universidade do Estado de Mato Grosso
Examinadora Externa

Profa. Dra. Lúcia Aparecida de Fátima Mateus
Universidade Federal de Mato Grosso
Examinadora Interna

André Pansonato

Prof. Dr. André Pansonato
Universidade Federal de Mato Grosso
Examinador Interno

Wsousa

Prof. Dr. Wesley Oliveira de Sousa
Universidade Federal de Mato Grosso
Examinador Interno

AGRADECIMENTOS

Agradeço minha família, principalmente a meus pais: José Vicente Filho e Maria Sônia Vega Salnite, e meus irmãos: Niéle Fernanda Vicente e André Luis Vicente, pelo incentivo em todos os momentos difíceis, compreensão em minhas ausências e principalmente pela educação e dignidade, fruto do carinho e dedicação deles. Família, amo muito vocês!

Também, agradeço meu orientador Thiago Izzo, que sempre será um grande exemplo pra mim. Obrigado por ter dedicado seu tempo a orientação desse trabalho, sempre com muita calma. Pelos constantes incentivos, reflexões e conselhos, sempre respeitando minhas decisões. Ao meu co-orientador Wesley Dáttilo (Instituto de Ecología - México) pelo auxilio durante a elaboração deste trabalho. Agradeço também a Viviane Layme, Victor Landeiro, Fernando Vaz-de-Mello, Angelico Asenjo, Leandro Battirola e Domingos de Jesus Rodrigues pelas constantes participações.

Aos membros da banca pelas acaloradas discussões e grandiosas contribuições ao trabalho final. Agradeço em especial a Rodrigo Feitosa (UFPR) pelas contribuições contantes a minha formação profissional desde o mestrado, mesclando extraordinariamente criticidade, mituculosidade, gentileza e cordialidade.

A meus queridos amigos que estiveram presentes nessa trajetória: Janaina Noronha, Vinícius Corrêa, Rogério Santos, Guilherme Pessoa, Mariana Silva, Bruno Souza, Bruna Valério, Monique Machiner, Andrea Ferreira, Jacqueline Pimentel e Fernando Cabeceira. Obrigado por fazerem esse caminho muito mais agradável.

Aos colegas Alexandre Ferreira [UFPR], Gabriela Camacho [UFPR], Itanna Fernandes [INPA], Jorge Souza [INPA], Lina Hernández [IAVH], Lívia Pires do Prado [MZSP], Mônica Ulysséa [MZSP] e Thiago Silva [UFPR] pelo auxilio na identificação do material e por compartilharem seus conhecimentos sobre aspectos biológicos e morfológicos dos grupos com o qual trabalham. Vocês enriqueceram, e muito, com este trabalho e com meu aprendizado.

Agradeço também à CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) pela bolsa, ao CNPq pelo financiamento do projeto que custeou toda pesquisa e ao NEBAM pelo apoio logístico.

A todos vocês meu muito obrigado.

SUMÁRIO

RESUMO

Uma notável interação mutualística entre formigas e plantas encontrada em florestas tropicais é conhecida como Jardins-de-formigas (JFs). A associação entre *Camponotus femoratus* (Fabricius, 1804) (Formicinae) e *Crematogaster levior* Longino, 2003 (Myrmicinae) está entre os mais comumente encontrados na região Neotropical. Nos JFs destas duas espécies de formigas parabióticas são frequentemente encontradas algumas espécies de epífitas filogenéticamente distantes. Então, para serem parceiras mutualistas eficientes as formigas precisam reconhecer e responder a todos os compostos químicos voláteis diferentes entre todas as espécies associadas. Por outro lado, é possível que as plantas de JFs demonstrem sinais químicos semelhantes como convergência sinalizando herbivoria. Se isso fosse verdade, as formigas recrutariam igualmente a todas as espécies de JFs localmente. Considerando isso, no primeiro capítulo além de descrever a composição e a frequência das espécies de epífitas associadas aos ninhos localmente, nós testamos as hipóteses de que 1) as formigas reconhecem estímulos químicos emitidos por diferentes plantas que habitam os JFs e 2) elas podem diferenciar este estímulo químico quando comparado com os voláteis de uma planta de sub-bosque. Nós encontramos que somente *Ca. femoratus* responde a estímulos de herbívoria em suas epífitas mutualistas e que sua reação está relacionada a frequência geral das epífitas. Quando expostas às folhas das epífitas obrigatórias de JFs *Peperomia macrostachya* (Piperaceae) e *Codonanthe uleana* (Gesneriaceae) observou-se que o recrutamento de operárias de *Ca. femoratus* foi, em média, respectivamente, 556% e 246% maior do que o controle (tiras de papel). O número de formigas recrutadas por *Markea longiflora* (Solanaceae) ou pela planta de sub-bosque *Piper hispidum* (Piperaceae) não diferiu do pedaço de papel. Devido a essa forte relação das formigas parabióticas com suas epífitas mutualistas que precisam de luz para crescer, no segundo capítulo nós criamos as hipóteses de que 1) a abertura do dossel das clareiras florestais influenciam a presença de JFs, sendo que, 2) maiores clareiras terão mais ninhos e 3) tanto com o aumento na abertura do dossel quanto no tamanho da clareira haverá um aumento no tamanho das colônias em clareiras florestais. Além disso, sabe-se que apesar do ninho arborícola, as formigas parabióticas são encontradas forrageando tanto no solo como na vegetação. Então, nós também acreditamos que 4) as formigas parabióticas são mais frequentemente amostradas na vegetação e que 5) o aumento da complexidade da vegetação e do volume de serapilheira acumulada no solo aumentam o forrageio dessas formigas na vegetação e no chão, respectivamente, sendo que o aumento na abertura de dossel aumenta a atividade das duas espécies em ambos estratos. A presença, o número de Jardins-de-formigas e tamanho da colônia de formigas foi afetado pela localidade, mas não pela abertura do dossel. No entanto, não houve uma diferença da utilização de estratos verticais por *Ca. femoratus*, nem por *Cr. levior*. Por outro lado, a frequência de *Ca. femoratus* no solo diminui com a abertura do dossel mas não é afetada pela complexidade da vegetação. Além da frequência de *Cr. levior* no chão também diminuir com o aumento da abertura do dossel, essa espécie também demonstrou ser influenciada pela complexidade da vegetação, sendo que com o aumento da complexidade na vegetação houve uma redução na frequência de forrageamento dessa espécie no solo. Porém, nem a complexidade, bem como abertura do dossel influenciam a freqüência de forrageamento dessas formigas no sub-bosque. Como essas espécies abundantes são consideradas dominantes comportamentalmente, no Capítulo 3, nós investigamos seu impacto em comunidades de formigas de solo e vegetação separadamente. Neste capítulo além de investigar o efeito das formigas parabióticas na abundância, riqueza e composição da comunidade em ambos os estratos separadamente, nós avaliamos se elas afetavam componentes diferentes da diversidade beta (substituição e aninhamento). Ainda, avaliamos quais espécies eram indicadoras de sua presença ou ausência.

Palavras-chave: Comunidade de formigas, Jardim-de-formigas, Mutualismo, Nicho

ABSTRACT

A remarkable mutualistic interactions between ants and plants found in tropical forests is known as Ants-Gardens (AGs). The association between *Camponotus femoratus* (Fabricius, 1804) (Formicinae) and *Crematogaster levior* Longino 2003 (Myrmicinae) is among the most commonly found in the Neotropics. In AGs of these two species of parabiotic ants some species of epiphytic phylogenetically distant are often found. So to be effective mutualist partner the ants need to recognize and respond to all the different volatile chemical compounds of all associated species. Moreover, it is possible that plant AGs have converged as chemical signals when attacked by herbivores. If this were true, the ants also recruit all species of AGs locally. Considering this, in addition to describing the composition and the frequency of epiphytic species associated with nests locally, in the first chapter we tested the hypotheses that 1) the ants recognize chemical stimuli issued by different plants that inhabit the AGs and 2) they can differentiate this chemical stimulus when compared to the volatiles from a abundant plant specie of the understory. We found that only *Ca. femoratus* responds to herbivory stimuli in their mutualist epiphytes and that his reaction is related to overall frequency of epiphytes. When exposed to the AG-epiphytes *Peperomia macrostachya* (Piperaceae) and *Codonanthe uleana* (Gesneriaceae) leaves it was observed that the recruitment of *Ca. femoratus* workers was, on average, respectively 556% and 246% higher than control (paper strips). The number of ants recruited by *Markea longiflora* (Solanaceae) or by the understory plant *Piper hispidum* (Piperaceae) did not differ from piece of paper. Because of this strong relationship of parabiotic ants with their mutualist epiphytes that need light to grow, in the second chapter we have created hypotheses that 1) the canopy openness of forest gaps influence the presence of AGs, and, 2) larger gaps will have more nests and 3) increase in both the canopy openness and the gap size will increase the colony size in forest gaps. Furthermore, it is known that although the arboreal nest, parabiotic ants are found foraging in the soil and in the vegetation. Then, we also believe that 4) the parabiotic ants are most frequently sampled in the vegetation and 5) increasing complexity of the vegetation and the litter accumulated volume in the soil increase the foraging of these ants in vegetation and ground, respectively, and the increase in canopy openness increases the activity of the two species in both strata. The presence and number Ants-Gardens, as colony size, was affected by the location, but not for the canopy openness. However, there was no difference in utilization of vertical strata by *Ca. femoratus* or by *Cr. levior*. On the other hand, the frequency of *Ca. femoratus* on the ground decreases with the canopy openness but is not affected by the complexity of the vegetation. In the frequency of *Cr. levior* on the ground also decrease with increasing the canopy openness. But, as opposed to *Ca. femoratus, Cr. levior* also shown to be influenced by the complexity of vegetation with a reduction in the frequency of workers that foraging on the ground with the increase of complexity in the vegetation. But not the complexity and canopy openness influence the foraging frequency of these ants in the understory. As these abundant species are considered dominant behaviorally, in Chapter 3, we investigated their impact on soil and vegetation ant communities separately. In this chapter in addition to investigating the effect of parabiotic ants in abundance, richness and community composition in both strata separately, we assessed whether they affected different components of beta diversity (turnover and nesting). Still, we assess which species are indicators of its presence or absence.

Keywords: Ants Community, Ants-Garden, Mutualism, Niche

INTRODUÇÃO GERAL

As formigas (Hymnoptera, Formicidae) são insetos altamente abundantes e diversificados tanto em termos de espécies quanto grupos funcionais (Fittkau & Klinge 1973; Hölldobler & Wilson 1990; Baccaro et al. 2015; Vicente et al. 2016a,b). Desempenharem várias funções no ambiente, por esse motivo, as formigas são consideradas engenheiras ecossistêmicas (Folgarait 1998; Meyer et al. 2011). As formigas também favorecem a diversidade de organismos por estarem envolvidas em diversos tipos de interações com diversos outros animais (Gallego-Ropero et al. 2013; Puker et al. 2015; Dáttilo et al. 2012a), inclusive com outras formigas (Gallego-Ropero & Feitosa 2014, Sanhudo et al. 2008), microorganismos (Bekker et al. 2014, Marsh et al. 2014, Nepel et al. 2014, Sanders et al. 2014) e plantas (Vicente et al. 2014, 2012, Izzo & Benelli-Petini 2011, Izzo & Vasconcelos 2002, Dáttilo et al. 2009a,b).

Entre essas interações nas quais as formigas estão envolvidas, as interações cooperativas entre as espécies são um dos temas centrais em ecologia, e provavelmente todos os organismos na Terra estão envolvidos em pelo menos uma interação mutualística ao longo de sua história de vida (Bronstein 2001). Neste tipo de relacionamento uma espécie fornece um serviço ou um produto que seu parceiro não pode adquirir sozinho e, em troca, recebe algum tipo de pagamento ou recompensa (Hoeksema & Bruna 2000). Uma notável interação mutualística envolvendo formigas e plantas encontrada em florestas tropicais é conhecida como Jardins-de-formigas (JFs – Figura 1). Nessa interação as formigas constroem seus ninhos e plantam epífitas especificas onde incorporam matéria orgânica constantemente para o crescimento das epífitas e então, expadir os ninhos (Davison 1988; Orivel & Leroy 2011).

Em regiões neotropicais são encontradas nove espécies de formigas e 53 espécies de epífitas habitantes obrigatórias de JFs (Orivel & Leroy 2011). Dentre essas espécies de formigas que geralmente habitatam solitariamente os JFs, a associação entre *Camponotus femoratus* (Fabricius, 1804) (Formicinae) e *Crematogaster levior* Longino, 2003 (Myrmicinae) está entre as mais comumente encontradas na Região Neotropical (Davidson 1988). *Ca. femoratus* e *Cr. levior* além de interagirem com algumas espécies de epífitas em uma relação mutualista, elas convivem em parabiose, ou seja, dividem o mesmo ninho e trilhas de forrageamento (Swain 1980; Hölldobler & Wilson 1990). Nos Jardins-de-formigas destas duas espécies de formigas parabióticas são frequentemente encontradas algumas espécies de epífitas de famílias diferentes e filogenéticamente distantes (Schmit-

Neuerburg & Blüthgen 2007; Orivel & Leroy 2011). Então, para serem parceiras mutualistas eficientes as formigas precisam reconhecer e responder a todos os compostos químicos voláteis diferentes entre todas as espécies associadas. Por outro lado, é possível que as plantas de Jardins-de-formigas demonstrem sinais químicos semelhantes como convergência para um sinal generalizado ligado à herbivoria. Se isso fosse verdade, as formigas recrutariam igualmente a todas as espécies de JFs presentes localmente. Sendo assim, no primeiro capítulo (Differential recruitment of *Camponotus femoratus* (Fabricius) ants in response to Ant Garden herbivory), além de descrever a composição e a frequência das espécies de epífitas associadas aos ninhos em Cotriguaçu-MT (Figura 2), nós testamos as hipóteses de que 1) as formigas reconhecem estímulos químicos emitidos por diferentes plantas que habitam os Jardins-de-formigas e ainda 2) elas podem diferenciar este estímulo químico, quando comparado com um planta de sub-bosque.

Devido a essa forte relação das formigas parabióticas com suas epífitas mutualistas que precisam de luz para crescer (Leroy et al. 2016; Orivel & Leroy 2011), Jardins-de-formigas têm sido documentados em clareiras formadas por árvores caídas, margens de rios e estradas abandonadas (Dáttilo & Izzo 2012b; Davidson 1988). Além disso, clareiras maiores têm mais área disponível para construção de ninhos e para as operarias forragearem. Portanto, no segundo capítulo (Defining the niche of parabiotic ants *Camponotus femoratus* (Fabricius, 1804) and *Crematogaster levior* Longino, 2003) nós criamos as hipóteses de que 1), a abertura do dossel das clareiras florestais influencia a presença de Jardins-de-formigas, sendo que, 2) maiores clareiras terão mais ninhos e 3) tanto com o aumento na abertura do dossel quanto no tamanho da clareira haverá um aumento no tamanho das colônias em clareiras florestais. Além disso, apesar das formigas parabióticas serem encontradas forrageando tanto no solo quanto na vegetação (Ryder Wilkie et al. 2010; Dejean et al. 2007; Wilson 1987), possuem ninhos arborícolas (Davidson 1988; Paolluci et al. 2016). Então, nós também acreditamos que 4) as formigas parabióticas são mais frequentemente amostradas na vegetação e 5) o aumento da complexidade da vegetação e do volume de serapilheira acumulada no solo aumentam o forrageio dessas formigas na vegetação e no chão, respectivamente, sendo que o aumento na abertura de dossel aumenta a atividade das duas espécies em ambos estratos. As hipóteses 1 e 2 foram testadas em clareiras do município de Claudia-MT e as hipóteses 4, 5, 6 em parcelas dos municípios de Claudia-MT e Novo Mundo-MT (Figura 1).

Apesar da diversidade filogenética e comportamental das formigas que ocorrem nestas localidades da Amazônia (Vicente et al. 2016a, b), as espécies *Ca. femoratus* e *Cr.*

levior são frequentemente coletadas. Isso por que essas espécies são dominantes ocupando cerca de 95% dos Jardins-de-formigas nas áreas florestais da Amazônia (Orivel & Leroy 2011; Youngsteadt et al. 2010; Davidson 1988). Como estas formigas são encontradas frequentemente forrageando do solo até o dossel das florestas (Ryder Wilkie et al. 2010; Dejean et al. 2007; Wilson 1987) e são comportamentalmente dominantes nas comunidades de formigas onde ocorrem (Mertl et al. 2010; Vasconcelos et al. 2003), no Capítulo 3, nós investigamos seu impacto em comunidades de formigas de solo e vegetação separadamente. Neste capítulo, além de investigar o efeito das formigas parabióticas sobre a abundância, riqueza e composição da comunidade de formigas em ambos os estratos separadamente, nós avaliamos se elas afetavam componentes diferentes da diversidade beta (substituição e aninhamento). Ainda, avaliamos quais espécies e formigas eram indicadoras de sua presença ou ausência. É importante compreender esse efeito num bioma tão rico quanto a Amazônia, que possui tantas espécies de formigas tão raramente coletadas e principalmente da vegetação (Vicente et al. 2011, 2012, 2015; Santos-Silva et al. 2016; Prado et al. 2016).

Figura 1 - Jardins de formigas de *Camponotus femoratus* (Fabricius, 1804) e *Crematogaster levior* Longino, 2003 fotografados em clareiras dos municipos de Novo Mundo (A, B) e Claudia-MT (C) durante as coletas de dados.

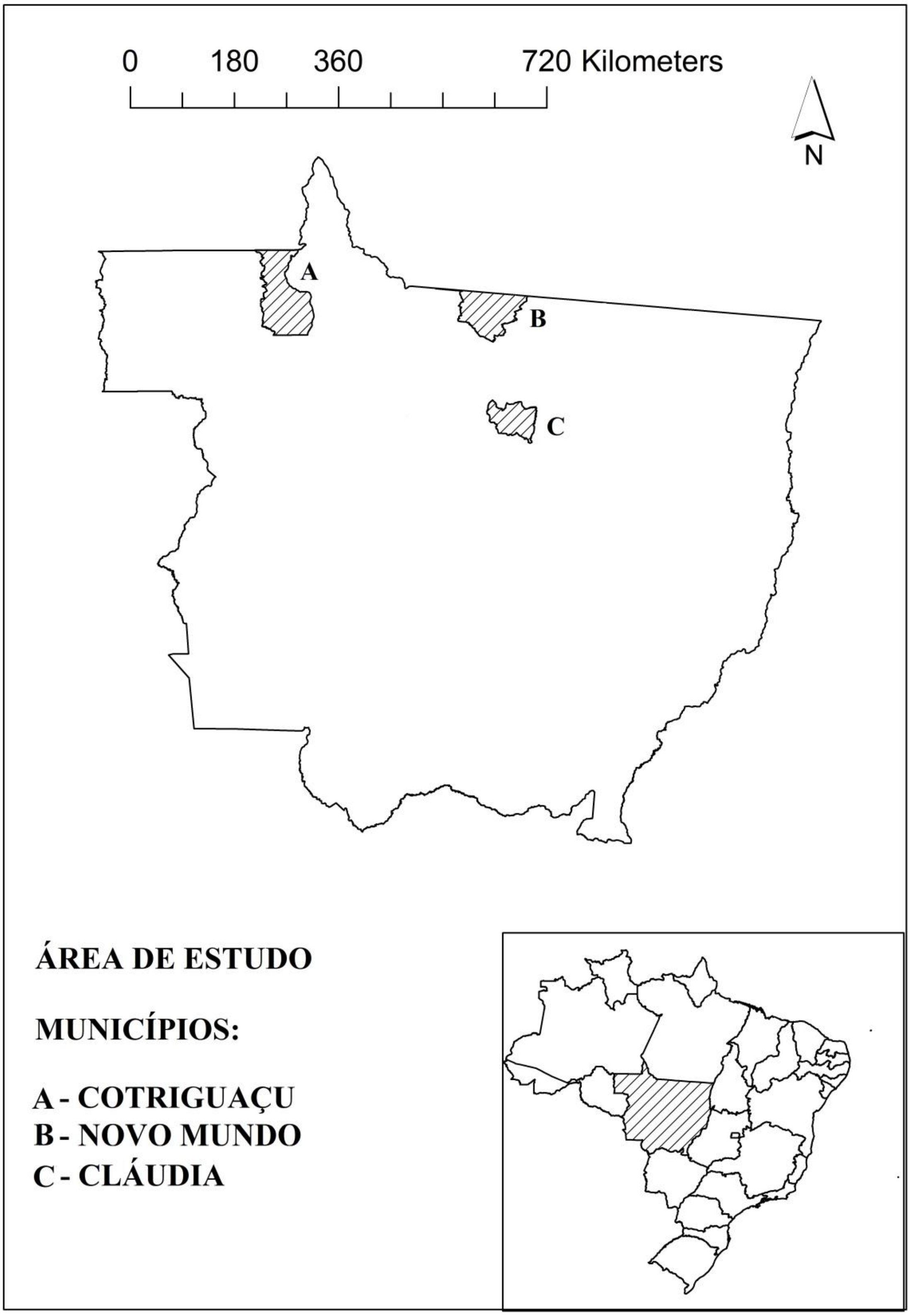


Figura 2 – Mapa ilustrando os munícipios onde os dados foram coletados, sendo A) Cotriguaçu-MT, B) Novo Mundo-MT e C) Claudia-MT. Mapa confeccionado no software ArcMap 10.1.

REFERÊNCIAS BIBLIOGRÁFICAS

Baccaro, F.B., Feitosa, R.M., Fernández, F., Fernandes, I.O., Izzo, T.J., Souza, J.L.P. & Solar, R. (2015). *Guia para os gêneros de formigas do Brasil*. Manaus: Editora INPA. doi: 10.5281/zenodo.32912

Bronstein, J.L. (2001). The costs of mutualism. *American Zoologist*, 41, 127-141.

Dáttilo, W. & Izzo, T.J. (2012b). Temperature influence on species co-occurrence patterns in treefall gap and dense forest ant communities in a terra-firme forest of Central Amazon, Brazil. *Sociobiology*, 59(2), 351-367. doi: 10.13102/sociobiology.v59i2.599

Dáttilo, W., Marques, E.C., Falcão, J.C.F. & Moreira, D.D.O. (2009a). Interações mutualísticas entre formigas e plantas. *EntomoBrasilis,* 2:32-36.

Dáttilo, W., Martins, R.L., Uhde, V., Noronha, J.C., Florêncio, F.P. & Izzo, T.J. (2012a). Floral resource partitioning by ants and bees in a jambolan *Syzygium jambolanum* (Myrtaceae) agroforestry system in Brazilian Meridional Amazon. *Agroforestry Systems*, 85: 105-111.

Dáttilo, Wesley F.C., Izzo, Thiago J., Inouye, Brian D., Vasconcelos, Heraldo L. & Bruna, Emilio M. (2009b). Recognition of Host Plant Volatiles by *Pheidole minutula* Mayr (Myrmicinae), an Amazonian Ant-Plant Specialist. *Biotropica*, 41: 642-646.

Davidson, D.W. (1988). Ecological studies of neotropical ant gardens. *Ecology*, 69: 1138-1152.

Dejean, A., Corbara, B., Orivel, J. & Leponce, M. (2007). Rainforest canopy ants: the implications of territoriality and predatory behavior. *Functional Ecosystems and Communities*, 1, 105-120.

de Bekker, C., Quevillon, L.E., Smith, P.B., Fleming, K.R., Ghosh, D., Patterson, A.D. & Hughes, D.P. (2014). Species-specific ant brain manipulation by a specialized fungal parasite. BMC Evolutionary Biology, 14:166.

Fittkau, E.J. & Klinge, H. (1973). On biomass and trophic structure of the central Amazonian rain forest ecosystem. *Biotropica*, 5: 1-14.

Folgarait, P.J. (1998). Ant biodiversity and its relationship to ecosystem functioning: a review. *Biodiversity and Conservation*, 7:1221-1244.

Gallego-Ropero, M.C., Feitosa, R.M. & Pujol-Luz, J.R. (2013). Formigas (Hymenoptera, Formicidae) associadas a ninhos de *Cornitermes cumulans* (Kollar) (Isoptera, Termitidae) no Cerrado do Planalto Central do Brasil. *EntomoBrasilis,* 6:97-101.

Hoeksema, J.D. & Bruna, E.M. (2000). Pursuing the big questions about interspecific mutualism: a review of theoretical approaches. *Oecologia*, 125, 321-330. doi:10.1007/s004420000496

Hölldobler, B., Wilson, E.O. (1990). *The ants*. Cambridge, MA: Belknap Press of Harvard University Press, p 764

Izzo, T.J. & Benelli-Petini, A. (2011). Relação entre diferentes espécies de formigas e a mirmecófita *Cordia nodosa* Lamarck (Boraginaceae) em áreas de mata ripária na Amazônia mato-grossense. *Acta Amazonica*, 41:355-360.

Izzo, T.J. & Vasconcelos, H. (2012). Cheating the cheater: domatia loss minimizes the effects of ant castration in an Amazonian ant-plant. *Oecologia*, 133: 200-205.

Leroy, C., Petitclerc, F., Orivel, J., Corbara, B., Carrias, J.-F., Dejean, A. & Céréghino, R. (2016). The influence of light, substrate and seed origin on the germination and establishment of an ant-garden bromeliad. *Plant Biology Journal*. doi:10.1111/plb.12452

Marsh, S.E., Poulsen, M., Pinto-Tomás, A. & Currie, C.R. (2014). Interaction between Workers during a Short Time Window Is Required for Bacterial Symbiont Transmission in *Acromyrmex* Leaf-Cutting Ants. *PLoS ONE*, 9(7): e103269. doi:10.1371/journal.pone.0103269

Mertl, A.L., Sorenson, M.D. & Traniello, J.F.A. (2010). Community-level interactions and functional ecology of major workers in the hyperdiverse ground-foraging Pheidole (Hymenoptera, Formicidae) of Amazonian Ecuador. *Insectes Sociaux*, 57, 441-452. doi:10.1007/s00040-010-0102-5

Meyer, S.T., Leal, I.R., Tabarelli, M. & Wirth, R. (2011). Ecosystem engineering by leaf-cutting ants: nests of *Atta cephalotes* drastically alter forest structure and microclimate. *Ecological Entomology*, 36, 14–24

Nepel, M., Voglmayr, H., Schonenberger, J. & Mayer, V.E. (2014). High diversity and low specificity of Chaetothyrialean Fungi in carton galleries in a neotropical ant–plant association. *PLoS ONE* 9(11): e112756

Orivel, J. & Leroy, C. (2011). The diversity and ecology of ant gardens (Hymenoptera: Formicidae, Spermatophyta: Angiospermae). *Myrmecological News*, 14, 73-85

Paolucci, L.N., Solar, R.R.C. & Leal, L.C. (2016). Proximity shapes similarity in epiphytic composition of Neotropical ant gardens. *Journal of Tropical Ecology*, 32(4), pp. 325–329. doi: 10.1017/S0266467416000298.

Prado, L.P.; Vicente, R.E.; Silva, T.S.R. & Souza, J.L. (2016). Strumigenys fairchildi Brown, 1961 (Formicidae, Myrmicinae): first record of this rarely collected ants from Brazil. *Check List*, 12(4): 1922. doi: 10.15560/12.4.1922

Puker, A., Rosa, C.S., Orozco, J., Solar, R.R.C. & Feitosa, R.M. (2015). Insights on the association of American Cetoniinae beetles with ants. *Entomological Science*, 18: 21-30.

Ryder Wilkie, K.T., Mertl, A.L. & Traniello, J.F.A. (2010). Species diversity and distribution patterns of the ants of Amazonian Ecuador. *PLoS ONE*, 5(10): e13146. doi: 10.1371/journal.pone.0013146

Sanders, J.G., Powell, S., Kronauer, D.J., Vasconcelos, H.L., Frederickson, M.E. & Pierce, N.E. (2014). Stability and phylogenetic correlation in gut microbiota: lessons from ants and apes. *Molecular Ecology*, 23: 1268-1283.

Sanhudo, C.E.D., Izzo, T.J. & Brandão, C.R.F. (2008). Parabiosis between basal fungus-growing ants (Formicidae, Attini). *Insectes Sociaux*, 55: 296-300.

Santos-Silva, L., Vicente, R.E. & Feitosa, R.M. (2016). Ant species (Hymenoptera, Formicidae) of forest fragments and urban areas in a Meridional Amazonian landscape. *Check List*, 12(3), 1-7. doi: 10.15560/12.3.1885.

Schmit-Neuerburg, V. & Blüthgen, N. (2007). Ant-garden epiphytes are protected against drought in a Venezuelan lowland rain forest. *Ecotropica*, 13: 93–100.

Swain, R.B. (1980). Trophic competition among parabiotic ants. *Insectes Sociaux*, 27: 377-390.

Vasconcelos, H.L., Macedo, A.C.C. & Vilhena, J.M.S. (2003). Influence of topography on the distribution of ground-dwelling ants in an Amazonian forest. *Studies on Neotropical Fauna and Environment*, 38, 115-124. doi:10.1076/snfe.38.2.115.15923.

Vicente, R.E., Dambroz, J. & Barreto, M. (2011). New distribution record of Daceton boltoni Azorsa & Sosa-Calvo, 2008 (Insecta: Hymenoptera) ant in the Brazilian Amazon. *Check List*, 7: 878-879. doi: 10.15560/7.6.878

Vicente, R.E., Dáttilo, W. & Izzo, T.J. (2012). New record of a very specialized interaction: *Myrcidris epicharis* Ward 1990 (Pseudomyrmecinae) and its myrmecophyte host *Myrcia madida* McVaugh (Myrtaceae) in Brazilian Meridional Amazon. *Acta Amazonica*, 42, 567-570. doi:10.1590/S0044-59672012000400016

Vicente, R.E., Dáttilo, W. & Izzo, T.J. (2014). Differential recruitment of Camponotus femoratus (Fabricius) ants in response to ant garden herbivory. *Neotropical Entomology*, 43:519-525.

Vicente, R.E., Prado, L.P. & Izzo, T.J. (2015). Fauna de formigas (Insecta, Hymenoptera, Formicidae). In: *Biodiversidade do Parque Estadual Cristalino*. (Org. Rodrigues, D.J., Noronha, J.C., Vindica, V.F. & Barbosa, F.R.). Áttema Editorial, São Paulo, BR, pp. 125-139

Vicente, R.E., Prado, L.P. & Izzo, T.J. (2016a). Amazon Rainforest Ant-Fauna of Parque Estadual do Cristalino: Understory and Ground-Dwelling Ants. – *Sociobiology*, 63(3). doi: 10.13102/sociobiology.v63i3.1043

Vicente, R.E., Prado, L.P. & Izzo, T.J. (2016b). Formigas. In: Rodrigues, D.J., Noronha, J.C., Vindica, V.F. & Barbosa, F.R. *Biodiversidade do Parque Estadual Cristalino*. Áttema editorial, São Paulo, Brasil, pp. 124-139.

Vicente, R.E., Prado, L.P. & Souza, R.C.L. (2015). Expanding the Distribution of the Remarkable Ant *Gnamptogenys vriesi* Brandão & Lattke (Formicidae: Ectatomminae): First Record From Brazil. *Sociobiology*, 62(4): 615-619. doi: 10.13102/sociobiology.v62i4.920

Wilson, E.O. (1987). The arboreal ant fauna of Peruvian Amazon forests: a first assessment. *Biotropica*, 19, 245-251.

Youngsteadt, E., Guerra-Bustios, P. & Schal, C. (2010). Divergent chemical cues elicit seed collecting by ants in an obligate multi-species mutualism in lowland Amazonia. *PLoS ONE*, 5(12), e15822. doi:10.1371/journal.pone.0015822

CAPITULO 1 - Differential recruitment of *Camponotus femoratus* (Fabricius) ants in response to Ant Garden herbivory

Artigo publicado pela revista Neotropical Entomology (ISSN: 1519-566X; Classificação CAPES: B2):

Vicente, R.E., Dáttilo, W. & Izzo, T.J. (2014). Differential Recruitment of *Camponotus femoratus* (Fabricius) Ants in Response to Ant Garden Herbivory. Neotropical Entomology, 43: 519-525. doi:10.1007/s13744-014-0245-6

Submitted to: Neotropical Entomology

Section: Ecology, Behavior and Bionomics

Running title: Ant's defense and Ant-gardens epiphytes frequency

Differential recruitment of *Camponotus femoratus* (Fabricius, 1804) ants in response to Ant-Gardens herbivory

R. E. Vicente[1,3], W. Dáttilo[2], T. J. Izzo[1]

[1] Department of Ecology and Botany, Community Ecology Laboratory, Universidade Federal de Mato Grosso, Cuiabá, MT, CEP 78060-900, Brazil

[2] Institute of Neuroethology, Universidad Veracruzana, Xalapa, VZ, CP 91190, Mexico

** Corresponding author:*

Ricardo Eduardo Vicente

UFMT-IB-PPGECB

Avenida Fernando Correa/ SN

Cuiabá, Mato Grosso, 78068-900, Brazil

E-mail ricardomyrmex@gmail.com

ABSTRACT: Although several studies have shown that ants can recognize chemical cues from their host plants in ant-plant systems, it is poorly demonstrated in Ant-gardens (AGs). In this interaction, ant species constantly interact with various epiphyte species. Therefore it's possible to expect a convergence of chemical signals released by plants that could be acting to ensure that ants are able to recognize and defend epiphyte species frequently associated with AGs. In this study it was hypothesized that ants recognize and differentiate among chemical stimuli released by AGs-epiphytes and non AGs-epiphytes. With this aim, it was experimentally simulated leaf herbivore damage on three epiphytes species restricted to AGs and a locally abundant understory herb: *Piper hispidum* in order to quantify the number of recruited *Camponotus femoratus* (Fabricius, 1804) defenders. When exposed to the AG-epiphytes *Peperomia macrostachya* and *Codonanthe uleana* leaves it was observed that the recruitment of *Ca. femoratus* workers was, on average, respectively 556% and 246% higher than control. However, the number of ants recruited by the AGs-epiphyte *Markea longiflora* or by the non-AG plant did not differ from paper pieces. This indicated that ants could discern between chemicals released by different plants, suggesting that ants can select better plants. These results can be explained by evolutionary process acting on both: ants' capability in discerning plants' chemical compounds (innate attraction); or by ant´s learning based on the epiphytes frequency in AGs (individual experience). To disentangle an innate behavior, a product of classical co-evolutionary process, from an ant´s learned behavior is a complicated but important subject to understand in the evolution of ant-plant mutualisms.

Keywords: Ant-gardens, ant-plant system, *Peperomia macrostachya*, *Codonanthe uleana*, herbivory, mutualism.

1) Introduction

Cooperative interactions among species are one of the central issues in ecology, and probably every organism on Earth is engaged in at least one mutualistic interaction throughout its life history (Bronstein 2001). In this kind of relationship one species provides a service or a product that its partner cannot acquire alone and, in exchange, receives some kind of payment or reward (Hoeksema & Bruna 2000). Ants and plants can interact in different ways, from facultative to highly specialized mutualistic relationships (Fonseca & Ganade 1996, Rico-Gray & Oliveira 2007, Vicente *et al* 2012). Studies focusing on the mutualism between ant and plant approaches have made a notable contribution to the current understanding on mutualistic interactions (e.g. Bronstein 1998, Izzo & Vasconcelos 2002, Heil & McKey 2003).

One remarkable ant-plant mutualism found in tropical forests is known as Ant-Gardens (hereafter AGs). This interaction in Neotropical regions includes nine species of ants (obligate AGs inhabitant) and 53 epiphyte species (Orivel & Leroy 2011). However the association between *Camponotus femoratus* (Fabricius, 1804) (Formicinae) and *Crematogaster levior* Longino, 2003 (Myrmicinae) is among the most commonly found in neotropics and is categorized as parabiosis (where two species share the same nest and foraging trails - Hölldobler & Wilson 1990, see: Swain 1980, Sanhudo *et al* 2008). About 95% of AGs in the Amazon forest areas are occupied by them (Davidson 1988, Youngsteadt *et al* 2010, Orivel & Leroy 2011). Indeed, these ants are found foraging from the ground to the canopy (Wilson 1987, Dejean *et al* 2007, Ryder Wilkie *et al* 2010) and are behaviorally dominant in the ant community wherever they occur (Davidson 1988, Mertl *et al* 2010).

In AGs, ants build arboreal nests using some specific epiphyte seeds (Davidson 1988). During seed harvesting the differentiation between their mutualistic partners and other plants is made through the recognition of volatiles present in the seeds of AGs-epiphytes (Youngsteadt *et al* 2008). When the seeds sprout and grow, the epiphyte roots increase the structural stability and complexity of the ants' nests (Yu 1994). Moreover, some AGs-epiphytes can provide food for ants through nectaries, fruits and seed arils, or indirectly, serving as a substrate to tend honeydew-producing insects (Kleinfeldt 1986, Davidson 1988, Orivel & Leroy 2011). On the other hand, epiphytes are benefited by seed dispersion, provision and maintenance of a substrate with high concentration of nutrients (Blüthgen *et al* 2001, Schmit-Neuerburg & Blüthgen 2007) and protection against herbivory (Vantaux *et al* 2007).

Several studies have shown that in other protective ant-plant interactions, as myrmecophyte systems, ants can recognize the herbivores presence on their host plants using cues. Some myrmecophyte-ants can detect physical stimuli of the herbivore on plants as Volatile Organic Compounds (VOCs) released by plants when the leaf tissue is ruptured at the moment of herbivory and immediately recruit nest mates (Romero & Izzo 2004, Christianini & Machado 2004, Dejean *et al* 2007). Just one study demonstrated such response in AGs-epiphytes, but the authors described the response of ants to herbivory simulated in only one host plant (Vantaux *et al* 2007). In AGs, the ant chemical recognition of leaf volatiles comes up against a more complex picture because more than one ant species constantly interacts with various epiphyte species that compose the same nest. In such scenario, as in AG-seeds (Youngsteadt 2010), AG-ants face several plants belonging to different families (Orivel & Leroy 2011) and, consequently, distinct phylogenetic histories. This diversity of partners can be associated to a diversity of chemical compounds released when the leaf is damaged by herbivores. Thus to be an efficient partner, the ants needs to recognize and respond to all different chemicals. In other hand, it is possible that the AGs plants show similar chemical signals by convergence to a generalized signal linked to herbivory. So, the ants would to recruit equally to all AG species in a given site. Therefore we hypothesize that: 1) ants recognize chemical stimuli emitted by different

AGs-plants and 2) they can differentiate this stimulus when compared with a plant understory. To test these hypotheses, we used as a study model a colony of *Ca. femoratus*, their sympatric epiphytes in a secondary forest located in the southern Brazilian Amazon.

2. Material and Methods

2.1) Study area

This study was conducted on the São Nicolau Farm (9º48'S and 58º15'W, elev. 254m), located in the municipality of Cotriguaçu, north of Mato Grosso State, Brazil. According to the Köppen classification, the climate is tropical humid (Am) with annual average: 24-26 °C and precipitation of 3,000 mm year^{-1} (Alvares *et al* 2013). There are two well-defined seasons, a rainy season between November and April and a dry season between May and October (pers. obs). The local vegetation is classified as Open Ombrophylous Forest and Dense Ombrophylous Forest contrasting with large areas of Teak (*Tectona grandis*) plantations and 28 native arboreal tree species (Vicente *et al* 2011). The experiments were conducted on a native forest edge with approximately 7.250m² bordering a reforestation site of *Ficus* spp. (Moraceae). Canopy in this area was composed by young trees (about 3 meters high), mainly *Vismia* sp. (Hypericaceae) a typical plant of open areas and forest edges (Santos & Machado 1998).

2.2 Experimental design

Previously, to determine the composition of epiphytes in this study site, the frequency epiphytes found in 17 AGs of one *Ca. femoratus* colony were recorded. Only the species with established roots inside ant colonies (Kaufmann & Maschwitz 2006) were considered as epiphytic plants. Based on this ratio, three AGs-restricted epiphytes were selected so as to conduct the recruitment of ants experiment, two common plant species *Peperomia macrostachya* (Piperaceae) and *Codonanthe uleana* (Gesneriaceae) and the least common, *Markea longiflora* (Solanaceae).

For recognition experiments 20 AGs were chosen in this same *Ca. femoratus* colony. We selected nests with at least two of the three species found in the region. These nests were found at least 10 meters one to another. Twenty-four hours before the beginning of the experiments a circular transparent plastic platform 15cm in diameter was fixed with wire to the arboreal phorophyte trunk, at a distance of 30cm from the each selected nest, in order to allow easy access by the ants. This time period (24 hours) was required to reduce the disturbance caused by the installation of the experiment.

We simulated leaf herbivore damage by placing gently leaf pieces of 5cm² in center of each platform. Leaf pieces were obtained immediately before we start the experiment and collected in others AGs at least 10 meters apart the one we conduct the experiment. As the ants could recruit when exposed to any leaf volatile, a herb that occurs abundantly in understory of the study site but is not present in the AGs: *Piper hispidum* (Piperaceae) was used. Furthermore, in order to control the effect of the manipulative disturbance when inserting new material near the colony, pieces of paper (5cm²) were used. All five treatments (three epiphytes, one non-epiphyte and one control) were carried out in each of the 20 AGs. At the beginning of all experiments (time zero) there was no ant worker in any platforms. The order of administration of each treatment was randomized at the moment of the experiment. Thereafter, before the administration of each, the number of ants patrolling on these platforms was quantified in 1, 3, 7 and 10 minutes. In order to reduce any other external interference, at the end of each experimental trial any residue was removed and the platforms were washed using ethanol. Additionally, there was a interval of 24 hours among each experiment. Despite the variety linked to activity time of ants of the genus *Camponotus* (for examples see: Yamamoto & Del-Claro 2008) *Ca. femoratus* patrol equally during the whole day (Vantaux *et al* 2007). However, the period of the experiment was always the same, between 13 and 15 pm. order to avoid climatic variations that come interfere in volatilization of the compounds or the effect of temperature on ant´s behavior.

2.3) Data analysis

To test the hypothesis that ants' recruitment is stimulated by volatile to AGs-epiphytes over time, a randomized block repeated measures ANOVA was used. In this analysis the number of recruited worker ants was the dependent variable. Each species of plant and control was the independent factor. Each ant-garden where five treatments were carried out was the blocking factor and the time factor (0, 1, 3, 7 or 10 minutes) was the repetition factor. Later, each leaf strip was tested against control (paper strip) in *a posteriori* analysis in order to determine to which plant the ants were effectively recruiting. In this case, the Bonferroni correction for multiple comparisons was employed. All analyzes were performed using the SYSTAT v.13.0 software (Wilkinson 1998) and the figure prepared using GraphPad Prism version 5.0 (Motulsky 1999).

3) Results

3.1 Ant-gardens composition

In the AGs survey (n=17) four epiphyte species were observed. Seven AGs harbored more than one epiphyte species. *Peperomia macrostachya* (Piperaceae) was the most frequent, present in 88% of the observed AGs. The second most frequent was *Codonanthe uleana* (Gesneriaceae) (41%), followed by *Philodendron* sp. (Araceae) (18%) and *Markea longiflora* (Solanaceae) (6%). Combinations of species varied among nests but *P. macrostachya* was the only one to be associated with all other epiphyte species. *Co. uleana* was recorded with *P. macrostachya* or *Philodendron* sp., sometimes the three species being present together. *M. longiflora* occurred only once, in a large nest sharing substrate only with *P. macrostachya*. Only *Co. uleana* and *P. macrostachya* were found alone in the AGs, usually in nests at early development stages. In not-sampled nearby AGs other epiphyte species such as *Anthurium* sp. (Araceae) and an unidentified Bromeliad (Bromeliaceae) occurring in extremely low frequencies were found. The ant species *Ca. femoratus* and its parabiotic partner *Cr. levior* were recorded in all studied AGs. Except for them, only two species of ants were seen foraging near the nest: *Cephalotes* sp. and *Cephalotes clypeatus*. However neither of them occurred on experimental platforms during the experiment.

3.2 AGs' Ant recruitment

Camponotus femoratus account for almost 100% of the ants recruited in the experiment. *Crematogaster levior* was observed only on a few occasions represented by solitary workers, almost always occurring when *Codonanthe uleana* strips were exposed, but as they did not perform massive recruitments, this fact was not consider as biologically significant. Thus, all following statistical analyzes were performed for *Ca. femoratus*.

Different recruitment among treatments ($F_{4,100} = 20.92$, $P < 0.001$) were observed, with no variation among AGs (block effect - $F_{18,100} = 0.78$, $P > 0.5$) or different response patterns among different AGs (block effect*treatments - $F_{72,100} = 1.74$, $P = 0.36$). During 10 minutes of experiment the recruitment of *Ca. femoratus* workers increased 556% in *Pe. macrostachya* (Mean of ants workers ± SD: 3.89 ± 2.37) and 246% in *Co. uleana* (1.72 ± 1.89) than paper strip (0.7 ± 1.07) ($F_{1,37}= 50.412$, $P < 0.001$ and $F_{1,38} = 6.633$, Bonferroni $P = 0.014$, Table 1).

The higher ant recruitment occurred after three minutes of experiment in *Pe. macrostachya* (6.21 ± 3.14) ($F_{3,111}= 17.234$, $P <0.001$). In *Co. uleana* the recruitment was more intense in the seventh (2.15 ± 2.25) and tenth (2.15 ± 2.41) minute of the experiment ($F_{3,111}= 17.234$, $P <0.001$). The average number of worker ants in other treatments did not exceed 1.2 recruited at any time (Figure 1). Additionally, the number of ants recruited by *M. longiflora* or the non-AGs *Piper hispidum* did not differ from those found when paper pieces were placed on platforms (respectively, $F_{1,37} = 0.004$ and $F_{1,38} = 1.282$, Bonferroni P

> 0.5). Although the *Camponotus femoratus* recruitment increased only when ants faced volatiles from the two most abundant epiphytes (*Pe. macrostachya* and *Co. uleana*), differences were found between them ($F_{1,37}$ = 15.496, P < 0.001). In addition, the recruitment strength was different between these two epiphytes over time ($F_{3,111}$ = 10.586, Bonferroni P < 0.001).

4) Discussion

The epiphytic species found in this study are reported constantly associated with Ant-gardens (AGs) in a wide geographic range throughout Amazon (Yu 1994, Orivel & Dejean 1999, Dejean *et al* 2000, Orivel & Leroy 2011) often associated with *Ca. femoratus* and its parabiotic partner *Cr. levior* (Orivel & Dejean 1999). These results indicate a high specificity of this relationship over the whole geographic range. Indeed, this partner stability in such large geographic area is a scenario that may result from the development of local co-evolutionary mechanisms of recognition among mutualistic partners (Thompson 2005). Moreover, we note that only *Ca. femoratus* workers recruit to AGs leaf pieces drumming, and becoming agitated and walking randomly around the nest, a behavior that may be linked to the recruitment of other workers (Santos *et al* 2005). It's not surprising, since *Cr. levior* lost their chemical defense relying on the protection of *Ca. femoratus* (Longino 2003) and, additionally, *Cr. levior* is mainly nocturnal, unlike *Ca. femoratus* that patrols throughout the day (Vantaux *et al* 2007). Indeed, *Cr. femoratus* recruiting workers at different intensities and only to more common AGs epiphytes.

Plants defense by ants has been related to the specificity of the interaction (Bruna *et al* 2008, Dáttilo *et al* 2009) probably because the quantity and quality of food resources offered by different plants species can vary (Bronstein 1998, Ness *et al* 2009, Heil & Mckey 2003) and resource intake is intrinsically connected to ant fitness (Byk & Del-Claro 2011). In fact, part of the difference observed in plant attractivity to ants can be supported by the food reward provided by the plants. *Markea longiflora* and *Codonanthe uleana* provide extrafloral nectar to *Ca. femoratus* ants, and *P. macrostachya* have oil glands on their leaves, inflorescence and fruits (Madison 1979, Benzing 1990, Carvalho-Silva 2008). AGs usually occur in areas with high-light incidence and productivity, as treefall gaps and riverbanks (Davidson 1988). In such habitats, *Ca. femoratus* can use a plethora from other plants with extrafloral nectar and cultivate honeydew-producing insects in other plants nearby AGs (Davidson 1988, Schupp & Feener 1991, TJI pers. obs.). This suggests that the demand for extrafloral nectar (sugar) could not be the key factor for the AGs ants. On the other hand, the oil provided by *Pe. macrostachya* is a rare reward among plants and can be more valuable in such environments when compared to extrafloral nectar. In fact, *Ca. femoratus* were observed several times feeding on *Pe. macrostachya* oil glands, but no ant was observed foraging on the extrafloral nectaries of either *M. longiflora* or *Co. uleana*. Indeed, *Co. uleana* is more frequently found than *M. longiflora* and bear fruits throughout the year from the early stages of the plant life cycle. Nevertheless, *M. longiflora* invests more in growth and reproduce late (Davidson 1988). Despite these environments being apparently Nitrogen rich resources, *Co. uleana* can be considered as a predictable resource over the year.

Experiments on seed harvesting by *Ca. femoratus* claim no direct relationship between the choice of the seed and the resource offer (Orivel and Dejean 1999, Davidson 1988). In such cases the seed dispersal is linked mainly to the chemical composition of volatiles released by seeds (Youngstead *et al* 2008). However, there is probably a link among the plant defense by *Ca. femoratus* and the plant frequency and the quality of the existence of food resource. So, the high frequency of *P. macrostachya* can be a product of an evolutionary pattern, once plants should emit specific volatile compounds, imposing a possibility of selection of *Ca. femoratus* to discern between resource-rich, resource-poor or cheater plants. However, better plants, with the denser root system and/or that produce better food resources could be positively selected and more vigorously defended. Therefore, it is possible to expect a coevolutionary scenario, in which the better-defended plants would produce more seeds and become more frequent and the better defender ant, with the better VOCs detection capability, will receive more food and nest and, consequently, produce more alates (reproductive ants).

On the other hand, VOCs released by plants during herbivory play other roles in the plant life cycle and are present in a large number of plant species (Heil 2008, Kessler & Heil 2011). Other studies show no evidence of adaptation traits of VOCs to the alarm of herbivores, suggesting that communication among plants and a third trophic level may not be a coevolutive trait (reviewed on Kessler & Heil 2011). In this present study, the coevolutionary hypothesis fits as a reasonable explanation, but one cannot expel an alternative hypothesis that it is not necessarily a product of a direct evolutionary pressure: the VOCs recognition can be a product of imprinting (Djeto-Lordon & Dejean 1999a,b) or also a product of the ant´s learning capacity. There are several examples in which some ant species have the ability to learn from past experiences (Langridge *et al* 2004, Blatrix & Sermage 2005, Ravary *et al* 2007, Langridge *et al* 2008, Van-Wilgenburg *et al* 2010) and also when it comes to discrimination of chemical cues (Dupuy *et al* 2006, Errard *et al* 2008, Bos *et al* 2010). The learning process demands a certain frequency of similar repeated experiences (Takabayashi *et* al. 2006). Indeed, *P. macrostachya* is the most common plant on AGs of the study area. It suggests that the higher *Camponotus femoratus* recruitment to the most frequent plant volatiles may be a product of learning. *Camponotus femoratus* could have learned that frequent VOCs release is associated to the presence of a herbivore (a possible food resource). Distinguish an innate behavior, a product of a classical co-evolutionary process, from an ant´s learned behavior is complicated but an important subject in understanding the evolution of ant-plant mutualisms (see for example: Djeto-Lordon & Dejean 1999a,b). Future experiments manipulating plant frequency in

AGs along its ontogeny should be made in order to determine if the chemical recognition of plants is due to a coevolutive process or learning from multiple experiences.

REFERENCES

Alvares CA, Stape JL, Sentelhas PC, De-Moraes-Gonçalves JL, Sparovek G (2013) Köppen's climate classification map for Brazil. Meteorologische Z. (Berlin) 22:711-728. doi:10.1127/0941-2948/2013/0507

Benzing DH (1990) Vascular Epiphytes. General Biology and related Biota. Cambridge University Press, Cambridge, p 354

Blatrix R, Sermage C (2005) Role of early experience in ant enslavement: a comparative analysis of a host and a non-host species. Frontiers in Zoology 2:13. doi:10.1186/1742-9994-2-13

Blüthgen N, Schmit-Neuerburg V, Engwald S, Barthlott W (2001) Ants as epiphyte gardeners: comparing the nutrient quality of ant and termite canopy substrates in a Venezuelan lowland rain forest. J. Trop. Ecol. 17:887-894. doi:10.1017/S0266467401001651

Bos N, Guerrieri FJ, d'Ettorre P (2010) Significance of chemical recognition cues is context dependent in ants. Anim. Behav. 80:839-844. doi:10.1016/j.anbehav.2010.08.001

Bronstein JL (1998) The contribution of ant-plant protection studies to our understanding of mutualism. Biotropica 30:150-161

Bronstein JL (2001) The costs of mutualism. American Zoologist 41:127-141

Bruna EM, Darrigo MR, Furuya-Pacheco AM, Vasconcelos HL (2008) Interspecific variation in the defensive responses of ant mutualists to plant volatiles. Biol. J. Linn. Soc. 94:241-249. doi:10.1111/j.1095-8312.2008.00962.x

Byk J, Del-Claro K (2011) Ant plant interaction in the Neotropical savanna: direct beneficial effects of extrafloral nectar on ant colony fitness. Popul. Ecology 53:327-332. doi:10.1007/s10144-010-0240-7

Carvalho-Silva M (2008) *Peperomia* Ruiz & Pav. No Brasil: morfologia e taxonomia do subgênero Rhynchophorum (Miq.) Dahlst. PhD. Thesis, Instituto de Pesquisas Jardim Botânico do Rio de Janeiro/Escola Nacional de Botânica Tropical, Rio de Janeiro, Brasil, p 145

Christianini AV, Machado G (2004) Induced biotic responses to herbivory and associated cues in the Amazonian ant-plant *Maieta poeppigii*. Entomologia Experimentalis et Applicata 112:81-88. doi:10.1111/j.0013-8703.2004.00188.x

Dáttilo WFC, Izzo TJ, Inouye BD, Vasconcelos HL, Bruna EM (2009) Recognition of host plant volatiles by *Pheidole minutula* Mayr (Myrmicinae), an amazonian ant-plant specialist. Biotropica (Lawrence, KS), 41:642-646. doi:10.1111/j.1744-7429.2009.00518.x

Davidson DW (1988) Ecological studies of neotropical ant gardens. Ecology 69:1138-1152

Dejean A, Corbara B, Orivel J, Snelling RR, Delabie JHC, Belin-Depoux M (2000) The importance of ant gardens in the pioneer vegetal formations of French Guiana. Sociobiol. 35:425-439

Dejean A, Corbara B, Orivel J, Leponce M (2007) Rainforest canopy ants: the implications of territoriality and predatory behavior. Functional Ecosystems and Communities 1:105-120

Djieto-Lordon C, Dejean A (1999a) Innate attraction supplants experience during host plant selection in an obligate plant-ant. Behav. Processes 46(3):181-187. doi:10.1016/S0376-6357(99)00032-7

Djieto-Lordon C , Dejean A (1999b) Tropical arboreal ant mosaics: innate attraction and imprinting determine nest site selection in dominant ants. Behavioral Ecology and Sociobiol. 45:219-225. doi:10.1007/s002650050556

Dupuy F, Sandoz JC, Giurfa M, Josens R (2006) Individual olfactory learning in *Camponotus* ants. Anim. Behav. 72:1081-1091. doi: 10.1016/j.anbehav.2006.03.011

Errard C, Le Guisquet AM, Christides JP., Mercier JL, Lenoir A, Hefetz A (2008) Early learning of volatile chemical cues leads to interspecific recognition between two ant species. Insect. Soc. 55:115-122. doi:10.1007/s00040-008-0979-4

Fonseca CR, Ganade G (1996) Asymmetries, compartments and null interactions in an Amazonian ant-plant community. J. Anim. Ecology 65: 339-347. doi: 10.2307/5880

Heil M (2008) Indirect defence via tritrophic interactions. New Phytologist 178:41-61. doi:10.1111/j.1469-8137.2007.02330.x

Heil M, McKey D (2003) Protective ant-plant interactions as model systems in ecological and evolutionary research. Annual Rev. of Ecology, Evolution, and Systematics 34:425-453. doi:10.1146/annurev.ecolsys.34.011802.132410

Hoeksema JD, Bruna EM (2000) Pursuing the big questions about interspecific mutualism: a review of theoretical approaches. Oecologia 125:321-330. doi:10.1007/s004420000496

Hölldobler B, Wilson EO (1990) The ants. Cambridge, MA: Belknap Press of Harvard University Press, p 764

Izzo TJ, Vasconcelos HL (2002). Cheating the cheater: domatia loss minimizes the effects of ant castration in an Amazonian ant-plant. Oecologia, 133:200-205. doi:10.1007/s00442-002-1027-0

Kaufmann E, Maschwitz U (2006) Ant-gardens of tropical Asian rainforests. Naturwissenschaften 93:216-227. doi:10.1007/s00114-005-0081-y

Kessler A, Heil M (2011) The multiple faces of indirect defenses and their agents of natural selection. Functional Ecology 25:348-357. doi:10.1111/j.1365-2435.2010.01818.x

Kleinfeldt SE (1986) Ant-gardens: mutual exploitation. In: Juniper B, Southwood TRE (eds) Insects and the plant surface. Edward Arnold, London, pp 283-291

Langridge EA, Franks NR, Sendova-Franks AB (2004) Improvement in collective performance with experience in ants. Behavioral Ecology and Sociobiol. 56:523-529. doi:10.1007/s00265-004-0824-3

Langridge EA, Sendova-Franks AB, Franks NR (2008) How experienced individuals contribute to an improvement in collective performance in ants. Behavioral Ecology and Sociobiol. 62:447-456. doi:10.1007/s00265-007-0472-5

Longino JT (2003) The Crematogaster (Hymenoptera, Formicidae, Myrmicinae) of Costa Rica. Zootaxa, Auckland, 151:1-150

Madison M (1979) Additional observations on ant-gardens in Amazonas. Selbyana 5:107-115

Mertl AL, Sorenson MD, Traniello JFA (2010) Community-level interactions and functional ecology of major workers in the hyperdiverse ground-foraging Pheidole (Hymenoptera, Formicidae) of Amazonian Ecuador. Insect. Soc. 57:441-452. doi:10.1007/s00040-010-0102-5

Motulsky H (1999) Analyzing data with graph pad prism software. Graph Pad Software, San Diego

Ness J, Morris WF, Bronstein J (2009) For ant-protected plants, the best defense is a hungry offense. Ecology 90:2823-2831

Orivel J, Dejean A (1999) Selection of epiphyte seeds by ant-garden ants. Ecoscience 06(1):56-61

Orivel J, Leroy C (2011) The diversity and ecology of ant gardens (Hymenoptera: Formicidae, Spermatophyta: Angiospermae). Myrmecological News 14:73-85

Ravary F, Lecoutey E, Kaminski G, Chaline N, Jaisson P (2007) Individual experience alone can generate lasting division of labor in ants. Curr. Biol. 17:1308-1312. doi: 10.1016/j.cub.2007.06.047

Rico-Gray V, Oliveira PS (2007) The Ecology and Evolution of Ant–Plant Interactions. Chicago, Illinois, The University of Chicago Press, Chicago, p 331

Ryder-Wilkie KT, Mertl AL, Traniello JFA (2010) Species diversity and distribution patterns of the ants of Amazonian Ecuador. PLoS ONE 5(10): e13146. doi:10.1371/journal.pone.0013146

Romero GQ, Izzo TJ (2004) Leaf damage induces ant recruitment in the Amazonian ant-plant *Hirtella myrmecophila*. J. Trop. Ecology 20:675-682. doi:10.1017/S0266467404001749

Santos JC, Korndörfer AP, Del-Claro K (2005) Defensive behavior of the weaver ant *Camponotus* (*Myrmobrachys*) *senex* (Formicidae: Formicinae): Drumming and Mimicry. Sociobiol. (Estados Unidos) 46(2): 279-288

Santos MJL, Machado IC (1998) Biologia floral e heterostilia em *Vismia guianensis* (Aubl.) Choisy (Clusiaceae). Acta Botanica Brasilica 12:451-464. doi:10.1590/S0102-33061998000400014

Schmit-Neuerburg V, Blüthgen N (2007) Ant gardens protect epiphytes against drought in a Venezuelan lowland rain forest. Ecotropica 13:93-100

Schupp GW, Feener DHJ (1991) Phylogeny, lifeform, and habitat dependence of ant-defended plants in a Panamanian forest. In: Huxley CR, Cutler DF (eds) Ant-plant interactions. Oxford University Press, Oxford, pp 175-197

Sanhudo CED, Izzo TJ, Brandão CRF (2008) Parabiosis between basal fungus-growing ants (Formicidae, Attini). Insec. Soc. 55: 296-300

Swain RB (1980) Trophic competition among parabiotic ants. Insect. Soc. 27: 377-390

Takabayashi J, Shimoda T, Dicke M, Ashihara W, Takafuji A (2000) Induced response of tomato plants to injury by green and red strains of *Tetranychus urticae*. Experimental and Appl. Acarology. 24:377-383. doi:10.1023/A:1006497024175

Thompson JN (2005) The geographic mosaic of coevolution. University of Chicago Press, Chicago, p 400

Van-Wilgenburg E, Clémencet J, Tsutsui ND (2010) Experience influences aggressive behaviour in the Argentine ant. Biology Letters 6:152-155. doi:10.1098/rsbl.2009.0616

Vantaux A, Dejean A, Dor A, Orivel J (2007) Parasitism versus mutualism in the ant-garden parabiosis between *Camponotus femoratus* and *Crematogaster levior*. Insect. Soc. 54:95-99. doi:10.1007/s00040-007-0914-0

Vicente RE, Dambroz J, Barreto M (2011) New distribution record of *Daceton boltoni* Azorsa and Sosa-Calvo, 2008 (Insecta: Hymenoptera) ant in the Brazilian Amazon. Check List (São Paulo. Online) 7:878-879

Vicente RE, Dáttilo W, Izzo TJ (2012) New record of a very specialized interaction: *Myrcidris epicharis* Ward 1990 (Pseudomyrmecinae) and its myrmecophyte host *Myrcia madida* McVaugh (Myrtaceae) in Brazilian Meridional Amazon. Acta Amazonica. 42:567-570. doi:10.1590/S0044-59672012000400016

Wilson EO (1987) The arboreal ant fauna of Peruvian Amazon forests: a first assessment. Biotropica 19:245-251

Yamamoto M., Del-Claro K (2008) Natural history and foraging behavior of the carpenter ant *Camponotus sericeiventris* Guérin, 1838 (Formicinae, Campotonini) in the Brazilian tropical savanna. Acta Ethologica, 11:55-65. doi: 10.1007/s10211-008-0041-6

Youngsteadt E, Nojima S, Haberlein C, Schulz S, Schal C (2008) Seed odor mediates an obligate ant-plant mutualism in Amazonian rainforest. PNAS 105:4571-4575. doi:10.1073/pnas.0708643105

Youngsteadt E, Guerra-Bustios P, Schal C (2010) Divergent chemical cues elicit seed collecting by ants in an obligate multi-species mutualism in lowland Amazonia. PLoS ONE 5(12):e15822. doi:10.1371/journal.pone.0015822

Yu DW (1994) The structural role of epiphytes in ant gardens. Biotropica 26:222-226

Wilkinson L (1998) Systat: the system for statistics. Illinois: SYSTAT Inc. Evaston

Acknowledgements

We thank Rafael Arruda and Georgia Sinimbu for reviewing and useful contribution over previous design of manuscript, also to the anonymous reviewers for their great contribution to the final version of the work and Jéssica Falcão for her invaluable fieldwork support in the collection data. We also would like to thank Office National des Forêts Brazil and the National Council for Scientific and Technological Development, Brazil (CNPq n° 479243/2012–3) for logistical and financial support. REV thanks Enhancement Coordination of Personnel of Superior Level, Brazil (CAPES) for doctoral fellowship. WD is grateful for financial support by National Council for Scientific and Technological Development, Brazil (CNPq) and National Council on Science and Technology, Mexico (CONACYT). TJI is grateful to CAPES (BEX 2548-14-3). This work is part of the doctoral thesis of REV in Ecology and Biodiversity Conservation Postgraduate Program – UFMT and is publication 43 in the NEBAM technical series.

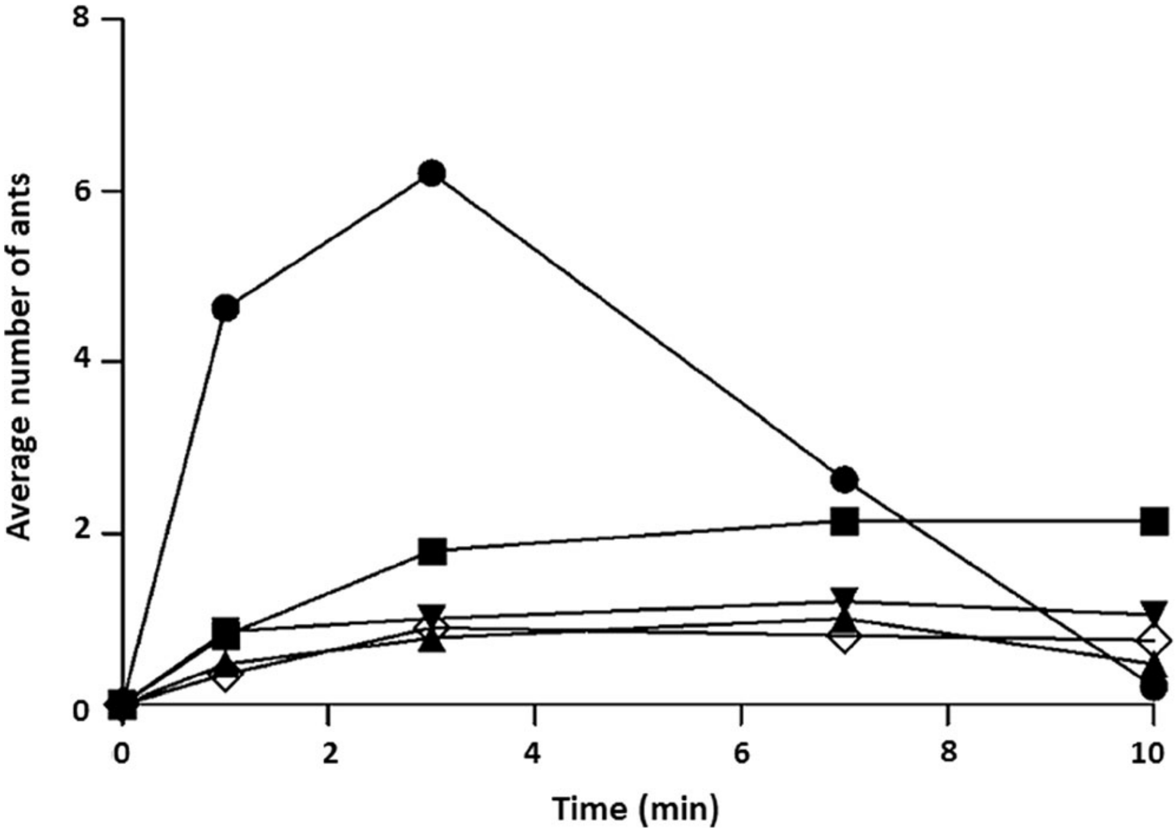
Table 1. Repeated measures ANOVA for the effect of chemicals cues released by plants in recruitment of *Camponotus femoratus* workers

Experiment	Source of variation	d.f.	MS	F
Peperomia macrostachya versus Control	Plant	1	397,786	50,412***
	Error	37	7,891	
	Time	3	35,264	17,234***
	Time × Plant	3	35,401	17,300***
	Error	111	2,046	
Codonanthe uleana versus Control	Plant	1	42,025	6,633 **
	Error	38	6,336	
	Time	3	7,342	5,810***
	Time × Plant	3	1,975	1,563
	Error	114	1,264	
Markea longiflora versus Control	Plant	1	0,010	0,004
	Error	37	2,344	
	Time	3	1,968	2,758*
	Time × Plant	3	0,464	0,650
	Error	111	0,714	
Piper hispidum versus Control	Plant	1	4,225	1,282
	Error	38	3,296	
	Time	3	1,292	1,462
	Time × Plant	3	0,292	0,330
	Error	114	0,884	
Peperomia macrostachya versus *Codonanthe uleana*	Plant	1	183,482	15,496***
	Error	37	11,841	
	Time	3	27,008	10,586***
	Time × Plant	3	50,461	19,779***
	Error	111	2,551	

Significance values: *P ≤ 0.05, **P ≤ 0.01, *** P ≤ 0.001.

FIGURE LEGEND

Fig 1 - Mean number of *Camponotus femoratus* workers recruited along time after administration of five experimental treatments: *Peperomia macrostachya* (circle symbol), *Codonanthe uleana* (squared), *Markea longiflora* (triangle), understory plant *Piper hispidum* (inverted-triangle) and control paper strips (lozenge). There are no difference between treatments in the beginning of experiment (Time 0).



CAPÍTULO 2 - Defining the niche of parabiotic ants *Camponotus femoratus* (Fabricius, 1804) and *Crematogaster levior* Longino, 2003

Artigo em preparação, formatado para submissão à revista Sociobiology (ISSN: 0361-6525; Classificação CAPES: B2).

Running title: Niche of Ant-garden ants

Manuscript type: Article

Defining the niche of parabiotic ants *Camponotus femoratus* (Fabricius, 1804) and *Crematogaster levior* Longino, 2003

R.E. Vicente[1,2,3], T.J. Izzo[1,2,3]

[1] Laboratório de Ecologia de Comunidades do Departamento de Ecologia e Botânica - Instituto de Biologia da Universidade Federal de Mato Grosso, Cuiabá, MT, Brazil.

[2] P.P.G. Ecologia e Conservação da Biodiversidade da Universidade Federal do Mato Grosso, Cuiabá, MT, Brazil.

[4] Núcleo de Estudos da Biodiversidade da Amazônia Mato-grossense, Universidade Federal de Mato Grosso, Sinop, Mato Grosso, Brazil.

Key-words: Canopy openness, Complexity, Gap size, Habitat use, Niche partitioning, Vertical habitat

** Corresponding author:*
Ricardo Eduardo Vicente
UFMT-IB-PPGECB
Avenida Fernando Correa/ SN
Cuiabá, Mato Grosso, 78068-900, Brazil
E-mail ricardomyrmex@gmail.com

ABSTRACT - Ant-garden ants have a strong relationship with epiphytes that need light to grow, for these reason, it has been previously documented in forest gaps. Moreover, larger gaps have more available area for nesting and habitats for use as forage. Thus we hypothesize that 1) openness canopy influence the presence of ant´s gardens in gaps, and 2) greater gaps will have more nests, and 3) both openness canopy and area determine the colony size in forest gaps. Furthermore, it is known that parabiotic ants foraging on the ground and in vegetation, the nests are arboreal. So, we also hypothesize that 4) parabiotic ants are more often sampled in arboreal strata and 5) increasing complexity of vegetation and the volume of accumulated litter in the soil increase the foraging of the ants in vegetation and ground, respectively, with the increase in canopy openness increasing the activity of the two species in both strata. Presence, number of Ant-gardens, as colony size, was affected by area and locality, but not by canopy openness. Nevertheless, there was not overall difference in the use of strata by *Camponotus femoratus*, neither by *Crematogaster levior*. On the other hand, frequency of *Ca. femoratus* on the ground decreases with canopy openness but is not affected by the complexity of vegetation. Also, *Cr. levior* frequency on the ground also decreases with the increase of complexity of vegetation and canopy openness. In addition, neither complexity, or canopy openness influence the frequency of foraging of these ants in understory.

Key-words: Canopy openness, Complexity, Gap size, Habitat use, Niche partitioning, Vertical habitat

INTRODUCTION

Niche is the interaction between tolerances and requirements of conditions and resources of a species (Hutchinson, 1957) and has been employed to describe various biological and evolutionary aspects of species and to test functional ecology hypotheses (Blonder et al., 2014). The niche concept was historically important due to its application in the understanding of several practical issues such as management of economic species (Milstein et al., 2000; Almeida & Valle, 2007; Penha & Mateus, 2007), policies of public health (Medeiros et al., 2006; Dicko et al., 2014; Guichard et al., 2014) and conservation (Leite-Rezende et al., 2014; Dorado-Rodrigues et al., 2015; Nekaris et al., 2015). However, little is known about the niche characteristics of ant species at various scales (Dáttilo et al., 2012a,b; Nakano et al., 2013, Gallego-Ropero et al., 2013, Gallego-Ropero & Feitosa, 2014; Pape, 2016). Especially because the distribution of many ant species still has many gaps (Brandão et al., 2008; Vicente et al., 2015; Schmidt et al., 2014; Camacho & Feitosa, 2016; Prado et al., 2016; Santos-Silva et al., 2016). Works such as these are scarce, but important to disassemble old concepts about the species and help to understand patterns in ant communities (Feitosa et al., 2008, 2016; Delabie et al., 2010).

The ecological role, and as a consequence, the niche of two Neotropical ants *Camponotus femoratus* (Fabricius, 1804) (Formicinae) and *Crematogaster levior* Longino, 2003 (Myrmicinae) is virtually unknown. These ants share the same foraging trails and their arboreal nests in a mutualism relationship known as parabiosis (Swain, 1980). In the nests, they actively plant one or several epiphyte species, forming a complex nest, known as Ant-Gardens (hereafter AGs) (Davidson, 1988; Longino, 2003; Youngsteadt et al., 2009). This interaction includes nine species of ants (obligate AGs inhabitant) however, AGs with parabiotic association between *Ca. femoratus* and *Cr. levior* are among the most commonly found in the Amazon (Davidson, 1988; Orivel & Leroy, 2011). In exchange for support and humidity control for the nest and, in some cases, extrafloral nectar (Davidson, 1988; Schmit-

Neuerburg & Blüthgen, 2007), the ants offer dispersion and protection to their mutualistic epiphyte (Vantaux et al., 2007; Youngsteadt et al., 2008, 2009; Vicente et al., 2014). However, it is important to know the aspects of the niche of these parabiotic ant species whose one species extinction can harm the survival of their partner and can lead to a cascade effect of the loss of other species (Guimarães et al., 2007; Dáttilo, 2012).

Ant-garden ants have a strong relationship with epiphytes that need light to grow (Leroy et al. 2016; Orivel & Leroy 2011), for this reason, they have been previously documented in tree-fall gaps, river banks and abandoned roads (Dáttilo & Izzo, 2012; Vicente et al., 2014). Moreover, larger gaps have more available area for the building of nests and habitats for use as forage. Thus we hypothesize that 1) the openness canopy influences the presence of ant´s gardens in gaps, and 2) greater gaps will have more nests, and 3) both openness canopy and area determine the colony size in forest gaps. Furthermore, even though the nests are essentially arboreal, it is known that parabiotic ants forage on the ground and in vegetation. So, we also hypothesize that 4) parabiotic ants are more often sampled in arboreal strata and 5) increasing complexity of vegetation and the volume of accumulated litter on the soil increase the foraging of the ants in vegetation and ground, respectively, with the increase in canopy openness increasing the activity of the two species in both strata.

MATERIAL AND METHODS

Study area

The study was carried out on two municipalities of the southern Amazonia as part of the Research Program in Biodiversity (PPBio). The standard sampling protocol used in PPBio is the RAPELD methodology (see Costa & Magnusson 2010). In each of the two municipality a set of trails of 250m in length are installed at a minimum distance of 1 km each other, linked by access trails (henceforward Module). In Claudia municipality, three modules are installed close to each other (less than 20km), in a large fragment surrounded by plantations. The

Claudia modules are Module I (11°34’S, 55°17’W) and Module II (11°35’S, 55°17’W) that are broadly connected, and Module III (11°39’S, 55°04’W) that is an area with about 900ha almost completely surrounded by plantations and narrowly connected to the rest of the fragment. The area of these three modules had selective logging more than eight years ago. Because of this, they have older gaps caused by the management of selective logging as wood storage yards and trails used for the dragging of cut trees (abandoned roads). One other area is the Parque Estadual do Cristalino Reserve, a continuous pristine forest in the municipality of Novo Mundo municipality, Mato Grosso States (9°28’S, 55°50’W).

According to the Köppen classification, the climate is tropical humid (Am) with annual average of 25°C. Precipitation is about 2.500 to 2.800 mm year in forest remnants of the municipality of Claudia and 2.800 to 3.100 mm year in Parque Estadual do Cristalino (Alvares et al., 2013). In both, there are two well-defined seasons, a rainy season between November and April and a dry season between May and October (Vicente et al., 2014). The local vegetation in Claudia is classified as area of ecological tension between Open Ombrophylous Forest and Savanna. For the Parque Estadual do Cristalino local vegetation is classified as Open Ombrophylous Forest and ecological tension areas between Ombrophylous Forest and Savanna, Savanna and Seasonal Forest, Seasonal Forest and Ombrophylous Forest (Instituto Brasileiro de Geografia e Estatística, 2004).

Data collection

Gap-occupation

We carried out the experiment about occupation of forest-gaps only in forest remnants in the municipality of Claudia. In these areas, we surveyed all access trails that link plots, totaling approximately 32km. In these trails, all forest-gaps, including the gaps caused by selective logging, within the range of 10 meters of each side of the trails (20 m wide) were selected and we recorded the presence or absence of AGs, number of nests and colony size. Furthermore, we measured the canopy openness and the length of the two central perpendicular axes of the forest gap.

Canopy openness was measured with Concave Spherical Densiometer. It is considered a practical and cheap device that provides a reliable proxy as to the relative availability of light (Baudry et al., 2014). In the center of each forest-gap, we recorded four measurements in the cardinal directions to calculate an average availability of light (Dáttilo et al., 2013, 2014; Baudry et al., 2014). The first two major perpendicular measures of gaps were used as length and width to calculate the gap area, using the formula of the ellipse area (Runkle, 1981; Arihafa & Mack, 2013). In forest-gaps formed by abandoned roads, because of the difficulty in measuring their main axes, we considered a continuous habitat and we assigned an arbitrary value area, the double of our largest forest gap.

Vertical habitat use

To access the information about the use of the vertical habitat by parabiotic ants thirty four (34) plots allocate in the four areas previously mentioned were investigated. In each plot, every 25 meters a collection of *Ca. femoratus* and *Cr. levior* ants on the ground and in vegetation was performed, totaling 680 samples (340 on ground and 340 in vegetation). For the collection of ground-dwelling ants, we installed pitfall-traps buried at ground level containing water and detergent. Pitfalls were on field for 48 hours. For sampling arboreal ants was used beating-tray. At four points on the North, South, East and West, 2 meters away from each pitfall all vegetation within 1m^2 between 1 to 3 meters tall was sampled (more details: Vicente et al., 2016). Posteriorly we made comparisons with specimens deposited at the Laboratório de Ecologia de Comunidades from the Centro de Biodiversidade da Universidade Federal de Mato Grosso (UFMT) and the ant collection from the Laboratório de Sistemática, Evolução e Biologia de Hymenoptera from the Museu de Zoologia da Universidade de São Paulo (MZSP). Vouchers were deposited in the collections mentioned above and in Setor de Entomologia da Coleção Zoológica da Universidade Federal de Mato Grosso, Departamento de Biologia e Zoologia, Cuiabá, Mato Grosso, Brazil (CEMT).

In these points, measurements of vegetation complexity and litter height were taken. Vegetation complexity was accessed with a number of touches in the understory of a stem of 2 meters positioned one meter high, perpendicular to the ground. Litter height was accessed with a rule and canopy openness with Concave Spherical Densiometer as explained earlier in the section gap-occupation.

Data analysis

Gap-occupation

To test which characteristics determine the colonization and abundance of Ant-gardens in gaps, presence of AG and number of nests were the dependent variables and forest-gap area and canopy openness average were the independent variables. We tested the correlation between independent variables with Pearson correlation (Pearson: 0.026). Among the three sampled areas, Module III is almost totally isolated area and which has the least amount of gaps colonized by parabiotic ants (only 10.3%) while Module I and Module II showed more than twice the number of colonized gaps (24.2% and 25.5% respectively). This is an indication of the intrinsic characteristics of this locality, as area and edge effects, affecting the population dynamics of this ant species. Consequentely, the location was inserted into the GLM analyses using Orthogonal Contrast established a priori, considering the principles described by Gotelli & Ellison (2011), being set up as Contrast: Module I (+1), Module II (+1) and Module III (-2). We used the R software to perform all analyzes (R Core Team, 2014).

To test whether the colony size, which indirectly is represented by the volume of the nests, was related to independent variables a GLM was performed. The variable colony size was calculated using the formula of the volume of spheres (V), where r is the radius of the sphere and π is the constant pi:

$$V = \frac{4 * \pi * r^3}{3}$$

Finally, to test whether the colony size was related to the amount of nests one Pearson correlation was made.

Vertical habitat use

To confirm the hypothesis that *Ca. femoratus* and *Cr. levior* have different preferences about the use of vertical habitat a Test-t was performed for each species. In this analysis the frequency of each species per plot was the dependent variable and stratum was the independent factor. To access the information about what structural environmental variable affects the strata use of *Ca. femoratus* and *Cr. levior* a GLM with Negative binomial distribution was used. This error distribution is indicated when Poisson error distribution shows overdispersion **(**Hilbe, 2007; Lindén & Mäntyniemi, 2011). Because a correlation between independent variables was detected with Pearson correlation with Bonferroni correction, we excluded litter height variable of analyses.

RESULTS

Gap-occupation

We recorded 27 colonies of ant-garden ants in all 142 forest-gaps (125 in tree-fall gaps and 17 in abandoned roads). Regarding environmental variables of forest gaps, they had an average size of 215.125 m^2 (SD: 130.947 - values excluding the 880.44m^2 value established for abandoned roads). The canopy openness had an average of 32.94% (SD: 14.61).

Presence of Ant-gardens colony was affected by area ($Z_{1,138}$: 2.470, p: < 0.05 – Table 1) and locality ($Z_{1,138}$: 2.269, p: < 0.05), but not by canopy openness ($Z_{1,138}$: -1.849, p: < 0.05). Abundance of Ant-gardens nests was also affected by area ($Z_{1,138}$: 2.090, p: < 0.05) and locality ($Z_{1,138}$: 2.570, p: 0. 010) and also not by canopy openness ($Z_{1,138}$: -1.583, p: 0.113 – Table 1). Ants colony size was also influenced by the gap area ($Z_{1,138}$: 3.494, p: < 0.05), the locality ($Z_{1,138}$: 2.422, p: < 0.05) and not the canopy opening ($Z_{1,138}$: -1.230, p: 0.221 – Table 1). Therefore, the abundance of Ant-gardens and the colony size present a strong correlation

(Pearson: 0.883).

Vertical habitat use

Camponotus femoratus and *Crematogaster levior* were sampled in 21 of the 34 plots studied. At least one of the two species was collected in 69 samples (30 on the ground and 39 on vegetation) of the 420 samples (210 on the ground and 210 on vegetation) corresponding to 21 plots where these ants were found. *Ca. femoratus* was collected in 49 samples of 18 plots (30 samples in soil and 19 on vegetation) and *Cr. levior* on 30 samples (15 times in each stratum). We assumed that in all cases both species are co-occurring in the same area, but with differences in abundance and, thus, in the probably of being collected. Therefore, these species were collected in the same sample in 13 cases (8 on the ground and 5 on vegetation). Regarding the environmental variables evaluated, they had an average of vegetation complexity of 1.417 (SD: 0.645). The canopy openness had an average of 32.94% (SD: 14.61).

Nevertheless, there was no an overall difference in the use of vegetation and ground strata by *Camponotus femoratus* ($Z_{1,66}$: -1.519, p: 0.129 – Figure 1), nor by *Crematogaster levior* ($Z_{1,66}$: 0.908, p: 0.364 – Figure 1). *Ca. femoratus* occurs in average 1.67 (SD: 1.63) samples per plot in ground and 1.06 (SD: 1.47) on vegetation. *Cr. levior* occurs in average 1.25 (SD: 1.16) samples per plot in ground and 1.25 (SD: 1.23) on vegetation. On the other hand, the frequency of *Ca. femoratus* on the ground decreases with canopy openness ($Z_{1,31}$: -2.435, p: < 0.05 – Table 2) but is not affected neither by the complexity of vegetation ($Z_{1,31}$: -1.407, p: 0.159) nor for interaction of two factor ($Z_{1,31}$: 1.771, p: < 0.05). Also, *Cr. levior* frequency on the ground also decreases with complexity of vegetation ($Z_{1,31}$: -2.243, p: < 0.05 – Table 2), but, in this case, a decrease was also noted in the frequency associated with canopy openness ($Z_{1,31}$: -1.977, p: < 0.05) and an interaction between these factors ($Z_{1,31}$: 2.265, p: < 0.05). In addition, neither complexity (*Ca. femoratus*: $Z_{1,32}$: 0.200, p: 0.841; *Cr. levior* $Z_{1,31}$: -1.225, p: 0.221 – Table 2), nor canopy openness (*Ca. femoratus*: $Z_{1,32}$: 0.580, p: 0.562; *Cr.*

levior $Z_{1,32}$: 0.804, p: 0.421) influence the frequency of foraging of these ants in understory.

DISCUSSION

Our results demonstrate that the size and local intrinsic characteristics of the forest gaps are determinant to the occupation by the parabiotic ants *Camponotus femoratus* and *Crematogaster levior*. These factors influence the presence as well as the quantity of Ant-Gardens and the ants colony size. Also, larger gaps host more and larger AGs than smaller forest gaps. This can be explained because large forest gaps remains available for longer once the time of full restoration of a large forest gap, from its formation till the canopy closure is probably much longer than in small gaps. In fact, larger patchs implies in a higher probability of colonization and a lower risk of extinction (MacArthur & Wilson, 1967; Donner et al., 2010; McCarthy & Lindenmayer, 1999). Thus, a colony of parabiotic ants has more time to colonize, grow and cultivate its mutualistic epiphytes in large gaps. As a consequence, larger gaps are probably a much more profitable resource to maintain *Ca. femoratus* and *Cr. levior* populations.

As in gaps the incident light in the lower vegetation is higher, there is an associated increase in the total primary productivity, including a major production by extrafloral nectar (Radhika et al. 2010; Bixenmann et al., 2011; Brenes-Arguedas et al., 2011). Several studies also demonstrate that this increase in primary production attracts more herbivores (Harrison, 1987; Coley & Barony, 1996; Louda & Rodman 1996; Sipura & Tahvanainen, 2000). The increase in both extrafloral nectar and herbivores means an increase in food resources for ants (Swain, 1980; Davidson, 1988; Vantaux et al., 2007). However, canopy openness of forest gaps has not influenced on AGs presence, neither quantity of AGs or colony size. Probably the lack of a relationship in the occupation of forest gaps and canopy openness can be explained by the low variation among the sampled gaps. Furthermore, the size of the forest gaps induces changes that go beyond the light intensity, changing moisture and biological properties of soil are characteristics responsible for the forest recovery (Muscolo et al., 2014).

Parabiotic ants do not show any preference for foraging in the understory plants or on the ground. In fact, these ants are widespread and found in the soil and in vegetation in the Amazon (Davidson, 1988; Dejean et al., 2000; Ryder Wilkie et al., 2010; Vicente et al., 2014, 2016). Nevertheless, canopy openness was a determining factor on the habitat use by *Ca. femoratus* and *Cr. levior*. With the increase of canopy openness, and consequently an increase in food resources in vegetation (as discussed above) inducing a preferential foraging by ants, there was a reduction in the parabiotic ants frequency foraging on the ground. However, the decrease of ants on soil is not associated to an increase in the frequency of this ant species on vegetation.

Although the increased complexity of vegetation does not influence the use of the arboreal strata by *Cr. levior*, there was a decrease in soil use. The increase of the vegetation complexity means a more connected understory, forming bridges among plants. Thus, valuable resources for *Cr. levior* as extrafloral nectary (Davidson, 1988) are easier to access, and run away from ant predators and competitors, with a complexity increase. This reduction in the need of the ground use minimizes possible confrontations with other ant species, once the ground strata is naturally richer in ant species (Vasconcelos & Vilhena, 2006; Vicente et al., 2016; Neves et al., 2013). On the other hand, *Ca. femoratus* did not show influence of complexity in use of strata, showing a partition in the niche between the two ant species. This niche partitioning should go beyond the influence of plant complexity in resource exploration demonstrated in this work. Davidson (1988) showed that *Cr. levior* accumulates more workers in sugary baits than *Ca. femoratus*. Also, while workers of *Cr. levior* did not show any preference among plants with extrafloral nectaries, *Ca. femoratus* actively choose plant species with larger nectaries and with greater concentration of nectar (Davidson, 1988). Therefore, plant traits are probably not associated to the complexity of the habitat.

Our results demonstrate that although these parabiotic ants occupy the same sites sharing their nests and maintenance activities of the colonies, they have divergences in their niche with regards to the exploitation of habitat. The use of habitat by *Ca. femoratus* and *Cr. levior* differ among each other depending on the stratum and environmental characteristics. It also shows that these dominant ants, with different biological characteristics, can influence both soil and vegetation communities differently. Therefore, the influence of both *Ca. femoratus* and *Cr. levior* on soil and vegetation ant communities should be investigated in order to understand whether these parabiotic ants alter the ant communities, where they occur and what the mechanisms involved in this alteration are.

Acknowledgements

Authors also thanks Wesley Dáttilo, Rodrigo S. M. Feitosa, Danielle Stork-Tonon, Lúcia A. F. Mateus, André Pansonato and Wesley O. Souza for reviewing and useful contribution over previous design of manuscript, also to the anonymous reviewers for their great contribution to the final version of the work. We also would like to thank the National Council for Scientific and Technological Development, Brazil (CNPq n° 479243/2012–3) for logistical and financial support. REV thanks Enhancement Coordination of Personnel of Superior Level, Brazil (CAPES) for doctoral fellowship. This work is part of the doctoral thesis of REV in Programa de Pós-Graduação em Ecologia e Conservação da Biodiversidade – UFMT.

Author Contributions

REV collected data, REV and TJI analysed data and wrote the text.

REFERENCES CITED

Almeida, A.F. & Valle, R.R. (2007). Ecophysiology of the cacao tree. Brazilian Journal of Plant Physiology, 19(4): 425-448. doi: 10.1590/S1677-04202007000400011

Alvares, C.A., Stape, J.L., Sentelhas, P.C., De-Moraes-Gonçalves, J.L. & Sparovek, G.

(2013). Köppen's climate classification map for Brazil. Meteorologische Z. (Berlin), 22: 711-728. doi: 10.1127/0941-2948/2013/0507

Arihafa, A. & Mack, A.L. (2013). Treefall gap dynamics in a tropical rain forest in Papua New Guinea. Pacific Science, 67(1): 47-58. doi: 10.2984/67.1.4

Baudry, O., Charmetant, C., Collet, C. & Ponette, Q. (2014). Estimating light climate in forest with the convex densiometer: operator effect, geometry and relation to diffuse light. European Journal of Forest Research, 133: 101-110. doi:10.1007/q10342-013-0746-6

Bixenmann, R.J., Coley, P.D. & Kursar, T.A. (2011). Is extrafloral nectar production induced by herbivores or ants in a tropical facultative ant–plant mutualism? Oecologia, 165: 417-425. doi: 10.1007/s00442-010-1787-x

Blonder, B., Lamanna, C., Violle, C. & Enquist, B.J. (2014). The n-dimensional hypervolume. Global Ecology and Biogeography, 23: 595–609. doi:10.1111/geb.12146

Brandão, C.R.F., Feitosa, R.M., Schmidt, F.A. & Solar, R.R.C. (2008). Rediscovery of the putatively extinct ant species *Simopelta minima* (Brandão 1989) (Hymenoptera, Formicidae), with a discussion on rarity and conservation status of ant species. Revista Brasileira de Entomologia, 52:480-483. doi: 10.1590/S0085-56262008000300026

Brenes-Arguedas, T., Roddy, A., Coley, P.D. & Kursar, T.A. (2011). Do differences in understory light contribute to species distributions along a tropical rainfall gradient?. Oecologia, 166, 443-456. doi: 10.1007/s00442-010-1832-9

Camacho, G.P. & Feitosa, R.M. (2016). First record of the Neotropical myrmicine ant genus *Kempfidris* Fernández, Feitosa & Lattke, 2014 (Hymenoptera: Formicidae) for Peru. Check List, 12(3): 1911. doi: 10.15560/12.3.1911

Costa, F.R.C. & Magnusson, W.E. (2010). The need for large-scale, integrated studies of biodiversity the experience of the Program for Biodiversity Research in Brazilian Amazonia. Natureza & Conservação, 8(1): 3-12. doi: 10.4322/natcon.00801001

Dáttilo, W. (2012). Different tolerances of symbiotic and nonsymbiotic ant-plant networks to species extinctions. Network Biology, 2(4): 127-138. Retrived from: http://www.iaees.org/publications/journals/nb/articles/2012-2(4)/2-Dattilo-Abstract.asp

Dáttilo, W. & Izzo, T.J. (2012). Temperature influence on species co-occurrence patterns in treefall gap and dense forest ant communities in a terra-firme forest of Central Amazon, Brazil. Sociobiology, 59(2): 351-367. doi: 10.13102/sociobiology.v59i2.599

Dáttilo, W., Falcão, J.C.F. & Teixeira, M.C. (2012a). Predictive model of distribution of *Atta robusta* Borgmeier 1939 (Hymenoptera: Formicidae): subsidies for conservation of a Brazilian leaf-cutting ant endangered species. Studies on Neotropical Fauna and Environment, 48(3): 1-9. doi: 10.1080/01650521.2012.700791

Dáttilo, W., Vicente, R.E., Nunes, R.V. & Feitosa, R.M. (2012b). Influence of cave size and presence of bat guano on ant visitation. Sociobiology, 59(2): 549-560. doi: 10.13102/sociobiology.v59i2.617

Dáttilo, W., Rico-Gray, V., Rodrigues, D.J. & Izzo, T.J. (2013). Soil and vegetation features determine the nested pattern of ant–plant networks in a tropical rainforest. Ecological Entomology, 38: 374–380. doi: 10.1111/een.12029

Davidson, D.W. (1988). Ecological studies of neotropical ant gardens. Ecology, 69: 1138-1152.

Dejean, A., Corbara, B., Orivel, J., Snelling, R.R., Delabie, J.H.C. & Belin-Depoux, M. (2000). The importance of ant gardens in the pioneer vegetal formations of French Guiana. Sociobiology, 35: 425-439.

Delabie, J.H.C, Rocha, W.D., Feitosa, R.M., Devienne, P. & Fresnau, D. (2010). *Gnamptogenys concinna* (F. Smith, 1858) (Hymenoptera: Formicidae: Ectatomminae): nouvelles données sur sa distribution et commentaires sur ce cas de gigantisme dans le genre *Gnamptogenys*. Bulletin de la Société Entomologique de France, 115(3): 269-277.

Dicko, A.H., Lancelot, R., Seck, M.T., Guerrini, L., Sall, B., Lo, M., Vreysen, M.J.B., Lefrancois, T., Fonta, W.M., Peck, S.L. & Bouyer, J. (2014). Using species distribution models to optimize vector control in the framework of the tsetse eradication campaign in Senegal. Proceedings of the National Academy of Sciences, 111(28): 10149. doi: 10.1073/pnas.1407773111

Donner, D.M., Ribic, C.A. & Probst, J.R., (2010). Patch dynamics and the timing of colonization-abandonment events by male Kirtland’s Warblers in an early succession habitat. Biological Conservation, 143: 1159-1167.

Dorado-Rodrigues, T.F., Layme, V.M.G., Silva, F.H.B., Nunes-da-Cunha, C. & Strüssmann, C. (2015). Effects of shrub encroachment on the anuran community in periodically flooded grasslands of the largest Neotropical wetland. Austral Ecology. doi: 10.1111/aec.12222

Feitosa, R.M., Hora, R.R., Delabie, J.H.C., Valenzuela, J. & Fresneau, D. (2008). A new social parasite in the ant genus *Ectatomma* F. Smith (Hymenoptera: Formicidae: Ectatomminae). Zootaxa 1713: 47-52.

Feitosa, R.M., Silva, R.R. & Aguiar, A.P. (2016). Diurnal flight periodicity of a Neotropical ant assemblage (Hymenoptera, Formicidae) in the Atlantic Forest. Revista Brasileira de Entomologia, 60(3):241-247. doi: 10.1016/j.rbe.2016.05.006

Folgarait, P.J. (1998). Ant biodiversity and its relationship to ecosystem functioning: a review. Biodiversity and Conservation, 7(9): 1221-1244. doi: 10.1023/A:1008891901953

Gallego-Ropero, M.C., Feitosa, R.M. & Pujol-Luz, J.R. (2013). Formigas (Hymenoptera, Formicidae) associadas a ninhos de *Cornitermes cumulans* (Kollar) (Isoptera, Termitidae) no Cerrado do Planalto Central do Brasil. EntomoBrasilis, 6(1): 97-101. doi: 10.12741/ebrasilis.v6i1.283

Gallego-Ropero, M.C. & Feitosa, R.M. (2014). Evidences of batesian mimicry and parabiosis in ants of the Brazilian Savanna. Sociobiology, 61: 281-285. doi: 10.1007/s10841-015-9785-2.

Gotelli, N.J., Ellison, A.M. (2011). Princípios de estatística em ecologia. Editora

Artmed, Porto Alegre, BR, pp. 352-362.

Guichard, S., Guis, H., Tran, A., Garros, C., Balenghien, T. & Kriticos, D.J. (2014). Worldwide niche and future potential distribution of *Culicoides imicola*, a major vector of Bluetongue and African Horse Sickness Viruses. PLoS ONE, 9(11): e112491. doi: 10.1371/journal.pone.0112491

Guimarães, P.R., Izzo, T.J., Rico-Gray, V., Oliveira, P.S., Reis, S.F. & Thompson, J.N. (2007). Interaction intimacy affects structure and coevolutionary dynamics in mutualistic networks. Current Biology, 17(20): 1797-1803. doi: 10.1016/j.cub.2007.09.059

Hilbe, J.M. (2007). Negative binomial regression. Cambridge University Press, Cambridge, UK. 570p.

Hutchinson, G.E., 1957. Concluding remarks. Cold Spring Harbor Symposia on Quantitative Biology, 22: 415-457.

Instituto Brasileiro de Geografia e Estatística. (2004). Mapa da vegetação brasileira. 3ª edição. Ministério do Planejamento, Orçamento e Gestão.

Leite-Rezende, V., Oliveira-Filho, A.T., Eisenlohr, P.V., Kamino, L.Y. & Vibrans, A.C. (2014). Restricted geographic distribution of tree species calls for urgent conservation efforts in the Subtropical Atlantic Forest. Biodiversity and Conservation, 24(5): 1057-1071. doi: 10.1007/s10531-014-0721-7

Leroy, C., Petitclerc, F., Orivel, J., Corbara, B., Carrias, J.-F., Dejean, A. & Céréghino, R. (2016). The influence of light, substrate and seed origin on the germination and establishment of an ant-garden bromeliad. Plant Biology Journal. doi:10.1111/plb.12452

Lindén, A. & Mäntyniemi, S. (2011). Using negative binomial distribution to model overdispersion in ecological count data. Ecology 92:1414–1421.

Longino, J.T. (2003). The *Crematogaster* (Hymenoptera, Formicidae, Myrmicinae) of Costa Rica. Zootaxa, 151(1): 1-150. doi: 10.11646/zootaxa.151.1.1

Louda, S.M. & Rodman, J.E. (1996). Insect herbivory as a major factor in the shade distribution of a native crucifer (*Cardamine cordifolia* A. Gray, Bittercress). Journal of Ecology, 84(2): 229-237.

McCarthy, M.A. & Lindenmayer, D.B. (1999). Incorporating metapopulation dynamics of greater gliders into reserve design in disturbed landscapes. Ecology, 80(2): 651-667.

Medeiros, J.F., Py-Daniel, V. & Izzo, T.J. (2006). The influence of climatic parameters in the haematophagic daily activity of *Cerqueirellum argentiscutum* (Shelley & Luna Dias) (Diptera: Simuliidae) in Amazonas, Brazil. Acta Amazonica, 36(4):563-568. doi: 10.1590/S0044-59672006000400019

Milstein, A., Zoran, M., Peretz, Y. & Joseph, D. (2000). Low temperature tolerance of pacu, *Piaractus mesopotamicus*. Environmental Biology of Fishes, 58(4): 455–460. doi: 10.1023/A:1007672401544

Muscolo, A., Bagnato, S., Sidari, M. & Mercurio, R. (2014). A review of the roles of forest canopy gaps. Journal of Forestry Research, 25(4), 725-736. doi: 10.1007/s11676-014-0521-7

Nakano, M.A., Miranda, V.F.O., Souza, D.R., Feitosa, R.M. & Morini, M.S.C. (2013). Occurrence and natural history of *Myrmelachista* Roger (Formicidae: Formicinae) in the Atlantic Forest of southeastern Brazil. Revista Chilena de Historia Natural, 86: 169-179

Nekaris, K.A.I., Arnell, A.P. & Svensson, M.S. (2015). Selecting a conservation surrogate species for small fragmented habitats using Ecological Niche Modelling. Animals 5(1) :27-40. doi:10.3390/ani5010027

Neves, F.S., Dantas, K.S.Q., Rocha, W.D. & Delabie, J.H.C. (2013). Ants of three adjacent habitats of a transition region between the Cerrado and Caatinga biomes: The effects of heterogeneity and variation in canopy cover. Neotroprical Entomology, 42: 258-268. doi: 10.1007/s13744-013-0123-7

Orivel, J. & Leroy, C. (2011). The diversity and ecology of ant gardens (Hymenoptera: Formicidae, Spermatophyta: Angiospermae). Myrmecological News, 14:73-85

Pape, R.B. (2016). The importance of ants in cave ecology, with new records and behavioral observations of ants in Arizona caves. International Journal of Speleology, 45: 185-205. doi: 10.5038/1827-806X.45.3.1936

Prado, L.P.; Vicente, R.E.; Silva, T.S.R. & Souza, J.L. (2016). *Strumigenys fairchildi* Brown, 1961 (Formicidae, Myrmicinae): first record of this rarely collected ants from Brazil. Check List, 12(4): 1922. doi: 10.15560/12.4.1922

R Core Team. (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Retrived from: http://www.R-project.org/

Radhika, V., Kost, C., Mithöfer, A. & Boland, W. (2010). Regulation of extrafloral nectar secretion by jasmonates in lima bean is light dependent. Proceedings of the National Academy of Sciences, 107(40): 17228–17233. doi: 10.1073/pnas.1009007107

Penha, J.M.F. & Mateus, L.A.F. (2007). Sustainable harvest of two large predatory catfish in the Cuiabá river basin, northern Pantanal, Brazil. Brazilian Journal of Biology, 67(1): 81-89. doi: 10.1590/S1519-69842007000100011

Runkle, J.R. (1981). Gap regeneration in some old-growth forests of the eastern United States. Ecology, 62: 1041-1051. doi:10.2307/1937003

Ryder-Wilkie, K.T., Mertl, A.L. & Traniello, J.F.A. (2010). Species diversity and distribution patterns of the ants of Amazonian Ecuador. PLoS ONE, 5(10): e13146. doi: 10.1371/journal.pone.0013146

Santos-Silva, L., Vicente, R.E. & Feitosa, R.M. (2016). Ant species (Hymenoptera, Formicidae) of forest fragments and urban areas in a Meridional Amazonian landscape. Check List, 12(3):1-7. doi: 10.15560/12.3.1885.

Schmidt, F.A., Feitosa, R.M., Rezende, F.M. & Jesus, R.S. (2014). News on the enigmatic ant genus *Anillidris* (Hymenoptera: Formicidae: Dolichoderinae: Leptomyrmecini). Myrmecological News, 19:25-30

Schmit-Neuerburg, V. & Blüthgen, N. (2007). Ant gardens protect epiphytes against drought in a Venezuelan lowland rain forest. Ecotropica 13:93-100

Swain, R.B. (1980). Trophic competition among parabiotic ants. Insectes Sociaux, 27(4): 377-390. doi: 10.1007/BF02223730

Sipura, M. & Tahvanainen, J. (2000). Shading enhances the quality of willow leaves to leaf beetles – but does it matter?. Oikos, 91: 550-558. doi: 10.1034/j.1600-0706.2000.910317.x

Vantaux, A., Dejean, A., Dor, A. & Orivel, J. (2007). Parasitism versus mutualism in the ant-garden parabiosis between *Camponotus femoratus* and *Crematogaster levior*. Insectes Sociaux, 54:95-99. doi: 10.1007/s00040-007-0914-0

Vasconcelos, H.L. & Vilhena, J.M.S. (2006). Species turnover and vertical partitioning of ant assemblages in the Brazilian Amazon: A comparison of forests and savannas. Biotropica, 38: 100-106. doi: 10.1111/j.1744-7429.2006.00113.x

Vicente RE, Dáttilo W, Izzo TJ (2014) Differential Recruitment of Camponotus femoratus (Fabricius) Ants in Response to Ant Garden Herbivory. Neotropical Entomology, 43:519-525. doi:10.1007/s13744-014-0245-6

Vicente, R.E., Prado, L.P. & Izzo, T.J. (2016) Amazon Rainforest Ant-Fauna of Parque Estadual do Cristalino: Understory and Ground-Dwelling Ants. Sociobiology 63 (3). doi:10.13102/sociobiology.v63i3.1043

Vicente, R.E., Prado, L.P. & Souza, R.C.L. (2015). Expanding the distribution of the remarkable ant *Gnamptogenys vriesi* Brandão & Lattke (Formicidae: Ectatomminae): first record from Brazil. Sociobiology, 62(4): 615-619. doi: 10.13102/sociobiology.v62i4.920

Wilson, E.O. (1987). The arboreal ant fauna of Peruvian Amazon forests: a first assessment. Biotropica, 19:245-251.

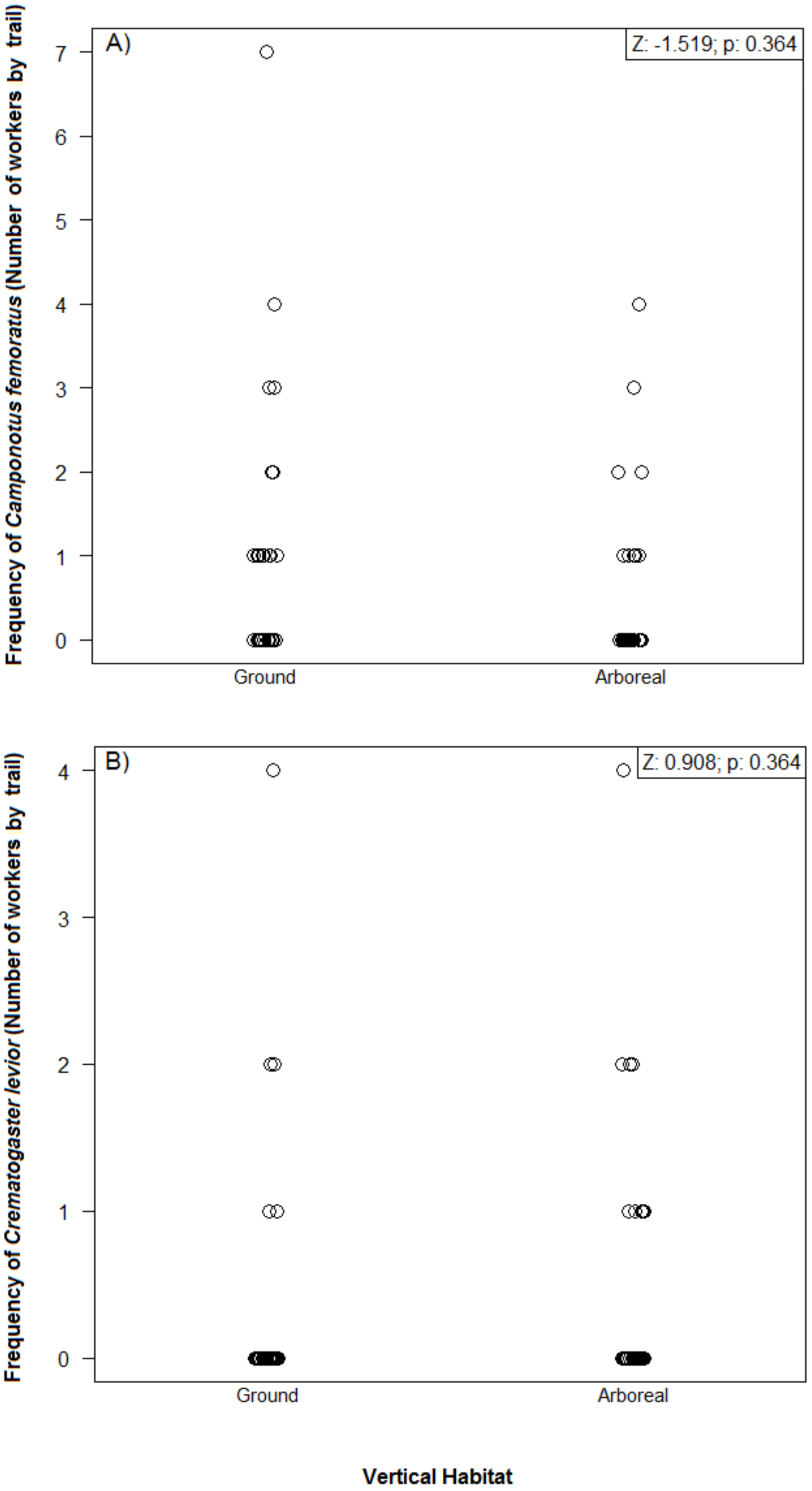
Youngsteadt, E., Nojima, S., Haberlein, C., Schulz, S. & Schal, C. (2008). Seed odor mediates an obligate ant-plant mutualism in Amazonian rainforest. PNAS, 105: 4571-4575.

doi: 10.1073/pnas.0708643105

Youngsteadt, E., Alvarez Baca, J., Osborne, J. & Schal, C. (2009). Species-Specific Seed Dispersal in an obligate ant-plant mutualism. PLoS ONE, 4(2): e4335. doi: 10.1371/journal.pone.0004335

List of figures

Fig 1 – Works frequency by trail of ant species *Camponotus femoratus* and *Crematogaster levior* on the ground (A) ou arboreal (B) vertical stratum.



List of tables

Table 1. Influence of factors in gap occupation by Ant-Gardens nests of parabiotic ants *Camponotus femoratus* and *Crematogaster levior*.

		Z	p-value
Presence of AGs	Area	2.470	< 0.05*
	Locality	2.269	< 0.05*
	Canopy openness	-1.849	0.064
Abundance of AGs	Area	2.090	< 0.05*
	Locality	2.570	< 0. 05*
	Canopy openness	-1.583	0.113
Colony size of AGs ants	Area	3.494	< 0.05*
	Locality	2.422	< 0.05 *
	Canopy openness	-1.230	0.221

* Significative

Table 2. Factors that influence the frequency of use of each stratum by *Camponotus femoratus* and *Crematogaster levior*.

	Camponotus femoratus		*Crematogaster levior*	
	Z	p-value	Z	p-value
GROUND				
Canopy openness	-2.572	< 0.05*	-1.977	< 0.05*
Complexity of vegetation	-1.407	0.159	-2.243	< 0.05*
Interaction	1.771	0.077	2,265	< 0.05*
VEGETATION				
Canopy openness	-0.700	0.484	-1.034	0.301
Complexity of vegetation	-1.006	0.315	-1.474	0.141
Interaction	1.022	0.307	1.396	0.163

* Significative

CAPÍTULO 3 - Effect of dominant parabiotic ants *Camponotus femoratus* (Fabricius) and *Crematogaster levior* Longino on the arboreal and ground-dwelling ant community in amazon rainforest

Artigo em preparação, formatado para submissão à revista Myrmecological News (ISSN: 1994-4136; Classificação CAPES: A2).

Effect of dominant parabiotic ants *Camponotus femoratus* (Fabricius) **and** *Crematogaster levior* Longino **on the arboreal and ground-dwelling ant community in Amazon rainforest**

Ricardo Eduardo Vicente[1,2,*], Thiago Junqueira Izzo[1,2]

1 - Universidade Federal de Mato Grosso-UFMT, Programa de Pós-Graduação em Ecologia e Conservação da Biodiversidade, Laboratório de Ecologia de Comunidades. Avenida Fernando Correa da Costa, Coxipó, CEP 78557-267. Cuiabá, MT, Brazil

2 - Centro de Estudos Integrados da Biodiversidade Amazônica - CENBAM, CEP 69080–971, Manaus, AM, Brazil

* email: ricardomyrmex@gmail.com

Key-words – Beta-diversity, Community, Dominance, Neotropical, Nested, Parabiosis, Partition of diversity, Turnover.

Number of pages: 26

Figures: 4

Tables: 2

Effect of dominant parabiotic ants *Camponotus femoratus* (Fabricius) **and** *Crematogaster levior* Longino **on the arboreal and ground-dwelling ant community in Amazon rainforest**

Ricardo Eduardo Vicente[1,2,*], Thiago Junqueira Izzo[1,2]

1 - Universidade Federal de Mato Grosso-UFMT, Programa de Pós-Graduação em Ecologia e Conservação da Biodiversidade, Laboratório de Ecologia de Comunidades. Avenida Fernando Correa da Costa, Coxipó, CEP 78557-267. Cuiabá, MT, Brazil

2 - Centro de Estudos Integrados da Biodiversidade Amazônica - CENBAM, CEP 69080–971, Manaus, AM, Brazil

* email: ricardomyrmex@gmail.com

ABSTRACT. *Camponotus femoratus* (Fabricius, 1804) and *Crematogaster levior* Longino, 2003 are ants that live together in a parabiotic association nesting arboreally. They are locally abundant and aggressive, occupying the ground and vegetation. In this paper we evaluated the effect of these abundant and aggressive parabiotic ants on the ants in the southern Amazon. We found that *Ca. femoratus* and *Cr. levior* decrease both the abundance and richness of ground ants and change the community composition causing a nested pattern. However, we find that they do not cause changes in the community of arboreal ants.

Key-words – Beta-diversity, Community, Dominance, Neotropical, Nested, Parabiosis, Partition of diversity, Turnover.

INTRODUCTION

Camponotus femoratus (FABRICIUS, 1809) (Formicinae) and *Crematogaster levior* LONGINO, 2003 (Myrmicinae) are ants that live together in a parabiotic association (DAVIDSON 1988). In this mutualistic interaction, most often found in the tropics, two or more species share the same nest keeping their brood separate, and share the trails of foraging (HÖLLDOBLER & WILSON 1990; see: SWAIN 1980; SANHUDO & al. 2008). These ants build their nests by planting seeds of some specific epiphyt plants known as Ant Gardens (hereafter called AGs) (ORIVEL & LEROY 2011). These epiphytes provide stability and moisture to the nest and a food supply for the ants (SCHMIT-NEUERBURG & BLÜTHGEN 2007, DAVIDSON 1988). *Ca. femoratus* and *Cr. levior* are widely distributed species in the Amazon, being often collected in all vertical strata of vegetation and on the ground (RYDER-WILKIE & al. 2010, DÁTTILO & IZZO 2012, DEJEAN & al. 2015a, SOUZA & al. 2015).

Both ant species in the association differ in behavior. *Ca. femoratus* defends the AGs nest, showing massive recruitment after any kind of perturbation, becoming agitated and walking randomly around the nest (VICENTE & al. 2014). Several studies so far demonstrated the local abundance and aggressiveness of this parabiotic ant species (WHEELER 1921, WILSON 1987, VICENTE & al. 2014), mainly in and around the AG (VASCONCELOS & al. 2003, VICENTE & al. 2014). On the other hand, *Cr. levior* seems to take advantage of the defensive behavior of their mutualistic partner *Ca. femoratus*. This ant species does not show massive recruitment and supposedly has lost the chemical defense common to the *Cr.* genus (DAVIDSON 1988, LONGINO 2003, VICENTE & al. 2014).

Studies have demonstrated that there are two distinct types of ants assembly occupying the soil and vegetation of the forest and they can share few species (BRUHL & al. 1998, FRIZZO & al. 2012, CAMPBEL & al. 2015), with the parabiotic ants being among them (VICENTE & al. 2016). Agonistic interspecific interactions are considered one of the main factors structuring ant communities, in both soil and vegetation (CERDÁ & al. 2013, STUBLE & al. 2012). However, most part of studies about the factors that structure ant communities is focused on ground dwelling communities (SOLAR & al. 2016, BACCARO al. 2013, DÁTTILO & al. 2012). Little is known about the factors that structure the arboreal communities (CAMAROTA & al. 2015, KLIMES & al. 2015, RIBAS & SCHOEREDER 2002).

One parameter commonly evaluated in ant communities is dissimilarity (DÁTTILO & IZZO 2012, VASCONCELOS & al. 2003, SOUZA & al. 2012, PAOLLUCI & al. 2016). The dissimilarity between samples is an ancient measure that was called diversity-beta by WHITTAKER 1960. There were many discussions aiming at proposing a measure of beta-diversity independent of alpha-diversity, ie, regardless of the richness of the species (BASELGA 2010a,b, BASELGA 2012, BASELGA & LEPRIRUR 2015). From these discussions, it was shown that diversity-beta is formed by two antithetical components: Turnover (species substitution) and nesting-resultant (poorest sites as sub-samples of the richest sites) (BASELGA 2007, BASELGA 2012). Understanding these components can help understand the patterns that structure the biological communities (BASELGA 2012, SI & al. 2015, BASELGA & al. 2015, MATEO & al. 2015).

AGs ants are locally abundant and aggressive and are sampled foraging on the vegetation and on the soil (WHEELER 1921, WILSON 1987, VASCONCELOS & al. 2003, VICENTE & al. 2014). They are so aggressive that are observed driving out other species of ants (REV. pers. obs.). Therefore, these species can be a strong competitor, structuring the ant community. In this study, we determined if the presence of parabiotic ants, *Ca. femoratus* and *Cr. levior,* could be a factor structuring the ant community of a southern Amazon forest hypothesizing that the frequency of parabiotic ants from AGs 1) decrease the abundance and 2) the number of species of ground and vegetation ants communities. Furthermore, we believe that the frequency of parabiotic ants from AGs 3) alter the composition of the ground and arboreal communities, making the communities where they are in a poorer set than where they are not present (nested-resultant component) and not causing a replacement of species (turnover component). Finally, we check which species were being influenced by the presence of parabiotic ants from AGs. All questions are made for both the ground and arboreal ant communities separately.

MATERIAL AND METHODS

Study area

This study was carried out on two municipalities in the southern Brazilian Amazon, north of Mato Grosso state, as part of the Research Program in Biodiversity (PPBio). The standard sampling protocol used in PPBio is the RAPELD methodology (see: COSTA & MAGNUSSON 2010). Each municipality has a set of trails of 250m in length installed at a minimum distance of 1 km from each other, hereinafter called modules. Three modules are located in Claudia municipality (MCLA), installed close to each other (less than 20km), in a fragment connected by forest corridors and surrounded by plantations: Module I (11°34’S, 55°17’W – ten trails sampled), Module II (11°25’S, 55°18’W – six trails sampled), and Module III (11°39’S, 55°16’W – eight trails sampled). Nonetheless, the other modules are installed in the Parque Estadual do Cristalino (henceforward PEC), a continuous pristine forest in Novo Mundo municipality (9°28’S, 55°50’W – 10 trails sampled) that are about 220 km distant far from the first three.

Ant sampling

The ant inventory was conducted in 34 trails (24 in MCLA and 10 in PEC). In each trail, ants were collected every 25m on the ground and vegetation, resulting in 20 samples per trail (10 on the ground and 10 in low vegetation) and totaling 680 samples (340 on the ground and 340 in the understory). The collection of the ground ant community was done using a single pitfall trap installed in each sample point. The pitfalls consisted of plastic containers of 500ml with 14cm radius and 9.5cm high, installed at ground level, with water and detergent. We sampled ants foraging on vegetation at 4 points around each pitfall using the beating-tray method. At each point herein, all vegetation within 1m² which was between 1 to 3 meters high was shaken totaling 4m² of inspected vegetation per sample. Invertebrates that fell on the entomological umbrella were collected (for more details: VICENTE & al. 2016).

The ants collected were carried out the laboratory where they were processed and identified using dichotomous key for subfamilies and genera available in BACCARO & al. (2015). Posteriorly, to separate into morphospecies and identify to a specific level we used several taxonomic keys (BRANDÃO 1990, FERNÁNDEZ 2003, LONGINO 2003, MACKAY & MACKAY 2010, FERNANDES & al. 2014). Finally, we compare with specimens deposited at the Laboratório de Ecologia de Comunidades from the Centro de Biodiversidade da Universidade Federal de Mato Grosso (UFMT) and the ant collection from the Laboratório de Sistemática, Evolução e Biologia de Hymenoptera from the Museu de Zoologia da Universidade de São Paulo (MZSP), where vouchers were deposited. The morphotypes not identified at the species level received the epithet of the collection (TJI) of the Laboratório de Ecologia de Comunidades from the Centro de Biodiversidade da Universidade Federal de Mato Grosso (UFMT) that also has epithets of morphotypes of myrmecology collection Instituto Nacional de Pesquisas da Amazônia (INPA). We also consulted specialists to confirm species identification (see acknowledgments).

Data analysis

Ant abundance of each trail was accessed with the sum of frequencies of each species per sample in trail (0 to 10). We opted for this sample-based measure because real ant abundance is not an independent information on biodiversity estimates, since they are social insects (GOTELLI & al. 2011). So, the sampled abundance of workers in pitfalls may be strongly related to the proximity to the nest (GOTELLI & al. 2011) and the workers' number in a colony varies greatly between species (BACCARO al. 2015). Due to the aforementioned reasons, sample-based measurement is commonly used in studies with ants (BACCARO al. 2013; DÁTTILO & IZZO 2012; DEJEAN & al. 2015a; RYDER WILKIE & al. 2010). The variable "*frequency of parabiotic ants*" was created with the same principle. Since both, *Ca. femoratus* and *Cr. levior*, they were seen always together in areas, the collection of any of them in a single sample implies in the existence of an AG nearby. The frequency of AGs per trail was independent of the stratum where they were collected.

In order to evaluate the effect of parabiotic ants in abundance and richness of ground and arboreal ant species along of Amazon forest, we performed a generalized linear mixed-effects models (GLMM) with frequency of parabiotic ants as factor and geographical region (PEC or MCLA) as random factor. The total beta diversity, turnover and nestedness components of ant community was calculated between pair of trails based in a binary matrix with presence and absence data with Sorensen and Simpson index. The proposed framework is a partition of true diversity independent of richness difference (BASELGA & LEPRIRUR 2015, BASELGA 2010a, b). Then the dissimilarity matrices were used in Multiple Regression on distance Matrices (MRM) with frequency of parabiotic ants as a discrete factor and geographical region as categorical factor, in order to evaluete the effect of *Ca. femoratus* and *Cr. levior* on composition of ant community. The MRM was used because it is a flexible method in terms of the types of data that may be analyzed, whether data of presence-absence, discrete, continuous or categorical (LICHSTEIN 2007)

Furthermore, an analysis of indicator species (IndVal) was performed to determine which species of ants were being affected by the presence of parabiotic ants (occurring in more than one point) or its absence indicator (not occurring at any point). We know previously that abundance, richness and composition of community are different between vertical strata (VICENTE & al. 2016). Therefore, we decided to conduct all the analysis separately by vertical strata.

All graphs and analysis are performed with R-software (R CORE TEAM 2015) using packages: betapart (partition of beta diversity - BASELGA & ORME 2012), ecodist (MRM – LICHSTEIN 2007), effects (graphics - FOX & HONG 2009), indicspecies (IndVal - DE CÁCERES & JANSEN 2010), lme4 (GLMM - BATES & al. 2016), vegan (OKSANEN & al. 2015).

RESULTS

We registered a total of 4.408 occurrences and 328 species of ants in all sample plots with 85 species collected in both strata. The most frequent species, independent of strata, was *Pheidole transversostriata* Mayr, 1887 (210 samples, 30.88% of both strata samples), *Crematogaster tenuicula* Forel, 1904 (177 samples, 26.03%), *Ectatomma lugens* Emery, 1894 (157 samples, 23.09%), *Pachycondyla crassinoda* (Latreille, 1802) (129 samples, 18.97%) and *Ochetomyrmex semipolitus* Mayr, 1878 (106 samples, 15.59%).

The ground was the most diverse stratum with 3.121 occurrence of 251 species, including 168 species collected only in this stratum. The most frequent species on the ground were *Pheidole transversostriata* (205 samples, 60.29% of ground samples), *Ectatomma lugens* (157 samples, 46.18%), *Pachycondyla crassinoda* (129 samples, 37.94%), *Trachymyrmex* TJI01 (92 samples, 27.06%), *Crematogaster tenuicula* (90 samples, 26.47%). In vegetation, the abundance was of 1.287 records of 158 species with 75 species collected exclusively in this stratum. The most frequent species in vegetation were *Ochetomyrmex semipolitus* (93 samples, 27.35% of arboreal samples), *Crematogaster* *tenuicula* (87 samples, 25.59%), *Crematogaster brasiliensis* Mayr, 1878 (67 samples, 19.71%), *Ectatomma tuberculatum* (Olivier, 1792) (59 samples, 17.35%) and *Solenopsis* TJI01 (44 samples, 12.94%). Parabiotic ants, *Ca. femoratus* and *Cr. levior*, were collected in 20 of the 34 trails in both vertical strata.

The abundance of ground ants was negatively influenced by frequency of parabiotic ants ($Z_{2,34} = -4.64$, $p < 0.05$ – Fig. 1). The mean abundance of ants in plots where the AGs is found is 85.9 (SD: 20.60) and 94.1 (SD: 17.16) in plots where the AGs are absent. The number of ground ant species per plot also was influenced by frequency of parabiotic ants ($Z_{2,34} = 2.76$, $p < 0.05$ – Fig. 2). The mean number of richness of species in plots where AGs are found is 45.57 (SD: 8.58) and 48 (SD: 8.199) where the AGs were not present.

In vegetation, ant abundance was not influenced by frequency of parabiotic ants ($Z_{2,34} = -0.984$, $p > 0.05$). The mean abundance was of 85.9 (SD: 20.62) where parabiotic ants are present and 94.07 SD: 17.16) where AGs were absent. Richness of arboreal ants already was not influenced by frequency of parabiotic ants ($Z_{2,34} = -0.673$, $p > 0.05$). The mean number of species was 22.35 (SD: 7.46) where parabiotic ants are present and 22.35 (SD: 7.46) where the AGs were not present.

The analysis of the composition of the ground ant community demonstrates that the beta diversity is related to frequency of parabiotic ants in the site ($r = 0.688$, $p < 0.05$). This dissimilarity related to the frequency of AG ants was also related as a nested-resultant component ($r = 0.132$, $p < 0.05$). However, the dissimilarities are not resultant of turnover component ($r = 0.609$, $p > 0.05$) not being related to the frequency of parabiotic ants. Beta diversity of arboreal ant communities shows no difference related to frequency of parabiotic ants ($r = 0.419$, $p > 0.05$). The frequency of parabiotic ants also does not cause influence of nested-resultant component ($r = 0.002$, $p > 0.05$) or turnover component ($r = 0.286$, $p > 0.05$).

Alteration in composition of ground ants can be observed by changes in the abundance of 26 species that indicated the absence (19 species) and presence (7 species) of AGs ants (Table I). The indicator species of AGs absence that where more frequent in soil samples were *Pheidole transversostriata* (202 samples, 59.41% of ground samples), *Pachycondyla crassinoda* (125 samples, 36.76%), *Solenopsis* TJI06, *Pheidole nitella* Wilson 2003 and *Nylanderia* TJI02 (70 samples each, 20.59% each). Also, the more frequent indicator ground species of AGs presence were *Megalomyrmex* pr. *wallacei* (48 samples, 14.12% of ground samples), *Pheidole* INPA14 (34 samples, 10%), *Pheidole bufo* Wilson 2003 (25 samples, 7.35%) and *Gnamptogenys moelleri* (Forel, 1912) (23 samples, 6.76%). Only three arboreal ant species were related to the occurrence of AGs. *Ochetomyrmex semipolitus* (92 samples, 27.06% of arboreal samples) and *Neoponera unidentata* (Mayr, 1862) (32 samples, 9.41%) indicated the presence of AGs ants whereas only *Crematogaster wardi* Longino, 2003 (16 samples, 2.77%) indicate the absence of AGs (Table 1).

DISCUSSION

Although there are several studies on Ant-Gardens (DAVIDSON 1988, ORIVEL & LEROY 2011, VICENTE & al. 2014), this is the first to investigate the influence of the AGs ants on ant community of ground and vegetation habitats. It has been suggested so far that *Camponotus femoratus* and *Crematogaster levior* ants can be considered as dominant species in the community (VASCONCELOS & al. 2003). Dominant ants are locally abundant and have aggressive behavior (PARR & GIBB 2010). Parabiotic ants occur in large numbers of workers' on the ground and in the canopy (RYDER WILKIE & al. 2010, VASCONCELOS & al. 2003) and are aggressive in the defense of their nests (VICENTE & al. 2014) and territory (VANTAUX & al. 2008), often being seen driving out other species (REV. obs. pers.). This aggressive behavior of parabiotic ants can prevent access to resources by other species, leading to a decrease in the number of nests (abundance) and even to exclusion of some competitor species (richness) as seen in our results. In this way, AGs ants promote the decrease of both, the abundance and the species richness of ground ants. A similar pattern can be seen in French Guiana, in which the richness and abundance of ants decreases with the abundance of the dominant ant *Solenopsis saevissima* (DEJEAN & al. 2015b). Also, in three habitats in South African savanna, the richness of ants' community decreases in presence of other dominant species (PARR 2008).

The frequency of parabiotic ants in a given site also affects the dissimilarity of the ground ant community by a non-random removal of ant species, causing nested patterns. Whereas allowing for the permanence of some ant species, the AG-ants drive out others, probably species that compete for resources. Consequently, the AGs promote a modification in the ant community by decreasing the local number of species by forming poorer sites that are subsets of the richest sites (nesting-resultant component). Hence, some species may be favored by the presence or being eliminated by parabiotic ants. In fact, our data show that there are 19 species that indicate (and thus are favored by) the AG-ants absence, but just 7 are identified as indicators of AG-ants presence. Among the 19 species favored by the absence of AG ants in the soil samples were *Pheidole transversostriata* and *Pheidole nitella*. Both species are very small and their biology are partially unknown (WILSON 2003). *P. nitella* inhabit the soil or leaf litter of humid forests and also nest in small cavities in dead wood or, less frequently, in low vegetation (LONGINO 2005, ANTWEB 2016). Despite the lack of biological information, the phylogenetic relationship and since both are often collected in the soil when parabiotic ants are absent, can represent that both *Pheidole* species have narrow niches that overlap with parabiotic ants.

Pheidole bufo and *Gnamptogenys moelleri* are Neotropical ant species that indicate the presence of parabiotic ants in samples collected in the soil. *P. bufo* is a recently described specie and occurs from the western Amazonia to the northeast of the Brazilian Atlantic forest (WILSON 2003, SALAZAR & al. 2015, SANTOS & al. 2006, VICENTE

& al. 2016). Workers of *P. bufo* were observed eating beetle larvae but no biological information is available for this species and neither for conspecific species (WILSON 2003). *G. moelleri* a widely collected species (SOUZA & al. 2007, 2015, RYDER WILKIE & al. 2010, ULYSSÉA & al. 2011, ULYSSÉA & BRANDÃO 2013) is an arboreal ant with a very wide food niche that varies between seasons and items from live or dead invertebrates, extrafloral nectaries and fleshy seeds and fruits (COGNI & OLIVEIRA 2004). Even parabiotic ants feed on nectaries and dead matter or hunt invertebrates (SWAIN 1980), these species take advantage of the niche width to occupy the ground where other species are driven out by parabiotic ants.

Despite the observed effect on the ground-dwelling ant fauna, the parabiotic ants have not changed either in abundance, richness, nor the composition of the vegetation ants. Many times we have seen in field *Ca.. femoratus* driving out other species of ants, mainly in the vicinities of extrafloral nectaries (REV pers. obs.). Extrafloral nectaries are predictable resources (RICO-GRAY & OLIVEIRA 2007) and parabiotic ants can potentially be only defending the plants with nectaries, driving out other ant species from these plants. However, even considering that nectary bearing plants are abundant in Amazonia, the major part of the understory plants do not have nectaries (DÁTTILO & al. 2013). These plants can be seen by the parabiotic ants as foraging sites for prey or even as arboreal bridges linking resource rich locations to the nest. It has been seen that these access bridges (complexity) comprise a very important factor that has been considered as being responsible for myrmecophilous ants pruning neighboring plants (WEIR & al. 2012, DÁTTILO & DYER 2014).

The major part of the understory plants are connected among each other by branches, vines and other plants forming a very complex environment. This complexity provides important routes of resource access or ways to flee from dominant species (POWELL & al. 2011, YANOVIAK & SCHNITZER 2013, YANOVIAK 2015). Thus, the understory can be seen as a complex three dimentional environment where the resource (e.g. nectary bearing plants) is path distributed. Indeed, in other environments, the connectivity of the vegetation has proven to be an important factor influencing the community of arboreal ants (RIBAS & al. 2003, POWELL & al. 2011, YANOVIAK & SCHNITZER 2013). We suggest that, if a dominant ant specie has any effect on the diversity of their competitors, this effect should be on and in the vicinities of the resource path, (so nectaries or by analogy, baits in some studies). Once there was no difference in the composition of vegetation ants, a very low number (3) of species could be named as indicators of the presence of ant gardens. Of these, two species have a broad niche, *Ochetomyrmex semipolitus* and *Neoponera unidentata*, and both occur most frequently and can be found in sites where AGs also occurs. The Neotropical species *O. semipolitus* was mainly observed at ground level feeding of animal protein and also in the vegetation feeding in nectaries (RYDER WILKIE & al. 2007, 2010, SOUZA & al. 2012, 2015, DÁTTILO & DYER 2014). *Neoponera unidentata* is a relatively common species, observed nesting mainly in hollow branches both in vegetation and in the soil of the forest, but also in rotten logs, stumps and epiphytes (MACKAY & MACKAY 2010, LONGINO 2010). Only *Crematogaster wardi* indicated the absence of parabiotic ants in understory. In fact, *C. wardi* workers were collected foraging in extrafloral nectaries of low vegetation (LONGINO 2003). This specie was recently described, with little known distribution only to Nicaragua, Costa Rica, French Guiana and in Brazil only for the state of Pará, resulting in several distribution gaps. But probably this specie has a wider distribution, occurring in habitat patches where AGs are not present.

The parabiotic ants *Ca. femoratus* and *Cr. levior* usually inhabit areas with high light intensity such as forest gaps (DAVIDSON 1988, DEJEAN & al. 2000, VICENTE & al. 2014). Natural gaps are formed by fallen trees, being a very common and predictable habitat in natural environments (MUSCOLO & al. 2014). This habitat, however, is ephemeral and along the succession a temporal change in the composition of plants and animals is observed. Whereas some species inhabit more frequently open environments (in the begining of sucession), others species replace them in more advanced stages of gap regeneration (VAN TEEFFELEN & al. 2012, VAN BREUGEL & al. 2013, MUSCOLO & al. 2014). The time of the replacement and the final composition of the area is determined by a miriad of factors (MUSCOLO & al. 2014) and by random (HUBBEL 2001) but these processes are in part responsible for the maintenance of diversity in a regional and biome scale (DÁTTILO & IZZO 2012, NEVES & al. 2010, BICKNELL & al. 2014, MUSCOLO & al. 2014, ALTMAN & al. 2016, VÉLE & al. 2016). Therefore, as demonstrated here, the presence of parabiotic ants in a given forest gap changes the ground ant community by eliminating several ant species. As ants are ecological engeniers and interact with several other organisms in tropical habitats (DEL TORO & al. 2012), the effect of the parabiotic ants can be extended to other organisms inhabiting gaps along succession. Also, the parabiotic ants can have a direct effect on succession in these gaps by modifying for example, the quality of the protection of nectary-being plants, the herbivory or other processess in the gaps that occur. So, more than modifying ant composition, the effect of these dominant species can influence the final stage of the forest succession. However, future studies should address these questions in order to measure the influence of the direct and indirect effect of dominant ants on biodiversity.

Acknowledgments

We thank the researchers Vinicius Soares, Mariana Silva, Bruna E. Valério and Bruno Carvalho for assistance in field data collection and to Alexandre Ferreira [UFPR], Gabriela Camacho [UFPR], Itanna Fernandes [INPA], Jorge Souza [INPA], Lina Hernández [IAVH], Lívia Pires do Prado [MZSP], Mônica Ulysséa [MZSP] and Thiago Silva [UFPR] for their help with the identification of the ant species. Authors also thanks Wesley Dáttilo, Rodrigo S. M. Feitosa, Danielle Stork-Tonon, Lúcia A. F. Mateus, André Pansonato and Wesley O. Souza for reading the previous version of this manuscript. REV thanks CAPES to their PhD scholarship. TJI thanks CAPES (BEX 2548--3) to financial support. Furthermore, we thanks Conselho Nacional de Pesquisas (CNPq - 479243/2012–3, 558225/2009-8, 501408/2009-6 e 457466/2012-0) for fund research, Secretaria Estadual de Meio Ambiente (SEMA) and Universidade Federal de Mato Grosso (UFMT) for logistical support.

REFERENCES

ALTMAN, J., FIBICH, P., LEPS, J., UEMURA, S., HARA, T. & DOLEZAL, J. 2016: Linking spatiotemporal disturbance history with tree regeneration and diversity in an old-growth forest in northern Japan. – Perspectives in Plant Ecology, Evolution and Systematics 21: 1-13. doi:10.1016/j.ppees.2016.04.003.

ANTWEB. Species: Pheidole nitella. – AntWeb version: 6.8.1. <https://www.antweb.org/description.do?genus=pheidole&species=nitella&rank=species&project=allantwebants>, retrieved on 24 June 2016.

BACCARO, F.B., FEITOSA, R.M., FERNÁNDEZ, F., FERNANDES, I.O., IZZO, T.J., SOUZA, J.L.P. & SOLAR, R. 2015: Guia para os gêneros de formigas do Brasil. – Editora INPA, Manaus, pp. 388.

BACCARO, F.B., ROCHA, I.F., DEL AGUILA, B.E.G., SCHIETTI, J., EMILIO, T., PINTO, J.L.P.D.V., LIMA, A.P. & MAGNUSSON, W.E. 2013: Changes in ground-dwelling ant functional diversity are correlated with water-table level in an Amazonian Terra Firme forest. – Biotropica 45: 755–763. doi:10.1111/btp.12055.

BASELGA, A. 2010a: Partitioning the turnover and nestedness components of beta diversity. – Global Ecology and Biogeography 19: 134–143. doi:10.1111/j.1466-8238.2009.00490.x.

BASELGA, A. 2010b: Multiplicative partition of true diversity yields independent alpha and beta components, additive partition does not. – Ecology 91: 1974-1981. doi:10.1890/09-0320.1.

BASELGA, A. & LEPRIEUR, F. 2015: Comparing methods to separate components of beta diversity. – Methods in Ecology and Evolution 6: 1069-1079. doi:10.1111/2041-210X.12388.

BASELGA, A. 2012: The relationship between species replacement, dissimilarity derived from nestedness, and nestedness. – Global Ecology and Biogeography 21: 1223-1232. doi:10.1111/j.1466-8238.2011.00756.x

BASELGA, A. & ORME, C.D.L. 2012: betapart: an R package for the study of beta diversity. Methods in Ecology and Evolution 3: 808-812. doi:10.1111/j.2041-210X.2012.00224.x.

BASELGA, A., BONTHOUX, S. & BALENT, G. 2015: Temporal Beta Diversity of Bird Assemblages in Agricultural Landscapes: Land Cover Change vs. Stochastic Processes. – PloS ONE 10(5): e0127913. doi:10.1371/journal.pone.0127913.

BASELGA, A. 2007: Disentangling distance decay of similarity from richness gradients: response to Soininen et al. 2007. – Ecography 30: 838-841. doi:10.1111/j.2007.0906-7590.05191.x.

BATES, D., MAECHLER, M., BOLKER, B. & WALKER S. 2016: Package ‘lme4’: Linear mixed-effects models using Eigen and S4. – R package version: 1.1-12. <http://CRAN.R-project.org/package=lme4>, retrieved on 24 June 2016.

BICKNELL, J.E., PHELPS, S.P., DAVIES, R.G., MANN, D.J., STRUEBIG, M.J. & DAVIES, Z.G. 2014: Dung beetles as indicators for rapid impact assessments: evaluating best practice forestry in the neotropics. – Ecological Indicators 43: 154-161.

doi:10.1016/j.ecolind.2014.02.030.

BRANDÃO, C.R.F. 1990: Systematic revision of the Neotropical ant genus *Megalomyrmex* Forel (Hymenoptera: Myrmicinae), with the description of thirteen new species. – Arquivos de Zoologia 31: 411-494. doi:10.11606/issn.2176-7793.v31i5p1-91

BRUHL, C.A., GUNSALAM G. & LINSENMAIR, K.E. 1998: Stratification of ants (Hymenoptera: Formicidae) in a primary rain forest in Sabah, Borneo. – Journal of Tropical Ecology 14: 295-297.

CAMAROTA, F.C., POWELL, S., VASCONCELOS, H.L., PRIEST, G. & MARQUIS, R.J. 2015: Extrafloral nectaries have a limited effect on the structure of arboreal ant communities in a Neotropical savanna. – Ecology 96: 231-240. doi:10.1890/14-0264.1.

CAMPBELL, H., FELLOWES, M. D., & COOK, J. M. 2015: Species diversity and dominance-richness relationships for ground and arboreal ant (Hymenoptera: Formicidae) assemblages in Namibian desert, saltpan, and savannah. – Myrmecological News 21: 37-47.

CERDÁ, X., ARNAN X. & RETANA J. 2013: Is competition a significant hallmark of ant (Hymenoptera: Formicidae) ecology? – Myrmecological News 18: 131-477.

COGNI, R. & OLIVEIRA, P.S. 2004: Patterns in foraging and nesting ecology in the arboreal neotropical ponerine ant, *Gnamptogenys moelleri*. – Insectes Sociaux 51: 123-130. doi:10.1007/s00040-003-0711-3.

COSTA, F.R.C. & MAGNUSSON, W.E. 2010: The need for large-scale, integrated studies of biodiversity: the experience of the Program for Biodiversity Research in Brazilian Amazonia. – Natureza & Conservação 8(1): 3-10. doi:10.4322/natcon.00801001,

DÁTTILO, W. & DYER, L. 2014: Canopy openness enhances diversity of ant-plant interactions in the Brazilian Amazon rain forest. – Biotropica 46: 712-719. doi:10.1111/btp.12157.

DÁTTILO, W. & IZZO, T.J. 2012: Temperature Influence on Species Co-Occurrence Patterns in Treefall Gap and Dense Forest Ant Communities in a Terra-Firme Forest of Central Amazon, Brazil. – Sociobiology 59(2): 351-367. doi:10.13102/sociobiology.v59i2.599.

DÁTTILO, W., VICENTE, R.E., NUNES, R.V. & FEITOSA, R. 2012: Influence of cave size and presence of bat guano on ant visitation. – Sociobiology 59(2): 549-559. doi:10.13102/sociobiology.v59i2.617.

DAVIDSON, D.W. 1988: Ecological studies of neotropical ant-gardens. – Ecology 69:1138-1152.

DE CÁCERES, M. & JANSEN, F. 2015: Package 'indicspecies': Relationship Between Species and Groups of Sites. – R package version: 1.7.5. <http://CRAN.R-project.org/package=indicspecies>, retrieved on 24 June 2016.

DEJEAN, A., CORBARA, B., ORIVEL, J., SNELLING, R. R., DELABIE, J.H.C. & BELIN-DEPOUX, M. 2000: The importance of ant gardens in the pioneer vegetal formations of French Guiana (Hymenoptera: Formicidae). – Sociobiology 35(3): 425-439.

DEJEAN, A., GROC, S., HÉRAULT, B., RODRIGUEZ-PÉREZ, H., TOUCHARD, A., CÉRÉGHINO, R., DELABIE, J.H.C. & CORBARA, B. 2015a: Bat aggregation mediates the functional structure of ant assemblages. – Comptes Rendus Biologies 338(10): 688-695. doi:10.1016/j.crvi.2015.06.011.

DEJEAN, A.; CÉRÉGHINO, R. LEPONCE, M.; ROSSI, V.; ROUX, O.; COMPIN, A.; DELABIE, J.H.C. & CORBARAI, B. 2015b: The fire ant Solenopsis saevissima and habitat disturbance alter ant communities. – Biological Conservation 187:145-153. doi:10.1016/j.biocon.2015.04.012.

DEL TORO, I., RIBBONS, R.R. & PELINI, S.L. 2012: The little things that run the world revisited: a review of ant-mediated ecosystem services and disservices (Hymenoptera: Formicidae). – Myrmecological News 17: 133-146.

FERNANDES, I.O., OLIVEIRA, M.L. & DELABIE, J.H.C. 2014: Description of two new species in the Neotropical *Pachycondyla foetida* complex (Hymenoptera: Formicidae: Ponerinae) and taxonomic notes on the genus. – Myrmecological News 19: 133-163.

FERNÁNDEZ, F. 2003: Myrmicine ants of the genera Ochetomyrmex and *Tranopelta* (Hymenoptera: Formicidae). – Sociobiology 41: 633-661.

FOX, J. & HONG, J. 2009: Effect displays in R for multinomial and proportional-odds logit models: Extensions to the effects package. – Journal of Statistical Software 32:1, 1-24. <http://www.jstatsoft.org/v32/i01/>, retrieved on 24 June 2016.

FRIZZO, T.L.M., CAMPOS, R.I. & VASCONCELOS, H.L. 2012: Contrasting effects of fire on arboreal and ground-dwelling ant communities of a Neotropical savanna. – Biotropica 44: 254-261. doi:10.1111/j.1744-7429.2011.00797.x.

GOTELLI, N.J.; ELLISON, A.M.; DUNN, R.R. & SANDERS, N.J. 2011: Counting ants (Hymenoptera: Formicidae): Biodiversity sampling and statistical analysis for myrmecologists. – Myrmecological News 15: 13-19.

HÖLLDOBLER, B. & WILSON, E.O., 1990. The ants. Cambridge, MA: Belknap Press of Harvard University Press, pp. 732.

HUBBELL, S.P. 2001: A Unified Neutral Theory of Biodiversity and Biogeography. Princeton University Press, Princeton, pp. 392.

KLIMES, P., FIBICH, P., IDIGEL, C. & RIMANDAI, M. 2015: Disentangling the diversity of arboreal ant communities in tropical forest trees. – PloS One 10(2):e0117853. doi:10.1371/journal.pone.0117853.

LICHSTEIN, J.T. 2007: Multiple regression on distance matrices: A multivariate spatial analysis tool. – Plant Ecology 188: 117-131. doi:10.1007/s11258-006-9126-3.

LONGINO, J.T. 2005: Formicidae: *Pheidole nitella*. <http://academic.evergreen.edu/projects/ants/genera/PHEIDOLE/SPECIES/nitella/nitella.h

tml>, retrieved on 24 June 2016.

LONGINO, J.T. 2010: Formicidae: *Pachycondyla unidentata*. <http://academic.evergreen.edu/projects/ants/genera/pachycondyla/SPECIES/unidentata/unidentata.html>, retrieved on 24 June 2016.

LONGINO, J.T., 2003. The *Crematogaster* (Hymenoptera, Formicidae, Myrmicinae) of Costa Rica. Zootaxa 151: 1-150.

MACKAY, W.P. & MACKAY, E.E. 2010: The systematics and biology of the New World ants of the genus *Pachycondyla* (Hymenoptera: Formicidae). – Edwin Mellen. Press Lewiston, pp. 642.

MATEO, R.G., BROENNIMANN, O., NORMAND, S., PETITPIERRE, B., ARAÚJO, M.B., SVENNING, J-C., BASELGA, A., FERNÁNDEZ-GONZÁLEZ, F., GÓMEZ-RUBIO, V., MUÑOZ, J., SUAREZ, G.M., LUOTO, M., GUISAN, A. & VANDERPOORTEN, A. 2016: The mossy North: an inverse latitudinal diversity gradient in European bryophytes. – Scientific Reports 25546. doi:10.1038/srep25546.

MUSCOLO, A., BAGNATO, S., SIDARI, M. & MERCURIO, R. 2014: A review of the roles of forest canopy gaps. – Journal of Forestry Research 25:725-736. doi:10.1007/s11676-014-0521-7

NEVES, F.S., BRAGA, R.F., ESPÍRITO-SANTO, M.M., DELABIE, J.H.C., FERNANDES, G.W. & SÁNCHEZ-AZOFEIFA, G.A. 2010: Diversity of arboreal ants in a Brazilian tropical dry forest: effects of seasonality and successional stage. – Sociobiology 56:177–194.

OKSANEN, J., BLANCHET, F.G., KINDT, R., LEGENDRE, P., MINCHIN, P.R., O'HARA, R.B., SIMPSON, G.L., SOLYMOS, P., STEVENS, M.H.H. & WAGNER, H., 2016: Package ‘vegan’: Community Ecology Package. R package version 2.3-0. <http://CRAN.R-project.org/package=vegan>, retrieved on 24 June 2016.

ORIVEL, J. & LEROY, C. 2011: The diversity and ecology of ant gardens

(Hymenoptera: Formicidae; Spermatophyta: Angiospermae). Myrmecological News 14: 73-85.

PAOLUCCI, L.N., MAIA, M.L.B, SOLAR, R.R., CAMPOS, R.I., SCHOEREDER, J.H. & ANDERSEN, A. 2016: Fire in the Amazon: impact of experimental fuel addition on responses of ants and their interactions with myrmecochorous seeds. Oecologia 1-12. doi:10.1007/s00442-016-3638-x.

PARR, C.L. & GIBB, H. 2010: Competition and the role of dominant ants. In: LACH, L., PARR, C.L. & ABBOTT, K.L.: Ant Ecology – Oxford University Press Inc, New York, pp. 77-96.

PARR, C.L. 2008: Dominant ants can control assemblage species richness in a South African savanna. – Journal of Animal Ecology 77: 1191-1198. doi:10.1111/j.1365-2656.2008.01450.x.

POWELL, S., COSTA, A.N., LOPES, C.T. & VASCONCELOS, H.L. 2011: Canopy connectivity and the availability of diverse nesting re-sources affect species coexistence in arboreal ants. – Journal of Animal Ecology 80: 352–360. doi:10.1111/j.1365-2656.2010.01779.x.

R CORE TEAM. 2016: R: A language and environment for statistical computing. – R Foundation for Statistical Computing, Vienna. <https://www.R-project.org>, retrieved on 24 June 2016.

RIBAS, C., & SCHOEREDER, J. 2002: Are all ant mosaics caused by competition? Oecologia 131(4): 606-611. doi:10.1007/s00442-002-0912-x.

RIBAS, C.R., SCHOEREDER, J.H., PIC, M. & SOARES, S.M. 2003: Tree heterogeneity, resource availability, and larger scale processes regulating arboreal ant species richness. – Austral Ecology 28: 305-314. doi:10.1046/j.1442-9993.2003.01290.x.

RICO-GRAY, V. & OLIVEIRA, P.S. 2007: The ecology and evolution of ant–plant interactions. University of Chicago Press, Chicago. pp. 320.

RYDER WILKIE, K.T., MERTL, A.L. & TRANIELLO, J.F.A. 2007: Biodiversity below ground: probing the subterranean ant fauna of Amazonia. – Naturwissenschaften 94: 725-731. doi:10.1007/s00114-007-0250-2.

RYDER WILKIE, K.T., MERTL, A.L. & TRANIELLO, J.F.A. 2010: Species diversity and distribution patterns of the ants of Amazonian Ecuador. – Plos One 5(10): e13146. doi:10.1371/journal.pone.0013146.

SALAZAR, F., REYES-BUENO, F., SANMARTIN, D. & DONOSO, D. A. 2015: Mapping continental Ecuadorian ant species. – Sociobiology 62(2): 132-162. doi:10.13102/sociobiology.v62i2.132-162.

SANHUDO, C.E.D., IZZO, T.J. & BRANDÃO, C.R.F. 2008: Parabiosis between basal fungus-growing ants (Formicidae, Attini). – Insectes Sociaux 55: 296-300. doi:10.1007/s00040-008-1005-6.

SANTOS, M.S., LOUZADA, J.N.C., DIAS, N., ZANETTI, R., DELABIE, J.H.C. & NASCIMENTO, I.C. 2006: Litter ants richness (Hymenoptera, Formicidae) in remnants of a semi-deciduous forest in the Atlantic rain forest, Alto do Rio Grande region, Minas Gerais, Brazil. – Iheringia: Série Zoológica 96(1): 95-101. doi:10.1590/S0073-47212006000100017.

SCHMIT-NEUERBURG, V. & BLÜTHGEN, N. 2007: Ant gardens protect epiphytes against drought in a Venezuelan lowland rain forest. – Ecotropica 13: 93-100.

SI, X., BASELGA, A. & DING, P. 2015: Revealing Beta-Diversity Patterns of Breeding Bird and Lizard Communities on Inundated Land-Bridge Islands by Separating the Turnover and Nestedness Components. – PloS ONE 10(5): e0127692. doi:10.1371/journal.pone.0127692.

SOLAR, R.R.C., BARLOW, J., ANDERSEN, A.N., SCHOEREDER, J.H.. BERENGUER, E., FERREIRA, J.N. & GARDNER, T.A. 2016: Biodiversity consequences of land-use change and forest disturbance in the Amazon: A multi-scale assessment using ant communities. – Biological Conservation, 197: 98-107. doi:10.1016/j.biocon.2016.03.005.

SOUZA, J.L.P., BACCARO, F.B., LANDEIRO, V.L., FRANKLIN, E., MAGNUSSON, W.E., PEQUENO, P.A.C.L. & FERNANDES, I.O. 2015: Taxonomic sufficiency and indicator taxa reduce sampling costs and increase monitoring effectiveness for ants. – Diversity and Distributions 1-12. doi:10.1111/ddi.12371.

SOUZA, J.L.P., BACCARO, F.B., LANDEIRO, V.L., FRANKLIN, E. & MAGNUSSON, W.E. 2012: Trade-offs between complementarity and redundancy in the use of different sampling techniques for ground-dwelling ant assemblages. – Applied Soil Ecology, 56: 63-73. doi:10.1016/j.apsoil.2012.01.004.

SOUZA, J.L.P., MOURA, C.A.R., HARADA, A.Y. & FRANKLIN, E. 2007: Diversidade de espécies dos gêneros de *Crematogaster*, *Gnamptogenys* e *Pachycondyla* (Hymenoptera: Formicidae) e complementaridade dos métodos de coleta durante a estação seca numa estação ecológica no estado do Pará, Brasil. – Acta Amazonica 37(4): 649-656. doi:10.1590/S0044-59672007000400022.

STUBLE, K.L., RODRIGUEZ-CABAL, M.A., MCCORMICK, G.L., JURIĆ, I., DUNN, R.R., SANDERS, N.J. 2012: Tradeoffs, competition, and coexistence in eastern deciduous forest ant communities. – Oecologia 171(4): 981-992. doi:10.1007/s00442-012-2459-9.

SWAIN, R.B. 1980: Trophic competition among parabiotic ants. Insectes Sociaux 27: 377-390.

ULYSSÉA, M.A. & BRANDÃO, C.R.F. 2013: Ant species (Hymenoptera, Formicidae) from the seasonally dry tropical forest of northeastern Brazil: a compilation from field surveys in Bahia and literature records. – Revista Brasileira de Entomologia 57: 217-224. doi:10.1590/S0085-56262013005000002.

ULYSSÉA, M.A., CERETO, C.E., ROSUMEK, F.B., SILVA, R.R. & LOPES, B.C.

2011: Updated list of ant species (Hymenoptera, Formicidae) recorded in Santa Catarina State, southern Brazil, with a discussion of research advances and priorities. – Revista Brasileira de Entomologia 55(4): 603-611. doi:10.1590/S0085-56262011000400018.

VAN BREUGEL, M., HALL, J.S., CRAVEN, D., BAILON, M., HERNANDEZ, A., ABBENE, M., VAN BREUGEL, P. 2013: Succession of Ephemeral Secondary Forests and Their Limited Role for the Conservation of Floristic Diversity in a Human-Modified Tropical Landscape. – PLoS ONE 8(12): e82433. doi: 10.1371/journal.pone.0082433

VAN TEEFFELEN, A.J.A., VOS, C.C. & OPDAM, P. 2012: Species in a dynamic world: consequences of habitat network dynamics on conservation planning. – Biological Conservation 153, 239-253.

VANTAUX, A., DEJEAN, A., DOR, A. & ORIVEL, J. 2007: Parasitism versus mutualism in the ant-garden parabiosis between *Camponotus femoratus* and *Crematogaster levior*. – Insectes Sociaux 54: 95-99. doi:10.1007/s00040-007-0914-0.

VASCONCELOS, H.L., MACEDO, A.C.C. & VILHENA, J.M.S. 2003: Influence of topography on the distribution of ground-dwelling ants in an Amazonian forest. – Studies on Neotropical Fauna and Environment 38: 115-124. doi:10.1076/snfe.38.2.115.15923.

VÉLE, A., HOLUSA, J. & HORÁK, J. 2016: Ant abundance increases with clearing size. – Journal of Forest Research 21(2): 110-114. doi:10.1007/s10310-016-0520-y.

VICENTE, R.E., DÁTTILO, W. & IZZO, T.J. 2014: Differential recruitment of *Camponotus femoratus* (Fabricius) ants in response to ant garden herbivory. – Neotropical Entomology 43: 519-525. doi:10.1007/s13744-014-0245-6.

VICENTE, R.E., PRADO, L.P. & IZZO, T.J. 2016: Amazon Rainforest Ant-Fauna of Parque Estadual do Cristalino: Understory and Ground-Dwelling Ants. – Sociobiology 63 (3). doi:10.13102/sociobiology.v63i3.1043

WEIR, T.L., NEWBOLD, S., VIVANCO, J.M., VAN HAREN, M., FRITCHMAN, C., DOSSEY, A.T., BARTRAM, S., BOLAND, W., COSIO, E.G. & KOFER, W. 2012:

Plant-inhabiting ant utilizes chemical cues for host discrimination. – Biotropica 44: 246-253. doi:10.1111/j.1744-7429.2011.00786.x.

WHEELER, W.M. 1921: A new case of parabiosis and the "ant gardens" of Britsh Guiana. Ecology, 2:89-103.

WILSON, E.O. 1987: The arboreal ant fauna of Peruvian Amazon forests: a first assessment. – Biotropica, 19:245-251.

WILSON, E.O., 2003. *Pheidole* in the New World: A dominant, hyperdiverse ant genus. – Harvard University Press, Cambridge, pp. 818.

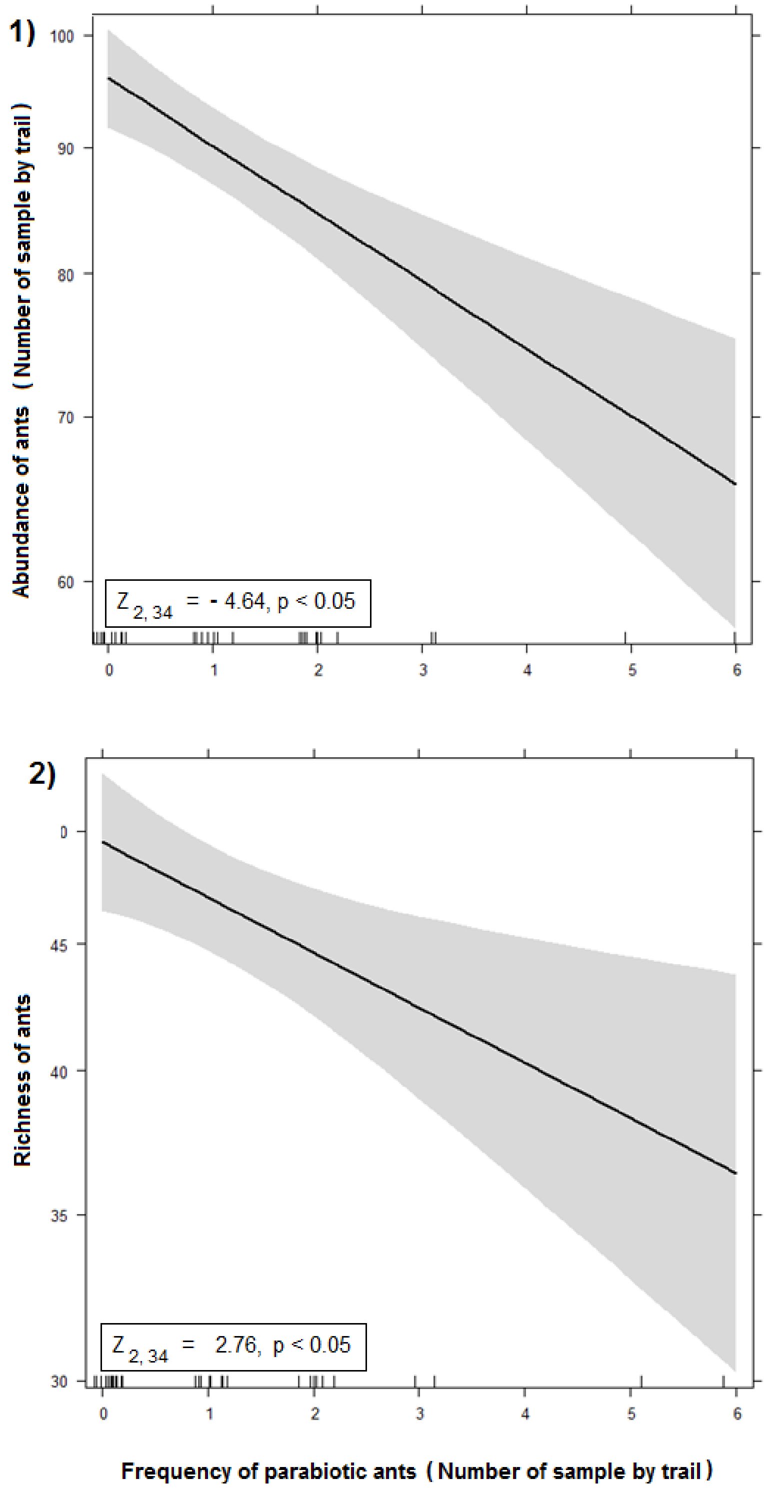
WHITTAKER, R.H. 1960: Vegetation of the Siskiyou Mountains, Oregon and California. – Ecological Monographs 30: 280-338.

YANOVIAK, S.P. 2015: Effects of lianas on canopy arthropod community structure, in SCHNITZER, S.A., BONGERS, F., BURNHAM, R. J. & PUTZ, F.E. (eds): Ecology of Lianas. John Wiley & Sons, Ltd, Chichester, UK. doi: 10.1002/9781118392409.ch24

YANOVIAK, S.P. & SCHNITZER, S.A. 2013: Functional roles of lianas for forest canopy animals, in: LOWMAN, M., DEVY, S. & GANESH, T. (eds): Treetops at Risk. Springer Verlag, New York, pp. 209–210.

Table 1 – Indicator species of parabiotic ants in ground and arboreal ant community.

Taxa	Fidelity (A)	Specificity (B)	Stat	Vertical Strata	*Ca. femoratus* and *Cr. levior*	
					Absence	Presence
Trachymyrmex cf. *bughioni*	0.5861	0.7857	0.679	Ground	X	
Pachycondyla crassinoda Latreille, 1802)	0.4670	0.9286	0.659	Ground	X	
Pheidole nitella Wilson 2003	0.4196	1.0000	0.648	Ground	X	
Pheidole TJI41	0.6022	0.6429	0.622	Ground	X	
Pheidole transversostriata Mayr, 1887	0.3633	1.0000	0.603	Ground	X	
Pheidole TJI49	0.7200	0.5000	0.600	Ground	X	
Solenopsis TJI06	0.3878	0.8571	0.577	Ground	X	
Pheidole TJI21	0.3453	0.9286	0.566	Ground	X	
Odontomachus cf. *meinerti*	0.6316	0.5000	0.562	Ground	X	
Apterostigma urichii Forel, 1893	0.4400	0.7143	0.561	Ground	X	
Atta cephalotes (Linnaeus, 1758)	0.4818	0.6429	0.557	Ground	X	
Pheidole TJI22	0.6067	0.5000	0.551	Ground	X	
Neoponera apicalis (Latreille, 1802)	0.4235	0.7143	0.550	Ground	X	
Nylanderia TJI02	0.3667	0.7857	0.537	Ground	X	
Pheidole INPA019	0.7552	0.3571	0.519	Ground	X	
Pheidole TJI35	0.4465	0.5714	0.505	Ground	X	
Trachymyrmex INPA03	0.5243	0.4286	0.474	Ground	X	
Acromyrmex hystrix (Latreille, 1802)	1.0000	0.2143	0.463	Ground	X	
Myrmicocrypta sp02	0.6316	0.2857	0.425	Ground	X	
Gnamptogenys moelleri (Forel, 1912)	0.5385	0.7500	0.635	Ground		X
Pheidole INPA014	0.4619	0.6667	0.555	Ground		X
Megalomyrmex pr. *wallacei*	0.4570	0.6667	0.552	Ground		X
Pheidole bufo Wilson 2003	0.4413	0.6667	0.542	Ground		X
Camponotus ager (Smith, 1858)	0.7000	0.4167	0.540	Ground		X
Pheidole TJI17	0.5746	0.5000	0.536	Ground		X
Mycocepurus smithii (Forel, 1893)	1.0000	0.2500	0.500	Ground		X
Ochetomyrmex semipolitus Mayr, 1878	0.6372	0.4286	0.4286	Arboreal	X	
Neoponera unidentata (Mayr, 1862)	0. 5161	0.8333	0.656	Arboreal	X	
Crematogaster wardi Longino, 2003	0.3772	0.8333	0.561	Arboreal		X



Figures: Abundance (1) and richness (2) of ground ants.

ANEXO 1 – Fauna de formigas (Insecta, Hymenoptera, Formicidae)

Capítulo publicado no livro Biodiversidade do Parque Estadual do Cristalino (ISBN: 978-85-65551-06-9):

Vicente, R.E., Prado, L.P. & Izzo, T.J. (2015). Fauna de formigas (Insecta, Hymenoptera, Formicidae). In: Biodiversidade do Parque Estadual Cristalino. (Org. Rodrigues, D.J., Noronha, J.C., Vindica, V.F. & Barbosa, F.R.). Áttema Editorial, São Paulo, BR, pp. 125-139

FAUNA DE FORMIGAS (INSECTA, HYMENOPTERA, FORMICIDAE) DO PARQUE ESTADUAL DO CRISTALINO, MT, BRASIL

Ricardo E. Vicente[1,2], Lívia P. Prado[3,4], Thiago J. Izzo[1,2]

[1] Laboratório de Ecologia de Comunidades do Instituto de Biologia da Universidade Federal de Mato Grosso, Cuiabá, MT, Brasil.

[2]P.P.G. Ecologia e Conservação da Biodiversidade, UFMT, Cuiabá, MT, Brasil.

[3]Laboratório de Sistemática, Evolução e Biologia de Hymenoptera do Museu de Zoologia da Universidade de São Paulo (MZSP), São Paulo, São Paulo, Brasil.

[4]P.P.G. Sistemática, Taxonomia e Diversidade Animal do MZSP, São Paulo, Brasil.

Resumo: Este trabalho lista os gêneros de formigas coletados tanto no solo quanto na vegetação do Parque Estadual do Cristalino, MT, Brasil. Também traz o número de morfoespécies para cada um dos gêneros identificados, o local de ocorrência e informações complementares quanto à distribuição e biologia. **Palavras-chaves:** Amazônia, Formicidae, Inventário faunístico, Mirmecologia, Unidades de Conservação.

Abstract: This work lists the genera of ants collected both on the ground and in the vegetation of Parque Estadual do Cristalino (9 ° 32'47 "S, 55 ° 47'38" W), MT, Brazil. Also, we provided information on the number of species by genus, occurence and information about the distribution and biology. **Keywords:** Amazon, Formicidae, Myrmecology, Protected area, Wildlife survey.

INTRODUÇÃO

As formigas são insetos eussociais altamente abundantes e diversificados tanto em termos de espécies quanto comportamentalmente (Kaspari 2005; Brandão et al. 2009). Até o momento, a família Formicidae Latreille (1809) reúne 16 subfamílias e cerca de 15.000 espécies descritas (Bolton 2015), mas estimativas sugerem que haja o dobro de espécies (Hölldobler & Wilson 1990; Fernández 2003a). Os formicídeos são ecologicamente dominantes, desempenham diversas funções no ambiente sendo consideradas engenheiras ecossistêmicas (Folgarait 1998; Meyer et al. 2011) e influenciam profundamente as comunidades terrestres devido sua abundância e relações estabelecidas com diversos grupos como microrganismos (Nepel et al. 2014; Sanders et al. 2014), plantas (Izzo & Vasconcelos 2002; Dáttilo et al. 2009; Izzo & Petini-Benelli 2011; Vicente et al. 2012, 2014) e animais (Dáttilo et al. 2012; Gallego-Ropero et al. 2013; Puker et al. 2015), inclusive com outras formigas (Sanhudo et al. 2008; Gallego-Ropero & Feitosa 2014). Além disso, formigas são modelos para mimetismo para mais de 2.000 espécies de artrópodes (Grimaldi & Engel 2005). Logo, dada sua alta diversidade, fácil amostragem e taxonomia relativamente bem resolvida formigas são modelos para avaliações de biodiversidade (Agosti et al. 2000) e confiáveis indicadores biológicos (Andersen et al. 2002).

Apesar das listagens disponíveis de espécies de formigas que ocorrem na região Neotropical (Kempf 1972; Fernández & Sendoya 2004), os trabalhos envolvendo a fauna brasileira se concentram em biomas como o Cerrado (Silva & Silvestre 2004, Silva & Brandão 2014; Schoereder et al. 2010; Brandão et al. 2011), Mata Atlântica (Feitosa & Ribeiro 2005; Silva et al. 2007; Figueiredo et al. 2013), Pantanal (Battirola et al. 2005; Ribas et al. 2007; Silva et al. 2013) e Caatinga (Neves et al. 2013; Ulysséa & Brandão 2013). Na Amazônia estes estudos se concentram principalmente nas regiões Central e Oriental (Vasconcelos et al. 2006, 2010; Santos et al. 2007; Oliveira et al. 2009; Bastos &

Harada 2011; Baccaro et al. 2012; Souza et al. 2012; Harada et al. 2013) e são extremamente restritos a algumas localidades na Amazônia Meridional (Dáttilo et al. 2013, Falcão et al. 2015). Dessa forma, este trabalho tem como objetivo 1) listar os gêneros de formigas que ocorrem no Parque Estadual do Cristalino, Mato Grosso, localizado na Amazônia Meridional, uma área de alta, porém pouco conhecida, diversidade de diversos taxa (Peres 2005) e 2) apresentar resumidamente informações sobre a distribuição geográfica e biologia desses gêneros.

METODOLOGIA

As coletas foram realizadas entre novembro de 2012 e maio de 2013, em 11 parcelas que possuem 250 m de comprimento, instaladas a uma distância mínima de 1 km (ver Capitulo 1 deste livro). Em cada parcela, a cada 25 metros foram realizadas coletas de formigas no solo e na vegetação, totalizando 220 amostras. Para coleta de formigas no solo, foram utilizadas armadilhas de queda do tipo *Pitfall*. Para amostragem de formigas que forrageiam na vegetação foi utilizado Guarda-chuva Entomológico sendo que em quatro pontos a dois metros de distância de cada *Pitfall* foram feitas batidas na vegetação. Em cada ponto deste, toda vegetação dentro de 1m² que possuísse entre 1 a 3 metros foi agitada. Os invertebrados que caíram sobre o guarda-chuva entomológico foram coletados, armazenados em álcool e posteriormente separados em subfamílias e gêneros seguindo a classificação de Bolton (2015) e os *vouchers* foram depositados no Laboratório de Ecologia de Comunidades do Instituto de Biologia da Universidade Federal de Mato Grosso e na coleção de formigas do Laboratório de Sistemática, Evolução e Biologia de Hymenoptera do Museu de Zoologia da Universidade de São Paulo.

RESULTADOS E DISCUSSÃO

A fauna do Parque Estadual do Cristalino conta com 1.566 ocorrências de formigas divididas em 202 morfoespécies, 47 gêneros e oito subfamílias. Quanto aos gêneros, quatro foram coletados somente na vegetação, 22 somente no solo, e 21 em ambos os estratos. Abaixo a lista dos gêneros de formigas amostrados no Parque Estadual do Cristalino:

SUBFAMÍLIA AMBLYOPONINAE

Prionopelta Mayr, 1866: Distribuição cosmopolita. Dentre as 15 espécies descritas (Bolton 2015), uma foi amostrada no solo do Parque Estadual do Cristalino. São predadoras especialidas que nidificam no solo, sob a casca de árvores ou em troncos podres caídos (Hölldobler *et al.* 1992; Jiménez et al. 2008).

SUBFAMÍLIA DOLICHODERINAE

Azteca Forel, 1878: Distribuição Neotropical (Fernández 2003a). Possui 84 espécies descritas (Bolton 2015) sendo nove amostradas na vegetação do P. E. Cristalino. São territorialistas (Dejean et al. 2009) e constroem seus ninhos de cartão na vegetação, em alguns casos associados a epífitas, ou ocupam galhos vivos ou mortos de plantas (Longino 2007). As que habitam plantas vivas, muitas vezes se alimentam de herbívoros (Dejean et al. 2009) ou possuem relações mutualísticas com hemípteros (Longino 2007).

Dolichoderus Lund, 1831 (fig. A): Distribuição cosmopolita. Possui 132 espécies descritas (Bolton 2015) sendo oito amostradas (cinco no solo, sete na vegetação) no P. E. Cristalino. Nidificam tanto no solo quanto na vegetação, sendo as espécies tropicais quase exclusivamente arborícolas (MacKay 1993). Alimentam-se de pequenos artrópodes, de líquidos açucarados excretados por hemípteros ou por nectários (Fernández 2003a).

Tapinoma Foerster, 1850: Distribuição cosmopolita. Possui 69 espécies descritas (Bolton 2015) sendo duas amostradas na vegetação do P. E. Cristalino. Podem apresentar dieta baseada principalmente em líquidos açucarados (Fernández 2003a), porém, as que habitam ambientes urbanos possuem hábitos omnívoros, podendo apresentar saprofagia ou necrofagia (David & Venkatesha 2013; Bonacci & Vercillo 2015).

SUBFAMÍLIA DORYLINAE

Eciton Latreille, 1804 (fig. B): Distribuição Neotropical. Possui 12 espécies descritas (Bolton 2015) e uma foi amostrada no solo do P. E. Cristalino. Todas as espécies conhecidas do gênero são nômades (Longino 2010).

Neivamyrmex Borgmeier, 1940: Distribuição Neotropical e Neártica. Possui 127 espécies descritas (Bolton 2015) sendo duas amostradas, uma no solo e uma navegetação do P. E. Cristalino. São formigas nômades com colônias numerosas e são predadoras de artrópodes, especialmente de insetos eussociais (LaPolla et al. 2002).

SUBFAMÍLIA ECTATOMMINAE

Ectatomma Smith, 1858: O gênero ocorre na região Neotropical, possui 15 espécies descritas (Bolton 2015) sendo três amostradas (três no solo e uma na vegetação) para o P. E. Cristalino. Nidificam no solo e possuem hábitos generalistas e oportunistas, são predadores de artrópodes e consomem líquidos açucarados de hemípteros e de nectários extraflorais além de restos orgânicos de animais, plantas e frutas (Fernández 1991; Fernández 2003a).

Gnamptogenys Roger, 1863 (fig. C): Possui ampla distribuição (Neártica, Neotropical, Oriental e Australiana) com 137 espécies descritas (Bolton 2015) sendo oito amostradas (sete no solo e uma na vegetação) no P. E. Cristalino. Nidificam no solo, troncos podres caídos ou então podem ser arborícolas. Possuem colônias relativamente pequenas (Lattke 2008). Podem ser predadoras generalistas, enquanto outras espécies são predadoras especialistas de besouros e milípedes (Brown 1993; Brandão et al. 2009).

SUBFAMÍLIA FORMICINAE

Acropyga Roger, 1862: O gênero possui distribuição cosmopolita, com 40 espécies descritas (Bolton 2015) e uma amostrada em solo para o P. E. Cristalino. São formigas que nidificam e forrageiam no solo se alimentando do líquido açucarado excretado por hemípteros que sugam seiva das raízes de plantas (Fernández 2003a).

Brachymyrmex Mayr, 1868: Distribuição Neártica e Neotropical. Possui 44 espécies (Bolton 2015) sendo três amostradas (1 no solo e 3 na vegetação) para o P. E. Cristalino. Nidificam em pequenas cavidades de plantas, em epífitas e na serapilheira (Longino 2010).

Camponotus Mayr, 1861 (fig. D): Distribuição cosmopolita. Possui 1,096 espécies descritas (Bolton 2015) sendo 16 amostradas (sete no solo e 13 na vegetação) no P. E. Cristalino. No geral são espécies omnívoras, que nidificam no solo, em raízes ou copas das árvores (Fernández 2003a). Algumas constroem ninhos de cartão associados à epífitas, interação conhecida como Jardins-de-formigas (Vicente et al. 2014). *Camponotus femoratus* (Fabricius, 1804) é um exemplo frequentemente encontrado nessa região.

Gigantiops Roger, 1863 (fig. E): Distribuição Neotropical. Possui uma espécie descrita (Bolton 2015) que foi amostrada no solo e na vegetação do P. E. Cristalino. Nidificam no solo, em troncos podres ou em galerias escavadas por outros insetos (Mariano *et al.* 2011).

Myrmelachista Roger, 1863: Distribuição Neotropical. Possui 56 espécies descritas (Bolton 2015) e uma foi amostrada na vegetação do P. E. Cristalino. Forrageiam na vegetação e nidificam em cavidades de plantas ou em troncos caídos (Davidson & McKey 1993; Nakano et al. 2013).

Nylanderia Emery, 1906: Distribuição cosmopolita, com 108 espécies descritas (Bolton 2015). Cinco morfoespécies foram amostradas (cinco no solo e quatro na vegetação) no P. E. Cristalino. Habitam desde desertos à florestas tropicais, podendo nidificar na serapilheira, no solo ou em troncos podres (LaPolla *et al*. 2011).

SUBFAMÍLIA MYRMICINAE

Apterostigma Mayr, 1865 (fig. F): Distribuição Neotropical. Possui 45 espécies descritas (Bolton 2015) e quatro foram amostradas (três em solo e uma na vegetação) no P. E. Cristalino. São formigas micetófagas que nidificam em troncos podres, debaixo de pedras, entre as folhas na serapilheira, em epífitas e nas bases de folhas de bromélias (Longino 2010).

Atta Fabricius, 1804: Distribuição Neotropical e Neártica (Bolton 1995). Possui 17 espécies descritas (Bolton 2015) e duas amostradas em solo para o P. E. Cristalino. São conhecidas popularmente como Saúvas e transportam folhas, frutos, galhos e partes de flores para o interior do ninho, onde elas cultivam os fungos dos quais se alimentam (Fernández 2003a).

Carebara Westwood, 1840: Distribuição cosmopolita, com 200 espécies descritas (Bolton 2015) sendo duas amostradas em solo para o P. E. Cristalino. São formigas relativamente pequenas de hábitos crípticos. Alimentam-se de pequenos invertebrados (Fischer 2014) podendo ser oportunistas (Fernández 2010).

Cephalotes Latreille, 1802 (fig. G): Distribuição Neotropical. Possui 118 espécies descritas (Bolton 2015) e cinco amostradas (1 no solo e 5 na vegetação) para o P. E. Cristalino. São formigas arborícolas que nidificam em troncos vivos ou mortos (Longino 2010). Alimentam-se principalmente de pólen (Prado & Brandão 2013) e em nectários extraflorais ou de secreção de hemípteros, frutas caídas, fezes de aves, matéria orgânica animal e de pequenos insetos (Corn 1980; Moretti & Ribeiro 2006).

Crematogaster Lund, 1831 (fig. H): O gênero possui distribuição cosmopolita, com 487 espécies descritas (Bolton 2015) e 10 foram amostradas (seis em solo e nove na vegetação) no P. E. Cristalino. Nidificam em galhos vivos ou mortos, troncos de árvores caídos, ou ainda constroem seus ninhos na vegetação, que em alguns casos estão associados à epífitas (Longino 2003), conhecidas como Jardins-de-formigas (Vicente et al.

2014). Muitas espécies se alimentam do líquido açucarado de nectários ou excretado por hemípteros, ou então de animais mortos (Longino 2003).

Cyphomyrmex Mayr, 1862: Distribuição Neártica e Neotropical. Possui 39 espécies descritas (Bolton 2015) e sete amostradas (seis em solo e uma na vegetação) para o P. E. Cristalino. Nidificam em pequenas câmaras no solo, debaixo de pedras, em pequenos troncos caídos na serapilheira, entre raízes de plantas (Snelling & Longino 1992), ou ainda em amontoados de terra suspensos (Adams & Longino 2007). São formigas micetófagas e cultivam os fungos com fezes de insetos e detritos vegetais (Snelling & Longino 1992).

Daceton Perty, 1833 (fig. I): Distribuição restritas às florestas da América do Sul. Duas espécies simpátricas são conhecidas (Vicente et al. 2011; Bolton, 2015). Uma espécie foi amostrada (solo) no P. E. Cristalino. São formigas arborícolas generalistas cuja dieta é composta por pequenos artrópodes e secreções açucaradas de hemípteros (Dejean et al. 2012). ***Hylomyrma*** Forel, 1912: Distribuição Neotropical. Possui 13 espécies descritas (Bolton 2015) e uma amostrada em solo para o P. E. Cristalino. Possui a biologia relativamente pouco conhecida, mas sabe-se que algumas espécies podem nidificar na serapilheira e em troncos podres caídos (Fernandez 2003a).

Megalomyrmex Forel, 1885: O gênero ocorre na região Neotropical. Possui 44 espécies descritas (Bolton 2015) e quatro foram amostradas no solo do P. E. Cristalino. Podem nidificar no solo ou em troncos podres caídos na serapilheira (Brandão 2003).

Mycetarotes Emery, 1913: Distribuição Neotropical. Possui quatro espécies descritas (Bolton 2015) e uma foi amostrada no solo do P. E. Cristalino. São formigas micetófagas e cultivam os fungos do qual se alimentam utilizando matéria orgânica vegetal como sementes e hastes florais (Mayhé-Nunes & Brandão 2006).

Mycocepurus Forel, 1893: Distribuição Neotropical. Possui seis espécies descritas (Bolton 2015) e uma amostrada (solo) para o P. E. Cristalino. São formigas micetófagas que nidificam no solo (Rabeling et al. 2007).

Myrmicocrypta Smith, 1860: Distribuição Neotropical. Possui 27 espécies descritas (Bolton 2015) sendo duas amostradas (solo) no P. E. Cristalino. São formigas micetófagas que nidificam no solo ou madeira podre (Leal & Oliveira 2000; Sosa-Calvo & Schultz 2010).

Nesomyrmex Wheeler, 1910: Distribuição cosmopolita. Possui 51 espécies descritas (Bolton 2015) sendo cinco amostradas (vegetação) no P. E. Cristalino. O gênero é arborícola e nidifica em cavidades de plantas e forrageiam de modo solitário (Longino 2010).

Ochetomyrmex Mayr, 1878: O gênero é restrito as florestas da América do Sul (Fernández 2003b). Possui duas espécies descritas (Bolton 2015), ambas amostradas no P. E. Cristalino (solo e vegetação).

Octostruma Forel, 1912: O gênero ocorre na região Neotropical, possui 34 espécies descritas (Bolton 2015) e uma espécie foi amostrada no solo do P. E. Cristalino. Nidificam na serapilheira, em pequenos troncos podres e em epífitas e são geralmente predadoras de pequenos artrópodes (Brown & Kempf 1960).

Pheidole Westwood, 1839 (fig. J, K): Este é o gênero mais abundante e diverso de formigas (Wilson 2003). Distribuição cosmopolita. Possui 1.007 espécies descritas (Bolton 2015) e trinta e oito foram amostradas (35 em solo e 11 em vegetação) no P. E. Cristalino. As espécies possuem os mais variados hábitos de nidificação e alimentação (Wilson 2003).

Rogeria Emery, 1894: Distribuição conhecida para o Novo Mundo e Australásia (LaPolla & Sosa-Calvo 2006). Possui 40 espécies descritas (Bolton, 2015) e uma amostrada em solo do P. E. Cristalino. São espécies crípticas que nidificam na serapilheira, em troncos caídos, debaixo de rochas e em galhos de árvores (LaPolla & Sosa-Calvo 2006).

Sericomyrmex Mayr, 1865 (fig. L): Distribuição Neotropical. Possui 19 espécies descritas (Bolton 2015) sendo duas amostradas no solo do P. E. Cristalino. São micetófagas e nidificam no solo (Longino 2010).

Solenopsis Westwood, 1840: Distribuição cosmopolita. Possui 196 espécies descritas (Bolton 2015) e oito foram amostradas (oito em solo e duas na vegetação) no P. E. Cristalino. As formigas deste gênero, em sua maioria onívoras, alimentando-se de carcaças de vertebrados, invertebrados vivos ou mortos, frutos e sementes caídos, néctar de plantas (Trager 1991; Pacheco & Mackay 2013). Nidificam no solo e algumas espécies vivem associadas a ninhos de outras formigas, para predar a prole de sua hospedeira (Pacheco & Mackay 2013).

Strumigenys Smith, 1860 (fig. M): Distribuição cosmopolita. Possui 836 espécies descritas (Bolton 2015) e oito amostradas (cinco em solo e três na vegetação) para o P. E. Cristalino. Habitam a serapilheira, podendo nidificar em galhos podres e no solo. São predadores de pequenos artrópodes (Wilson 1953).

Trachymyrmex Forel, 1893: Distribuição cosmopolita, com 47 espécies descritas (Bolton 2015) e cinco amostradas (cinco em solo e uma em vegetação) no P. E. Cristalino. São micetófagas e nidificam no solo (Longino 2010).

Wasmannia Forel, 1893: Gênero endêmico da região Neotropical, porém, *W. auropunctata* foi introduzida ao longo de outras regiões tropicais (Longino & Fernández 2007), possui 10 espécies descritas (Bolton 2015) e três foram amostradas (três em solo e duas na vegetação) no P. E. Cristalino. As espécies deste gênero nidificam em folhas e galhos mortos caídos, debaixo de pedras, em domáceas de mirmecófitas e em epífitas (Longino & Fernández 2007). São onívoras e sua dieta é composta de animais mortos, secreções de plantas e hemípteros (Armbrecht & Ulloa-Chacón 2003; Longino & Fernández 2007).

SUBFAMÍLIA PONERINAE

Anochetus Mayr, 1861: Regiões tropicais, subtropicais e temperadas (Schmidt &

Shattuck 2014). Possui 114 espécies descritas (Bolton 2015) e duas amostradas em solo no P. E. Cristalino. São predadoras e utilizam de um tipo de armadilha mandibular para subjugar suas presas (Fernández 2003a). Nidificam em galhos podres, sob a casca dos troncos das árvores e no solo. Algumas espécies são arborícolas e outras vivem associadas a Isoptera (Schmidt & Shattuck 2014).

Dinoponera Roger, 1861: Distribuição Neotropical. Possui oito espécies descritas (Bolton 2014) e uma morfoespécie amostrada em solo no P. E. Cristalino. São formigas que possuem colônia com cerca de 100 indivíduos e forrageiam de forma solitária. Nidificam no solo, são predadoras generalistas de insetos, mas consomem frutas e outras fontes de alimento (Paiva & Brandão 1995; Araújo & Rodrigues 2006; Monnin & Peeters 2008).

Hypoponera Santschi, 1938*:* Distribuição cosmopolita. Dentre as 148 espécies descritas (Bolton 2015) três foram amostradas em solo no P. E. Cristalino. Nidificam no solo, em troncos podres e na serapilheira. São predadores generalistas de pequenos artrópodes (Brandão *et al*. 2009; Schmidt & Shattuck 2014).

Leptogenys Roger, 1861: Distribuição cosmopolita, com 307 espécies descritas (Bolton 2015) e uma amostrada em solo no P. E. Cristalino. Nidificam no solo, debaixo de pedras, em troncos podres, em cavidades de galhos ou sob a casca de troncos (Longino 2010). São predadoras de invertebrados, especialmente isópodos e Dermaptera (Brandão et al. 2009).

Mayaponera Schmidt & Shattuck, 2014: Distribuição Neotropical. Possui uma espécie descrita, *M. constricta* (Mayr, 1884) (Bolton 2015), que foi amostrada no solo e na vegetação do P. E. Cristalino. Nidificam no solo, debaixo de pedras ou em troncos podres, são predadoras e forrageiam durante a noite (Schmidt e Shattuck 2014).

Neoponera Emery, 1901 (fig. N): Distribuição Neotropical. Possui 57 espécies descritas (Bolton 2015) e nove amostradas (quatro em solo e seis na vegetação) no P. E.

Cristalino. Nidificam no solo, em troncos podres e galhos mortos. Algumas espécies são predadoras generalistas enquanto outras espécies são predadoras especialistas de Isoptera (Schmidt e Shattuck 2014).

Odontomachus Latreille, 1804 (fig. O): Distribuição Neotropical. Possui 67 espécies descritas (Bolton 2015) e três amostradas em solo no P. E. Cristalino. Nidificam no solo, serapilheira, troncos podres e algumas espécies são arborícolas (Brown 1976). São predadoras generalistas de pequenos artrópodes (Brown 1976; Jiménez et al. 2008).

Pachycondyla Smith, 1858: Distribuição Neotropical. Possui 17 espécies descritas (Bolton 2015) e duas amostradas em solo no P. E. Cristalino. As formigas deste gênero nidificam no solo e são predadoras generalistas e detritívoras (Schmidt & Shattuck 2014).

Pseudoponera Emery, 1900: Distribuição cosmopolita. Possui seis espécies descritas (Bolton 2015) e uma amostrada em solo no P. E. Cristalino. Nidificam no solo, troncos em decomposição e forrageiam solitariamente, sendo provavelmente predadoras generalistas e necrófagas (Schmidt & Shattuck 2014).

SUBFAMÍLIA PSEUDOMYRMECINAE

Pseudomyrmex Lund, 1831 (fig. P): Distribuição Neotropical. Possui 134 espécies descritas (Bolton 2015) e oito amostradas (uma em solo e oito na vegetação) no P. E. Cristalino. São arborícolas de hábitos generalistas ou se alimentam de secreções de cochonilhas, nidificam na cavidade de troncos, em galhos de plantas ou em troncos podres (Ward 1985, Ward 1991).

Este trabalho traz dois diferenciais em relação a inventários de formigas disponíveis na literatura. O primeiro é a listagem de formigas tanto que forrageiam pela vegetação do subbosque quanto ao nível do solo. A grande maioria dos inventários trazem registros de espécies que habitam o solo, sendo a fauna sub-arborícola negligenciada na maioria desses estudos, principalmente na Amazônia (e.g. Ryder-Wilkie et al. 2010, Monteiro et al. 2013). Esses poucos estudos tem demonstrado a importância de amostrar ambos os estratos, visto o considerável acréscimo na contribuição para o conhecimento da fauna local. O segundo diferencial deste trabalho é a compilação de informações biológicas locais e disponíveis na literatura sobre os gêneros de formigas, que é extremamente escasso quando se trata da fauna Neotropical (e.g. Fernández 2003; Suguituru et al. 2015). Tanto essa listagem que refleta melhor a biodiversidade local por amostrar formigas de solo e vegetação, juntamente com as informações biológicas desses grupos, são informações importantes e podem auxiliar tanto em outros estudos com formigas, bem como as tomadas de decisões conservacionistas regionais.

REFERÊNCIAS BIBLIOGRÁFICAS

Adams, R.M.M.; Longino, J. 2007. Nesting biology of the arboreal fungus-growing ant *Cyphomyrmex cornutus* and its social parasite *Megalomyrmex mondabora*. Insectes Sociaux 54(2):136-143.

Agosti, D.; Majer, J.D.; Alonso, L.E.; Schultz, T.R. (Eds). 2001. Ants: Standard methods for measuring and monitoring biodiversity. Smithsonian Institution Press, Washington, p.1-8.

Andersen, A.N.; Hoffmann, B.D.; Müller, W.J.; Griffiths, A.D. 2002. Using ants as bioindicators in land management: simplifying assessment of ant community responses. Journal of Applied Ecology, 39: 8-17.

Araújo, A.; Rodrigues, Z. 2006. Foraging behavior of the queenless ant *Dinoponera quadriceps* Santschi (Hymenoptera: Formicidae). Neotr Entomol, 35(2):159-164.

Armbrecht, I; Ulloa-Chacón, P. 2003. The little fire ant *Wasmannia auropunctata* (Roger) (Hymenoptera : Formicidae) as a diversity indicator of ants in tropical dry forest fragments of Colombia. Environmental Entomology 32(3) : 542-547.

Baccaro, F.B.; Souza, J.L.P.; Franklin, E.; Landeiro, V.L.; Magnusson, W.E. 2012. Limited effects of dominant ants on assemblage species richness in three Amazon forests. Ecological Entomology, 37:1-12.

Bastos, A.H.S.; Harada, A.I. 2011. Leaf-litter as a factor in the structure of a Ponerine ants community (Hymenoptera, Formicidae, Ponerinae) in an eastern Amazonian rainforest, Brazil. Revista Brasileira de Entomologia, 55:589-596.

Battirola, L.D.; Marques, M.I.; Adis, J.; Delabie, J.H.C. 2005. Composição da comunidade de Formicidae (Insecta: Hymenoptera) em copas de *Attalea phalerata* Mart. (Arecaceae), no Pantanal de Poconé, Mato Grosso, Brasil. Revista Brasileira de Entomologia, 49(1):107-117.

Bolton, B. 1995. A taxonomic and zoogeographical census of the extant ant taxa (Hymenoptera. Formicidae). J. Nat. Hist, 29, 1037–1056.

Bolton, B. 2015. An online catalog of the ants of the world. (http://www.antcat.org/catalog). Acessado em: junho de 2015.

Bonacci, T.; Vercillo, V. 2015. Outdoor post-mortem bite injuries by Tapinoma nigerrimum (Hymenoptera, Formicidae) on a human corpse: Case report. Journal of Forensic and Legal Medicine 33:5-8.

Brandão, C.R.F. 2003. Further revisionary studies on the ant genus *Megalomyrmex* Forel (Hymenoptera: Formicidae: Myrmicinae: Solenopsidini). Papéis Avulsos de Zoologia, 43(8):145-159.

Brandão, C.R.F.; Silva, R.R.; Delabie, J.C.H. 2009. Formigas. In: Panizzi, A.R.; Parra, J.R.P. (Eds.). Bioecologia e nutrição de insetos. Base para o manejo integrado de pragas. Embrapa Informação Tecnológica, Brasília, p.323-370.

Brandão CRF, Esteves FA, Prado LP (2010) A catalogue of the Pseudomyrmecinae ants type specimens (Hymenoptera, Formicidae) deposited in the Museu de Zoologia da Universidade de São Paulo, Brazil. Papéis Avulsos de Zoologia, 50:693-699.

Brandão, C.R.F.; Silva, R.R.; Feitosa, R.M. 2011. Cerrado ground-dwelling ants (Hymenoptera: Formicidae) as indicators of edge effects. Zoologia, 28:379-387.

Brown, W.L. 1976. Contributions toward on a reclassification of Formicidae. VI. Ponerinae, tribe Ponerini, subtribe Odontomachiti. Section A. Introduction, subtribal characters. Genus Odontomachus. Studia Entomologica, 19:67-171.

Brown, W.L. 1993. Two new species of Gnamptogenys, and an account of millipede predation by one of them. Psyche, 99:275-289.

Brown, W.L.; Kempf, W.W. 1960. A world revision of the ant tribe Basicerotini. Studia Entomologica, 3:161-250.

Brown W.L. 1993. Two new species of Gnamptogenys, and an account of millipede predation by one of them. Psyche (Camb.) 99: 275-289.

Corn, M.L. 1980. Polymorphism and polyethism in the Neotropical ant *Cephalotes* atratus L. Insectes Sociaux 27: 29-42.

Dáttilo, W.; Marques, E.C.; Falcão, J.C.F.; Moreira, D.D.O. 2009. Interações mutualísticas entre formigas e plantas. EntomoBrasilis (Vassouras), 2:32-36.

Dáttilo, W.; Martins, R.L.; Uhde, V.; Noronha, J.C.; Florêncio, F.P.; Izzo, T.J. 2012. Floral resource partitioning by ants and bees in a jambolan *Syzygium jambolanum* (Myrtaceae) agroforestry system in Brazilian Meridional Amazon. Agroforestry Systems, 85: 105-111.

Dáttilo, W.; Rico-Gray, V.; Rodrigues, D.J.; Izzo, T.J. 2013. Soil and vegetation features determine the nested pattern of ant–plant networks in a tropical rainforest. Ecological Entomology, 38: 374-380.

David, A.I.; Venkatesha, M.G. 2013. Attraction of household ants (Hymenoptera: Formicidae) to various food sources in different seasons. Journal of Entomology, 10:66-75.

Davidson, D.W.; Mckey, D. 1993. Ant plant symbioses - stalking the chuyachaqui. Trends in Ecology & Evolution, 8:326-332.

Dejean, A.; Grangier, J.; Leroy, C.; Orivel, J. 2009. Predation and aggressiveness in host plant protection: a generalization using ants from the genus *Azteca*. Naturwissenschaften. 96:57-63.

Dejean, A.; Delabie, J.H.C.; Corbara, B.; Azémar, F.; Groc, S.; Orivel, J.; Leponce, M. 2012. The ecology and feeding habits of the arboreal trap-jawed ant *Daceton armigerum*. PLoS ONE 7(6): e37683.

Dejean, A.; Evraerts, C. 1997. Predatory behavior in the genus *Leptogenys*: A comparative study. Journal of Insect Behavior, 10:177-191.

Esteves, F.A.; Brandão, C.R.F.; Prado, L.P. 2011. The type specimens of Dorylomorph ants (Hymenoptera, Formicidae: Aenictinae, Ecitoninae, Cerapachyinae, Leptanilloidinae) deposited in the Museu de Zoologia da Universidade de São Paulo, Brazil. Papéis Avulsos de Zoologia, 51:341-357.

Falcão, J.C.F.; Dáttilo, W.; Izzo, T.J. (2015) Efficiency of different planted forests in recovering biodiversity and ecological interactions in Brazilian Amazon. Forest Ecology and Management, 339:105-111.

Feitosa, R.M.; Ribeiro, A.S. 2005. Mirmecofauna (Hymenoptera, Formicidae) de serapilheira de uma área de Floresta Atlântica no Parque Estadual da Cantareira - São Paulo, Brasil. Biotemas, 18(2):51-71.

Fernández, F. 1991. Las hormigas cazadoras del género *Ectatomma* (Formicidae: Ponerinae) en Colombia. Caldasia, 16:551-564.

Fernández, F. (Ed.). 2003a. Introducción a las Hormigas de la región Neotropical. Instituto de Investigación de Recursos. Biológicos Alexander von Humboldt, Bogotá, Colombia. XXVI + 398 p.

Fernández, F. 2003b. Myrmicine ants of the genera *Ochetomyrmex* and *Tranopelta* (Hymenoptera: Formicidae). Sociobiology 41:633-661

Fernández, F. 2010. A new species of *Carebara* from the Philippines with notes and comments on the systematics of the *Carebara* genus group (Hymenoptera: Formicidae: Myrmicinae). Caldasia, 32(1): 191-203

Fernández, F.; Sendoya, S. 2004. List of Neotropical ants (Hymenoptera: Formicidae). Biota Colombiana 5(1):3-93.

Figueiredo, C.J.; Silva, R.R.; Munhae, C.B.; Morini, M.S.C. 2013. Ant fauna (Hymenoptera: Formicidae) attracted to underground traps in Atlantic Forest. Biota Neotropica, 13(1):176-182.

Folgarait, P.J. 1998. Ant biodiversity and its relationship to ecosystem functioning: a review. Biodiversity and Conservation, 7:1221-1244.

Gallego-Ropero, M.C.; Feitosa, R.M. 2014. Evidences of batesian mimicry and parabiosis in ants of the Brazilian Savanna. Sociobiology, 61:281-285.

Gallego-Ropero, M.C.; Feitosa, R.M. Pujol-Luz, J.R. 2013. Formigas (Hymenoptera, Formicidae) associadas a ninhos de *Cornitermes cumulans* (Kollar) (Isoptera, Termitidae) no Cerrado do Planalto Central do Brasil. EntomoBrasilis, 6:97-101.

Grimaldi, D.; Engel, M.S. (Eds). 2005. Evolution of the insects. Cambridge University Press, p. 468-480.

Harada, A.I.; Farias, P.R.S.; Lopes, L.F.C.; Silva, A.G.; Brandão, A.D.S. 2013. Assessment of ant communities in secondary forest in the eastern amazon. Comunicata Scientiae, 4:186-194.

Hölldobler, B.; Obermayer, M.; Wilson, E.O. 1992. Communication in the primitive cryptobiotic ant *Prionopelta amabilis* (Hymenoptera: Formicidae). Journal of Comparative Physiology A: Neuroethology, Sensory, Neural, and Behavioral Physiology, 170:9-16.

Hölldobler, B.; Wilson, E.O. 1990. The ants. Cambridge, MA: Belknap Press of Harvard University Press, 764 p.

IBGE (Instituto Brasileiro de Geografia e Estatística). 2004. Mapa da vegetação brasileira. 3ª edição. Ministério do Planejamento, Orçamento e Gestão.

Izzo, T.J.; Benelli-Petini, A. 2011. Relação entre diferentes espécies de formigas e a mirmecófita *Cordia nodosa* Lamarck (Boraginaceae) em áreas de mata ripária na Amazônia mato-grossense. Acta Amazonica, 41:355-360.

Izzo, T.J.; Vasconcelos, H.L. 2002. Cheating the cheater: domatia loss minimizes the effects of ant castration in an Amazonian ant-plant. Oecologia, 133: 200-205.

Jiménez, E.; Fernández, F.; Arias, T.M.; Lozano-Zambrano, F.H. 2008. Sistemática, biogeografía y conservación de las hormigas cazadoras de Colombia. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Bogotá, Colombia, 622 p.

Kaspari, M. 2005. Global energy gradients and the regulation of body size: worker mass and worker number in ant colonies. PNAS, 102:5079-5083.

Kempf, W.W. 1972. Catálogo abreviado das formigas da região neotropical. Studia Entomologica, 15:3-344.

Kempf, W.W. 1973. A revision of the Neotropical myrmicine ant genus *Hylomyrma* Forel (Hymenoptera: Formicidae). Studia Entomologica, 16:225-260.

LaPolla, J.S.; Hawkes, P.G; Fisher, B.L. 2011. Monograph of *Nylanderia* (Hymenoptera: Formicidae) of the World, Part I: *Nylanderia* in the Afrotropics. Zootaxa 3110: 10-36.

LaPolla, J.S.; Müeller, U.G.; Seid, M.; Cover, S.P. 2002. Predation by the army ant *Neivamyrmex rugulosus* on the fungus-growing ant *Trachymyrmex arizonensis*. Insectes Sociaux, 49:251–256.

LaPolla, J.S.; Sosa-Calvo, J. 2006. Review of the ant genus *Rogeria* (Hymenoptera: Formicidae) in Guyana. Zootaxa 1330: 59-68.

Lattke, J. E., F. Fernández, T. M. Arias-Penna, E. E. Palacio, W. Mackay and E. Mackay. 2008. Género Gnamptogenys Roger Pages 66-105 in Jiménez, E., F. Fernández, T. M. Arias-Penna and F. H. Lozano-Zambrano. Sistemática, biogeografía y conservación de las hormigas cazadores de Colombia. Instituto Humboldt, Colombia. 621 pp.

Leal, I.R.; Oliveira, O.S. 2000. Foraging ecology of attine ants in a Neotropical savanna: seasonal use of fungal sub-strate in the cerrado vegetation of Brazil. Insec. Sociaux 47:376-382.

Longino, J.T. 2003. The Crematogaster (Hymenoptera, Formicidae, Myrmicinae) of Costa Rica. Zootaxa, Auckland, 151:1-150.

Longino, J.T.; Fernández, F. 2007. Taxonomic review of the genus *Wasmannia*. *In* Snelling, R.R.; Fisher, B.L.; Ward, P.S. (Eds.). Advances in ant systematics (Hymenoptera: Formicidae): homage to E. O. Wilson – 50 years of contributions. Memoirs of the American Entomological Institute, pp. 271-289.

Longino, J.T. 2010. Ants of Costa Rica. (http://www.evergreen.edu/ants/AntsofCostaRica.html). Acesso em junho de 2015.

MacKay, W.P. 1993. A review of the New World ants of the genus *Dolichoderus* (Hymenoptera: Formicidae). Sociobiology 22:1-148.

Mariano, C.A.S.F.; Santos, I.D.S.; Groc, S.; Leroy, C.L.; Malé, P.J.; Ruiz-González, M.X.; Cerdan, P.; Dejean, A.; Delabie, J.H.C. 2011. The karyotypes of *Gigantiops destructor* (Fabricius) and other ants from French Guiana (Formicidae). Annales de la Société Entomologique de France, 47:140.

Meyer, S.T.; Leal, I.R.; Tabarelli, M.; Wirth, R. 2011. Ecosystem engineering by leaf-cutting ants: nests of *Atta cephalotes* drastically alter forest structure and microclimate. Ecological Entomology, 36, 14–24

Monteiro, D.S.; Vicente, R.E.; Oliveira, J.; Izzo, T.J. 2013. Composição e riqueza de formigas (Hymenoptera: Formicidae) em áreas de floresta ombrófila densa e reflorestamento de Teca (*Tectona grandis* L.F. - Verbenaceae) na Fazenda São Nicolau, Cotriguaçu, MT. In: Rodrigues, D.J.; Izzo, T.J.; Battirola, L.D. (Org.). Descobrindo a Amazônia Meridional: Biodiversidade da Fazenda São Nicolau. Editora da UFMS, p.281-297.

Moretti, T.C.; Ribeiro, O.B. 2006. *Cephalotes clypeatus* Fabricius (Hymenoptera: Formicidae): hábitos de nidificação e ocorrência em carcaça animal. Neotr Entomol, 35(3): 412-415.

Nakano, M.A.; Miranda, V.F.O.; Souza, D.R.; Feitosa, R.M.; Morini, M.S.C. 2013. Ocurrence and natural history of Myrmelachista Roger (Formicidae: Formicinae) in the Atlantic Forest of southeastern Brazil. Revista Chilena de Historia Natural, 86:169-179.

Nepel, M.; Voglmayr, H.; Schonenberger, J.; Mayer, V.E. 2014. High diversity and low specificity of Chaetothyrialean Fungi in carton galleries in a neotropical ant–plant association. PLoS ONE 9(11): e112756.

Neves, F. Queiros-Dantas, K.S.; Rocha, W.D.; Delabie, J.H.C. 2013. Ants of three adjacent habitats of a transition region between the Cerrado and Caatinga Biomes: The effects of heterogeneity and variation in canopy cover. Neotr Entomol, 42: 258-268.

Oliveira, P.I.; Souza, J.L.P.; Baccaro, F.B.; Franklin, E. 2009. Ant species distribution along a topographic gradient in a "terra-firme" forest reserve in Central Amazonia. Pesquisa Agropecuária Brasileira, 44:852-860.

Pacheco, J.A.; Mackay, W.P. 2013. The systematics and biology of the New World thief ants of the genus Solenopsis (Hymenoptera: Formicidae). Lewiston, New York: Edwin Mellen Press, 501 pp.

Paiva, R.V.S.; Brandão, C.R.F. 1995. Nests, worker population, and reproductive status of workers, in the giant queenless ponerine ant *Dinoponera* Roger (Hymenoptera : Formicidae). Ethology, Ecology and Evolution, 7:297-312.

Peres, C.A. 2005. Porque precisamos de megareservas na Amazônia. Megadiversidade 1(1): 175-180.

Prado, L.P.; Brandão, C.R.F. 2013. A catalogue of Cephalotini ant types (Hymenoptera: Formicidae: Myrmicinae) deposited in the Museu de Zoologia da Universidade de São Paulo, Brazil. Papéis Avulsos de Zoologia, 53:285-293.

Puker, A.; Rosa, C.S.; Orozco, J.; Solar, R.R.C.; Feitosa, R.M. 2015. Insights on the association of American Cetoniinae beetles with ants. Entomological Science, 18: 21-30.

Ribas CR, Schoereder JH (2007) Ant communities, environmental characteristics and their implications for conservation in the Brazilian Pantanal. Biodiversity and Conservation, 16:1551-1520.

Ryder-Wilkie, K.T.; Mertl, A.L.; Traniello, J.F.A. 2010. Species diversity and distribution patterns of the ants of Amazonian Ecuador. PLoS ONE 5(10): e13146.

Sanders, J.G.; Powell, S.; Kronauer, D.J.; Vasconcelos, H.L.; Frederickson, M.E.; Pierce, N.E. 2014. Stability and phylogenetic correlation in gut microbiota: lessons from ants and apes. Molecular Ecology, 23: 1268-1283.

Sanhudo, C.E.D.; Izzo, T.J.; Brandão, C.R.F. 2008. Parabiosis between basal fungus-growing ants (Formicidae, Attini). Insectes Sociaux, 55: 296-300.

Santos, I.A.; Harada, A.I.; Alves, S.B.; Santos, M.P.D.; Ribas, C.R. 2007. Diversity of ants on plams in Varzea habitats at Amazonia (Hymenoptera: Formicidae). Sociobiology, 50:23-33.

Schoereder, J.H.; Sobrinho, T.G.; Madureira, M.S.; Ribas, C.R.; Oliveira, P.S. 2010. The arboreal ant community visiting extrafloral nectaries in the Neotropical cerrado savanna. Terrestrial Arthropod Reviews, 3:3-27.

Schmidt, C.A.; Shattuck, S O. 2014. The higher classification of the ant subfamily Ponerinae (Hymenoptera: Formicidae), with a review of ponerine ecology and behavior. Zootaxa, 3817(1): 1-242.

Silva, F.H.O.; Delabie, J.H.C.; Santos, G.B.; Meurer, E.; Marques, M.I. 2013. Mini-winkler extractor and pitfall trap as complementary methods to sample Formicidae. Neotr Entomol, 42:351-358.

Silva, R.R.; Brandão, C.R.F. 2014. Ecosystem-wide morphological structure of leaf-litter ant communities along a tropical latitudinal gradient. PlosOne, 9:e93049.

Silva, R.R.; Feitosa, R.M.; Eberhardt, F. 2007. Reduced ant diversity along a habitat regeneration gradient in the southern Brazilian Atlantic Forest. Forest Ecology and Management, 240:61-69.

Silva, R.R.; Silvestre, R. 2004. Riqueza da fauna de formigas subterrâneas (Hymenoptera: Formicidae) em Seara, Oeste de Santa Catarina, Brasil. Papéis Avulsos de Zoologia (São Paulo), 44(1):1-11.

Snelling, R.R.; Longino, J.T. 1992. Revisionary notes on the fungus-growing ants of the genus *Cyphomyrmex*, *rimosus* group (Hymenoptera: Formicidae: Attini). In: Quintero, D.; Aiello, A. (Eds.). Insects of Panama and Mesoamerica: selected studies. Oxford: Oxford University Press, p. 479-494.

Souza, J.L.P.; Baccaro, F.B.; Landeiro, V.L.; Franklin, E.; Magnusson, W.E. 2012. Trade-offs between complementarity and redundancy in the use of different sampling techniques for ground-dwelling ant assemblages. Applied Soil Ecology, 56:63-73.

Sosa-Calvo, J.; Schultz, T.R. 2010. Three remarkable new fungus-growing ant species of the genus *Myrmicocrypta* (Hymenoptera: Formicidae), with a reassessment of the characters that define the genus and its position within the Attini. Ann. Entomol. Soc. Am. 103: 181-195.

Suguituru, S.S.; Souza, D.R.; Munhae, C.B.; Pacheco, R.; Morini, M.S.C. 2013. Diversidade e riqueza de formigas (Hymenoptera: Formicidae) em remanescentes de Mata Atlântica na Bacia Hidrográfica do Alto Tietê, SP. Biota Neotropical, 13(2):141-152.

Suguituru, S.S.; Morini, M.S.C.; Feitosa, R.M.; Silva, R.R. 2015. Formigas do Alto Tietê. Bauru: Canal 6, 456p.

Trager, J.C. 1991. A revision of the fire ants, *Solenopsis geminata* group (Hymenoptera: Formicidae: Myrmicinae). Journal of the New York Entomological Society, 99:141-198.

Ulyssea, M.A.; Brandão, C.R.F. 2013 . Ant species (Hymenoptera, Formicidae) from the seasonally dry tropical forest of northeastern Brazil: a compilation from field surveys in Bahia and literature records. Revista Brasileira de Entomologia, 57: 217-224.

Vasconcelos, H.L.; Vilhena, J.M.S.; Magnusson, W.E.; Albernaz, A.L.K.M. 2006. Long-term effects of forest fragmentation on Amazonian ant communities. Journal of Biogeography, 33:1348-1356.

Vasconcelos, H.L.; Vilhena, J.M.S.; Facure, C.G.; Albernaz, A.L.K.M. 2010. Patterns of ant species diversity and turnover across 2000km of Amazonian floodplain forest. Journal of Biogeography, 37:432-440.

Vicente, R.E.; Dambroz, J.; Barreto, M. 2011. New distribution record of *Daceton boltoni* Azorsa and Sosa-Calvo, 2008 (Insecta: Hymenoptera) ant in the Brazilian Amazon. Check List 7:878-879.

Vicente, R.E.; Dáttilo, W.; Izzo, T.J. 2012. New record of a very specialized interaction: *Myrcidris epicharis* Ward 1990 (Pseudomyrmecinae) and its myrmecophyte host *Myrcia madida* McVaugh (Myrtaceae) in Brazilian Meridional Amazon. Acta Amaz. 42:567-570.

Vicente, R.E.; Dáttilo, W.; Izzo, T.J. 2014. Differential recruitment of *Camponotus femoratus* (Fabricius) ants in response to ant garden herbivory. Neotr Entomol, 43:519-525.

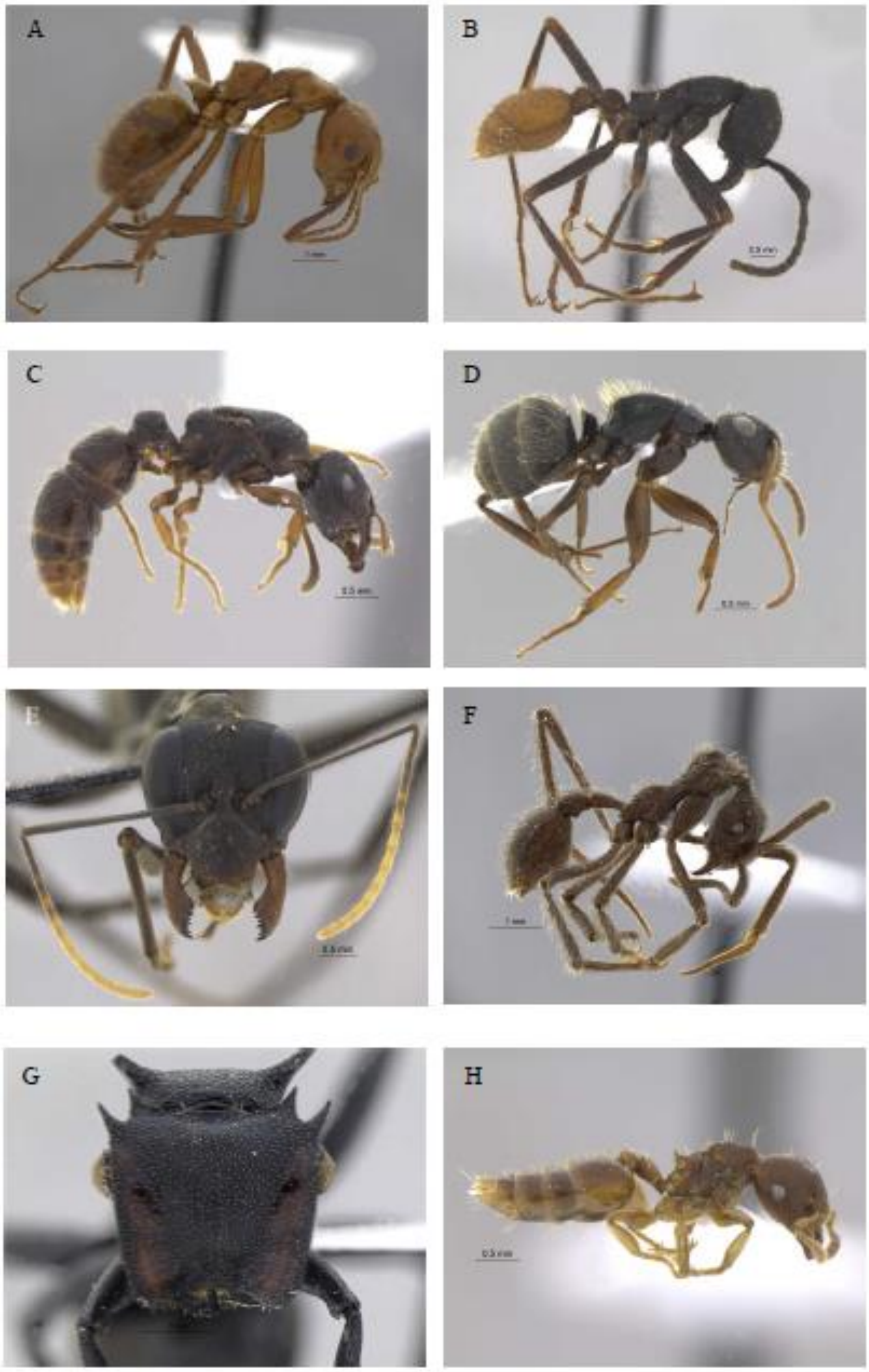
Ward P.S. 1985. The Nearctic species of the genus *Pseudomyrmex* (Hymenoptera: Formicidae). Quaestiones Entomologicae, 21:209-246.

Wilson, E.O. 1953. The ecology of some north American dacetine ants. Annals of the Entomological Society of America, 46:479-495.

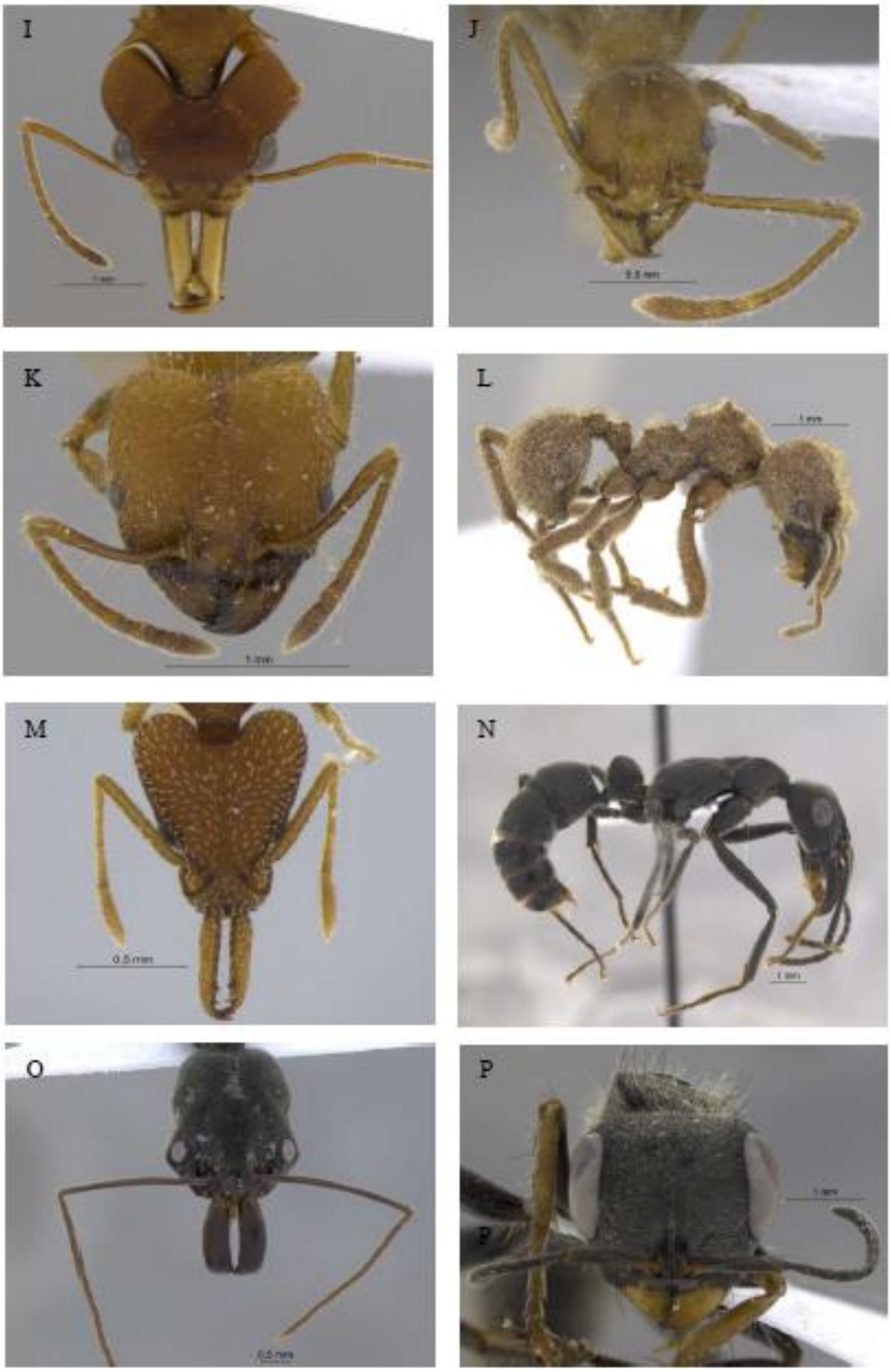
Wilson, E.O. 2003. *Pheidole* in the New World: A dominant, hyperdiverse ant genus. Harvard University Press, Cambridge, 818p.

Agradecimentos: Agradecemos aos colegas Vinicius Soares, Mariana Silva, Bruna E.

Valério, Bruno Carvalho pelo auxilio nas coletas. Ao Prof. Dr. Carlos R. F. Brandão (MZSP) pela disponibilização da Automontagem do Laboratório de Hymenoptera do MZSP. REV agradece a CAPES pela bolsa de Doutorado e LPP pela bolsa de mestrado. TJI agradece a Capes (BEX 2548-14-3) pelo auxílio financeiro. Também ao Conselho Nacional de Pesquisas (CNPq - processo nº 479243/2012–3, 558225/2009-8, 501408/2009-6 e 457466/2012-0) pelo apoio financeiro. À Secretaria Estadual de Meio Ambiente pelo apoio financeiro através do Programa Áreas Protegidas da Amazônia - ARPA e permissão para acessar a área de estudo. À UFMT pelo suporte logístico.



Fauna de formigas do Parque Estadual do Cristalino: Figura A) *Dolichoderus* sp., B) *Eciton* sp., C) *Gnamptogenys* sp., D) *Camponotus* sp., E) *Gigantiops* sp., F) *Apterostigma* sp., G) *Cephalotes* sp., H) *Crematogaster* sp.



Fauna de formigas do Parque Estadual do Cristalino: Figura I) *Daceton* sp., J) *Pheidole* sp. (operária menor), K) *Pheidole* sp. (operária menor), L) *Sericomyrmex* sp., M) *Strumigenys* sp., N) *Neoponera* sp., O) *Odontomachus* sp., P) *Pseudomyrmex* sp.

ANEXO 2 - Amazon rainforest ant-fauna of Parque Estadual do Cristalino: Understory and ground-dwelling ants

Artigo publicado pela revista Sociobiology (ISSN: 0361-6525; Classificação CAPES: B2):

Vicente, R.E., Prado, L.P. & Izzo, T.J. (2016) Amazon Rainforest Ant-Fauna of Parque Estadual do Cristalino: Understory and Ground-Dwelling Ants. Sociobiology 63 (3).
doi:10.13102/sociobiology.v63i3.1043

Corresponding author: Ricardo Eduardo Vicente
E-mail: ricardomyrmex@gmail.com

Amazon Rainforest Ant-Fauna of Parque Estadual do Cristalino: Understory and Ground-Dwelling Ants

RE Vicente[1,2], LP Prado[3,4], TJ Izzo[1,2]

[1] Laboratório de Ecologia de Comunidades do Instituto de Biologia da Universidade Federal de Mato Grosso, Cuiabá, MT, Brazil.

[2] P.P.G. Ecologia e Conservação da Biodiversidade da Universidade Federal do Mato Grosso, Cuiabá, MT, Brazil.

[3] Laboratório de Sistemática, Evolução e Biologia de Hymenoptera do Museu de Zoologia da Universidade de São Paulo, São Paulo, SP, Brazil.

[4] P.P.G. Sistemática, Taxonomia e Diversidade Animal do MZSP, São Paulo, Brazil.

Running title: Amazon Rainforest Ant-fauna of Parque Estadual do Cristalino

Abstract - Ants are ecologically dominant and have been used as valuable bio-indicators of environmental change or disturbance being used in monitoring inventories. However, the majority of inventories have concentrated on ground-dwelling ant fauna disregarding arboreal fauna. This paper aimed to list the ant species collected both on the ground and in the vegetation of the Parque Estadual do Cristalino, an important protected site in the center of the southern Amazon. Moreover, we compared the composition of the ground dwelling and vegetation foraging ants. Two hundred and three (203) species distributed among 23 genera and eight subfamilies were sampled, wherein 34 species had not yet been reported in the literature for Mato Grosso State. As expected, the abundance and richness of ants was higher on the ground than in the understory. Also, the composition of the ant assemblages was different between these habitats (with only 20% occurring in both) indicating that complementary methods which include arboreal and terrestrial ants are indicated for efficient inventory. This study provides an inventory of the arboreal and ground ant fauna contributing to the knowledge and conservation of Amazonian ant fauna.

Keywords: Arboreal ants; Conservation; Diversity; Formicidae; Inventory.

INTRODUCTION

Ants are ecologically dominant, playing several ecosystem services in the environment (Del Toro *et al.*, 2012) and occupying the most varied habitats (Bruhl *et al.*, 1998; Dejean *et al.* 2015; Rocha et al. 2015; Pape *et al.*, 2016). Ants strongly influence several terrestrial communities due to their abundance and potential relationships with various biological groups. The interactions of ants can be positive or negative, ranging from interactions with microorganisms (Hanshew *et al.*, 2014; Sanders *et al.*, 2014), plants (Izzo & Vasconcelos, 2009; Vicente *et al.*, 2012, 2014; Koch *et al.*, 2015) and other invertebrates (Dáttilo *et al.*, 2012a; Freitas & Rossi, 2015; Puker *et al.*, 2015), even other ants (Adams *et al.*, 2007; Sanhudo *et al.*, 2008; Gallego-Ropero & Feitosa, 2014). Therefore, ants have been used as a model to understand the various ecological patterns and as valuable bio-indicators of environmental change or disturbance (Andersen *et al.*, 2002; Bruna *et al.*, 2014; Falcão *et al.*, 2015).

Regardless of their ecological importance and diversity, studies on Brazilian ant fauna were usually concentrated in the Atlantic Forest (Feitosa & Ribeiro, 2005; Figueiredo *et al.*, 2013; Silva *et al.*, 2007), the Cerrado (Dáttilo *et al.*, 2012b; Silva & Brandão, 2014; Camacho & Vasconcelos, 2015), and Pantanal (Ribas & Schoereder, 2007; Silva *et al.*, 2013; Meurer *et al.*, 2015). Although the Amazon is one of the largest and heterogeneous tropical forests remaining, the panorama is not different. The studies of Amazonian ants in Brazil are generally concentrated in small parts of the Central region (e.g. Vasconcelos *et al.*, 2006, 2010; Santos *et al.*, 2007; Baccaro *et al.*, 2013; Souza *et al.*, 2012). Studies in the southern Amazon region are few, and because they focus on local ecological patterns, the list of species therein usually does not have confirmation of specialists and comprises a large number of morphospecies (for example: Dáttilo *et al.*, 2013; Falcão *et al.*, 2015). The absence of surveys in this area is particularly problematic to the knowledge of the distribution of ant diversity in the tropics. More than being a frontier between the Amazonia and Cerrado biomes, the south of Amazonia is a frontier of fast agricultural expansion, being subject to enormous rates of deforestation (Fearnside, 2005). In such a scenario, several species could become, and probably some already have become extinct without being known by science. This is worrying in a region that has many species with unknown distribution (Vicente et al. 2011, 2012, 2015, 2016; Prado et al. 2016).

Whereas inventories are fundamental to promote conservation of tropical forest remnants and the ants are important components of biodiversity, this work aims to contribute to the knowledge of the Amazonian ground-dwelling and arboreal ant fauna. The reserve is a *terra firme* Tropical Rainforest located in the Southern Amazon, but with little known diversity of various taxa. In this study, we list the fauna of ground-dwelling ants and the assemblages of ants foraging on lower vegetation in the same site. We compared the difference between the strata in order to demonstrate the increase in local biodiversity by using a simple additional method.

MATERIAL AND METHODS

Study area

The surveys were conducted in an Amazonian Research Program Station in Biodiversity in the Brazilian Parque Estadual do Cristalino (henceforward PEC), with RAPELD methodology (see Magnusson *et al.*, 2005). The park is a large protected area defined as “Priority for Conservation Site” (Ministério do Meio Ambiente [MMA], 2001) that hosts an area of 184,900 ha, situated in the middle of an area called “Arc of Deforestation” (Fearnside, 2005), comprising the Brazilian municipality of Alta Floresta and Novo Mundo, state of Mato Grosso bordering on Pará state. The research study was carried in a station installed in the north of the park (9° 32'47 "S, 55° 47'38" W) (Fig 1) in the municipality of Novo Mundo. The vegetation is characterized as transition zones between ombrophilous and seasonal forest, seasonal forest and savanna (Cerrado), and ombrophilous and savanna (Cerrado) (Instittituto Brasileiro de Geografia e Estatística [IBGE], 2004).

Ant sampling

The inventory of ants was conducted between November 2012 (begining of the rainy season with sporadic rains) and May 2013 (end of the rainy season with sporadic rains) in 11 trails 250m long, with a distance between sites of at least 1 km. In each trail, ants were collected every 25m, resulting in 20 samples per trail (10 samples of the ground-dwelling ants and 10 samples of the arboreal ants) and totaling 220 samples (110 samples of ground-dwelling ants and 110 samples of arboreal ants). The collection of the ground ant assemblages was made using a single pitfall trap that remains installed for 48 hours in each sample point. For sampling arboreal ants a beating-tray method was used in vegetation of understory. In each of these points, we selected the four treelets equidistant of about 2 m of the pitfall. Under each treelet, a white canvas was installed to prevent some ants from jumping and getting away from the sampling (Dáttilo *et al.*, 2013), and about one meter from the ground to prevent ants from walking on the ground and climbing on the canvas. Then all vegetation in each treelet within 1m² with between 1-3 meters in height was steadily shaken and the ants that fell on the canvas were properly collected. The sampling of ground and arboreal ants was carried out concomitantly, so the sampling of arboreal ants was performed between 9 am and 3 pm on the same day that the pitfall was removed.

Ant identification

Ants collected initially were identified using dichotomous key for subfamilies and genera available in Baccaro et al. (2015). So as to separate into morphospecies and identify to a specific level we used several taxonomic keys (Brandão, 1990; Fernández, 2003; Longino, 2003a; MacKay & MacKay, 2010; Fernandes *et al.*, 2014). Posteriorly we made comparisons with specimens deposited at the Laboratório de Ecologia de Comunidades from the Centro de Biodiversidade da Universidade Federal de Mato Grosso (UFMT) and the ant collection from the Laboratório de Sistemática, Evolução e Biologia de Hymenoptera from the Museu de Zoologia da Universidade de São Paulo (MZSP). We also consulted specialists to confirm species identification (see acknowledgments). Vouchers were deposited in the collections mentioned above. After the identification and confirmation by specialists we consulted the distribution of each species using the AntMaps (Janicki *et al.*, 2016), a new interactive tool recently used by taxonomists and ecologists (Gérnard & Economo, 2015; Vicente *et al.*, 2015; Santos-Silva *et al.* 2016; Wepfer *et al.*, 2016). This tool comprises the geographic distributions of more than 15,000 species/subspecies in over 1.7 million records of about 8,650 publications, museum collections and specimen databases (Janicki *et al.*, 2016). Furthermore, we researched in bibliographic references related to taxonomy of species or lists of ants from region.

Data analysis

We carried out a t-test to access the difference of ant abundance and richness patterns between ground and understory. Because ants are social insects, the sampled abundance of workers in pitfalls may be strongly related to the proximity to the nest (Gotelli *et al.*, 2011) or workers' number in a colony, which varies greatly between species (Baccaro *et al.*, 2015). To minimize this effect, we treated the abundance as sample-based occurrences (Gotelli *et al.*, 2011) as is commonly done in studies with ants (Ryder-Wilkie *et al.*, 2010; Dáttilo & Izzo, 2012; Baccaro *et al.*, 2013). To access the distribution patterns of the ant assemblages we performed an ordenation with Principal Coordinate Analysis (PCoA) technique based on a matrix of Raup-Crick dissimilarity measures calculated in a binary matrix with presence and absence date. Raup-Crick was used because it is a robust index that calculates how different pairwise samples are than expected by chance implementing null models which consider the variation in the number of local species and alpha diversity (Chase *et al.*, 2011). This index is frequently used to compare the dissimilarity of invertebrate communities between different habitats (Ryder-Wilkie *et al.*, 2010; Ribas *et al.*, 2012; Reis *et al.*, 2013). We utilized the first two PCoA axis (which represented 66.76 % of explication) in a Multivariate Analysis of Variance (MANOVA) as dependent variables and vertical habitat (ground and understory) as a factor. All analysis were performed with R-software (R Core Team, 2015) using the Vegan-package (Oksanen *et al.*, 2015).

RESULTS

We recorded 1,581 occurrences of ants in the 220 samples. The ants collected belong to 203 species, 45 genera and eight subfamilies. Subfamilies with greater richness were Myrmicinae with 23 genera and 113 species, Ponerinae with eight genera and 23 species and Formicinae with five genera and 27 species. The genus with greater richness was *Pheidole* (37 species), *Camponotus* (17), *Neoponera* and *Crematogaster* (both 10 species).

Both abundance ($p < 0.001$) and richness ($p < 0.001$) of ants were different between the vertical strata (Table 1 – Fig 2), being greater on the ground than on the understory. We collected almost 63.4% of ant occurrences (total: 1,002, mean: 89.1, SD: ±26.3 per sample) and 65% of ant species (total: 143 species, mean: 47.91, SD: ±10.26) on the ground stratum. The understory showed a total of 579 occurrences (mean: 51±, SD: 15.1) and a total of 100 species (mean: 26.6, ±SD: 6.67). Of these 203 species, 164 species were restricted to a vertical stratum with 104 species collected only on the ground and 60 only on the understory, and just 39 species collected in both strata (Table 2). Although on average 41.09 species by trail (±SD: 9.07) were exclusive to the ground, there is a mean increase of 19.73 species by trail (±SD: 5.85) by adding beating tray in the ant collection. Only one subfamily (Amblyoponinae) was sampled exclusively on the ground. Consequently, the species composition was different between the habitats (MANOVA - Pillai-Trace: 0.852, $F_{1,20}$: 54.873, $p < 0.001$ – Fig 3). Among the species sampled, 34 were recorded for the first time for Mato Grosso State, Brazil (Table 2).

DISCUSSION

Of the inventories on ant assemblages conducted in the Amazon, the major part of the studies focused just on ground-dwelling ants (Miranda *et al.*, 2012; Souza et al., 2012, 2015; Baccaro *et al.*, 2013) and few comprised both terrestrial and arboreal ant fauna detailing the strata in which each species was collected (e.g.: Vasconcelos & Vilhena, 2006; Ryder-Wilkie *et al.*, 2010). These few studies carried out in the Amazon embracing both soil and vegetation ants have demonstrated extremely different ant assemblages between these habitats (Vasconcelos & Vilhena, 2006; Ryder-Wilkie *et al.*, 2010). The methods employed here are very different. The both methods capture active foraging ants, however the pitfall traps were active during day and night whereas the beating tray method was used only during the day. This can explain the small number of species collected on vegetation, preventing strong inferences towards the patterns of species richness. However we observed a strong turnover on ant composition, since only about 20% of all collected species were sampled both on the ground and on vegetation. Hence, even missing several nocturnal species on vegetation strata, the species collected just on vegetation were certainly absent on ground strata. Therefore, the vertical stratification in the ant fauna is a robust ecological pattern found in both the Amazon forest and in other biomes (Bruhl *et al.*, 1998; Vasconcelos & Vilhena, 2006; Neves *et al.*, 2013; Camacho & Vasconcelos, 2015). Additionally our results indicate that, using an additional simple method focusing on vegetation foraging ants, as beating-tray, one can increase the number of collected species. Therefore, besides the vegetation foraging ant community can show different ecological patterns they contribute to our understanding of the real ant biodiversity in an area and, as well as the knowledge of biogeographical patterns.

The Amblyoponinae subfamily, considered as a basal group in the evolution of ants (Saux *et al.*, 2004), as well as the 18 other genera were sampled exclusively on the ground.

Among these genera collected only in soil are the fungus-growing ants *Atta*, *Mycetarotes*, *Mycocepurus*, *Myrmicocrypta* and *Sericomyrmex*. These ants nest directly on the ground or in rotten wood in contact with the soil (Baccaro *et al.*, 2015). Except for the *Atta* species which climbs into vegetation to cut fresh vegetable matter, the other abovementioned species take advantage of organic matter found in litter such as fallen leaves, fruits, flowers, feces and corpses (Leal & Oliveira, 2000; Mayhé-Nunes & Brandão, 2006). *Hylomyrma immans*, *Octostruma balzani, Rogeria scobinata* and three unidentified *Hypoponera* species also were collected exclusively in the soil. These genera have species with cryptic behavior (Lapolla & Sosa-Calvo, 2006; Longino, 2013b). The sampling of only one *Daceton armigerum* worker on the ground should be considered as an accidental record, since species of this genus have adaptations such as hook-shaped claws which provide remarkable adhesion to the arboreal substrate (Billen *et al*., 2016) where they nest in tree branches (Azorsa & Sosa-Calvo, 2008; Vicente *et al.*, 2011) and forage (Dejean *et al.*, 2012).

Despite their hypogeal origin, ants diversify occupying other habitats (Lucky *et al.*, 2013) and the occupation of the arboreal environment resulted in morphological and behavioral adaptations both to get around and feed on available resources in vegetation (Orivel & Dejean, 1999; Dejean *et al.*, 2005). These adaptations were observed in the various *Neoponera* species sampled. *Neoponera* is composed mainly by arboreal behavior species (Schmidt & Shattuck, 2014) that live or forage on vegetation, and have morphological adaptations regarding modifications on claws, shape and adhesion (Orivel *et al.*, 2001). Four other genera were restricted to vegetation: *Azteca*, *Myrmelachista, Nesomyrmex* and *Tapinoma*. Species of these genera usually nest on plants (Longino, 2007; Nakano *et al.*, 2013; Longino, 2004). *Cephalotes* was another genus with a greater number of arboreal species, with just *C. atratus* being collected in both strata. The *Cephalotes* ant genus has as their main features a diet based largely on pollen and nectar and nesting in pre-existing plant cavities (Byk & Del-Claro, 2010), however, *C. atratus* can often be found foraging on the ground (Corn, 1980). Although some subfamilies as Pseudomyrmecinae and Dolichoderinae had a large proportion of species collected in the vegetation, no subfamily has been sampled exclusively to only this vertical strata. In Pseudomyrmecinae, only *Pseudomyrmex tenuis* was collected in both soil (one worker) and vegetation (seven workers). *P. tenuis* is a widespread ant species, frequently sampled foraging in all strata as epigaeic, arboreal and canopy stratum (Vasconcelos & Vilhena, 2006; Neves *et al.*, 2013; Camacho & Vasconcelos, 2015; Souza *et al.*, 2015). Also, in a Dolichoderinae subfamily with 18 ant species, only five species of *Dolichoderus* genus, occurred also on the ground.

Camponotus genus was particularly representative (17 species; 84 samples) in relation to the total number of collected species (5.6%). In two areas of Central Amazon, both in Amazonas state, Brazil, *Camponotus* species comprises 2.7% and 2.3% of total species collect on the ground (Souza *et al.*, 2015). In addition, in the Central South Amazon this proportion ranges from 1.99% to 4.62% of ground ants in preserved areas of Rondônia state (Souza *et al.*, 2015). On the other hand, in samples made in ground and understory of patches of forest in Southern Amazon in Rondonia state and Central East Amazon in Pará state, both in Brazil, there was a ratio of 9.33% and 7.09%, respectively (Santos-Silva et al. 2016; Vasconcelos *et al.*, 2006). Therefore, this high proportion of *Camponotus* found in the Parque Estadual do Cristalino confirm that simple methodologies could sampled a greater number of considered arboreal ant species, such as *Camponotus*.

Mato Grosso State is the third largest state in Brazil, hosting three different Biomes and the many new records in an inventory (18 species collected in the soil, seven in vegetation and 10 in both strata) demonstrating a gap or shortcoming related mainly to the lack of surveys throughout the South American territory (but see: Kempf 1972; Brandão

1991; Silva *et al.*, 2013; Meurer *et al.*, 2015). Although there are a number of studies on the ecology and distribution of ants in the Amazon in northern Mato Grosso (Dáttilo *et al.*, 2013; Falcão *et al.*, 2015; Vicente *et al.*, 2011, 2012, 2014, 2015) this is the first list of ant species for the region, as well as being the most complete list published until now for the southern Amazon. In summary, this work demonstrates that inventories should consider ants of both ground and vegetation for a better sampling of local ant diversity. In addition, the number of new records of ant fauna (35 species) for Mato Grosso state and the number of unnamed species (97 morphospecies), show that the ant fauna of the Amazon in general are not common or are extremely unknown. The tropical forests are being increasingly threatened by anthropic activities and Mato Grosso state in particular because they are located in a region with a historically strong pressure for disturbance, being an agricultural frontier. Therefore, efforts should be made to understand ant diversity distribution patterns and propose conservation strategies in this region.

ACKNOWLEDGMENTS

We thank the researchers Vinicius Soares, Mariana Silva, Bruna E. Valério and Bruno Carvalho for assistance in field data collection. REV and LPP thanks Coordenação de Aperfeiçoamento de Pessoal de Nível Superior [CAPES] to their PhD and Master scholarship (respectively). TJI thanks CAPES (BEX 2548-14-3) to financial support. Furthermore, we thanks Conselho Nacional de Pesquisas (CNPq - 479243/2012–3, 558225/2009-8, 501408/2009-6 e 457466/2012-0) for fund research and Secretária Estadual de Meio Ambiente and Universidade Federal de Mato Grosso for logistical support. We also thank to Alexandre Ferreira [UFPR], Gabriela Camacho [UFPR], Itanna Fernandes [INPA], Jorge Souza [INPA], Lina Hernández [IAVH], Mônica Ulysséa [MZSP] and Thiago Silva [UFPR] for their help with the identification of the ant species and Antônio Queiroz (UFLA) and two anonymous reviewers for the critical review of the

manuscript. This work is publication 53 in the NEBAM technical series.

REFERENCES

Adams, R.M.M. & Longino, J. (2007). Nesting biology of the arboreal fungus-growing ant *Cyphomyrmex cornutus* and its social parasite *Megalomyrmex mondabora*. Insect. Soc., 54(2): 136-143. doi: 10.1007/s00040-007-0922-0

Andersen, A.N., Hoffmann, B.D., Müller, W.J. & Griffiths, A.D. (2002). Using ants as bioindicators in land management: simplifying assessment of ant community responses. J. Appl. Ecol., 39: 8-17. doi: 10.1046/j.1365-2664.2002.00704.x

Azorsa, F. & Sosa-Calvo, J. (2008). Description of a remarkable new species of ant in the genus *Daceton* Perty (Formicidae: Dacetini) from South America. Zootaxa 1749: 27-38.

Baccaro, F.B., Feitosa, R.M., Fernández, F., Fernandes, I.O., Izzo, T.J., Souza, J.L.P. & Solar, R. (2015). Guia para os gêneros de formigas do Brasil. Manaus: Editora INPA. doi: 10.5281/zenodo.32912

Baccaro, F.B., Rocha, I.F., Del Aguila, B.E.G., Schietti, J., Emilio, T., Pinto, J.L.P.D.V., Lima, A.P. & Magnusson, W.E. (2013). Changes in ground-dwelling ant functional diversity are correlated with water-table level in an Amazonian Terra Firme forest. Biotropica, 45: 755–763. doi: 10.1111/btp.12055

Brandão, C.R.F. (1990). Systematic revision of the Neotropical ant genus *Megalomyrmex* Forel (Hymenoptera: Myrmicinae), with the description of thirteen new species. Arq. Zoo., 31(4):411-494. doi: 10.11606/issn.2176-7793.v31i5p1-91

Brandão, C.R.F. (1991). Adendos ao catalogo abreviado das formigas da regiao neotropical (Hymenoptera: Formicidae). Rev. Bras. Entomol., 35: 319-412.

Billen, J., Al-Khalifa, M.S. & Silva, R.R. (2016) Pretarsus structure in relation to climbing ability in the ants *Brachyponera sennaarensis* and *Daceton armigerum*. Saudi

Journal of Biological Sciences. doi:10.1016/j.sjbs.2016.06.007

Bruhl, C.A., Gunsalam, G. & Linsenmair, K.E. (1998). Stratification of ants (Hymenoptera: Formicidae) in a primary rain forest in Sabah, Borneo. J. Trop. Ecol., 14: 295-297.

Bruna, E.M., Izzo, T.J., Inouye, B.D. & Vasconcelos, H.L. (2014). Effect of mutualist partner identity on plant demography. Ecology, 95: 3237-3243. doi: 10.1890/14-0481.1

Byk J. & Del-Claro, K. (2010). Nectar- and pollen-gathering *Cephalotes* ants provide no protection against herbivory: a new manipulative experiment to test ant protective capabilities. Acta Ethol., 13: 33-38. doi: 10.1007/s10144-010-0240-7

Camacho, G.P. & Vasconcelos, H.L. (2015). Ants of the Panga Ecological Station, a Cerrado Reserve in Central Brazil. Sociobiology, 62: 281-295. doi: 10.13102/sociobiology.v62i2.281-295

Chase, J.M., Kraft, N.J.B., Smith, K.G., Vellend, M. & Inouye, B.D. (2011). Using null models to disentangle variation in community dissimilarity from variation in α-diversity. Ecosphere, 2: 1-11. doi: 10.1890/ES10-00117.1

Corn, M.L. (1980). Polymorphism and polyethism in the neotropical ant *Cephalotes atratus* (L.). Insect. Soc., 27(1): 29-42. doi: 10.1007/BF02224519

DaRocha, W.D.; Ribeiro, S.P.; Neves, F.; Fernandes, G.W.; Leponce, M. & Delabie, J.H.C. (2015). How does bromeliad distribution structure the arboreal ant assemblage (Hymenoptera: Formicidae) on a single tree in a Brazilian Atlantic forest agroecosystem?. Myrmecological News, 21:83-92.

Dáttilo, W. & Izzo, T.J. (2012). Temperature Influence on Species Co-Occurrence Patterns in Treefall Gap and Dense Forest Ant Communities in a Terra-Firme Forest of Central Amazon, Brazil. Sociobiology, 59(2): 351-367. doi: 10.13102/sociobiology.v59i2.599

Dáttilo, W., Martins, R.L., Uhde, V., Noronha, J.C., Florêncio, F.P. & Izzo, T.J.

(2012a). Floral resource partitioning by ants and bees in a jambolan Syzygium jambolanum (Myrtaceae) agroforestry system in Brazilian Meridional Amazon. Agroforest. Syst., 85: 105-111. doi:10.1007/s10457-012-9489-5

Dáttilo, W., Rico-Gray, V., Rodrigues, D.J. & Izzo, T.J. (2013). Soil and vegetation features determine the nested pattern of ant–plant networks in a tropical rainforest. Ecol. Entomol., 38: 374-380. doi: 10.1111/een.12029

Dáttilo, W., Vicente, R.E., Nunes, R.V. & Feitosa, R. (2012b). Influence of cave size and presence of bat guano on ant visitation. Sociobiology, 59(2): 549-559. doi: 10.13102/sociobiology.v59i2.617

Dejean, A., Delabie, J.H.C., Corbara, B., Azémar, F., Groc, S., Orivel, J. & Leponce, M. (2012). The ecology and feeding habits of the arboreal trap-jawed ant *Daceton armigerum*. Plos One, 7(6): e37683. doi: 10.1371/journal.pone.0037683

Dejean, A., Groc, S., Hérault, B., Rodriguez-Pérez, H., Touchard, A., Céréghino, R., Delabie, J.H.C. & Corbara, B. (2015). Bat aggregation mediates the functional structure of ant assemblages. Comptes Rendus Biologies 338(10): 688-695. doi:10.1016/j.crvi.2015.06.011.

Dejean, A., Solano, P.J., Ayroles, J., Corbara, B. & Orivel, J. (2005). Arboreal ants build traps to capture prey. Nature 434: 973. doi: 10.1038/434973a.

Del Toro, I., Ribbons, R.R. & Pelini, S.L. (2012). The little things that run the world revisited: a review of ant-mediated ecosystem services and disservices (Hymenoptera: Formicidae). Myrmecological News, 17: 133-146.

Falcão, J.C.F., Dáttilo, W. & Izzo, T.J. (2015). Efficiency of different planted forests in recovering biodiversity and ecological interactions in Brazilian Amazon. Forest Ecol. Manag., 339: 105-111. doi: 10.1016/j.foreco.2014.12.007

Fearnside, P.M. (2005). Deforestation in Brazilian Amazonia: History, Rates, and Consequences. Conserv. Biol., 19: 680-688. doi: 10.1111/j.1523-1739.2005.00697.x

Feitosa, R.M. & Ribeiro, A.S. (2005). Mirmecofauna (Hymenoptera, Formicidae) de serapilheira de uma área de Floresta Atlântica no Parque Estadual da Cantareira - São Paulo, Brasil. Biotemas, 18(2): 51-71.

Fernandes, I.O., Oliveira, M.L. & Delabie, J.H.C. (2014). Description of two new species in the Neotropical *Pachycondyla foetida* complex (Hymenoptera: Formicidae: Ponerinae) and taxonomic notes on the genus. Myrmecological News, 19: 133-163.

Fernández, F. (2003). Myrmicine ants of the genera *Ochetomyrmex* and *Tranopelta* (Hymenoptera: Formicidae). Sociobiology, 41:633-661.

Figueiredo, C.J.; Silva, R.R.; Munhae, C.B. & Morini, M.S.C. (2013). Ant fauna (Hymenoptera: Formicidae) attracted to underground traps in Atlantic Forest. Biota Neotropica, 13(1): 176-182. doi: 10.1590/S1676-06032013000100020

Freitas, J.D. & Rossi, M.N. (2015). Interaction between trophobiont insects and ants: The effect of mutualism on the associated arthropod community. Journal of Insect Conservation. doi: 10.1007/s10841-015-9785-2

Gallego-Ropero, M.C. & Feitosa, R.M. (2014). Evidences of batesian mimicry and parabiosis in ants of the Brazilian Savanna. Sociobiology, 61: 281-285. doi:10.1007/s10841-015-9785-2

Gotelli, N.J.G., Ellison, A.M., Dunn, R.R. & Sanders, N.J. (2011). Counting ants (Hymenoptera: Formicidae): biodiversity sampling and statistical analysis for myrmecologists. Myrmecological News, 15: 13-19.

Guénard, B. & Economo, E.P. (2015). Additions to the checklist of the ants (Hymenoptera: Formicidae) of Peru. Zootaxa, 4040(2): 225-235. doi: 10.11646/zootaxa.4040.2.8

Hanshew, A.S., McDonald, B.R., Díaz-Díaz, C., Djieto-Lordon, C., Blatrix, R. & Currie, C.R. (2014). Characterization of Actinobacteria Associated with Three Ant–Plant Mutualisms. Microbial Ecol., 69(1): 192-203. doi: 10.1007/s00248-014-0469-3

Instituto Brasileiro de Geografia e Estatística. 2004. Mapa da vegetação brasileira. 3ª edição. Ministério do Planejamento, Orçamento e Gestão.

Izzo T.J. & Vasconcelos H.L. (2002). Cheating the cheater: domatia loss minimizes the effects of ant castration in an Amazonian ant–plant. Oecologia, 133: 200-205. doi: 10.1007/s00442-002-1027-0.

Janicki, J., Narula, N., Ziegler, M., Guénard, B. & Economo, E.P. (2016). Visualizing and interacting with large-volume biodiversity data using client-server web-mapping applications: The design and implementation of antmaps.org. Ecological Informatics, 32: 185-193.

Kempf W.W. (1972). Catalago abreviado das formigas da região Neotropical (Hym. Formicidae). Studia Entomologica, 15:1-4.

Koch, E.B.A., Camarota, F. & Vasconcelos, H.L. (2016). Plant Ontogeny as a Conditionality Factor in the Protective Effect of Ants on a Neotropical Tree. Biotropica, 48: 198–205. doi: 10.1111/btp.12264

Lapolla, J.S. & Sosa-Calvo, J. (2006). Review of the ant genus *Rogeria* (Hymenoptera: Formicidae) in Guyana. Zootaxa, 1330: 59-68.

Leal, I.R. & Oliveira, P.S. (2000). Foraging ecology of attine ants in a Neotropical savanna: seasonal use of fungal substrate in the cerrado vegetation of Brazil. Insect. Soc., 47: 376-382. doi: 10.1007/PL00001734

Longino, J.T. (2003a). The *Crematogaster* (Hymenoptera, Formicidae, Myrmicinae) of Costa Rica. Zootaxa, 151: 1-150.

Longino, J.T. (2004). Ants of Costa Rica. http://academic.evergreen.edu/projects/ants/Genera.html. (accessed date: 20 July, 2015).

Lucky, A., Trautwein, M.D., Guénard, B.S., Weiser, M.D. & Dunn, R.R. (2013). Tracing the Rise of Ants - Out of the Ground. PLoS ONE, 8(12): e84012. doi: 10.1371/journal.pone.0084012

MacKay, W.P. & MacKay, E.E. (2010). The systematics and biology of the New World ants of the genus *Pachycondyla* (Hymenoptera: Formicidae). Edwin Mellen: Press Lewiston, NY.

Magnusson, W.E., Lima, A.P., Luizão, R., Luizão, F., Costa, F.R.C., Castilho, C.V. & Kinupp, V.P. (2005). RAPELD: a modification of the Gentry method for biodiversity surveys in long-term ecological research sites. Biota Neotropica, 5: 19-24.

Mayhé-Nunes, A.J. & Brandão, C.R.F. (2006). Revisionary notes on the fungus-growing ant genus *Mycetarotes* Emery (Hymenoptera, Formicidae). Revista Brasileira de Entomologia, 50: 463-72. doi: 10.1590/S0085-56262006000400005

Meurer, E., Battirola, L.D., Delabie, J.H.C. & Marques, M.I. (2015). Influence of the Vegetation Mosaic on Ant (Formicidae: Hymenoptera) Distributions in the Northern Brazilian Pantanal. Sociobiology, 62(3): 382-388. doi:10.13102/sociobiology.v62i3.359

Miranda, P.N., Oliveira, M.A., Baccaro, F.B., Morato, E.F. & Delabie, J.H.C., (2012). Check list of ground-dwelling ants (Hymenoptera: Formicidae) of the eastern Acre, Amazon, Brazil. Check List, 8: 722-730.

Ministério do Meio Ambiente (2001). Avaliação e identificação de ações prioritárias para a conservação, utilização sustentável e repartição dos benefícios da biodiversidade na amazônia brasileira. Brasília: Ministério do Meio Ambiente, MMA/SBF.

Nakano, M.A., Miranda, V.F.O., Souza, D.R., Feitosa, R.M. & Morini, M.S.C. (2013). Occurrence and natural history of *Myrmelachista* Roger (Formicidae: Formicinae) in the Atlantic Forest of southeastern Brazil. Revista Chilena de Historia Natural, 86: 169-179.

Neves, F., Queiros-Dantas, K.S., Rocha, W.D. & Delabie, J.H.C. (2013). Ants of three adjacent habitats of a transition region between the Cerrado and Caatinga Biomes: The effects of heterogeneity and variation in canopy cover. Neotropical Entomology, 42: 258-268. doi: 10.1007/s13744-013-0123-7

Oksanen, J., Blanchet, F.G., Kindt, R., Legendre, P., Minchin, P.R., O'Hara, R.B., Simpson, G.L., Solymos, P., Stevens M.H.H. & Wagner H. (2015). vegan: Community Ecology Package. R package version 2.3-0. http://CRAN.R-project.org/package=vegan. (accessed date: 20 November, 2015).

Orivel J. & Dejean A. (1999). L'adaptation á la vie arboricole chez les fourmis. L'Année biologique. 38: 1-18.

Orivel, J., Malherbe, M.C. & Dejean, A. (2001). Relationships between pretarsus morphology and arboreal life in ponerine ants of the genus *Pachycondyla* (Formicidae: Ponerinae). Ann. Entomol. Soc. Am., 94: 449-456.

Prado, L.P.; Vicente, R.E.; Silva, T.S.R. & Souza, J.L. (2016). *Strumigenys fairchildi* Brown, 1961 (Formicidae, Myrmicinae): First record of this rarely collected ants from Brazil. Check List, 12(4): 1-5. doi: 10.15560/12.4.1922

Puker, A., Rosa, C.S., Orozco, J., Solar, R.R.C. & Feitosa, R.M. (2015). Insights on the association of American Cetoniinae beetles with ants. Entomol. Science, 18: 21-30. doi: 10.1111/ens.12085

R Core Team (2015). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/. (accessed date: 20 November, 2015).

Reis, P.C.J., DaRocha, W.D., Falcão, L.A.D., Guerra, T.J. & Neves F.S., 2013. Ant fauna on *Cecropia pachystachya* Trécul (Urticaceae) trees in an Atlantic Forest Area, Southeastern Brazil. Sociobiology 60(3): 222-228. doi:10.13102/sociobiology.v60i3.222-228

Ribas, C.R., Schmidt, F.A., Solar, R.R.C., Campos, R.B.F., Valentim, C.L. & Schoereder, J.H. (2012). Ants as Indicators of the Success of Rehabilitation Efforts in Deposits of Gold Mining Tailings. Restor. Ecol., 20: 712-720. doi: 10.1111/j.1526-100X.2011.00831.x

Ribas, C.R. & Schoereder, J.H. (2007). Ant communities, environmental characteristics and their implications for conservation in the Brazilian Pantanal. Biodivers. Conserv., 16: 1511-1520. doi: 10.1007/s10531-006-9041-x

Ryder-Wilkie, K.T., Mertl, A.L. & Traniello, J.F.A. (2010). Species diversity and distribution patterns of the ants of Amazonian Ecuador. Plos One, 5(10): e13146. doi: 10.1371/journal.pone.0013146

Sanders, J.G., Powell, S., Kronauer, D.J., Vasconcelos, H.L., Frederickson, M.E. & Pierce, N.E. (2014). Stability and phylogenetic correlation in gut microbiota: lessons from ants and apes. Mol. Ecol., 23: 1268-1283. doi:10.1111/mec.12611

Sanhudo, C.E.D., Izzo, T.J. & Brandão, C.R.F. (2008). Parabiosis between basal fungus-growing ants (Formicidae, Attini). Insect. Soc., 55: 296-300. doi: 10.1007/s00040-008-1005-6

Santos, I.A., Harada, A.I., Alves, S.B., Santos, M.P.D. & Ribas, C.R. (2007). Diversity of ants on palms in Varzea habitats at Amazonia (Hymenoptera: Formicidae). Sociobiology, 50: 23-33.

Santos-Silva, L., Vicente, R.E. & Feitosa, R.M. (2016). Ant species (Hymenoptera, Formicidae) of forest fragments and urban areas in a Meridional Amazonian landscape. Check List. 12(3):1-7. doi: 10.15560/12.3.1885.

Saux, C., Fisher, B.L. & Spicer, G.S. (2004). Dracula ant phylogeny as inferred by nuclear 28S rDNA sequences and implications for ant systematics (Hymenoptera: Formicidae: Amblyoponinae). Mol. Phylogenet. Evol., 33:457-68.

Schmidt, C.A. & Shattuck, S.O. (2014). The higher classification of the ant subfamily Ponerinae (Hymenoptera: Formicidae), with a review of ponerine ecology and behavior. Zootaxa, 3817(1): 1-242.

Silva, F.H.O., Delabie, J.H.C., Santos, G.B., Meurer, E. & Marques, M.I. (2013). Mini-winkler extractor and pitfall trap as complementary methods to sample Formicidae.

Neotropical Entomology, 42: 351-358. doi: 10.1007/s13744-013-0131-7

Silva, R.R. & Brandão, C.R.F. (2014). Ecosystem-wide morphological structure of leaf-litter ant communities along a tropical latitudinal gradient. Plos One, 9:e93049. doi: 10.1371/journal.pone.0093049

Silva, R.R., Feitosa, R.M. & Eberhardt, F. (2007). Reduced ant diversity along a habitat regeneration gradient in the southern Brazilian Atlantic Forest. Forest Ecol. Manag., 240: 61-69. doi: 10.1016/j.foreco.2006.12.002

Souza, J.L.P., Baccaro, F.B., Landeiro, V.L., Franklin, E., Magnusson, W.E., Pequeno, P.A.C.L. & Fernandes, I.O. (2015). Taxonomic sufficiency and indicator taxa reduce sampling costs and increase monitoring effectiveness for ants. Diversity and Distributions, doi: 10.1111/ddi.12371

Souza, J.L.P., Baccaro, F.B., Landeiro, V.L., Franklin, E. & Magnusson, W.E. (2012). Trade-offs between complementarity and redundancy in the use of different sampling techniques for ground-dwelling ant assemblages. Appl Soil Ecol., 56: 63-73. doi: 10.1016/j.apsoil.2012.01.004

Vasconcelos, H.L. & Vilhena, J.M.S. (2006). Species turnover and vertical partitioning of ant assemblages in the Brazilian Amazon: A comparison of forests and savannas. Biotropica, 38: 100-106. doi: 10.1111/j.1744-7429.2006.00113.x

Vasconcelos, H.L., Vilhena, J.M.S., Facure, C.G. & Albernaz, A.L.K.M. (2010). Patterns of ant species diversity and turnover across 2000km of Amazonian floodplain forest. J. Biogeogr., 37: 432-440. doi: 10.1111/j.1365-2699.2009.02230.x

Vasconcelos, H.L., Vilhena, J.M.S., Magnusson, W.E. & Albernaz, A.L.K.M. (2006). Long-term effects of forest fragmentation on Amazonian ant communities. J. Biogeogr., 33: 1348-1356. doi:10.1111/j.1365-2699.2006.01516.x

Vicente, R.E., Dambroz, J. & Barreto, M. (2011). New distribution record of *Daceton boltoni* Azorsa & Sosa-Calvo, 2008 (Insecta: Hymenoptera) ant in the Brazilian

Amazon. Check List, 7: 878-879. doi: 10.15560/7.6.878

Vicente, R.E., Dáttilo, W. & Izzo, T.J. (2012). New record of a very specialized interaction: *Myrcidris epicharis* Ward 1990 (Pseudomyrmecinae) and its myrmecophyte host *Myrcia madida* McVaugh (Myrtaceae) in Brazilian Meridional Amazon. Acta Amazonica, 42: 567-570. doi: 10.1590/S0044-59672012000400016

Vicente, R.E., Dáttilo, W. & Izzo, T.J. (2014). Differential recruitment of *Camponotus femoratus* (Fabricius) ants in response to ant garden herbivory. Neotropical Entomology, 43: 519-525. doi: 10.1007/s13744-014-0245-6

Vicente, R.E., Prado, L.P. & Souza, R.C.L. (2015). Expanding the Distribution of the Remarkable Ant *Gnamptogenys vriesi* Brandão & Lattke (Formicidae: Ectatomminae): First Record From Brazil. Sociobiology, 62(4): 615-619. doi: 10.13102/sociobiology.v62i4.920

Wepfer, P., Guénard, B. & Economo, E.P. (2016). Influences of climate and historical land connectivity on ant beta diversity in East Asia. Journal of Biogeography. doi: 10.1111/jbi.12762

Table 1: Test-t measures for difference in abundance and richness between ground and arboreal ant assemblages.

Parameters	t	df	p-value
Abundance	4.1599	15.979	<0.001
Richness	5.7656	17.167	<0.001

Table 2: List of species recorded at the Parque Estadual do Cristalino. Numbers represent the total number of occurrences in strata. *First record in literature from Mato Grosso state.

Subfamily/Genus/Species	**Ground** (pitfall trap)	**Understory** (beating-tray method)	**Total**
Amblyoponinae			
Prionopelta			
Prionopelta punctulata Mayr, 1866*****	4	-	4
Dolichoderinae			
Azteca			
Azteca alfari Emery, 1893	-	4	4
Azteca prox.*aurita* Emery, 1893	-	3	3
Azteca INPA01	-	19	19
Azteca TJI02	-	5	5
Azteca TJI04	-	2	2
Azteca TJI05	-	1	1
Azteca TJI07	-	4	4
Azteca TJI08	-	2	2
Azteca TJI09	-	3	3
Dolichoderus			
Dolichoderus abruptus (Smith, 1858)*****	-	1	1
Dolichoderus attelaboides (Fabricius, 1775)*****	2	3	5
Dolichoderus bidens (Linnaeus, 1758)*****	1	2	3
Dolichoderus bispinosus (Oliver, 1792)	1	-	1
Dolichoderus gagates Emery, 1890	1	5	6
Dolichoderus ghilianii Emery, 1894	-	1	1
Dolichoderus imitator Emery, 1894	3	2	5
Tapinoma			
Tapinoma CR1	-	12	12
Tapinoma CR2	-	5	5
Dorylinae			
Eciton			
Eciton burchellii (Westwood, 1842)	3	-	3
Neivamyrmex			
Neivamyrmex prox. *pilosus*	1	-	1

(Smith, 1858)			
Neivamyrmex INPA02	-	1	1
Ectatomminae			
Ectatomma			
Ectatomma edentatum Roger, 1863	14	-	14
Ectatomma lugens Emery, 1894*	65	-	65
Ectatomma tuberculatum (Olivier, 1792)	3	31	34
Gnamptogenys			
Gnamptogenys prox. *ericae* (Forel, 1912)	5	-	5
Gnamptogenys horni (Santschi, 1929)*	17	-	17
Gnamptogenys kempfi Lenko, 1964*	1	-	1
Gnamptogenys moelleri (Forel, 1912)*	10	-	10
Gnamptogenys pleurodon (Emery, 1896)	-	1	1
Gnamptogenys striatula Mayr, 1884	5	13	18
Gnamptogenys prox. *sulcata* (Smith, 1858)	1	-	1
Gnamptogenys TJI4	1	-	1
Formicinae			
Acropyga			
Acropyga TJI1	3	-	3
Brachymyrmex			
Brachymyrmex CR1	4	41	45
Brachymyrmex CR2	-	1	1
Brachymyrmex CR3	-	13	13
Camponotus			
Camponotus atriceps (Smith, 1858)	1	1	2
Camponotus diversipalpus Santschi, 1922	3	-	3
Camponotus femoratus (Fabricius, 1804)	13	10	23
Camponotus latangulus Roger, 1863	-	8	8
Camponotus mus Roger, 1863	-	1	1
Camponotus nidulans (Smith, 1860)	-	5	5
Camponotus novogranadensis Mayr, 1870	1	-	1
Camponotus scissus Mayr, 1887*	-	1	1
Camponotus trapezoideus	-	5	5

Mayr, 1870			
Camponotus CR02	-	2	2
Camponotus CR06	-	1	1
Camponotus CR07	-	2	2
Camponotus CR11	-	8	8
Camponotus CR16	3	2	5
Camponotus CR19	2	-	2
Camponotus TJI01	-	3	3
Camponotus TJI04	10	2	12
Gigantiops			
Gigantiops destructor (Fabricius 1804)	2	1	3
Nylanderia			
Nylanderia prox. *caeciliae* (Forel, 1899)	15	11	26
Nylanderia prox. *fulva* (Mayr, 1862)	4	1	5
Nylanderia CR1	26	16	42
Nylanderia CR5	1	-	1
Nylanderia TJI2	17	3	20
Myrmicinae			
Apterostigma			
Apterostigma urichii Forel, 1893	9	-	9
Apterostigma CR1	-	2	2
Apterostigma INPA01	4	-	4
Apterostigma INPA04	5	-	5
Atta			
Atta cephalotes (Linnaeus, 1758)	13	-	13
Atta sexdens (Linnaeus, 1758)	1	-	1
Carebara			
Carebara urichi (Wheeler, 1922)	13	-	13
Carebara JTI1	2	-	2
Cephalotes			
Cephalotes atratus (Linnaeus, 1758)	3	3	6
Cephalotes oculatus (Spinola, 1851)*	-	5	5
Cephalotes pallens (Klug, 1824)	-	1	1
Cephalotes CR1	-	2	2
Cephalotes CR3	-	1	1
Crematogaster			
Crematogaster arcuata Forel, 1899	-	2	2

Crematogaster brasiliensis Mayr, 1878	-	14	14
Crematogaster carinata Mayr, 1862*	-	1	1
Crematogaster curvispinosa Mayr, 1862*	-	1	1
Crematogaster erecta Mayr, 1866	3	8	11
Crematogaster levior Longino 2003*	8	7	15
Crematogaster limata Smith, 1858*	6	23	29
Crematogaster nigropilosa Mayr, 1870*	3	26	29
Crematogaster stollii Forel, 1885	1	-	1
Crematogaster tenuicula Forel, 1904*	32	24	56
Cyphomyrmex			
Cyphomyrmex laevigatus Weber, 1938*	7	-	7
Cyphomyrmex peltatus Kempf, 1966	5	-	5
Cyphomyrmex prox. *rimosus*	-	3	3
Cyphomyrmex CR7	1	-	1
Cyphomyrmex TJI02	1	-	1
Cyphomyrmex TJI03	9	-	9
Cyphomyrmex TJI06	1	-	1
Daceton			
Daceton armigerum (Latreille, 1802)	1	-	1
Hylomyrma			
Hylomyrma immanis Kempf, 1973*	8	-	8
Megalomyrmex			
Megalomyrmex ayri Brandão, 1990	16	-	16
Megalomyrmex cuatiara Brandão, 1990*	1	-	1
Megalomyrmex drifti Kempf, 1961	2	-	2
Megalomyrmex CR3	1	-	1
Mycetarotes			
Mycetarotes CR1	1	-	1
Mycocepurus			
Mycocepurus smithii (Forel, 1893)	4	-	4
Myrmelachista			
Myrmelachista TJI01	-	1	1
Myrmicocrypta			

Myrmicocrypta INPA01	2	-	2
Myrmicocrypta INPA02	1	-	1
Nesomyrmex			
Nesomyrmex prox. *asper* (Mayr, 1887)	-	1	1
Nesomyrmex prox. *pleuriticus* (Kempf, 1959)	-	1	1
Nesomyrmex tonsuratus (Kempf, 1959)	-	1	1
Nesomyrmex CR1	-	1	1
Nesomyrmex TJI2	-	1	1
Ochetomyrmex			
Ochetomyrmex neopolitus Fernández, 2003	18	8	26
Ochetomyrmex semipolitus Mayr, 1878	3	56	59
Octostruma			
Octostruma balzani (Emery, 1894)	1	-	1
Pheidole			
Pheidole biconstricta Mayr, 1870*****	4	4	8
Pheidole bufo Wilson, 2003	1	-	1
Pheidole gertrudae Forel, 1886*****	1	-	1
Pheidole prox. *gilva* Wilson, 2003	-	2	2
Pheidole nitella Wilson, 2003*****	22	-	22
Pheidole radoszkowskii Mayr, 1884*****	17	7	24
Pheidole transversostriata Mayr, 1887*****	65	2	67
Pheidole vorax (Fabricius, 1804)*****	1	-	1
Pheidole CR16	22	-	22
Pheidole CR44	2	-	2
Pheidole INPA008	2	2	4
Pheidole INPA019	6	-	6
Pheidole INPA020	4	-	4
Pheidole INPA025	1	-	1
Pheidole INPA026	1	-	1
Pheidole INPA037	5	-	5
Pheidole INPA045	3	2	5
Pheidole INPA048	8	-	8
Pheidole INPA049	2	-	2
Pheidole INPA051	13	-	13
Pheidole TJI02	16	1	17
Pheidole TJI07	-	1	1
Pheidole TJI09	10	1	11
Pheidole TJI10	2	2	4

Pheidole TJI17	6	-	6
Pheidole TJI21	22	-	22
Pheidole TJI22	8	-	8
Pheidole TJI23	2	-	2
Pheidole TJI24	3	-	3
Pheidole TJI26	3	-	3
Pheidole TJI28	5	-	5
Pheidole TJI29	6	-	6
Pheidole TJI30	4	-	4
Pheidole TJI31	4	-	4
Pheidole TJI33	3	-	3
Pheidole TJI40	1	-	1
Pheidole TJI41	1	-	1
Rogeria			
Rogeria scobinata Kugler, 1994	3	-	3
Sericomyrmex			
Sericomyrmex INPA001	14	-	14
Solenopsis			
Solenopsis prox. *geminata* (Fabricius, 1804)	4	-	4
Solenopsis CR1	2	44	46
Solenopsis CR6	18	-	18
Solenopsis CR7	6	-	6
Solenopsis CR8	8	-	8
Solenopsis CR9	6	-	6
Solenopsis TJI2	22	6	28
Solenopsis TJI4	1	-	1
Strumigenys			
Strumigenys alberti Forel, 1893	-	1	1
Strumigenys beebei (Wheeler, 1915)*****	2	-	2
Strumigenys elongata Roger, 1863	3	-	3
Strumigenys fairchildi Brown, 1961	-	1	1
Strumigenys trinidadensis Wheeler, 1922	-	3	3
Strumigenys vilhenai Bolton, 2000*****	8	-	8
Strumigenys INPA03	1	-	1
Strumigenys TJI8	1	-	1
Trachymyrmex			
Trachymyrmex INPA03	8	-	8
Trachymyrmex INPA05	6	-	6
Trachymyrmex INPA10	5	-	5
Trachymyrmex TJI1	33	1	34

Trachymyrmex TJI4	7	-	7
Trachymyrmex sp.	3	-	3
Wasmannia			
Wasmannia auropunctata (Roger, 1893)	22	9	31
Wasmannia rochai Forel, 1912*****	2	-	2
Wasmannia scrobifera Kempf, 1961*****	24	4	28
Ponerinae			
Anochetus			
Anochetus diegensis Forel, 1912*****	1	-	1
Anochetus horridus Kempf, 1964*****	1	-	1
Dinoponera			
Dinoponera quadriceps Kempf, 1971*****	4	-	4
Hypoponera			
Hypoponera TJI1	1	-	1
Hypoponera TJI2	2	-	2
Hypoponera TJI3	2	-	2
Leptogenys			
Leptogenys INPA02	2	-	2
Mayaponera			
Mayaponera constricta (Mayr, 1884)	10	1	11
Neoponera			
Neoponera apicalis (Latreille, 1802)	4	-	4
Neoponera commutata (Roger, 1860)	2	-	2
Neoponera crenata (Roger, 1861)	-	2	2
Neoponera globularia (MacKay & MacKay, 2010)*****		1	1
Neoponera inversa (Smith, 1858)	1	3	4
Neoponera striatinodis (Emery, 1890)*****	-	2	2
Neoponera unidentata (Mayr, 1862)	-	4	4
Neoponera verenae Forel, 1922*****	14	-	14
Neoponera villosa (Fabricius, 1804)	-	1	1
Neoponera TJI8	-	4	4
Odontomachus			
Odontomachus haematodus (Linnaeus,	1	-	1

1758)			
Odontomachus meinerti Forel, 1905	2	-	2
Odontomachus TJI1	3	-	3
Pachycondyla			
Pachycondyla crassinoda (Latreille, 1802)	31	-	31
Pachycondyla harpax (Fabricius, 1804)	6	-	6
Pseudomyrmecinae			
Pseudomyrmex			
Pseudomyrmex oculatus (Smith, 1855)	-	2	2
Pseudomyrmex tenuis (Fabricius, 1804)	1	7	8
Pseudomyrmex tenuissimus (Emery, 1906)	-	2	2
Pseudomyrmex unicolor (Smith, 1855)	-	1	1
Pseudomyrmex INPA001	-	1	1
Pseudomyrmex TJI3	-	3	3
Pseudomyrmex TJI8	-	1	1
Total occurrences	**1002**	**579**	**1581**

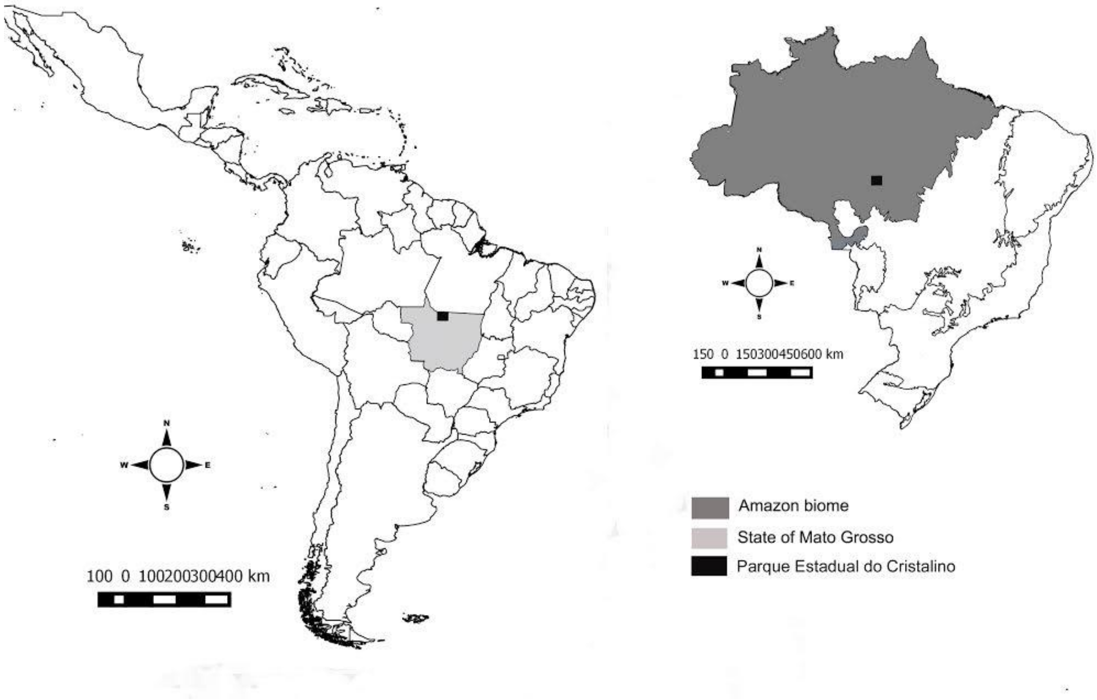


Fig 1. Location map of the Parque Estadual do Cristalino (filled circle).

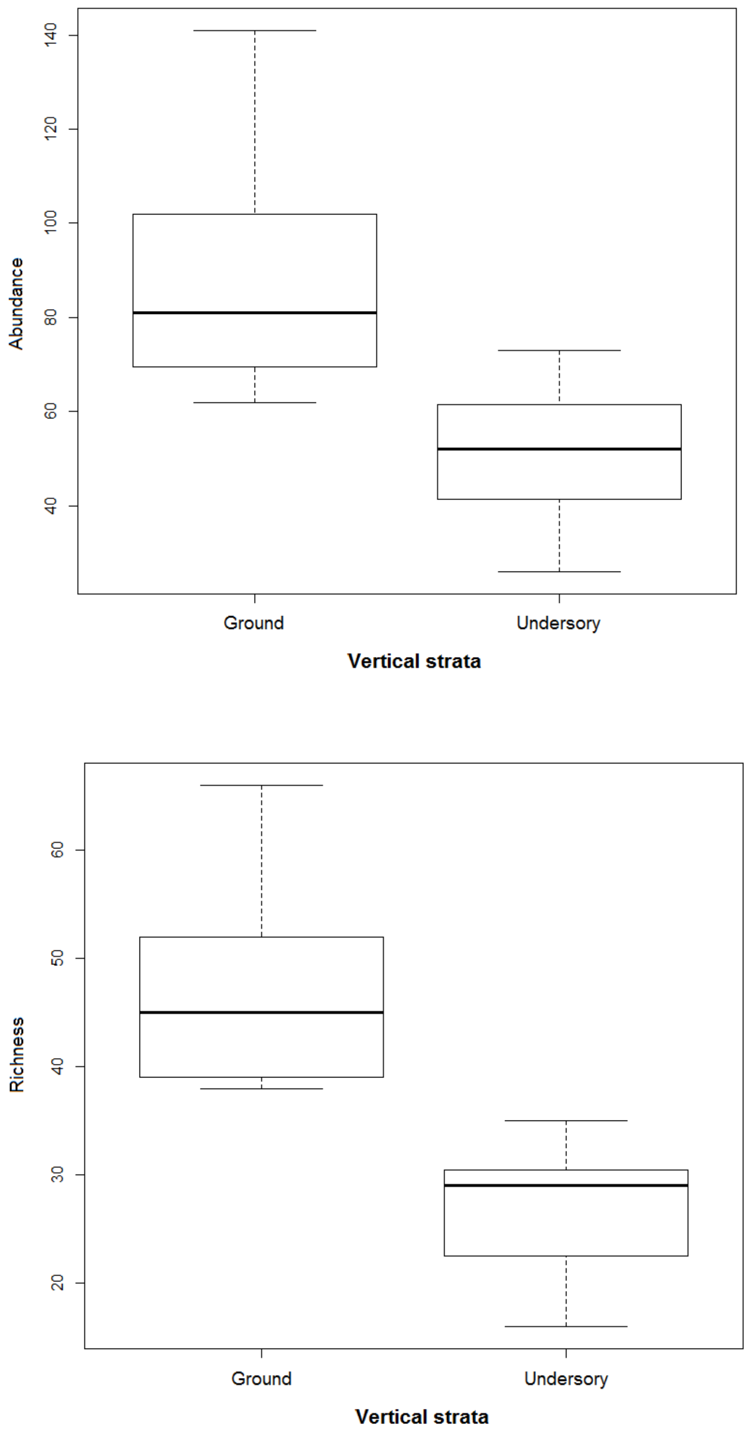


Fig 2. (a) Abundance mean of ants and (b) richness of ant species in vertical strata (ground and understory).

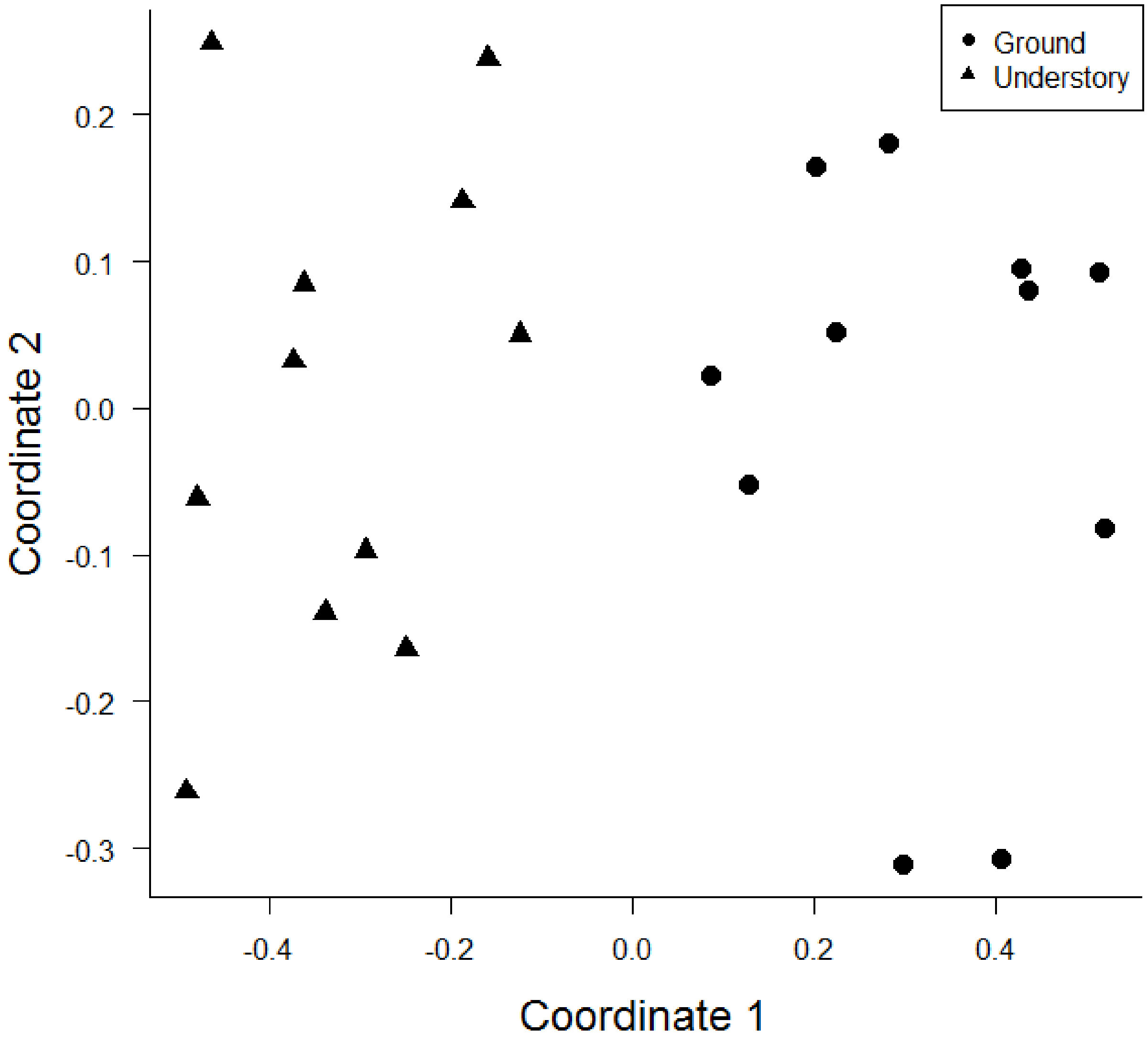


Fig 3. Composition of ground (filled circle) and understory (filled circle) ant community of the Parque Estadual do Cristalino. Principal Coordinate Analysis axis represented 71.6% of total ordination.

ANEXO 3 - *Strumigenys fairchildi* Brown, 1961 (Formicidae, Myrmicinae): first record of this rarely collected ant from Brazil

Artigo publicado pela revista Check List (ISSN: 1809-127X; Classificação CAPES: B4):

Prado, L.P., Vicente, R.E., Silva, T.S.R., Souza, J.L. (2016). *Strumigenys fairchildi* Brown, 1961 (Formicidae, Myrmicinae): first record of this rarely collected ant from Brazil. Check List, 12: 1922. doi: 10.15560/12.4.1922

NGD 16369

Strumigenys fairchildi Brown, 1961 (Formicidae, Myrmicinae): first record of this rarely collected ant from Brazil

Lívia P. Prado[1]*, **Ricardo Eduardo Vicente**[2,3], **Thiago S. R. Silva**[4] and **Jorge L. P. Souza**[3, 5]

1 Museu de Zoologia da Universidade de São Paulo-MZSP, Programa de Pós Graduação em Sistemática, Taxonomia e Diversidade Animal do MZSP, São Paulo, SP, Brazil. Avenida Nazaré, 481, Ipiranga, CEP 04263-000. São Paulo, SP, Brazil

2 Universidade Federal de Mato Grosso-UFMT, Programa de Pós-Graduação em Ecologia e Conservação da Biodiversidade, Laboratório de Ecologia de Comunidades. Avenida Fernando Correa da Costa, Coxipó, CEP 78557-267. Cuiabá, MT, Brazil

3 Centro de Estudos Integrados da Biodiversidade Amazônica - CENBAM, CEP 69080–971, Manaus, AM, Brazil

4 Universidade Federal do Paraná-UFPR. Avenida Coronel Francisco Heráclito dos Santos, Jardim das Américas, CEP 81531-980. Curitiba, PR, Brazil

5 Instituto Nacional de Pesquisas da Amazônia-INPA, Programa de Pós-Graduação em Entomologia. Avenida André Araújo, 2936, Petrópolis, CEP 63083-970. Manaus, AM, Brazil

* Corresponding author. E-mail: livia.pires7@gmail.com

Abstract: *Strumigenys fairchildi* Brown, 1961 is recorded for the first time in Brazil. This ant species was previously known only from a few specimens collected in Costa Rica, Panama and Ecuador. The worker *S. fairchildi* was collected at the Parque Estadual do Cristalino, a continuous area of Amazon tropical rain forest protected for biodiversity conservation in the municipality of Novo Mundo, Mato Grosso state. In addition, we present a distribution map and high-resolution images of the worker.

Key words: Amazon basin; Brazilian ant fauna; distribution; Formicidae; Neotropical ants

<INTRODUCTION>

The ant genus *Strumigenys* Smith, 1860 (Formicidae: Myrmicinae), found worldwide, is represented by 838 extant species, and four fossil species (AntWeb 2016); 25% of the species occur in the Neotropics (Lattke and Aguirre 2015). Most species of this genus occur in tropical rainforest, some in grassland and scrub, usually nesting in soil and rotting wood, though a few species live in arboreal cavities in tropical rain forest (Brown and Wilson 1959; Bolton 2000). Besides the most common form of reproductive females (gyne) some species of *Strumigenys* have the ergatoid forms (Silva and Brandão 2014). Species of the genus are predators of Collembola, mites, insect larvae, and other small arthropods (Wilson 1953; Hölldobler and Wilson 1990; Bolton 1999; Kaufmann et al. 2003), although, some few species occasionally feed on sugary substances (Brown and Wilson 1959). To capture their prey, some species use a kinetic mode of attack (Gronenberg 1996; Bolton 1999).

Despite being a relatively speciose genus and commonly sampled in biodiversity surveys (Morini et al. 2007; Silva et al. 2007; Suguituru et al. 2013; Ulysséa and Brandão 2013; Camacho and Vasconcelos 2015; Souza et al. 2015) most species records are based upon a few specimens (Bolton 2000), as is the case with *S. fairchildi* Brown, 1961. *Strumigenys fairchildi* belongs to the *tococae*-group (comprised by *S. anthocera* Lattke & Goitía, *S. extirpa* Bolton, *S. fairchildi* Brown, *S. tococae* Wheeler & Bequaert, and *S. usbensis* Lattke & Goitía) and was originally described based on one worker collected in Panama (Brown 1961). Since then, the species has been recorded in Costa Rica (Bolton 2000) and most recently in Ecuador (Salázar et al. 2015). In the present paper we report the first record of *S. fairchildi* in Brazil, considerably extending the distribution limits for the species.

<MATERIALS AND METHODS>

One *S. fairchildi* worker (Figure 1) was collected in November 2013, during the beginning of the rainy season in a protected area for biodiversity conservation of the Parque Estadual do Cristalino (Figure 2), a continuous pristine forest in the Novo Mundo municipality, of Mato Grosso state (09°28′ S, 055°50′ W). In this region, known as the Arc of Deforestation (Michalski et al. 2008), the ant fauna is still not very well known with just a few studies contributing to expand our knowledge of the distribution of some rarely collected species (Vicente et al. 2011, 2012, 2015). According to the Köppen classification, the climate in this region is characterized as tropical humid (Am) with a mean annual temperature of 25°C and an annual precipitation ranging from 2,800mm to 3,100mm (Alvares et al. 2013). There are two well-defined seasons, a rainy season between November and April and a dry season between May and October (Vicente et al. 2014). The local altitude ranges from 100 to 400 m above sea level and the vegetation is classified as Open Ombrophilous Forest and ecological tension zones between the Ombrophilous Forest and Savanna (Cerrado), Savanna and Seasonal Forest, Seasonal Forest and Ombrophilous Forest (Instituto Brasileiro de Geografia e Estatística 2004). The specimen was collected in understory vegetation (plants 1–3 m high) using a beating tray in one trail of the Research Program in Biodiversity (Programa de Pesquisas em Biodiversidade, PPBio grid 09°28′29.2″ S, 055°50′00.2″ W, altitude 304 m as estimated in Google Earth™).

The specimen is deposited in the ant collection of the Laboratório de Sistemática, Evolução e Biologia de Hymenoptera of the Museu de Zoologia da Universidade de São Paulo (MZSP), SP, Brazil (the ant collection of the MZSP does not have numerical identifiers, therefore, the author's number is REV_Strumi001). It was photographed with a Leica Application Suite V3 system at the MZSP and edited in Adobe Photoshop© version 7.0. The distribution map was generated using the Quantum GIS 2.6.0 software, with shapes available at Natural Earth, the coordinates were imported from Google Earth™ after consulting the records for *S. fairchildi* in the literature (Bolton 2000;

Salazar et al. 2015).

<IDENTIFICATION>

To identify *Strumigenys* ant species we used the taxonomic key provided by Bolton (2000). According to Bolton (2000), *S. fairchildi* (Figure 1) is morphologically characterized by the combination of (1) first gastral tergite finely and very densely longitudinally costulate-striolate; (2) surface of this sclerite with minute inconspicuous appressed pubescence only, without spatulate hairs such as are present on the cephalic dorsum but with a few scattered flagellate hairs that are extremely fine, easily broken or lost; (3) apicoscrobal hair absent; (4) maximum diameter of eye ca 0.14; (5) propodeum in profile with a pair of long spines at top of declivity; (6) base of declivity with a pair of much shorter acute teeth that are narrowly triangular; (7) ventral surface of petiole with a narrow continuous strip of spongiform tissue.

The intraspecific morphological variability observed in specimens collected in Brazil and Costa Rica are variations in patterns of pilosity of the cephalic dorsum, waist and gaster. In addition, the body color is variable; the specimen collected in Brazil is slightly darker than the specimen collected in the Costa Rica.

Morphologically, *S. fairchildi* is very similar to *S. anthocera* and *S. usbensis*, species with a possible overlapping distribution. This species differs from the first by the apicoscrobal hair (absent in *S. fairchildi* and present in *S. anthocera*) and by the length of the spine at the propodeal lobe (shorter than the dorsal propodeal spine in *S. fairchildi* and as long as the dorsal propodeal spine in *S. anthocera*). In addition, *S. usbensis* differs from *S. fairchildi* by the modifications of the spongiform tissue on the ventral surface of the petiole (present in *S. fairchildi* and absent in *S. usbensis*) and shape of hairs in the first gastral surface (flagellate hairs in *S. fairchildi* and spatulate hairs in *S.*

usbensis).

<DISCUSSION>

Strumigenys fairchildi (Figure 1) was previously recorded in Cerro Campana, Panama (Brown 1961), Heredia province, Costa Rica (Bolton 2000) and recently in Sucumbios province, Ecuador (Salazar et al. 2015) (Figure 2). The new record of this work expands its occurrence to Parque Estadual do Cristalino (09°28′ S, 055°50′ W), a continuous Amazonian forest in the Novo Mundo municipality, of Mato Grosso state, Brazil (Figure 2). This is more than 2,000 km from the nearest record of this species.

Despite growing knowledge about the diversity of Neotropical ants (Silva et al. 2013; Baccaro et al. 2015; Bezděčková et al. 2015; Brandão et al. 2015; Delabie et al. 2015; Salazar et al. 2015), the distribution of many species, especially those primarily associated with the Amazonian biome, is still virtually unknown (Fernandes et al. 2015a, 2015b; Vicente et al. 2011, 2012, 2015). Several ground-dwelling ant inventories have been carried out in what can be now considered the range of *S. fairchildi* (Vasconcelos et al. 2006, 2010; Mertl et al. 2010; Miranda et al. 2012; Ryder-Wilkie et al. 2009; Souza et al. 2016) but they all failed to detect this species. Because *S. fairchildi* lives in vegetation and considering the scarcity of inventories of arboreal ants (but see: Vasconcelos and Vilhena 2006; Ryder-Wilkie et al. 2010), the distribution of this species is probably much broader than reported in the literature.

Furthermore, four ant collections (Museu de Zoologia da Universidade de São Paulo [MZSP], Instituto Nacional de Pesquisas da Amazônia [INPA], Laboratório de Ecologia de Comunidades da Universidade Federal do Mato Grosso [LEC/UFMT] and Collection Padre Jesus Santiago Moure of the Universidade Federal do Paraná [DZUP])that house a large number of specimens of both the

Amazon and Brazilian ant fauna were consulted and no other specimen of *S. fairchildi* was found. Thus, the new record reported here suggests that more sampling efforts applying different techniques of sampling should be used to reveal the distribution of this species and contribute to increase the knowledge of the Brazilian ant fauna that remains underestimated, especially for species that inhabit vegetation strata. As seen in the present paper, the use of beating trays is a viable technique for sampling ants that live and forage in shrubby environments. Available information on niche preference is still scarce for most groups of this family of insects, hampering advances on studies such as behavioral ecology. Applying beating trays as a standardized technique in sampling inventories of ants, in this particular arboreal stratum, will certainly provide useful information to boost studies in disciplines in which knowledge regarding habitat preference is needed, especially in those genera believed to be exclusively epigaeic, such as *Strumigenys*.

ACKNOWLEDGEMENTS

We thank Vinicius Soares, Mariana Silva for the fieldwork support, andDr. Carlos Roberto F. Brandão (MZSP) for Automontage from MZSP Hymenoptera Lab and Henrique Miranda Rodrigues (CASE) for his help with previous draft. We also would like to thank Secretaria de Estado do Meio Ambiente (SEMA) and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq numbers 479243/2012–3, 558225/2009-8, 501408/2009-6and 457466/2012-0) for logistical and financial support. The authors acknowledge their grants from CAPES (REV, LPP and TSRS) and FAPEAM (JLPS). This work is publication 33 in the NEBAM technical series.

LITERATURE CITED

AntWeb. [2016]. Genus *Strumigenys*. Accessed at https://www.antweb.org/browse.do?subfamily=myrmicinae&genus=strumigenys&rank=genus&project=allantwebants, 17 May 2016.

Alvares, C.A., J.L. Stape, P.C. Sentelhas, J.L. De-Moraes-Gonçalves and G. Sparovek. 2013. Köppen's climate classification map for Brazil. Meteorologische Zeitschrift 22: 711–728. doi: http://dx.doi.org/10.1127/0941-2948/2013/0507

Baccaro, F.B., R.M. Feitosa, F. Fernández, I.O. Fernandes, TJ Izzo, J.L.P. Souza and R. Solar. 2015. Guia para os gêneros de formigas do Brasil. Manaus: Editora INPA. 388 pp.

Bezděčková, K., P. Bezděčka and I. Machar. 2015. A checklist of the ants (Hymenoptera: Formicidae) of Peru. Zootaxa 4020(1): 101–133. doi: http://dx.doi.org/10.11646/zootaxa.4020.1.4

Bolton, B. 1999. Ant genera of the tribe Dacetonini (Hymenoptera: Formicidae). Journal of Natural History 3(33): 1639–1689.

Bolton, B. 2000. The ant tribe Dacetini. Mem. American Entomological Institute 65: 1—1028.

Brandão, C.R.F., R.M. Feitosa and J.L.M. Diniz. 2015. Taxonomic revision of the Neotropical Myrmicinae ant genus Blepharidatta Wheeler. Zootaxa 4012(1): 033–056. doi: http://dx.doi.org/10.11646/zootaxa.4012.1.2

Brown, W.L. 1961. The Neotropical species of the ant genus *Strumigenys* Fr. Smith: miscellaneous concluding studies. Psyche 68: 58–69.

Brown, W.L. and E.O. Wilson. 1959. The evolution of the dacetine ants. The Quarterly Review of

Biology 34: 278–294.

Camacho, G.P. and H.L. Vasconcelos. 2015. Ants of the Panga Ecological Station, a Cerrado Reserve in Central Brazil. Sociobiology. 62: 281—295. doi: http://dx.doi.org/10.13102/sociobiology.v62i2.281-295

Delabie, J.H.C., R.M. Feitosa, J.E. Serrão, C.S.F. Mariano and J.D. Majer (eeds.). 2015. As formigas poneromorfas do Brasil. Ilhéus: Editus. 477 pp. doi: http://dx.doi.org/10.5281/zenodo.32400

Fernandes, I.O., J.L.P. Souza, F.Fernandez, J.H.C. Delabie and T.R. Schultz. 2015. A new species of *Simopelta* (Hymenoptera: Formicidae: Ponerinae) from Brazil and Costa Rica. Zootaxa 3956(2): 295–300. doi: http://dx.doi.org/10.11646/zootaxa.3956.2.10

Fernandes, I.O., J.L.P. Souza, J.H.C. Delabie and F. Fernandez. 2015. New records of the Dorylinae ant genus *Cheliomyrmex* for the Brazilian Amazon Basin. Sociobiology 62(1): 128–131. doi: http://dx.doi.org/10.13102/sociobiology.v62i1.128-131

Gronenberg, W. 1996. The trap-jaw mechanism in the Dacetine ants *Daceton armigerum* and *Strumigenys* sp. The Journal of Experimental Biology 199: 2021–2033.

Hölldobler, B. and E.O. Wilson. 1990. The ants. Cambridge, MA: Harvard University Press. 732 pp.

Instituto Brasileiro de Geografia e Estatística. 2004. Mapa da vegetação brasileira. 3ª edição. Ministério do Planejamento, Orçamento e Gestão. Accessed at http://www.obt.inpe.br/prodes/index.php, 12 September 2015.

Kaufmann, E., A.K.F. Malsch, M. Erle and U. Maschwitz. 2003. Compound nesting of *Strumigenys* sp. (Myrmicinae) and *Diacamma* sp. (Ponerinae), and other nesting symbioses of myrmicine and ponerine ants in Southeast Asia. Insectes Sociaux 50: 88–97. doi: http://dx.doi.org/10.1007/s000400300014

Lattke, J.E. and N. Aguirre. 2015. Two new *Strumigenys* F. Smith (Hymenoptera: Formicidae: Myrmicinae) from montane forests of Ecuador. Sociobiology. 62: 175–180. doi: http://dx.doi.org/10.13102/sociobiology.v62i2.175-180

Lattke, J.E. and W. Goitía. 1997. El género *Strumigenys* en Venezuela. Caldasia 19: 367–396.

Mertl, A.L., M.D. Sorenson and J.F.A. Traniello. 2010. Community-level interactions and functional ecology of major workers in the hyperdiverse ground-foraging *Pheidole* (Hymenoptera, Formicidae) of Amazonian Ecuador. Insectes Sociaux 54: 441–452. doi: http://dx.doi.org/10.1007/s00040-010-0102-5

Michalski, F., C.A. Peres and I.R. Lake. 2008. Deforestation dynamics in a fragmented region of southern Amazonia: evaluation and future scenarios. Environmental Conservation 35: 93—103. doi: http://dx.doi.org/10.1017/S0376892908004864

Miranda, P.N., M.A. Oliveira, F.B. Baccaro, E.F. Morato and J.H.C. Delabie. 2012. Check list of ground-dwelling ants (Hymenoptera: Formicidae) of the eastern Acre, Amazon, Brazil. Check List 8: 722–730. doi: http://dx.doi.org/10.15560/8.4.722

Morini, M.S.C., C.B. Munhae, R. Leung, D.F. Candiani and J.C. Voltolini. 2007. Comunidades de formigas (Hymenoptera: Formicidae) em fragmentos de Mata Atlântica urbanizados. Iheringia, Série Zoologia 97: 246–252. doi: http://dx.doi.org/10.1590/S0073-47212007000300005

Ryder-Wilkie, K.T., A.L. Mertl and J.F.A. Traniello. 2009. Diversity of ground-dwelling ants

(Hymenoptera: Formicidae) in primary and secondary forests in Amazonian Ecuador. Myrmecological News 12: 139–147.

Ryder-Wilkie, K.T., A.L. Mertl and J.F.A. Traniello. 2010. Species diversity and distribution patterns of the ants of Amazonian Ecuador. PLoS ONE 5(10): e13146. doi: http://dx.doi.org/10.1371/journal.pone.0013146

Salazar, F., F. Reyes-Bueno, D. Sanmartin and D.A. Donoso. 2015. Mapping continental Ecuadorian ant species. Sociobiology. 62(2): 132–162. doi: http://dx.doi.org/10.13102/sociobiology.v62i2.132-162

Silva, R.R., R.M. Feitosa and F. Eberhardt. 2007. Reduced ant diversity along a habitat regeneration gradient in the southern Brazilian Atlantic Forest. Forest Ecology and Management. 240: 61– 69. doi: http://dx.doi.org/10.1016/j.foreco.2006.12.002

Silva, R.R., R.M. Feitosa, C.R.F. Brandão and V.L. Freitas. 2013. The first Leptanilloides species (Hymenoptera: Formicidae: Leptanilloidinae) from eastern South America. Journal of Natural History 47: 2039–2047. doi: http://dx.doi.org/10.1080/00222933.2012.763058

Silva, T.S.R. and C.R.F. Brandão. 2014. Further ergatoid gyne records in the ant tribe Dacetini (Formicidae: Myrmicinae). Neotropical Entomology 43(2): 161–171. doi: http://dx.doi.org/10.1007/s13744-013-0192-7

Souza, J.L.P., F.B. Baccaro, V.L. Landeiro, E. Franklin, W.E. Magnusson, P.A.C.L. Pequeno and I.O. Fernandes. 2016. Taxonomic sufficiency and indicator taxa reduce sampling costs and increase monitoring effectiveness for ants. Diversity and Distributions 22(1):): 111–122. doi: http://dx.doi.org/10.1111/ddi.12371

Suguituru, S.S., D.R. Souza, C.B. Munhae, R. Pacheco, M.S.C. Morini. 2013. Diversidade e riqueza de formigas (Hymenoptera: Formicidae) em remanescentes de Mata Atlântica na Bacia Hidrográfica do Alto Tietê, SP. Biota Neotropica 13: 1–11. http://www.biotaneotropica.org.br/v13n2/en/abstract?inventory+bn00813022013

Ulysséa, M.A. and C.R.F. Brandão. 2013. Ant species (Hymenoptera, Formicidae) from the seasonally dry tropical forest of northeastern Brazil: a compilation from field surveys in Bahia and literature records. Revista Brasileira de Entomologia 57: 217–224. doi: http://dx.doi.org/10.1590/S0085-56262013005000002

Vasconcelos, H.L. and J.M.S. Vilhena. 2006. Species turnover and vertical partitioning of ant assemblages in the Brazilian Amazon: a comparison of forests and savannas. Biotropica 38: 100–106. doi: http://dx.doi.org/10.1111/j.1744-7429.2006.00113.x

Vasconcelos, H.L., J.M.S. Vilhena, C.G. Facure and A.L.K.M. Albernaz. 2010. Patterns of ant species diversity and turnover across 2000km of Amazonian floodplain forest. Journal of Biogeography 37: 432–440. doi: http://dx.doi.org/10.1111/j.1365-2699.2009.02230.x

Vasconcelos, H.L., J.M.S. Vilhena, W.E. Magnusson and A.L.K.M. Albernaz. 2006. Long-term effects of forest fragmentation on Amazonian ant communities. Journal of Biogeography 33: 1348–1356. doi: http://dx.doi.org/10.1111/j.1365-2699.2006.01516.x

Vicente, R.E., J. Dambroz and M. Barreto. 2011. New distribution record of *Daceton boltoni* Azorsa and Sosa-Calvo, 2008 (Insecta: Hymenoptera) ant in the Brazilian Amazon. Check List 7: 878–879. doi: http://dx.doi.org/10.15560/7.6.878

Vicente, R.E., W. Dáttilo and T.J. Izzo. 2012. New record of a very specialized interaction: *Myrcidris epicharis* Ward 1990 (Pseudomyrmecinae) and its myrmecophyte host *Myrcia madida*

McVaugh (Myrtaceae) in Brazilian Meridional Amazon. Acta Amazonica 42(4): 567–570. doi: http://dx.doi.org/10.1590/s0044-59672012000400016

Vicente, R.E., W. Dáttilo and T.J. Izzo. 2014. Differential recruitment of *Camponotus femoratus* (Fabricius) ants in response to ant garden herbivory. Neotropical Entomology 43(6): 519–525. doi: http://dx.doi.org/10.1007/s13744-014-0245-6

Vicente, R.E., L.P. Prado and R.C.L. Santos.2015. Expanding the distribution of the remarkable ant *Gnamptogenys vriesi* Brandão & Lattke (Formicidae, Ectatomminae): first record From Brazil. Sociobiology 62(4): 615–619. doi: http://dx.doi.org/10.13102/sociobiology.v62i4.920

Wilson, E.O. 1953. The ecology of some North American dacetine ants. Annals of the Entomological Society of America 46: 479–495.

Author contributions: LPP wrote the text, checked MZUSP collection, imaged *Strumigenys fairchildi* specimen; REV collected the specimen, checked LEC/UFMT collection and wrote the text, TSRS identified the ant species, checked DZUP collection and reviewed the text, JLPS checked INPA collection and reviewed the text.

Received: 15 November 2015

Accepted: 15 June 2016

Academic editor: Luiz Alexandre Campos

[FIGURE CAPTIONS]

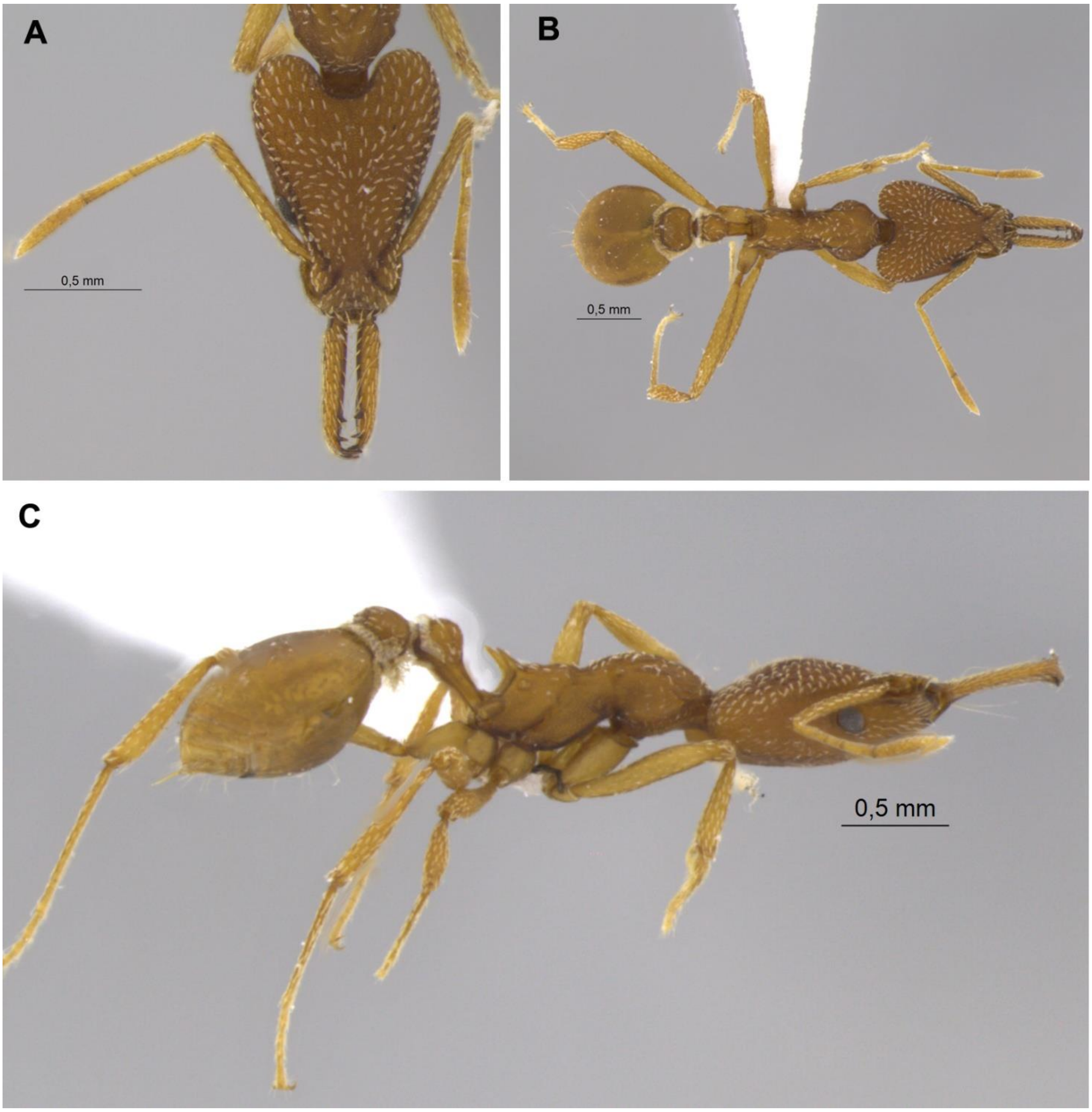


Figure 1. Worker of *Strumigenys fairchildi* from Mato Grosso, Brazil in full-face view (**A**), dorsal view (**B**) and lateral view (**C**).

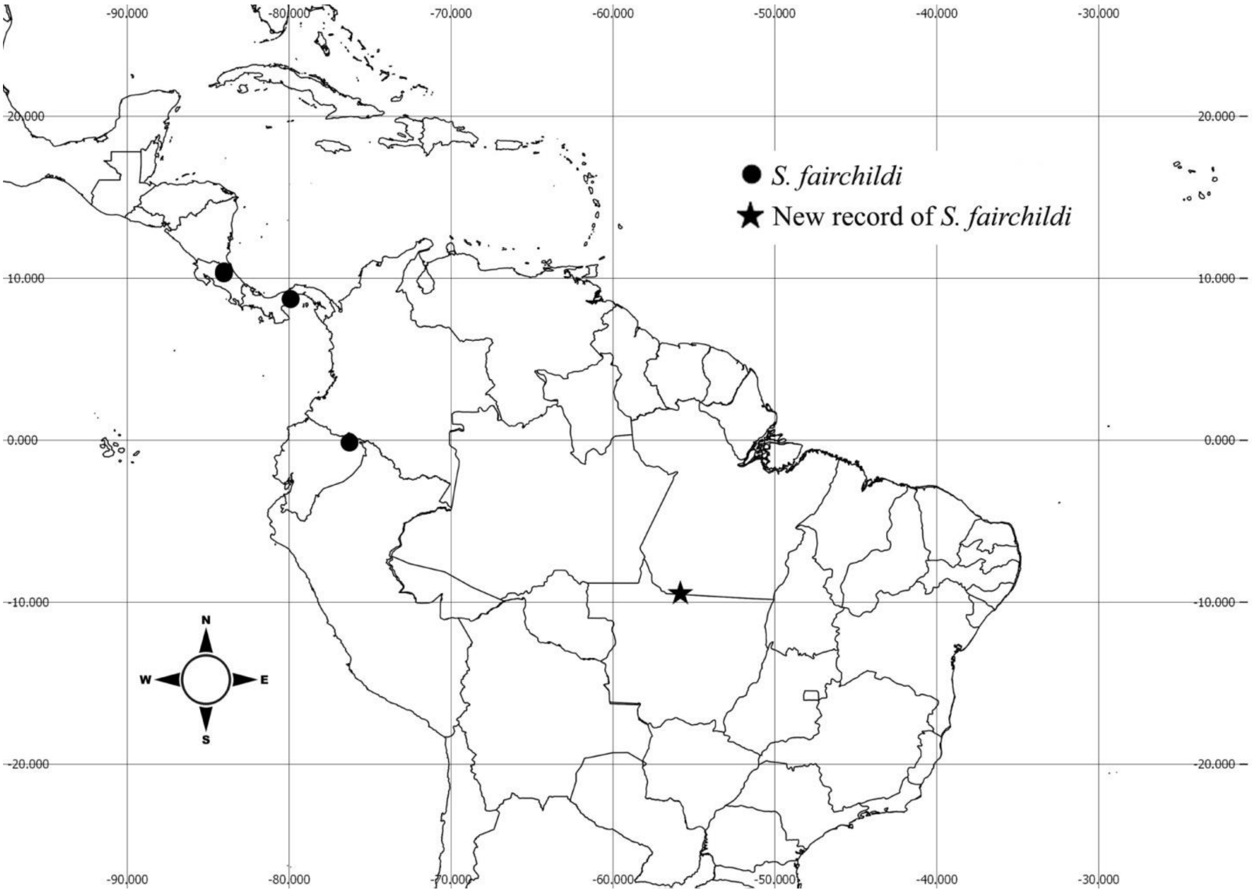


Figure 2. Distribution of *Strumigenys fairchildi*.

CONCLUSÃO GERAL

As epifitas mais abundantes nos Jardins-de-formigas foram *Peperomia macrostachya* (Piperaceae, presente em 88% dos JFs observados), *Codonanthe uleana* (Gesneriaceae - 41%), *Philodendron* sp. (Araceae - 18%) e *Markea longiflora* (Solanaceae - 6%). As formigas apresentaram recrutamento diferente entre as epífitas associadas e a planta não mutualista de subbosque. Os resultados demonstraram que as formigas parabióticas conseguem reconhecer os compostos químicos voláteis diferentes entre todas as espécies associadas. Além de reconhecer os voláteis químicos das epífitas, conseguem diferenciar entre epífítas habitants obrigatórias de JFs e epífitas não obrigatórias. O fato de *Camponotus femoratus* reagir aos voláteis das epífitas obrigatórias, principalmente *P. macrostachya*, e não a da abundante planta de subbosque pertencente a mesma família botânica, reforça o refinamento do reconhecimento químico de *Camponotus*.

A presença, número e volume de Jardins-de-formigas foi afetado pelo tamanho da clareira mas não pela abertura de dossel, que influenciou somente o forrageamento das formigas parabióticas. As espécies *Ca. femoratus* e *Cr. levior* utilizam igualmente os estratos verticais sendo a frequência de ambas espécies no solo diminuída pela abertura do dossel. Porém, somente a frequência de *Cr. levior* no chão diminuiu com o aumento da complexidade da vegetação, demonstrando que o nicho de *Cr. levior* é mais ligado a vegetação do que o de *Ca. femoratus*.

A abundância, riqueza e composição da comunidade de formigas de solo é afetada pela presença das formigas parabióticas, sendo que, sua presença torna as comunidades presentes subamostras de comunidades onde as formigas parabióticas estão ausentes (Aninhamento). Por fim, nem a complexidade, bem como abertura do dossel influenciam a frequencia de forrageamento dessas formigas no sub-bosque. Nem sua presença altera a comunidade de formigas arborícolas. Esses resultados demonstram que essas formigas parabióticas podem retardar a recuperação da biodiversidade de formigas de solo em clareiras amazônicas, porém, não afetam a diversidade de formigas na vegetação. Isto demonstra que é importante compreender como as formigas parabióticas, dominantes nesses ambientes, impedem a colonização de espécies cosmopolitas comuns em ambientes degradados. Além disso, esses resutados ainda demonstram que, se deve empenhar esforços para compreender o padrão de dominância em formigas arborícolas na Região Neotropical e como estas interferem nos processos ecosistêmicos locais.