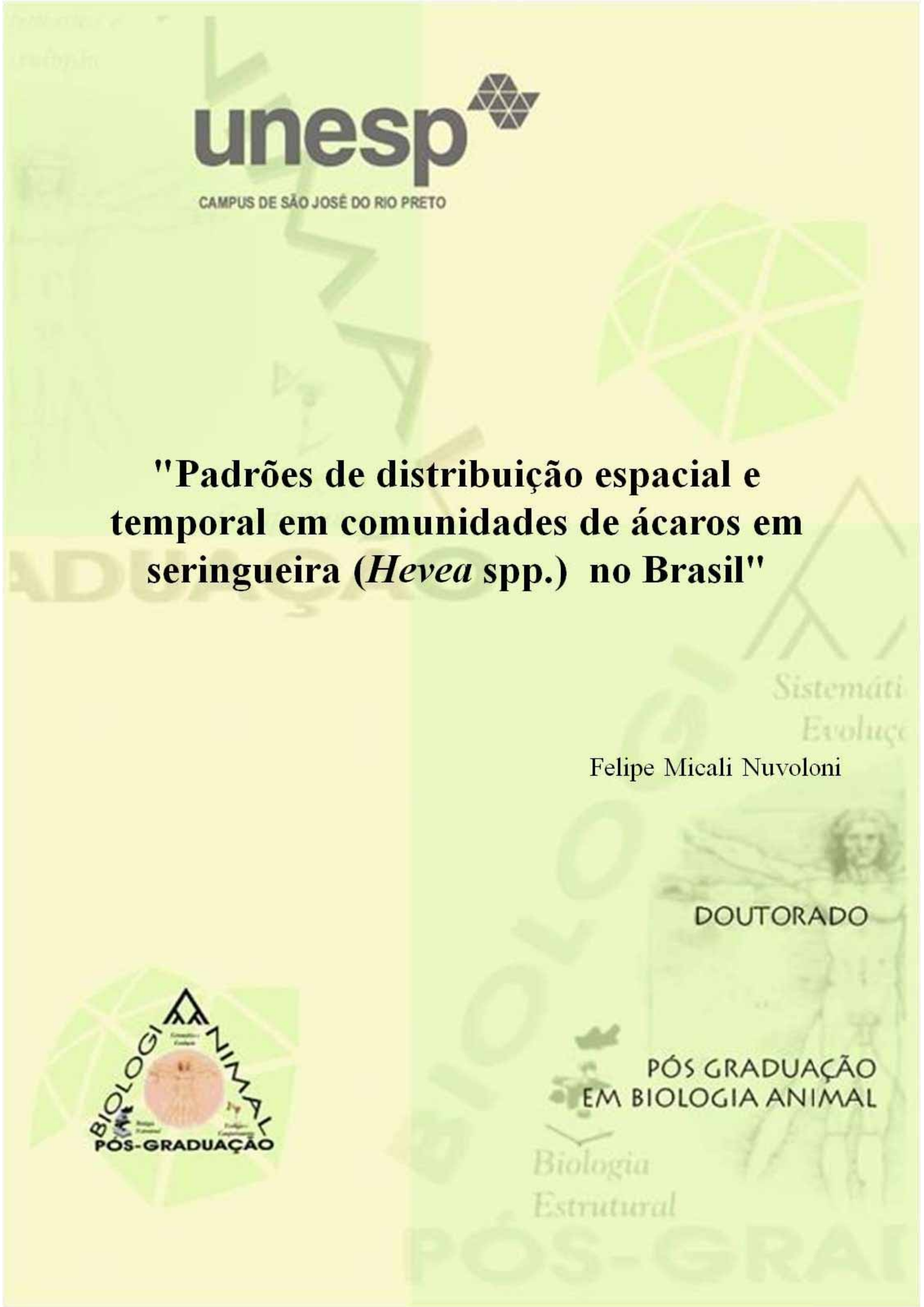


unesp

CAMPUS DE SÃO JOSÉ DO RIO PRETO

"Padrões de distribuição espacial e temporal em comunidades de ácaros em seringueira (*Hevea* spp.) no Brasil"

Felipe Micali Nuvoloni

DOUTORADO

PÓS GRADUAÇÃO
EM BIOLOGIA ANIMAL

UNIVERSIDADE ESTADUAL PAULISTA
INSTITUTO DE BIOCIÊNCIAS, LETRAS E CIÊNCIAS EXATAS
PROGRAMA DE PÓS-GRADUAÇÃO EM BIOLOGIA ANIMAL

FELIPE MICALI NUVOLONI

"PADRÕES DE DISTRIBUIÇÃO ESPACIAL E TEMPORAL EM COMUNIDADES DE ÁCAROS EM SERINGUEIRA (*HEVEA* SPP.) NO BRASIL"

Tese apresentada como parte dos requisitos para obtenção do título de Doutor em Biologia Animal, junto ao Programa de Pós-Graduação em Biologia Animal, Instituto de Biociências, Letras e Ciências Exatas da Universidade Estadual Paulista "Júlio de Mesquita Filho", Campus de São José do Rio Preto.

ORIENTADOR: PROF. DR. REINALDO JOSÉ FAZZIO FERES

SÃO JOSÉ DO RIO PRETO
2015

BANCA EXAMINADORA

TITULARES

PROF. DR. REINALDO J. F. FERES (ORIENTADOR) ___________________
UNESP / SÃO JOSÉ DO RIO PRETO-SP

PROF. DR. RODRIGO D. DAUD ___________________
UFG / GOIÂNIA – GO

PROF. DR. GILBERTO J. DE MORAES ___________________
UNIVERSIDADE DE SÃO PAULO, PIRACICABA (SP)

PROF. DR. THIAGO G. SOUZA ___________________
UNIVERSIDADE FEDERAL RURAL DE PERNAMBUCO, RECIFE (PE)

PROF. DR. FERNANDO R. SILVA ___________________
UNIVERSIDADE FEDERAL DE SÃO CARLOS, SOROCABA (SP)

SUPLENTES

PROFA. DRA. MARIA S. CASTILHO NOLL ___________________
UNIVERSIDADE ESTADUAL PAULISTA, SÃO JOSÉ DO RIO PRETO (SP)

PROF. DR. CARLOS H. W. FLECHTMANN ___________________
UNIVERSIDADE DE SÃO PAULO, PIRACICABA (SP)

DR. FABIO R. A. HERNANDES ___________________
UNIVERSIDADE ESTADUAL PAULISTA, RIO CLARO (SP)

São José do Rio Preto, 26 de março de 2015

Agradecimentos

COLABORAÇÃO. Creio que esta palavra resume muito do que foi essa tese. A execução desta tese só foi possível graças ao apoio, contribuição, esforço, suor, e paciência, de muitas pessoas (muitas mesmo). Difícil conseguir citar todos que de alguma forma, científica, braçal ou psicologicamente foram essenciais para mim nesta longa caminhada, mas tento deixar aqui o meu muito obrigado a todos vocês.

Este projeto nasceu de uma idéia em conjunto com meu orientador, Reinaldo, quando ao término de meu mestrado, discutíamos sobre a possibilidade de “juntar” tudo o que o laboratório já havia coletado e produzido, abrangendo ácaros em seringueira. Assim, tivemos a idéia de utilizar os dados da coleção científica do laboratório, que reúne mais de 20 anos de trabalhos dedicados ao tema. Além disso, vimos a possibilidade de tentar preencher algumas lacunas ainda existentes no assunto, como por exemplo, realizar coletas em seringueiras em meio à floresta Amazônica.

Nesse momento foi inestimável o apoio que recebemos da Prof. Elizabeth Franklin, que me recebeu em seu laboratório no INPA, e me abriu as portas para realizar as coletas na floresta. Quero expressar minha gratidão aos colegas do INPA, Nikolas, Breno, Fabinho, Isaura, Vitão, Prof. José Wellington, que me receberam e auxiliaram nas coletas de campo, triagem do material, foram meus guias na cidade, e passeios de barco. Fica aqui um agradecimento especial ao grande Gaúcho (Alexandre Somavilla) pelo apoio total e além do teto que me forneceu nesse período! Além disso, agradeço também ao Dr. Éverton Rabelo Cordeiro e demais pesquisadores e técnicos da EMBRAPA Amazônia Ocidental, que me auxiliaram nas coletas da área.

Descobri também que SIM, o Acre existe! Agradeço aos colegas acreanos da UFAC, Márcia e o seu pequeno Edu, Tatiana, Eliz, Martin, Jhon, Edilaine, Álisson, e Wenderson, que me acolheram, e guiaram nas aventuras e coletas de campo no meio do Acre!

Continuando a rede de colaboradores envolvidos nesse trabalho, agradeço aos Professores Marcos Antonio M. Fadini, Ester Azevedo, e Marineide R. Vieira, por terem gentilmente aceitado contribuir com nosso trabalho. Creio que a ciência caminha a passos mais largos quando há a colaboração e apoio entre pesquisadores. E aqui preciso ressaltar o quanto estas três pessoas foram importantes para nosso trabalho, pois forneceram dados de coletas anuais para que fossem incorporados ao nosso estudo.

Agradeço em especial aos companheiros de laboratório, Elizeu, Zézão, Carioca, Alexandre, Paulo, Eduardo, Madá, com os quais tenho convivido quase que diariamente pelos últimos quatro anos! Pelo ótimo relacionamento e por fazerem deste laboratório um ótimo ambiente de trabalho!

Agradeço também aos ex-companheiros de laboratório, Yoda, Fábio e Peterson, que foram fundamentais na minha iniciação no laboratório (quase 10 anos atrás!), e que ainda hoje me socorrem nos momentos de dúvida. Além de tudo, esta tese não teria sido possível sem a participação de todos os três, pois também forneceram detalhes e dados de coleta de seus projetos de mestrado/doutorado.

Agradeço aos amigos que desde tempos de graduação ainda se fazem presentes, e importantes em minha vida, fazendo com que essa caminhada seja mais fácil, engraçada e prazerosa ao lado deles. Muito obrigado Getúlio, Denti, Kabação, Necrose, Paula e Koshi.

Sou grato aos amigos da pós , especialmente aos antigos companheiros do futebol arte! Ressalto aqui o quanto que estas pessoas foram importante no meu crescimento científico, e fundamentais para o meu amadurecimento como principiante à pesquisador, e ainda hoje são inspiração para seguir em frente nesta carreira! Fica aqui um sincero obrigado aos grandes amigos, e hoje professores, Toyoyo, Michel, Nandão e ao Dioguinho que também está quase lá!

Este projeto também me possibilitou uma experiência nas terras, ou melhor, no gelo canadense. Foi uma grande honra poder trabalhar junto com o Benjamin Gilbert, que além de excelente pesquisador, também uma grande pessoa. Experiência única poder ter compartilhado de suas ideias e rabiscos no quadro, durante seis meses. Além do próprio Ben, foi muito satisfatório ter sido tão bem recebido pelas meninas de sua “crew” Rachel, Kelly, Tess, Natalie e Emily.

Agradeço ao Prof. Antonio Carlos Lofego pela parceria, ajuda e ensinamentos no estudo e taxonomia dos ácaros Phytoseiidae. Além de, em conjunto com a Profa. Maria Stela Noll, pela avaliação e comentários durante minha aula de qualificação.

Agradeço/devo muito ao meu orientador professor Reinaldo pela oportunidade de trabalho, ensinamentos, compreensão, e que além da orientação científica também foi muito importante em meu amadurecimento pessoal e profissional. Agradeço imensamente também o voto de confiança e liberdade para ter desenvolvido este trabalho.

Sem o esforço e apoio incondicional de meus pais, Fernando e Yara, desde os tempos de graduação, esta tese nunca poderia ter sido realizada. Sempre foram meu exemplo de caráter, trabalho duro, humildade e grande coração. Também sou grato pelo apoio de meus avós, Laides, Ademar, Nedes e Antônio, e meus grandes irmãos Eduardo e Gustavo.

Por fim, sem minha amiga, namorada, noiva, e hoje esposa, Jaque, não teria forças pra ter chegado até aqui. Compartilhou, e suportou o frio do Canadá em nosso porãozinho, além dos bons e maus momentos durante estes 9 anos de relacionamento, e hoje ainda é minha fonte de segurança, força e inspiração.

O projeto foi financiado pela Fundação de Apoio à Pesquisa do Estado de São Paulo (FAPESP, proc. 2010-19935-1).

RESUMO

A seringueira, *Hevea brasiliensis* (Muell. Arg. Euphorbiaceae) é a principal fonte de borracha natural do mundo, e tem como centro de origem e ocorrência natural a região Amazônica. Nos últimos anos o estudo da acarofauna associada à heveicultura tem ganhado destaque, principalmente devido aos danos e perdas econômicas ocasionados por *Calacarus heveae* Feres, e *Tenuipalpus heveae* Baker. Entretanto, a maioria dos resultados obtidos refletem particularidades locais, não havendo análise de dados em grande escala e em conjunto. Dessa forma, realizamos a integração dos dados de literatura com incursões a campo visando preencher lacunas no conhecimento da acarofauna associada a seringueiras no Brasil. Nossos resultados enfatizam a elevada diversidade de espécies (250) registradas em seringueiras, sendo *C. heveae, T. heveae,* e *Phyllocoptruta seringueirae* Feres*,* as mais abundantes. Estas espécies tiveram seus picos populacionais compreendidos entre os meses de fevereiro e maio. As seringueiras nativas da Amazônia podem abrigam uma enorme diversidade de ácaros Phytoseiidae, visto que sete novas espécies foram descritas a partir desta região. Além disso, baseando-se nos estudos de dinâmica temporal das comunidades, verificamos que independentemente da localização geográfica, as comunidades exibem um mesmo padrão de acumulação temporal de espécies, e a abordagem tradicional (*"species-time-relationship*", STR) não pode ser aplicada ao nosso sistema de estudo. Dessa forma, elaboramos uma nova abordagem baseada na taxa de *turnover* temporal, a partir do desmembramento dos componentes de Colonização e Extinção da métrica de *turnover* (Sorensen). Por fim, considerando-se a estruturação das comunidades no espaço, os processos baseados na dispersão das espécies, e o componente ambiental autocorrelacionado com o espaço, são os principais fatores determinando a montagem das comunidades em uma escala biogeográfica. Por outro lado, o efeito destes componentes também é variável de acordo com o táxon estudado. Por fim, verificamos que a riqueza de espécies também é modelada negativamente por fatores climáticos relacionados ao clima seco (p. ex. baixa umidade relativa, e baixa precipitação mensal).

Palavras-chave: Acarologia, Biodiversidade, Ecologia, Metacomunidades, Seringueira

ABSTRACT

The rubber tree, *Hevea brasiliensis* (Muell. Arg. Euphorbiaceae) is the main source of natural rubber in the world, being originated and constrained to the Amazon basin. In the last years, the study of species of mites associated with rubber crop have been focused due to the importance of *Calacarus heveae* Feres, and *Tenuipalpus heveae* Baker, which occasionally induce severe defoliation and losses on latex production. Although, most of studies has highlighted local results, being absent broad-scale studies, and connected data analysis. We performed a compilation of literature data, and complemented it with field sampling, aiming to diminish the lack of knowledge about the mites associated with rubber trees in Brazil. Our results highlight the huge diversity of species (250) recorded on rubber trees, from which *C. heveae, T. heveae* and *Phyllocoptruta seringueirae* Feres were the most abundant. These species present a populational peak comprised between February to May. Native rubber trees from Amazon also can harbor a great diversity of Phytoseiidae species, since seven new species were described from there. Beyond that, based on the communities temporal dynamics, we verified that regardless of the locality, all the communities of mites follow the same strict patter of species accumulation through time. In this sense, the traditional approach, that relies on the *species-time-relationship* “STR” could not be applied to our data. As a result, we built a new approach based on the turnover rates, disentangling the Colonization and Extinction components from turnover metric (Sorensen). At least, the spatial structure of the communities was driven by the dispersion-based component, and in the environmental component autocorrelated with space, in a biogeographic scale. On the other hand, the effect of these components also changed according to the taxon. At least, number of species was also negatively modeled by the dry weather, mainly low humidity and precipitation.

Keywords: Acarology, Biodiversity, Ecology, Metacommunity, Rubber trees

Sumário

Introdução Geral

Diversidade de ácaros em seringueiras

A seringueira, *Hevea brasiliensis* (Muell. Arg. Euphorbiaceae) é a principal fonte de borracha natural do mundo (Gonçalves *et al.*, 2001). O gênero *Hevea* inclui 11 espécies, e tem como centro de origem e ocorrência natural a região Amazônica (Shultes, 1987; Secco, 2008). Entre as espécies de *Hevea*, a mais cultivada e comercialmente utilizada é a *H. brasiliensis* devido à qualidade de seu látex e elevada produtividade (Gonçalves & Marques, 2008). A introdução de cultivos comerciais em diversas regiões do país favoreceu a insurgência de diversas pragas e doenças, não relatadas enquanto a extração do látex se dava de forma extrativista no norte do país.

Nos últimos anos o estudo da acarofauna associada à heveicultura tem ganhado destaque, visto que algumas espécies como o *Calacarus heveae* Feres, e *Tenuipalpus heveae* Baker estão entre as suas principais pragas, sendo responsáveis por ocasionais danos e perdas econômicas (Vieira & Gomes 1999, Vieira *et al.* 2010, Feres *et al*. 2002). Nesse sentido, nos últimos anos foram alcançados avanços significativos no entendimento da dinâmica populacional das espécies pragas, interações com agentes de controle biológico, influência da heterogeneidade ambiental, susceptibilidade de clones, e influência de variáveis climáticas (Bellini *et al.* 2008; Castro *et al.* 2013; Daud & Feres 2014; Daud *et al.* 2012b, 2007, 2010, 2012a; Demite & Feres 2005, 2007, 2008; Feres *et al.* 2002, 2010; Ferla & Moraes 2008; Hernandes & Feres 2006; Nuvoloni *et al.* 2014, 2015; Pontier *et al.* 2000; Tanzini *et al.* 2000; Vieira & Gomes 1999, Vieira *et al.* 2009, 2010; Zacarias & Moraes 2001, 2002). Entretanto, a maioria dos resultados obtidos refletem particularidades locais, não havendo análises conjuntas dos dados. Além disso, a maioria dos estudos foram conduzidos nos estados de São Paulo e Mato Grosso, visto que respondem por mais de 70% da produção nacional de látex (IBGE, 2008), mas por outro lado, ainda muito pouco se sabe sobre a ocorrência e importância das espécies de ácaros em seringueiras da região Norte, e cultivos no Nordeste.

A floresta Amazônica é o maior e menos estudado bioma brasileiro, e tem sofrido severa intervenção humana nas últimas décadas (Laurance *et al.*, 2001; Brooks *et al.*, 2002). Elevadas taxas de desmatamento aumentam as chances de que muitas espécies estejam sendo extintas antes mesmo de serem conhecidas pela ciência (Rangel, 2012). Assim, um maior conhecimento sobre a diversidade de ácaros, ou demais artrópodes, associados a vegetação nativa amazônica poderia fornecer subsídios importantes para estudos de conservação (Kremen *et al.*, 1993). Além da importância direta de estudos taxonômicos para a conservação de espécies, o conhecimento da acarofauna associada à *Hevea* nativa pode ser útil também dentro do contexto do controle biológico, visto que a utilização de predadores locais para o controle de pragas é uma opção válida, e que se encaixa nos pressupostos do controle biológico clássico (Kogan, 1998).

Processos ambientais e espaciais modelando as comunidades

Entender como a diversidade de espécies muda ao longo do espaço e através do tempo tem sido dois objetivos principais na ecologia (Rosenzweig, 1995, 1998; Whittaker *et al.*, 2001; Villéger & Brosse, 2012). Espacialmente, sabe-se que padrões de similaridade na composição das espécies são influenciados pelos efeitos combinados da variação ambiental, distância geográfica e propriedades de dispersão das espécies

(Steinitz *et al.*, 2006b). A dualidade no confronto entre teoria do nicho e teoria neutra tem gerado grande embate nos últimos anos (Legendre, 1993; Borcard & Legendre, 1994, 2002; Svenning & Skov, 2002; Tuomisto *et al.*, 2003; Steinitz *et al.*, 2006a; Whittaker *et al.*, 2007). Enquanto a teoria baseada no nicho defende que a composição das comunidades é determinada pela interação entre espécies, e sua relação com recursos e condições do hábitat (Cornell & Lawton, 1992), por outro lado, segundo Hubbel (2001) na teoria neutra as espécies são equivalente ecologicamente, e os padrões de distribuição são determinados pela capacidade de dispersão, bem como migrações e extinções aleatórias. A emergência de uma nova abordagem teórica, baseada na teoria de metacomunidades (Leibold *et al.*, 2004; Cottenie, 2005), tem promovido uma maior aproximação entre ambas as teorias do nicho e neutra, visto que ao invés de concorrentes, elas operariam conjuntamente, e em escalas diferentes, na organização das comunidades (Chase & Leibold, 2003). Nesse sentido, estudos têm sugerido que processos ambientais, baseados no nicho, operam em maior intensidade em escala local, enquanto processos espaciais, baseados na dispersão, atuam com maior intensidade em escalas espaciais maiores.

Relação entre diversidade e o tempo-espaço

A relação de dependência entre diversidade e tamanho da área (*"species-area-relationship"* ou "*SAR*") foi primeiramente formalizada por Preston (1960), e tem sido ampla e consistentemente testada em diversos sistemas naturais (MacArthur & Wilson 1967; Rosenzweig 1995). Por outro lado, o efeito temporal sobre a diversidade (*"species-time-relationship"* ou "*STR*") tem sido pouco abordado, sendo poucos os pesquisadores que investiram esforços nessa direção (Preston, 1960; Rosenzweig, 1995, 1998). Nesse sentido, como proposto também por Preston (1960), assumiu-se a que a acumulação de espécies no espaço e tempo podem ser análogas, ou seja obtém-se o mesmo efeito na taxa de acumulação de espécies coletando-se em uma área maior, ou em um período de tempo maior (Adler & Lauenroth 2003). A abordagem de substituição do tempo pelo espaço (*“species-time-area-relationship”*, or *“STAR”*) foi recentemente formalizada (Adler & Lauenroth 2003) e tem recebido apoio da comunidade científica, visto que muitos modelos biológicos testados se enquadraram bem nesta abordagem, apresentando padrões semelhantes de acumulação no espaço e tempo (e.g., Adler *et al.* 2005; Matthews & Pomati 2012; Juan & Hewitt 2014). Entretanto, os processos ou mecanismos que promovem o *turnover* de espécies no tempo (White & Gilchrist, 2007), bem como as predições de Preston (1960) que sustentam a relação entre espécies e o tempo, ainda permanecem obscuros e pouco estudados.

Um dos pressupostos para se estimar a razão entre espécies-área se baseia na arbitrariedade da escolha do primeiro quadrado (área amostral), sendo que a riqueza de espécies nesta área “1” seja calculada a partir da riqueza média de todos os demais quadrados, isso necessariamente garantiria que a riqueza média sempre aumentaria conforme uma maior área seja considerada (Preston 1960). Para que a analogia entre espaço-tempo fosse válida, seria necessário que a amostragem no tempo também seguisse o mesmo pressuposto, ou seja, também deveria ser arbitrária, visando assegurar a equivalência das razões espécies-área e espécies-tempo. Entretanto, a maioria dos estudos envolvendo a relação espécies-tempo tem desconsiderado o pressuposto da aleatoriedade do tempo, e isso torna-se especialmente problemático quando as comunidades estão submetidas a uma mudança temporal determinística, como no caso de comunidades em sucessão. Nesse caso, a mudança do tempo “1” para o tempo “2”, não necessariamente representa a mesma mudança do tempo “2” para o tempo “3”, nem do tempo “1” para o tempo “3”, como assumido pela abordagem inicial de Preston para a estimativa da relação espécies-área.

Empregando uma nova abordagem baseada na recente teoria de metacomunidades, a taxa de acumulação de espécies, ou *turnover*, seria definido pelo balanço dos eventos de colonização e extinção de todas as espécies durante um determinado período de tempo (Leibold *et al.*, 2004). Assim, ao isolarmos as taxas de colonização e extinção da métrica de *turnover* (Sorensen, Bray-Curtis, etc), poderíamos acessar quais os mecanismos (e.g. clima, ambiente, hospedeiro) que promovem maior colonização ou extinção de espécies, ao invés de simplesmente verificar quais os mecanismos estão associados a um maior *turnover* espacial ou temporal. Desta forma, seria possível determinar se a abordagem da substituição do espaço pelo tempo pode ser aplicada ao nosso conjunto de dados, bem como acessar quais os mecanismos promotores da colonização e extinção, e se os mesmos diferem daqueles responsáveis pela mudança no *turnover* das espécies de ácaros em seringueira.

Referências

Adler, P.B. & Lauenroth, W.K. (2003) The power of time: spatiotemporal scaling of species diversity. *Ecology Letters*, **6**, 749–756.

Adler, P.B., White, E.P., Laurenroth, W.K., Kaufman, D.M., Rassweiler, A. & Rusak, J.A. (2005) Evidence for a general species–time–area relationship. *Ecology*, **86**, 2032–2039.

Bellini, M.R., Feres, R.J.F. & Buosi, R. (2008) Ácaros (Acari) de Seringueira (*Hevea brasiliensis* Muell. Arg., Euphorbiaceae) e de Euforbiáceas Espontâneas no Interior dos Cultivos. *Neotropical Entomology*, **37**, 463–471.

Borcard, D. & Legendre, P. (1994) Environmental control and spacial structure in ecological communities: an example using oribatid mites (Acari, Oribatei). *Environmental and Ecological Research*, **1**, 37–61.

Borcard, D. & Legendre, P. (2002) All-scale spatial analysis of ecological data by means of principal coordinates of neighbour matrices. *Ecological Modelling*, **153**, 51–68.

Brooks, T.M., Mittermeier, R.A., Mittermeier, C.G., Fonseca, G.A.B.D.A., Rylands, A.B., Konstant, W.R., *et al.* (2002) Habitat Loss and Extinction in the Hotspots of Biodiversity. *Conservation Biology*, **16**, 909–923.

Castro, E.B., Nuvoloni, F.M., Mattos, C.R.R. & Feres, R.J.F. (2013) Population fluctuation and damage caused by phytophagous mites on three rubber tree clones. *Neotropical entomology*, **42**, 95–101.

Chase, J.M. & Leibold, M.A. (2003) *Ecological Niches: Linking Classical and Contemporary Approaches*. The University of Chicago Press.

Connor, E.F. & Mccoy, E.D. (1979) The Statistics and Biology of the Species-Area Relationship. *American Naturalist*, **113**, 791–833.

Cornell, H.V. & Lawton, J.H. (1992) Species interactions, local and regional processes, and limits to the richness of ecological communities: a theoretical perspective. *Journal of Animal Ecology*, **61**, 1–12.

Cottenie, K. (2005) Integrating environmental and spatial processes in ecological community dynamics. *Ecology letters*, **8**, 1175–82.

Daud, R.D., Conforto, E. de C. & Feres, R.J.F. (2012a) Changes in leaf physiology caused by *Calacarus heveae* (Acari, Eriophyidae) on rubber tree. *Experimental and Applied Acarology*, **57**, 127–137.

Daud, R.D. & Feres, R.J.F. (2014) Community structure of mites (Arachnida: Acari) in six rubber tree clones. *International Journal of Acarology*, **39**, 589–596.

Daud, R.D., Feres, R.J.F. & Hernandes, F.A. (2012b) Seasonal suitability of three rubber tree clones to *Calacarus heveae* (Acari, Eriophyidae). *Experimental & applied acarology*, **56**, 57–68.

Daud, R.D., José, R. & Feres, F. (2007) Dinâmica populacional de ácaros fitófagos (Acari , Eriophyidae , Tenuipalpidae) em seis clones de seringueira no sul do Estado de Mato Grosso. *Revista*, **51**, 377–381.

Daud, R.D., Silva, E.R.O. da & Feres, R.J.F. (2010) Influência de Cecropia pachystachya na incidência de ácaros (Arachnida, Acari) e de *Leptopharsa heveae* (Insecta, Hemiptera) em cultivo de seringueira. *Revista de Biologia Neotropical*, **7**, 49–60.

Demite, P.R. & Feres, R.J.F. (2005) Influência de Vegetação Vizinha na Distribuição de Ácaros em Seringal (*Hevea brasiliensis* Muell . Arg ., Euphorbiaceae em São José do Rio Preto, SP. *Neotropical Entomology*, **34**, 829–836.

Demite, P.R. & Feres, R.J.F. (2007) Ocorrência e Flutuação Populacional de Ácaros Associados a Seringais Vizinhos de Fragmentos de Cerrado. *Neotropical entomology*, **36**, 117–127.

Feres, R.J.F., Del'Arco, M. & Daud, R.D. (2010) Biological cycle of *Tenuipalpus heveae* Baker (Acari, Tenuipalpidae) on leaflets of three rubber tree clones. *Revista Brasileira de Entomologia*, **54**, 298–303.

Feres, R.J.F., Rossa-feres, D.D.C., Daud, R.D. & Santos, R.S. (2002) Diversidade de acaros (Acari, Arachnida) em seringueiras (*Hevea brasiliensis* Muell. Arg., Euphorbiaceae) na região noroeste do Estado de São Paulo, Brasil. *Revista Brasileira de Zoologia*, **19**, 137–144.

Ferla, N.J. & Moraes, G.J. de. (2008) Flutuação populacional e sintomas de dano por Ácaros (Acari) em seringueira no Estado do Mato Grosso, Brasil. *Revista Árvore*, **32**, 365–376.

Gonçalves, P.S., Bataglia, O.C., Ortolani, A.A. & Fonseca, F.S. (2001) Manual de heveicultura para o estado de São Paulo. *Boletim Técnico IAC*, **189**, 77p.

Gonçalves, P.S. & Marques, J.R.B. (2008) Melhoramento genético da seringueira: passado, presente e futuro. In *Seringueira*. EPAMIG - Viçosa, Viçosa, MG, pp. 399–498.

Hernandes, F.A. & Feres. (2006) Review about mites (Acari) of rubber trees (*Hevea* spp., Euphorbiaceae) in Brazil. *Biota Neotropica*, **6**.

Hubbel, S.P. (2001) *The unified neutral theory of biodiversity and biogeography*. Princeton University Press, Princeton, New Jersey, USA.

Instituto Brasileiro de Geografia e Estatística (2008) Produção da extração vegetal e silvicultura [WWW Document]. *http://www.ibge.gov.br*. URL [accessed on 2008].

Juan, S. & Hewitt, J. (2014) Spatial and temporal variability in species richness in a temperate intertidal community. *Ecography*, **37**, 183–190.

Kogan, M. (1998) Integrated pest management: historical perspectives and contemporary developments. *Annual Review of Entomology*, **43**, 243–270.

Kremen, C., Colwell, R.K., Erwin, T.L., Murphy, D.D., Noss, R.F. & Sanjayan, M.A. (1993) Terrestrial Arthropod Assemblages: Their Use in Conservation Planning. *Conservation Biology*, **7**, 796–808.

Laurance, W.F., Cochrane, M.A., Bergen, S., Fearnside, P.M., Delamônica, P., Barber, C., *et al.* (2001) The Future of the Brazilian Amazon. *Science*, **291**, 438–439.

Legendre, P. (1993) Spatial Autocorrelation: Trouble or New paradigm? *Ecology*, **74**, 1659–1673.

Leibold, M. a., Holyoak, M., Mouquet, N., Amarasekare, P., Chase, J.M., Hoopes, M.F., *et al.* (2004) The metacommunity concept: a framework for multi-scale community ecology. *Ecology Letters*, **7**, 601–613.

MacArthur, R.A. & Wilson, E.O. (1967) *The theory of island biogeography*. Princeton University Press, Princeton, NJ, USA.

Matthews, B. & Pomati, F. (2012) Reversal in the relationship between species richness and turnover in a phytoplankton community. *Ecology*, **93**, 2435–2447.

Nuvoloni, F.M., Castro, E.B. de & Feres, R.J.F. (2014) The role of native vegetation on infection rates of *Calacarus heveae* (Acari: Eriophyidae) by *Hirsutella thompsonii* (Ascomycota: Ophiocordycipitaceae). *Experimental & applied acarology*, **63**, 157–69.

Nuvoloni, F.M., Lofego, A.C., Rezende, J.M. & Feres, R.J.F. (2015) Phytoseiidae mites associated with *Hevea* spp. from the Amazon region: a hidden diversity under the canopy of native trees. *Systematics and Biodiversity*.

Palmer, M.W. & White, P.S. (1994) Scale dependence and the species-area relationship. *American Naturalist*, **144**, 717–740.

Pontier, K.J.B., Moraes, G.J. de & Kreiter, S. (2000) Biology of *Tenuipalpus heveae* (Acari, Tenuipalpidae) on rubber tree leaves. *Acarologia*, **41**, 423–427.

Preston, F.W. (1960) Time and Space and the Variation of Species. *Ecology*, **41**, 612–627.

Rangel, T. (2012) Amazonian Extinction Debts. *Science*, **162**, 1–3.

Rosenzweig, M.L. (1995) *Species diversity in space and time*. Cambridge University Press, New York, NY.

Rosenzweig, M.L. (1998) Preston's ergodic conjecture: the accumulation of species in space and time. In *Biodiversity dynamics* (ed. M. L. Mckinney & J. A. Drake). Columbia University Press, New York, NY, pp. 311–348.

Secco, R. de S. (2008) A Botânica da seringueira [*Hevea brasiliensis* (Willd. ex Adr. Jussieu) Muell. Arg (Euphorbiaceae)]. In *Seringueira* (ed. Alvarenga, A. de P. & Carmo, C.A.F. de S. do). EPAMIG - Viçosa, Viçosa, MG, pp. 1–24.

Shultes, R.E. (1987) Studies in the *Hevea*. VIII. Notes on infrespecific variants on *Hevea brasiliensis* (Euphorbiacea). *Economic Botany*, **41**, 125–147.

Steinitz, O., Heller, J., A.Tsoar, Rotem, D. & Kadmon, R. (2006) Environment, dispersal and patterns of species similarity. *Journal of Biogeography*, **33**, 104–105.

Svenning, J.C. & Skov, F. (2002) Mesoscale distribution of understory plants in temperate forest (Kalø, Denmark): the importance of environment and dispersal. *Plant Ecology*, **160**, 169–185.

Tanzini, M.R., Alves, S.B., Tamai, M.A., Moraes, G.J. de & Ferla, N.J. (2000) An epizootic of *Calacarus heveae* (Acari: Eriophyidae) caused by *Hirsutella thompsonii* on rubber trees. *Experimental and Applied Acarology*, **24**, 141–144.

Tuomisto, H., Ruokolainen, K. & Yli-Halla, M. (2003) Dispersal, environment, and floristic variation of western Amazonian forests. *Science (New York, N.Y.)*, **299**, 241–244.

Vieira, M.R. & Gomes, E.C. (1999) Sintomas, desfolhamento e controle de *Calacarus heveae* Feres, 1992 (Acari: Eriophyidae) em seringueira (*Hevea brasiliensis* Muell. Arg.). *Cultura Agronômica*, **8**, 53–71.

Vieira, M.R., Gomes, E.C. & Silva, H.A.S. da. (2010) Reduçao na produçao de látex da seringueira provocada pela infestaçao de ácaros. *Revista Ceres*, **57**, 608–613.

Vieira, M.R., Silva, H.A. de S., Cardoso, M.M. & Figueira, J.C. (2009) Progênies de seringueira com potencial para conferir resistência a ácaros (*Calacarus heveae* Feres e *Tenuipalpus heveae* Baker). *Ciência Rural*, **39**, 1953–1959.

Villéger, S. & Brosse, S. (2012) Measuring changes in taxonomic dissimilarity following species introductions and extirpations. *Ecological Indicators*, **18**, 552–558.

White, E.P. & Gilchrist, M.A. (2007) Effects of population-level aggregation , autocorrelation , and interspecific association on the species – time relationship in two desert communities. *Evolutionary Ecology Research*, **9**, 1329–1347.

Whittaker, R.J., Nogues-Bravo, D. & Araujo., M.B. (2007) Geographical gradients of species richness: a test of the water-energy conjecture of Hawkins et al. (2003) using European data for five taxa. *Global Ecology and Biogeography*, **16**, 76–89.

Whittaker, R.J., Willis, K.J. & Field, R. (2001) Scale and species richness: towards a general, hierarchical theory of species diversity. *Journal of Biogeography*, **28**, 453–470.

Objetivos

Visando conhecer a composição e distribuição das espécies de ácaros associados a seringueiras no Brasil, realizamos o levantamento de toda a bibliografia referente ao tema, bem como incursões a campo focando em seringueiras nativas e cultivadas de regiões ainda pouco estudadas. Com base nas informações reunidas, foi confeccionada uma base de dados onde todo o material pôde ser comparado, padronizado e inserido na coleção de Acari do DZSJRP. Foram realizadas as descrições das novas espécies, principalmente aquelas pertencentes a Phytoseiidae e *Brachytydeus.* A base de dados foi utilizada para verificar o padrão de acumulação de espécies no tempo e espaço, bem como testar se a abordagem que assume a analogia do espaço-tempo pode ser aplicada ao nosso sistema de estudo. Por fim também investigamos a importância relativa de processos espaciais e ambientais na estruturação das comunidades de ácaros em uma escala continental.

A tese está dividida em seis capítulos, cujos objetivos foram:

Capítulo 1: Fornecer um panorama atualizado sobre a ocorrência das espécies de ácaros em seringueiras nativas e cultivadas no Brasil, baseado em dados de literatura e amostragens de campo.

Capítulo 2: Conhecer a diversidade de Phytoseiidae associados a *Hevea* spp. nativa e cultivada da região Amazônica, bem como descrever as espécies novas.

Capítulo 3: Conhecer a diversidade de Phytoseiidae associados a diferentes clones de *Hevea brasiliensis* do estado da Bahia, bem como descrever as espécies novas.

Capítulo 4: Revisar as espécies de *Brachytydeus* registrados em seringueiras no Brasil, descrevendo as possíveis espécies novas.

Capítulo 5: Testar se a abordagem tradicional (STR) é adequada para estimar o padrão de acumulação temporal de espécies para o nosso conjunto de dados, examinando se a dinâmica de colonização e extinção é direcional no tempo; além de testar se as condições ambientais podem ser preditivas do turnover e colonização relativa.

Capítulo 5: Verificar a importância relativa de processos espaciais e ambientais na estruturação das comunidades de ácaros, e em particular na composição de espécies fitófagas e ácaros Phytoseiidae.

Capítulo I

Review about mites from rubber trees (*Hevea* spp.) in Brazil with remarks by regions

Felipe M. Nuvoloni, Reinaldo J. F. Feres

Abstract

Inventories concerning the mite fauna on rubber trees have been widely performed on Brazil in the last two decades, and have a great importance in view to comprehend the local distribution and abundance of mite species on the crop. The rubber cultivation has been focus of interest of acarologists due to the importance of pest mites on the cultivation. In this paper we review the literature concerning the mite fauna recorded on rubber trees in that country complemented with exploratory surveys in Bahia, Amazonas, Goiás, Acre, Minas Gerais, Maranhão and Rondônia states. Phytoseiidae was the most diverse family (62 species), while the Eriophyidae *Calacarus heveae* and *Phyllocoptruta seringueirae* were far the most abundant, and with broad occurrence. Native specimens of *Hevea brasiliensis*, as well as *H. microphylla*, *H. spruceana*, *H. pauciflora*, and *H. guiannenses* can harbor phytophagous mites and, mainly, a great number of Phytoseiidae species. We figure out that most of species recorded were endemic, and 75% of them had the occurrence restricted to one or two states. In spite of the composition of species differs among macroregion, the yearly dynamic of the dominant species seems similar among all the areas, being the months between January to April the period of populational peaks, and main infestations. *Calacarus heveae* was the main pest on most of the areas, followed by *T. heveae* that was dominant in Minas Gerais and the northern sites, and *P. seringueirae* which was the most abundant in some clones in the State of Mato Grosso. Our results bring a general and updated panorama about the occurrence of mites on rubber trees in Brazil.

Keywords: Acari, Biodiversity, inventory, *Calacarus heveae, Hevea brasiliensis*

Introduction

The rubber tree (*Hevea brasiliensis* Euphorbiaceae) is an important and valuable crop due to the latex production, being broadly cultivated the Brazilian territory. In the last 25 years many studies have been accomplished due to the emergence of new pests and diseases on the "escape areas" of South America Leaf Blight disease (*Microcyclus ulei*), which includes São Paulo and Mato Grosso states. *Calacarus heveae* Feres, and *Tenuipalpus heveae* Baker are among the main pests on the referred areas, occasionally inducing severe defoliation and losses on latex production (Vieira & Gomes 1999; Vieira *et al.* 2010). Such as pointed out by Hernades & Feres (2006), the discovery of *C. heveae* aroused the interest for studies on mites associated with rubber trees in the 1990's. More than 30 surveys approaching the mite fauna on rubbers have been carried out therefore, and they aimed to study some aspects of: taxonomy, biological or chemical control, populational and seasonal dynamics, community structure, pathogen infections, influence of native vegetation, among others (Baker 1945; Bellini *et al.* 2005, 2008; Castro 2012; Castro *et al.* 2013; Chiavegato 1968; Daud & Feres 2014; Daud *et al.* 2012b, 2007, 2010, 2012a; Demite & Feres 2005, 2007, 2008; Deus *et al.* 2012; Fazolin & Pereira 1989; Feres & Nunes 2001; Feres 1992, 1998, 2000, 2001; Feres *et al.* 2002, 2010; Ferla & Moraes 2002, 2003b, 2008; Flechtmann & Arleu 1984; Gallo *et al.* 2002; Hernandes & Feres 2006a; b; Nuvoloni 2011; Nuvoloni *et al.* 2014, 2015; Pontier *et al.* 2000; Silva 1972; Tanzini *et al.* 2000; Vieira & Gomes 1999, 2001; Vieira *et al.* 2000, 2006, 2009, 2010; De Vis *et al.* 2006a; b; Zacarias & Moraes 2001, 2002)

In spite of all species of *Hevea* being originated on the Amazon basin, most of mite surveys have been carried out on cultivated crops from São Paulo and Mato Grosso, and more recently on the State of Bahia. The concentration of the studies on these areas can be due to their relative importance on the rubber production, since they contribute with more than 80% in the national scenario (IBGE 2008). On the other hand, the only surveys which focused the occurrence of mites on rubber trees from Amazon were Fazonlin & Pereira (1989) that reported damage caused by *Oligonychus gossypii* Zacher on Acre and Amazonas; Feres (2001) which reported Eriophyidae mites from wild *Hevea* of Amazonas; and the surveys of Flechtmann & Arleu (1984), and Flechtmann (1989) with the casual records of *O. gossypii* on Rio Branco (Acre) and *T. heveae* in Belém (Pará).

Chiavegato (1968) published the first inventory, listing eigh acarine species on rubber trees. The first review was set up by Silva (1972), with the record of six species, being lately updated by Feres (2000), which increase the number to 20 nominal species, and more recently Hernandes and Feres (2006) accurate the number to 54 species and 50 unidentified. The last review was taken as basis for the present study, since the prior research have summarized all available information about mite fauna on rubber trees in Brazil until its publication time.

Due to necessity to update the list of occurrence of mites on rubber trees, and including areas still uncovered by previous surveys, we built a new review concerning all available information about rubber tree mites on Brazil. In the current study we assembled the recent data of literature from 2006 so far, and carried out field surveys on the forest and cultivated areas of Amazonas, Acre, Goiás, Rondônia, Maranhão and Minas Gerais states. Therefore, we aimed to gather all available information about distribution of mites on wild and cultivated rubber trees in Brazil, providing a current panorama about the occurrence of species on each region in Brazil. We also reviewed, updated, and standardized the identification of specimens deposited at collection of Acari from DZSJRP.

Material and Methods

Our research summarizes all available information from surveys about mites on rubber trees into a dataset that included information from approximately 60 sites and 13 Brazilian states (Table 1).

In the current work we gathered information from two distinct sources: bibliography, and field samplings. Below, we summarize the particularities of each survey included on the review.

Literature compilation

The review set up by Hernandes & Feres (2006) was taken as the starting point for the current research, and it was embodied for all the previous investigations about mites on rubber trees in Brazil until 2006. Thus, since 2006 seven inventory papers about mites on rubber trees were released, so we compiled and summarized them bellow:

- **Demite & Feres 2007, Demite & Feres 2008:** the surveys were conducted on "Plantações Edouard Michelin ltda." at Itiquira, State of Mato Grosso. The samplings were carried out fortnightly throughout one year (March 2004 to March 2005), on two plots of clone PB 235, near a riparian vegetation and native *Cerradão* area. Seven leaves of twenty five trees were sampled on each survey per plot.

- **Bellini *et al.* 2008:** the collections were performed on three rubber plantations in the State of São Paulo, Cedral, Taquaritinga and Pindorama, for the period of one year. The samples were taken quarterly in three random trees of each plantation.

- **Nuvoloni 2011:** the survey was also conducted on “Plantações Michelin da Bahia ltda”, from May 2008 to April 2009. Five plots were selected for the collection, which in turn three of them were sorted as agroforestry system, with native plants in the interior and border of plantations. The plots were cultivated with the clones MDF 180 and FX 3864 (master’s dissertation).

- **Daud *et al.* 2010:** the research was developed from February 2007 to January 2008 on two plots of a rubber plantation in São José do Rio Preto, State of São Paulo. Ten rubber threes of clone PB 235 were sampled by month on each area.

- **Castro 2012:** the survey was conducted from April 2008 to May 2009 on “Plantações Michelin da Bahia ltda.”. A total of 28 rubber trees of the clones PMB 01, FDR 5788 and CDC 312 were monthly sampled (master’s dissertation).

- **Daud & Feres 2013:** the survey was carried out from March 2004 to March 2005, on “Plantações Edouard Michelin ltda.” Itiquira, State of Mato Grosso. Ten rubber trees of the clones GT1, PB 235, PB 217, PB 260, PR 225, RRIM 600, from six plots were fortnightly sampled.

- **Deus *et al.* 2013:** the sampling procedures were conducted on May and June 2010, in a private plantation of 16ha at Santana, State of Amapá. Twenty five plants of the clone FX 2261 were randomly sampled on each date.

Collections

Several samples were performed concerning the mite fauna from different localities in Brazil. The collection plots were choose in order to cover the regions that still remain uncovered or even barely studied so far. Thus we established the northern as our prime concern region to be studied, being the collections carried out on the Amazon Forest, that included the Amazonas, Acre, and Rondônia states, besides a site on the State of Goiás. The sites are located in the Amazon domain, however they encompass heterogeneous local characteristics due to distinct phytophysiognomies, covering an area of approximately 1.200 km.

We also set up collaborative projects with researches from Minas Gerais, Maranhão and São Paulo states, which carried out field surveys on rubber trees on their localities. The collaborations were performed with Profa. Dra. Ester Azevedo da Silva, from "Universidade Estadual do Maranhão" (UEMA), and Prof. Dr. Prof. Dr. Marcos Antonio M. Fadini "Universidade Federal de São João Del-rei" (UFSJ), e Profa. Dra. Marineide Rosa Vieira "Universidade Estadual Paulista" (UNESP Ilha Solteira). All the specimens were originally mounted on microscope slides with Hoyer´s medium on their respective laboratories, and sent to Laboratório of Acarologia for identification and deposit in the Collection of Acari (DZSJRP).

The sampling methodology and description of each collection plot are thereafter discriminated:

Acre

The study was conducted on August 2012 in four sites on the surrounding area of Rio Branco municipality. The samplings were performed on cultivated *H.brasiliensis*, and native specimens of *H. spruceana* Benth. and *H. pauciflora* Spruce ex. Benth. from Amazon Forest remnants (Figure 1).

The local weather is Aw Köppen tropical seasonal, with annual total rainfall between 1,600 and 2,750 mm, mainly comprised between October and April, wich receives 83% of the total amount for the whole year. The relative humidity follows the rain pattern, being around 88% on the rainy season and lower than 75% on drier season. The mean annual temperature ranges between 24 to 26^{o}C, with maximum of 31 and 33^{o}C and the minimum upper to 18^{o}C (Duarte 2006)

- **Universidade Federal do Acre (67°87’ W, 9°96’ S):** Cultivated *H. brasiliensis* trees from the experimental area of UFAC, placed at urban limits of Rio Branco city. The plot encompasses about 200 rubber trees without clone specification, from which we randomly sampled 20 of them. It is an area on the university campus, free of pesticides exposition or any chemical control, surrounded by grass field.

- **Parque Zoobotânico (67°85’ W, 9°95’ S)**: Wild rubber trees from urban fragment situated in the UFAC campus at Rio Branco city, which includes native remnant of Amazon vegetation. The collections were performed in five rubber trees from *H. spruceana* which is the dominant species of *Hevea* in the region. It is also a “*terra firme”* vegetation from the Amazon Forest domain.

- **Rubber Plantation (67°65’ W, 10°01’ S):** Commercial rubber tree plantation of *H. brasiliensis* with 10 ha, at KM 15 on BR 364 highway. We took samples from 15 rubber trees randomly selected in the midst of plantation.

- **Fazenda Experimental Catuaba (67°50’ W, 10°11’S):** Wild *H. pauciflora* sampled in a protected forest fragment named, which is a farm of “UFAC” (Federal University of Acre) with 1.281 ha, far 20 km from Rio Branco city. The vegetation is an alluvial forest, with patches of bamboo and palm trees, with trails covering the fragment. The samples were conducted in seven trees along the trails on the interior of the fragment.

Amazonas

The collections were carried out on July 2012, in four sites on the surrounding area of Manaus municipality. The samplings were performed on wild and cultivated specimens of *Hevea brasiliensis*, and native specimens of *H. guianensis* Aubl., *H. microphylla* Ule from the Amazon Forest (Figure 2).

The regional weather is Af Köppen, with mean annual temperature between 25.8 and 27.9 ^{o}C, humidity higher than 80% (Salati Marques 1989). Mean daily annual temperature and mean annual rainfall between 1992 and 2002 were 26.7 ◦C and 2479 mm (Coordenação de Pesquisas em Clima e Recursos Hídricos, CPCRH, INPA), although the precipitation being higher between November to March there is no a typical dry season.

- **Embrapa (59°97’ W, 2°89’ S)**: the samples were performed on cultivated *H. brasiliensis* trees from five plots of the experimental area of “Empresa Brasileira de Pesquisa Agropecuária” situated on the road AM 010, km 29. We took samples from a parcel with 15 rubber trees of the clones IAN 6590 and another parcel that includes 15 trees without cloning classification cultivated as an agroforestry management with forest vegetation. The studied area is other by the *terra firme* vegetation, a dryland evergreen formation of the Amazon Forest.

- **Reserva Florestal Adolpho Ducke (59°96' W, 3°02’ S)**: the collections were performed in 10 wild specimens of *H. guianensis* found in the interior of “Reserva Florestal Adolpho Ducke” (RFAD), which is under the jurisdiction of the Brazilian National Institute for Amazon Research (INPA), and issued permits for the sampling involved in the present study. Ducke is a “*terra firme”* tropical forest that covers an area of 100 km^{2} at the northern limit of the city of Manaus (59°59’W, 02°55’S), on the

AM 010 road, Km 26. It is a closed canopy forest, with trees reaching 35–40 m height and includes a high abundance of understory palms.

- **Careiro da Várzea (59°88’ W, 3°24’S):** We took samples from two wild specimens of *H. microphylla,* in a parcel sorted as “Site 3a”, and from five wild trees of *H. brasiliensis*, situated in another parcel sorted as “Site 3b” far 5 km from the previous plot, both placed at the margins of the Negro River, a tributary of Amazonas River, about 15 km southern of Manaus. The area is a wetland forest subject to seasonal flood, being denominated as “*Igapó Forest”* (Prance 1979).
- **Instituto Nacional de Pesquisas da Amazônica (INPA) (59°98’ W, 3°09’ S):** Grove area with 5ha of Amazon Forest remnant owned to INPA, located at the urban area of Manaus city. Collections were performed in three wild specimens of *H. brasiliensis* situated along the trails.

Goiás

Samplings were conducted on November 2012 in one rubber crop situated in the heart of the Goiás State. The region is settled on the Cerrado Bioma (Brazilian Savana), being surrounded by large amounts of soybean crops, and few fragments of native vegetation remnants. The climate is Aw Koppen, with two well distinct seasons, a hot and wet period from November to March, and a dry and colder period between April and September (Figure 3).

- **Fazenda Tamoio (48°92’ W, 15°12’ S)**: Rubber plantation situated on the rural area of Goianésia municipality, with 20 ha. The farmer is divided into blocks set by rubbers of different ages and clones, so our samples were conducted on 60 trees from four plots settled in the plantation. In total, 15 trees of the clones RRIM 600, PB 235, PR 255, GT 1, were randomly sampled on each plot.

Maranhão

- **São Luiz (44°25 W, 5°02 S):** The surveys were performed on a rubber plantation of 2ha on the State of Maranhão, from February 2010 to January 2011. The clone was unidentified.

Minas Gerais

- **Oratórios (42°48 W, 20°25 S):** The survey was conducted in the "Fazenda Experimental do Vale de Piranga, Empresa Agropecuária de Minas Gerais (EPAMIG)" in the State of Minas Gerais. The rubber plantation comprises two parcels of 1ha with the clones RRIM 600 and IAN 873. On each parcel 20 leaves from six trees were sampled fortnightly from September 2010 to July 2011.

Rondônia

The research was conducted on December 2012, in one site on the surrounding area of Porto Velho municipality (Figure 3). The local weather is quite similar to those prior described for the plots situated on the State of Acre.

- **Parque Ciruito (63°88' W, 8°71' S):** This area is a former rubber plantation (*H. brasiliensis*) with 10 ha, which was changed in a recreational garden of Porto Velho city. We took 15 trees for sampling, randomly selected in the area. Besides the remnants rubber trees, there are other typical trees from the Amazon formation secondarily planted on the site and grassy opened areas.

Sampling and mite extraction

Considering the surveys previously reported, about 50 leaves were collected from each tree, in a total of 150 leaflets. The mite extraction were performed washing the leaves of each tree in buckets with five liters of 30 % ethanol, following methodology of Rezende & Lofego (2011). After each washing the ethanol was filtered through sieves with 25 µm nylon mesh. With a wash-bottle, the debris on the mesh was washed with 70% ethanol into vials filled with the same alcohol for preservation.

All the vials were sent to the "Laboratório de Acarologia" at UNESP São José do Rio Preto (SP), where the mites were examined under stereoscopic microscope (40x) and mounted on microscope slides with Hoyer's medium (Krantz & Walter 2009). The type and voucher specimens are deposited in the Acari collection (DZSJRP), Department of Zoology and Botany, Universidade Estadual Paulista (UNESP), São José do Rio Preto, São Paulo, available at: http://www.splink.cria.org.br.

Results

General patterns of distribution

Considering both Hernandes & Feres' (2006) review and the dataset recently gathered by us, we set up a new database that includes about 190 morphospecies and more 100 nominal species of mites on *Hevea* spp. recorded in Brazil. The new database set up information about mites occurrence from 60 sites, distributed along 13 Brazilian states: Acre, Amazonas, Amapá, Bahia, Espírito Santo, Goiás, Maranhão, Minas Gerais, Mato Grosso do Sul, Mato Grosso, Para, Rondônia e São Paulo (Figure 4). For further considerations we discard information based on Pará and Espírito Santo states, due to the absence of a full inventory, since a unique survey was performed there, aiming to report only the occurrence of *Tenuipalpus heveae* and *O. gossypii*, and did not mentioned other species if present.

The number of species deeply varied through time and among sites. August was the month with the highest diversity (145 species) (Figure 5a). Nonetheless, the results may be due to the sampling artifacts, since all the collections on Acre, Amazonia and Rondônia were performed uniquely during August. Thus, whether discarding these data, the number of species follows the same temporal pattern showed by abundance, being the diversity peak on April (Figure 5b), and August and September the months with lowest number of species and individuals.

Phytoseiidae was the most diverse family with 62 species, followed by Tydeidae (34) and Tarsonemidae (30) (Table 1). Altough, whether considering only the number of nominal species, Phytoseiidae was still the most diverse (50 nominal species), but now followed by Tydeidae (15 nominal species), and Tetranychidae and Stigmaidae (9 nominal species) (Table 1). The new registers include 9 new species (seven Phytoseiidae and two *Brachytydeus* spp.) described from *Hevea* spp. from Amazonia, Acre, and Bahia states, besides new records for Rondônia, Maranhão and Minas Gerais. We could identify a well established seasonality of the species through the year, based on the one-year-long surveys. During the months of August to November the abundance of species was somewhat low, starting to increase on December, achieving the abundance peak on April (Figure 5a).

In general terms, we noticed that a small parcel of the species had a widespread distribution on the Brazilian states, since about 15% of them were recorded on at least half of the sites. Species broadly distributed on most of the areas encompass either phytophagous and predator mites, such as: *C. heveae, P. seringueirae, Shevtchenkella* *petiolula* Feres*, T. heveae, B. phoenicis, O. gossypii, Agistemus floridanus Gonzalez, Euseius alatus* De Leon*, E. concordis* (Chant)*, Iphiseiodes zuluagai* Denmark & Muma*, Cunaxatricha tarsospiosa* Castro & Den Heyer*, Zetzellia quasagistemas* Hernandes & Feres*, Hexabdella cinquaginta* Hernandes, Daud & Feres*, Galendromus annectens* De Leon*, Eutetranychus banksi* McGregor and *Tetranychus mexicanus* (McGregor)*.* The prior species have been regularly reported in the rubber trees inventories, and seems to have a deeper association with the host. Meanwhile the phytophagous species *C. heveae, P. seringueirae, S. petiolula* and *T. heveae* have an intrinsic and exclusive relationship with genus *Hevea,* on the other hand, *O. gossypii*, *E. banksi*, and *T. mexicanus* have been reported in a wide range of hosts.

Taking in consideration the phytophagous mites, 16 nominal species were recorded, from the families Eriophyidae, Tetranychidae, and Tenuipalpidae. The species *C. heveae* and *T. heveae*, actually known as the pest mites "microácaro da seringueira" and "ácaro vermelho" are potentially found in any rubber trees in Brazil. Although their occurrence has been occasionally related with the observance of damage on the leaves, most of time their abundance does not reach to the damage level, such as observed on the *Hevea* spp. from the Amazon Forest, Maranhão, Rondônia and Minas Gerais. These species were found in high densities in the surveys performed on the State of Bahia, with indicative of damage on clones FX 3864, and FX 2784, beyond those previous reported for Mato Grosso and São Paulo (Hernandes & Feres 2006). Considering all the reports that include the seasonal abundance of *C. heveae, T. heveae,* and *P. seringueirae* until now, we verified that these species have a synchronized dynamics through the year regardless of the studied site, with a remarkable populational peak on March and April (Figure 6a). Other species, such as *B.*

phoenicis, E. banksi, O. gossypii, and *B. formosus*, were not as abundant as the later species, but may represent potential pests for the crop, with seasonal dynamics without pattern (Figure 6b).

Remarks by locality

Acre

Fazolin & Pereira (1989), Flechtmann 1989 AC (1) , and exploratory samples. **Sites:** Rio Branco municipality. **Host:** *Hevea brasiliensis, H. spruceana,* and *H. pauciflora.*

The surveys were carried out on five plots in Acre and could find out 1352 mites from 35 morphospecies and 36 nominal species, from which 21 belong to Phytoseiidae and six were new. *Calacarus heveae* was sampled on all the sites, either in all *Hevea* spp. *Tenuipalpus heveae* was the most abundant species (147*),* followed by *A. chicomendesi* Nuvoloni, Lofego, Rezende & Feres (93), *C. heveae* (87) and *T. mexicanus* (87). Most of the phytophagous species (*C. heveae, S petiolula, T. heveae, B. phoenicis and T. mexicanus*) could be found living the three species of *Hevea* (*H. brasiliensis, H. spruceana,* and *H. pauciflora)*. Six new species were discovered from the State of Acre (*Ambldromalus akiri* Nuvoloni, Lofego, Rezende & Feres*, Ambliseuis chicomendesi, Iphiseiodes raucuara* Nuvoloni, Lofego, Rezende & Feres*, Iphiseiodes katukina* Nuvoloni, Lofego, Rezende & Feres, and *Tiphlodromips igapo* Nuvoloni, Lofego, Rezende & Feres) (Nuvoloni *et al.* 2015).

Amapá

Deus *et al.* 2012. **Sites**: Santana municipality. **Host:** *Hevea brasiliensis.*

A total of 1722 mites from 16 morphospecies were collected in two samples. *Tenuipalpus heveae* (1327) and *Brachytydeus formosus* (Cooreman) (129) were the most abundant species, and the only two nominally identified by the authors.

Amazonas

Fazolin & Pereira 1989, Feres 2001, Flechtmann & Arleu 1984, exploratory samples. **Sites:** Manaus municipality. **Host:** *Hevea brasiliensis, H. guianensis,* and *H. microphylla.*

A total amount of 810 mites were sampled from five plots of *H. brasiliensis, H. guianensis,* and *H. microphylla.* The mites belong to 25 morphospecies and 25 nominal species. *Tenuipalpus heveae* (125), and *C. heveae* (116) were the most abundant species, in addition, both were recorded on native *H. guianensis* and *H. brasiliensis*, but not on *H. microphylla.* Phytoseiidae was the most diverse group with 15 species, being *Amblyseius duckei* and *A. perditus* Chant & Baker, the most abundant species. Three new species were discovered from the studied sites (*Amblyseius duckei*, *Iphiseiodes katukina, Typhlodromips igapo*).

Bahia

Castro *et al.* 2013, Castro 2012, Flechtmann & Arleu 1984, Nuvoloni 2011. **Sites:** Igrapiúna and Itabuna municipalities. **Host:** *Hevea brasiliensis.*

The samples were carried out at “Plantações Michelin da Bahia” on the clones FX 3864, FX 2784, MDF 180, CDC312, FDR 5638, PMB 01. More than 269.700 mites were sampled, from 50 nominal species and 94 morphospecies. *Calacarus heveae* was the most abundant species (175.850), followed by *T. heveae* (36.737) and *S. petiolula*

(2.981), being FX 2784, and FX 3864 the more susceptible clones. The period of higher abundance of phytophagous species were between January to May, and peak in April. Phytoseiidae were the most diverse group (20 spp.), being *A. perditus* (223), and *Leonseius regularis* De Leon (203) the most abundant species. Two new species of Phytoseiidae (*Amblydromalus insolitus*, and *Typhlodromips paramilus*) and four new Tydeidae (*Brachytydeus*) were discovered in this area (Nuvoloni *et al.* in press).

High levels of fungal infection by *Hirsutella thompsonii* (Fischer) on *C. heveae* were recorded on plots close to native vegetation and when the rubber was managed in an agroforestry system, reaching 30% of all mites infected on wet season (Nuvoloni *et al.* 2014).

Espírito Santo

Flechtmann & Arleu 1984. **Sites:** Viana. **Host:** *Hevea brasiliensis*

Only one survey was performed on this locality, with the record of *O. gossypii.*

Goiás

Hernandes & Feres (2006a), exploratory samples. **Sites**: Goianésia. **Host:** *Hevea brasiliensis.*

The surveys found out a total of 349 mites, from 11 species and four morphospecies. *Oligonychus gossypii* (108) and *E. banksi* (70) were the most abundant phytophagous species, and *E. citrifolius* (106) was the most important phytoseiid.

Maranhão

Exploratory samples. **Sites:** São Luis municipality. **Host:** *Hevea brasiliensis.*

On this survey we recorded 541 mites from 11 species and 18 morphospecies. *Brevipalpus phoenicis* (162), and *E. concordis* (72) were the most abundant mites. The poulational peak was registered on June and July.

Mato Grosso

Feres 2000, Ferla & Moraes 2002, 2008, Demite & Feres 2007, Daud 2013. **Sites:** Itiquira and Pontes e Lacerda municipalities. **Host:** *H benthamiana, H. pauciflora, H. rigidiflora* and *H. viridis.*

The surveys revealed high infestations of *P. seringueirae* and *T. heveae,* which overcome *C. heveae* in abundance. The period of populational increasing was comprised between January and June. More than 550,000 mites were collected, belonging to 40 nominal species and 50 morphospecies. *Euseius concordis and E. citrifoilis* were the most common and abundant Phytoseiidae.

Minas Gerais

Exploratory samples, Feres 2000. **Sites:** Frutal and Oratórios municipalities. **Host:** *Hevea brasiliensis.*

The surveys were performed on rubber plantations, and a total of 1618 mites from 22 species, and six morphospecies were recorded. *Tenuipalpus heveae* were the most abundant species (933) with populational peak occurring on March and April. Six species of Phytoseiidae were identified, being *I. zuluagai* the most abundant.

Accordingly to Ferla & Moraes (2008) the clones PB 260 and PB 255 were more susceptible to the phytophagous attack, on the other hand, Daud & Feres (2007) pointed out for a differential suitability of the clones for each species of mites. They show that while the clone RRIM 600 had a higher abundance o *T. heveae*, the PB 235 and PB 260 were more susceptible to *P. seringueirae* and *C. heveae.*

Pará

Flechtmann 1979. **Sites:** Belém municipality. **Host:** *Hevea brasiliensis*

Only one survey was performed on this locality, with the record of *T. heveae.*

Rondônia

Exploratory samples. **Sites:** Porto Velho municipality. **Host:** *Hevea brasiliensis*.

More than 2400 mites belonging to 21 species and 10 morphospecies were sampled on the survey. During the survey was noticed damage on leaves and fruits caused by *O. gossypii* and *T. heveae.* The most abundant species were *E. alatus* (647), *C. heveae* (434), *T. heveae* (398), and *O. gossypii* (367).

São Paulo

Bellini *et al.* 2005, 2008, Chiavegato 1968, De Vis *et al.* 2006a, Demite & Feres 2005, Daud *et al.* 2010, Feres 2000, Feres *et al.* 2002, Flechtmann & Arleu 1984, Flechtmann & Abreu 1973; Hernandes & Feres 2006b, Zacarias & Moraes 2001,2002. **Sites:** Américo de Campos, Bálsamo, Barretos, Buritama, Campinas, Cananéia, Cedral, Ibitinga, Ilha solteira, José Bonifácio, Macaubal, Monte Aprazível, Olímpia, Pariquera-Açu, Pindorama, Piracicaba, Planalto, Reginópolis, Rio Claro, São José do Rio Preto, Taquaritinga. **Host:** *Hevea brasiliensis, H. pauciflora, H. benthamiana.*

The most numerous surveys were conducted in the State of São Paulo, nonetheless the region concentrates a vast number of rubber plantations, which in turn have the clones RRIM 600 and PB 235 as the majority cultivated. Most of the papers *Calacarus heveae* has been usually reported as the main pest in the crops of this region, whereas recently, *T. heveae, O. gossyppi and E. banksi* have received more attention due to occasional damage on plantations. *Euseius citrifolius* and *Metaseiulus camelliae* (Chant & Yoshida-Shaul) were the most abundant and common phytoseiid, moreover, *Zetzellia quasagistemas* Hernandes & Feres is also a very common predatory mite on this locality, usually found in association with *T. heveae.*

Discussion

Concerning the whole dataset of mites on rubber trees assembled so far, we could join evidences of similarities and divergences about species composition, seasonality, and population dynamics of the main species. Also, we enhanced the knowledge about the occurrence of mites on rubber trees, performing samples on native species of *Hevea* from Amazonas and Acre, besides the monitoring of mites from sites that were still uncovered, such as Maranhão, Minas Gerais and Rondônia.

Phytophagous mites have shown a well established dynamic pattern across sites, being the first semester the main period for population increasing. Visible damage on the leaves is frequently reported starting on late January or February (Castro *et al.* 2013, Vieira & Gomes 1999, Ferla & Moraes 2003, Hernandes & Feres 2006b), and in case of becoming more severe can anticipates the senescence of the leaves as a consequence. Recent advances on the understanding of physiological changes on the leaf physiology, and biological development of *C. heveae* (Daud *et al.* 2012ab), confirms that beyond climate driving the species dynamics, the favorable physiological condition of the rubber tree leaves during January to April is the main process underpinning of populational grown of *C. heveae* and probably for other phytophagous.

Such as highlighted above, *C. heveae* particularly increases in density strictly between February to April, regardless of the region where it was studied (De Vis *et al.* 2006a, Ferla & Moraes 2008, Hernandes & Feres 2006b, Daud & Feres 2007, Demite & Feres 2007,2008, Castro *et al.* 2013, Daud & Feres 2007). This species seems the most important phytophagous occurring on the rubber trees of Bahia, São Paulo and for some clones of Mato Grosso, whereas also can be a potential pest on crops of northern region, since it was recorded at medium densities in few localities, and is able to colonize other species of *Hevea* beyond *H. brasiliensis*. On the other hand, crop areas located on moist regions, as Bahia and nearby Amazon, could benefit the activity of *H. thompsonii,* the main pathogen of *C. heveae.*

Differently from *C. heveae*, *Tenuipalpus heveae* were reported as the main phytophagous occurring on the northern states, Amapá (Deus *et al.* 2012), Amazonas, Acre, Rondônia, and also in Minas Gerais and in some clones of Mato Grosso (Daud *et al.* 2007). This species also had a secondary importance on the rubbers of Bahia, and in the last ten years has increased the reports of damage assigned to this species in São Paulo. Similarly to *C. heveae*, this species also presents a well established dynamic through the year, and a distinct populational peak between February to April. *Oligonychus gossypii* as well as *T. heveae,* had notable importance on the surveys performed in Rondônia, damaging seriously leaves and fruits, being also the most abundant phytophagous on Goiás.

Phyllocoptruta seringueirae has recently being in focus as the main phytophagous mite occurring on plantations of Mato Grosso (Pontier 2000, Daud &

Feres 2007, Ferla & Moraes 2008), although it was firstly reported on high abundances in the São Paulo State (Feres 2000, Feres *et al.* 2002). The period of higher density is the same of *C. heveae* and *T. heveae*, being restricted to February to April.

Two other phytophagous, *Brevipalpus phoenicis* and *Eutetranychus banksi,* have emerged as potential pest in the plantations of Maranhão and Bahia. Castro *et al.* (2013) had pointed out the punctual infestation of *E. banksi* on the clone FX 2764, on the middle January, achieving more than 1 mite/cm^2. *Brevipalpus phoenicis* appeared on most of the surveys across Brazilian territory, but it was hardly never associated with the onset of symptoms.

Predator mites usually present lower level of association with their host than phytophagous, being more dependent of the availability of their resources than the type of substrate per se (Kreiter *et al.* 2003). The most common predatory mites, *A. floridanus, E. alatus, E. concordis, I. zuluagai, C. tarsospinosa, Z. quasagistemas, H. cinquaginta, Parapronematus* sp. 1, and *G. annectens,* were recorded on more than 50% of the sites, being an indicative that they can be related to the resources provided by the rubber trees. Studying some of these species, De Vis *et al.* 2006a, Castro & Moraes 2010, Cardoso *et al.* 2010, and Ferla & Moraes 2003a, highlighted the ability of *I. zuluagai, A. floridanus,* and *C. tarsospinosa* on consuming adults of *T. heveae*, as well as its eggs and immature. Otherwise, none of the studied predators presented a satisfactory development when feed with *C. heveae.* Major efforts are required in the search of an efficient predator candidate of *C. heveae,* which can have the species recently found on the Amazon as the start point for the search (Nuvoloni *et al.* 2015, De Vis et al. 2006). The tuber trees from Amazon region seem to harbor a large diversity of predatory mites, thus further studies aiming to test new species for biological control purposes on rubber trees may be targeted on that direction.

Despite many predatory species occur on most of the sites, we noticed that their abundance strongly vary among regions. While both *E. citrifolius* and *E. concordis* are the most abundant Phytoseiidae species on the middlewest and southeastern areas, *E. alatus* and *L. regularis* take their place on the sites of Bahia and along the Amazon region (Acre, Amazonas and Rondônia states). These species may represent a same functional group, feeding on similar resources, although their occurrences did not overlap each other. These species may be restricted by climatic conditions, availability of resources and also due to the surrounding vegetation that can limit the occurrence of one or another species on both environments.

As the same way, tarsonemid mites and species of *Brachytydeus* were consistently more diverse and abundant on rubbers from Amazon region and on the State of Bahia. Both areas also share similar moist weather, and surrounding forestry vegetation, which seems to enhance the diversity of species on the rubber trees, additionally, these areas have been kept free of the pesticide applications. Despite the large diversity and abundance of Tarsonemidae mites on rubber trees, none studies focusing the taxonomy, biology, and ecology, was performed so far. Thereby, these studies must be encouraged in order to find the actual diversity and functional importance, such as fungivorous feeders, potential pests, or even beneficial mites on the rubber trees.

Similarly, studies concerning *Brachytydeus* spp. on rubber trees have been neglected through time. Since the research of Hernandes et al. (2006) about life cycle and feeding habit of *B. formosus* on rubber trees, our survey take place again the studies on the genus. Consequently, we found out that beyond *B. formosus*, other five new species, and four more species already known (*Brachytydeus turrialbensis* (Baker), *Brachytydeus podocarpus* (Baker), *Brachytydeus argentinensis* (Baker), *Brachytydeus manitobensis* (Momen & Sinha) were reported now on the rubber trees in Brazil. In contrast, *Brachytydeus formosus* was the unique species of the genus reported on rubbers trees so far, mainly due to the lack of taxonomists, and certain complexity of the taxa. Thus, getting deeper on the study of *Brachytydeus* spp. may reveal its actual diversity, and consequently the role on the mite community

The current research updated and complemented prior studies on rubber trees in Brazil. In conclusion, the new set of data allows us to reach a better understanding about general patterns of species occurrence, and seasonal dynamics of mites on rubber trees. Noteworthy, we suggest that forthcoming research on *heveae* spp. may be driven to provide long term data from more areas in Brazil, besides, we also encourage more studies with taxon that usually receives few attention, such as Tarsonemid, Stigmaeidae, Cheyletidae, and finally more experiments testing more aspects of the association between species of mites and the genus *Hevea*.

Acknowledgements

We are grateful to Prof. Dr. Elizabeth Franklin, Prof. Dr. José W. de Morais, and collaborators from ‘Instituto Nacional de Pesquisas da Amazônica’ (INPA) for providing laboratory assistance and support for the fieldwork in Amazonas State; the post-graduate students, and staff from ‘Universidade Federal do Acre’ (UFAC) for the valuable help in the fieldwork in Acre State; the staff from ‘Empresa Brasileira de Pesquisa Agronômica’ (EMBRAPA, Amazônia Ocidental), in particular to Dr. Everton

Rabelo Cordeiro for the permission and help in the field work on EMBRAPA; to Prof. Dr. Antonio C. Lofego for the assistance on the identification of Phytoseiidae mites; to Prof. Dr. Rodrigo Daud, Dr. Peterson R. Demite, Dr. Fabio A. Hernandes, Msc. Elizeu B. Castro, and Msc. Eduardo R. da Silva for providing fully access to the data from their thesis and dissertations. To Prof. Dr. Ester A. da Silva, from "Universidade Estadual do Maranhão" (UEMA), and Prof. Dr. Prof. Dr. Marcos Antonio M. Fadini "Universidade Federal de São João Del-rei" (UFSJ), and Profa. Dra. Marineide Rosa Vieira "Universidade Estadual Paulista" (UNESP Ilha Solteira), for the donation of part of the material used on the research. This work was funded by FAPESP, 'Fundação de Amparo à Pesquisa do Estado de São Paulo' by fellowship to Felipe M. Nuvoloni (Process. 2010/19935-1) and 'Conselho Nacional de Desenvolvimento Científico e Tecnológico' (CNPq) (Proc. No 303435/2013-5), by fellowship and research grant to Reinaldo J.F. Feres.

References

Baker, E.W. (1945) Mites of the genus *Tenuipalpus* (Acarina: Trichadenidae). *Proceedings of the Biological Society of Washington* 47, 333–344.

Bellini, M.R., Feres, R.J.F. & Buosi, R. (2008) Ácaros (Acari) de Seringueira (*Hevea brasiliensis* Muell. Arg., Euphorbiaceae) e de Euforbiáceas Espontâneas no Interior dos Cultivos. *Neotropical Entomology* 37, 463–471.

Bellini, M.R., Moraes, G.J. & Feres, R.J.F. (2005) Ácaros (Acari) de dois sistemas de cultivo da seringueira no Noroeste do Estado de São Paulo. *Neotropical Entomology* 34, 475–484.

Cardoso, M.S.M., Vieira, M.R., Figueira, J.C. V & Silva, H.A.S. (2010) Atividade predatoria de *Euseius citrifolius* Denmark & Muma (Acari: Phytoseiidae) sobre *Tenuipalpus heveae* Baker (Acari: Tenuipalpidae). *Arquivos do Instituto Biológico de São Paulo* 77, 471–476.

Castro, E.B. de (2012) Diversidade e sazonalidade da comunidade de ácaros em três clones de seringueira no sudeste do Estado da Bahia. 77pp.

Castro, E.B., Nuvoloni, F.M., Mattos, C.R.R. & Feres, R.J.F. (2013) Population fluctuation and damage caused by phytophagous mites on three rubber tree clones. *Neotropical entomology* 42, 95–101.

De Castro, T.M.M.G. & de Moraes, G.J. (2010) Life cycle and behaviour of the predaceous mite *Cunaxatricha tarsospinosa* (Acari: Prostigmata: Cunaxidae). *Experimental & Applied acarology* 50, 133–9.

Chiavegato, L.G. (1968) Contribuição para o conhecimento de alguns ácaros que ocorrem na seringueira (*Hevea brasiliensis* Muell. Arg.). In: *I Reunião Anual Sociedade Brasileira de Entomologia*. , pp. 67.

Daud, R.D., Conforto, E. de C. & Feres, R.J.F. (2012a) Changes in leaf physiology caused by *Calacarus heveae* (Acari, Eriophyidae) on rubber tree. *Experimental and Applied Acarology* 57, 127–137.

Daud, R.D. & Feres, R.J.F. (2014) Community structure of mites (Arachnida: Acari) in six rubber tree clones. *International Journal of Acarology* 39, 589–596.

Daud, R.D., Feres, R.J.F. & Hernandes, F.A. (2012b) Seasonal suitability of three rubber tree clones to *Calacarus heveae* (Acari, Eriophyidae). *Experimental & applied acarology* 56, 57–68.

Daud, R.D., José, R. & Feres, F. (2007) Dinâmica populacional de ácaros fitófagos (Acari, Eriophyidae, Tenuipalpidae) em seis clones de seringueira no sul do Estado de Mato Grosso. *Revista* 51, 377–381.

Daud, R.D., Silva, E.R.O. da & Feres, R.J.F. (2010) Influência de *Cecropia pachystachya* na incidência de ácaros (Arachnida, Acari) e de *Leptopharsa heveae* (Insecta, Hemiptera) em cultivo de seringueira. *Revista de Biologia Neotropical* 7, 49–60.

Demite, P.R. & Feres, R.J.F. (2005) Influência de Vegetação Vizinha na Distribuição de Ácaros em Seringal (*Hevea brasiliensis* Muell. Arg ., Euphorbiaceae em São José do Rio Preto, SP. *Neotropical Entomology* 34, 829–836.

Demite, P.R. & Feres, R.J.F. (2007) Ocorrência e Flutuação Populacional de Ácaros Associados a Seringais Vizinhos de Fragmentos de Cerrado. *Neotropical entomology* 36, 117–127.

Demite, P.R. & Feres, R.J.F. (2008) Influência de fragmentos de cerrado na distribuiçao de ácaros em seringal. *Neotropical Entomology* 37, 196–204.

Deus, E., Souza., M.S.M., Mineiro, J.L.C., Adaime, R. & Santos, R.S. 2012. (2012) Mites (Arachnida: Acari) collected on rubber trees *Hevea brasiliensis* (Willd. ex A.Juss.) Müll.Arg. in Santana, Amapá state, Brazi. *Brazilian Journal of Biology* 72, 915–918.

Fazolin, M. & Pereira, L. V. (1989) Ocorrência de *Oligonychus gossypii* (Zacher 1921) (Acari:Tetranychidae) em seringueiras cultivadas. *Anais da Sociedade Entomológica do Brasil* 18, 1999–202.

Feres, R.J.F. (1992) A new species os *Calacarus* Keifer (Acari, Eriophyidae, Phyllocoptinae) from *Hevea brasiliensis* MUELL. ARG (Euphorbiaceae) from Brazil. *International Journal of Acarology* 18, 61–65.

Feres, R.J.F. (1998) Two new Phyllocoptine mites (Acari: Eriophyidae) from *Hevea brasiliensis* MUELL. Arg. (Euphorbiaceae) from Brazil. *International Journal of Acarology* 24, 69–74.

Feres, R.J.F. (2000) Levantamento e observações naturalísticas da acarofauna (Acari, Arachnida) de seringueiras cultivadas (*Hevea* spp., Euphorbiaceae) no Brasil. *Revista Brasileira de Zoologia* 17, 157–173.

Feres, R.J.F. (2001) Primeiro registro de ácaros eriofiídeos (Acari, Eriophyidae) em seringueiras (*Hevea brasiliensis* Muell. Arg., Euphorbiaceae) da Floresta Amazônica, Brasil. *Revista Brasileira de Zoologia* 18, 343–345.

Feres, R.J.F., Del'Arco, M. & Daud, R.D. (2010) Biological cycle of *Tenuipalpus heveae* Baker (Acari, Tenuipalpidae) on leaflets of three rubber tree clones. *Revista Brasileira de Entomologia* 54, 298–303.

Feres, R.J.F. & Nunes, M.A. (2001) Ácaros (Acari, Arachnida) associados a euforbiáceas nativas em áreas de cultivo de seringueiras (*Hevea brasiliensis* MUELL. Arg., Euphorbiaceae) na região noroeste do estado de São Paulo, Brasil. *Revista Brasileira de Zoologia* 18, 1253–1256.

Feres, R.J.F., Rossa-feres, D.D.C., Daud, R.D. & Santos, R.S. (2002) Diversidade de acaros (Acari, Arachnida) em seringueiras (*Hevea brasiliensis* Muell. Arg., Euphorbiaceae) na região noroeste do Estado de São Paulo, Brasil. *Revista Brasileira de Zoologia* 19, 137–144.

Ferla, N.J. & Moraes, G.J. de (2002) Ácaros (Arachnida, Acari) da seringueira (*Hevea brasiliensis* Muell. Arg.) no Estado do Mato Grosso, Brasil. *Revista Brasileira de Zoologia* 19, 867–888.

Ferla, N.J. & Moraes, G.J. de (2003a) Biologia de *Agistemus floridanus* Gonzalez (Acari: Stigmaeidae). *Revista Brasileira de Zoologia* 20, 261–264.

Ferla, N.J. & Moraes, G.J. de (2003b) Ciclo biológico de *Calacarus heveae* Feres, 1992. *Revista Brasileira de Entomologia* 47, 399–402.

Ferla, N.J. & Moraes, G.J. de (2008) Flutuação populacional e sintomas de dano por Ácaros (Acari) em seringueira no Estado do Mato Grosso, Brasil. *Revista Árvore* 32, 365–376.

Flechtmann, C.H.W. & Arleu, R.J. (1984) *Oligollychus coffeae* (Nietner, 1861), um ácaro tetraniquídeo da seringueira (*Hevea brasiliensis*) novo para o Brasil e observações sobre outros ácaros desta planta. *Ecossistema* 9, 123–125.

Gallo, D., Nakano, O., Silveira-Neto, S., Carvalho, R.P.L., Baptista, G.C., Filho, E.B., Parra, J.R.P., Zucchi, R.A., Alves, S.B., Vendramim, J.D., Marchini, L.C., Lopes, J.R.S. & Omoto., C. (2002) *Entomologia agrícola*. 920 pp.

Hernandes, F.A. & Feres (2006)a) Review about mites (Acari) of rubber trees (*Hevea* spp., Euphorbiaceae) in Brazil. *Biota Neotropica* 6.

Hernandes, F.A. & Feres, R.J.F. (2006)b) Diversidade e Sazonalidade de Ácaros (Acari) em Seringal (*Hevea brasiliensis*, Muell. Arg.) no Noroeste do Estado de São Paulo. *Neotropical Entomology* 35, 523–535.

IBGE, I.B. de G. e E. (2008) Produção da extração vegetal e silvicultura. *http://www.ibge.gov.br*.

Krantz, W. & Walter, D.E. (2009) *A manual of Acarology*. Third Edit. Texas Tech University Press, Lubbock, Texas, 807 pp.

Kreiter, S., Tixier, M.-S. & Bourgeois, T. (2003) Do generalist Phytoseiid mites (Gamasida: Phytoseiidae) have interactions with their host plants? Insect Science *and its Application* 23, 35–50.

Nuvoloni, F.M. (2011) Influência da vegetação nativa de Mata Atlântica sobre a ocorrência e distribuição de ácaros (Acari) da seringueira (*Hevea brasiliensis* Muell Arg.) no estado da Bahia. UNESP, 103pp.

Nuvoloni, F.M., Castro, E.B. de & Feres, R.J.F. (2014) The role of native vegetation on infection rates of *Calacarus heveae* (Acari: Eriophyidae) by Hirsutella thompsonii (Ascomycota: Ophiocordycipitaceae). *Experimental & applied acarology* 63, 157–69.

Nuvoloni, F.M., Lofego, A.C., Rezende, J.M. & Feres, R.J.F. (2015) Phytoseiidae mites associated with *Hevea* spp. from the Amazon region: a hidden diversity under the canopy of native trees. *Systematics and Biodiversity*.

Pontier, K.J.B., Moraes, G.J. de & Kreiter, S. (2000) Biology of *Tenuipalpus heveae* (Acari, Tenuipalpidae) on rubber tree leaves. *Acarologia* 41, 423–427.

Rezende, J.M. & Lofego, A.C. (2011) Phytoseiidae (Acari: Mesostigmata) on plants of the central region of the Brazilian Cerrado. *Acarologia* 51, 449–463.

Silva, P. (1972) Pragas de seringueira no Brasil, problemas e perspectivas. In: *Anais do I Seminário Nacional de Seringueira*. Cuiabá, pp. 143–152.

Tanzini, M.R., Alves, S.B., Tamai, M.A., Moraes, G.J. de & Ferla, N.J. (2000) An epizootic of *Calacarus heveae* (Acari: Eriophyidae) caused by *Hirsutella thompsonii* on rubber trees. *Experimental and Applied Acarology* 24, 141–144.

Vieira, M.R., Fabri, E.G. & Oliveira, E.A. (2000) Sintomatologia do ataque de *Calacarus heveae* Feres, 1992 (Acari: Eriophyidae) em seringueira (*Hevea brasiliensis* Muell. Arg.). *Revista de Agricultura* 75, 405–414.

Vieira, M.R. & Gomes, E.C. (1999) Sintomas, desfolhamento e controle de *Calacarus heveae* Feres, 1992 (Acari: Eriophyidae) em seringueira (*Hevea brasiliensis* Muell. Arg.). *Cultura Agronômica* 8, 53–71.

Vieira, M.R. & Gomes, E.C. (2001) Avaliação de acaricidas no controle de *Calacarus heveae* Feres, 1992 (Acari: Eriophyidae) em seringueira através de contagem em campo. *Cultura Agronômica* 10, 145–158.

Vieira, M.R., Gomes, E.C. & Figueira, J.C. (2006) Controle Químico do Ácaro *Calacarus heveae* Feres (Acari: Eriophyidae) em Seringueira. *Bioassay*.

Vieira, M.R., Gomes, E.C. & Silva, H.A.S. da (2010) Redução na produçao de látex da seringueira provocada pela infestaçao de ácaros. *Revista Ceres* 57, 608–613.

Vieira, M.R., Silva, H.A. de S., Cardoso, M.M. & Figueira, J.C. (2009) Progênies de seringueira com potencial para conferir resistência a ácaros (*Calacarus heveae* Feres e *Tenuipalpus heveae* Baker). *Ciência Rural* 39, 1953–1959.

De Vis, R.M.J., de Moraes, G.J. & Bellini, M.R. (2006a) Initial screening of little known predatory mites in Brazil as potential pest control agents. *Experimental & applied acarology* 39, 115–25.

De Vis, R.M.J., Moraes, G.J. de & Bellini, M.R. (2006b) Mites (Acari) of Rubber Trees (*Hevea brasiliensis* Muell. Arg., Euphorbiaceae) in Piracicaba, State of São Paulo, Brazil. *Neotropical entomology* 35, 112–120.

Zacarias, M.S. & Moraes, G.J. de (2001) Phytoseiid Mites (Acari) Associated With Rubber Trees And Other Euphorbiaceous Plants In Southeastern Brazil. *Neotropical Entomology* 30, 579–586.

Zacarias, M.S. & Moraes, G.J. de (2002) Mite diversity (Arthropoda: Acari) on euphorbiaceous plants in the State of São Paulo. *Biota Neotropica* 2, 1–12.

Figure 1. Sampling sites at Rio Branco State of Acre, rubber plantation **(a, b)**, experimental area at “UFAC” **(c, d)**, “Parque Zoobotânico” **(e)**, and “Fazenda Experimental Catuaba” **(f)**.

Figure 2. Sampling sites at Manaus State of Amazonas, "EMBRAPA" **(a, b)**, and "Careiro da Várzea" at the margins of Negro River **(c, d, e)**

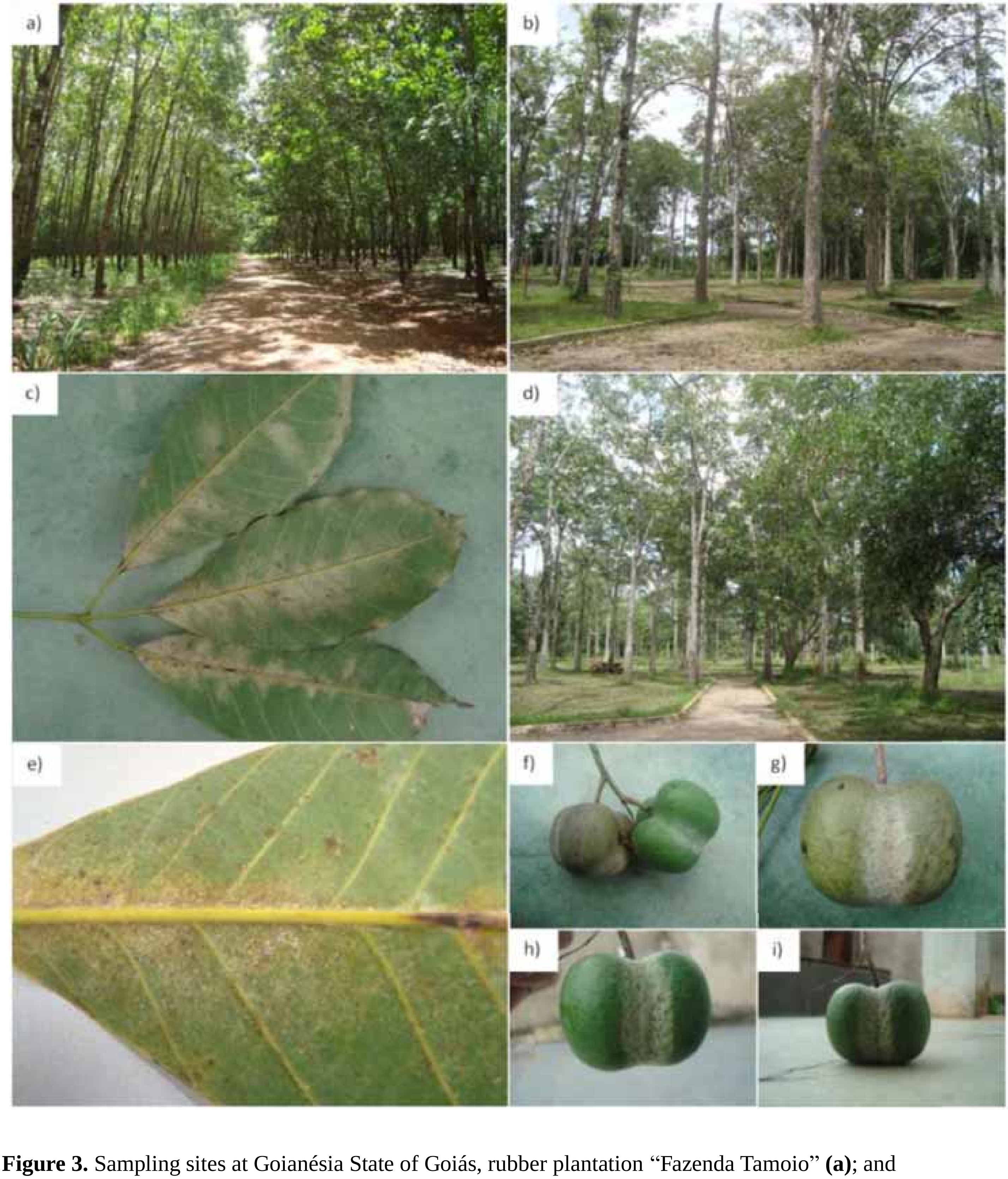


Figure 3. Sampling sites at Goianésia State of Goiás, rubber plantation “Fazenda Tamoio” **(a)**; and Rondônia, “Parque Circuito”, Porto Velho **(b,d)**; and leaves **(c)**, leaflets **(e)**, and fruits **(f,g,h,i,)** infested by *Tenuipalpus heveae* e *Oligonychus gossypii*

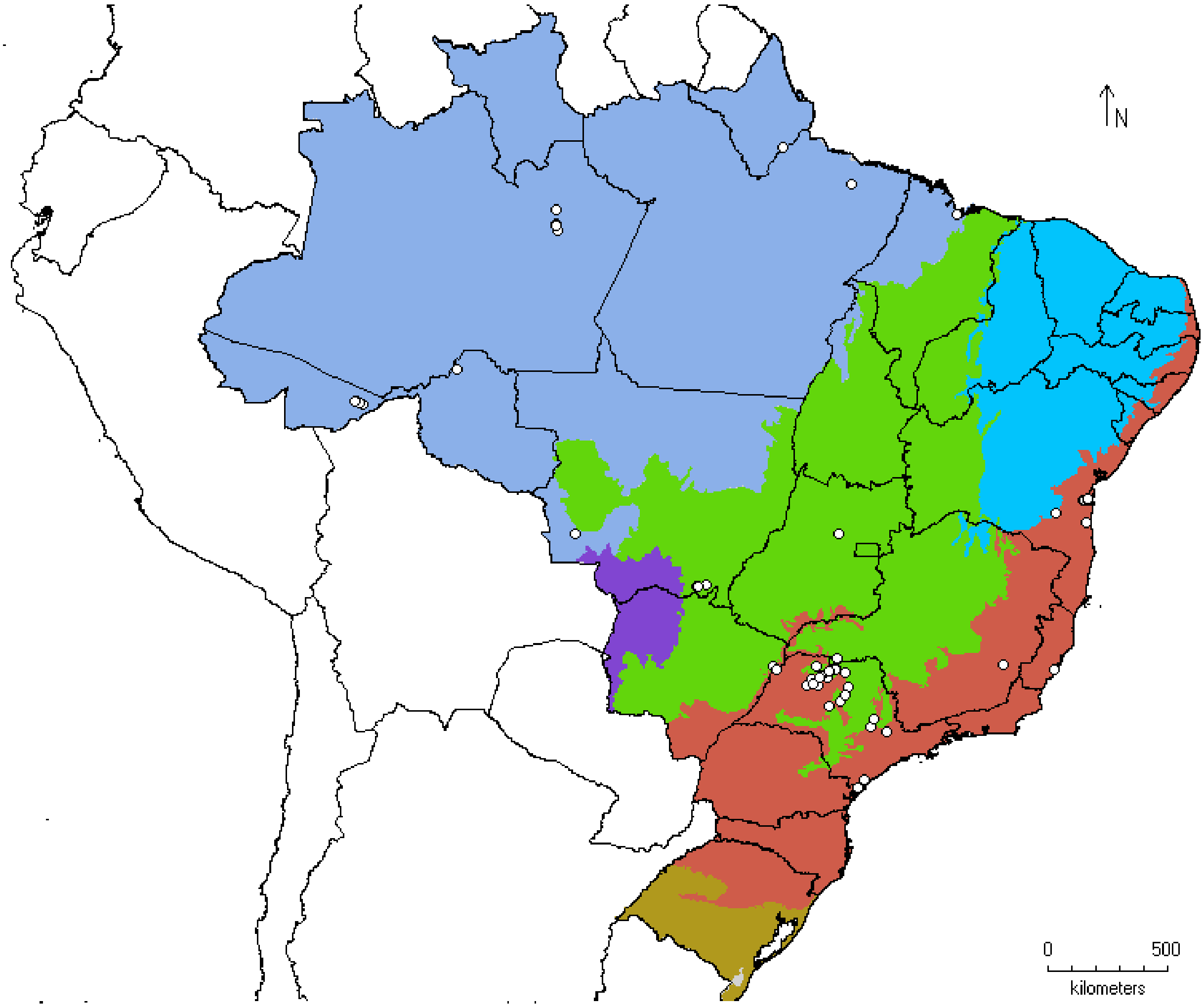


Figure 4. Sites sampled for rubber tree mites according to the State and biome.

c

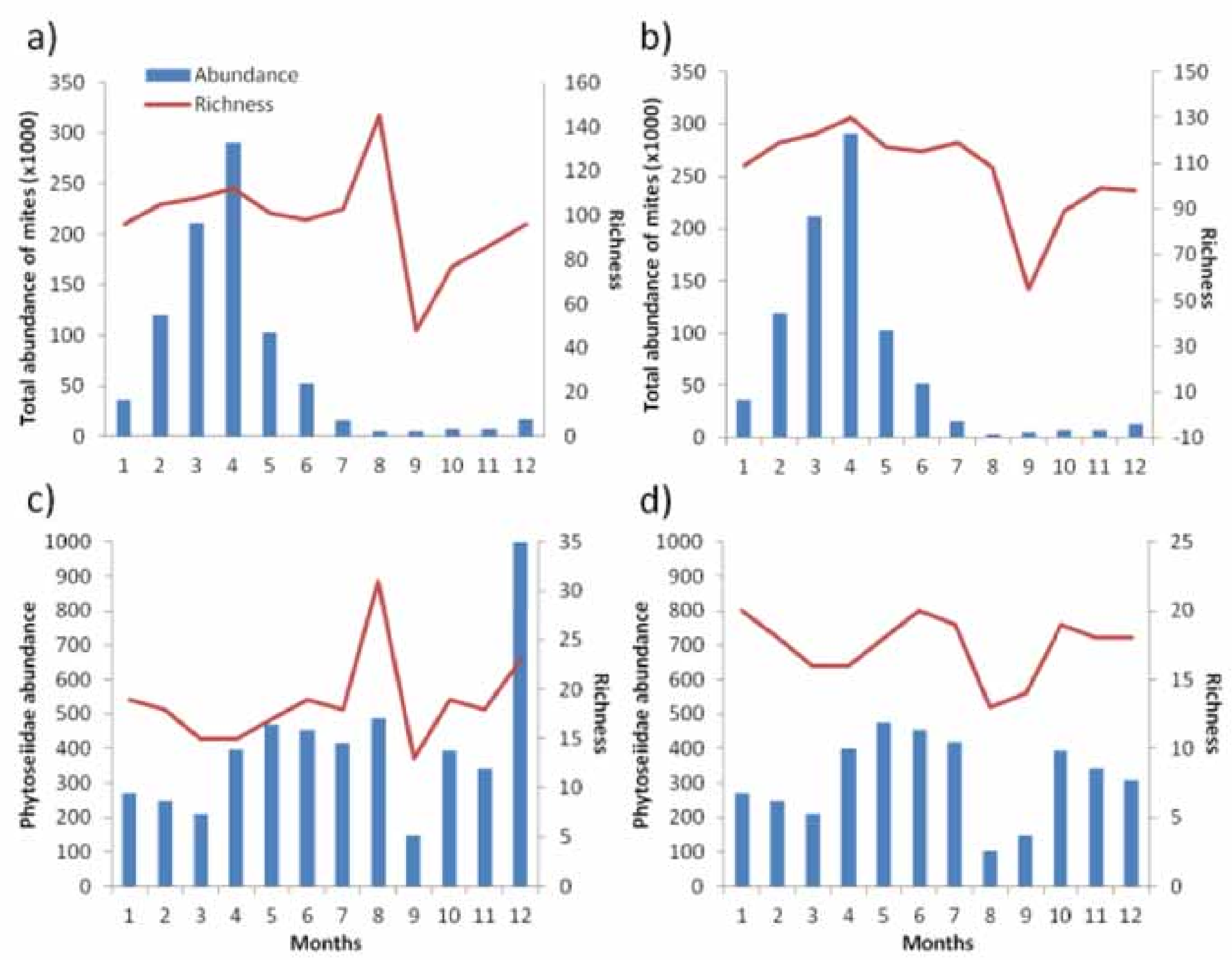


Figure 5. Seasonal dynamic of mites, considering the total abundance and number of species from all the studied sites per month **(a)**; total abundance and number of species excluding the samples on Amazonas, Acre, and Rondônia states **(b)**. Total abundance and number of species of Phytoseiidae found on all studied sites per month **(c)**; and total abundance and number of species of Phytoseiidae excluding the samples from Amazonas, Acre, and Rondônia states.

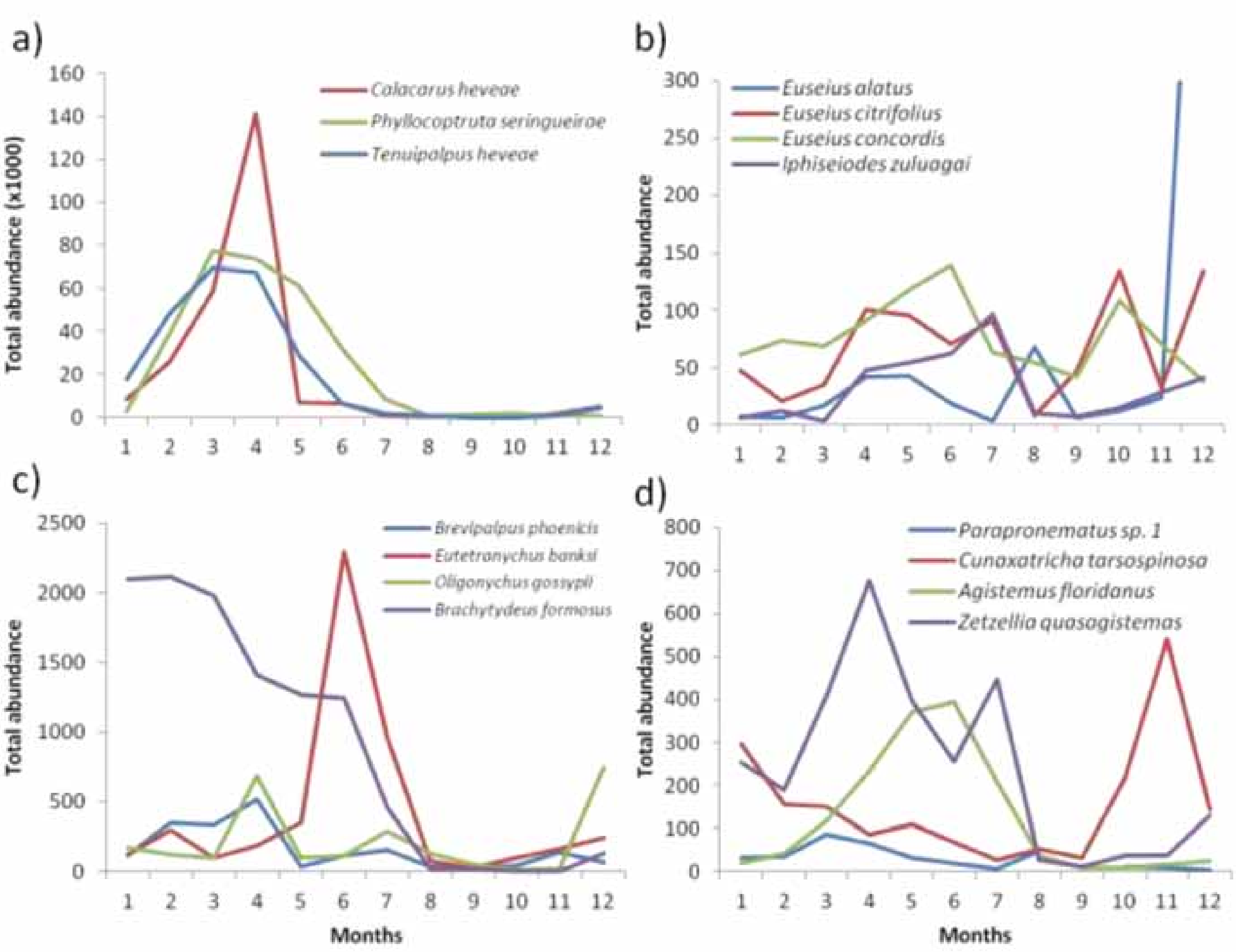


Figure 6. Monthly occurrence of the most abundant species considering all the records available: seasonal dynamic of *C. heveae*, *P. seringueirae* and *S. petiolula* **(a)**; *E. alatus*, *E. citrifolius*, and *I. zuluagai* **(b)**; *B. phoenicis*, *E. banksi*, *O gossypii*, and *B. formosus* **(c)**; and for *Parapronematus* sp.1, *C. tarsospinosa*, *A. floridanus*, and *Z. quasagistemas* **(d)**.

Table 1. Total abundance of the species of mites found in rubber trees in the Brazilian states*.

Family	Species	AC	AM	AP	BA	ES	GO	MA	MG	MS	MT	PA	RO	SP	Total
Acaridae	Acaridae sp. 1	79	10	10	790			22	203		8		24	1	1147
	Acaridae sp. 2				62										62
	Caloglyphus sp. 1				500									8	508
	Caloglyphus sp. 2				23										23
	Neotropacarus sp.										16			97	113
	Sancassania sp.				4						166				170
	Tyrophagus putrescentiae						1				1			4	6
Acarophenacidae	Acarophenacidae sp.													1	1
Ascidae	*Asca* sp. 1	15	26		58						5				104
	Asca sp. 2				1						2				3
	Asca sp. 3				2										2
	Asca sp. 4				3										3
	Asca sp. *5*				1										1
	Ascidae sp.	3	4											1	8
	Gamasellodes sp.												1		1
	Lasioseius sp.													1	1
Bdellidae	*Bdella ueckermanni*													1	1
	Hexabdella cf. *singula*										1				1
	Hexabdella cinquaginta				4				1		4		1	1	11
	Tetrabdella neotropica													481	481
Blatisoscidae	*Blattisocius* sp.	1	1		18										20
	Orthadenella sp.													1	1
Cheyletidae	*Cheletogenes* sp.						4							1	5
	Cheletomimus anarbora	1						6							7
	Cheletomimus bakery				3				1						4
	Cheletomimus cf. *notelaeae*				8										8
	Cheletomimus darwinia							5			1				6
	Cheletomimus duosetosus				9				8		173				190
	Cheletomimus sp.													78	78
	Cheletomimus wellsi				23				34		22			13	72
	Cheyletia sp.						1								1
	Chiapacheylus sp.	1						2						3	6
	Mexecheles cf. *hawaiiensis*				26				5				48		79
	Paracheyletia sp.								5						5
Cunaxidae	*Allocunaxa heveae*	4			2						16		30		52
	Armascirus aff. *anastosi*				6										6
	Armascirus bahiaensis	4	3					1							8
	Armascirus sp. 1	1		1	2										4
	Armascirus sp. 2	1													1
	Lupaeus cf. *lectus*								1						1
	Cunaxa aff. *lamberti*				1										1
	Cunaxatricha sp. 1	3	44		93										140

continue

Table 1. Total abundance of the species of mites found in rubber trees in the Brazilian states*.

Family	Species	AC	AM	AP	BA	ES	GO	MA	MG	MS	MT	PA	RO	SP	Total
Cunaxidae	*Cunaxatricha tarsospinosa*	45	2		5				31		318			1	402
	Cunaxoides sp.				1										1
	Neocunaxoides aff. *andrei*				45						1				46
	Pseudobonzia sp.										98			1	99
	Pulaeus sp.			1										1	2
	Riscus austroamericanus	73			237										310
	Scutopalus cf. *latisetosus*		1		106									1	108
Diptilomiopidae	*Catarhinus* sp.										1				1
	Diptilomiopidae sp.		65												65
Edbakerellidae	*Apotriophtydeus*				37										37
	Edbakerella sp.				8										8
Eriophyidae	*Acaphyllisa* sp.										16				16
	aff. *Chakrabartiella* sp.										2				2
	Calacarus heveae	87	116		175841		1	1	24	1	27681		434	307063	511249
	cf. *Tetra*										1				1
	Distacerya													3	3
	Eriophyidae sp.			1							1				2
	Phyllocoptruta seringueirae	25	41		2325		1		1		306477		13	6214	315097
	Shevtchenkella petiolula	9	74		2972		1		1	1	3595		21	3108	9782
	Eriophyidae sp. 1		29												29
Erythraeidae	*Erythraeidae* sp.				1										1
Eupalopsellidae	*Exothorhis caudata*				1									20	21
	Exothorhis cf. *armata*				1										1
	Paraeupalopsellus sp.	1													1
Eupodidae	*Eupodes* sp.1				140										140
	Eupodes sp.2				4										4
Hemisarcoptidae	*Hemisarcoptidae* sp.				1										1
Histiostomatidae	*Histiostomatidae* sp.				9									2	11
Iolinidae	*Homeopronematus* sp.				1		1							50	52
	Iolinidae sp.			7											7
	Metapronematus sp.	9			37						11			184	241
	Neopronematus sp.										8				8
	Parapronematus acaciae													42	42
	Parapronematus sp. 1	8	10		1795			52			44		2	6	1917
	Parapronematus sp. 2	31	3												34
	Pausia sp.													10	10
	Pronematus sp.				13						22			2097	2132
	Pronematus ubiquitus													4	4
Mecognathidae	*Paraeupalopsellus* sp.				3										3
Meyerellidae	Meyerellidae sp.													2	2
Oripodidae	*Oripoda* sp.										1				1
	Pirnodus sp.										8				8

continue

Table 1. Total abundance of the species of mites found in rubber trees in the Brazilian states*.

Family	Species	AC	AM	AP	BA	ES	GO	MA	MG	MS	MT	PA	RO	SP	Total
Phytoseiidae	*Amblydromalus akiri*	23													23
	Amblydromalus insolitus				76										76
	Amblydromalus manihoti	3	19		16										38
	Amblydromalus vilacarmelensis	5													5
	Amblyseius saopaulus													1	1
	Amblyseius acalyphus										124				124
	Amblyseius aerialis	11	2		4								38		55
	Amblyseius chiapensis	7	1				4								12
	Amblyseius chicomendesi	93													93
	Amblyseius compositus													379	379
	Amblyseius duckei	1	22												23
	Amblyseius herbicolus				1										1
	Amblyseius impeltatus													1	1
	Amblyseius largoensis							12							12
	Amblyseius martus	42	2												44
	Amblyseius neochiapensis										58				58
	Amblyseius operculatus				122				32					1	155
	Amblyseius perditus		13		223										236
	Amblyseius sp.	8	2	1				5						1	17
	Arrenoseius morgani	6	3										1		10
	Euseius alatus	53	1		156			38	8		41		647	2	946
	Euseius citrifolius						106		1		249			1077	1433
	Euseius concordis	18						72	38		982			81	1191
	Euseius sp.			7											7
	Galendromimus (Galendromimus)alveolaris										5				5
	Galendromus (*mugidromus*) sp.				1										1
	Galendromus annectens	1							1		14		20	11	47
	Galendromus sp.			4							1				5
	Iphiseiodes kamahorae		2												2
	Iphiseiodes katukina	3	9												12
	Iphiseiodes raucuara	3													3
	Iphiseiodes zuluagai	3	6		103				97		56		23	97	385
	Leonseius regularis	2			203										205
	Metaseiulus (Metaseiulus) adjacentis		2					26							28
	Metaseiulus camelliae													733	733
	Metaseiulus ferlai				6						6				12
	Neoseiulus anonymus										111				111
	Neoseiulus idaeus										4		1	156	161
	Neoseiulus sp.							1							1
	Neoseiulus tunus				1						1				2
	Paraamblyseius multicircularis	1	1												2
	Paraphytoseius orientalis	9													9

continue

Table 1. Total abundance of the species of mites found in rubber trees in the Brazilian states*.

Family	Species	AC	AM	AP	BA	ES	GO	MA	MG	MS	MT	PA	RO	SP	Total
Phytoseiidae	*Phytoscutus sexpilis*				8								1	2	11
	Proprioseiopsis aff. *jasmini*										1				1
	Proprioseiopsis dominigos		2											1	3
	Proprioseiopsis mexicanus												2		2
	Proprioseiopsis neotropicus				3										3
	Proprioseiopsis ovatus													25	25
	Ricoseius loxocheles				1										1
	Typhlodromalus aff. *horatii*										1				1
	Typhlodromalus feresi										1				1
	Typhlodromalus peregrinus	1			111										112
	Typhlodromina subtropica				5										5
	Typhlodromips aff. *amilus*										129				129
	Typhlodromips aff. *sinensis*										5				5
	Typhlodromips amilus										16				16
	Typhlodromips cananeiensis													2	2
	Typhlodromips igapo	5													5
	Typhlodromips paramilus				149										149
	Typhlodromips sp.				5			2							7
	Typhlodromips sp. 1			10											10
	Typhlodromips sp. 2			5											5
	Typhlodromus transvaalensis										1				1
Pyiemotidae	Pyemotidae sp.													1	1
Raphignatydae	*Raphygnathus*													3	3
Smariidae	Smariidae sp.				1										1
Stigmaeidae	*Agistemus brasiliensis*	2												35	37
	Agistemus cf. *terminalis*				18										18
	Agistemus pallini		3		40						118				161
	Agistemus floridanus	4	5		322		6	23	28		1107		2	8	1505
	Agistemus sp. 1			59			1				1			11	72
	Agistemus sp. 2				12										12
	Eryngiopus sp.				3									3	6
	Eustigmaeus aff. *mixtus*				8										8
	Eustigmaeus sp.													1	1
	Mediolata sp.													1	1
	Summersiella sp.				2										2
	Villersia sp.													8	8
	Zetzellia agistzellia													535	535
	Zetzellia languida				85				11				7		103
	Zetzellia malvinae													198	198
	Zetzellia mapuchina													4	4
	Zetzellia oudemansi				1										1

continue

Table 1. Total abundance of the species of mites found in rubber trees in the Brazilian states*.

Family	Species	AC	AM	AP	BA	ES	GO	MA	MG	MS	MT	PA	RO	SP	Total
Stigmaeidae	*Zetzellia quasagistemas*				1		1		6		366		18	4975	5367
	Zetzellia sp.							1							1
Tarsonemidae	*Daidalotarsonemus* cf. *tesselatus*	4			1						311				316
	Daidalotarsonemus sp. 1	4			8			1						25	38
	Daidalotarsonemus sp. 2	9			2									19	30
	Deleonia aff. *aguilari*				2										2
Tarsonemidae	*Deleonia* aff. *walteri*	1													1
	Deleonia cf. *laeselvia*				2										2
	Deleonia sp.	1			1						2				4
	Floridotarsonemus sp.				71										71
	Fungitarsonemus sp. 1	25	1		52			1			1			19	99
	Fungitarsonemus sp. 2	1			1										2
	Fungitarsonemus sp. 3				4										4
	Fungitarsonemus sp. 4				3										3
	Metatarsonemus sp.	49	2		1										52
	Neotarsonemoides sp.				8										8
	Polyphagotarsonemus latus				12				1		3.6			2	18
	Rhynchotarsonemus													1	1
	Tarsonemidae sp.	5	1		4										10
	Tarsonemus confusus										362			49	411
	Tarsonemus cf. *cornus*				131										131
	Tarsonemus floridanus				179										179
	Tarsonemus sp.	4		14					2		50			103	173
	Tarsonemus sp. 1	41	10		9				3		83		1	2	149
	Tarsonemus sp. 2	1	5		4						29			11	50
	Tarsonemus sp. 3		2		9						1				12
	Tarsonemus sp. 4	2			9									15	26
	Tarsonemus sp. *5*				3										3
	Tarsonemus sp. *6*				9									1	10
	Tarsonemus sp. *7*				32										32
	Tarsonemus sp. *8*				14										14
	Xenotarsonemus sp.				3						2			1	6
Tenuipalpidae	*Brevipalpus phoenicis*	3	12		1723			162	25		8.2		1	29	1963.2
	Brevipalpus sp.													1	1
	Tenuipalpus heveae	197	125	1397	36728		43		933		207254	1	398	40008	287084
	Tenuipalpus sp. 2	42	44												86
Tetranychidae	*Allonychus brasiliensis*													60	60
	Allonychus reisi	47	6		1										54
	Aponychus cf. *shultzi*										1				1
	Aponychus chiavegatoi	1			454										455
	Atrichoproctus uncinatus										1				1
	Eotetranychus sp.	1						1		5	51		46	2	106
	Eutetranychus banksi				162		70		15		3			6671	6921
	Mixonychus sp.													8	8

continue

Table 1. Total abundance of the species of mites found in rubber trees in the Brazilian states*.

Family	Species	AC	AM	AP	BA	ES	GO	MA	MG	MS	MT	PA	RO	SP	Total
Tetranychidae	*Mononychellus* sp.										24				24
	Neotetranychus sp.										1				1
	Oligonychus cf. *coffeae*										6				6
	Oligonychus coffeae										25				25
	Oligonychus gossypii	35	20		99	1	108	24			1324		367	793	2771
	Oligonychus ilicis				10										10
	Oligonychus sp. 1				80								144	100	324
	Oligonychus sp. 2				2			2							4
	Tetranychus mexicanus	87	1		57						603			1	749
	Tetranychus sp.				38			1					6	1	46
	Tetranychus urticae													1	1
Tydeidae	*Afrotydeus* sp.				157			5							162
	Afrotydeus kenyensis										1			1	2
	Homeopronematus sp.													45	45
	Krantzolorryia sp.				8										8
	Brachytydeus sp. nov. 1		10		2604			2			38		5	1000	3659
	Brachytydeus sp. nov. 2	19	1		107			2	30		32				191
	Brachytydeus sp. nov. 3	3			51				31						85
	Brachytydeus sp. nov. 4				3										3
	Brachytydeus sp. nov. *5*				1										1
	Brachytydeus turrialbensis	35	1		4			10			34				84
	Brachytydeus formosus			58				20	15	5	134		10	9500	9742
	Brachytydeus podocarpus				200								15	30	245
	Brachytydeus argentinensis		1		15										16
	Brachytydeus manitobensi		5		321										326
	Brachytydeus spp.			71										2	73
	Melissotydeus sp.													2	2
	Metalorryia sp.				1										1
	Neolorryia sp.													40	40
	Neolorryia boycei										14			6	20
	Paralorryia sp.										1				1
	Parapronematus sp. 1													4	4
	Prelorryia sp. 1	3	21		1										25
	Prelorryia sp. 2	10													10
	Pretydeus curiosa													1	1
	Pretydeus sp.				2						1			1638	1641
	Pseudolorryia cf. *nicaraguensis*													40	40
	Pseudolorryia sp.				1						117			75	193
	Triophtydeinae													21	21
	Triophtydeus sp.1													272	272
	Triophtydeus sp.2													40	40
	Tydeus (*Tydeus*) *costensis*													1	1
	Tydeus (*Tydeus*) *californicus*													1	1

continue

Table 1. Total abundance of the species of mites found in rubber trees in the Brazilian states *.

Family	Species	AC	AM	AP	BA	ES	GO	MA	MG	MS	MT	PA	RO	SP	Total
Tydeidae	*Tydeus* sp. 1				93									2	95
	Tydeus sp.2				2										2
Trombidiidae	Trombidiidae sp.				3										3
Tuckerellidae	Tuckerellidae sp.							2							2
Uropodina	*Uropodina* sp.	2											1		3
Winterschmidtiidae	*Czenspinskia* sp.	16	21	3	424			22			9		77	147	719
	Oulenzia sp. 1				77				30		1496			1195	2798
	Oulenzia sp.2				12						5				17
	Saproglyphus sp.				16										16
Xenocaligonellidae	*Xenocaligonellus* sp.				5										5

*AC: Acre, AM: Amazonas, AP: Amapá, BA: Bahia, ES: Espírito Santo, GO: Goiás, MA: Maranhão, MG: Minas Gerais, MS: Mato Grosso do Sul, MT: Mato Grosso, PA: Pará, RO: Rondônia, SP: São Paulo

Capítulo II

Phytoseiidae mites associated with *Hevea* spp. from the Amazon region: a hidden diversity under the canopy of native trees

Felipe M. Nuvoloni, Antonio C. Lofego, José M. Rezende, Reinaldo J. F. Feres

Paper published at Systematics and Biodiversity on February 2015

Abstract

Despite the Amazon Forest being the largest tropical forest in the world, and cradle of rubber trees (*Hevea brasiliensis*), no studies have been aimed to report the occurrence of mites associated with native trees from this ecosystem. Our survey investigates the phytoseiid mites associated with five species of native rubber trees from nine sites of the Amazon Forest, and also presents a major review about phytoseiid species from natural vegetation in Brazil. We found a total of 1.305 mites, belonging to 30 species, of which seven of them were new to science, *Amblydromalus akiri* **sp. nov.**, *Amblyseius chicomendesi* **sp. nov.**, *Amblyseius duckei* **sp. nov.**, *Amblyseius manauara* **sp. nov.**, *Iphiseiodes katukina* **sp. nov.**, *Iphiseiodes raucuara* **sp. nov.**, and *Typhlodromips igapo* **sp. nov.**; beyond two new records for Brazil, *Iphiseiodes kamahorae*, and *Amblyseius martus*. Our results emphasize the importance of Amazon native trees as an unexplored source of predator mites, which in turn may be further studied as biological control agents of pest mites on rubber trees. The impressive diversity, endemism, and rate of new species found, highlight the importance of studies on arthropod communities associated with the Amazon vegetation.

Keywords: Acari, *Amblydromalus, Amblyseius,* conservation, *Iphiseiodes*, new species, predator, tropical forest, *Typhlodromips.*

Introduction

Phytoseiidae (Mesostigmata) are plant living mites broadly found on cultivated and wild plants. They are among the most studied groups of mites due to their importance as biological control agents (Gerson, Smiley, & Ochoa, 2003; Sabelis & Van Rijn, 1997). Despite some species being considered efficient predators of other mites, most of them have diverse feeding habits, including fungi, plant exudates, and pollen as food resources (McMurtry & Croft, 1997; McMurtry, Moraes, & Sourassou, 2013)

The rubber tree, *heveae brasiliensis* (Muell. Arg. Euphorbiaceae) is the main source of natural rubber in the world (Gonçalves, Bataglia, Ortolani, & Fonseca, 2001). *Hevea* includes 11 species originated and constrained to the Amazon region (Pires, Secco, & Gomes, 2002), limited by the upper Orinoco and the oriental subandine Bolivia on the north, and by the Brazilian Savannah (Cerrado) of Mato Grosso State on the south (Secco, 2008; Shultes, 1987). Among the species of *Hevea*, the most cultivated and commercially exploited is *H. brasiliensis* due to its suitable latex characteristics and productivity (Gonçalves & Marques, 2008). Despite the social and economic importance of the *Hevea* exploitation in the Amazonic region in the past, the latex production based on wild rubber trees is no longer viable, so currently, the production in Brazil is mainly settled in plantations from the states of São Paulo, Mato Grosso, and Bahia (Alvarenga & Carmo, 2008). The *Hevea* domestication process allowed the settlement of intensive systems of production in different parts of the word, but also contributed to the establishment and rise of pests and diseases that had not been reported previously on the natural environment (Gonçalves & Marques, 2008).

Thus, interactions between rubber trees and its associated mite fauna in the natural environment tend to be harmonic in the most of the cases, as a result of an experienced and shared coevolution process by the host and their herbivores (Ehrlich & Raven, 1964). The most important phytophagous mites found in rubber trees, *Calacarus heveae* Feres (Eriophyidae)*, Phyllocoptruta seringueirae* Feres (Eriophyidae)*, Shevtchenkella petiolula* Feres (Eriophyidae)*,* and also *Tenuipalpus heveae* Baker (Tenuipalpidae)*,* are genus-specific mites with an intrinsic association with *Hevea* spp. In the plantation areas, *C. heveae* and *T. heveae* are usually reported as pests, causing severe damage to the leaflets and therefore latex losses on *H. brasiliensis* plantations (Feres, 2000).

Due to the relevance of mites species on rubber trees, more attention has been given to this interaction in the last decades, so the last review reported fifty-four nominal species of mites and fifty more unidentified from rubber plantations in Brazil (Hernandes & Feres, 2006). The review was based on previous seasonal samplings carried out in São Paulo and Mato Grosso states, and by punctual surveys performed for other purposes rather than mites inventory on rubber plantations scattered around Brazilian territory.

Therefore, except for few isolated studies (Deus, Souza, Mineiro, Adaime, & Santos, 2012; Feres, 2001; Flechtmann & Arleu, 1984; Flechtmann, 1979), no extensive mite survey has been performed in specimens of *Hevea* in their natural habitat. Taxonomic information about phytoseiid mites from Brazilian Amazon is scarce, the main studies encompass surveys from Roraima and Pará states, in which few species were registered for Amazon State, and none for Acre and Rondônia states (Demite, Moraes, McMurtry, Denmark, & Castilho, 2014). Previous surveys in Brazilian Northern region essentially covered cultivated fruit crops (Bobot *et al*., 2011; Gondim Jr. *et al*., 2012), i.e. pepper, orange, and palm tree plantations, whereas the mite fauna from native plants remained out of taxonomic interests.

The Amazon Forest is the largest and least studied Brazilian ecosystem and it has been subjected to severe human disturbance and high deforestation rates (Brooks et al., 2002; Laurance et al., 2001), giving a high chance of a large number of species going extinct before becoming known by science (Rangel, 2012). Beyond the importance of taxonomic studies for conservation implications, refined data from phytoseiid mites associated with *Hevea* spp. can also be valuable for future biological control studies. Since no effective biological control agent is known for pest mites of rubber trees, performing a survey of indigenous predatory mites on the area of origin of the pests entirely fits on the scope of traditional biological control concepts (Kogan, 1998). It is expected that host plants in their natural environment may harbor, besides the phytophagous species, also their specific predators, which in turn can be future tested as biological control agents for rubber tree pests.

Since no surveys have been performed on native individuals of *Hevea* spp. in Brazil, we carried out a series of samples both in wild and cultivated rubber trees throughout the Amazon region, in order to report the occurrence of Phytoseiidae species associated with this plant genus. We also described seven new species and compared the species composition with the previous records for the Northern region and sites with *Hevea* plantations in Brazil. This way, our objective was to test the importance of native Amazonic vegetation as a harbor for predator mites, improving the knowledge about the mite fauna associated with *Hevea* spp.

Material and methods

Study areas

The sampling was carried out during July and August 2012, in nine sites in Acre, Amazonas, and Rondônia states, all located throughout the Brazilian Amazon Forest (Fig. 1). The samplings were performed on wild and cultivated specimens of *Hevea brasiliensis*, and native specimens of *H. guianensis* Aubl., *H. microphylla* Ule, *H. spruceana* Benth. and *H. pauciflora* Spruce ex. Benth. The sites are located in the Amazon domain, however they encompass heterogeneous local characteristics due to distinct phytophysiognomies, covering an area of 1.200 km (distance between the two most distant sites). The characteristics of the sites varied from high and drylands for *H. guiannensis* to low and wetlands undergone to seasonal floods for *H. brasiliensis* and *H. microphylla*. The study also covered plantation areas of *H. brasiliensis* and distinct forest fragments from Acre State harboring *H. spruceana* and *H. pauciflora.*

Sites on the State of Amazonas

- **Site 1 (59°97’ W, 2°89’ S)**: Cultivated trees from an experimental area maintained by “Empresa Brasileira de Pesquisa Agropecuária” (EMBRAPA) situated at the rural area of Manaus city. We took samples from 15 rubber trees (*H. brasiliensis*) of the clones IAN 6590 and 15 trees without cloning classification cultivated as an agroforestry management. The studied area is surrounded by Amazon Forest vegetation, and the weather is Af Köppen, local mean annual temperature is 27 ^{o}C, humidity higher than 80%, and annual total rainfall of 2,300 mm.
- **Site 2 (59°96' W, 3°02’ S)**: The collections were performed in 10 wild specimens of *H. guianensis* found in the interior of “Reserva Florestal Adolpho Ducke”

(RFAD), “Instituto Nacional de Pesquisas da Amazônia” (INPA), located on the AM 010 road, Km 26, northeast of the city of Manaus. The area is covered by Amazon Forest, sorted as a typical dryland evergreen tropical forest, with 100 km^2 and a trail network that completely covers the reserve. The weather is Af Köppen, with annual temperature of 27^{o}C, humidity higher than 80%, and annual total rainfall of 2,300 mm.

- **Site 3 (59°88’ W, 3°24’S):** We took samples from two wild specimens of *H. microphylla,* in a parcel sorted as “Site 3a”, and from five wild trees of *H. brasiliensis*, situated in a parcel sorted as “Site 3b”, both placed at the margins of the Negro River, a tributary of Amazonas River, far 10 km from Manaus city. The area is in the Amazon Forest, but this phytophisiognomy is classified as Igapó Forest due to seasonal floods of the rivers. The weather is Af Köppen, with annual temperature of 27^{o}C, humidity higher than 80%, and annual total rainfall of 2,300 mm.

Site 4 (59°98’ W, 3°09’ S): grove area of Amazon Forest remnant owned to “Instituto Nacional de Pesquisas da Amazônica” (INPA), located at the urban area of Manaus city. Collections were performed in three wild specimens of *H. brasiliensis.* The local weather is Af Köppen, with annual temperature of 27^{o}C, humidity higher than 80%, and annual total rainfall of 2,300 mm.

Sites on the State of Acre

- **Site 5 (67°87’ W, 9°96’ S):** Cultivated trees from the experimental area in “Universidade Federal do Acre” (UFAC) placed at urban limits of Rio Branco city. The area encompasses about 200 rubber trees (*H. brasiliensis*) without clone specification, from which we randomly sampled 20 of them. The local weather is Aw Köppen, with annual total rainfall between 1,600 and 2,750 mm, and mean annual temperature between 24 to 26°C.

- **Site 6 (67°85’ W, 9°95’ S)**: Wild rubber trees from urban fragment named as “Parque Zoobotânico” situated in the “Universidade Federal do Acre” (UFAC) at Rio Branco city, which includes native remnant of Amazon vegetation. The collections were performed in five rubber trees from *H. spruceana* which is the dominant species of *Hevea* in the region. The local weather is Aw Köppen, with annual total rainfall between1,600 and 2,750 mm, and mean annual temperature between 24 to 26°C.

- **Site 7 (67°65’ W, 10°01’ S):** Commercial rubber tree plantation (*H. brasiliensis*) with 10 ha, at KM 15 on BR 364 highway. We took samples from 15 rubber trees randomly selected in the midst of plantation. The local weather is Aw Köppen, with annual total rainfall between 1,600 and 2,750 mm.

- **Site 8 (67°50’ W, 10°11’S):** Wild rubber trees sampled in a protected forest fragment named “Fazenda Experimental Catuaba”, a farm of “UFAC” (Universidade Federal do Acre) with 1.281 ha, far 20 km from Rio Branco city. The vegetation type is alluvial forest, with patches of bamboo and palm trees, with trails covering the fragment. The samples were conducted in seven trees of *H. pauciflora* along the trails. The local weather is Aw Köppen, with annual total rainfall between 1,600 and 2,750 mm and mean annual temperature between 24 to 26°C.

Sites on the State of Rondônia

- **Site 9 (63°88’ W, 8°71’ S):** This area is a former rubber plantation (*H. brasiliensis*) with 5 ha, which was transformed in a recreational garden of Porto Velho city. We took 15 trees for sampling, randomly selected in the area. The local weather is Aw Köppen, with annual total rainfall between 1,400 and 2,600 mm and mean annual temperature between 24 to 26^{o}C

Sampling and mite extraction

Around 50 leaves were collected from each tree, in a total of 150 leaflets, that were washed in buckets containing five liters of 30 % ethanol, according to Rezende & Lofego (2011). After each wash, the ethanol was filtered through sieves with 25 µm nylon mesh. With a wash-bottle, the debris on the mesh was washed with 70% ethanol into vials filled with the same alcohol for preservation. These procedures were performed in the field for samples taken in Acre and Rondônia sites, and in the "Laboratório de Sistemática e Ecologia de Invertebrados de Solo" at INPA, for samples obtained in the Amazonas State.

All the vials were sent to the "Laboratório de Acarologia" at UNESP São José do Rio Preto (SP), where the mites were examined under stereoscopic microscope (40 x) and mounted on microscope slides with Hoyer's medium (Krantz & Walter, 2009). The type and voucher specimens are deposited in the Acari Collection (DZSJRP), Department of Zoology and Botany, Universidade Estadual Paulista (UNESP), São José do Rio Preto, São Paulo, available at: http://www.splink.cria.org.br, and ESALQ-USP (Escola Superior de Agricultura "Luiz de Queiroz" Universidade de São Paulo, Piracicaba, Satate of São Paulo, Brazil).

Under the heading "Specimens examined", we list the scientific name of the host plant, collection date, and the number of mite specimens collected in parentheses. All measurements are given in micrometers (µm); each measurement corresponds to the holotype measurements, followed (in parentheses) by the respective range, if the measurement is variable. The systems of setal notation for the dorsum and venter follow Rowell et al. (1978) and Chant & Yoshida-Shaul (1991), respectively. Macrosetal notation (Sge, genual macroseta; Sti, tibial macroseta; St, tarsalmacroseta) is that of Muma et al. (1970). Chaetotaxy formula follows Krantz & Walter (2009). Leg macrosetae not mentioned in the text should be considered as indistinguishable.

Results

We found a total of 1,305 phytoseiids, from 30 species and 16 genera of Amblyseiinae and Typhlodrominae subfamilies (Table 1). From those, seven correspond to new species: *Amblydromalus akiri* **sp. nov.**, *Amblyseius chicomendesi* **sp. nov.**, *Amblyseius duckei* **sp. nov.**, *Amblyseius manauara* **sp. nov.**, *Iphiseiodes katukina* **sp. nov.**, *Iphiseiodes raucuara* **sp. nov.**, *Typhlodromips igapo* **sp. nov.**; beyond two new records for Brazil, *Iphiseiodes kamahorae* De Leon, and *Amblyseius martus* De Leon, both from Guyana.

The most abundant and widespread species were *Euseius alatus* De Leon (691) which occurred in all *Hevea* spp., *Amblyseius chicomendesi* **sp. nov.** (92) not occurring on *H. microphylla* and *H. guianensis*, and *Amblyseius aerialis* (Muma) (64) not occurring on *H. pauciflora* (Table 1). The highest diversity was recorded on *H. brasiliensis* with 24 species, followed by *H. pauciflora* (14), *H. spruceana* (9), *H. microphylla* (7), and *H. guianensis* (5). Eight species were exclusive for *H. brasiliensis*, three for *H. pauciflora*, one for *H. microphylla* and none for *H. spruceana* and *H. guianensis*.

Considering the mite occurrence by locality, 20 species were found on *Hevea* spp. from the State of Acre, being nine of them restricted to that state, whereas we had a total of 17 from the State of Amazonas, with six exclusive occurrences, and at last seven were recorded from Rondônia State being only *Neoseiulus idaeus* Denmark & Muma exclusive from there. On the other hand, three species were common for all the studied areas, *Amblyseius aerialis, Euseius alatu*s and *Iphiseiodes zuluagai* **(**Denmark & Muma) regardless of host species.

Among the 30 species recorded, nine matched with the previous records on rubber trees (Hernandes & Feres, 2006), and five were already registered in other plants from the Amazon region. Thus we have 25 new records for the Amazon region, 21 new for *Hevea* spp., the first phytoseiid mites formally described from Amazonas and Acre states, and first records of occurrence for Rondônia and Acre.

SUBFAMILY AMBLYSEIINAE MUMA, 1961

Amblydromalus akiri sp. nov.

(Figs 2–8)

Diagnosis: This new species is similar to *Amblydromalus hum* (Pritchard & Baker, 1962). However differs from the latter by having a less striated dorsal shield, about 20 µm shorter and narrower, dorsal setae Z5 at least 0.25 shorter, and setae j1 and j3 about 0.30 shorter. In addition, *A. akiri* **sp. nov.** also differs from *A. hum* by having macrosetae distally capitates in all legs, ventrianal shield narrower at ZV3 level, and atrium of spermatheca more conspicuous and mushroom-like. In the original description of *A. hum*, Pritchard & Baker (1962) described the macroseta of leg IV as capitate, however, we checked the holotype and found that all macrosetae of leg IV, in fact, have pointed tips in *A. hum*, which is in according to the redescription of this species by Moraes, Zannou, Oliveira, Yaninek & Hanna (2006).

Specimens examined. Holotype female, four paratypes females and three paratypes males from *H. brasiliensis* experimental area from “UFAC” (Site 5), Rio Branco City, Acre State, August 08, 2012, F.M. Nuvoloni coll., deposited at DZSJRP (n 9516, 9517, 9518, 9519); two paratypes females and one paratype male from *H. brasiliensis* experimental area from “UFAC” (Site 5), Rio Branco City, Acre State, August 08, 2012, F.M. Nuvoloni coll., are deposited at ESALQ-USP.

Etymology: The specific name *akiri* refers to the indigenous name (Tupi-Guarani) that designates a tribe situated on the former territory of Rio Branco city, where the samples were performed. The State of Acre was also named in reference to this local indigenous tribe.

Description. *Females* (n=6) (Figs 2–6).

Dorsum. Dorsal shield smooth with scanty anterolateral striae 300 (300–312) long and 195 (170–197) wide at level of s4; seven pairs of pores and eight pairs of lyrifissures visible. Setae j1 20 (15–21), j3 22 (22–25), j4 8 (8–8), j5 7 (7–10) , j6 9 (9–10), J2 11 (10–12), J5 7 (6–9), z2 10 (9–11), z4 9 (9–10), z5 8 (7–9), Z1 11 (10–12), Z4 10 (10–12), Z5 61 (60–61), s4 32 (27–32), S2 11 (10–12), S4 11 (10–11) and S5 9 (9–10), r3 8 (8–13), R1 7 (7–10). Setae r3 and R1 inserted in the border of lateral dorsal shield. All setae smooth and pointed, except Z5 with aspect slightly serrate.

Venter. Sternal shield smooth with scanty anterolateral striae; with three pairs of setae and two pairs of lyrifissures. Distances between st1-st3 53 (52–55), st2-st2 66 (60–70). Genital shield smooth, distance between st5-st5 76 (68–76). Ventrianal shield vase shape, smooth with 100 (87–100) long, 51 (48–58) wide at level of ZV2 and 42 (40–50) wide at median level of anus, with three pairs of pre-anal setae (JV1, JV2, ZV2) and a pair of pores in the transverse line with JV2. With a pair of metapodal shields.

Peritreme. Extending beyond level of j1.

Chelicera. Fixed digit 32 (28–32) long; movable digit 28 (23–28) long.

Spermatheca. Calyx sacular, 25 (20–25) long; atrium distinct, mushroom-like.

Legs. Macrosetae present on all legs: Sge I 27(23–34), Sge II 29 (27–31), Sge III 34 (33–38), Sti III 21 (20–26), Sge IV 50 (47–55), Sti IV 29 (28–35) and St IV 69 (65–73). All macrosetae with capitates tip, except St IV and Sti IV with blunt tip. Chaetotaxy of genu II 2,2/0–2/0,1; genu III 1,2/2–2/0,1.

Male. (n=4) (Figs 7–8).

Dorsum. Dorsal shield pattern similar to female, 225–237 long and 130–152 wide. Setae j1 18–20, j3 22–25, j4 6–8, j5 7–8, j6 6–9, J2 9–10, J5 4–6, z2 7–9, z4 7–10, z5 7, Z1 9–10, Z4 8–10, Z5 43–50, s4 22–25, S2 10, S4 8–10, S5 7–9, r3 7–10, R1 6–9. All dorsal setae smooth.

Venter. Sternogenital shield smooth. Ventrianal shield subtriangular, lightly reticulated, 90–95 long, 104–110 wide at anterior corners, and 60–65 wide at anus level, with three pairs of pre-anal setae (JV1, JV2 and ZV2), four pairs of rounded structures similar to lyrifissures or small pores. Seta JV5 smooth, more than 2.0 longer than pre-anal setae.

Peritreme. Reaching beyond level of j3.

Chelicera. Movable digit 16–17 long, with one teeth; fixed digit 11–12 long, with one teeth; "*pilus dentilis*" not visible. Spermatodactyl elongated, 14-20 long with a button tip, toe and heel inconspicuous.

Legs. Macrosetae present on all legs: Sge I 20–25 with pointed tip, Sge II 20–23 distally capitates, Sge III 22–26 distally capitates, Sti III 15–21 with blunt tip, Sge IV 32–42 distally capitates, Sti IV 24–28 with blunt tip, and St IV 47–56 blunt tip. Chaetotaxy as in female.

***Amblydromalus manihoti* (Moraes, 1994)**

Amblydromalus manihoti — Chant & McMurtry 2005: 207; Guanilo, Moraes, Toledo & Knapp,2008: 23; Demite, Feres, Lofego, Oliveira 2009: 47; Castro & Moraes 2010: 302; Demite, Lofego & Feres 2011: 33; Moraes, Barbosa & Castro 2013: 319.

Origin of the material examined — Acre: Site 8: *H. pauciflora,* VIII-12 (3), Amazonas: Site 3a: *H. microphylla*, VII-12 (1), Site 2: *H. guianensis,* VII-12 (28); Site 1: *H. brasiliensis*, VII-12 (4).

Remarks: This species was already recorded on rubber trees from Mato Grosso State (Demite & Feres, 2008), and on fruits of *Cocos nucifera* L. from Amazonia State (Navia, Moraes, Lofego, & Flechtmann, 2005).

***Amblydromalus villacarmelensis* Moraes, 1994**

Amblydromalus villacarmelensis — Chant & McMurtry 2005: 207; Guanilo *et al.* 2008: 24; Castro & Moraes 2010: 303; Moraes *et al.* 2013: 319.

Origin of the material examined — Acre: Site 8: *H. pauciflora*, VIII-12 (4), Site 7: *H. brasiliensis*, VIII-12 (1).

***Amblyseius aerialis* (Muma, 1955)**

Amblyseius aerialis; Athias-Henriot 1957: 338; Moraes, McMurtry & Denmark 1986:6; Moraes, Mesa & Braun 1991: 117; Moraes & Mesa 1988: 71; Kreiter & Moraes 1997: 377; Feres & Moraes 1998: 126; Gondim Jr & Moraes 2001: 67; Chant & McMurtry 2004a: 203, 2007: 75; Feres, Lofego & Oliveira 2005: 45; Buosi, Feres, Oliveira, Lofego & Hernandes 2006: 3; Guanilo, Moraes & Knapp. 2008a: 3; Mineiro, Raga, Sato & Lofego 2009: 4; Demite *et al.* 2011: 34; Rezende & Lofego 2011: 454; Lofego, Rezende, Verona & Feres 2013: 414.

Origin of the material examined — Acre: Site 6: *H. spruceana*, VIII-12 (4), Site 7: *H. brasiliensis*, VIII-12 (7); Amazonas: Site 3: *H. microphylla*, VIII-12 (14), Site 2: *H. guianensis,* VIII-12 (5), Site 1: *H. brasiliensis,* VIII-12 (1); Rondônia: Site 9: *H. brasiliensis*, XII-12 (38).

Remarks: This species was the third most abundant phytoseiid, and was previously recorded on the Amazonic region in *Citrus sinensis* (Bobot *et al.*, 2011) from Amazonas State, in palm trees from Pará and Roraima states (Gondim Jr. et al., 2012; Lawson-Balagbo, Gondim, Moraes, Hanna, & Schausberger, 2008), and fruitful trees from Amapá State (Mineiro, Silva, & Silva, 2009).

Amblyseius chiapensis DeLeon, 1961

Amblyseius chiapensis De Leon, 1961: 85, 1962: 175; McMurtry, 1983: 250; Moraes *et al.*, 1986:10, 1991:118; Moraes, McMurtry, Denmark & Campos, 2004:19; Moraes & Mesa, 1988: 72; McMurtry & Moraes, 1989: 185; Denmark, Evans, Aguilar, Vargas & Ochoa 1999: 22; Gondim Jr & Moraes, 2001: 67; Chant & McMurtry, 2004b: 199, 2007: 78; Lofego, Moraes & Castro, 2004: 3, Lofego, Demite, Kishimoto & Moraes, 2009: 42; Guanilo *et al.*, 2008a: 4, 2008c: 4.

Origin of the material examined — Acre: Site 5: *H. brasiliensis*, VIII-12 (7); Amazonas: Site 1: *H. brasiliensis*, VIII-12 (1).

Amblyseius chicomendesi **sp. nov.**

(Figs 9–15)

Diagnosis: This new species belongs to the *obtusus* species group and *aerialis* subgroup (Chant & McMurtry, 2004b). Within *aerialis* subgroup, this species is closer to *Amblyseius circumflexis* De Leon (1966)*,* however can be distinguished from it by having setae s4, Z4 and Z5, shorter, with respectively 0.6, 0.57 and 0.55.

Specimens examined. Holotype female and a paratype male from *Hevea spruceana*, "Parque Zoobotânico" (Site 6) Rio Branco city, State of Acre, August 20, 2012, F.M. Nuvoloni coll.; seven paratypes females and one paratype male from *H. pauciflora* from "Fazenda Experimental Catuaba" (Site 8), State of Acre, August 20, 2012, F.M. Nuvoloni coll., deposited at DZSJRP (n 9527, 9528, 9529); six paratypes females from *H. pauciflora* from "Fazenda Experimental Catuaba" (Site 8), State of Acre, August 20, 2012, F.M. Nuvoloni coll., deposited at ESALQ-USP.

Etymology: The specific name "*chicomendesi*" was named after Chico Mendes (Francisco Alves Mendes Filho), a remarkable Brazilian rubber tapper, trade union leader and environmentalist. He fought in defense of Amazon Forest, and advocated for the human rights of Brazilian peasants and indigenous people from the region of Acre State, where this species was found.

Description. *Female*s (n=16). (Figs 9–13)

Dorsum. Dorsal shield mostly smooth, with some anterolateral striae, with 11 pairs of distinguishable lyrifissure and six pairs of pores, 285 (279–287) long and 187 (180–190) wide. Setae j1 12 (12–16), j3 22 (22–27), j4 4 (4–7), j5 3 (3–5), j6 5 (4–6), J2 5 (4–7), J5 5 (5–7), z2 12 (11–13), z4 7 (7–12), z5 5 (5–6), Z1 5 (4–6), Z4 50 (46–50), Z5 75 (75–85), s4 40 (40–42), S2 5 (4–7), S4 5 (5–6), S5 5 (4–7), r3 12 (11–13), R1 7 (7–8). Setae smooth and pointed, except for Z4and Z5, serrate and pointed.

Venter. Sternal shield smooth, except for the lateral lines at fusion with the endopodal plate, three pairs of setae and two pairs of lyrifissures; distances between St1-St3 57 (56–58), St2-St2 62 (62–66). Genital shield smooth; distance between St5-St5 55 (54–60). Ventrianal shield pentagonal, mostly smooth, with scanty striae, 84 (84–95) long, 70 (68–75) wide at level of ZV2, 65 (61–66) wide at anus level, with three pairs of pre-anal setae (JV1, JV2 and ZV2); JV4, JV5, ZV1and ZV3 on unsclerotised cuticle, and a pair of pre-anal pores about in transverse line with JV2. Ventral setae smooth and pointed. Two pairs of metapodal plates present.

Peritreme. Reaching level of j1.

Chelicera. Movable digit 23–26 long, with three teeth; fixed digit 28–32 long, with two teeth.

Spermatheca. Calyx tubular, 27(22–27) long; atrium c-shaped.

Legs: Macrosetae presented on all legs Sge I 27–31, Sge II 24–27, Sge III 22–27, Sge IV 46–52, Sti III 17–20, Sti IV 19–22, St IV 47–50, all pointed. Chaetotaxy: genu II 2–2/0, 2/0–1; genu III 1–2/1, 2/0–1.

Male. (n=2). (Figs 14–15)

Dorsum. Dorsal shield pattern similar to female, 235–237 long and 135–137 wide. Setae j1 9–10, j3 20–22, j4 4–5, j5 5, j6 2, J5 5, z2 7–8, z4 7–8, z5 2, Z1 4–5, Z4

30–32, Z5 50–52, s4 26–27, S2 4–5, S4 5, S5 4–5, r3 4–5, R1 7–8. All dorsal setae smooth.

Venter. Sternogenital shield mostly smooth, with few posterolateral striae. Ventrianal shield subtriangular, reticulate, 90–92 long and 108–110 wide at anterior corners, with three pairs of pre-anal setae (JV1, JV2 and ZV2), five pairs of rounded structures similar to lyrifissures or pores. Seta JV5 smooth, 1.5–2.0 longer than pre-anal setae.

Peritreme. Reaching level of z2.

Chelicerae. Movable digit 16–17 long, with one teeth; fixed digit 11–12 long, with one teeth; "*pilus dentilis*" not visible. Spermatodactyl L-shaped, with shaft 18-20 long, with toe straight, 8 (7–8) long, heel 4 (3–4) wide.

Legs. Macrosetae present. Chaetotaxy and macrosetaes as in female.

***Amblyseius duckei* sp. nov.**

(Figs 16–19)

Diagnosis: This new species belongs to the *obtusus* species group and *ovalitectus* subgroup (Chant & McMurtry, 2004b), which was previously represented by a single species, *Amblyseius ovalitectus* van der Merwe (1968). *Amblyseius duckei* **sp. nov.** differs from *A*. *ovalitectus* by having setae s4 shorter (0.5); ventri-anal shield pentagonal and smooth, while in *A. ovalitectus* it is sub-triangular and reticulate; and by having the macrosetae StIV twice longer than the SgeIV, whereas both setae have the same length in *A. ovalitectus*.

Specimens examined. Holotype female and two paratypes from *Hevea guianensis*, "Adolpho Ducke Forest Reserve" (RFAD, Site 2), owned to "Instituto

Nacional de Pesquisas da Amazônia" (INPA) Manaus, State of Amazonas, July 20, 2012, F.M. Nuvoloni coll.; one paratype female from *H. spruceana*, "Parque Zoobotânico" (Site 8) Rio Branco city, State of Acre, August 20, 2012, F.M. Nuvoloni coll., deposited at DZSJRP (n 9525, 9526).

Etymology: The specific name *duckei* refers to the "Reserva Florestal Adolpho Ducke" (RFAD) that was established and named in honor of Adolph Ducke, a notable Germanic entomologist, botanist and ethnographer, who dedicated part of his life studying and living in the Amazon Forest.

Description. *Females* (n=4). (Figs 16-19)

Dorsum. Dorsal shield mostly smooth, with scanty anterolateral striae, with eight pairs of distinguishable lyrifissure and seven pairs of pores, 292 (288–294) long and 192 (187–192) wide. Setae j1 18 (16–18), j3 28 (23–28), j4 4 (4–5), j5 5, j6 6 (5–7), J2 6 (5–6), J5 6 (6–7), z2 12 (11–12), z4 10 (10–11), z5 7 (5–7), Z1 7 (6–8), Z4 55 (47–58), Z5 70 (70–75), s4 38 (37–40), S2 7 (7–9), S4 6 (5–7), S5 5 (5–6), r3 12 (10–12), R1 9 (7–9). Setae smooth and pointed, except for Z4and Z5, serrate and pointed.

Venter. Sternal shield smooth, except for the anterior and lateral striaes, three pairs of setae and two pairs of lyrifissures; distances between St1-St3 52 (51–55), St2-St2 62 (62–64). Genital shield smooth; distance between St5-St5 59 (59–64). Ventrianal shield pentagonal, smooth with 101 (98–101) long, 75 (75–77) wide at level of ZV2, 71 (69–71) wide at anus level, with three pairs of pre-anal setae (JV1, JV2 and ZV2); JV4, JV5, ZV1 and ZV3 on unsclerotised cuticle, and a pair of pre-anal pores in the transverse line with JV2. Ventral setae smooth and pointed. Two pairs of metapodal plates present and one lyrifissure. Peritreme extending beyond level of j1.

Chelicerae. Movable digit 26-27 long, with three teeth; fixed digit 28 long, with two teeth.

Spermathecae. Calyx conspicuous and funnel-shaped 30 (26–30); atrium nodular.

Legs. Macrosetae present on all legs. Sge I 26 (25-30), Sge II 24 (23–25), Sge III 27 (25–27), Sge IV42 (42–46), Sti III 25 (24–25), Sti IV 23 (23–25), St IV 49 (47–51), all pointed. Chaetotaxy: genu II 2–2/0, 2/0–1; genu III 2–2/1, 2/0–1.

Male. Unknown.

***Amblyseius manauara* sp. nov.**

(Figs 20–26)

Diagnosis: This new species belongs to the *obtusus* species group and *nicola* species subgroup (Chant & McMurtry, 2004b). Within this subgroup *A. manaurara* **sp. nov.** is more similar to *Amblyseius franzellus* Athias-Henriot (1967), however differs from it by having setae Z5 shorter (0.65 times as long) and macroseta Sti IV is distinctly shorter (0.40-0.55) than Sge and St IV, while in *A. franzellus* these macrosetae have similar lengths.

Specimens examined. Holotype female, six paratypes female and three paratypes male from *Hevea brasiliensis* from *H. brasiliensis*, "Empresa Brasileira de Pesquisa Agropecuária" (Site 1) Manaus, State of Amazonas, July 20, 2012, F.M. Nuvoloni coll., deposited at DZSJRP (n 9520, 9521, 9522, 9523, 9524).

Etymology: The specific name *manauara* refers to who lives or are born from Manaus city, capital of Amazonia State. The term *manauara* and Manaus city comes from the indigenous tribe Manaú, which was used to live on the mouth of Negro River, on the foundation area of the city.

Description. *Females* (n=7). (Figs 20–24)

Dorsum. Dorsal shield mostly smooth, with scanty anterolateral striae, with eight pairs of distinguishable lyrifissure and seven pairs of pores, 290 (289–300) long and 200 (195–210) wide. Setae j1 18 (17–20), j3 27 (26–29), j4 6 (5–7), j5 6 (5–6), j6 7 (7–9), J2 10 (8–10), J5 8 (8–9), z2 13 (11–14), z4 10 (8–14), z5 7 (6–7), Z1 10, Z4 50 (49–52), Z5 77 (76–82), s4 35 (30–37), S2 10 (8–10), S4 8 (6–8), S5 7 (5–8), r3 11 (11–14), R1 8 (7–8). Setae smooth and pointed, except for Z4 and Z5, serrate and pointed.

Venter. Sternal shield smooth, except for the anterior and lateral striae, three pairs of setae and two pairs of lyrifissures; distances between St1-St3 562 (56–61), St2-St2 63 (60–64). Genital shield smooth; distance between St5-St5 63 (59–64). Ventrianal shield pentagonal, smooth with 102 (85–102) long, 65 (64–75) wide at level of ZV2, 70 (65–70) wide at anus level, with three pairs of pre-anal setae (JV1, JV2 and ZV2); JV4, JV5, ZV1 and ZV3 on unsclerotised cuticle, and a pair of pre-anal pores in the transverse line with JV2. Ventral setae smooth and pointed. Two pairs of metapodal plates present and one pair of lyrifissures.

Peritreme. Extending beyond level of j1.

Chelicera. Movable digit 25 (19–25) long, with three teeth; fixed digit 28 long, with two teeth.

Spermatheca. Calyx saccular 8 (7–9) long; atrium nodular.

Legs. Macrosetae present in all legs. Sge I 25 (25-6), Sge II 25 (23–25), Sge III 31 (28–31), Sge IV 52 (50–56), Sti III 20 (17–22), Sti IV 25 (22–26), St IV 48 (43–49), all pointed. Chaetotaxy: genu II 2–2/0, 2/0–1; genu III 2–2/1, 2/0–1.

Male. (n=3). (Figs 25–26)

Dorsum. Dorsal shield pattern similar to female, 223–227 long and 140–150 wide. Setae j1 12–15, j3 20–25, j4 6–7, j5 5–6, j6 6–7, J5 5–7, z2 11–12, z4 9–10, z5 4–7, Z1 7–10, Z4 35–37, Z5 53–55, s4 21–25, S2 8–10, S4 6–8, S5 6–8, r3 8–10, R1 7–12. All dorsal setae smooth and pointed, except for Z4and Z5, serrate and pointed.

Venter. Sternogenital shield smooth. Ventrianal shield subtriangular, with anterior and lateral striae, 87–95 long and 124–130 wide at anterior corners, with three pairs of pre-anal setae (JV1, JV2 and ZV2), two pairs of lyrifissures and three pairs of small, rounded pores. Seta JV5 smooth, 1.5–2.0 longer than pre-anal setae. Peritreme between z2 and j3.

Chelicera. Movable digit 10–18 long, with two teeth; fixed digit 16–17 long, with one teeth; pilus dentilis not visible. Spermatodactyl L-shaped, with shaft 15-18 long, with toe straight, 5, heel 2–3 wide.

Legs. Macrosetae and chaetotaxy as in female.

***Amblyseius martus* De Leon, 1966**

Amblyseius martus; De Leon, 1966: 2; Denmark & Muma, 1975.

Origin of the material examined — Acre: Site 5: *H. brasiliensis*, VIII-12 (9), Site 6: *H. spruceana*, VIII-12 (15), Site 7: *H. brasiliensis*, VIII-12 (3), Site 8: *H. pauciflora*, VIII-12 (15); Amazonas: Site 1: *H. brasiliensis*, VIII-12 (2).

Remarks: This survey encompasses the first record of *A. martus* on Brazil. It was first recorded on *Swartzia leiocalycina* from Guyana.

Amblyseius perditus Chant & Baker, 1965

Amblyseius perditus; Denmark & Muma, 1989: 105; Denmark *et al.*, 1999: 28; Gondim Jr & Moraes, 2001: 73; Moraes *et al.*, 2004: 47.

Origin of the material examined — Amazonas: Site 1: *H. brasiliensis*, VIII-12 (12).

Remarks: This species was already recorded at Amazonas State, from *Citrus sinensis* (Bobot *et al.*, 2011).

Arrenoseius morgani (Chant, 1957)

Arrenoseius morgani; Chant & McMurtry, 2004c: 299; Faraji, 2006: 103; Moraes *et al.*, 2013: 309.

Origin of the material examined — Acre: Site 8: *H. pauciflora*, VIII-12 (6); Amazonas: Site 2: *H. guianensis*, VII-12 (3), Site 1: *H. brasiliensis*, VII-12 (1).

Euseius alatus De Leon, 1966

Euseius alatus; De Leon, 1966: 87; Denmark & Muma, 1973: 262; Moraes & McMurtry, 1983: 137; Moraes *et al.*, 1986: 36, 1991: 131, 2004: 60; Feres & Moraes, 1998: 127; Zacarias & Moraes, 2001: 581; Gondim Jr & Moraes, 2001: 73; Ferla & Moraes, 2002a: 780, 2002b: 1015; Chant & McMurtry, 2005b: 215, 2007: 120; Hernandes & Feres, 2006: 3; Guanilo *et al.*, 2008a: 16; Mineiro *et al.*, 2009b: 40.

Origin of the material examined — Acre: Site 8: *H. pauciflora*, VIII-12 (8), Site 6: *H. spruceana*, VIII-12 (19), Site 7: *H. brasiliensis*, VIII-12 (21), Site 5: *H. brasiliensis*, VIII-12 (5); Amazonas: Site 3a: *H. microphylla*, VII-12 (1), Site 2: *H. guianensis,* VII-12 (1).

Remarks: *Euseius alatus* was the most common and abundant species sampled on the rubber trees. It was also previously recorded on rubber trees from São Paulo (Hernandes & Feres, 2006) and Mato Grosso states (Ferla & Moraes, 2002a).

***Euseius concordis* (Chant, 1959)**

Euseius concordis — Denmark & Muma, 1973: 264; McMurtry, 1983: 258; Moraes & McMurtry, 1983: 138; Moraes *et al.*, 1986: 39, 2004: 64; Moraes & Mesa, 1988: 80; Feres & Moraes, 1998: 127; Denmark *et al.*, 1999: 65; Gondim Jr & Moraes, 2001: 74; Lofego *et al.*, 2009: 44, 2004: 5; Chant & McMurtry, 2005b: 215, 2007:120; Guanilo *et al.*, 2008a: 12, 2008c: 17; Demite *et al.*, 2011: 41.

Origin of the material examined — Acre: Site 8: *H. pauciflora*, VIII-12 (2), Site 6: *H. spruceana*, VIII-12 (2), Site 7: *H. brasiliensis*, VIII-12 (13), Site 5: *H. brasiliensis*, VIII-12 (1); Amazonas: Site 3a: *H. microphylla*, VII-12 (3).

Remarks: This species encompass one of the most common phytoseiid found on rubber trees from São Paulo (Bellini, Feres, & Buosi, 2008; Daud, Silva, & Feres, 2010; Hernandes & Feres, 2006) and Mato Grosso states (Daud & Feres, 2014; Ferla & Moraes, 2002a)

***Iphiseiodes katukina* sp. nov.**

(Figs 27–33)

Diagnosis: This new species is similar to *Iphiseiodes quadripilis* (Banks). However differs for it by having dorsal setae s4 and Z5 and macrosetae Sge IV shorter (0.5), in addition *I. quadripilis* have Z5 with a blunt tip, while in the new species Z5 has a sharp tip.

Specimens examined. Holotype female, four paratypes female and three paratypes male from *Hevea brasiliensis* "Empresa Brasileira de Pesquisa Agropecuária" (Embrapa, Site 1) Manaus, State of Amazonas, August 10, 2012; three females paratypes from *H. pauciflora* from "Fazenda Experimental Catuaba" (Site 8), close to Rio Branco city, State of Acre, August 20, 2012; F.M. Nuvoloni coll., deposited at DZSJRP (n. 9532, 9533, 9534)

Etymology: The specific name *katukina* refers to the indigenous tribe Katukina that used to inhabit the Amazon Forest, mainly in the Southwest of Amazonia and Acre states.

Description. *Female* (n=4). (Figs 27–31)

Dorsum. Dorsal shield smooth, 362 (350–375) long and 220 (205–225) wide at level of s4; seven pairs of pores and 12 pairs of lyrifissures visible. Setae j1 8 (7–10), j3 5 (4–6), j4 2(1–2), j5 2 (1–2), j6 2 (2–3), J2 2(1–2), J5 4 (3–4), z2 2 (2–3), z4 2, z5 3(2-3), Z1 4(2–4), Z4 4 (3–4), Z5 57 (55–57), s4 47 (46–55), S2 2, S4 (2–3) and S5 3 (2–3), r3 4 (3–4), R1 4 (3–4). Setae r3 and R1 inserted lateral dorsal shield in soft cuticle. All setae smooth and pointed.

Venter. Sternal shield much wider than long and partially smooth, with anterolateral striae; with three pairs of setae and two pairs of lyrifissures. Distances between st1-st3 43 (40–50), st2-st2 68 (66–70). Genital shield smooth with central striaes in a triangular shape, distance between st5-st5 100 (96–100). Ventrianal shield pentagonal, reticulated, 76 (75–77) long, 112 (105–113) wide at level of ZV2 and 89 (85–90) wide at median level of anus, with three pairs of pre-anal setae (JV1, JV2, ZV2) and a pair of pores in the transverse line with JV2. With two pairs of metapodal shields.

Peritreme. Extending to anterior of j3.

Chelicera. Fixed digit 36 (32–38) long, with 8 teeth and a *pilus dentilis*; movable digit 30 (28–34) long with 2 teeth.

Spermatheca. Calyx funnel-shaped, 6–8 long; atrium indistinct.

Legs. Macrosetae present on all legs: Sge I 18 (17–20), Sge II 23 (20–23), Sge III 25 (24–27), Sti III 19 (14–19), Sge IV 50 (46–50), Sti IV 35 (32–36) and St IV 27 (19–27). All macrosetae distally blunt, except Sge I and Sge II pointed. Chaetotaxy of genu II 2,2/1–2/0,1; genu III 1,2/1–2/0,1.

Male. (n=2). (Figs 32–33)

Dorsum. Dorsal shield pattern similar to female, 235–237 long and 135–137 wide. Setae j1 9–10, j3 20–22, j4 4–5, j5 5, j6 2–2, J5 5, z2 7–8, z4 7–8, z5 2, Z1 4–5, Z4 30–32, Z5 50–52, s4 26–27, S2 4–5, S4 5, S5 4–5, r3 4–5, R1 7–8. All dorsal setae smooth.

Venter. Sternogenital shield mostly smooth, with few posterolateral striae. Ventrianal shield subtriangular, reticulate, 90–92 long and 108–110 wide at anterior corners, with three pairs of pre-anal setae (JV1, JV2 and ZV2), five pairs of small rounded structures similar to lyrifissures or pores. Seta JV5 smooth, more than 2.0 longer than pre-anal setae.

Peritreme. Reaching level of z2.

Chelicera. Movable digit 16–17 long, with one teeth; fixed digit 11–12 long, with one teeth; pilus dentilis not visible. Spermatodactyl L-shaped, with shaft 18-20 long, with toe straight, 7–8 long, heel 3 wide.

Legs. Macrosetae present on all legs. Sge I 20–25, Sge II 20, Sge III 20, Sti III 15, Sge IV 30–33, Sti IV 23-25, St IV 25. Sg I and Sge II pointed, Sge III blunt, Sge and Sti IV slightly capitulate, and St IV blunt. Chaetotaxy as in female

Iphiseiodes kamahorae **De Leon, 1966**

Iphiseiodes kamahorae (De Leon, 1966): 84

Origin of the material examined — Amazonas: Site 1: *H. brasiliensis*, VII-12 (2).

Remarks: This is the first record of *I. kamahorae* on the Brazilian territory, described on *Pouteria* sp. in Guyana (De Leon 1966).

Iphiseiodes raucuara **sp. nov.**

(Figs 34–38)

Diagnosis: This new species is similar to *Iphiseiodes setillus* (Gondim Jr & Moraes, 2001). However differs from the latter by having dorsal setae Z5 at least 1.5 longer, and setae j1 and j3 with similar length, in *I. setillus* j3 is twice longer than j1. In addition, *Iphiseiodes raucuara* **sp. nov.** differs from all others species of genus by having a pair of circular structure near pores of ventri-anal shield.

Specimens examined. Holotype female, and two paratype female from *H. pauciflora* from “Fazenda Experimental Catuaba” (Site 8), owned to “UFAC”, located close to Rio Branco city, State of Acre, August 20, 2012, F.M. Nuvoloni coll., deposited at DZSJRP (n 9530, 9531, 9532).

Etymology: The specific name *raucuara* refers to the indigenous name (Tupi) *ráu* = fake; *cuára* = hole or pore. The diagnosis character of the species is a pair of rounded structures, similar to pores, near true pores of ventrianal shield.

Description. *Female* (n=4). (Figs 34–38)

Dorsum. Dorsal shield smooth with scanty anterolateral striae, 302 (265–300) long and 195 (182–195) wide at level of s4; seven pairs of pores and nine pairs of lyrifissures visible. Setae j1 11 (11–12), j3 10 (9–10), j4 17 (16–17), j5 18, j6 2 (2–3), J2 20, J5 9 (8–10), z2 12 (12–18), z4 20 (12–20), z5 15 (15–18), Z1 19 (19–20), Z4 19 (19–25), Z5 38 (35–38), s4 17 (17–20), S2 18 (18–20), S4 18 (16–18) and S5 18 (16–19), r3 12 (10–12), R1 12 (12–14). Setae r3 and R1 inserted in the border of lateral dorsal shield. All setae smooth and pointed, except Z5 slightly serrate.

Venter. Sternal shield wider than long, mostly smooth with anterolateral striae; with three pairs of setae and two pairs of lyrifissures. Distances between st1-st3 40, st2-st2 50–58. Genital shield smooth with lateral striaes, distance between st5-st5 78–80. Ventrianal shield pentagonal, mostly smooth with 75 long, 90 (87–91) wide at level of ZV2 and 75 (70–78) wide at median level of anus, with three pairs of pre-anal setae (JV1, JV2, ZV2) and a pair of pores and a pair of rounded buttons in the transverse line with JV2. With two pairs of metapodal shields.

Peritreme. Extending between j3 and j1.

Chelicera. Fixed digit 20–24 long; movable digit 24–26 long.

Spermatheca. Calyx pocular, 6–8 long; atrium indistinct.

Legs. Macrosetae present on all legs: Sge I 11–12, Sge II 12–13, Sge III 16–18, Sti III 18–19, Sge IV 22–26, Sti IV 16–20 and St IV 17–22. All macrosetae distally pointed. Chaetotaxy of genu II 2,2/0–2/0,1; genu III 1,2/1–2/0,1.

Male. Unknown

Iphiseiodes zuluagai **Denmark and Muma, 1972**

Iphiseiodes zuluagai; Denmark & Muma, 1972: 23, 1973: 251, 1975: 287; Moraes *et al.*, 1986: 61, 2004: 9; Aponte & McMurtry, 1995: 165; Kreiter & Moraes, 1997: 377; Feres & Moraes, 1998: 127; Zacarias & Moraes, 2001: 581; Gondim Jr & Moraes, 2001: 76; Lofego *et al.*, 2004: 7, 2013: 415; Guanilo *et al.*, 2008a: 9; Demite *et al.*, 2009: 48, 2011: 43; Rezende & Lofego, 2011: 456, 2012: 18; Rezende, Lofego, Návia & Roggia, 2012: 686.

Origin of the material examined — Acre: Site 7: *H. brasiliensis*, VIII-12 (2); Amazonas: Site 3a: *H. microphylla*, VII-12 (3), Site 4: *H. brasiliensis*, VII-12 (17); Rondônia: Site 9: XII-12 (23).

Remarks: This species was already recorded in the Amazon region, in *Citrus sinensis* from Amazonas State (Bobot *et al.*, 2011) and in palm trees from Roraima State (Gondim Jr. et al., 2012).

Neoseiulus idaeus **Denmark and Muma, 1973**

Neoseiulus idaeus; Denmark & Muma, 1973: 266; Moraes *et al.*, 1986: 83, 2004: 124; Chant & McMurtry, 2003: 21; 2007: 29; Demite *et al.*, 2011: 43; Rezende & Lofego, 2011: 456; Rezende *et al.*, 2012: 687; Lofego *et al.*, 2013: 456.

Origin of the material examined — Rondônia: Site 9: XII-12 (1).

Remarks: This species was once recorded on previous rubber tree survey from São Paulo State (Bellini, Moraes, & Feres, 2005), although it is commonly found on surveys on native vegetation (Demite et al., 2011; J.M. Rezende & Lofego, 2011).

***Paraamblyseius multicircularis* Gondim Jr. & Moraes, 2001**

Paraamblyseius multicircularis; Gondim Jr & Moraes, 2001: 79.

Origin of the material examined — Acre: Site 7: *H. brasiliensis*, VIII-12 (1); Amazonas: Site 1: *H. brasiliensis*, VIII-12 (1).

***Paraphytoseius orientalis* (Narayanan, Kaur & Ghai, 1960)**

Paraphytoseius orientalis; Chant & McMurtry, 2003: 220; Moraes *et al.*, 2004: 162; Lofego *et al.*, 2009: 51.

Origin of the material examined — Acre: Site 8: *H. pauciflora*, VIII-12 (1), Site 6: *H. spruceana*, VIII-12 (11), Site 5: *H. brasiliensis*, VIII-12 (1).

***Phytoscutus sexpilis* Muma, 1961**

Phytoscutus sexpilis; Muma, 1961: 275; De Leon, 1967: 17; Denmark & Muma, 1970: 24; Yoshida-Shaul & Chant, 1997: 234; Zacarias & Moraes, 2001: 589; Hernandes & Feres, 2006: 4; Chant & McMurtry, 2007: 101.

Origin of the material examined — Amazonas: Site 4: *H. brasiliensis*, VII-12 (8); Rondônia: Site 9: *H. brasiliensis*, XII-12 (1).

Remarks: This species was already recorded on rubber trees from São Paulo State (Bellini *et al.*, 2005; Hernandes & Feres, 2006).

***Proprioseiopsis dominigos* (El-Banhawy, 1984)**

Proprioseiopsis dominigos; (Moraes *et al.*, 1986: 114, 2004: 175; Zacarias & Moraes, 2001: 582; Gondim Jr & Moraes, 2001: 81; Chant & McMurtry, 2005c: 15; 2007: 89; Guanilo *et al.*, 2008a: 10; Demite *et al.*, 2009: 48, 2011: 45; Mineiro *et al.*, 2009b: 42; Rezende & Lofego, 2011: 457.

Origin of the material examined — Amazonas: Site 1: *H. brasiliensis*, VII-12 (2).

Remarks: *Proprioseiopsis dominigos* was already recorded on rubber trees from São Paulo State (Hernandes & Feres, 2006).

***Proprioseiopsis neotropicus* (Ehara, 1966)**

Proprioseiopsis neotropicus; Moraes *et al.*, 1986: 119, 2004: 183; Zacarias & Moraes, 2001: 582; Gondim Jr & Moraes, 2001: 81; Ferla & Moraes, 2002b: 1019; Lofego *et al.*, 2004: 9; Feres *et al.*, 2005: 46; Buosi *et al.*, 2006: 5; Chant & McMurtry, 2007: 89; Guanilo *et al.*, 2008a: 12, 2008c: 9; Demite *et al.*, 2009: 49, 2011: 45.

Origin of the material examined — Amazonas: Site 2: *H. guianensis,* VII-12 (1).

Remarks: This species was previously recorded on the Amazon State, in leaves of *Citrus sinensis* (Bobot *et al.*, 2011).

***Proprioseiopsis mexicanus* Garman, 1959**

Proprioseiopsis mexicanus; Moraes *et al.*, 1986: 118, 2004: 181, 2007: 17; Chant & McMurtry, 2005c: 13, 2007: 89; Guanilo *et al.*, 2008a: 11; Lofego *et al.*, 2009: 54

Origin of the material examined — Rondônia: Site 9: *H. brasiliensis*, XII-12 (2).

***Typhlodromalus peregrinus* (Muma, 1955)**

Typhlodromalus peregrinus; Muma *et al.*, 1970: 88; Moraes *et al.*, 1986: 132, 2004: 202; Zacarias & Moraes, 2001: 582; Chant & McMurtry, 2007: 11; Rezende & Lofego, 2011: 457.

Origin of the material examined — Acre: Site 8: *H. pauciflora*, VIII-12 (1).

Typhlodromips igapo **sp. nov.**

(Figs 39–43)

Diagnosis: This new species belongs to the *ariri* species group (Chant & Mcmurtry, 2005). Within this group *Typhlodromips igapo* **sp. nov.** is more similar to *T. cananeiensis* Gondim Jr & Moraes (2001) and *T. sabaculus* Denmark & Muma (1973). However differs from *T. cananeiensis* on length of dorsal setae, with z4, s4 and Z1 at least twice longer, and Z4 trespassing the base of S5, while in *T. cananeiensis* Z4 not reach the bases of S5. Besides also differs from *T. sabaculus* on the length of dorsal setal, with dorsum-central setae not minute as in *T. sabaculus*, and by having z2, z4, s4 and Z1 with similar length, while *T. sabaculus* has s4 at least twice longer than others.

Specimens examined. Holotype female, and three paratypes females from *Hevea microphylla* from a Igapó Forest fragment, 10 km far from Manaus city, Amazon State, August 10, 2012, F.M. Nuvoloni coll.; two paratypes females from *H. brasiliensis* from experimental area from "UFAC", Rio Branco City, Acre State; two paratypes females from *H. pauciflora*, from "Fazenda Experimental Catuaba", close to Rio Branco city, State of Acre, August 20, 2012; F.M. Nuvoloni coll., deposited at DZSJRP (n. 9535, 9536, 9537, 9538, 9539).

Etymology: The specific name *igapo* refers to the flooded Amazon Forest, called Igapó Forest. The term Igapó refers to an indigenous name (Tupi) *y*= water; *apó*= root.

The samples were performed on the flood season, when we could reach the canopy of the trees by boat, at the margins of Negro River.

Description. Female (n=8). (Figs 39–43)

Dorsum. Dorsal shield reticulate, with 14 pairs of distinguishable lyrifissures and six pairs of pores, 287 (287–320) long and 167 (167–192) wide. Setae j1 20 (12–20), j3 21 (17–21), j4 17 (13–17), j5 16 (15–17), j6 17 (15–17), J2 20 (18–20), J5 8 (8–12), z2 18 (11–18), z4 18 (15–18), z5 12 (12–16), Z1 21 (19–21), Z4 36 (31–41), Z5 62 (59–68), s4 24 (20–25), S2 24 (22–25), S4 19 (15–20), S5 17 (10–18), r3 14 (13–15), R1 15 (15–18). Setae smooth and pointed, except for Z4 and Z5, serrate and pointed.

Venter. Sternal shield smooth, with three pairs of setae and two pairs of lyrifissures; distances between St1-St3 53 (52–60), St2-St2 56 (56–65), with ST4 inserted on a metasternal shield. Genital shield smooth; distance between St5-St5 60 (60–65). Ventrianal shield pentagonal, smooth with 100 (100–110) long, 65 (65–80) wide at level of ZV2, 78 (78–95) wide at anus level, with three pairs of pre-anal setae (JV1, JV2 and ZV2); JV4, JV5, ZV1 and ZV3 on unsclerotised cuticle, and a pair of pre-anal pores about in transverse line with JV2. Ventral setae smooth and pointed. Two pairs of metapodal plates present and three lyrifissure.

Peritreme. Extending beyond level of j1.

Chelicera. Movable digit 23 (22–27) long, with three teeth; fixed digit 26 (25–30) long, with two teeth.

Spermatheca. Calyx cone-shaped 6 (5-9); and atrium nodular.

Legs. Macrosetae present on all legs. Sge I 18 (14–22), Sge II 14 (12–15), Sge III 22 (21–25), Sge IV 32 (30–40), Sti III 14 (12–19), Sti IV 13 (13–18), St IV 32 (32–45), all capitate. Chaetotaxy: genu II 2–2/0, 2/0–1; genu III 1–2/1, 2/0–1.

Male. Unknown.

SUBFAMILY TYPHLODROMINAE SCHEUTEN, 1857

Galendromus (_Galendromus_) _annectens_ (De Leon, 1958)

Galendromus (*Galendromus*) *annectens*; Muma, 1963: 30; Denmark & Muma, 1973: 274; Moraes *et al.*, 2004: 265; Chant & McMurtry, 2007: 167; Demite *et al.*, 2011: 49; Rezende & Lofego, 2011: 458, 2012: 18; Rezende *et al.*, 2012: 685.

Origin of the material examined — Acre: Site 7: *H. brasiliensis*, VIII-12 (1); Rondônia: Site 9: *H. brasiliensis*, XII-12 (20).

Remarks: This species is usually recorded on rubber trees surveys, being very common on plantations from São Paulo (Bellini et al., 2005; Daud, Silva & Feres, 2010; Hernandes & Feres, 2006) and Mato Grosso states (Daud & Feres, 2014; Ferla & Moraes, 2008)

Leonseius regularis (De Leon, 1965)

Leonseius regularis; Chant & McMurtry, 1994: 258; Denmark *et al.*, 1999: 81; Moraes *et al.*, 2004: 275; Vasconcelos *et al.*, 2006: 94; Castro & Moraes, 2010: 303; Moraes *et al.*, 2013: 338.

Origin of the material examined — Acre: Site 5: *H. brasiliensis*, VIII-12 (2).

Metaseiulus (_Metaseiulus_) _adjacentis_ (De Leon, 1959)

Metaseiulus (*Metaseiulus*) *adjacentis;* Moraes, Kreiter & Lofego, 2000: 256, 2004: 276; Buosi *et al.*, 2006: 5; Chant & McMurtry, 2007: 173; Guanilo *et al.*, 2008b: 54; Demite *et al.*, 2011: 49.

Origin of the material examined — Amazonas: Site 3a: *H. microphylla*, VII-12(3).

Discussion

Our data on plant inhabitant mites is the largest reported from the Amazon Forest so far, in terms of diversity of phytoseiid mites as well as geographical extension. Although the investigation has been composed by one collection event per site, our survey covered a huge spatial area (more than 1,200 km between the two most distant sites), and several different phytophysiognomies from Amazon Forest. The impressive heterogeneity among the studied environments was evidenced by the great diversity and endemism of species, which in turn 35 to 45% of them were restricted to each site, and 20% were new to science. The composition of plant species in the surrounding in each site resulted in a higher local mite diversity on rubber trees. . Unlikely phytophagous species, phytoseiid mites are not deeply influenced by the plant host, however, environmental and resources heterogeneity are vital for the maintenance of their diversity. Plant composition greatly influences phytoseiids diversity and occurrence, since they are dependent of leaf structure (trichomes, leaf domatia), resources abundance and heterogeneity, and habitat and micro-habitat conditions (Kreiter, Tixier, & Bourgeois, 2003).

Investigation performed by Demite *et al.* (2011) in 102 species of native plants from forest fragments of São Paulo State found out 47 phytoseiid species, which 2 were new. Moraes *et al.* (2013)) also conducted extensive collections in 187 native plants from Atlantic Rainforest, and 16 from Cerrado vegetation (Brazilian Savanah), being recorded a total of 50 species of phytoseiid from which 13 were new to science.- Rezende & Lofego (2011) studying the mite fauna from 57 native plants from Cerrado remnants of central Brazil, track record of 26 species of phytoseiid, but none was new. Concerning about the species composition, around 20 to 25% of the species previously recorded by Demite et al. (2011), Moraes et al. (2013), and Rezende & Lofego, (2011) were also registered by us. Although all investigations have been performed on native plants from forest fragments, they differ in terms of environment characteristics (temperature, rainfall, and seasonality), number and species of host plants, and Brazilian biome target.

Looking at recent surveys of mites (last 20 years) in native vegetation on Brazilian territory, about 400 species of plants from the Atlantic Rainforest domain were sampled and studied and about 30 new species of Phytoseiidae were discovered (Barbosa, Rocha, & Ferla, 2014; Buosi et al., 2006; Castro & Moraes, 2010; Demite, Lofego, & Feres, 2008a, 2008b; Demite et al., 2011; Demite, Lofego, & Feres, 2007; Feres & Moraes, 1998; Feres et al., 2005; Gondim Jr & Moraes, 2001; Gondim, Moraes, & Mcmurtry, 2000; Lofego, Demite, & Feres, 2011a, 2011b; Lofego & Feres, 2006; Lofego et al., 2009; Mineiro, Castro, & Moraes, 2011; Moraes et al., 2013; Silva, Reis, Zacarias, & Marafeli, 2010; Silva, Rocha, & Ferla, 2013; Zacarias, Moraes, & McMurtry, 2002; Zacarias & Moraes, 2001, 2002). Concerning the surveys performed at the Cerrado domain, four new phytoseiid were discovered from 100 species of plants studied (Demite et al., 2009; Lofego & de Moraes, 2006; Lofego et al., 2004; Lofego & Moraes, 2003; Rezende & Lofego, 2011). Making a rough comparison among these prior surveys, we may estimate a rate of 0.075 new species of phytoseiid per plant from the Atlantic Rainforest, while at the Cerrado domain the rate is approximately 0.04 new phytoseiid per plant. Contrasting these findings with our results, we have an impressive rate of more than 1 new phytoseiid species per native rubber tree species from the Amazon. Keeping in mind the differences among sample efforts and number of hosts, we can highlight that almost nothing is known in terms of mite fauna from Amazonian native vegetation in comparison to other environments.

The combination of some factors, such as the high level of diversity, endemism, and high rate of new species highlight the great importance of native Amazonian trees, in particular *Hevea* spp. as a valuable source and shelter for a huge and still unknown diversity. Species of arthropods associated with local vegetation and soil are usually overlooked when conservation and management plans are designed for natural areas, although monitoring these species can provide early warnings of ecological changes and be used to assay the effects of further fragmentation on natural areas (Kremen *et al.*, 1993). Beyond that, additional information about native and endemic arthropod fauna may be emphasized and used to support conservation plans due to their ecological importance.

Classical biological control techniques argue that the search for natural enemy has to be conducted in the country or the region of origin of the pest (van Lenteren, 2000). Following this statement, our results bring to the spotlight of science seven new phytoseiid species, which may represent new potential biological control agents to be tested. Among the new discovered species, we have three new species of *Amblyseius*, one *Amblydromalus*, two *Iphiseiodes*, and one *Typhlodromips*. From those genera there are some species currently used for biological control purposes, such as

Amblydromalus limonicus (Garman & McGregor) often found in citrus and commercialized for the control of whiteflies and thrips (Moraes *et al.*, 1986; McMurtry *et al.*, 2013), and *A. manihoti* (Moraes) a common predator on cassava plants in South America (Yaninek *et al.*, 1998). *Amblyseius swirskii* Athias-Henriot has been extensively used for the control of *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) and thrips species (Nomikou, Sabelis, & Janssen, 2010), *A. andersonii* (Chant) was observed as an effective predator of spider mites on grape with glabrous leaves (Duso, Pozzebon, Capuzzo, Bisol, & Otto, 2003). On the other hand, *Iphiseiodes* and many *Typhlodromips* spp. are sorted as generalist predators, with feeding preference for pollen or fungi (McMurtry *et al.* 2013).

In conclusion, our results pointed out the potential of native Amazonian vegetation as shelter and housing for a huge diversity of predator mites and therefore other arthropods. Even though the Amazon Forest is the largest tropical forest in the world, it is also the less studied, harboring a canopy mite fauna totally unexplored so far. Our findings highlight the need for more and deeper collaborative efforts in order to improve our knowledge about native plant inhabiting mites and other arthropods from the Amazon.

Acknowledgements

We are grateful to Dra. E. Franklin, Dr. J.W. de Morais and collaborators from "Instituto Nacional de Pesquisas da Amazônica" (INPA) for providing laboratory assistance and support for the field work on the Amazonas State; the post-graduate students, and staff from "Universidade Federal do Acre" (UFAC) for the valuable help on the field work on the Acre State; the staff from "Empresa Brasileira de Pesquisa

Agronômica” (EMBRAPA, Amazônia Ocidental), in particular to Dr. Everton Rabelo Cordeiro for the permission and help in the field work on EMBRAPA; to Dr. Ronald Ochoa from National Insect and Mite Collection, National Museum of Natural History, Smithsonian Institute (NMNH) for provide access of holotypes from NMNH used for comparison with the specimens considered in this study. This work was funded by FAPESP, “Fundação de Amparo à Pesquisa do Estado de São Paulo” by fellowship to F.M. Nuvoloni (Process. 2010/19935-1) and J.M. Rezende (Process. 2011/19890-0), and ‘’Conselho Nacional de Desenvolvimento Científico e Tecnológico’’ (CNPq) (Proc. No 303435/2013-5), by fellowship and research grant to R.J.F. Feres.

References

Alvarenga, A. de P., & Carmo, C. A. F. do. (2008). *Seringueira* (p. 894). Viçosa, MG: EPAMIG - Viçosa.

Aponte, O., & McMurtry, J. A. (1995). Revision of the genus *Iphiseiodes* De Leon (Acari: Phytoseiidae). *International Journal of Acarology*, *2*1, 165–183.

Athias-Henriot, C. (1957). Phytoseiidae et Aceosejidae (Acarina, Gamasina) d’Algerie. I. Genres *Blattisocius* Keegan, *Iphiseius* Berlese, *Amblyseius* Berlese, *Phytoseius* Ribaga, *Phytoseiulus* Evans. Naturelle de l'Afrique du Nord. *Bulletin de La Societe d’Histoire*, *48*, 319–352.

Barbosa, M. F. de C., Rocha, M. dos S., & Ferla, N. J. (2014). A new genus and species of phytoseiid mite (Acari: Phytoseiidae) from the Brazilian Atlantic Forest. *Zootaxa*, *3795*(May), 91–95.

Bellini, M. R., Feres, R. J. F., & Buosi, R. (2008). Ácaros (Acari) de Seringueira (*Hevea brasiliensis* Muell. Arg., Euphorbiaceae) e de Euforbiáceas Espontâneas no Interior dos Cultivos. *Neotropical Entomology*, *37*(4), 463–471.

Bellini, M. R., Moraes, G. J., & Feres, R. J. F. (2005). Ácaros (Acari) de dois sistemas de cultivo da seringueira no Noroeste do Estado de São Paulo. *Neotropical Entomology*, *34*(3), 475–484.

Bobot, E., Franklin, E., Navia, D., Ray, T., Gasnier, J., Lofego, A. C., & Oliveira, B. M. de. (2011). Mites (Arachnida, Acari) on *Citrus sinensis* L. Osbeck orange trees in the State of Amazonas, Northern Brazil. *Acta Amazonica*, *4*1(4), 557–566.

Brooks, T. M., Mittermeier, R. A., Mittermeier, C. G., Fonseca, G. A. B. D. A., Rylands, A. B., Konstant, W. R., … Hilton-taylor, C. (2002). Habitat Loss and Extinction in the Hotspots of Biodiversity. *Conservation Biology*, *16*(4), 909–923.

Buosi, R., Feres, R. J. F., Oliveira, A. R., Lofego, A. C., & Hernandes, F. A. (2006). Ácaros Plantícolas (Acari) da "Estação Ecológica de Paulo de Faria", Estado de São Paulo, Brasil. *Biota Neotropica*, *6*. Retrieved from http://www.biotaneotropica.org.br/v6n1/pt/abstract?article+bn02006012006

Castro, T. M. M. G., & Moraes, G. J. (2010). Diversity of phytoseiid mites (Acari: Mesostigmata: Phytoseiidae) in the Atlantic Forest of São Paulo. *Systematics and Biodiversity*, *8*(2), 301–307. doi:10.1080/14772001003801375

Chant, D. A., & McMurtry, J. A. (1994). A review of the subfamilies Phytoseiinae and Typhlodrominae (Acari: Phytoseiidae). *International Journal of Acarology*, *20*, 223–310.

Chant, D. A., & McMurtry, J. A. (2003). A review of the subfamily Amblyseiinae Muma (Acari: Phytoseiidae): Part II. The tribe Kampimodromini Kolodochka. *International Journal of Acarology*, *29*, 179–224.

Chant, D. A., & McMurtry, J. A. (2004a). A review of the subfamily Amblyseiinae Muma (Acari: Phytoseiidae): Part III. The tribe Amblyseiini Wainstein, subtribe Amblyseiina n. subtribe. *International Journal of Acarology*, *30*, 171–228.

Chant, D. A., & McMurtry, J. A. (2004b). A review of the subfamily Amblyseiinae Muma (Acari: Phytoseiidae): Part III. The tribe Amblyseiini Wainstein, subtribe Amblyseiina n. subtribe. *International Journal of Acarology*, *30*, 171–228.

Chant, D. A., & McMurtry, J. A. (2004c). A review of the subfamily Amblyseiinae Muma (Acari: Phytoseiidae): Part IV. Tribe Amblyseiini Wainstein, subtribe Arrenoseiina Chant & McMurtry. *International Journal of Acarology*, *30*, 291–312.

Chant, D. A., & McMurtry, J. A. (2005a). A review of the subfamily Amblyseiinae Muma (Acari: Phytoseiidae): Part V. Tribe Amblyseiini, subtribe Proprioseiopsina Chant & McMurtry. *International Journal of Acarology*, *3*1, 3–22.

Chant, D. A., & McMurtry, J. A. (2005b). A review of the subfamily Amblyseiinae Muma (Acari: Phytoseiidae): Part VI. The tribe Euseiini n. tribe, subtribes Typhlodromalina n. subtribe, Euseiina n. subtribe, and Ricoseiina n. subtribe. *International Journal of Acarology*, *3*1, 187–224.

Chant, D. A., & Mcmurtry, J. A. (2005c). A review of the subfamily Amblyseiinae muma Acari : Phytoseiidae): Part VII . Typhlodromipsini n . tribe. *International Journal of Acarology*, *3*1, 315–340.

Chant, D. A., & McMurtry, J. A. (2007). *Illustrated keys and diagnoses for the genera and subgenera of the Phytoseiidae of the world (Acari: Mesostigmata)* (p. 219). West Bloomfield, Michigan: Indira Publishing House.

Chant, D. A., & Yoshida-Shaul, E. (1991). Adult ventral setal patterns in the family Phytoseiidae (Acari: Gamasina). *International Journal of Acarology*, 1*7*, 187–199.

Daud, R. D., & Feres, R. J. F. (2014). Community structure of mites (Arachnida: Acari) in six rubber tree clones. *International Journal of Acarology*, *39*(8), 589–596. doi:10.1080/01647954.2013.856470

Daud, R. D., Silva, E. R. O. da, & Feres, R. J. F. (2010). Influência de *Cecropia pachystachya* na incidência de ácaros (Arachnida, Acari) e de *Leptopharsa heveae* (Insecta, Hemiptera) em cultivo de seringueira. *Revista de Biologia Neotropical*, *7*(2), 49–60.

De Leon, D. (1961). Eight new *Amblyseius* from Mexico with collection notes on two other species (Acarina: Phytoseiidae). *The Florida Entomologist*, *44*, 85–91.

De Leon, D. (1962). Twenty-three new phytoseiids, mostly from southeastern United States. *The Florida Entomologist*, *45*, 11–62.

De Leon, D. (1966). Phytoseiidae of British Guyana with keys to species (Acarina: Mesostigmata). *Studies on the Fauna of Suriname and Other Guyanas*, *8*, 81–192.

De Leon, D. (1967). *Some Mites of the Caribbean Area. Part I. Acarina on Plants in Trinidad, West Indies* (p. 66). Lawrence: Allen Press Inc.

Demite, P. R., & Feres, R. J. F. (2008). Influência de fragmentos de cerrado na distribuiçao de ácaros em seringal. *Neotropical Entomology*, *37*(2), 196–204.

Demite, P. R., Feres, R. J. F., Lofego, A. C., & Oliveira, A. R. (2009). Plant inhabiting mites (Acari) from the Cerrado biome of Mato Grosso State, Brazil. *Zootaxa*, *206*1, 45–60.

Demite, P. R., Lofego, A. C., & Feres, R. J. F. (2007). A new species of *Amblyseius* Berlese (Acari : Phytoseiidae) from Brazil. *Zootaxa*, *68*, 65–68.

Demite, P. R., Lofego, A. C., & Feres, R. J. F. (2008a). A New Species of *Galendromus* (Acari: Phytoseiidae): A Case of Intraspecific Variation and Redefinition of *carinulatus* Species Group. *Annals of the Entomological Society of America*, *278*, 804–807.

Demite, P. R., Lofego, A. C., & Feres, R. J. F. (2008b). Three new species of *Phytoseius* Ribaga (Acari : Phytoseiidae). *Zootaxa*, *26*, 16–26.

Demite, P. R., Lofego, A. C., & Feres, R. J. F. (2011). Phytoseiidae (Acari) in forest fragments in the State of São Paulo, Brazil. *Zootaxa*, *56*, 31–56.

Demite, P. R., Moraes, G. J. de, McMurtry, J. A., Denmark, H. A., & Castilho, R. C. (2014). Phytoseiidae Database. Retrieved May 10, 2014, from www.lea.esalq.usp.br/phytoseiidae

Denmark, H. A., Evans, G. A., Aguilar, H., Vargas, C., & Ochoa, R. (1999). *Phytoseiidae of Central America (Acari: Mesostigmata)* (p. 125). West Bloomfield, Michigan, USA,: Indira Publishing House.

Denmark, H. A., & Muma, M. H. (1970). Some phytoseiid mites of Paraguay (Acarina: Phytoseiidae). *The Florida Entomologist*, *53*, 219–227.

Denmark, H. A., & Muma, M. H. (1972). Some Phytoseiidae of Colombia (Acarina: Phytoseiidae). *The Florida Entomologist*, *55*, 19–29.

Denmark, H. A., & Muma, M. H. (1973). Phytoseiidae mites of Brazil (Acarina, Phytoseiidae). *Revista Brasileira de Biologia*, *33*, 235–276.

Denmark, H. A., & Muma, M. H. (1975). The Phytoseiidae (Acarina: Mesostigmata) of Puerto Rico. *The Journal of Agriculture of the University of Puerto Rico*, *59*, 279–304.

Denmark, H. A., & Muma, M. H. (1989). A revision of the genus *Amblyseius* Berlese, 1914 (Acari: Phytoseiidae). *Occasional Papers of the Florida State Collection of Arthropods*, *4*, 1–149.

Deus, E., Souza., M. S. M., Mineiro, J. L. C., Adaime, R., & Santos, R. S. (2012). Mites (Arachnida: Acari) collected on rubber trees *Hevea brasiliensis* (Willd. ex A.Juss.) Müll.Arg. in Santana, Amapá state, Brazi. *Brazilian Journal of Biology*, *72*, 915–918.

Duso, C., Pozzebon, A., Capuzzo, C., Bisol, P. M., & Otto, S. (2003). Grape downy mildew spread and mite sea-sonal abundance in vineyards: evidence for predatory mites *Amblyseius andersoni* and *Typhlodromus pyri*. *Biological Control*, *27*, 229–241.

Ehrlich, P. R. & Raven, P. H. (1964). Butterflies and Plants: A Study in Coevolution. *Evolution*, 1*8*(4), 586–608.

Faraji, F. (2006). *Arrenoseius* Wainsten and *Metaseiulus* Muma: two new records for the European phytoseiid mite fauna (Acari: Phytoseiidae). *International Journal of Acarology*, *32*, 103–106.

Feres, R. J. F. (2000). Levantamento e observações naturalísticas da acarofauna (Acari, Arachnida) de seringueiras cultivadas (*Hevea* spp., Euphorbiaceae) no Brasil. *Revista Brasileira de Zoologia*, 1*7*(1), 157–173.

Feres, R. J. F. (2001). Primeiro registro de ácaros eriofiídeos (Acari, Eriophyidae) em seringueiras (*Hevea brasiliensis* Muell. Arg., Euphorbiaceae) da Floresta Amazônica, Brasil. *Revista Brasileira de Zoologia*, 1*8*, 343–345.

Feres, R. J. F., Lofego, A. C., & Oliveira, A. R. (2005). Ácaros plantícolas (Acari) da “Estaçao Ecológica do Noroeste Paulista”, Estado de São Paulo, Brasil. *Biota Neotropica*, *5*(17), 1–14.

Feres, R. J. F., & Moraes, G. J. (1998). Phytoseiid mites (Acari: Phytoseiidae) from woody areas in the State of São Paulo, Brazil. *Systematic and Applied Acarology*, *3*, 125–132.

Ferla, N. J., & Moraes, G. J. de. (2002a). Ácaros (Arachnida, Acari) da seringueira (*Hevea brasiliensis* Muell. Arg.) no Estado do Mato Grosso, Brasil. *Revista Brasileira de Zoologia*, 1*9*(3), 867–888.

Ferla, N. J., & Moraes, G. J. de. (2002b). Ácaros predadores (Acari) em plantas nativas e cultivadas do Estado do Rio Grande do Sul, Brasil. *Revista Brasileira de Zoologia,*, 1*9*, 1011–1031.

Ferla, N. J., & Moraes, G. J. de. (2008). Flutuação populacional e sintomas de dano por Ácaros (Acari) em seringueira no Estado do Mato Grosso, Brasil. *Revista Árvore*, *32*(2), 365–376.

Flechtmann, C. H. W. (1979). *Tuckerella ornara* (Tucker), um ácaro novo para o Brasil e outros Tetranychoidea (Acari) do estado do Pará. *Anais Da Escola Superior de Agricultura “ Luiz de Queiroz”*, *36*, 615–620.

Flechtmann, C. H. W., & Arleu, R. J. (1984). *Oligollychus coffeae* (Nietner, 1861), um ácaro tetraniquídeo da seringueira (*Hevea brasiliensis*) novo para o Brasil e observações sobre outros ácaros desta planta. *Ecossistema*, *9*, 123–125.

Gerson, U., Smiley, L. R., & Ochoa, R. (2003). *Mites (Acari) for pest control* (p. 539). Oxford, Oxfordshire, UK: Blackwell Publishing Company.

Gonçalves, P. S., Bataglia, O. C., Ortolani, A. A., & Fonseca, F. S. (2001). Manual de heveicultura para o estado de São Paulo. *Boletim Técnico IAC*, 1*89*, 77p.

Gonçalves, P. S., & Marques, J. R. B. (2008). Melhoramento genético da seringueira: passado, presente e futuro. In *Seringueira* (pp. 399–498). Viçosa, MG: EPAMIG - Viçosa.

Gondim Jr, M. G. C., & Moraes, G. J. de. (2001). Phytoseiidae mites (Acari: Phytoseiidae) asociated with palm trees (Arecaceae) in Brazil. *Systematic and Applied Acarology*, *6*, 65–94.

Gondim Jr., M. G. C., Castro, T. M. M. G., Marsaro Jr, A. L., Navia, D., Melo, J. W. S., Demite, P. R., & Moraes, G. J. de. (2012). Can the red palm mite threaten the Amazon vegetation? *Systematics and Biodiversity*, *10*(4), 527–535.

Gondim, M. G. C., Moraes, G. J. de, & Mcmurtry, J. A. (2000). A New Species of *Cocoseius* (Acari : Phytoseiidae) from Brazil and Redefinition of the Genus. *Annals of the Entomological Society of America*, *45*(25ð 29), 1226–1229.

Guanilo, A. D., Moraes, G. J. de, & Knapp, M. (2008a). Phytoseiid mites (Acari: Phytoseiidae) of the subfamily Amblyseiinae Muma from Peru, with description of four new species. *Zootaxa*, 1*880*, 1–47.

Guanilo, A. D., Moraes, G. J. de, & Knapp, M. (2008b). Phytoseiid mites (Acari: Phytoseiidae) of the subfamilies Phytoseiinae Berlese and Typhlodrominae Wainstein from Peru, with descriptions of two new species. *Zootaxa*, 1*729*, 42–60.

Guanilo, A. D., Moraes, G. J. de, Toledo, S., & Knapp, M. (2008). Phytoseiid mites (Acari: Phytoseiidae) from Argentina, with description of two new species. *Zootaxa*, *35*, 1–35.

Hernandes, F. A., & Feres. (2006). Review about mites (Acari) of rubber trees (*Hevea* spp., Euphorbiaceae) in Brazil. *Biota Neotropica*, *6*(1). Retrieved from http://www.biotaneotropica.org.br/v6n1/pt/ abstract?article+bn00406012006

Kogan, M. (1998). Integrated pest management: historical perspectives and contemporary developments. *Annual Review of Entomology*, *43*, 243–270.

Krantz, W., & Walter, D. E. (2009). *A manual of Acarology* (Third Edit., p. 807). Lubbock, Texas, TX, Tech University Press.

Kreiter, S., & Moraes, G. J. de. (1997). Phytoseiid mites (Acari: Phytoseiidae) from Guadeloupe and Martinique. *Florida Entomologist*, *80*, 376–382.

Kreiter, S., Tixier, M.-S., & Bourgeois, T. (2003). Do generalist Phytoseiid mites (Gamasida: Phytoseiidae) have interactions with their host plants? *Insect Science and its Application*, *23*(1), 35–50.

Kremen, C., Colwell, R. K., Erwin, T. L., Murphy, D. D., Noss, R. F., & Sanjayan, M. A. (1993). Terrestrial Arthropod Assemblages: Their Use in Conservation Planning. *Conservation Biology*, *7*(4), 796–808.

Laurance, W. F., Cochrane, M. A., Bergen, S., Fearnside, P. M., Delamônica, P., Barber, C., … Fernandes, T. (2001). The Future of the Brazilian Amazon. *Science*, *29*1(5503), 438–439.

Lawson-Balagbo, L. M., Gondim, M. G. C., de Moraes, G. J., Hanna, R., & Schausberger, P. (2008). Exploration of the acarine fauna on coconut palm in Brazil with emphasis on *Aceria guerreronis* (Acari: Eriophyidae) and its natural enemies. *Bulletin of Entomological Research*, *98*(1), 83–96. doi:10.1017/S0007485307005421

Lofego, A. C., & de Moraes, G. J. (2006). Ácaros (Acari) Associados a Mirtáceas (Myrtaceae) em Áreas de Cerrado no Estado de São Paulo com Análise Faunística das Famílias Phytoseiidae e Tarsonemidae. *Neotropical Entomology*, *35*(6), 731–746.

Lofego, A. C., Demite, P. R., & Feres, R. J. F. (2011a). Two new species of phytoseiid mites (Acari: Phytoseiidae) from the State of São Paulo, Brazil. *Journal of Natural History*, *45*(37-38), 2347–2354. doi:10.1080/00222933.2011.596950

Lofego, A. C., Demite, P. R., & Feres, R. J. F. (2011b). Two new species of *Typhlodromips* (Acari: Phytoseiidae) from Brazil. *International Journal of Acarology*, *37*(2), 110–115. doi:10.1080/01647954.2010.502905

Lofego, A. C., Demite, P. R., Kishimoto, R. G., & Moraes, G. J. de. (2009). Phytoseiid mites on grasses in Brazil (Acari: Phytoseiidae). *Zootaxa*, *2240*, 41–59.

Lofego, A. C., & Feres, R. J. F. (2006). A new species of *Typhlodromus* Scheuten (Acari: Phytoseiidae) from Brazil. *Zootaxa*, *28*, 25–28.

Lofego, A. C., & Moraes, G. J. de. (2003). Two new species of *Neoseiulus* Hughes (Acari: Phytoseiidae) from Brazil. *International Journal of Acarology*, *29*, 113–117.

Lofego, A. C., Moraes, G. J. de, & Castro, L. A. S. (2004). Phytoseiid mites (Acari: Phytoseiidae) on Myrtaceae in the State of São Paulo, Brazil. *Zootaxa*, *516*, 1–18.

Lofego, A. C., Rezende, J. M., Verona, R. L. C., & Feres, R. J. F. (2013). Mites (Acari) associated with three species of the genus *Jatropha* (Euphorbiaceae) in Brazil, with emphasis on *Jatropha curcas*. *Systematic and Applied Acarology*, *18*(4), 411–423.

McMurtry, J. A. (1983). Phytoseiid mites from Guatemala, with description of two new species and redefinition of the genera *Euseius*, *Typhlodromus* and the *Typhlodromus occidentalis* species group (Acari: Mesostigmata). *International Journal of Acarology*, *25*, 249–272.

Mcmurtry, J. A., & Croft, B. A. (1997). Life-styles of phytoseiid mites and their role in biological control. *Annual*, *42*, 291–321.

McMurtry, J. A., & de Moraes, G. J. (1989). Some phytoseiid mites from Peru with descriptions of four new species (Acari: Phytoseiidae). *International Journal of Acarology*, *15*, 179–188.

McMurtry, J. A., Moraes, G. J. de, & Sourassou, N. F. (2013). Revision of the lifestyles of phytoseiid mites (Acari: Phytoseiidae). *Systematic and Applied Acarology*, 1*8*(4), 297–320.

Mineiro, J. L. C., Raga, A., Sato, M. E., & Lofego, A. C. (2009). Ácaros associados ao cafeeiro (*Coffea* spp.) no estado de São Paulo, Brasil. Parte I . Mesostigmata. *Biota Neotropica*, *9*(1), 0–10.

Mineiro, J. L. de C., Castro, T. M. M. G. de, & Moraes, G. J. de. (2011). Description of a new species and complementary description of a known species of *Iphiseiodes* De Leon (Acari: Phytoseiidae). *Zootaxa*, *34*(May), 30–34.

Mineiro, J. L. de C., Silva, W. R. da, & Silva, R. A. da. (2009). Ácaros em fruteiras e outras plantas no Estado de Amapá Ácaros. *Biota Neotropica*, *9*(2), 103–106.

Moraes, G. J. De, Kreiter, S., & Lofego, A. C. (2000). Plant mites (Acari) of the French Antilles. 3. Phytoseiidae (Gamasida). *Acarologia*, *40*, 237–264.

Moraes, G. J. de, & McMurtry, J. A. (1983). Phytoseiid mites (Acarina) of northeastern Brazil with descriptions of four new species. *International Journal of Acarology*, *9*, 131–148.

Moraes, G. J. de, McMurtry, J. A., & Denmark, H. A. (1986). *A Catalog of the Mite Family Phytoseiidae: References to Taxonomy, Synonym, Distribution and Habitat* (p. 356 pp). Brasilia: Embrapa-DDT.

Moraes, G. J. de, & Mesa, N. C. (1988). Mites of the family Phytoseiidae (Acari) in Colombia, with descriptions of three new species. *International Journal of Acarology*, 1*4*, 71–88.

Moraes, G. J. de, Mesa, N. C., & Braun, A. (1991). Some phytoseiid mites of Latin America (Acari: Phytoseiidae). *Journal of Acarology*, 1*7*, 117–139.

Moraes, G. J. de, Zannou, I. D., Oliveira, A. R., Yaninek, J. S., & Hanna, R. (2006). Phytoseiid mites of the subtribes Typhlodromalina and Euseiina (Acari: Phytoseiidae: Euseiini) from sub-Saharan Africa. *Zootaxa*, *52*, 1–52.

Moraes, G. J., Barbosa, M. F. C., & Castro, T. M. M. G. (2013). Phytoseiidae (Acari: Mesostigmata) from natural ecosystems in the State of São Paulo, Brazil. *Zootaxa*, *3700*(3), 301–347.

Moraes, G. J. D. E., Zannou, I. D., Ueckermann, E. A., Oliveira, A. R., Hanna, R., & Yaninek, J. S. (2007). Species of the subtribes Arrenoseiina and Proprioseiopsina (Tribe Amblyseiini) and the tribe Typhlodromipsini (Acari: Phytoseiidae) from sub-Saharan Africa. *Zootaxa*, *39*, 1–39.

Moraes, G. J., McMurtry, J. A., Denmark, H. A., & Campos, B. C. (2004). A revised catalog of the mite family Phytoseiidae. *Zootaxa*, *434*, 1–494.

Muma, M. H. (1961). Subfamilies, genera, and species of Phytoseiidae (Acarina: Mesostigmata). *Bulletin of the Florida State Museum, Biological Science*, *5*, 267–302.

Muma, M. H. (1963). The genus *Galendromus* Muma, 1961 (Acarina: Phytoseiidae). *Florida Entomologist, Suppl.*, 1, 15–41.

Muma, M. H., Denmark, H. A., & De Leon, D. (1970). Phytoseiidae of Florida. In *Arthropods of Florida and neighboring land areas, 6* (p. 150 pp.). Gainesville: Florida Department of Agriculture and Consumer Services, Division of Plant Industry.

Navia, D., Moraes, G. J. de, Lofego, A. C., & Flechtmann, C. H. W. (2005). Acarofauna Associada a Frutos de Coqueiro (*Cocos nucifera* L .) de Algumas Localidades das Américas. *Neotropical Entomology*, *34*(2), 349–354.

Nomikou, M., Sabelis, M. W., & Janssen, A. (2010). Pollen subsidies promote whitefly control through the numerical response of predatory mites. *BioControl*, *55*, 253–260.

Pires, J. M., Secco, R. de S., & Gomes, J. I. (2002). *Taxonomia e fitogeografia das seringueiras (Hevea spp.)* (p. 103). Belém: Embrapa Amazônia Oriental.

Pritchard, A. E., & Baker, E. W. (1962). Mites of the family Phytoseiidae from Central Africa, with remarks on genera of the world. *Hilgardia*, *33*, 205–309.

Rangel, T. (2012). Amazonian Extinction Debts. *Science*, 1*62*, 1–3. doi:10.1126/science.1224819

Rezende, J. M., & Lofego, A. C. (2011). Phytoseiidae (Acari: Mesostigmata) on plants of the central region of the Brazilian Cerrado. *Acarologia*, *5*1(4), 449–463. doi:10.1051/acarologia/20112027

Rezende, J. M., & Lofego, A. C. (2012). Mites (Mesostigmata, Prostigmata, Astigmatina) associated with weeds among physic nut crops (*Jatropha curcas* L.: Euphorbiaceae) in Brazil. *Systematic and Applied Acarology*, 1*7*(1), 15–26. doi:10.11158/saa.17.1.5

Rezende, J. M., Lofego, A. C., Navia, D., & Roggia, S. (2012). Mites (Acari: Mesostigmata, Sarcoptiformes and Trombidiformes) associated to soybean in Brazil, including new records from the Cerrado areas. *Florida Entomologist*, *95*, 683–693. Retrieved from http://journals.fcla.edu/flaent/article/view/80384

Rowell, H. J., Chant, D. A., & Hansell, R. I. C. (1978). The determination of setal homologies and setal patterns on the dorsal shield in the family Phytoseiidae (Acarina: Mesostigmata). *The Canadian Entomologist*, 11*0*, 859–876.

Sabelis, M. W., & Van Rijn, P. C. J. (1997). Predation by insects and mites. In T. Lewis (Ed.), *Thrips as crop pests* (pp. 259–354). UK: CAB-International.

Secco, R. de S. (2008). A Botânica da seringueira [*Hevea brasiliensis* (Willd. ex Adr. Jussieu) Muell. Arg (Euphorbiaceae)]. In A. de P. Alvarenga & C. A. F. de S. do Carmo (Eds.), *Seringueira* (pp. 1–24). Viçosa, MG: EPAMIG - Viçosa.

Shultes, R. E. (1987). Studies in the *Hevea*. VIII. Notes on infrespecific variants on *Hevea brasiliensis* (Euphorbiacea). *Economic Botany*, *4*1, 125–147.

Silva, E. A., Reis, P. R., Zacarias, M. S., & Marafeli, P. P. (2010). Fitoseídeos (Acari: Phytoseiidae) associados a cafezais e fragmentos florestais vizinhos. *Ciência Agronômica*, *34*(5), 1146–1153.

Silva, G. L., Rocha, M. dos S., & Ferla, N. J. (2013). First new species of the *Phytoseius horridus* group (Acari: Phytoseiidae) described from Brazil, with a key to the Brazilian species of *Phytoseius. Zootaxa*, *368*1, 595–599.

Van Lenteren, J. C. (2000). Success in Biological Control of Arthropods by Augmentation of Natural Enemies. In G. Gurr & S. Wratten (Eds.), *Biological Control: Measures of Success* (pp. 77–103). Springer Netherlands.

Vasconcelos, D. E., Silva, F. R., Barbosa, D. G. F., Gondim Jr., M. G. C., & Moraes, G. J. de. (2006). Diversidade de fitoseídeos (Acari: Phytoseiidae) em fruteiras tropicais no Estado de Pernambuco, Brasil. *Magistra*, 1*8*, 90–101.

Yaninek, J. S., Megevand, B., Ojo, B., Cudjoe, A. R., Abole, E., A., O. &, & Zannou, I. (1998). Establishment and spread of *Typhlodromalus manihoti* (Acari: Phytoseiidae), an introduced predator of *Mononychellus tanajoa* (Acari: Tetranychidae) on cassava in Africa. *Environmental Entomology*, *27*, 1496–1505.

Yoshida-Shaul, E., & Chant, D. (1997). A world review of the genus *Phytoscutus* Muma (Phytoseiidae: Acari). *Acarologia*, *38*, 219–238.

Zacarias, M. S., & Moraes, G. J. de. (2001). Phytoseiid Mites (Acari) Associated With Rubber Trees And Other Euphorbiaceous Plants In Southeastern Brazil. *Neotropical Entomology*, *30*, 579–586.

Zacarias, M. S., & Moraes, G. J. de. (2002). Mite diversity (Arthropoda: Acari) on euphorbiaceous plants in the State of São Paulo. *Biota Neotropica*, *2*, 1–12. Retrieved from http://www.biotaneotropica.org.br/v2n2/pt/abstract?article+BN00802022002

Zacarias, M. S., Moraes, G. J. de, & McMurtry, J. A. (2002). A new species of *Galendromimus* (Acari: Phytoseiidae) from Brazil. *Zootaxa*, 1*02*, 1–6.

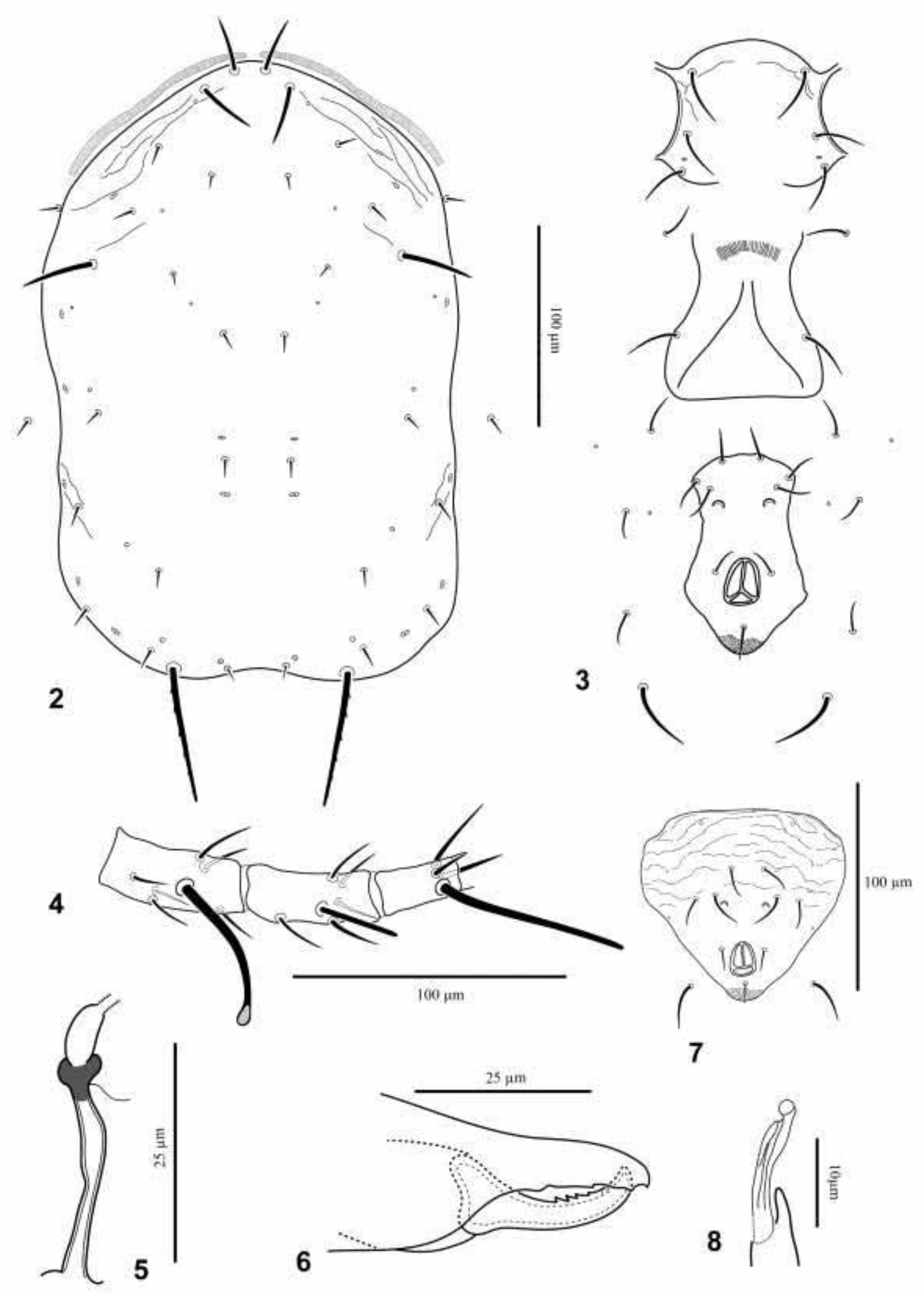
Table 1. Species of Phytoseiidae and their abundance recorded on *Hevea* spp. from Amazon Forest

Species	AM	AM	AM	AM	AM	AC	AC	AC	AC	RO	**Total**
	Site 1	Site 2	Site3a	Site3b	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	
Amblydromalus akiri **sp. nov.**	0	0	0	0	0	11	0	1	10	0	**22**
Amblydromalus manihoti	4	28	1	0	0	0	0	0	3	0	**36**
Amblydromalus villacarmelensis	0	0	0	0	0	0	0	1	4	0	**5**
Amblyseius aerialis	1	0	14	0	0	0	4	7	0	38	**64**
Amblyseius chiapensis	1	0	0	0	0	7	0	0	0	0	**8**
Amblyseius chicomendesi **sp. nov.**	0	0	0	0	0	5	80	0	7	0	**92**
Amblyseius duckei **sp. nov.**	0	5	0	0	0	0	1	0	0	0	**6**
Amblyseius martus	2	0	0	0	0	9	15	3	15	0	**44**
Amblyseius manauara **sp. nov.**	22	0	0	0	0	0	0	0	0	0	**22**
Amblyseius perditus	12	0	0	0	0	0	0	0	0	0	**12**
Arrenoseius morgani	1	3	0	0	0	0	0	0	6	0	**10**
Euseius alatus	0	1	1	0	0	5	19	21	8	636	**691**
Euseius concordis	0	0	3	0	0	1	2	13	2	0	**21**
Iphiseiodes kamahorae	2	0	0	0	0	0	0	0	0	0	**2**
Iphiseiodes katukina **sp.nov**.	9	0	0	0	0	0	0	0	3	0	**12**
Iphiseiodes raucuara **sp. nov.**	0	0	0	0	0	0	0	0	3	0	**3**
Iphiseiodes zuluagai	0	0	3	0	17	0	0	2	0	23	**45**
Neoseiulus idaeus	0	0	0	0	0	0	0	0	0	1	**1**
Paraamblyseius multicircularis	1	0	0	0	0	0	0	1	0	0	**2**
Paraphytoseius orientalis	0	0	0	0	0	1	7	0	1	0	**9**
Phytoscutus sexpilis	0	0	0	0	8	0	0	0	0	1	**9**
Proprioseiopsis dominigos	2	0	0	0	0	0	0	0	0	0	**2**
Proprioseiopsis neotropicus	0	1	0	0	0	0	0	0	0	0	**1**
Proprioseiopsis mexicanus	0	0	0	0	0	0	0	0	0	2	**2**
Typhlodromalus peregrinus	0	0	0	0	0	0	0	0	1	0	**1**
Typhlodromips igapo **sp. nov.**	0	0	5	0	0	2	0	0	3	0	**10**
Galendromus annectens	0	0	0	0	0	0	0	1	0	20	**21**
Leonseius regularis	0	0	0	0	0	2	0	0	0	0	**2**
Metaseiulus adjacentis	0	0	1	2	0	0	0	0	0	0	**3**
Imatures	18	2	1	0	0	20	51	20	35	0	**147**
Total	**75**	**40**	**29**	**2**	**25**	**63**	**179**	**70**	**101**	**721**	**1305**

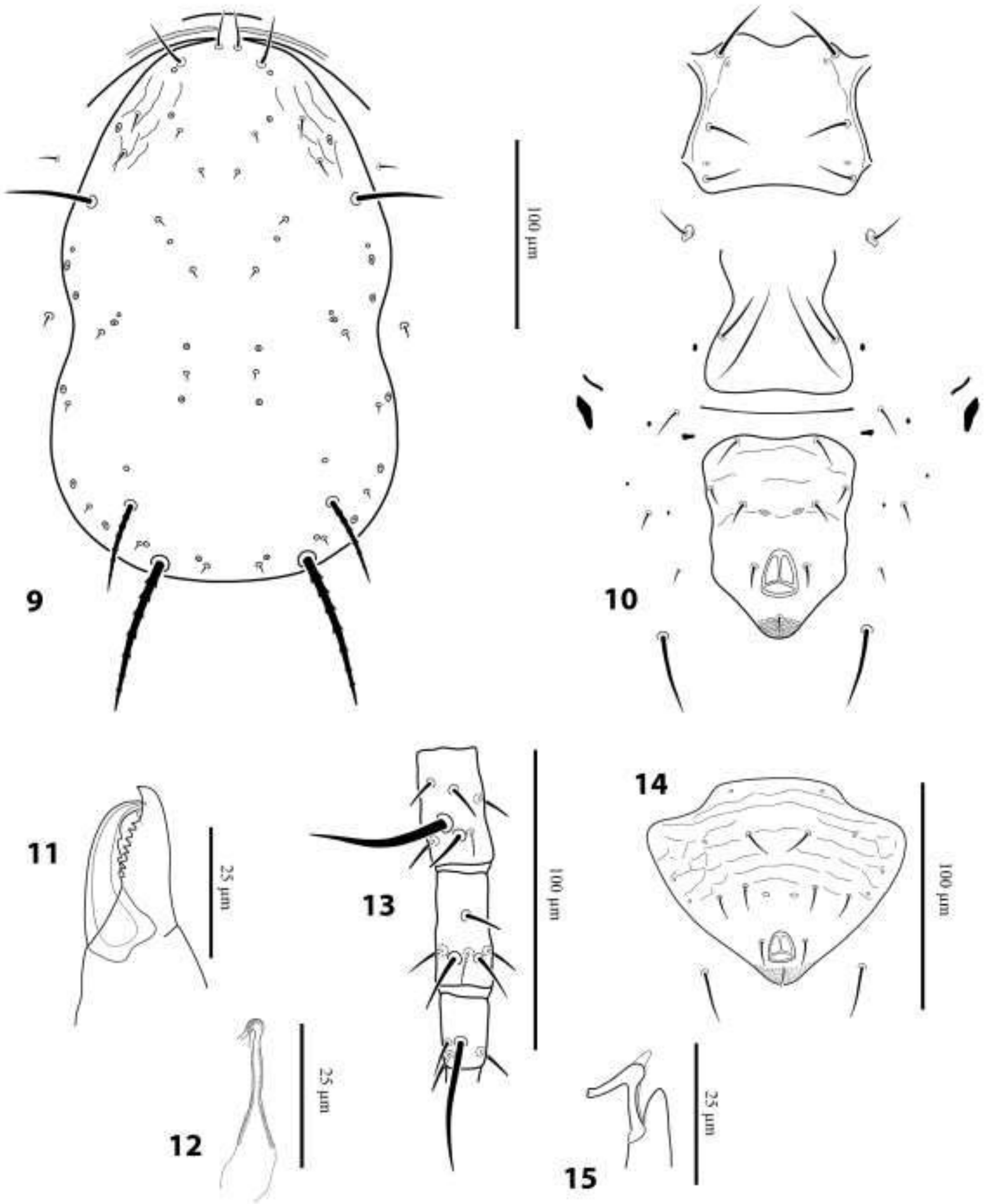
*(AM) Amazonas State, (AC) Acre State, (RO) Rondônia states; northern region of Brazil.

Fig. 1. Location of the sampling sites on the Brazilian Amazon Biome (dark grey), indicated by the letters: **a)** State of Amazonas, including sites 1, 2, 3a, 3b, 4; **b)** State of Acre, including the sites 5, 6, 7, 8; **c)** State of Rondônia, including the site 9.

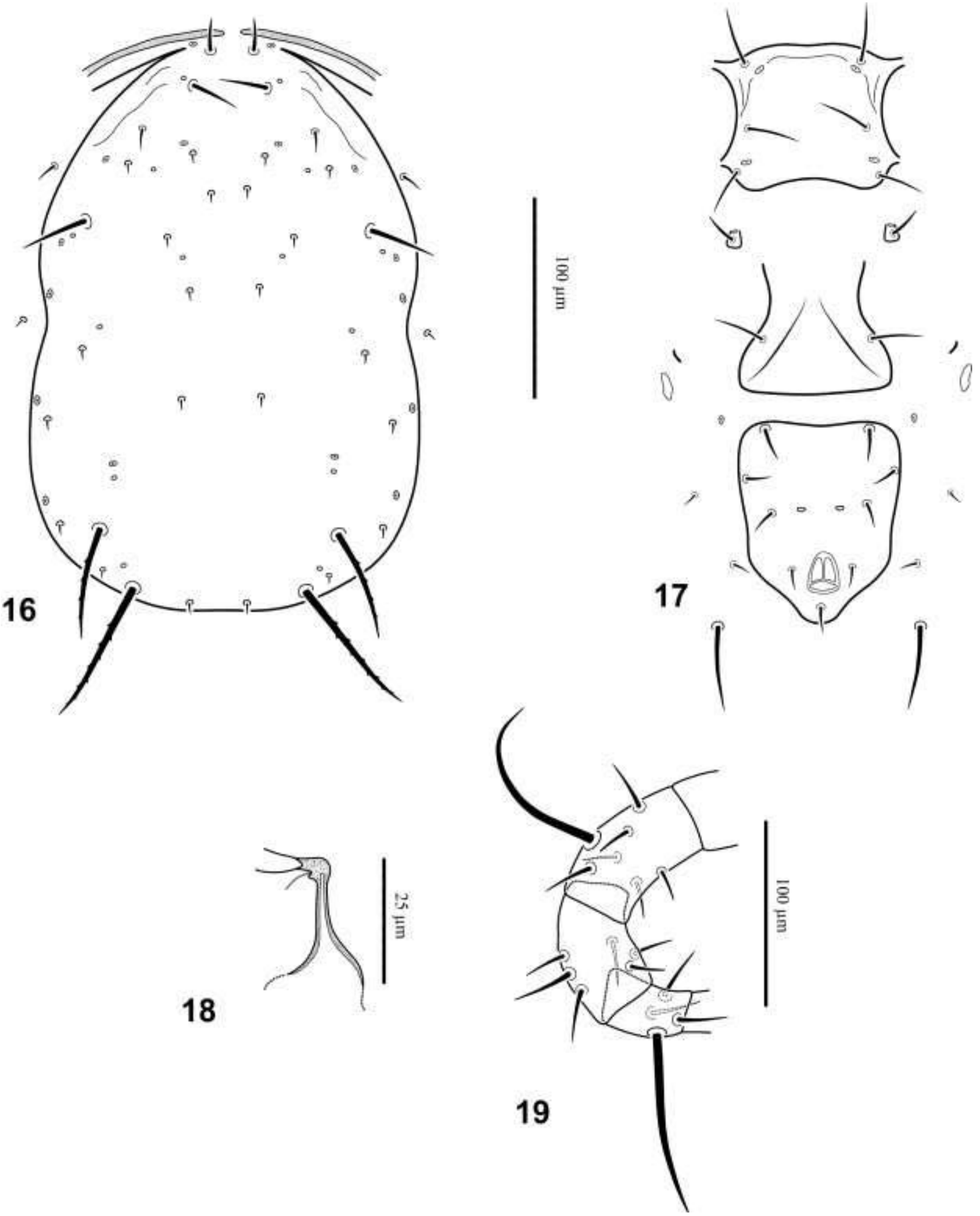
**Hevea brasiliensis* was sampled on the sites 1, 3b, 4, 5, 7, 9; *Hevea guianensis* on the site 2; *Hevea mycrophilla* on the site 3a; *Hevea spruceana* on the site 6; *Hevea pauciflora* on the site 8.



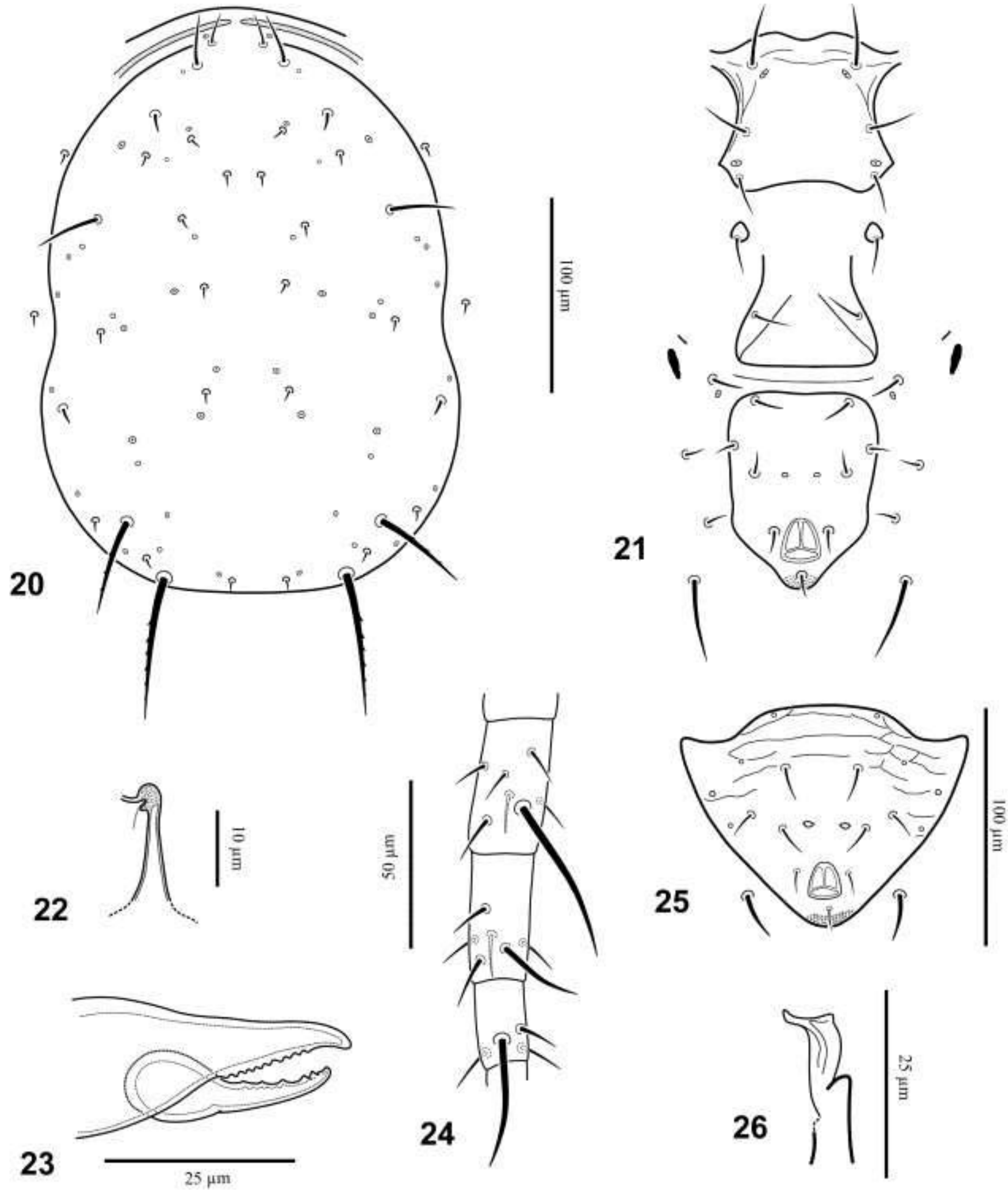
Figs. 2–8. *Amblydromalus akiri* n.sp. Female: 2. Dorsal idiosoma, 3. Ventral idiosoma, 4. Genu, tibia and tarsus of leg IV, 5. Spermatheca, 6. Chelicera. Male: 7. Ventrianal shield, 8. Spermatodactyl.



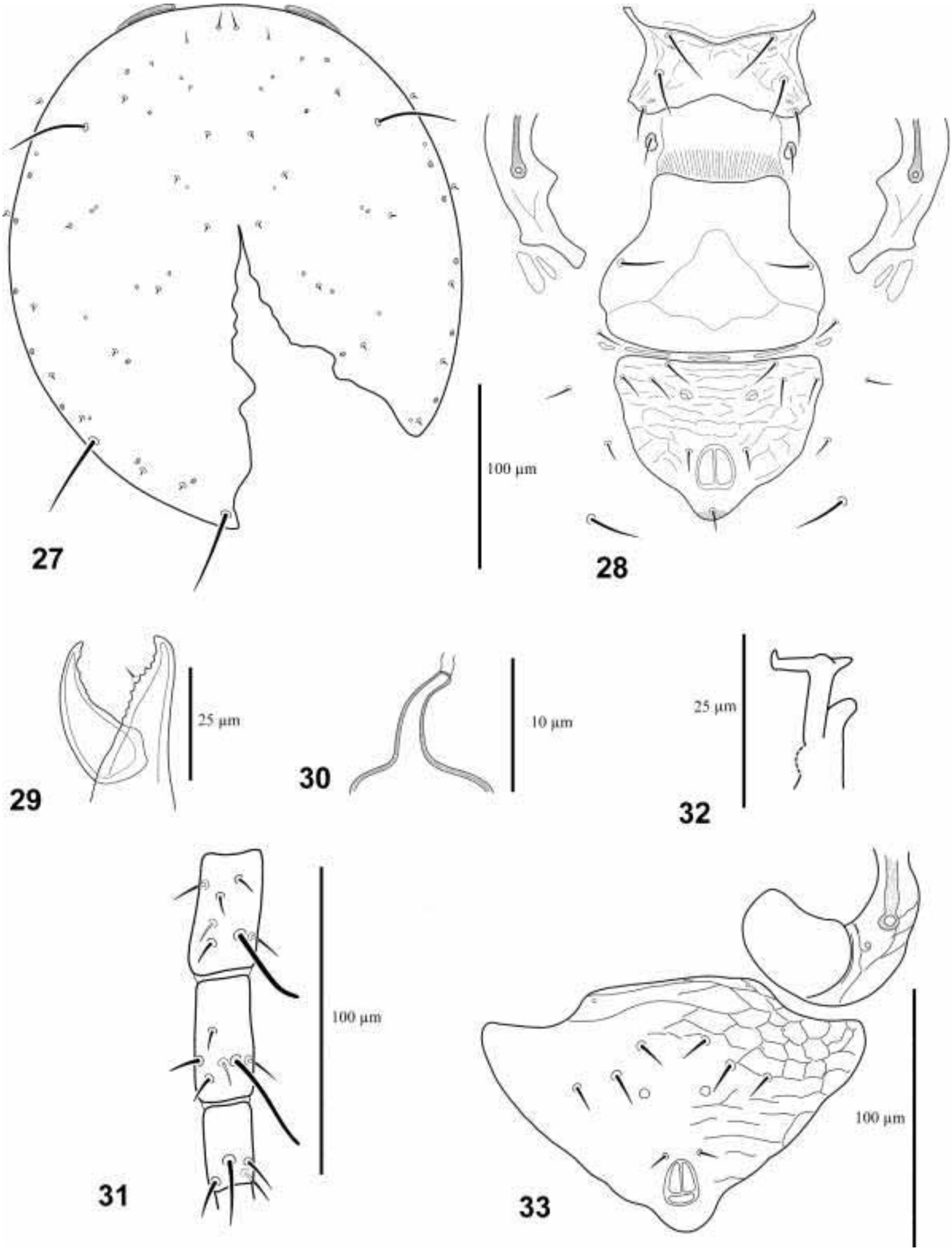
Figs. 9 –15. *Amblyseius chicomendesi* n.sp. Female: 9. Dorsal idiosoma, 10. Ventral idiosoma, 11. Chelicera, 12. Spermatheca, 13. Genu, tibia and tarsus of leg IV. Male: 14. Ventrianal shield, 15. Spermatodactyl.



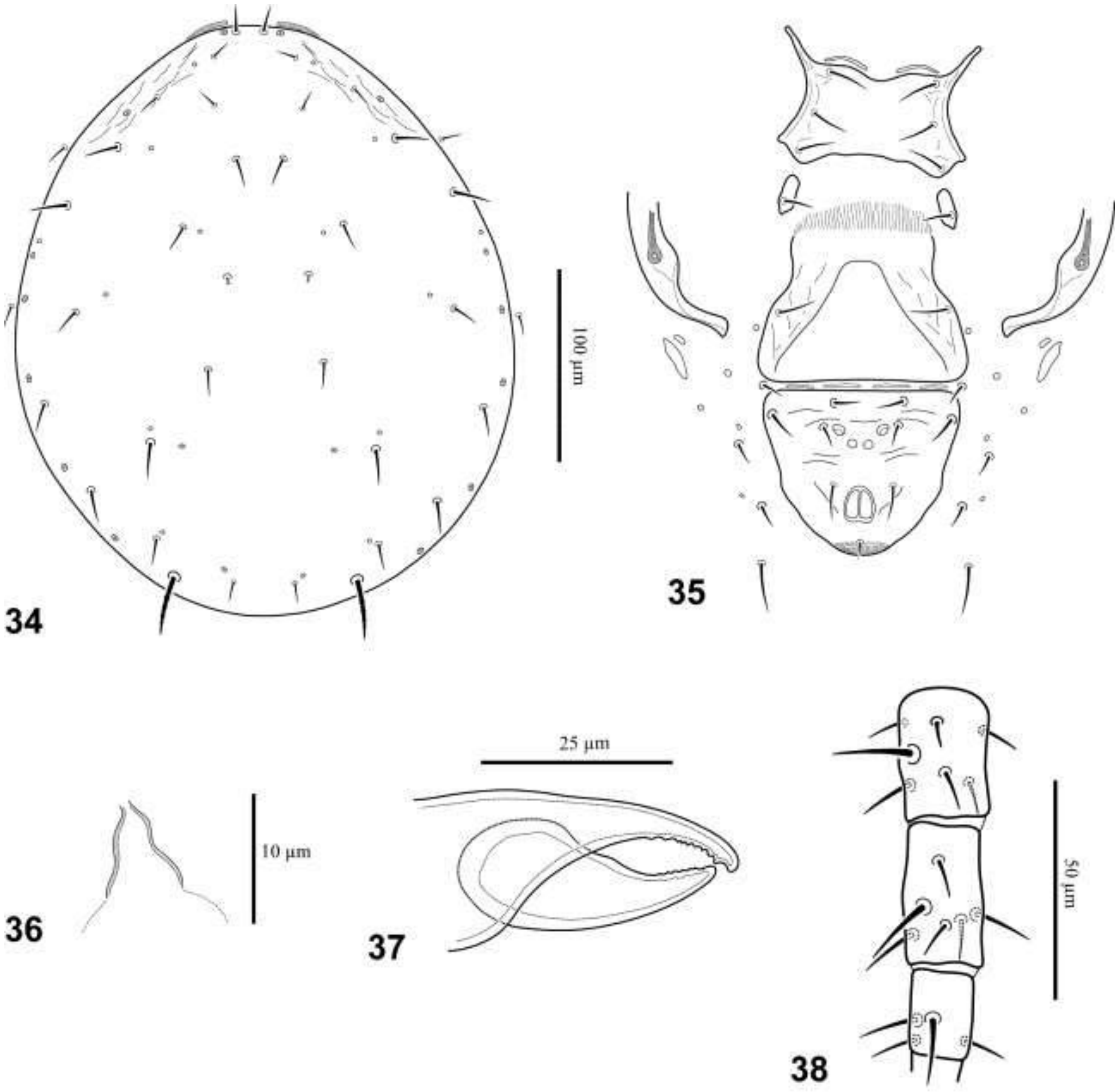
Figs. 16–19. *Amblyseius duckei* n.sp. Female: 16. Dorsal idiosoma, 17. Ventral idiosoma, 18. Spermatheca, 19. Genu, tibia and tarsus of leg IV.



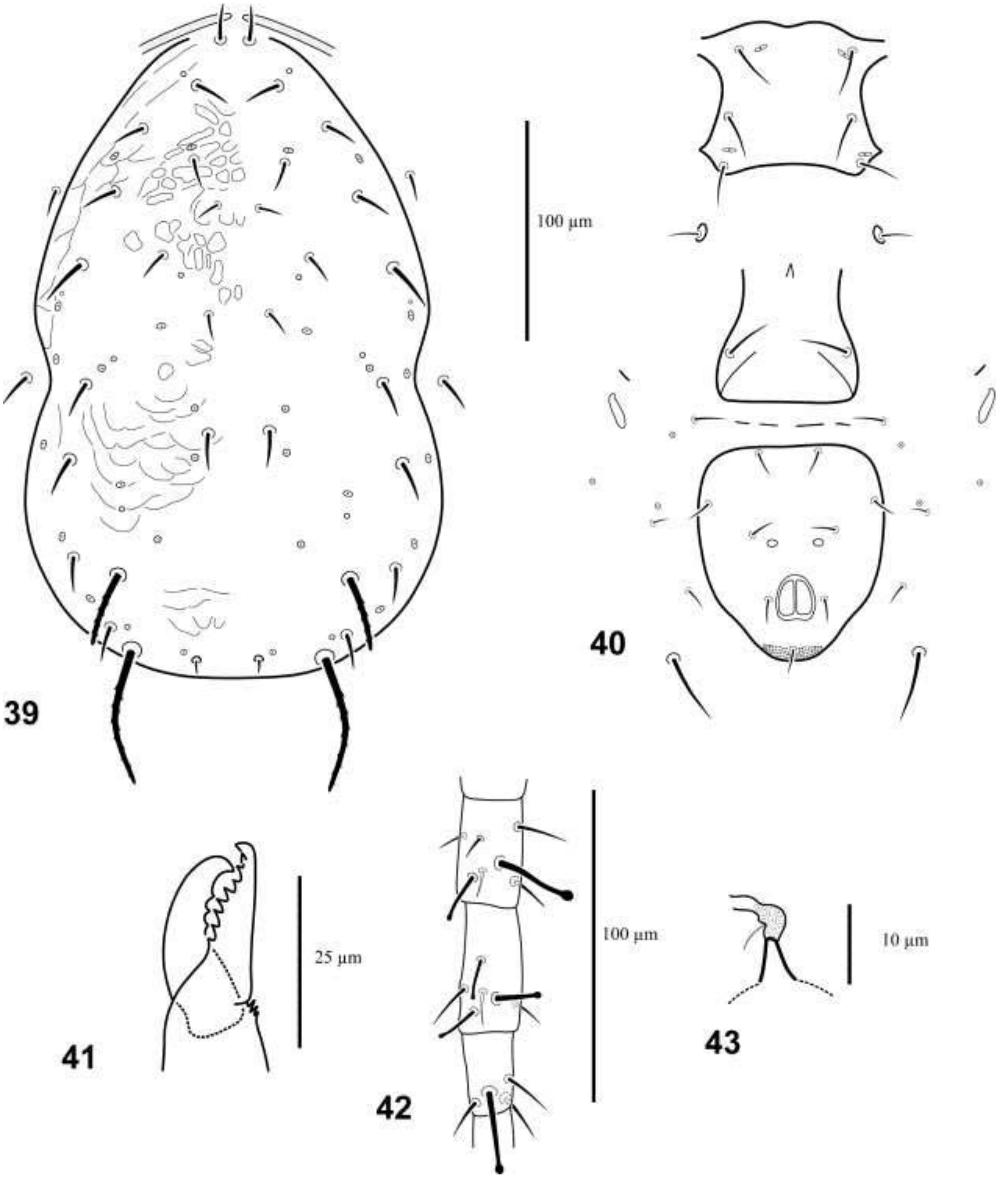
Figs. 20–26. *Amblyseius manauara* n.sp. Female: 20. Dorsal idiosoma, 21. Ventral idiosoma, 22. Spermatheca, 23. Chelicera, 24. Genu, tibia and tarsus of leg IV. Male: 25. Ventrianal shield, 26. Spermatodactyl.



Figs. 27–33. *Iphiseiodes katukina* n.sp. Female: 27. Dorsal idiosoma, 28. Ventral idiosoma, 29. Chelicera, 30. Spermatheca, 31. Genu, tibia and tarsus of leg IV. Male: 32. Spermatodactyl, 33 Ventrianal shield.



Figs. 34–38. *Iphiseiodes raucuara* n.sp. Female: 34. Dorsal idiosoma, 35. Ventral idiosoma, 36. Spermatheca, 37. Chelicera, 38. Genu, tibia and tarsus of leg IV.



Figs. 39–43. *Typhlodromips igapo* n.sp. Female: 39. Dorsal idiosoma, 40. Ventral idiosoma, 41. Chelicera, 42. Genu, tibia and tarsus of leg IV, 43. Spermatheca.

Capítulo III

Phytoseiidae (Acari: Mesostigmata) from rubber tree crops in the State of Bahia, Brazil, with description of two new species

Felipe M. Nuvoloni, Antonio C. Lofego, Elizeu B. Castro, Reinaldo J. F. Feres

Manuscript Submitted to Zootaxa

Status: in review

Abstract

The current study describes the results of a Phytoseiidae mites survey performed on a rubber plantation in the State of Bahia, Brazil. We present 22 species, two of which are new, *Amblydromalus insolitus* **n. sp.** Nuvoloni & Lofego, and *Typhlodromips paramilus* **n. sp.** Nuvoloni & Lofego, besides three new records for this host. The composition of species was more related with the records of the northern Brazilian Region, than with that of Southeastern and Midwestern.

Keywords: *Amblydromalus insolitus*, Amblyseiinae, Typhlodrominae, *Hevea brasiliensis*, predators, taxonomy, *Typhlodromips paramilus*.

Introduction

Phytoseiidae mites are commonly reported occurring on rubber tree (*Hevea brasiliensis* Muell. Arg, Euphorbiaceae) throughout Brazil (Daud & Feres, 2014; Demite & Feres, 2007; Deus *et al*., 2012; Ferla & Moraes, 2002a; Hernandes & Feres, 2006a; Nuvoloni *et al*., 2014), and may have an important part on the biological control of phytophagous species (Gerson *et al*., 2003). The state of Bahia is the third largest latex producer in Brazil, with more than 20% of national production (IBGE, 2008). Despite of its importance, no study on diversity of mites on rubber trees has been conducted in that state.

According to the Phytoseiidae Database (Demite *et al*., 2014) more than 190 valid phytoseiid species were reported occurring on Brazil, from which 53 were already recorded on the Bahia State. More than 50 species were recorded on rubber trees in Brazil although the state of Bahia still remains uncovered (Demite *et al.* 2014). In a recent paper, Nuvoloni *et al.* (2014) described seven new species, and highlighted the importance of rubber trees harboring a huge diversity of phytoseiid species on Amazon forest and rubber plantations on the northern of Brazil.

In the present study we list the phytoseiid species recorded on the one-year survey carried out on rubber tree plantations in the State of Bahia, with the description of new species of *Typhlodromips* and *Amblydromalus*.

Material and methods

The samplings were carried out on a rubber tree plantation (“Plantações Michelin da Bahia ltda”), on the clones PMB 01, FDR 5788, CDC 312, FX 3864 and MDF 180, during April 2008 to April 2009. The study area consists in a 5,000 ha of rubber crop surrounded by fragments of native vegetation of coastal Atlantic Rainforest (13° 48' S, 39° 10' W), in Igrapiúna, Bahia, northeastern Brazil. Some plantations border other Atlantic Rainforest plots, where the native vegetation encroaches on the edges of the plantations, and none of the management practices are applied.

All the samples were taken to “Departamento de Pesquisa e Desenvolvimento Michelin” where the leaves were examined under stereoscopic microscope (40 x) and the mites mounted on microscope slides with Hoyer’s medium (Krantz & Walter, 2009). The type and voucher specimens are deposited in the Acari collection (DZSJRP), Department of Zoology and Botany, Universidade Estadual Paulista (UNESP), São José do Rio Preto, São Paulo, available at: http://www.splink.cria.org.br.

Under the heading “Specimens examined”, we list the scientific name of the host plant and the clone of the rubber trees, the collection date, and number of mite specimens collected in parentheses. For nominal species we listed the reference of original description, followed by a summary of previous occurrence in Brazil. For new species all measurements were given in micrometers (μm); each measurement corresponds to the holotype measurements, followed (in parentheses) by the respective range of the specimens examined, if the measurement was variable. The systems of setal notation for the dorsum and venter follow Rowell *et al.* (1978) and Chant & Yoshida-Shaul (1991), respectively. Macrosetal notation (Sge, genual macroseta; Sti, tibial macroseta; St, tarsal macroseta) is that of Muma *et al.* (1970). Chaetotaxy formula follows (Krantz & Walter 2009).

Results

We have performed the first survey on phytoseiid mites on rubber trees on northeastern region of Brazil. We found a total of 1,473 mites, from 22 species and 15 genera of Amblyseiinae Muma, 1961 and Typhlodrominae Scheuten, 1857, subfamilies (Table 1), from which *Amblydromalus insolitus* **n. sp.**, and *Typhlodromips paramilus* **n. sp.** are new to science.

Leonseius regularis (De Leon, 1965), *Amblyseius perditus* Chant & Baker, 1965 and *Euseius alatus* De Leon, 1966 were the most abundant species. On the other hand, six species were rare with one single occurrence during all the survey (Table 1), *Amblyseius herbicolus* (Chant, 1959), *Arrenoseius morgani* (Chant, 1957), *Iphiseiodes metapodalis* (El-Banhawy, 1984), *Neoseiulus tunus* (De Leon, 1967), *Ricoseius loxocheles* Denmark and Muma 1970, and *Proprioseiopsis dominigos* (El-Banhawy, 1984). *Typhlodromina subtropica* Muma & Denmark, 1969, *Typhlodromips constrictatus* (El-Banhawy, 1984), and *Ricoseius loxocheles* were new registers for *H. brasiliensis* in Brazil.

Interestingly, the most abundant species were not listed in the rubber trees inventories for Brazilian southeastern and middlewest areas, except for of *E. alatus,* (Ferla & Moraes, 2002a; Zacarias & Moraes, 2001, 2002). *Euseius alatus* was far to be abundant on those surveys, being replaced by *Euseius citrifolius* Denmark and Muma, 1970, and *Euseius concordis* (Chant, 1959), as the most frequent species of *Euseius* on southeastern and Middle West rubber crops. In general, the species composition was 30% similar with those listed for Mato Grosso and São Paulo states, whereas more than 50% of the phytoseiids were similar with those from rubber trees of Amazon forest (Nuvoloni *et al*., 2014).

SUBFAMILY AMBLYSEIINAE MUMA, 1961

Amblydromalus insolitus Nuvoloni & Lofego n. sp.

(Figs 1–7)

Diagnosis: This new species belongs to *limonicus* species group, but is remarkable different from all *Amblydromalus* spp. due to the dorsal shield being covered mainly by roundish ornamentation, with anterolateral striae. The ornamentation is quite distinct on the median region, becoming more discrete posteriad to J2, and toward the shield border.

Specimens examined*.* Holotype and one paratype females collected from *H. brasiliensis,* clone FDR 5788, from Igrapiúna, Bahia, Brazil, (13° 48' S, 39° 10' W) August 08, 2012, E.B. Castro coll.; five females and two males paratypes collected from *H. brasiliensis*, clone PMB 01, August 08, 2012, E.B. Castro coll. All specimens are deposited at DZSJRP.

Etymology: The specific name *insolitus* refers to the unusual ornamentation pattern of the dorsal shield among the species of *Amblydromalus*.

Description. *Females* (n=7) (Figs 1–5).

Dorsum. Dorsal shield reticulated with anterolateral striae at level of z5, becoming less pronounced on the posteriad of S2, 300 (295–315) long and 175 (175–192) wide at level of s4; seven pairs of pores and eight pairs of lyrifissures visible. Setae j1 20 (17–20), j3 32 (30–32), j4 6 (5–7), j5 5 (5–7) , j6 9 (7–10), J2 12 (9–12), J5 10 (6–10), z2 10

(8–10), z4 10 (7–10), z5 6 (6–7), Z1 12 (10–12), Z4 10 (10–11), Z5 60 (60–65), s4 38 (32–41), S2 14 (11–15), S4 10 (10–12), S5 9 (9–10), r3 15 (12–15), R1 10 (8–10). Setae r3 and R1 inserted out of dorsal shield. All setae are smooth and pointed, except s4 and Z5 blunt tip, and Z5 serrate.

Venter. Sternal shield smooth; with three pairs of setae and two pairs of lyrifissures. Distances between st1-st3 60 (57–60), st2-st2 72 (65–72). Genital shield smooth, distance between st5-st5 70 (65–72). Ventrianal shield vase shape, smooth with 100 (85–107) long, 48 (48–55) wide at level of ZV2 and 45 (45–55) wide at median level of anus, with three pairs of pre-anal setae (JV1, JV2, ZV2) and a pair of pores in the transverse line with JV2. With a pair of metapodal shields.

Peritreme. Extending almost to j1.

Chelicera. Fixed digit 32 (27–32) long; movable digit 30 (25–30) long.

Spermatheca. Calyx sacular, 26 (20–26) long, atrium distinct blunt-like

Legs. Macrosetae present on all legs: Sge I 35 (20–35), Sge II 30 (30–35), Sge III 35 (32–40), Sti III 28 (25–30), Sge IV 60 (50–67), Sti IV 35 (35–40) and St IV 65 (65–75). All macrosetae pointed. Chaetotaxy of genu II 2,2/0–2/0,1; genu III 1,2/2–2/0,1.

Male. (n=2) (Figs 6–7).

Dorsum. Dorsal shield pattern similar to female, 232–237 long and 165–175 wide. Setae j1 15, j3 30–32, j4 6–7, j5 7, j6 7–10, J2 10, J5 6–8, z2 9–10, z4 9, z5 6, Z1 10, Z4 7–10, Z5 45–48, s4 30, S2 10, S4 10, S5 8, r3 9–12, R1 8. All dorsal setae smooth.

Venter. Sternogenital shield smooth. Ventrianal shield subtriangular, slightly striated, 95–102 long, 120–130 wide at anterior corners, and 70 wide at anus level, with three pairs of pre-anal setae (Jv1, Jv2 and Zv2), four pairs of rounded structures similar to lyrifissures or small pores.

Peritreme. Reaching beyond level of j3.

Chelicera. Movable digit 20 long, fixed digit 23 long; "*pilus dentilis*" not visible.

Spermatodactyl elongated, 23 long, toe and heel conspicuous.

Legs. Macrosetae present on all legs with pointed tip: Sge I 25–28 with, Sge II 25–30, Sge III 25, Sti III 22–25, Sge IV 40–42, Sti IV 30, and St IV 62. Chaetotaxy as in female.

Remarks: Differently from the other species of *Amblydromalus*, the dorsal shield of this new species is pronounced reticulated, resembling many *Typhlodromalus* species as reported by Chant & McMurtry (2005a). However this species fits on genus *Ambydromalus* by having ratio seta s4:Z1 > 3.0:1:0, dorsal shield with anterolateral striations, ventrianal shield vase-shaped with some forward migration of setae JV2 and ZV2, and deutosternal groove 5-7 µm in width.

***Amblydromalus manihoti* (Moraes, 1994)**

Amblyseius manihoti Moraes, 1994: 211.

Amblydromalus manihoti.— Demite *et al*., 2009: 47; 2011: 33; Castro & Moraes, 2010: 302; Moraes *et al*., 2013: 319.

Origin of the material examined: Igrapiúna, Bahia, *H. brasiliensis* II-12-2009 (2), X-10-2008 (1), XI-07-2008 (14).

Remarks: This species was previously recorded on rubber trees from Mato Grosso State (Demite & Feres 2008), and it is commonly found on cassava (*Manihot esculenta*, Euphorbiaceae) in the State of Bahia (Bonato *et al*., 1999; Moraes *et al*., 1994).

***Amblyseius aerialis* (Muma, 1955)**

Amblyseiopsis aerialis Muma, 1955: 264.

Amblyseius aerialis.— Moraes *et al*., 1986: 6; 1991: 117 Moraes & Mesa, 1988: 71; Feres & Moraes, 1998: 126; Gondim Jr & Moraes, 2001: 67; Feres *et al*., 2005: 45; Buosi *et al*., 2006: 3; Mineiro *et al*., 2009: 40; Demite *et al*., 2011: 34; Rezende & Lofego, 2011: 454; Lofego *et al*., 2013: 414.

Origin of the material examined: Igrapiúna, Bahia, *H. brasiliensis* IX-10-2008 (1), X-10-2008 (3).

Remarks: The species was recorded on diverse cultivated crops in the State of Bahia

(Fiaboe *et al.,* 2007; Lawson-Balagbo *et al.,* 2008; Noronha *et al.,* 2010; Oliveira *et al.,* 2007; Souza *et al.,* 2008).

Amblyseius herbicolus **(Chant, 1959)**

Typhlodromus (Amblyseius) herbicolus Chant, 1959: 84.

Amblyseius herbicolus: Zacarias & Moraes 2001:580; Ferla & Moraes 2002b: 1013; Moraes *et al.,* 2004: 27; Buosi *et al.,* 2006: 3; Vasconcelos *et al.,* 2006: 92; Mineiro *et al.,* 2009: 40; Demite *et al.,* 2011: 37; Demite *et al.,* 2013: 143.

Origin of the material examined — Igrapiúna, Bahia, *H. brasiliensis* XI-09-2008 (1).

Remarks: One only specimen was recorded. It is the first record for the State of Bahia, although it has been previously sampled on rubber trees in Brazil (Zacarias & Moraes, 2001).

Amblyseius operculatus **De Leon, 1967**

Amblyseius operculatus De Leon, 1967: 26.

Amblyseius operculatus.— Moraes *et al*., 1986: 26; 2004: 45; Gondim Jr & Moraes, 2001: 72; Zacarias & Moraes, 2001: 581; Lawson-Balagbo *et al*., 2008: 88; Souza *et al*., 2012: 225; Moraes *et al*., 2013: 308.

Origin of the material examined: Igrapiúna, Bahia, on *H. brasiliensis* I-10-2009 (7), II-20-2009 (6), III-20-2009 (4), IV-24-2009 (7), V-16-2008 (16), VI-10-2008 (23), VII-11-2008 (2), VIII-10-2008 (7), X-07-2008 (11), XI-09-2008 (23), XII-28-2008 (13).

Remarks: *Amblyseius operculatus* was very common in the survey, being recorded prior on cultivated plants in the State of Bahia, and rubber trees in São Paulo State, Brazil (Zacarias & Moraes, 2001).

***Amblyseius perditus* Chant & Baker, 1965**

Amblyseius perditus Chant & Baker, 1965: 13.

Amblyseius perditus.— Gondim Jr & Moraes, 2001: 73; Bobot *et al*., 2011: 559; Souza *et al*., 2013: 178.

Origin of the material examined: Igrapiúna, Bahia, on *H. brasiliensis* I-10-2009 (39), II-20-2009 (55), III-20-2009 (35), IV-24-2009 (17), V-16-2008 (24), VI-10-2008 (13), VII-11-2008 (5), VIII-10-2008 (2), IX-07-2008 (5), X-07-2008 (1), XI-09-2008 (6), XII-28-2008 (21).

Remarks: It was the third most abundant species on the survey, being the first record for rubber trees in Brazil.

***Arrenoseius morgani* (Chant, 1957)**

Typhlodromus morgani Chant, 1957: 294.

Arrenoseius morgani.— Castro & Moraes, 2010: 303; Moraes *et al.,* 2013: 309.

Origin of the material examined: Igrapiúna, Bahia, on *H. brasiliensis* X-10-2008(1).

Remarks: Only one specimen was recorded. This species was recently recorded on native rubber trees from Amazon forest (Nuvoloni *et al*., 2014)

Euseius alatus **De Leon, 1966**

Euseius alatus De Leon, 1966: 87.

Euseius alatus.— Denmark & Muma, 1973: 262; Moraes & McMurtry, 1983: 137; Moraes *et al.*, 1986: 36, 1991: 131, 2004: 60; Feres & Moraes, 1998: 127; Zacarias & Moraes, 2001: 581; Gondim Jr & Moraes, 2001: 73; Ferla & Moraes, 2002a: 780, 2002b: 1015; Hernandes & Feres, 2006a: 3; Mineiro *et al.*, 2009: 40; Lofego *et al*., 2013: 415; Demite *et al*., 2013: 145.

Origin of the material examined: Igrapiúna, Bahia, on *H. brasiliensis* I-10-2009 (6), II-20-2009 (5), III-20-2009 (16), IV-24-2009 (40), V-16-2008 (43), VI-10-2008 (18), X-07-2008 (2), XI-09-2008 (18), XII-28-2008 (8).

Remarks: *Euseius alatus* was a very common and abundant species sampled throughout the survey. It has been frequently recorded on wild and cultivated rubber trees along the Brazilian country (Ferla & Moraes, 2002a; Hernandes & Feres, 2006a; Nuvoloni *et al*., 2014).

Iphiseiodes metapodalis **(El-Banhawy, 1984)**

Amblyseius metapodalis El-Banhawy, 1984: 132.

Iphiseiodes metapodalis.— Ferla & Moraes, 2002a: 1018; Mineiro *et al*., 2009: 41; Castro & Moraes, 2010: 303; Diehl *et al*., 2012: 24; Souza *et al.*, 2012: 225; Johann *et al*., 2014: 139.

Origin of the material examined: Igrapiúna, Bahia, on *H. brasiliensis* X-07-2008 (1).

Remarks: *Iphiseiodes metapodalis* has never been recorded on rubber trees before, and it is even rarely found on surveys performed on cultivated plants in Brazil (Diehl *et al*., 2012; Fenilli & Flechtmann, 1990; Mecke *et al*., 2000; Souza *et al*., 2012, 2013).

***Iphiseiodes zuluagai* Denmark & Muma, 1972**

Iphiseiodes zuluagai Denmark & Muma, 1972: 23.

Iphiseiodes zuluagai.— Denmark & Muma, 1973: 251; Moraes *et al.*, 1986: 61, 2004: 9; Aponte & McMurtry, 1995: 165; Feres & Moraes, 1998: 127; Zacarias & Moraes, 2001: 581; Gondim Jr & Moraes, 2001: 76; Lofego *et al.*, 2004: 7, 2013: 415; Demite *et al.*, 2009: 48, 2011: 43; Rezende & Lofego, 2011: 456, 2012: 18; Rezende *et al.*, 2012: 686.

Origin of the material examined: Igrapiúna, Bahia, on *H. brasiliensis* I-10-2009 (6), II-20-2009 (9), III-20-2009 (2), IV-24-2009 (16), V-16-2008 (25), VI-10-2008 (7), VII-16-2008 (1), IX-07-2008 (5), X-07-2008 (13), XI-09-2008 (3), XII-28-2008 (12).

Remarks: This species is widely distributed in the Brazilian territory, including on rubber trees.

Neoseiulus tunus **(De Leon, 1967)**

Typhlodromips tunus De Leon, 1967: 29.

Neoseiulus tunus.— Feres & Moraes, 1998: 126; Ferla & Moraes, 2002a: 872; b: 1018; Lofego *et al*., 2004: 8; Moraes *et al*., 2004: 148; Bellini *et al*., 2005: 37; Feres *et al*., 2005: 45; Buosi *et al*., 2006: 5; Hernandes & Feres, 2006b: Demite *et al*., 2009: 48, 2011: 44; Rezende & Lofego, 2011: 456; Johann *et al*., 2014: 139.

Origin of the material examined: Igrapiúna, Bahia, on *H. brasiliensis* X-08-2008 (1).

Remarks: One only specimen was recorded. This species has been frequently recorded on rubber trees along the Brazil (Ferla & Moraes, 2002a,b; Hernandes & Feres, 2006a).

Phytoscutus sexpilis **Muma, 1961**

Phytoscutus sexpilis Muma, 1961: 275.

Phytoscutus sexpilis.— Zacarias & Moraes, 2001: 589; Hernandes & Feres, 2006a: 4; Gondim Jr. & Moraes, 2001: 80; Demite *et al*., 2013: 145.

Origin of the material examined: Igrapiúna, Bahia, on *H. brasiliensis* I-06-2009(1), VI-15-2008(1).

Remarks: *Phytoscutus sexpilis* was already recorded on rubber trees from São Paulo State (Zacarias & Moraes, 2001; Hernandes & Feres, 2006a).

Proprioseiopsis dominigos **(El-Banhawy, 1984)**

Amblyseius dominigos El-Banhawy, 1984: 130.

Proprioseiopsis dominigos.— Moraes *et al.*, 1986: 114, 2004: 175; Gondim Jr & Moraes, 2001: 81; Zacarias & Moraes, 2001: 582; Demite *et al.*, 2009: 48, 2011: 45; Mineiro *et al.*, 2009: 42; Rezende & Lofego, 2011: 457; Moraes *et al*., 2013: 143.

Origin of the material examined: Igrapiúna, Bahia, on *H. brasiliensis* I-03-2009(4), VIII-23-2008(1), XII-24-2008(3).

Remarks: *Proprioseiopsis dominigos* was recorded on rubber trees from São Paulo State (Hernandes & Feres, 2006a), and is a common species in natural vegetation abroad the country (Zacarias & Moraes, 2001; Demite *et al*., 2009; Rezende & Lofego, 2011)

Ricoseius loxocheles **(De Leon, 1965)**

Amblyseius (*Ricoseius*) *loxocheles* De Leon, 1965: 128.

Ricoseius loxocheles.— Denmark & Muma, 1970: 119, 1973: 249; Demite *et al.,* 2009: 49; Gondim Jr. *et al.,* 2012: 531; Lofego *et al.,* 2013: 415. Rezende & Lofego, 2011: 457.

Origin of the material examined: Igrapiúna, Bahia, on *H. brasiliensis* VI-13-2008(1).

Remarks: Only one specimen was recorded. It was the first record on rubber trees in Brazil.

Typhlodromalus peregrinus (Muma, 1955)

Typhlodromus peregrinus Muma, 1955: 270.

Typhlodromalus peregrinus.— Moraes *et al.*, 1986: 132, 2004: 202; Zacarias & Moraes, 2001: 582; Rezende & Lofego, 2011:457, Fiaboe *et al.*, 2007: 6; Souza *et al.*, 2012: 225.

Origin of the material examined: Igrapiúna, Bahia, on *H. brasiliensis* II-07-2009(1), V-03-2008(1), X-29-2008(51), XI-24-2008(47), XII-22-2008(11).

Remarks: It was the first record on rubber trees in Brazil.

Typhlodromips constrictatus (El-Banhawy, 1984)

Amblyseius constrictatus El-Banhawy, 1984: 134.

Typhlodromips constrictatus.— Silva *et al.*, 2010: 1151.

Origin of the material examined: Igrapiúna, Bahia, on *H. brasiliensis* II-15-2009(2), VI-23-2008(4), VII-20-2008(1), XI-11-2008(1).

Remarks: It was the first record on rubber trees in Brazil.

Typhlodromips paramilus Nuvoloni & Lofego n. sp.

(Figs 8–14)

Diagnosis: This new species belongs to the *lugubris* species group characterized by Chant & McMurtry (2005b) by having the spermatheca elongate and funnel-shaped. It is similar to *T. furcus* Lofego *et al*., (2011) by having leg macrosetae with knob tip, spermatheca funnel-shaped, and resembles *T. amilus* De Leon (1967) due to the dorsal shield reticulation, setae s4, S2, Z4 and Z5 knobbed, and similar length of dorsal setae. Otherwise, the new species distinguishes from *T. furcus* by having dorsal shield strongly reticulated, setae s4, S2, Z4 and Z5 with knob tip and spermatodactyl with different shape. *Typhlodromips paramilus* **n. sp.** either differs from *T. amilus* by having the calyx of spermatheca shorter, the atrium more prominent and ventri-anal shield pentagonal instead sub-triangular as in *T. amilus.*

Specimens examined. Holotype female and paratype male collected from *Hevea brasiliensis*, clone PMB 01, from Igrapiúna, Bahia, Brazil, (13° 48' S, 39° 10' W), August 08, 2008, E.B. Castro coll.; three paratypes females from *H. brasiliensis*, clone FDR 5788, August 08, 2008, E.B. Castro coll.; one paratype female collected from *Hevea brasiliensis*, clone PMB 01, August 08, 2008, F.M. Nuvoloni coll.; all specimens were deposited at DZSJRP.

Etymology: The name *paramilus* was designated due to the similarity between the new species and *Typhlodromips amilus.*

Description.

Females (n=6) (Figs 8–12).

Dorsum. Dorsal shield mostly reticulate, with pronounced lateral striation anteriad of S4, and light striation on the band posteriad of S4 and Z4, 307 (300–332) long and 175 (175–200) wide at level of s4; seven pairs of pores and eight pairs of lyrifissures visible. Setae j1 18 (13–19), j3 20 (20–21), j4 12 (11–14), j5 12 (11–13), j6 15 (13–15), J2 18 (17–20), J5 13 (10–13), z2 14 (12–15), z4 16 (15–18), z5 14 (13–16), Z1 18 (16–21), Z4 34 (32–37), Z5 58 (58–68), s4 26 (22–26), S2 23 (22–25), S4 15 (15–20) and S5 12 (12–15), r311 (11–14), R1 16 (13–16). Most of setae smooth and pointed, except s4, S2 which are smooth and knobed, and Z4 and Z5 serrated and knobed.

Venter. Sternal shield with anterolateral striae; three pairs of setae and two pairs of lyrifissures. Distances between st1-st3 56 (56–60), st2-st2 60 (60–70). Genital shield scanty striated, distance between st5-st5 63 (60–67). Ventrianal shield pentagonal, lightly striated with 100 (100–113) long, 56 (56–60) wide at level of ZV2 and 60 (60–70) wide at median level of anus, with three pairs of pre-anal setae (JV1, JV2, ZV2) and a pair of pores in the transverse line with JV2. With a pair of small metapodal shields. *Peritreme*. extending to level of j1.

Chelicera. Fixed digit 27 (25–30) long; movable digit 25 (24–29) long.

Spermatheca. Calyx funnel-shaped, 12 (12–20) long, atrium distinct blunt like

Legs. Macrosetae present on all legs: Sge I 17(17–22), Sge II 15 (15–17), Sge III 20 (20–25), Sti III 17 (14–17), Sge IV 30 (30–35), Sti IV 15 (12–20) and St IV 40 (37–45). All macrosetae with terminal knob. Chaetotaxy of genu II 2,2/0–2/0,1; genu III 1,2/2–2/0,1.

Male. (n=1) (Figs 13–14).

Dorsum. Dorsal shield pattern similar to female, 245 long and 160 wide. Setae j1 15, j3 17, j4 11, j5 12, j6 15, J2 16, J5 9, z2 15, z4 16, z5 12, Z1 18, Z4 27, Z5 45, s4 20, S2 18, S4 16, S5 17, r3 10, R1 15. Most of setae smooth and pointed, except s4, S2 which are smooth and knobed, and Z4 and Z5 serrated and knobed.

Venter. Sternogenital shield smooth. Ventrianal shield subtriangular, reticulated, 110 long, 145 wide at anterior corners, and 80 wide at anus level, with three pairs of pre-anal setae (Jv1, Jv2 and Zv2), one pair of pores in the transverse line with JV2. Seta Jv5 smooth, more than 1.5 longer than pre-anal setae.

Peritreme. Extending to level of j1.

Chelicera. Movable digit 20 long, with one teeth; fixed digit 25 long, with one teeth; "*pilus dentili*s" not visible.

Spermatodactyl elongated, 14-20 long, with toe and heel inconspicuous, and a terminal hook.

Legs. Macrosetae present on all legs: Sge I 15 with pointed tip, Sge II 14 knob tip, Sge III 15 pointed tip, Sti III 13 blunt tip, Sge IV 25 knobed, Sti IV 20 knobed, and St IV 32 knobed. Chaetotaxy as in female.

Remarks: *Typhlodromips paramilus* **n. sp**. was among the most abundant species found in the survey. This species presents some very distinct dorsal setae, such as Z4 and Z5, with knob tip, and serrated stem (Figs 15–16), similar to those of *T. amilus*. The seta has an evident terminal gap, with a hyaline mucous or waxy knob. The knob is variable in size and sometimes absent, being an indicative that it is secreted by an associated gland on the setae basis.

SUBFAMILY TYPHLODROMINAE SCHEUTEN, 1857

***Galendromus* (*Mugidromus*) sp.**

Origin of the material examined: Igrapiúna, Bahia, on *H. brasiliensis* III-15-2009(1), XI-02-2008(1).

***Leonseius regularis* (De Leon, 1965)**

Typhloseiopsis regularis De Leon, 1965: 122.

Leonseius regularis.— Moraes *et al.*, 2004: 275; 2013: 338; Vasconcelos *et al.*, 2006: 94; Castro & Moraes, 2010: 303. Gondim Jr. & Moraes, 2001: 88; Moraes *et al.*, 2013: 338.

Origin of the material examined: Igrapiúna, Bahia, on *H. brasiliensis* I-04-2009(24), II-09-2009(22), III-15-2009(10), IV-10-2009(09), V-09-2008(22), VI-30-2008(16), VII-23-2008(12), VIII-24-2008(5), IX-29-2008(9), X-12-2008(14), XI-02-2008(39), XII-04-2008(18).

Remarks: *Leonseius regularis* was the most abundant species in this study, and it has been recorded once in native rubber trees from Amazon (Nuvoloni *et al*., 2014).

***Metaseiulus* (*Metaseiulus*) *ferlai* Moraes, McMurtry & Lopes, 2006**

Metaseiulus (*Metaseiulus*) *ferlai* Moraes, McMurtry & Lopes, 2006: 352.

Metaseiulus (*Metaseiulus*) *ferlai*— Demite *et al*., 2011: 50; Moraes *et al*., 2006: 352; Rezende & Lofego, 2011:458.

Origin of the material examined: Igrapiúna, Bahia, on *H. brasiliensis* IV-04-2008(1), VII-16-2008(4).

Remarks: It species was described from specimens collected on *H. brasiliensis* from Mato Grosso State, being subsequently found on native plants in several states of the country.

***Typhlodromina subtropica* Muma & Denmark, 1969**

Typhlodromina subtropica Muma & Denmark, 1969: 412.

Typhlodromina subtropica.— Moraes & McMurtry, 1983; Gondim Jr & Moraes, 2001: 89; Rosa *et al*., 2005: 691; Vasconcelos *et al*., 2006: 95; Fiaboe *et al*., 2007: 7; Lawson-Balagbo *et al*., 2008: 88.

Origin of the material examined: Igrapiúna, Bahia, on *H. brasiliensis* IV-06-2008(1), XI-03-2008(1), XII-15-2008(3).

Remarks: It is a new register for *H. brasiliensis* in Brazil. *Typhlodromina subtropica* is commonly recorded in crops and natural vegetation in Brazil.

Discussion

The investigation features the first Phytoseiidae mites survey on rubber trees from the State of Bahia, describing two new species, and either brings a full inventory of the species occurrence. In general, considering that the samplings were conducted in a plantation area, the diversity of phytoseiids can be considered somewhat high, highlighting the importance of rubber trees housing predatory mites (Nuvoloni et al., 2015). Beyond that, the proximity between rubber plantation and areas of natural vegetation of Atlantic Rainforest may have positively influenced the local diversity. The higher similarity between the mite fauna found on the current survey and Amazonas region may be due to the fact of both areas, despite the distance, sharing similar climatic conditions and vegetation. Both are located on a tropical forest domain, although the first being on the Amazon Forest, and the former on the Atlantic Rainforest. Furthermore, in spite of most of species being largely sampled on previous inventories of rubber trees in Brazil, on the other hand a significative number of species represent new records for the host plant, for Brazil, also including the new species.

Although our study brings new and relevant information about distribution and taxonomy of Phytoseiidae mites on rubber trees, an actual challenge of accessing the contribution of these species on the biological control is the lack of laboratory and field experiments testing their effectiveness and feed preferences. So, more studies focusing on the biological aspects of these mites are essential looking forward to the development and implementation of an IPM (Integrated Pest Management) program on rubber trees.

Acknowledges

We are grateful to "Plantações Michelin da Bahia ltda" and the staff for the financial and logistical support during data collection. This work was also funded by FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo) by the fellowship to F.M. Nuvoloni (Process. 2010/19935-1), by CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) by fellowship to E.B.C., and CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) by fellowship and research grant to R.J.F.F (Proc. No 303435/2013-5).

References

Aponte, O. & McMurtry, J.A. (1995) Revision of the genus *Iphiseiodes* De Leon (Acari: Phytoseiidae). *International Journal of Acarology*, 21, 165–183.

Chant, D.A. & McMurtry, J.A. (2005a) A review of the subfamily Amblyseiinae Muma (Acari: Phytoseiidae): Part VI. The tribe Euseiini n. tribe, subtribes

Typhlodromalina n. subtribe, Euseiina n. subtribe, and Ricoseiina n. subtribe. *International Journal of Acarology*, 31, 187–224.

Chant, D.A. & McMurtry, J.A. (2005b) A review of the subfamily Amblyseiinae Muma (Acari: Phytoseiidae): Part V. Tribe Amblyseiini, subtribe Proprioseiopsina Chant & McMurtry. *International Journal of Acarology*, 31, 3–22.

Chant, D.A. & Yoshida-Shaul, E. (1991) Adult ventral setal patterns in the family Phytoseiidae (Acari: Gamasina). *International Journal of Acarology* 17, 187–199.

Daud, R.D. & Feres, R.J.F. (2014) Community structure of mites (Arachnida: Acari) in six rubber tree clones. *International Journal of Acarology*, 39, 589–596.

De Leon, D. (1967) *Some Mites of the Caribbean Area. Part I. Acarina on Plants in Trinidad, West Indies*. Allen Press Inc., Lawrence, 66 pp.

Demite, P.R. & Feres, R.J.F. (2007) Ocorrência e Flutuação Populacional de Ácaros Associados a Seringais Vizinhos de Fragmentos de Cerrado. *Neotropical Entomology*, 36, 117–127.

Demite, P.R. & Feres, R.J.F. (2008) Influência de fragmentos de cerrado na distribuiçao de ácaros em seringal. *Neotropical Entomology*, 37, 196–204.

Demite, P.R., Feres, R.J.F., Lofego, A.C. & Oliveira, A.R. (2009) Plant inhabiting mites (Acari) from the Cerrado biome of Mato Grosso State, Brazil. *Zootaxa*, 2061, 45–60.

Demite, P.R., Lofego, A.C. & Feres, R.J.F. (2011) Phytoseiidae (Acari) in forest fragments in the State of São Paulo, Brazil. *Zootaxa*, 56, 31–56.

Demite, P.R., Lofego, A.C. & Feres, R.J.F (2013) Mite (Acari; Arachnida) diversity of two native plants in fragments of a semideciduous seasonal forest in Brazil. *Systematics and Biodiversity*, 11:2, 141–148.

Demite, P.R., Moraes, G.J. de, McMurtry, J.A., Denmark, H.A. & Castilho, R.C. (2014) Phytoseiidae Database. Available from: www.lea.esalq.usp.br/phytoseiidae (May 10, 2014).

Denmark, H.A. & Muma, M.H. (1970) Some phytoseiid mites of Paraguay (Acarina: Phytoseiidae). *The Florida Entomologist*, 53, 219–227.

Denmark, H.A. & Muma, M.H. (1973) Phytoseiidae mites of Brazil (Acarina, Phytoseiidae). *Revista Brasileira de Biologia*, 33, 235–276.

Deus, E., Souza., M.S.M., Mineiro, J.L.C., Adaime, R. & Santos, R.S. (2012) Mites (Arachnida: Acari) collected on rubber trees *Hevea brasiliensis* (Willd. ex A.Juss.) Müll.Arg. in Santana, Amapá state, Brazi. *Brazilian Journal of Biology*, 72, 915–918.

Diehl, M., Ferla, N.J. & Johann, L. (2012) Plantas associadas à videiras: uma estratégia para o controle biológico no Rio Grande do Sul. *Arquivos do Instituto Biológico de São Paulo*, 79, 579–586.

El-Banhawy, E.M. (1984) Description of some phytoseiid mites from Brazil (Acarina: Phytoseiidae). *Acarologia*, 25, 125–144.

Fenilli, R. & Flechtmann, C.H.W. (1990) Ácaros do pinheiro-do-Paraná em Lages, Santa Catarina. *Anais da Escola Superior de Agricultura " Luiz de Queiroz"*, 47, 243–250.

Feres, R.J.F. & Moraes, G.J. (1998) Phytoseiid mites (Acari: Phytoseiidae) from woody areas in the State of São Paulo, Brazil. *Systematic and Applied Acarology*, 3, 125–132.

Feres, R.J.F., Lofego, A.C. & Oliveira, A.R. (2005) Ácaros plantícolas (Acari) da "Estaçao Ecológica do Noroeste Paulista", Estado de São Paulo, Brasil. *Biota Neotropica*, 5, 1–14.

Ferla, N.J. & Moraes, G.J. de (2002a) Ácaros (Arachnida, Acari) da seringueira (*Hevea brasiliensis* Muell. Arg.) no Estado do Mato Grosso, Brasil. *Revista Brasileira de Zoologia*, 19, 867–888.

Ferla, N.J. & Moraes, G.J. de (2002b) Ácaros predadores (Acari) em plantas nativas e cultivadas do Estado do Rio Grande do Sul, Brasil. *Revista Brasileira de Zoologia,* 19, 1011–1031.

Fiaboe, K.K.M., Gondim Jr., M.G.C., Moraes, G.J. de, Ogol, C.K.P.O. & Knapp, M. (2007) Surveys for natural enemies of the tomato red spider mite *Tetranychus envansi* (Acari: Tetranychidae) in northeastern and southeastern Brazil. *Zootaxa*, 1395, 33–58.

Gerson, U., Smiley, L.R. & Ochoa, R. (2003) *Mites (Acari) for pest control*. Blackwell Publishing Company, Oxford, Oxfordshire, UK, 539 pp.

Gondim Jr, M.G.C. & Moraes, G.J. de (2001) Phytoseiidae mites (Acari: Phytoseiidae) associated with palm trees (Arecaceae) in Brazil. *Systematic and Applied Acarology*, 6, 65–94.

Gondim Jr., M.G.C., Castro, T.M.M.G., Marsaro Jr, A.L., Navia, D., Melo, J.W.S., Demite, P.R. & Moraes, G.J. de (2012) Can the red palm mite threaten the Amazon vegetation? *Systematics and Biodiversity*, 10, 527–535.

Hernandes, F.A. & Feres, R.J.F. (2006a) Review about mites (Acari) of rubber trees (*Hevea* spp., Euphorbiaceae) in Brazil. *Biota Neotropica*, 6. Available from:

<http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1676-06032006000100005&lng=en&nrm=iso> (November 18, 2012).

Hernandes, F.A. & Feres, R.J.F. (2006b) Diversidade e Sazonalidade de Ácaros (Acari) em Seringal (*Hevea brasiliensis*, Muell. Arg.) no Noroeste do Estado de São Paulo. *Neotropical Entomology*, 35, 523–535.

Instituto Brasileiro de Geografia e Estatística—IBGE (2008) *Produção da extração vegetal e silvicultura*. http://www.ibge.gov.br. (July 16, 2011).

Johann, L., Horn, T.B., Carvalho, G.S. & Ferla, N.J. (2014) Diversity of mites (Acari) in vineyard agroecosystems (*Vitis vinifera*) in two viticultural regions of Rio Grande do Sul state, Brazil. *Acarologia*, 54, 137–154.

Krantz, W. & Walter, D.E. (2009) *A manual of Acarology*. Third Edit. Texas Tech University Press, Lubbock, Texas, 807 pp.

Lawson-Balagbo, L.M., Gondim, M.G.C., Moraes, G.J. de, Hanna, R. & Schausberger, P. (2008) Exploration of the acarine fauna on coconut palm in Brazil with emphasis on *Aceria guerreronis* (Acari: Eriophyidae) and its natural enemies. *Bulletin of entomological research*, 98, 83–96.

Lofego, A.C., Demite, P.R. & Feres, R.J.F. (2011) Two new species of *Typhlodromips* (Acari: Phytoseiidae) from Brazil. *International Journal of Acarology*, 37, 110–115.

Lofego, A.C., Moraes, G.J. de & Castro, L.A.S. (2004) Phytoseiid mites (Acari: Phytoseiidae) on Myrtaceae in the State of São Paulo, Brazil. *Zootaxa*, 516, 1–18.

Lofego, A.C., Rezende, J.M., Verona, R.L.C. & Feres, R.J.F. (2013) Mites (Acari) associated with three species of the genus *Jatropha* (Euphorbiaceae) in Brazil, with emphasis on *Jatropha curcas*. *Systematic and Applied Acarology*, 18, 411–423.

Mecke, R., Galileo, M.H.M. & Engels, W. (2000) Insetos e ácaros associados a *Araucaria angustifolia* (Araucariaceae, Coniferae) no Sul do Brasil. *Ilheringia, Série Zoologia*, 88, 165–172.

Mineiro, J.L.C., Raga, A., Sato, M.E. & Lofego, A.C. (2009) Ácaros associados ao cafeeiro (*Coffea* spp.) no estado de São Paulo, Brasil. Parte I . Mesostigmata. *Biota Neotropica*, 9, 37–46.

Moraes, G.J. de & McMurtry, J.A. (1983) Phytoseiid mites (Acarina) of northeastern Brazil with descriptions of four new species. *International Journal of Acarology*, 9, 131–148.

Moraes, G.J. de & Mesa, N.C. (1988) Mites of the family Phytoseiidae (Acari) in Colombia, with descriptions of three new species. *International Journal of Acarology*, 14, 71–88.

Moraes, G.J. de, McMurtry, J.A. & Denmark, H.A. (1986) *A Catalog of the Mite Family Phytoseiidae: References to Taxonomy, Synonym, Distribution and Habitat*. Embrapa-DDT, Brasilia, 356 pp.

Moraes, G.J. de, McMurtry, J.A., Denmark, H.A. & Campos, C.B. (2004) A revised catalog of the mite family Phytoseiidae. *Zootaxa*, 434, 1–494.

Moraes, G.J. de, Mesa, N.C. & Braun, A. (1991) Some phytoseiid mites of Latin America (Acari: Phytoseiidae). *International Journal of Acarology*, 17, 117–139.

Moraes, G.J. de, Mesa, N.C., Braun, A. & Melo, E.L. (1994) Definition of the *Amblyseius limonicus* species group (Acari: Phytoseiidae), with descriptions of two new species and new records. *International Journal of Acarology*, 20, 209-217.

Moraes, G.J., Barbosa, M.F.C. & Castro, T.M.M.G. (2013) Phytoseiidae (Acari: Mesostigmata) from natural ecosystems in the State of São Paulo, Brazil. *Zootaxa*, 3700, 301–347.

Muma, M.H., Denmark, H.A. & De Leon, D. (1970) Phytoseiidae of Florida. In: *Arthropods of Florida and neighboring land areas, 6*. Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Gainesville, 150 pp.

Noronha, A.C.S., Argolo, P.S., Boaventura, V.J. & Ritzinger, R. (2010) Ácaros (Acari) em mudas de aceroleira. *Boletin de Sanidad Vegetal Plagas*, 36, 189–195.

Nuvoloni, F.M., Lofego, A.C., Rezende, J.M. & Feres, R.J.F. (2015) Phytoseiidae mites associated with *Hevea* spp. from the Amazon region: a hidden diversity under the canopy of native trees. *Systematics and Biodiversity*,

Oliveira, V.S., Noronha, A.C.S., Argolo, P.S. & Carvalho, J.E.B. de (2007) Acarofauna em pomares cítricos nos municípios de Inhambupe e Rio Real no estado da Bahia. *Magistra*, 19, 257–261.

Rezende, J.M. & Lofego, A.C. (2011) Phytoseiidae (Acari: Mesostigmata) on plants of the central region of the Brazilian Cerrado. *Acarologia*, 51, 449–463.

Rezende, J.M., Lofego, A.C., Návia, D. & Roggia, S. (2012) Mites (Acari: Mesostigmata, Sarcoptiformes and Trombidiformes) associated to soybean in Brazil, including new records from the Cerrado areas. *Florida Entomologist*, 95, 683–693.

Rosa, A.A., Gondim Jr., M.G.C., Fiaboe, K.K.M., Moraes, G.J. de & Knapp, M. (2005) Predatory mites associated with *Tetranychus evansi* Baker & Pritchard (Acari: Tetranychidae) on native solanaceous plants of coastal Pernambuco State, Brazil. *Neotropical Entomology*, 34, 689–692.

Rowell, H.J., Chant, D.A. & Hansell, R.I.C. (1978) The determination of setal homologies and setal patterns on the dorsal shield in the family Phytoseiidae (Acarina: Mesostigmata). *The Canadian Entomologist*, 110, 859–876.

Silva, E.A., Reis, P.R., Zacarias, M.S. & Marafeli, P.P. (2010) Fitoseídeos (Acari: Phytoseiidae) associados a cafezais e fragmentos florestais vizinhos. *Ciência Agronômica*, 34, 1146–1153.

Souza, I.V. de, Gondim Jr., M.G.C., Ramos, A.L.R., Santos, E.A. dos, Ferraz, M.I.F. & Oliveira, A.R. (2008) Exploration of the acarine fauna on coconut palm in Brazil with enphasis on *Aceria guerreronis* (Acari: Eriophyidae) and its natural enemies. *Bulletin of Entomological Research*, 98, 83–96.

Souza, I.V. de, M.G.C., G.J., Ramos, A.L.R., Santos, E.A. dos, Ferras, M.I.F. & Oliveira, A.R. (2012) Population dynamics of *Aceria guerreronis* (Acari: Eriophyidae) and other mites associated with coconut fruits in Una, state of Bahia, northeastern Brazil. *Experimental and Applied Acarology*, 58, 221–233.

Souza, M. S.M., Deus, E.G., Mineiro, J.L.C., Adaime, R. & Merr, S. (2013) Mites (Arachnida: Acari) associated with hog plum trees (*Spondias mombin* L.) in the Brazilian Amazon. *Biota Amazônica*, 3, 177–180.

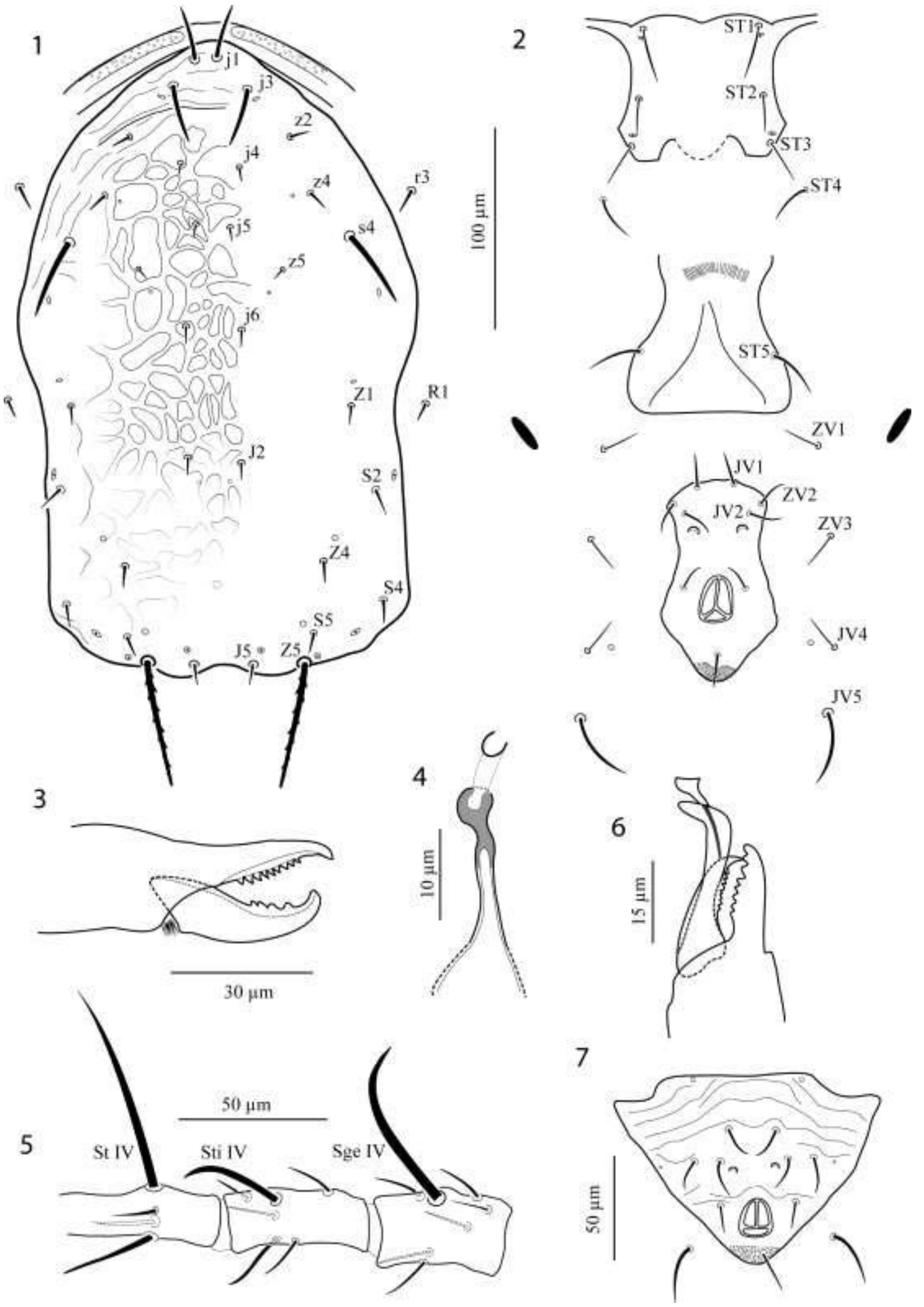
Vasconcelos, D.E., Silva, F.R., Barbosa, D.G.F., Gondim Jr., M.G.C. & Moraes, G.J. de (2006) Diversidade de fitoseídeos (Acari: Phytoseiidae) em fruteiras tropicais no Estado de Pernambuco, Brasil. *Magistra*, 18, 90–101.

Zacarias, M.S. & Moraes, G.J. de (2001) Phytoseiid Mites (Acari) Associated With Rubber Trees And Other Euphorbiaceous Plants In Southeastern Brazil. *Neotropical Entomology*, 30, 579–586.

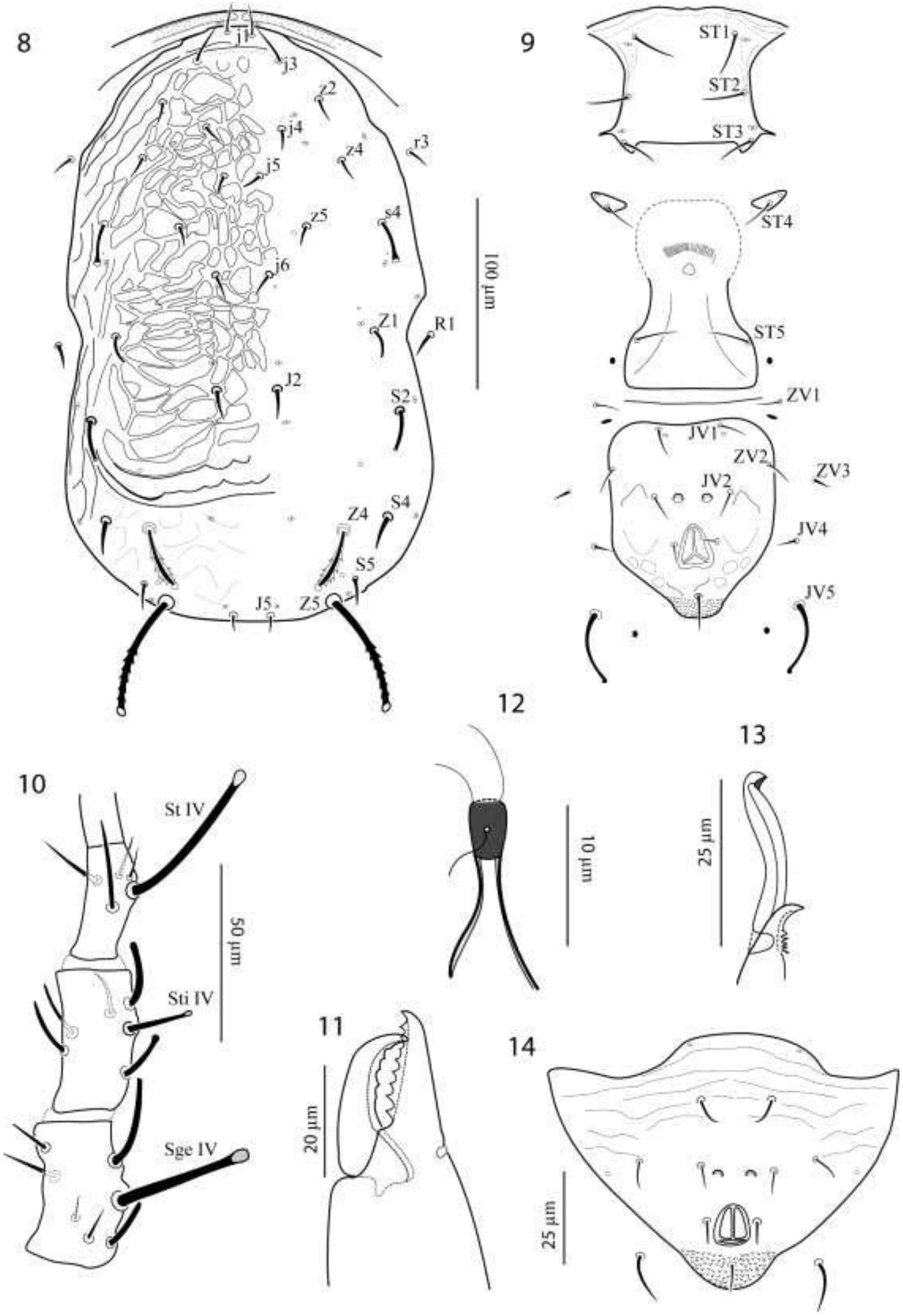
Zacarias, M.S. & Moraes, G.J. de (2002) Mite diversity (Arthropoda: Acari) on euphorbiaceous plants in the State of São Paulo. *Biota Neotropica*, 2, 1–12.

Table 1. Species of Phytoseiidae and their abundance recorded on five clones of *Hevea brasiliensis* from a rubber plantation at Igrapiúna, Bahia, Brazil, during April 2008 to April 2009.

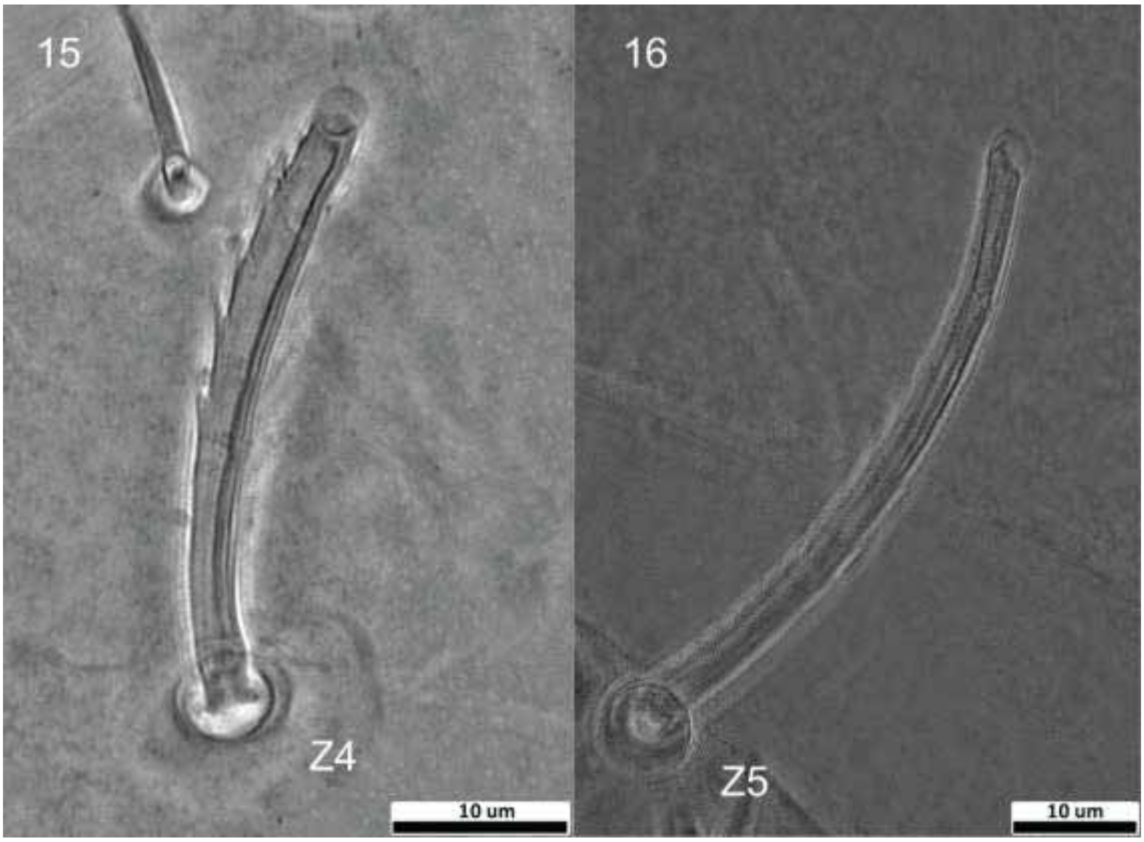
Species	**CDC 312**	**FDR 5788**	**PMB 01**	**FX 3864**	**MDF 180**	**Total**
Amblydromalus insolitus **n. sp.**	5	3	43			51
Amblydromalus manihoti				1	15	16
Amblyseius aerialis		2	1			3
Amblyseius herbicolus				1		1
Amblyseius operculatus	24	6	11	9	62	112
Amblyseius perditus	41	71	44			156
Arrenoseius morgani			1			1
Euseius alatus	5			78	72	155
Galendromus (*Mugidromus*) sp.				2		2
Iphiseiodes metapodalis	1					1
Iphiseoides zuluagai	3	1		70	20	94
Leonseius regularis	10	6	3	98	75	192
Metaseiulus ferlai				2	4	6
Neoseiulus tunus				1		1
Phytoscutus sexpilis				11		11
Proprioseiopsis dominigos	1					1
Ricoseius loxocheles					1	1
Typhlodromalus peregrinus	20	4	38	4	6	71
Typhlodromina subtropica	2			2	1	5
Typhlodromips paramilus **n. sp.**	56	26	14		1	97
Typhlodromips constrictatus				3	2	5
Typhlodromips sp.					2	2
Imatures	110	87	112	99	77	485
Total	**278**	**206**	**267**	**383**	**340**	**1474**



Figs. 1–7. *Amblydromalus insolitus* n. sp. Female: 1. Dorsal idiosoma, 2. Ventral idiosoma, 3. Chelicera, 4. Spermatheca, 5. Genu, tibia and tarsus of leg IV; Male: 6. Spermatodactyl, 7. Ventrianal shield.



Figs. 8–14. *Typhlodromips paramilus* n. sp. Female: 8. Dorsal idiosoma, 9. Ventral idiosoma, 10. Genu, tibia and tarsus of leg IV, 11. Chelicera, 12. Spermatheca; Male: 13. Spermatodactyl, 14. Ventrianal shield.



Figs. 15–16. *Typhlodromips paramilus* n. sp. Female dorsal setae: 16. Seta Z4, 15. Seta Z5.

Capítulo IV

Review of *Brachytydeus* Thor 1931 *sensu* André 2005 (Acari: Tydeidae, Tydeinae) associated with *Hevea* spp.

Felipe M. Nuvoloni, Alexandre de S. Mondin, Reinaldo J. F. Feres

Abstract

Tydeidae are free living mites, found in plants, moss and fungi, established around the world, on a high variety of environments. Tydeidae has 340 species, and is composed by Australotydeinae, Pretydeinae and Tydeinae, and half of species belongs to *Brachytydeus*. Brachytyd mites are commonly found on rubber trees surveys in Brazil, although only *Brachytydeus formosus* has been currently cited occurring on the host. In this study, we reviewed the records of *Brachytydeus* collected on wild rubber trees and rubber plantations distributed in 10 Brazilian States. We found out the actual diversity of these mites are bigger than expected, whereas of 10 *Brachytydeus* species analyzed, five are new for the science and, of five already known, four are new records on *Hevea* spp. in Brazil. Thus, descriptions of *Brachytydeus* sp. nov. 1, *Brachytydeus* sp. nov. 2, *Brachytydeus* sp. nov. 3, *Brachytydeus* sp. nov. 4 e *Brachytydeus* sp. nov. 5 were made. Furthermore, we discuss the importance of morphological studies on *Brachytydeus* and observations about genus' nomenclature.

Keywords: Acari, agroecossystem, rubber tree, taxonomy, Tydeidae.

Introduction

Tydeidae is composed by Australotydeinae, Pretydeinae and Tydeinae (André & Fain 2000), with 340 species and 30 genera (Krantz & Walter 2009), which half of them belongs to a unique genus, *Brachytydeus* Thor (Tydeinae) (André 2005). In spite of its huge diversity and worldwide distribution, some biological, behavioral, and even systematic aspects of these mites still remain uncovered. André (2005) redefined the genus and synonymized *Lorryia* Oudemans (except *L. superba* Oudemans) and *Raphitydeus* Thor with *Brachytydeys* (senior synonym) due to the presence of the same chaetotaxy, which is also the same of *Tydeus cruciatus* Koch (designated as type species of *Brachytydeus*).

Most of *Brachytydeus* species is assigned by the phytophagous feeding habit (Flechtmann 1973; Hernandes *et al.* 2006), although no findings of damage have been reported even in high densities (Mendel & Gerson 1982). *Brachytydeus formosus* (Cooreman) is the most studied species, and has been broadly recorded on several species of plants around the world (Feres *et al.* 2007; Ueckermann & Meyer 1979). Twenty seven species of *Brachytydeus* were already listed for North and South America (Silva *et al.* 2013), from which only *B. scutatus* Silva, Rocha & Ferla and *B. formosus* were recorded in Brazil (Silva *et al.* 2014). Quite a few surveys have been recorded *B. formosus* not only on commercial plantations, such as rubber trees (*Hevea brasiliensis*, Euphorbiaceae) (Feres 2000; Flechtmann & Arleu 1984; Hernandes & Feres 2006b; Vis *et al.* 2006), soybean (*Glycine max,* Fabaceae) (Rezende *et al.* 2012), citrus (*Citrus* spp. Rutaceae) (Silva *et al.* 2012) and grapevine (*Vitis vinifera*, Vitaceae) (Silva *et al.* 2014), but also in native vegetation from Cerrado and Atlantic Rainforest (Daud *et al.* 2010;

Feres *et al.* 2007; Feres *et al.* 2010; Ferla & Moraes 2008; Lofego & de Moraes 2006; Rezende *et al.* 2012; Zacarias & Moraes 2002).

Besides *B. formosus* being commonly recorded on diverse hosts, many inventories have pointed out the occurrence of non identified *Brachytydeus* spp., which in turn may represents new species, or even though a possible misidentification due to the absence of specialists on Neotropical *Brachytydeus,* and to the complexity and similarity among the species.

Rubber trees correspond to the main source of natural rubber on the world (Gonçalves *et al.* 2001), and *Hevea* attain eleven species originally constrained to the Amazon region, but only *H. brasiliensis* has been commercially exploited around the world. Rubber production in Brazil is mainly conducted on São Paulo, Mato Grosso, and Bahia states (Alvarenga & Carmo 2008). In summary, similar queries can be observed on the mitefauna associated with rubber trees, since a large number of *Brachytydeus* morphospecies have been reported on this plant crop, whereas only *B. formosus* was nominally confirmed so far (Bellini *et al.* 2005; Ferla & Moraes 2002; Flechtmann & Arleu 1984; Hernandes & Feres 2006b; Vis *et al.* 2006; Zacarias & Moraes 2002a). Considering the wide territorial extension from which *Brachytydeus* have been reported on rubber trees, it is expected that may exist more species on rubber trees that were actually reported so far.

The current study brings relevant contributions to the understanding of *Brachytydeus* from Brazil, since our goal was review the identifications and distribution of species belonging to the genus sampled on wild and cultivated rubber trees from Brazil, also study, compare and standardize the specimens of *Brachytydeus formosus* deposited at Acari collection of Departamento de Zoologia e Botânica UNESP, campus de São José do Rio Preto (DZSJRP), and finally describe the new species.

Material and Methods

The research encompass a taxonomic review of the species of *Brachytydeus* associated with *Hevea* spp., deposited in the Acari Collection (DZSJRP) Laboratório de Acarologia UNESP, São José do Rio Preto, São Paulo State, Brazil. Most of the studied material was collected during several faunal surveys in diverse plots in Brazil. Currently, 557 *Brachytydeus* specimens are deposited in the collection, as a result of the prior surveys.

The specimens collected by Demite & Feres (2005, 2007, 2008), Hernandes & Feres (2006), Daud & Feres (2014), Daud *et al.* (2010), Nuvoloni (2011) and Castro (2012) were included in the set of studied data. The surveys constitute extensive studies of mite fauna associated with rubber trees in northwest of São Paulo, south of Mato Grosso and Bahia. Beyond that, were analyzed specimens sampled during the PhD. project of Felipe Micali Nuvoloni, from rubber trees located at Acre, Amazonas, Rondônia, Mato Grosso do Sul and Goiás states, and also included material of loan from professors Ester Azevedo da Silva, of Universidade Estadual do Maranhão (UEMA) and Marcos Antonio Matiello Fadini, of Universidade Federal de São João del-Rei (UFSJ), from Maranhão and Minas Gerais states, respectively. On these researches, *Brachytydeus* specimens were collected from *Hevea brasiliensis* Muell. Arg., *H. guianensis* Aubl. 1775, *H. camargoana* Pires 1981 *H. spruceana* Muell. Arg. 1865 e *H. microphylla* Ule 1905. The study area of these previous surveys can be seen on Figure 1.

Collection of mites were carried out directed from the leaflets under stereoscope microscope, and mounted on microscope slides with Hoyer's medium (Krantz & Walter 2009). All the studied material, including type and voucher specimens of new species are deposited in the Acari collection (DZSJRP), Department of Zoology and Botany, São Paulo State University (UNESP), São José do Rio Preto, São Paulo, Brazil, available at: http://www.splink.cria.org.br.

Chaetotaxy and measures

Under the heading "Specimens examined", we list the scientific name of the host plant and clone variety (in case of *H. brasiliensis*), the collection date, and number of mite specimens collected. All measurements are given in micrometers (µm); each measurement corresponds to the holotype measurements, followed (in parentheses) by the respective range of paratypes, if the measurement is variable. Prodorsal and ventral setal notation follows Kaźmierski (1989), meanwhile podorsal notation follows André (1981). We present the measures of idiosoma (major length without gnatosoma, and width at the line of sejugal groove), and dorsal setae. On the gnatosoma were measured the palp and eupathidium, while legs were measured from trochanter to tarsi, since coxae are partially fused with ventral region of podossoma, which hamper the correct observation of its limits.

Illustrations

The sketches were made by pencil with a Leica® DM 2500 microscope with a light chamber. After that, the definitive illustrations were obtained with greaseproof paper over the sketches, using nankin pen. The illustrations were digitalized and the plates of figures mounted on Adobe Photoshop CS6®.

Results

A total amount of 10 species were found on the plots covered by the study (Fig. 1), which in turn five are already known by science, and five are actually new species (Tab. 1). Considering its distribution, *Brachytydeus* species could be found on every studied sites regardless those in Goiás state. Thus, the precise distribution of all species per state can be seen on Table 1.

Despite seven species of *Hevea* have been examined, *Brachytydeus* specimens were recorded only on *Hevea brasiliensis*, *H. spruceana* and *H. guianensis*. *Brachytydeus* sp. nov. 2, *Brachytydeus* sp. nov. 3, *B. turrialbensis* Baker and *B. podocarpus* Baker were also found in the wild and cultivated rubber trees (Table 2). We recorded the highest diversity of species in Bahia and Amazonas states, whereas on the plots of Goiás and Mato Grosso do Sul states we have none and one species, respectively. In the plots of State of Bahia, all the species were recorded, regardless *B. formosus*, which was also absent on Acre and Amazonas states. *Brachytydeus formosus* is usually reported as the most widespread species on plants, however *Brachytydeus*. sp. nov 1 and *Brachytydeus* sp. nov 2, were as common as *B. formosus*.

New species

Brachytydeus Thor, 1931

Lorryia Oudemans 1925 – Baker 1944: 2005, 1968: 986; Cooreman 1958: 6; Kaźmierski 1998: 293; Ripka *et al.* 2013: 1; Ueckermann & Meyer 1979: 43.

Brachytydeus Thor 1931 – André 2005: 995; Kaźmierski 2008a: 357; Silva *et al.* 2013: 1; Theron *et al.* 2012: 257.

Brachytydeus is defined by a recurved prodorsum, and rarely can present a pair of eyes. 10 pairs of dorsal setae, six pairs of genital setae (rarely five, or four, or three, or two) and four pairs of aggenital setae (rarely three or two), exhibits typical epimeral formula (3-1-4-2) and coxal organ. The adult specimens have the legs chaetotaxy as follows: I (8-3+1-3-3-1), II (6-2-2-3-0), III (5-2-1-2-1), IV (5-2-1-1-0) (Kaźmierski 1989).

Brachytydeus sp. nov. 1 (Fig. 2)

Diagnosis: *Brachytydeus* sp. nov. 1 has slightly serrated dorsal setae, except trichobothria, which is smooth, and dorsal ornamentation with small reticulated areas, which do not reach the basis of setae, including aspidossoma (AA0 region).

Dorsum (Fig. 2A): Prodorsum recurved. Thirteen pairs of lanceolated setae, slightly squamous, medium length (Fig. 2C), except for the trichobothria (*bo*) (Fig. 2D), which is filiform and smooth. Dorsal striation type "*Tydeus*" (Kaźmierski 1998), with reticulation on aspidosoma (AA0) and areas that do not reach the basis of setae, such as between *bo, c*1*, d*1, and *f*1*,* setae *f*1 shorter than the distance *f*1–*h*1. Lyrisfissure *ia* (Fig. 2E) lies posteriorly to *c2*, at the distance as long as 2/3 of *c*1-*c2* sector. Lyrifissure *im* (Fig. 2F) lies in the same longitudinal row with *ia*, slightly anteriorly to *e*.

Dimensions: Lenght of idiossoma 193 (192–212) and width 145 (135–154). Dorsal setae: *ro* 10 (10–14), *la* 11 (10–12), *bo* 31 (31–36), *ex* 10 (10–14), *c*1 10 (8–14), *c2* 12 (10–14), *d* 11 (8–13), *e* 10(7–14), *f*1 13(11–15), *f2* 13(12–17), *h*1 12(12–15), *h2* 12(12–16), *ps*1 12 (8–15).

Venter (Fig. 2B): Ornamentation on metasternal region with a "V" like striation, anogenital region with six pairs of genital setae, four pairs of agenital and one pseudanal setae.

Gnathosoma: Palp chaetotaxy: 2–2–5 (1ω). Acute eupathidium (Fig. 2G) without terminal dilation, palptarsus longer than stylet. Palp dimension: 45 (42-47).

Legs: All tarsi with terminate claw and a hairy empodium, empodial claw present (Fig. 2H). Solenidium I (ω I) short and thin, as long as half of tarsi width. Solenidium II (ω II) very short. Oval coxal organ (Fig. 2I). Vestigial seta k on tibia I spatulated. Measures of each leg: leg I 101 (82-109), leg II 79 (77-90), leg III 133 (88-133), leg IV 135 (90-135).

Specimens examined. Holotype female from *H. brasiliensis*, clone MDF180 from Igrapiúna, Bahia State, 11 December 2008, F. M. Nuvoloni coll; 10 paratypes females from *H. brasiliensis*, clone FDR 5788, from Igrapiúna, Bahia State, collected on May, June and September 2008, E. B. Castro coll. Specimens deposited at Acari collection DZSJRP. Male not found.

Remarks: The new species resembles *Brachytydeus opimus* (Kuznetzov & Zapletina) due to the pattern of striation type "*Tydeus*" , serrated dorsal setae, medium solenidium I (as long as width of tarsus I) and ventral striation with "V" pattern between metasternal setae.

The species can be distinguished by the following characters:

Brachytydeus sp. nov. 1

1. Dorsal reticulation on aspidossoma (AA0 region) and areas that do not reach the basis of setae, such as between *bo, c*1*, d*1, and *f*1.

2. All tarsi with empodial hooks.

3. *f*1 setae longer than *f*1–*h*1 distance.

Brachytydeus opimus

1. Dorsal reticulation only on aspidossoma (AA0 region).

2. Empodial hooks absent.

3. *f*1 setae with length about half of *f*1–*h*1 distance.

Brachytydeus sp. nov. 2 (Fig. 3)

Diagnosis: *Brachytydeus* sp. nov. 2 has acute and serrated dorsal setae, except for the trichobothria (*bo*), which is filiform and smooth. Dorsal striation type "*Tydeus*", without reticulated areas.

Dorsum (Fig. 3A): Prodorsum recurved. Thirteen pairs of serrated and acute dorsal setae, with medium length (Fig. 3C), except for the trichobothria (*bo*) (Fig. 3D), which is filiform and smooth. Dorsal striation type "*Tydeus*" (Kaźmierski 1998), without reticulation elements . Lyrisfissure *ia* (Fig. 3E) lies posteriorly to *c2*, at the distance as long as 1/2 of *c*1-*c2* sector. Lyrifissure *im* (Fig. 3F) lies in the same longitudinal row with *ia*, anteriorly to *e*.

Dimensions: Lenght of idiossoma 190 (180–195) and width 125 (120–125). Dorsal setae: *ro* 12 (11–13), *la* 13 (10–13), *bo* 28 (28–30), *ex* 12 (11–13), *c*1 12 (11–12), *c2* 12 (8–12), *d* 13 (11–13), *e* 14 (12–14), *f*1 15 (11–15), *f2* 15 (12–15), *h*1 16 (11–16), *h2* 15 (11–15), *ps*1 8(8–12).

Venter (Fig. 3B): Ornamentation on metasternal region with a "V" like striation, anogenital region with six pairs of genital setae, four pairs of agenital and one pseudanal setae.

Gnathosoma: Palp chaetotaxy: 2–2–5 (1ω). Acute eupathidium (Fig. 3G) without terminal dilation, palptarsus longer than stylet. Palp dimension: 53 (46-53).

Legs: All tarsi with terminate claw and a hairy empodium, empodial claw present (Fig. 3H). Solenidium I (ω I) short and thin, as long as half of tarsus I width. Solenidium II (ω II) very short. Oval coxal organ (Fig. 3I). Vestigial seta k on tibia I spatulated. Measures of each leg: leg I 92 (70-92), leg II 76 (62-76), leg III 83 (64-83), leg IV 95 (71-95).

Specimens examined: Holotype female from *H. brasiliensis*, from Amazon forest remnant owned to INPA (Instituto Nacional de Pesquisas da Amazônia), Manaus, Amazonas State, 08 August 2012, F. M. Nuvoloni coll; 5 paratypes females from *H. brasiliensis*, from rubber plantation, km 15 of BR 364, Acre State, collected on August 2012, F. M. Nuvoloni coll.. Specimens deposited at Acari collection DZSJRP.

Remarks: The new species resembles *Brachytydeus manitobensis* (Momen & Sinha, 1991), due to type "*Tydeus*" dorsal striation (Kaźmierski 1998), where reticulation is absent, acute eupathidium, rectangular tubercles on striae, acute and serrated dorsal setae, solenidium I (ωI) about half the width of tarsus and gnathosoma visible from above. The species are distinguished by following characters:

Brachytydeus sp. nov. 2:

1. Medium dorsal setae (about 12 µm).
2. Empodial claws present.
3. Five setae on palpal tarsus.
4. Vestigial seta k on tibia I spatulate.

Brachytydeus manitobensis:

1. Long dorsal setae (about 18 µm).
2. Empodial claws absent.
3. Six setae on palpal tarsus.
4. Vestigial seta k on tibia I forked.

Brachytydeus sp. nov. 3 (Fig. 4)

Diagnosis: *Brachytydeus* sp. nov. 3 has acute, nude dorsal setae. The dorsal ornamentation is characterized by the absense of reticulated area, with dense striation pattern.

Dorsum (Fig. 4A): Prodorsum recurved. Thirteen pairs of smooth and lanceolated setae, with medium length (Fig. 4C), except the tricobothria (*bo*) (Fig. 4D), which is filiform. Dorsal striation type "*Tydeus*" (Kazmierski 1998), without reticulated areas. Dimensions: lenght of idiossoma 200(185–257) and width 138(135–195). Dorsal setae: *ro* 15(10–15), *la* 12(10–13), *bo* 34(26–42), *ex* 13(10–14), *c*1 13(10–13), *c2* 13(9–13), *d* 14(11–14), *e* 13(11–13), *f*1 13(11–15), *f2* 15(12–15), *h*1 15(11–15), *h2* 15(10–15), *ps*1 9(5–11). Lyrisfissure *ia* (Fig. 2E) lies posteriorly to *c2*, at the distance as long as *c*1-*c2* sector. Lyrifissure *im* (Fig. 2F) lies in the same longitudinal row with *ia*, anteriorly and close to *e*.

Venter (Fig. 4B): Ornamentation on metasternal region with "V" like striation, anogenital region with six pairs of genital setae, four pairs of agenital and one pseudanal setae.

Gnathosoma: Palp chaetotaxy: 2–2–5. Acute eupathidium without terminal dilation (Fig. 4G). Palp dimensions: 43 (38-52).

Legs: All tarsi with terminate claw and a hairy empodium, with empodial claw present (Fig. 3H). Solenidium I (ω I) short and thin, as long as two thirds of tarsi width. Solenidium II (ω II) very short. Oval coxal organ (Fig. 4I). Vestigial seta k on tibia I spatulated. Measures of each leg: leg I 129 (92-136), leg II 112 (75-115), leg III 118 (83-122), leg IV 129 (85-142).

Specimens examined. Holotype female from *H. brasiliensis*, clone FDR 5788 from Igrapiúna, Bahia State, 19 November 2008, E. B. Castro coll; 10 paratypes females from *H. brasiliensis*, clone FDR 5788, from Igrapiúna, Bahia State, collected on October and November 2008, E. B. Castro coll. Specimens deposited at Acari collection DZSJRP.

Remarks: Resembles *Brachytydeus devexus* (Kuznetzov, 1973) due to the pattern of striation type *Tydeus*, palpal tarsi longer than stylet, dorsal setae equally shaped, short f1 setae (shorter than a quarter of f1–h1 distance). The new species is distinguished by *Brachytydeus devexus* due to slightly elongated body shape, setae *f*1 as long as 1/3 distance *f*1–*h*1, and also by a delicate and small empodial hook.

Brachytydeus sp. nov. 4 (Fig. 5)

Diagnosis: *Brachytydeus* sp. nov. 4 has rod-like dorsal setae, dorsal reticulation predominantly elongated, so it resembles type *"Veniparalorryia"* ornamentation, while reticulation is regular on the areas A(ro)(la) e A(h1)(h2)(ps1).

Dorsum (Fig. 5A): Prodorsum recurved. Thirteen pairs of smooth, rod-like setae (Fig. 5C), except the tricobothria (*bo*) (Fig. 5D), which is filiform. Dorsal reticulation predominantly elongated, but regular on areas A(ro)(la) e A(h1)(h2)(ps1) and on the basis of the others setae. Dimensions: lenght of idiossoma 198(198–242) and width 150(150–197). Dorsal setae: *ro* 26 (25–29), *la* 26(26–28), *bo* 41 (35–41), *ex* 21 (21–30), *c*1 25 (25–26), *c2* 24 (23–29), *d* 24(24–25), *e* 26(25–26), *f*1 25(25–28), *f2* 31 (26–31), *h*1 29 (23–29), *h2* 29 (25–30), *ps*1 22 (21–22). Lyrisfissure *ia* (Fig. 5E) lies posteriorly to *c2*, at the distance as long as 1/3 of *c*1-*c2* sector. Lyrifissure *im* (Fig. 5F) lies in the same longitudinal row with *ia*, posteriorly and close to *e*.

Venter (Fig. 5B): Ornamentation on metasternal region with "V" like striation, anogenital region with six pairs of genital setae, four pairs of agenital and one pseudanal setae.

Gnathosoma: Palp chaetotaxy: 2–2–5. Acute eupathidium without terminal dilation (Fig.5G). Palp dimensions: 57 (55-61).

Legs: All tarsi with terminate claw and a hairy empodium, with empodial claw present (Fig. 5E). Solenidium I (ω I) long and thin, as long as tarsi width. Solenidium II (ω II) very short. "Eight"-shaped" coxal organ (Fig. 5I). Vestigial seta k on tibia I spatulated. Measures of each leg: leg I 133 (133-145), leg II 107 (107-114), leg III 125 (125-146), leg IV 128 (123-136).

Specimens examined: Holotype female from *H. brasiliensis*, CDC 312 clones from Igrapiúna, Bahia State, 05 May 2009, E. B. Castro coll; 3 paratypes females from *H. brasiliensis*, PMB 01 and CDC 312 clones from Igrapiúna, Bahia State, collected on August 2008 and May 2009, E. B. Castro coll.. Specimens deposited at Acari collection DZSJRP.

Remarks: Resembles *Brachytydeus incrustatus* (Kuznetzov, 1972) due to the dorsal ornamentation, which is predominantly elongated, long solenidium I (ω I) (about tarsus I width) and acute eupathidium. The new species is distinguished by the following characters:

Brachytydeus sp. nov. 4:

1. Rod-like dorsal setae.
2. Elongated reticulation, forming a "*Veniparalorryia"* pattern.

3. Regular reticulation on A(ro)(la) and A(h1)(h2)(ps1) areas, which is noticed on the ventral region, and on the basis of the others dorsal setae: A(ex), A(c1), A(c2), A(d), A(e), A(f1), A(f2).
4. Three pointed-star-shape tubercles, present in all forms of reticulation.

Brachytydeus incrustatus

1. Club-like and hairy dorsal setae.
2. Elongated reticulation forming a *"Paralorryia"* pattern.
3. Regular reticulation absent.
4. Rectangular tubercles.

Brachytydeus sp. nov. 5 (Fig. 6)

Diagnosis: *Brachytydeus* sp. nov. 5 has a striated dorsum, which the area A(h1)(h2)(ps1) featuring dense and more opaque tubercles.

Dorsum (Fig. 6A): Prodorsum recurved, with thirteen pairs of smooth, and acute setae (Fig. 6C), *ro, la, ex, c*1*, c2, d*1 and *e*1 has medium length, while *f*1*, f2, h*1*, h2* and *ps*1 are longer. Tricobothria (*bo*) filiform (Fig. 6D). Dorsal striation type "*Paralorryia*", sub-type *Veniparalorryia* (Kazmierski 1998), which the area A(h1)(h2)(ps1) featuring dense and more opaque tubercles (Fig. 6I) than the other areas (Fig. 6H), reticulated areas absent. Dimensions: lenght of idiossoma 210 and width 165. Dorsal setae: *ro* 17, *la* 19, *bo* 37, *ex* 16, *c*1 19, *c2* 18, *d* 17, *e* 23, *f*1 23, *f2* 26, *h*1 23, *h2* 23, *ps*1 16. . Lyrisfissure *ia* (Fig. 6E) lies in the same longitudinal row and posteriorly to *c2*, at the distance as long as 1/4 of *c*1-*c2* sector. Lyrifissure *im* (Fig. 6F) lies in the same longitudinal row with *ia*, posteriorly to *e*.

Venter (Fig. 6B): Metasternal region with a "V" like striation, anogenital region with six pairs of genital setae, four pairs of agenital and one pseudanal setae.

Gnathosoma: Palp chaetotaxy: 2–2–5. Acute eupathidium without terminal dilation (Fig. 6G). Palp dimension: 55.

Legs: All tarsi with terminate claw and a hairy empodium, with empodial claw present (Fig. 6J). Solenidium I (ω I) very short and thin, as long as one quarter of tarsi width. Solenidium II (ω II) very short, as long as one half of ω I. Rounded coxal organ (Fig. 6). Vestigial seta k on tibia I spatulated. Measures of each leg: leg I 129, leg II 106, leg III 113, leg IV 121.

Specimen examined: Holotype female from *H. brasiliensis*, FDR 5788 clone from Igrapiúna, Bahia State, 15 December 2008, E. B. Castro coll..

Remarks: Resembles *Brachytydeus artichokei* (El Bagouri & Momen 1989) due to striation type "*Paralorryia*" without reticulated areas, acute eupathidium, gnathossoma dorsally visible and nude dorsal setae. The new species is distinguished by *Brachytydeus artichokei* due to eupathidium shorter and thinner than palpal tarsus and different striation sub-type, since the sub-type of the new species is "*Paralorryia-incerta*", while the subtype of *B. artichokei* is "*Biparalorryia-incerta*".

Discussion

Considering the whole dataset gathered about the distribution of species of *Brachytydeus* in Brazil, we noticed that *B. formosus, B. turrialbensis, Brachytydeus.* sp. nov. 1 and *Brachytydeus* sp. nov. 2 were finding in a broad territorial range. The outcomes differ from previous surveys, since *B. formosus* has been reported as the most common and widespread species on *Hevea* (Demite & Feres 2005, 2007, 2008, Hernandes & Feres 2006, Daud *et al.* 2010, Nuvoloni 2011 and Castro 2012), . *Brachytydeus turrialbensis*, which occurred in Amazonas, Acre, Mato Grosso, Maranhão and Bahia, has never been officially registered on *Hevea* spp. before, but it can be due to misidentifications, since *B. turrialbensis* has been abundant on surveys we have studied.

Brachytydeus sp. nov. 1 was registered in all states except Acre, Mato Grosso do Sul and Minas Gerais, while *Brachytydeus* sp. nov. 2 occurred in all states except Rondônia, Mato Grosso do Sul and São Paulo. The large distribution of these new species is comparable to *B. formosus*, and may reinforces the deficiency on the study of this genus. On the other hand, *Brachytydeus* sp. nov. 4 and *Brachytydeus* sp. nov. 5 were exclusively found on plantations of Bahia. The prior species may be endemic of these plots, however its absence on the other areas also could be caused by sampling error.

The highest diversity of species, nine and five, were found in the sites located in Bahia and Amazonas states, respectively. Both areas share similar moist weather, and surrounding forestry vegetation, which seems to enhance the diversity of species on the rubber trees, additionally, these areas have been kept free of the pesticide applications.

Brachytydeus turrialbensis, *B. formosus* and *B. podocarpus* were already found in Brazil. *Brachytydeus turrialbensis* occurs associated with *Annona* spp. (Annonaceae), in Pernambuco and Alagoas states (Sousa 2008). *Brachytydeus formosus* has been broadly recorded on several crop plants, for example rubber trees, (Feres 2000; Flechtmann & Arleu 1984; Hernandes & Feres 2006b; Vis *et al.* 2006), soybean (*Glycine max,* Fabaceae) (Rezende *et al.* 2012), citrus (*Citrus* spp. Rutaceae) (Silva *et al.* 2012), and grapevine (*Vitis vinifera*, Vitaceae) (Silva *et al.* 2014). *Brachytydeus podocarpus* was recorded on wild plants from natural environments of Rio Grande do Sul State. *Brachytydeus manitobensis* and *B. argentinensis* was already found in the Americas (Silva *et al.* 2013), but not in Brazil. Thereby, all these species, except *Brachytydeus formosus,* has not been recorded in rubber trees in Brazil so far.

Despite a huge diversity of mites has the rubber trees as the main habitat, few species have been on the spotlight of studies focusing on biologic, morphologic or behavioral aspects. The first step for a better comprehension of the mite fauna associated with any crop is to scrutinize and understand the actual diversity of species, since many misidentifications may happen during their recognition. The prior situation is more likely to occur with neglect and complex groups of mites (e.g. Tydeidae, Astigmata, Tarsonemidae), rather than taxa with more specialists and consequently more studied (Phytoseiidae, Tetranychidae, Eriophyidae).

Little importance is given to this group, since Tydeidae does not represent predatory mites that could help on control of pests, neither phytophagous mites that could perform any evident damage on the crop. Thus, in spite of *Brachytydeus* spp. being often recorded in inventories of rubber trees, they are usually sorted into morphospecies, which brings some clarification for ecological studies but none taxonomic gain. *Brachytydeus formosus* is actually the unique and consequently its role on the mite community species of the genus recorded on this host, evidencing the lack of information and specialists on the group (Hernandes e Feres, 2006).

Thus, getting deeper on the study of *Brachytydeus* spp. may reveal its actual diversity, and consequently its role on the mite community. Although the species are hardly distinguished alive when seen on the leaves, they can be easier separated by morphological characters on microscopy, as the shape and length of dorsal setae and type of dorsal ornamentation, like reticulated or striated pattern, and the presence and position of reticulated areas on striation.

Furthermore, considering André's review (2005), the synonymizaton between *Lorryia* and *Brachytydeus* must follow the rules of International Code of Zoology Nomenclature (article 31.2), which in turn defines that if the species is a latinized adjective, it must agree with genus' gender. For example, *Brachytydeus formosus* has been wrongly cited as "*Brachytydeus formosa*" in more recent papers, as a result of the former use in "*Lorryia formosa".*

Thereby, the current study contributed to the understanding of *Brachytydeus* from Brazil, since the description of new species, correct identification, and the analysis of their distribution will favor systematic and ecological studies of the taxa.. Therewith, in terms of taxonomic diversity we found a higher diversity than expected at the beginning, due to the new occurrences and new species that were discovered. Further studies on *Brachytydeus* spp. may consider to settle more attention on characters that are not usually considered for differentiation of species and genus, like dorsal ornamentation, shape of setae, and presence and shape of some organs like empodial hook, lirifissures and coxal organ, instead of legs chaetotaxy. However, filogenetic studies are still needed to determine the relative importance of these characters.

Acknowledgements

We would thank Dr. Eddie Ueckermann, Dr. Carlos H.W. Flechtmann and Msc. Guilherme Liberato da Silva for providing baseline knowledge for our studies, and Msc.

Marcel Santos de Araujo, Msc. José Marcos Rezende, and Msc. Elizeu B. de Castro for suggestions on drafting process of the study. The Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) that provided the fellowship to A.S. Mondin (2013/18265-0), to F.M. Nuvoloni (2010/19935-1), and 'Conselho Nacional de Desenvolvimento Científico e Tecnológico' (CNPq) (Proc. No 303435/2013-5), by fellowship and research grant to Reinaldo J.F. Feres.

References

Alvarenga, A. de P. & Carmo, C.A.F. do (2008) *Seringueira*. EPAMIG - Viçosa, Viçosa, MG, 894 pp.

André, H.M. (1981) A generic revision of the family Tydeidae (Acari, Actinedida). Organotaxy of the legs. *Acarologia* 22, 165–178.

André, H.M. (2005) In search of the true *Tydeus* (Acari, Tydeidae). *Journal of Natural History* 39, 975–1001.

André, H.M. & Fain, A. (2000) Phylogeny, ontogeny and adaptive radiation in the superfamily Tydeoidea (Acari: Actinedida), with a reappraisal of morphological characters. *Zoological Journal of the Linnean Society* 130, 405–448.

Baker, E.W. (1944) Seis especies de *Lorryia* (Acarina, Tydeidae). *Anales del Instituto de Biologia México* 15, 215–222.

Baker, E.W. (1968) The genus *Lorryia*. *Annals of the Entomological Society of America* 61, 986–1008.

Bellini, M.R., de Moraes, G.J. & Feres, R.J.F. (2005) Ácaros (Acari) de Dois Sistemas de Cultivo da Seringueira no Noroeste do Estado de São Paulo. *Neotropical Entomology* 34, 475–484.

Castro, E.B. (2012) Diversidade e sazonalidade da acarofauna em três clones de seringueira no sudeste do Estado da Bahia. Unesp São José do Rio Preto.

Cooreman, J. (1958) Notes et observations sur les acariens. VII - *Photia graeca* n. sp. (Acaridae, Canestrinidae) et *Lorryia formosa* n. sp. (Stomatostigata, Tydeidae). *Bulletin Institut Royal des Sciences Naturelles de Belgique* 34, 1–10.

Daud, R.D. & Feres, R.J.F. (2014) Community structure of mites (Arachnida: Acari) in six rubber tree clones. *Int. J. Acarol.* 39, 589–596.

Daud, R.D., Silva, E.R.O. da & Feres, R.J.F. (2010)a) Influência de *Cecropia pachystachya* na incidência de ácaros (Arachnida, Acari) e de *Leptopharsa heveae* (Insecta, Hemiptera) em cultivo de seringueira. *Revista de Biologia Neotropical* 7, 49–60.

Demite, P.R. & Feres, R.J.F. (2005) Influência de vegetação vizinha na distribuição de ácaros em seringal (*Hevea brasiliensis* Muell. Arg., Euphorbiaceae) em São José do Rio Preto, SP. *Neotropical Entomology* 34, 829–836.

Demite, P.R. & Feres, R.J.F. (2007) Ocorrência e Flutuação Populacional de Ácaros Associados a Seringais Vizinhos de Fragmentos de Cerrado. *Neotropical Entomology* 36(1), 117–127.

Demite, P.R. & Feres, R.J.F. (2008) Influência de Fragmentos de Cerrado na Distribuição de Ácaros em Seringal. *Neotropical Entomology* 37, 196–204.

Feres, R.J.. (2000) Levantamento e observações naturalísticas da acarofauna (Acari, Arachnida) de seringueiras cultivadas (*Hevea* spp., Euphorbiaceae) no Brasil. *Revista Brasileira de Zoologia* 17, 157–173.

Feres, R.J.F., Buosi, R., Daud, R.D. & Demite, P.R. (2007) Padrões ecológicos da comunidade de ácaros em euforbiáceas de um fragmento de mata estacional semidecidual, no Estado de São Paulo. *Biota Neotropica* 7, 0–0.

Feres, R.J.F., Russo, V. & Daud, R.D. (2010) Diversidade de ácaros (Arachnida : Acari) em *Hymenaea martiana* (Leguminosae) em gradiente de tamanho de plantas

Diversidade de ácaros (Arachnida : Acari) em *Hymenaea martiana* (Leguminosae) em gradiente de tamanho de plantas. *Biota Neotropica* 10, 119–126.

Ferla, N.J. & Moraes, G.J. De (2002) Ácaros (Arachnida, Acari) da seringueira (*Hevea brasiliensis* Muell. Arg.) no Estado do Mato Grosso, Brasil. *Revista Brasileira de Zoologia* 19, 867–888.

Ferla, N.J. & Moraes, G.J. de (2008) Flutuação populacional e sintomas de dano por Ácaros (Acari) em seringueira no Estado do Mato Grosso, Brasil. *Revista Árvore* 32, 365–376.

Flechtmann, C.H.W. (1973) *Lorryia formosa* Cooreman, 1958 – Um ácaro dos citros pouco conhecido no Brasil. *Ciência e Cultura* 25, 1179–1181.

Flechtmann, C.H.W. & Arleu, R.J. (1984) *Oligollychus coffeae* (Nietner, 1861), um ácaro tetraniquídeo da seringueira (*Hevea brasiliensis*) novo para o Brasil e observações sobre outros ácaros desta planta. *Ecossistema* 9, 123–125.

Gonçalves, P.S., Bataglia, O.C., Ortolani, A.A. & Fonseca, F.S. (2001) Manual de heveicultura para o estado de São Paulo. *Boletim Técnico IAC* 189, 77p.

Hernandes, F. a. & Feres, R.J.F. (2006)a) Diversidade e sazonalidade de ácaros (Acari) em seringal (*Hevea brasiliensis*, Muell. Arg.) no Noroeste do Estado de São Paulo. *Neotrop. Entomol.* 35, 523–535.

Hernandes, F.A. & Feres (2006)b) Review about mites (Acari) of rubber trees (*Hevea* spp., Euphorbiaceae) in Brazil. *Biota Neotropica* 6.

Hernandes, F.A., Feres, R.J.F. & Nomura, F. (2006) Biological cycle of *Lorryia formosa* (Acari, Tydeidae) on rubber tree leaves: A case of thelytoky. *Experimental and Applied Acarology* 38, 237–242.

Kaźmierski, A. (1989) Revision of the genera *Tydeus* Koch sensu André, *Homeotydeus* André and *Orthotydeus* André with description of a new genus and four new species of Tydeinae (Acari: Actinedida: Tydeidae). *Mitteilungen aus dem Hamburgischen Zoologischen Museum und Institut* 86, 289–314.

Kaźmierski, A. (1998) Tydeinae of the world: generic relationships, new and redescribed taxa and keys to all species. A revision of the subfamilies Pretydeinae and Tydeinae (Acari: Actinedida: Tydeidae) – part 4. *Acta Zoologica Cracoviensia* 41, 283–455.

Kaźmierski, A. (2008) Description of Two New Species of Tydeinae (Acari: Actinedida: Tydeidae) from Spain with the Remarks About the Iberian Species of Subfamily. *Annales Zoologici* 58, 357–363.

Krantz, W. & Walter, D.E. (2009) *A manual of Acarology*. Third Edit. Texas Tech University Press, Lubbock, Texas, 807 pp.

Lofego, A.C. & de Moraes, G.J. (2006) Ácaros (Acari) Associados a Mirtáceas (Myrtaceae) em Áreas de Cerrado no Estado de São Paulo com Análise Faunística das Famílias Phytoseiidae e Tarsonemidae. *Neotropical Entomology* 35, 731–746.

Mendel, Z. & Gerson, U. (1982) Is the mite *Lorryia formosa* Cooreman (Prostigmata Tydeidae) a sanitizing agent on citrus groves. *Acta Oecologica–Oecologia Applicata* 3, 47–51.

Nuvoloni, F.M. (2011) Influência da vegetação nativa de Mata Atlântica sobre a ocorrência e distribuição de ácaros (Acari) da seringueira (*Hevea brasiliensis* Muell Arg.). Unesp São José do Rio Preto.

Oudemans, A.C. (1925) Willoughby's Historia Insectorum en Methodus Insectorum. *Entomologische Berichten Helder* 7, 14–16.

Rezende, J.M., Lofego, A.C., Návia, D. & Roggia, S. (2012) Mites (Acari: Mesostigmata, Sarcoptiformes and Trombidiformes) associated to soybean in Brazil, including new records from the Cerrado areas. *Florida Entomologist* 95, 683–693.

Ripka, G., Laniecka, I. & Kazmierski, A. (2013) On the arboreal acarofauna of Hungary: Some new and rare species of prostigmatic mites (Acari: Prostigmata: Tydeidae, Iolinidae and Stigmaeidae). 3702, 1–50.

Silva, G.L. da, Cunha, U.S. da, Rocha, M. dos S., Panou, E.N. & Ferla, N.J. (2014) Tydeid and triophtydeid mites (Acari: Tydeoidea) associated with grapevine (Vitaceae: Vitis spp.) in Brazil, with the descriptions of species of *Prelorryia* (André, 1980) and Tydeus Koch, 1835. *Zootaxa* 3814, 495–511.

Da Silva, G.L., dos Santos Rocha, M., Reichert, M.B. & Ferla, N.J. (2013) A new species of the genus *Brachytydeus* Thor, 1931 sensu André, 2005 (Acari: Tydeidae) from Rio Grande do Sul State, Brazil, with a key to the species in the Americas. *International Journal of Acarology* 39, 620–624.

Silva, M.Z. da, Sato, M.E., Amadeu, C. & Oliveira, L. De (2012) Diversidade e dinâmica populacional de ácaros em pomar cítrico. *Bragantia* 71, 210–218.

Sousa, J.M. (2008) Diversidade de ácaros (acari) e biologia de *Tetranychus mexicanus* (McGregor) em Annonaceae. 65pp.

Theron, N., Roets, F., Dreyer, L.L., Esler, K.J. & Ueckermann, E. a (2011) A new genus and eight new species of Tydeoidea (Acari: Trombidiformes) from *Protea* species in South Africa. *International Journal of Acarology* 38, 257–273.

Thor, S. (1931) Norwegisohe Tydeidae I–VII, mit Kennzeiohnung vier neuer Gattungen. *Zoologischer Anzeiger Leipzig Bd* 94, 89–104.

Ueckermann, E.A. & Meyer, M.K.P.S. (1979) African Tydeidae (Acari). 1. The genus *Lorryia* Oudemans, 1925. *Phytophylactica* 11, 43–50.

Vis, R.M.J. de, Moraes, G.J. de & Bellini, M.R. (2006) Mites (Acari) of Rubber Trees (*Hevea brasiliensis* Muell. Arg., Euphorbiaceae) in Piracicaba, State of São Paulo, Brazil. *Neotropical entomology* 35, 112–120.

Zacarias, M.S. & Moraes, G.J. (2002)b) Mite diversity (Arthropoda: Acari) on euphorbiaceous plants in three localities in the state of São Paulo. *Biota Neotropica* 2, 1–12.

Table 1. *Brachytydeus* species analyzed and its distribution over Brazilian states.

Species/States	**AM**	**AC**	**RO**	**MT**	**MS**	**MA**	**BA**	**MG**	**SP**
Brachytydeus sp. nov. 1	X		X	X		X	X		X
Brachytydeus sp. nov. 2	X	X		X		X	X	X	
Brachytydeus sp. nov. 3		X					X	X	
Brachytydeus sp. nov. 4							X		
Brachytydeus sp. nov. 5							X		
Brachytydeus turrialbensis Baker	X	X		X		X	X		
Brachytydeus formosus Cooreman			X	X	X	X		X	X
Brachytydeus podocarpus Baker			X				X		X
Brachytydeus argentinensis Baker	X						X		
Brachytydeus manitobensis Momen & Sinha	X						X		

Table 2. Distribution of *Brachytydeus* species on *Hevea* spp.

Species	***H. brasiliensis***	***H. spruceana***	***H. guianensis***
Brachytydeus sp. nov. 1	X		
Brachytydeus sp. nov. 2	X	X	
Brachytydeus sp. nov. 3	X		X
Brachytydeus sp. nov. 4	X		
Brachytydeus sp. nov. 5	X		
Brachytydeus turrialbensis	X	X	X
Brachytydeus formosus	X		
Brachytydeus podocarpus	X		X
Brachytydeus argentinensis	X		
Brachytydeus manitobensis	X		

Figure 1. Plots studied on previous surveys, where *Brachytydeus* specimens were collected.

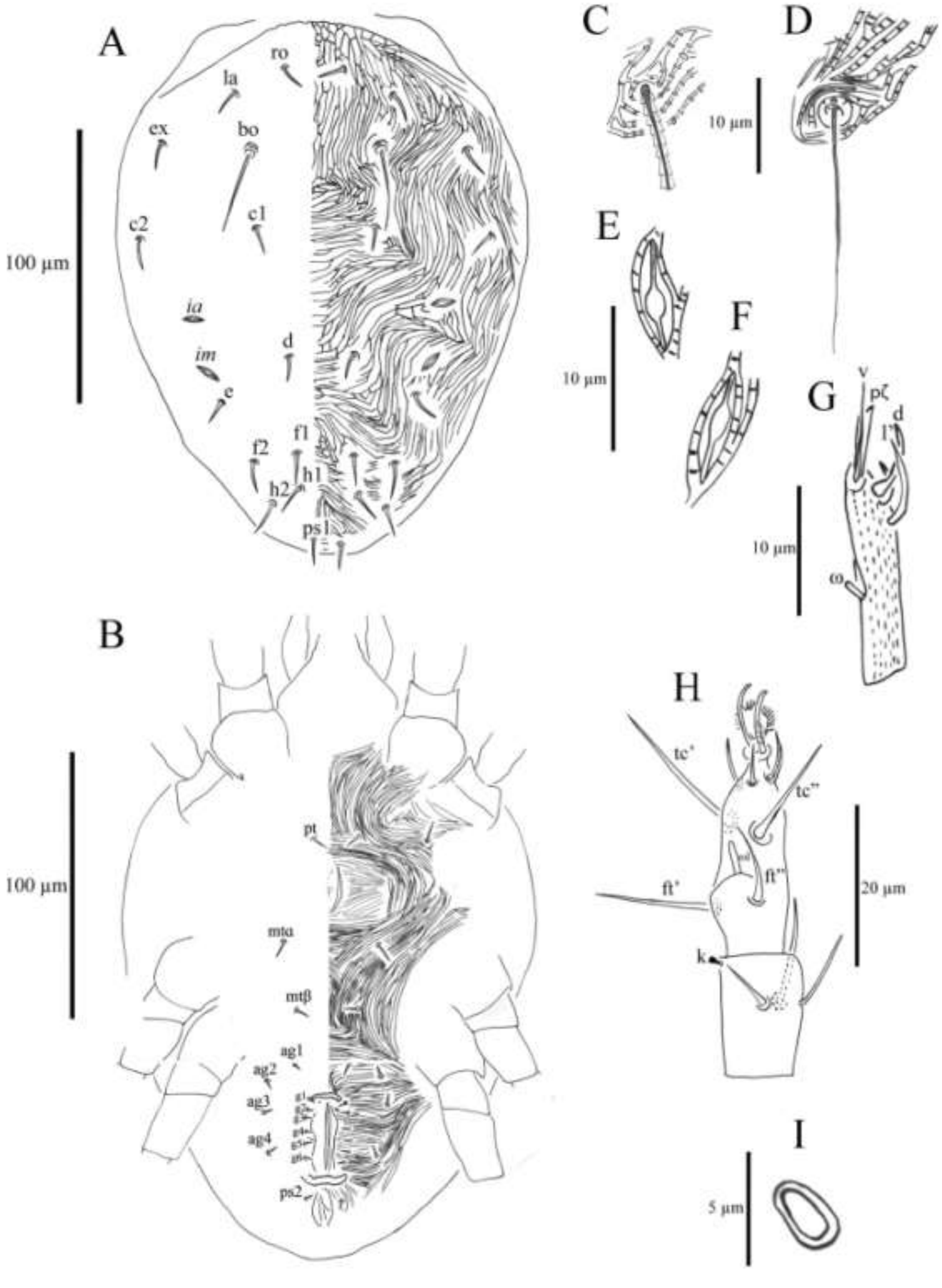


Figure 2. *Brachytydeus* sp. nov. 1. A – Dorsum. B – Venter. C – *f*1 seta. D – Tricobothria (*bo*). E – Lirifissure *ia*. F – Lirifissure *im*. G – Palpal tarsus. H – Tibia and tarsus leg I – Coxal organ.

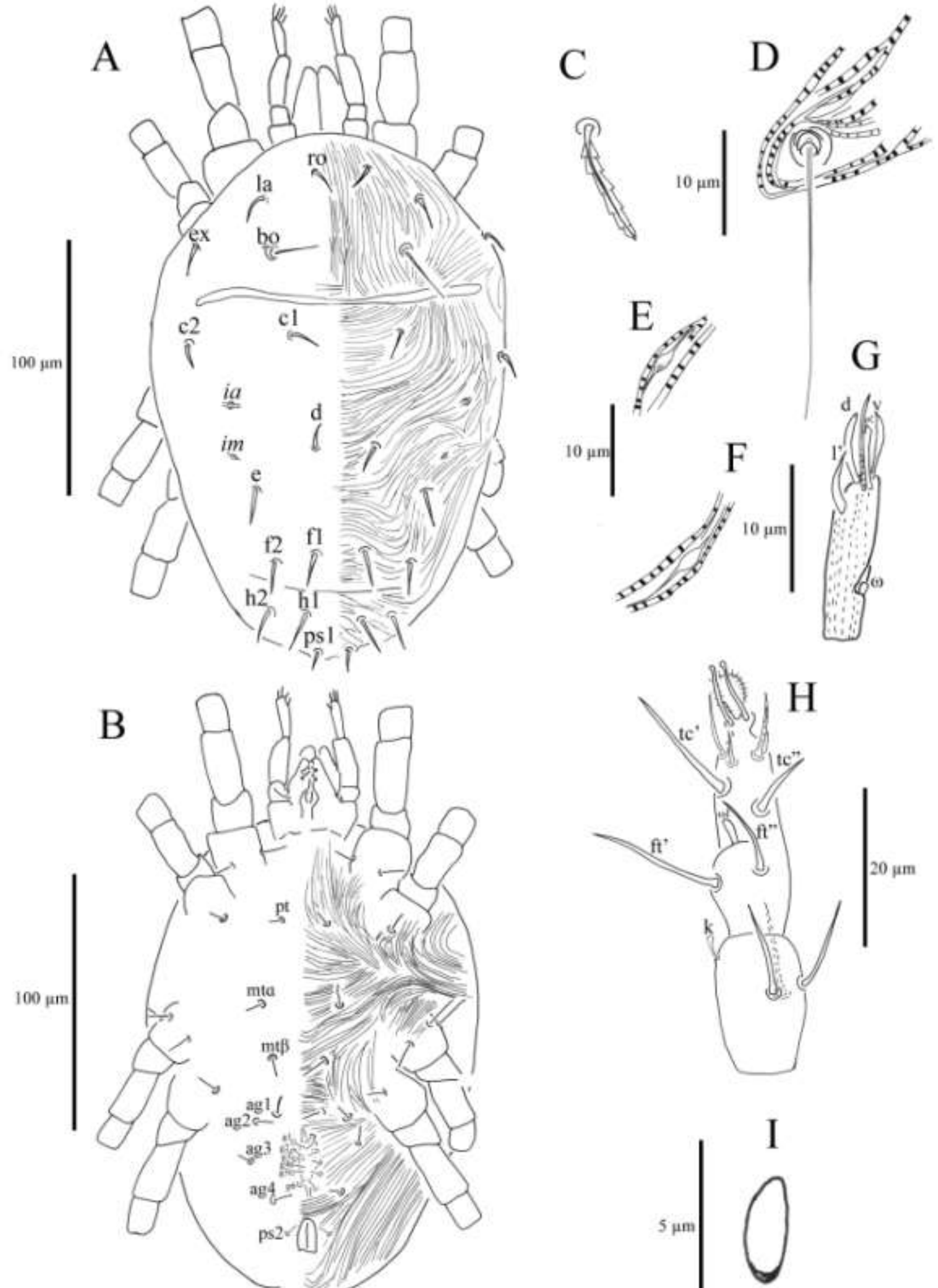


Figure 3. *Brachytydeus* sp. nov. 2. A – Dorsum. B – Venter. C – *d*1 seta. D – Tricobothria (*bo*). E – Lirifissure (*ia*). F – Lirifissure (*im*). G – Palpal tarsus. H – Tibia and tarsus leg I. I – Coxal organ.

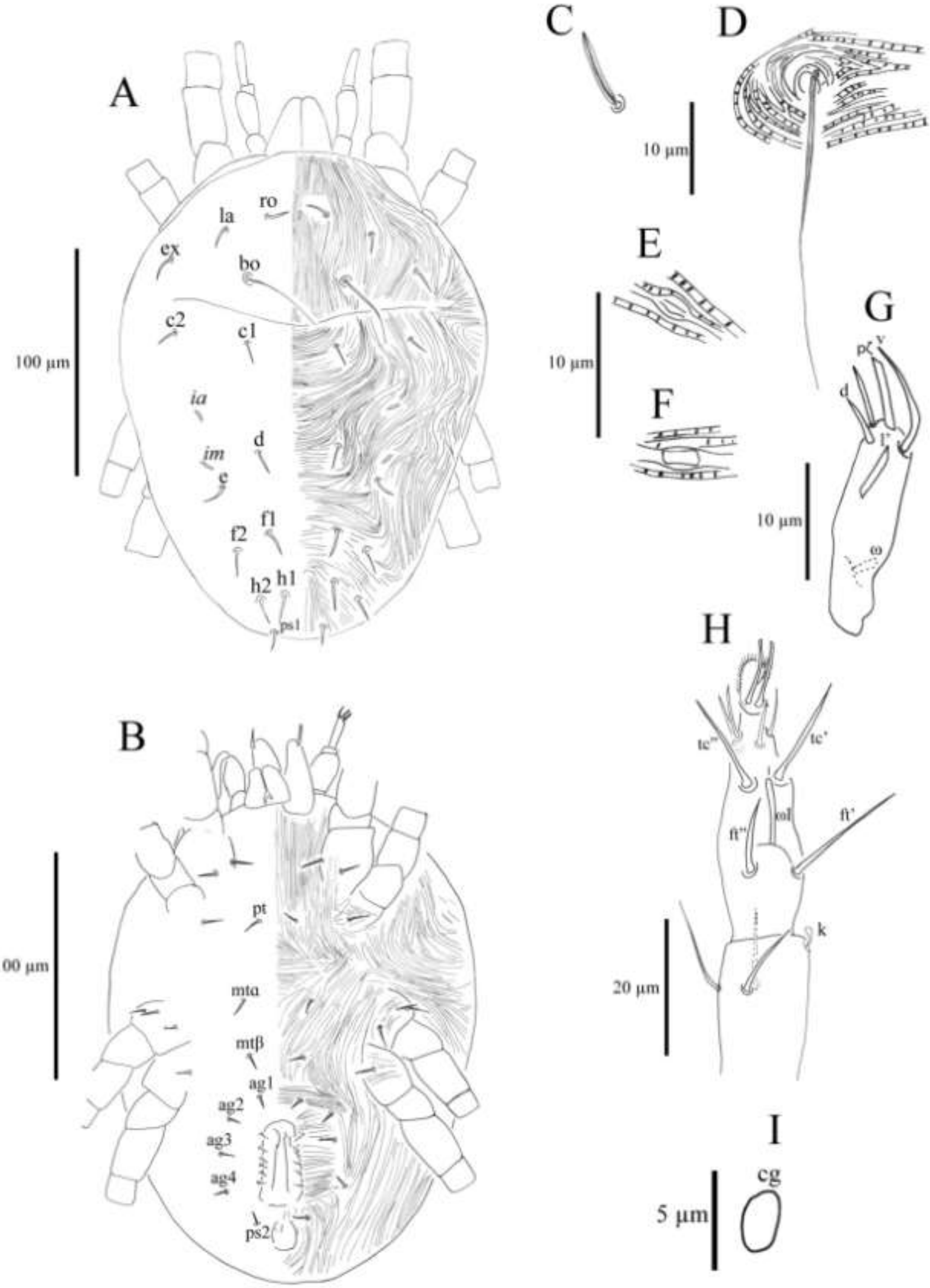


Figure 4. *Brachytydeus* sp. nov. 3. A – Dorsum. B – Venter. C – *d*1 seta. D – Tricobothria (*bo*). E – Lirifissure *ia*. F – Lirifissure *im*. G – Palpal tarsus. H – Tibia and tarsus leg I. I – Coxal organ.

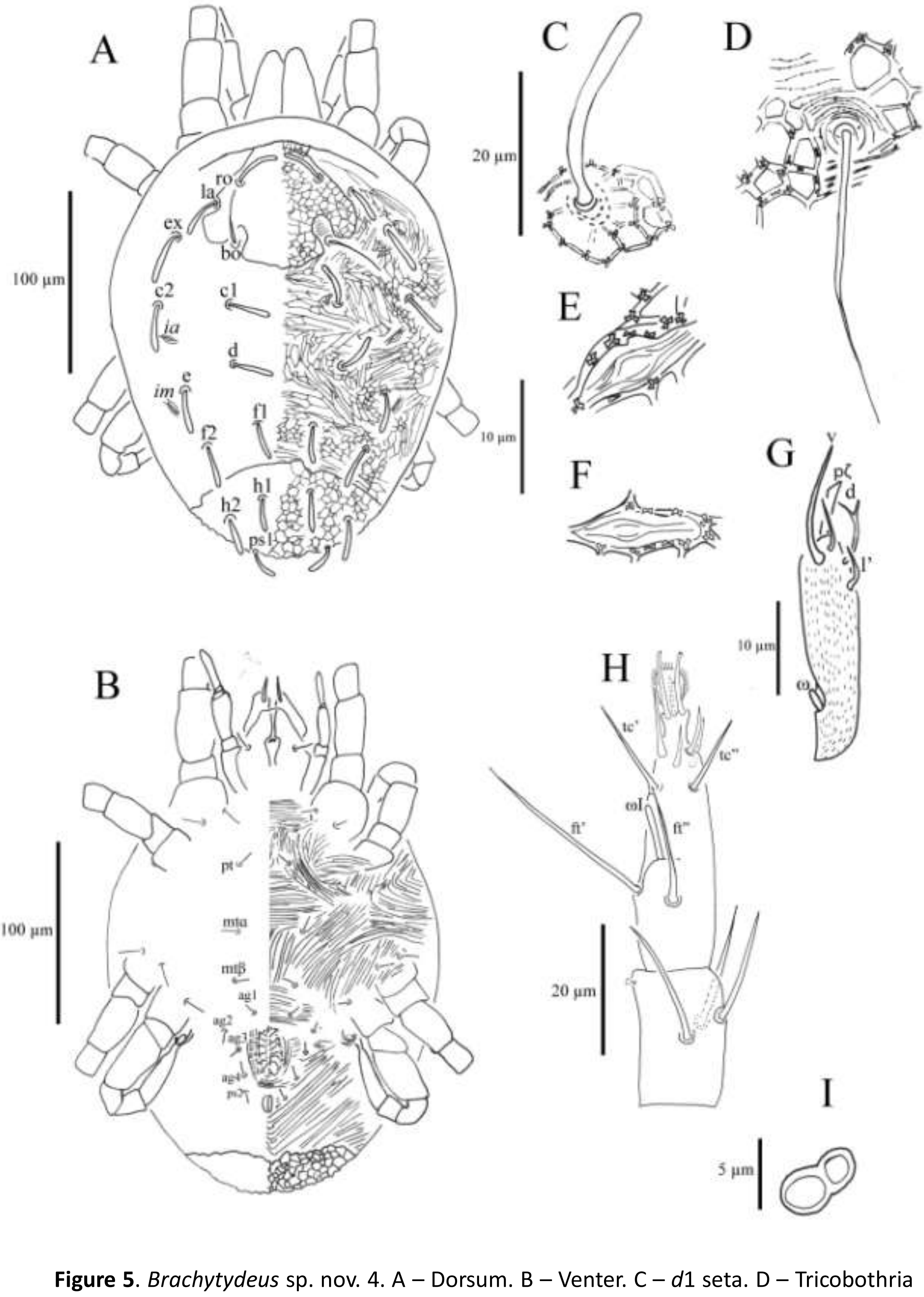


Figure 5. *Brachytydeus* sp. nov. 4. A – Dorsum. B – Venter. C – *d*1 seta. D – Tricobothria (*bo*). E – Lirifissure *ia*. F – Lirifissure *im*. G – Palpal tarsus. H – Tibia and tarsus leg I. I – Coxal organ.

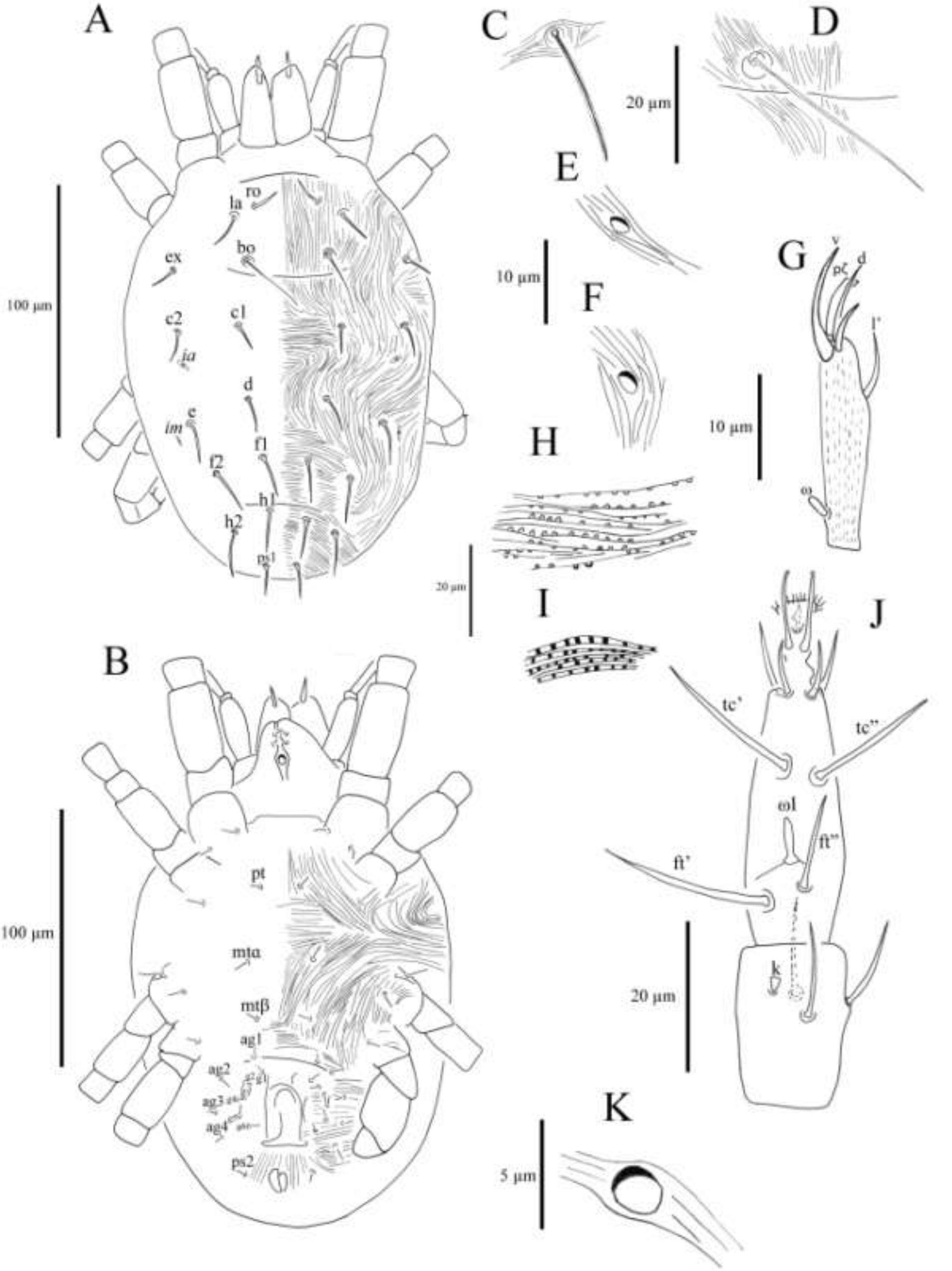


Figure 6. *Brachytydeus* sp. nov. 5. A – Dorsum. B – Venter. C – *f*1 seta. D – Tricobothria (*bo*). E – Lirifissure *ia*. F – Lirifissure *im*. G – Palpal tarsus. H- Striation and tubercles predominant on the dorsum. I- Striation and tubercles on the A(h1)(h2)(ps1) region. J – Tibia and tarsus leg I. K – Coxal organ.

Capítulo V

Species turnover through time: colonization and extinction dynamics across metacommunities

Felipe M. Nuvoloni, Reinaldo J. F. Feres, Benjamin Gilbert

Manuscript Submitted to The American Naturalist Journal.

Status: In review

Abstract

Studies of species-time relationships often assume that species accumulation in space and time are analogous, yet fail to justify this assumption. Many temporal dynamics, including successional change and several metacommunity processes, are inconsistent with this assumption because sampling through time cannot be considered random. We developed a new approach for species-time relationships that decomposes species turnover into colonization and extinction components, which may change predictably but unequally as a result of successional dynamics and environmental changes. We applied this approach to metacommunities of mites associated with rubber trees distributed over large spatial (>1000 km) and temporal (> 150 – 350 generations) scales in Brazil. Temporal turnover was synchronous among communities and driven by high colonization during some months and high extinction in others. These dynamics tracked climatic conditions that shifted seasonally – turnover was highest at low temperatures and high humidity, whereas colonization peaked at moderate temperatures and when temperature showed large increases between subsequent sample periods. These correlations with environmental conditions provide signatures of underlying processes, such as temporal species sorting, that produce patterns inconsistent with regular species-time models. Our approach uncovers the processes that generate temporal turnover and their mechanistic underpinnings, providing new insights into the temporal structure of diversity.

Keywords: acari, metacommunity, patch dynamic, species time relationship, species sorting, turnover, partitioning, *Hevea brasiliensis,* succession, colonization, extinction, STR, STAR

Introduction

Understanding how species diversity changes across space and through time are two fundamental goals in ecology (Rosenzweig 1995, 1998, Whittaker et al. 2001, Villéger and Brosse 2012). Since species area relationships (SARs) were first formalized, they have been broadly applied and have shown fairly consistent relationships between diversity and area sampled (Preston 1960; MacArthur & Wilson 1967; Rosenzweig 1995). In contrast, the species time relationship (STR) has lagged in its development, with only a few studies in the 1900s (Preston 1960; Rosenzweig 1995, 1998).

The underlying processes that generate species turnover through time are central to many ecological theories (Rosenzweig 1995, 1998), and development of approaches that are sufficiently flexible to test divergent spatio-temporal models is fundamental to understanding the underlying causes of this turnover (White et al. 2010). For example, island biogeography theory and neutral theory propose distinct temporal signatures of diversity that should be amenable to empirical tests (MacArthur and Wilson 1967, Hubbel 2001, Gilbert et al. 2006). Many metacommunity models also contain mechanisms that could allow for non-random species turnover through time, such as species-environment relationships that should be sensitive to fluctuating environmental conditions (e.g., Loreau *et al.* 2003; Leibold *et al.* 2004), but these mechanisms have yet to be empirically tested on temporal patterns of diversity.

Efforts to quantify species turnover through time, as well as the outcome of space and time interactions, have increased greatly in the last decade, with the approaches used mirroring those of SARs (Adler & Lauenroth 2003; Adler *et al.* 2005; White *et al.* 2010; Sheiner *et al.* 2011; Matthews & Pomati 2012). For example, the species-time relationship (STR) and integrative species-time-area relationship approach (STAR) argue in favor of a time for space substitution (Adler & Lauenroth 2003). This approach is based on Preston´s analogy between space and time, where diversity is driven by similar processes: ecological and evolutionary change, as well as sampling error (Preston 1960).

The STAR approach has provided good statistical fits to species richness data and has shown similar patterns of species accumulation through time and space (e.g., Adler *et al.* 2005; Matthews & Pomati 2012; Juan & Hewitt 2014). Nonetheless, little progress has been made to clarify the processes or mechanisms underpinning species turnover through time (White & Gilchrist 2007, but see Korhonen *et al.* 2010) or even to test Preston´s assumptions that underlie the STR approach. In this paper, we develop a new approach that tests the underlying processes that cause temporal turnover and relaxes the assumptions of the STR approach.

One assumption for applying the SAR to quadrats is that the quadrat that is first considered is arbitrary, so that the richness in one quadrat is calculated as the mean richness across all quadrats, and the increase in species with area measures the change in this mean as more quadrats are combined in each sample; this assumption of arbitrary sampling ensures that scaling exponents are always positive (Preston 1960). The space-time analogy requires that sampling in time also be arbitrary in order to constrain the scaling exponent. In many STR studies the strict assumption of completely random sampling is dropped, with authors using a temporally nested approach whereby the order of sampling sequences is maintained, but all transitions of equal length are considered equally probable. For example, Adler & Lauenroth (2003) consider all transitions from year *n* to year *n*+1 to be equally representative of the change in species richness for one year. This assumption only holds if species turnover through time represents an equilibrium condition of stochastic colonization and extinction events (Fig. 1A).

When species turnover has an underlying deterministic signal, as may be expected in successional communities or those undergoing chronic environmental change, the space-time analogy fails (Fig. 1B). Although (Preston 1960) and others have noted that the STR may result from deterministic changes, they have not recognized that the calculation of STR will obscure rather than clarify the effects of these changes because it uses an averaging approach (but see White & Gilchrist 2007). Even when the space-time analogy holds, the mechanisms that drive temporal turnover in communities remain untested with STRs, suggesting an alternate approach is needed to meet the goal of identifying the ecological processes responsible for changes in diversity through time.

In this paper we develop a method for testing species turnover through time that draws on metacommunity and Island Biogeography theory, and does not rely on STR assumptions. In metacommunity models, the change in diversity (ΔS) of any patch is defined as the balance between colonization (**C)** and extinction (**E)** events for all species over a given period of time. Temporal turnover, defined as the change in species present in a patch from one period of time to the next, is the sum of colonization and extinction events across all species. Some multivariate distance metrics, such as Sorensen distance ($D_{Sorensen}$), provide a measure of turnover that can be decomposed into colonization and extinction components:

$$D_{Sorensen} = \frac{\mathbf{C+E}}{S_1+S_2} \qquad \textbf{(1)}$$

Sorensen distance is standardized by the species richness at both time periods; this is useful when variation increases with mean species richness, as is expected through random sampling processes and has been derived for some models (e.g. MacArthur & Wilson 1967). At equilibrium or quasi-equilibrium conditions, net colonization and extinction rates must be roughly equal. In this case, eqn (1) would be sufficient for modeling turnover, and indeed $D_{Sorensen}$ can be used to determine the scaling exponent for SARs and STRs. However, if colonization or extinction dynamics are changing as a function of time, environment or metacommunity characteristics, then measuring the relative contributions of **C** and **E** will inform the underlying process. This can be done by recognizing that $D_{Sorensen}$ is the mean of **C** and **E** when the latter are standardized by the mean species richness ($\bar{S}$) of the two periods measured:

$$D_{Sorensen} = \left(\frac{\mathbf{C}}{\bar{S}} + \frac{\mathbf{E}}{\bar{S}}\right)/\mathbf{2} \qquad \mathbf{(2)}$$

We define relative colonization (RC) as a metacommunity metric that quantifies the amount of turnover due to **C**. Using the same standardization that accounts for higher turnover with more species, RC is defined as:

$$Relative\ colonization\ (RC) \equiv \frac{\mathbf{C}}{\bar{S}} - D_{Sorensen} \qquad \mathbf{(3a)}$$

$$= \frac{\mathbf{C\text{-}E}}{2\bar{S}} \qquad \mathbf{(3b)}$$

which expresses colonization of a patch relative to turnover (eqn. 3a), or equally, the amount of turnover that is due to colonization compared to extinction (eqn. 3b). In systems with high **C** and **E**, or when measurements are taken at long periods relative to colonization and extinction rates, RC will not show deterministic trends whereas Sorensen distance will increase. The RC metric attains a maximum value of one when all turnover results from colonization events. Similarly, it attains negative values when more turnover results from extinction events than colonization events, reaching a minimum of negative one when turnover is due solely to extinction (Fig. A1). When a metacommunity is at equilibrium such that **E** = **C** on average, the mean RC of the metacommunity will be zero regardless of the rate of species turnover, and the STR approach may then appropriate (Fig. 1A). In contrast, when **E** and **C** are temporally structured, RC can be used to understand these changes.

An advantage of the isolating colonization from turnover using the RC metric is that it allows researchers to separate mechanisms that drive greater colonization or extinction from those that simply cause higher turnover. More concretely, changes in species diversity over time are often modeled as a function of environmental conditions, such as changes in temperature or rainfall. By testing the effect of environmental variables on turnover and RC separately, it is possible to determine when changes in the environment simply speed up both colonization and extinction dynamics, and when they actually promote a greater diversity of species.

We test the effectiveness of our RC metric in metacommunities of mites associated with rubber trees (*Hevea brasiliensis* Muell. Arg. Euphorbiaceae) in three provinces in Brazil. These communities comprise a spatially extensive sample (>1000 km) that was collected over the course of five years, for a total of thirteen sites that included 250 to 400 rubber trees each. Each site functions as a metacommunity, with trees acting as local assemblages with hundreds of leaves that are habitat for the mites. Species passively disperse within and among trees by wind or phoresis over long distances and actively disperse over short distances. Rubber trees are deciduous and have synchronized phenological cycles across regions so that all leaves senesce during the dry season (late July or August) and new leaves emerge in September. This annual cycle corresponds to 30-60 generations depending on the mite species (Feres et al. 2010, Daud et al. 2012). The combination of seasonal and dispersal dynamics makes the mite system particularly well suited to testing metacommunity processes over time.

Our goals for this study were to (1) determine whether the STR approach was appropriate for our data by examining whether colonization and extinction dynamics were directional over time, (2) to determine whether environmental conditions are predictive of turnover and RC, and (3) to test if environmental conditions that drive turnover differ from those that influence RC. We show that the RC index we develop is not only better suited to the temporal dynamics of our system than the STR approach, but also that it clarifies the importance of ecological processes that other measures of turnover fail to detect.

Methods

Study system

We built a data set from five previous surveys: (Demite & Feres 2008; Nuvoloni 2010; Castro 2011; Daud *et al.* 2010; Daud & Feres 2014). These surveys covered 13 sites from 3 provinces in Brazil, and were sampled between 2004 and 2009. The surveys applied the same methodology of sampling, with collection of leaflets occurring monthly or bi-weekly for the period of one year; we included monthly samples in our data set. A set number of trees were sampled in each site by removing a fixed number of leaves from the tree crown. The number of trees sampled and number of leaves varied among surveys but was consistent within surveys (appendix A). We discuss how these differences in sampling were addressed in our statistical methods below.

In total, our data contained more than 150 species of mites and approximately one million individuals from a total of 225m^2 of leaf area.Voucher specimens are housed at the Acari collection (DZSJRP; available at http://www.splink.cria.org.br) of the Laboratório de Acarologia, Departamento de Zoologia e Botânica, Universidade Estadual Paulista, São José do Rio Preto, Brazil. All identification was standardised by F. Nuvoloni from voucher specimens.

Climatic data were obtained from local meteorological stations and the authors of surveys. The variables included were average temperatures (°C), average relative humidity (%), rainfall for 30 days prior to sampling (mm), and sunlight duration (h) (all variables taken monthly). From these data, we created two types of variables that were used in analysis. First, we created 'change variables', expressed below as Δ temperature, Δ relative humidity, and so on. Change variables give the change in each variable from month to month, and were calculated as the value in the later month minus the earlier month (e.g., $\text{temperature}_{\text{June}} - \text{temperature}_{\text{May}}$). These variables test the hypothesis that a change in diversity is driven by changes in environmental conditions. We then calculated 'mean variables' by taking the means of each environmental variable for each set of two adjacent months (e.g., mean of September and October, of October and November, and so on). This was done to test associations with the mean environmental condition experienced during a period of turnover. There were no significant correlations between the 'mean' variables and their associated 'change' variables (largest absolute value of $r = 0.08$). We included both groups of variables in our statistical analyses, as turnover or colonization could be favoured by certain conditions, such as high temperatures, or could respond more strongly to changes in environmental conditions, as is often assumed in multivariate tests of turnover (e.g., Gilbert & Bennett 2010). Relative colonization showed a hump-shaped relationship with one variable (Δ temperature; residuals of linear analysis had clear pattern), and a quadratic term for this (centered) variable was therefore included in the analysis. Similarly, rainfall was log-transformed to meet analysis assumptions.

Data analysis

September was established as the first phenological month (T_0) for all the data sets in order to standardize all sites by date of leaf emergence. To understand how species vary throughout the year and across sites, we estimated temporal alpha diversity (species richness) and gamma diversity, as well as species temporal turnover rates (RC and Sorensen) by considering the change in composition from each month to the following month. Our data excludes changes from time 0 to 1 if there were initially no leaves to sample and similarly excludes the end of the phenological year if a given tree had no leaves to sample. Excluding these data points avoids obvious directionality in colonization and extinction that must occur with habitat creation or destruction.

Due to differences in sampling effort across surveys (different numbers of trees sampled per time period), we first calculated each of these indices on a per-tree basis, and then generated mean indices for each site by month combination by averaging across all trees within sites for a given month. To account for systematic differences among sites, we used mixed models for all analyses with site considered a random factor. Alpha diversity was calculated as the mean diversity per tree in a given site and month. Observed gamma diversity was calculated as the observed cumulative number of species per tree up to the sampling date given. 'Estimated', or 'averaged' gamma was calculated in two ways. First, the cumulative number of species observed on average for the same number of months but assuming sampling through time is random (R software for this and all subsequent analyses; vegan library using function specaccum with the ‘exact’ method). This first approach is closest to Preston’s initial proposal for the STR. Second, we used a nested approach where ‘month 1’ was the average alpha of all months, month ‘2’ was the average of all species accumulated over a two month period (i.e. from month 1 to 2, month 2 to 3, month 3 to 4, etc.), as so on (following Adler and Laurenroth 2003). This nested approach provides twelve data points for ‘1 month’, eleven for ‘2 months’, and so on until there is a single data point for ’12 months’ – we used the mean of each time point for each tree. Species turnover was measured using Sorensen distance (eqn. 1; vegdist function in vegan library) and RC was calculated according to eqn. 2; both metrics have a single value for each transition (i.e. one transition from September to October, another for October to November, and so on), providing one less measure per tree than our original number of observations.

We first tested whether the random sampling assumptions of the STR approach was appropriate for our data. To do this, we calculated the ratio between estimated gamma (using random sampling assumptions) and observed gamma. By definition, these two measures of gamma need to converge at 12 months, when the estimated gamma and observed gamma are both equal to the total number of species observed. If the STR approach is appropriate, the slope of the ratio of these indices should not be statistically different from zero, meaning that the relative importance of **C** and **E** are essentially random through time and thus observed gamma diversity does not diverge from a random expectation; a significant slope indicates that the STR is not appropriate. This first test was performed using a linear mixed model (*lmer* function from lme4 library), with site considered a random factor and both the slope and slope by site terms tested for significance. Appendix B provides more details on how missing data were accounted for in both fully random and nested calculations of gamma diversity.

Following this initial analysis, we tested the influence of time and environmental covariates on RC and Sorensen distance using linear mixed models (lme function in nlme library). The RC index is designed to be independent of Sorensen distance (for our data, $r = 0.03$, $p = 0.7$), and they were therefore tested separately. The first set of tests was performed using phenological month as the predictor (with September equal to 1). Month was treated as a linear or class variable as was appropriate from examinations of the data and residuals.

The second set of tests determined the combination of the mean and change variables that predicted each index. For each index, we first calculated the variables that were significant predictors alone, and then included these alone and in all linear combinations to create a set of candidate models. These candidate models were then compared using AICc for model selection (aictab function in AICcmodavg library) and the best fitting model (highest weight) was tested for statistical significance. For these tests, rain was log transformed, and temperature was included as both a (centered) linear variable and a quadratic term.

Results

Our data showed non-random patterns of relative colonization and turnover with time, as well as temporal synchronization among metacommunities (Figs. 2-4). The relationship between alpha diversity and time period was non-linear but appeared consistent among sites. When gamma diversity was estimated assuming random temporal sampling (the STR approach), it appeared to consistently overestimate observed gamma diversity in the first months following leaf-out (Fig. 2A, Fig. A2). To examine this more formally, we tested the ratio of estimated gamma diversity (using STR assumptions) to observed gamma diversity, and found that there were consistent biases across sites although the exact slope differed (Fig. 2B; mean slope and slope x site interaction $p<0.0001$, using either nested STR or completely random sampling assumptions). It is important to note that this bias is not due to any fitting of the STR, but rather to systematic differences between observed gamma diversity in our sites and gamma that is estimated when temporal samples are considered completely random or nested. In other words, the assumption that the order of temporal sampling is arbitrary does not hold in our metacommunities.

Species turnover and RC showed distinct temporal patterns with underlying environmental correlates (Fig. 3). Relative colonization was highest at the beginning of the season, but showed a sharp decline in the third month followed by increases in the fourth and fifth months (Fig. 3A). This drop in the third month caused the overall trend in RC to diverge from a simple linear trend (AICc weight of analysis by month was 1, although linear analysis was still a significantly better fit than an intercept only model; Table A1). This abrupt period of extinction, coupled with high total turnover in the mite metacommunity, suggests that different communities of mites could be found in the young (less than 3 months) and the mature leaves. Months six through nine were the only months in which RC was not significantly different from zero (all other months with $p<0.01$), meaning that species turnover was driven by approximately equal colonization and extinction events in only this subset of four months.

Relative colonization was largely driven both by mean temperature and change in temperature from month to month – large increases in temperature between months caused RC to increase, and RC peaked at mean ambient temperatures close to 25° C (Fig. 3C, E). These two measures were independent ($r = 0.045$) and were both present in all models with the highest AICc weighting. Sunlight and mean ambient temperature (as a linear term) were present in some of the most highly weighted models, but the improvement in model fit was not sufficient to justify including either of these terms (Table A2).

Turnover (Sorensen distance) showed different trends through time than RC, and also varied significantly by phenological month (Fig. 3B; $p<0.001$); turnover was low from months six through nine, and highest in the final month before leaf senescence. Mean monthly turnover rates ranged from 0.5 to 0.75, indicating that species composition changed considerably among adjacent months. When considered in conjunction with RC, turnover was lowest when extinction and colonization rates were close to equal, and highest when extinction processes dominated (Fig. 3A, B).

Turnover was driven by ambient environmental conditions, not the change in those conditions between adjacent months (all change variables had $p > 0.05$). High relative humidity and temperature were the best predictors of Sorensen distance (Table A3), with turnover increasing with relative humidity (Fig. 3D) and decreasing at higher temperatures (Fig. 3F).

Discussion

The mite metacommunities showed distinct patterns of species accumulation and turnover through time that were inconsistent with STR assumptions (Fig. 2). These temporal patterns in species diversity resulted from changing rates of species turnover throughout the growing season, a phenomenon that is likely common in many ecosystems (e.g., Korhonen *et al.* 2010). Using our metacommunity approach to decompose turnover, we were able to determine when species turnover was driven by higher colonization rates, thus increasing species accumulation, and when it was largely driven by extinction events. Taken together, our measures of turnover and relative colonization clarified when temporal dynamics caused directional shifts in metacommunity dynamics, and the proximate environmental drivers of these dynamics. These insights provide a novel understanding of species turnover through time and how it differs from our understanding of species accumulation in space.

Many authors have proposed that metapopulation and metacommunity dynamics underlie both species-area and species-time relationships, both through extinction-colonization dynamics and sampling of environmental heterogeneity (e.g., Rosenzweig 1998; Rosenzweig & Ziv 1999; Adler et al. 2005; Scheiner et al. 2011). Metacommunities offer a clear example of why space and time approaches are often convoluted; species spatial turnover among similar habitat patches results from species changing over time through colonization and extinction events. Similarly, temporal turnover requires that species have refuges in order to persist over the long-term – these refuges may often be spatial (e.g., Venable and Brown 1988, Loreau et al. 2003). This joint dependence of spatial and temporal turnover on ecological processes has so far prevented a theoretical justification of any particular functional form for STAR studies, and more generally underlies the challenge of attributing different functional forms of SARs and STRs to specific ecological processes (White et al. 2010, Rosenzweig 1988). Our study raises a further concern that the data fit by STR studies rely on an averaging approach that may mask temporal trends in the data (Fig. 2). However, even without this concern, our approach bypasses many of the identified problems of STR studies by modeling colonization and extinction dynamics directly, thus allowing a more mechanistic understanding of temporal turnover.

Our approach allowed us to identify distinct effects of environmental drivers on species turnover and relative colonization that highlight the importance of isolating temporal metacommunity processes. For example, if species turnover were considered alone, it would appear that species accumulation increased with relative humidity and decreased with mean temperature (Fig. 3 D, F). However, species turnover was highest in months with very high colonization or extinction (Fig. 3 A, B). As a result, high average temperatures tended to lower turnover, but relative colonization peaked at intermediate temperatures (Fig. 3 E, F). In contrast, high relative humidity increased both colonization and extinction rates, and therefore was not a significant predictor of relative colonization.

The impact of environmental change on temporal diversity reflects its influence on the net colonization and extinction rates of all species, and as a result may be predictable from the population ecology of constituent species. Although data is lacking for most mite species, our results are consistent with the biology of mite species that have been well studied. For example, relative humidity increases egg hatching rates of six common predatory mite species on rubber trees, with RH above 70% causing the highest rates of hatching and below 50% causing hatching failure in some species (De Vis et al. 2006). These higher hatching rates should increase colonization rates for the predatory mites, which may in turn lower population sizes and increase the risk of extinction in their prey species. Relative humidity is also a strong predictor of mite infection by the fungal pathogen *Hirsutella thompsonii* (Nuvoloni et al. 2014). The *Hirsutella* genus produces many of the most important pathogens of eriophyoid mites, and likely represents an important cause of mortality and extinction in the mite community (Nuvoloni et al. 2014). Given the opposing effects of relative humidity on community dynamics through increased hatching, predation and pathogen infection, it is not surprising to find it predicts species turnover but not relative colonization.

The effect of temperature and seasonal changes in temperature are also consistent with the biology of well-studied mites and general metabolic processes. For many organisms, reproductive rates increase exponentially with temperature to a maximum, at which point they quickly decline (Savage *et al.* 2004; Amarasekare & Savage 2012; Dell *et al.* 2011). Although the temperature dependence of neotropical mites is not well studied, the data available indicate that the highest net reproductive rates and finite rates of increase occur from 25 - 30°C (Childers *et al.* 1991; Gerson 1992; Ali 1998). This peak in reproductive rates is slightly higher than the temperatures that lead to the highest level of relative colonization (Fig. 3C), a difference that is expected because of the non-linearity of the temperature-fitness relationship (Vasseur et al. 2014). Importantly, high reproductive rates are expected to lead to high colonization and low extinction because they reduce the probability of stochastic extinction events when populations are initially rare and lengthen time to extinction (Lande *et al.* 2003).

Temperature change between subsequent months was an additional driver of relative colonization rates, where large increases in temperature led to higher colonization than extinction rates (Fig. 3C). This additional role of temperature reflects the influence that a change in environmental conditions, rather than mean environmental conditions, has on metacommunity processes. Although it is not surprising that a shift from low to high population growth rates would increase the relative importance of colonization, it is interesting that changes in environmental conditions were not predictive of species turnover; many spatial analyses of turnover test the effects of environmental change, not the ambient environment *per se* (e.g., Tuomisto *et al.* 2003). Our data suggest that the ambient environment may simultaneously increase colonization and extinction rates, whereas change in the environment influences the relative size of these rates. Because only temporal data is suited to the decoupling of colonization and extinction, an important question for future studies is whether the different effects of ambient versus changing environments that we observed hold across ecosystems.

Temporal changes in diversity are likely due not only to external environmental conditions, but also to changes in habitat quality – the rubber tree leaf in the case of mites. As an example, mature rubber tree leaves are partially defended by the release hydrogen cyanide when damaged, but the amount of hydrogen cyanide released changes with leaf age (Lieberei 1988, 2007, Kadow et al. 2012). Similarly, leaf maturation alters leaf photosynthetic properties and associated chemical composition, such as the amount of soluble proteins and the presence of lignin (Miguel et al. 2007, Lieberei 2007). These changes are expected to favour some species while disadvantaging others, causing predictable shifts in species composition (Lieberei 2007, Daud et al. 2012, Kadow et al. 2012). In our system, full leaf maturation occurs after approximately fifty days in natural field conditions (Miguel et al. 2007); species changes associated with leaf maturation would be captured in our month 2 and 3 measurements, which is when we observe the first shift towards large numbers of extinctions. More generally, our results suggest that deterministic shifts in habitat quality with habitat age likely influence mite temporal diversity, just as they have been shown to be important to a variety of other ecosystems (e.g. Nilsson & Rosenberg 2000; Steffan-Dewenter & Tscharntke 2002).

The temporal dynamics in our metacommunities are distinct from those in classic metacommunity paradigms, yet have clear analogs to some of the spatial determinants of diversity proposed in classic paradigms (Leibold et al. 2004). For example, the species sorting paradigm is simply niche partitioning driven by spatial environmental heterogeneity (Leibold et al. 2004); this spatial partitioning allows species to coexist if they differ sufficiently in how they partition the environment and have some restriction to dispersal (Gilbert 2012). Environmental partitioning through time is only slightly more restrictive than the spatial partitioning required for species sorting (Abrams et al. 2013), and should produce signatures of species turnover like those we observed. Similarly, mass effects usually consider demographic sources and sinks that are spatially distributed, but these could equally arise through temporal sources and sinks that occur with seasonal shifts in environmental conditions (Rosenzweig 1998). More generally, our results raise the possibility that these temporal mechanisms may be important determinants of diversity in real metacommunities despite their absence from much of the classic metacommunity literature (Leibold et al. 2004). Although direct tests of hypotheses such as temporal source-sink dynamics require more detailed tests at a species level, their potential importance suggests that further study is warranted.

The metacommunity patterns that we observed also highlight other questions for future research, such as the role of environmental synchrony in maintaining diversity. Most previous research has predicted that synchronous environmental fluctuations destabilize metapopulations and metacommunities, either due to correlated extinctions across patches (Ovaskainen and Hanski 2004), or the inability of species to persist during periods of unsuitable conditions (Loreau *et al.* 2003). The temporal changes in mite diversity that we observed was surprisingly consistent over the large spatial scales of our study and over multiple years, and were further reflected in the seasonality of significant environmental covariates. This spatial synchrony appears inconsistent with conditions for stable persistence but is likely common in many ecosystems that experience predictable temporal changes, be it seasonally or over longer periods as is typical of multi-year climatic oscillations (e.g., Wright & Calderón 2006; Kane 2011). An important goal for these systems is to identify when temporal storage mechanisms structure diversity (e.g. Angert *et al.* 2009), and when synchrony functions opposite to classic predictions by stabilizing metacommunity dynamics (Vasseur and Fox 2007).

In summary, our research identifies a new approach to understanding species turnover that isolates the relative importance of colonization and extinction dynamics from species turnover, providing new perspectives on how these processes drive temporal diversity. Our approach is more mechanistic than previous STR methods, and avoids assumptions of random sampling through time that may invalidate STR methods in communities that experience temporally fluctuating environments. Additionally, because we link temporal dynamics to patterns of diversity and underlying environmental drivers, it promises to identify general trends across communities and provide new insights into the maintenance of diversity through time.

Acknowledgements

We thank P.R. Demite, F.A. Hernandes, E.R. Silva, E.B. de Castro, and R.D. Daud for providing access to the datasets from publications, theses and dissertations. The Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) provided fellowships to FMN (2010/19935-1, 2013/09600-0), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) provided research support and funding to RJFF (303435/2013-5), "Plantações Michelin da Bahia Ltda" and "Plantações E. Michelin Ltda" supported the field work, and the Canadian Natural Sciences and Engineering Research Council (NSERC) provided research funding to BG.

Literature Cited

Abrams, P. a, Tucker, C.M. & Gilbert, B. (2013). Evolution of the storage effect. Evolution 67: 315–27.

Adler, P.B. & Lauenroth, W.K. (2003). The power of time: spatiotemporal scaling of species diversity. Ecology Letters 6: 749–756.

Adler, P.B., White, E.P., Laurenroth, W.K., Kaufman, D.M., Rassweiler, A. & Rusak, J.A. (2005). Evidence for a general species–time–area relationship. Ecology 86: 2032–2039.

Ali, F. (1998). Life tables of *Phytoseiulus macropilis* (Banks)(Gamasida: Phytoseiidae) at different temperatures. Experimental and Applied Acarology 22: 335–342.

Amarasekare, P. & Savage, V. (2012). A framework for elucidating the temperature dependence of fitness. American Naturalist 179: 178–91.

Angert, A.L., Huxman, T.E., Chesson, P. & Venable, D.L. (2009). Functional tradeoffs determine species coexistence via the storage effect. Proceedings of the National Academy of Sciences USA 106: 11641–5.

Childers, C.C., Abou-Setta, M.M. & Nawar, M.S. (1991). Biology of *Eutetranychus banksi*: Life Tables on “Marsh” Grapefruit Leaves at Different Temperatures (Acari: Tetranychidae). International Journal of Acarology 17: 29–35.

Daud, R.D. & Feres, R.J.F. (2014). Community structure of mites (Arachnida: Acari) in six rubber tree clones. International Journal of Acarology 39: 589–596.

Daud, R.D., Feres, R.J.F. & Hernandes, F.A. (2012). Seasonal suitability of three rubber tree clones to *Calacarus heveae* (Acari, Eriophyidae). Experimental and Applied Acarology 56: 57–68.

Daud, R.D., Silva, E.R.O. da & Feres, R.J.F. (2010). Influência de *Cecropia pachystachya* na incidência de ácaros (Arachnida, Acari) e de *Leptopharsa heveae* (Insecta, Hemiptera) em cultivo de seringueira. Revista de Biologia Neotropical 7: 49–60.

Dell, A.I., Pawar, S. & Savage, V.M. (2011) Systematic variation in the temperature dependence of physiological and ecological traits. Proceedings of the National Academy of Sciences USA 108: 10591-10596.

Demite, P.R. & Feres, R.J.F. (2008). Influência de fragmentos de cerrado na distribuiçao de ácaros em seringal. Neotropical Entomology 37: 196–204.

Feres, R.J.F., Del’Arco, M. & Daud, R.D. (2010). Biological cycle of *Tenuipalpus heveae* Baker (Acari, Tenuipalpidae) on leaflets of three rubber tree clones. Revista Brasileira de Entomologia 54: 298–303.

Fridley, J.D., Peet, R.K., Maarel, E. Van Der & Willems, J.H. (2006). Integration of Local and Regional Species-Area Relationships from Space-Time Species Accumulation. American Naturalist 168: 133–143.

Gerson, U. (1992). Biology and control of the broad mite, Polyphagotarsonemus latus (Banks) (Acari: Tarsonemidae). Experimental and Applied Acarology 13: 163–178.

Gilbert, B. (2012). Joint consequences of dispersal and niche overlap on local diversity and resource use. Journal of Ecology 100: 287-296.

Gilbert, B. & Bennett, J.R. (2010). Partitioning variation in ecological communities: do the numbers add up? Journal of Applied Ecology 47: 1071-1082.

Gilbert, B., W. F. Laurance, E. G. Leigh, and H. E. M. Nascimento. 2006. Can neutral theory predict the responses of Amazonian tree communities to forest fragmentation? American Naturalist 168:304–17.

Hubbel, S.P. (2001). *The unified neutral theory of biodiversity and biogeography*. Princeton University Press, Princeton, New Jersey, USA.

Juan, S. & Hewitt, J. (2014). Spatial and temporal variability in species richness in a temperate intertidal community. Ecography 37: 183–190.

Kadow, D., Voß, K., Selmar, D. & Lieberei, R. (2012). The cyanogenic syndrome in rubber tree *Hevea brasiliensis*: tissue-damage-dependent activation of linamarase and hydroxynitrile lyase accelerates hydrogen cyanide release. Annals of Botany 109: 1253–62.

Kane, J. (2011). Multiyear variability of phytoplankton abundance in the Gulf of Maine. ICES Journal of Marine Science 68: 1833–1841.

Korhonen, J.J., Soininen, J. & Hillebrand, H. (2010). A quantitative analysis of temporal turnover in aquatic species assemblages across ecosystems. Ecology 91: 508–17.

Lande, R., Engen, S. & Sæther, B.-E. (2003). *Stochastic population dynamics in ecology and conservation*. Oxford University Press, Oxford, UK.

Leibold, M. A., Holyoak, M., Mouquet, N., Amarasekare, P., Chase, J.M., Hoopes, M.F., Holt, R.D., Shurin, J.B., Law, R., Tilman, D., Loreau, M. & Gonzalez, A. (2004). The metacommunity concept: a framework for multi-scale community ecology. Ecology Letters 7: 601–613.

Lieberei, R. (1988). Relationship of Cyanogenic Capacity (HCN-c) of the Rubber Tree *Hevea brasiliensis* to Susceptibility to *Microcylus ulei*, the Agent Causing South American Leaf Blight. Journal of Phytopathology 122: 54–67.

Lieberei, R. (2007). South American leaf blight of the rubber tree (*Hevea* spp.): new steps in plant domestication using physiological features and molecular markers. Annals of Botany 100: 1125–42.

Loreau, M., Mouquet, N. & Gonzalez, A. (2003). Biodiversity as spatial insurance in heterogeneous landscapes. Proceedings of the National Academy of Sciences USA 100: 12765–70.

MacArthur, R.A. & Wilson, E.O. (1967). *The theory of island biogeography*. Princeton University Press, Princeton, NJ, USA.

Matthews, B. & Pomati, F. (2012). Reversal in the relationship between species richness and turnover in a phytoplankton community. Ecology 93: 2435–2447.

Miguel, A.A., Oliveira, L.E.M. de, Cairo, P.A.R. & Oliveira, D.M. de. (2007). Photosynthetic behavior during the leaf ontogeny of rubber tree clones [*Hevea* *brasiliensis* (Wild. ex. Adr. de Juss) Muell. Arg.], in Lavras MG. *Ciência e Agrotecnologia*, 31, 91–97.

Nilsson, H.C. & Rosenberg, R. (2000). Succession in marine benthic habitats and fauna in response to oxygen deficiency: analysed by sediment profile-imaging and by grab samples. Marine Ecology Progress Series 197: 139–149.

Nuvoloni, F.M., Castro, E.B. de & Feres, R.J.F. (2014). The role of native vegetation on infection rates of *Calacarus heveae* (Acari: Eriophyidae) by *Hirsutella thompsonii* (Ascomycota: Ophiocordycipitaceae). Experimental and Applied Acarology 63: 157–69.

Ovaskainen, O. & Hanski, I. (2004). Metapopulation dynamics in highly fragmented landscape. In: *Ecology, Genetics and Evolution of Metapopulations* (eds. Hanski, I. & Gaggiotti, O.E.). Elsevier, Amsterdam, pp. 73–103.

Preston, F.W. (1960). Time and Space and the Variation of Species. Ecology 41: 612–627.

Rosenzweig, M.L. (1995). *Species diversity in space and time*. Cambridge University Press, New York, NY.

Rosenzweig, M.L. (1998). Preston's ergodic conjecture: the accumulation of species in space and time. In: *Biodiversity Dynamics: Turnover of Populations, Taxa and Communities* (ed. M. L. Mckinney & J. A. Drake). Columbia University Press, New York, NY, pp. 311–348.

Rosenzweig, M.L. & Ziv, Y. (1999). The echo pattern of species diversity: pattern and processes. Ecography 22: 614–628.

Savage, V.M., Gilloly, J.F., Brown, J.H. & Charnov, E.L. (2004). Effects of body size and temperature on population growth. American Naturalist 163: 429–41.

Sheiner, S.M., Chiarucci, A., Fox, G.A., Helmus, R.M., McGlinn, D.J. & Willig, M.R. (2011). The unerpinnings of the relationship of species richness with space and time. Ecological Monographs 81: 195–213.

Steffan-Dewenter, I. & Tscharntke, T. (2002). Insect communities and biotic interactions on fragmented calcareous grasslands—a mini review. Biological Conservation 10: 275–284.

Tuomisto, H., Ruokolainen, K. & Yli-Halla, M. (2003). Dispersal, environment, and floristic variation of western Amazonian forests. Science 299: 241–244.

Vasseur, D. A. & Fox, J.W. (2007). Environmental fluctuations can stabilize food web dynamics by increasing synchrony. Ecology Letters 10: 1066–74.

Vasseur, D.A., DeLong, J.P., Gilbert, B., Greig, H.S., Harley, C.D.G., McCann, K.S., et al. (2014). Increased temperature variation poses a greater risk to species than climate warming. Proceedings of the Royal Society B Biological Sciences 281: 20132612; doi: 10.1098/rspb.2013.2612.

Venable, D.L. & Brown, J.S. 1988. The selective interactions of dispersal, dormancy and seed size as adaptations for reducing risk in variable environments. American Naturalist 131: 360-384.

De Vis, R.M.J., Moraes, G.J. & Bellini, M.R. (2006). Effect of air humidity on the egg viability of predatory mites (Acari: Phytoseiidae, Stigmaeidae) common on rubber trees in Brazil. Experimental and Applied Acarology 38: 25–32.

White, E.P. (2004). Two-phase species-time relationships in North American land birds. Ecology Letters 7: 329–336.

White, E.P., Ernest, S.K.M., Adler, P.B., Hurlbert, A.H. & Lyons, S.K. (2010). Integrating spatial and temporal approaches to understanding species richness. Philosophical Transactions of the Royal Society B Biological Sciences 365: 3633–43.

White, E.P. & Gilchrist, M.A. (2007). Effects of population-level aggregation, autocorrelation , and interspecific association on the species – time relationship in two desert communities. Evolutionary Ecology Research 9: 1329–1347.

Whittaker, R.J., Willis, K.J. & Field, R. (2001). Scale and species richness: towards a general, hierarchical theory of species diversity. Journal of Biogeography 28: 453–470.

Wright, S.J. & Calderón, O. (2006). Seasonal, El Niño and longer term changes in flower and seed production in a moist tropical forest. Ecology Letters 9: 35–44.

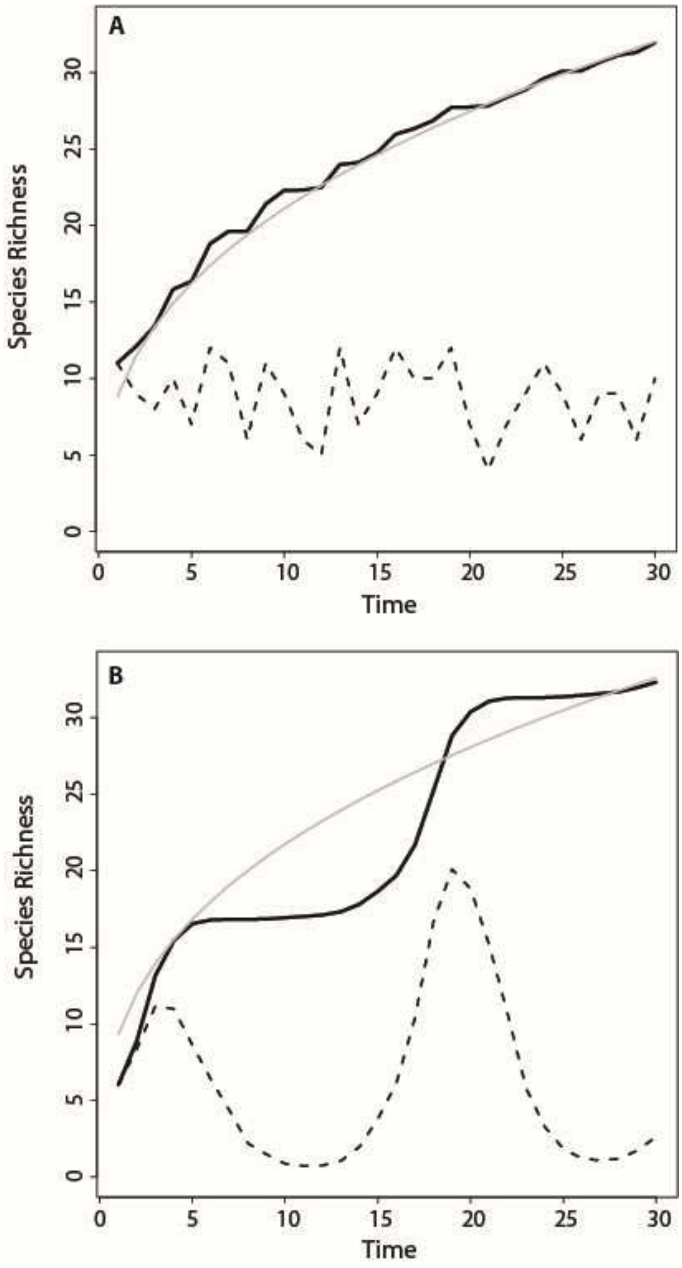


Figure 1: Conceptual model illustrating STRs in a single patch of a metacommunity (A) with random extinction and colonization events and no deterministic change in turnover, and (B) in a successional community undergoing non-random temporal turnover caused by changes in the relative importance of colonization and extinction events. Black and grey continuous lines represent observed and estimated (using nested averaging) Gamma diversity, calculated as the total number of species occurring at a site over time. Dashed lines show local (Alpha) diversity, calculated as the number of species present at a single point in time.

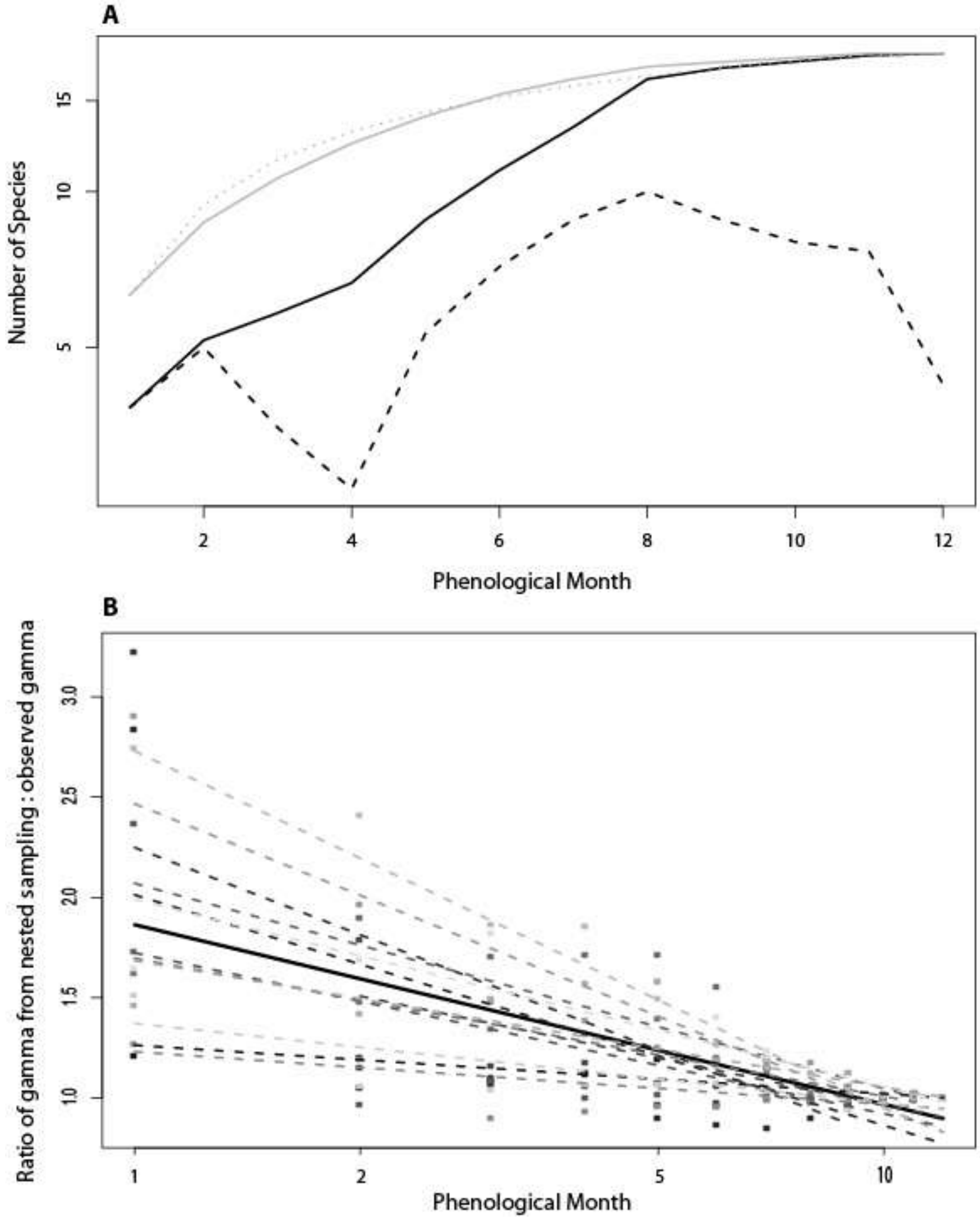


Figure 2: Consistent bias between estimated Gamma (using STR methods) and observed Gamma diversity. (A) Alpha (dashed line), observed Gamma (black line) and estimated Gamma (through nested resampling, gray line and completely random resampling, grey dotted line) by phenological month. This figure shows one representative site, with similar plots for all sites shown in Fig. A2. (B) Estimated gamma diversity (based on nested sampling) was consistently higher than observed gamma diversity early in the season, with their ratio always greater than unity. In (B), each dashed line is the best fit curve for one metacommunity, and the solid line is the mean ratio for all metacommunities. The site shown in (A) has the most similar intercept to the mean fitted model in (B).

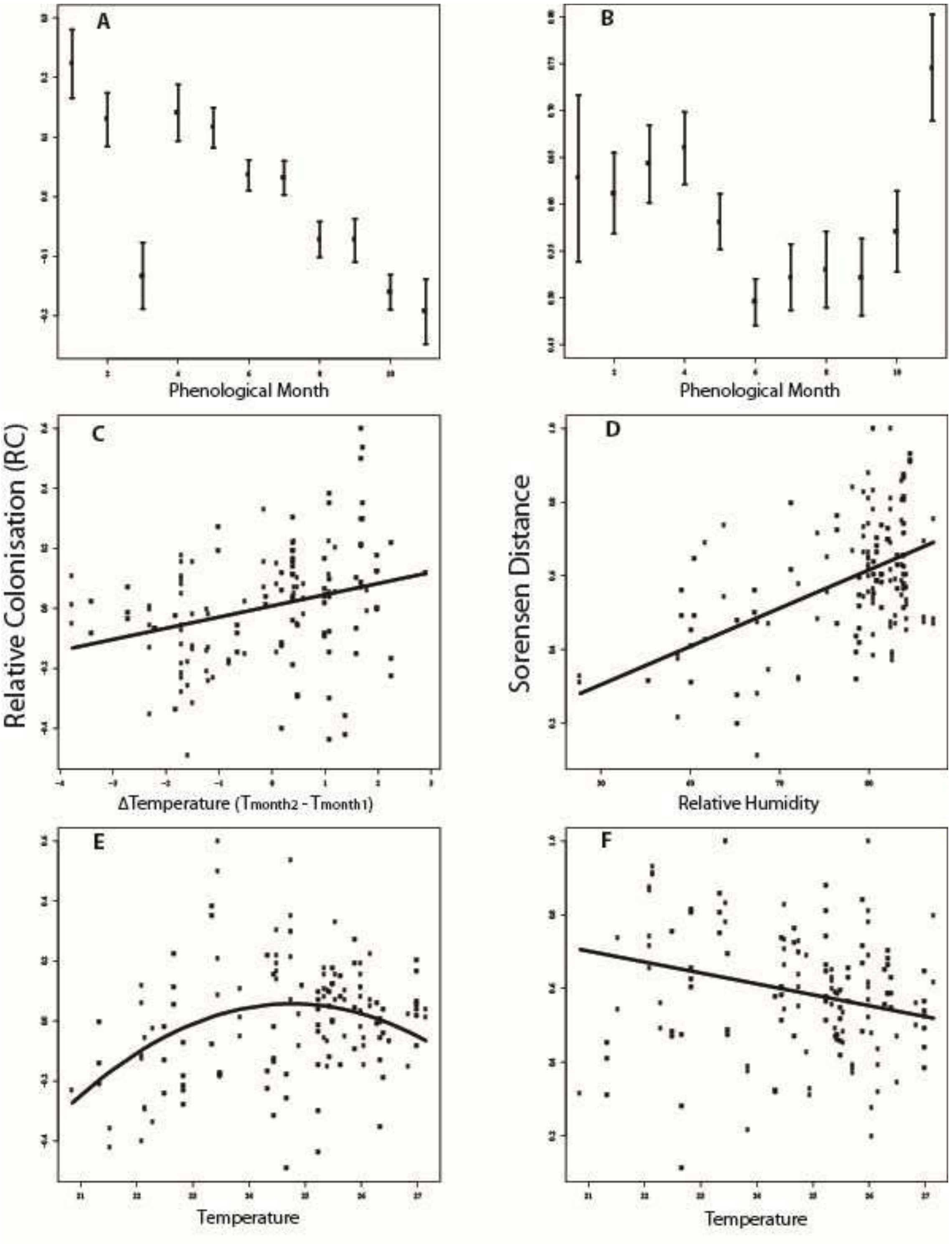


Figure 3: Relative Colonization (RC; panels A,C,E) and species turnover (Sorensen distance; panels B,D,F) respond differently to age of the metacommunity (A,B). Relative colonization increases with greater temperature increases between subsequent months (C), and responds additionally to mean temperature (E), with maximum colonization peaking at 25° C. Turnover does not depend on changes in environmental conditions between months, but instead increases with relative humidity (D) and decreases with temperature (F).

Appendix A

A.1: Survey methodologies

Although the sampling methodology was standardized among surveys, the surveys varied in terms of number of trees, leaflets and plots sampled. They also differed with respect to the cultivated clone that infers more or less resistance against phytophagous species and diseases, latex productivity, genetic and physiological conditions of the plant, crop age, climatic conditions, surrounding vegetation, biome domain, and year when the survey started. All the plantations were free of pesticides or fungicides exposure. The specific methodologies for each survey follows.

Daud and Feres 2013

The study was conducted in the experimental areas owned by Plantations E. Michelin Ltda. (17° 23′ S, 54° 45′ W), in Itiquira, Mato Grosso, central Brazil. The cultivated area covers 8484 ha, with over 100 rubber tree clones. Plants were 18 years old, and did not receive chemical pesticides during the study.

The leaflets were collected every 14 days, on average, from mid March 2004 to early March 2005, in six plots, which covered about 0.42 ha. Samplings were limited to the core area of the plot to avoid edge effect. The studied clones included GT 1, PB 217, PB 235, PB 260, PR 255, and RRIM 600. The authors sampled ten leaves of 10 plants, up to 7-m high in each plot, with a total of 100 leaves per plot. Only one leaflet from leaf was considered for analysis.

The region is located in the Cerrado biome domain. The climate is Koppen’s Aw tropical seasonal, characterized by distinctly rainy season, between October and Marc and a pronounced dry season between April and September, that receives 15% of the annual rainfall amount, that ranges from 1200mm to 1800mm (Ribeiro and Walter 1998). The mean annual temperature ranges between 20 and 26°C in average, reaching the maximum of 40°C (Ab´Saber 2003).

Demite and Feres 2007

The study was carried out in two plantations of rubber tree clone PB 235, also owned by Plantations E. Michelin Ltda, in Itiquira, Mato Grosso, central Brazil. The plantation areas were neighbored by two native fragments of Cerrado (sensu Ribeiro and Walter 1998) sorted as “Cerradão”, a tall closed savannah (17º 23’S, 54º 42’W) and a riparian forest (17º 22’S, 54º 41’W). The first plantation was about 17ha and the second, about 45ha. The samples were carried out from March 2004 to March 2005, and for both areas 7 leaves were taken from each 25 trees selected for collection and one leaflet per leaf was analysed, amounting to 175 leaflets per sample/area.

The region is located in the Cerrado biome domain. The climate is Koppen’s Aw tropical seasonal, characterized by distinctly rainy season, between October and Marc and a pronounced dry season between April and September, that receives 15% of the annual rainfall amount, that ranges from 1200mm to 1800mm (Ribeiro and Walter 1998). The mean annual temperature ranges between 20 and 26°C in average, reaching the maximum of 40°C (Ab´Saber 2003).

Daud *et al.* 2010

Daud and colleagues carried out samples from February 2007 to January 2008, in two rubber tree plantations of PB 235 clone, located in the rural area of São José do

Rio Preto municipality, São Paulo, southeast Brazil (20° 47’S, 49° 19’W). For both areas 10 trees were selected for collection and 10 leaves from each one was sampled every month, amounting 100 leaves per sample/site. Only one leaflet from each leaf was considered for analysis.

The sampling areas are located in the Brazilian Atlantic Forest domain, sorted by seasonal semi-deciduous forests physiognomy. The region’s climate is seasonal tropical with annual mean temperature between 22 and 23°C, with a rainy season between October and March, and dry season between April and September, when only 15% of the total annual rainfall of 1,100 mm (±225 mm) occurs (Barcha and Arid 1971).

Castro 2011

The collection of mites was carried out in an experimental area owned by Plantations Michelin from Bahia Ltda. (PMB), located in Igrapiúna, Bahia, northeastern Brazil (13°48’S, 39°10’W). The total cultivated area covers 5,000 ha, with over 100 rubber tree clones, while the experimental area is comprised by four blocks that include ten rubber tree clones, randomly situated in four lines of 20 trees. The samples were performed monthly from April 2008 to March 2009 and the clones CDC 312, FDR 5788 and PMB 01 were chosen for evaluation. For these clones, seven trees were selected per block, and seven leaves per tree with one leaflet taken from each leaf, amounting to 28 trees and 196 leaflets per clone/month.

The regional climate is Köppen’s Af, tropical humid, without a dry season, and mean annual rainfall higher than 1,500 mm. Mean average temperature is 24^{o}C, and the relative humidity remains close to 80% throughout the year (Ab´Saber 2003). The region is included in the domain of coastal Atlantic Rainforest, characterized as a tropical lowland rainforest.

Nuvoloni 2010

This study was conducted on five 1-ha plots placed in the Plantations Michelin from Bahia Ltda. (PMB (13°48’S, 39°10’W)), municipality of Igrapiúna, Bahia, northeastern Brazil. The total cultivated area covers 8,000 ha, that encloses a 5,000 ha of rubber tree plantation and 3,000 ha of native vegetation of coastal Atlantic Rainforest.

Each studied plot had 400 rubber trees approximately 12 years of age. Two plots were located in the core area of the plantation, and three plots were in the border are with native vegetation, classified as agroforestry systems. The samples were performed monthly from May 2008 to April 2009, in 15 rubber trees in each of the five plots. On each sample date, seven leaves were collected from around the tree crown of each plant up to 8 m high and one leaflet per leaf was surveyed, yielding 105 leaves per plot/month.

The climate is Köppen’s AF, tropical humid, without a dry season, with an average annual rainfall of 1,500–1,750 mm. Mean average temperature is 24^{o}C, and the relative humidity remains close to 80% throughout the year (Ab´Saber 2003).

Appendix B: Comparing observed gamma to randomized measures of species accumulation

To test the assumptions of the STR approach, we used both fully randomized and nested methods of estimating species accumulation through time and compared these to the observed species accumulation through time. As for all tests, we did this on a per tree basis and averaged all trees within a site for analysis.

The compiled data had occasional missing data points that occurred when a sample was lost or a leaf was unavailable to sample – this latter case occurred most frequently in September and August, the months of leaf out and senescence. To ensure that our comparison was fair, we used a few approaches to deal with this missing data and confirmed that they gave qualitatively similar results. First, we subset our data so that only trees present in the first month were used for all measures of species accumulation. Of the trees remaining in the data set, any tree that had a missing observation at a given month was removed from the analysis from that month onwards. For example, a tree sampled in months 1-4 and 6-12 would only be included in the analysis from months 1-4. This restriction was necessary for both nested and observed species accumulation to be comparable to the fully randomized species accumulation. We also reran the analyses without removing trees that had missing sampling dates – the former analysis was more conservative (showed a less pronounced difference between observed gamma and that found with the STR approaches, although all tests were highly statistically significant) and we therefore report this more conservative test.

For our indices (Sorensen and RC) we only removed a tree with a missing observation from the associated observation (e.g., a tree with missing data in month 4 would not have indices for the month 3-4 and month 4-5 comparisons).

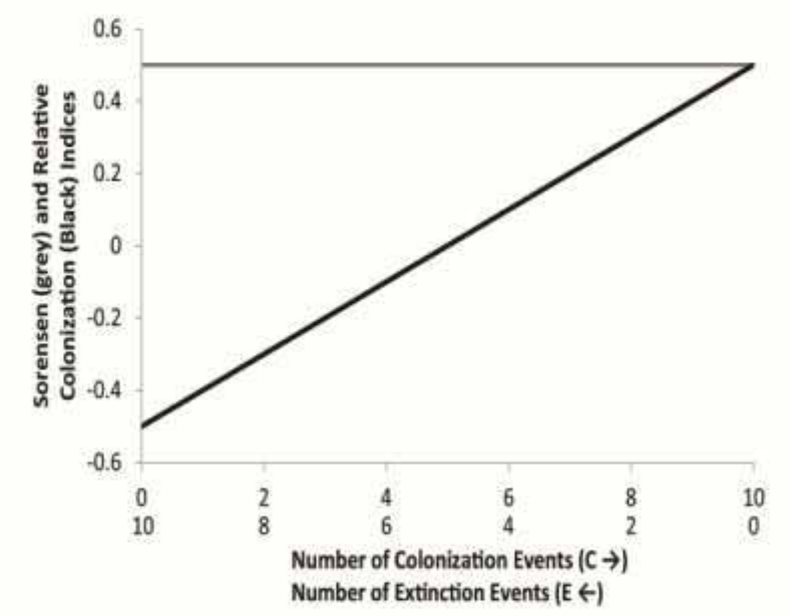


Figure A1: The relative colonisation index (RC; black line) compared species turnover (as measured by to Sorensen distance; grey line). The x-axis gives the number of colonisations and extinctions, here shown for a community with a turnover of 10 species between two periods in time and a total species diversity of 20 species across both time periods. The turnover is made up of colonisation and extinction events (x-axis). Relative colonisation is highest and equals Sorensen distance when all turnover is due to colonisation and lowest (equal to -1*Sorensen) when all turnover is due to extinction.

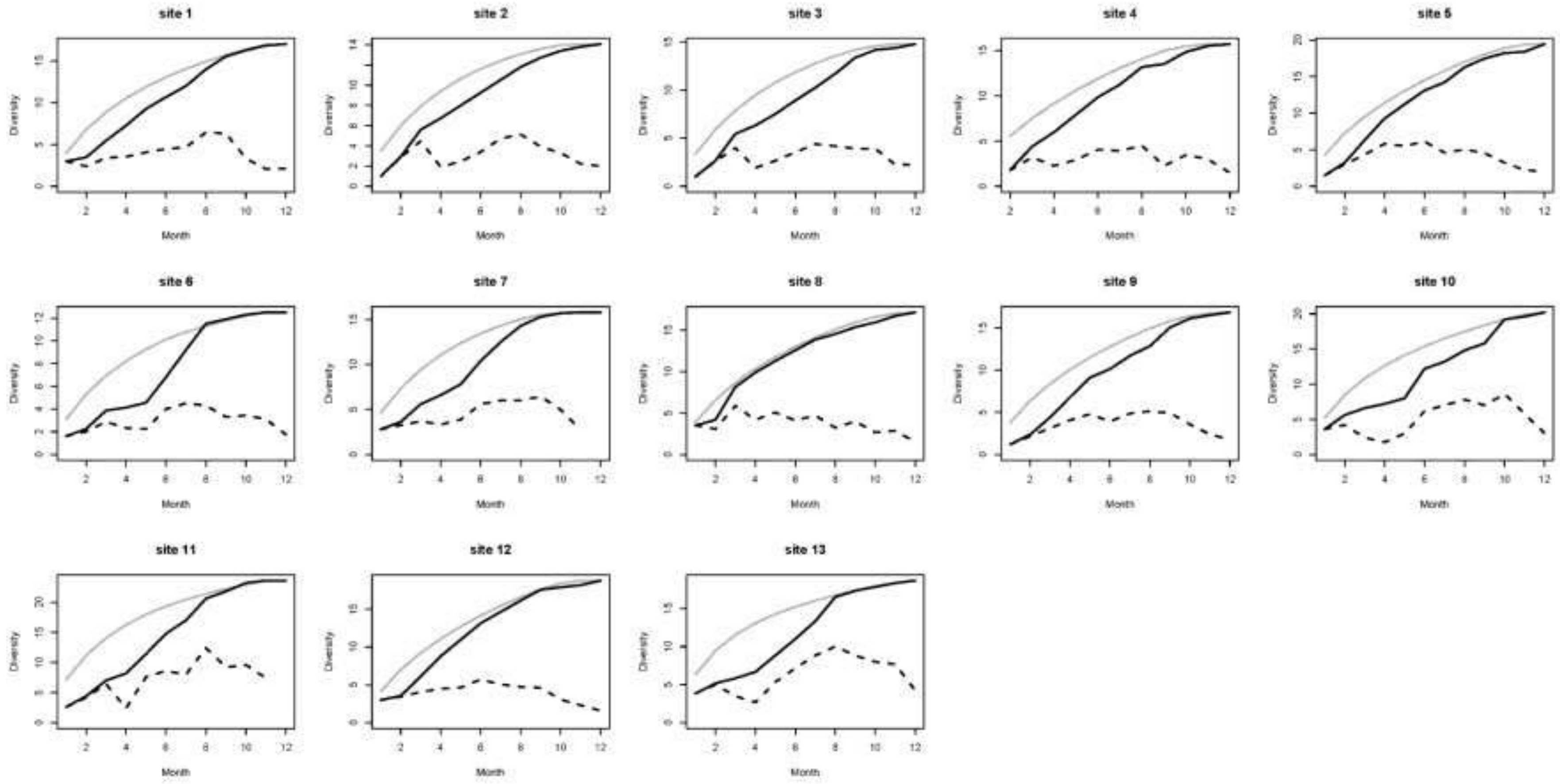


Figure A2: Components of Species Time Relationship by Site. Alpha (dashed line), observed Gamma (black line) and estimated Gamma (through rarefaction; gray line) diversities for metacommunities of mites over 12 months of sampling. Each plot shows the components for one site, with b17t_ok shown both here and in the main text (Fig. 2A).

Table A1: AICc Tables for competing explanatory models of RC over time. All variables included were all significant ($p<0.05$) alone and were included in all linear (non-interacting) combinations. The model in bold font was selected as the best model based on AICc statistics, with the model with fewest parameters chosen if AICc did not differ by more than 2.

Predictor Variable	K	AICc	Delta_AICc	AICcWt	Cum.Wt	LL
Month (as factor)	**13**	**-121.55**	**0**	**1**	**1**	**75.22**
Month (as linear predictor)	4	-99.63	21.92	0	1	53.96
intercept	3	-58.23	63.32	0	1	32.2

Table A2: AICc Tables for competing explanatory models of RC. All variables included were all significant ($p<0.05$) alone and were included in all linear (non-interacting) combinations. The model in bold font was selected as the best model based on AICc statistics, with the model with fewest parameters chosen if AICc did not differ by more than 2.

Predictor Variables	K	AICc	Delta_AICc	AICcWt	Cum.Wt	LL
Δ Temp + Temp^2+sunlight	6	-85.68	0	0.37	0.37	49.16
Δ Temp + Temp^2	**5**	**-85.52**	**0.17**	**0.34**	**0.7**	**47.98**
Temp + Temp^2+ Δ Temp	6	-83.87	1.81	0.15	0.85	48.25
Temp + Temp^2+ Δ Temp + sunlight	7	-83.7	1.99	0.14	0.99	49.27
Temp^2 + sunlight	5	-76.28	9.4	0	0.99	43.37
Temp + Δ Temp	5	-75.61	10.07	0	0.99	43.03
Temp + Δ Temp + sunlight	6	-75.51	10.17	0	1	44.07
Temp + Temp^2 + sunlight	6	-74.41	11.28	0	1	43.52
Temp^2	4	-72.97	12.71	0	1	40.63
Δ Temp + sunlight	5	-72.11	13.57	0	1	41.28
Temp + Temp^2	5	-71.76	13.93	0	1	41.1
Δ Temp	4	-70.46	15.23	0	1	39.38
Temp + sunlight	5	-67.05	18.63	0	1	38.75
Temp	4	-64.42	21.27	0	1	36.36
sunlight	4	-63.57	22.11	0	1	35.93
intercept	3	-58.23	27.46	0	1	32.2

Table A3: AICc Tables for competing explanatory models of Sorensen distance (turnover). All variables included were all significant ($p<0.05$) alone and were included in all linear (non-interacting) combinations. The model in bold font was selected as the best model based on AICc statistics, with the model with fewest parameters chosen if AICc did not differ by more than 2.

Predictor Variables	K	AICc	Delta_AICc	AICcWt	Cum.Wt	LL
Temp + Relative Humidity	**5**	**-147.21**	**0**	**0.73**	**0.73**	**78.83**
Temp + Relative Humidity + Sunlight	6	-145.22	1.99	0.27	1	78.93
Relative Humidity + Sunlight	5	-135.54	11.67	0	1	72.99
Relative Humidity	4	-134.88	12.33	0	1	71.59
Temp + Sunlight	5	-123.71	23.5	0	1	67.08
Sunlight	4	-122.52	24.69	0	1	65.41
Temp	4	-118.64	28.57	0	1	63.47
intercept	3	-114.77	32.44	0	1	60.47

Capítulo VI

Patterns of broad-scale spatial distribution of plant dwelling mites

Felipe Micali Nuvoloni, Reinaldo J. F. Feres

Abstract

Spatial and environmental processes account for species composition at distinct scales. At biogeographic scales the combined effects of evolutionary processes, dispersal limitations, and niche-based processes, in more or less intensity, are driven the patterns of species distribution. Altough, considering the species trade-off between dispersal ability, colonization and competition, we suppose that the strength of structuring processes would vary among species. Based on communities of mites associated with rubber trees in Brazil, as we expected, dispersal was the main structuring force acting on the communities of mites at biogeographic scale, although its relative importance was higher for phytophagous than for predatory species. Furthermore while phytophagous mites were spatially structured based on broad-scale elements, the predatory species were mainly driven by fine-scale elements, such as local dispersal processes, biotic interactions, or micro-site effects. We also figured out that the number of species was negatively related with the dry season. Our findings sum evidences for the dominance of dispersal-based processes at larger scales, altought relative importance of spatial components (broad or fine-scale) may change according to the intrinsec characterist of the species, or groups of species considered.

Keywords: Acari, biogeography, *Hevea brasiliensis*, scale, spatial dynamics, species diversity.

Introduction

One of the biggest concerns in ecology is the understanding of spatial patterns of species distribution, composition and diversity (Legendre, 1993). Bearing in mind that species distribution is usually nonrandom, and display spatial or temporal structures, studies have been focusing on to determinate the mechanisms that account for these patterns at different scales (Levin, 1992). The prevalence of regional (e.g., dispersal, speciation) or local based processes (e.g., species interactions) was for a long time subject of interest and discussion among ecologist (Chesson, 2000; Hubbel, 2001; Tilman, 2004; Gravel *et al.*, 2006). Nonetheless, the current emergence of new ecological approaches assembling these "competing" ideas (metacommunity theory), endorses for the complementary state of both local and regional processes assembling communities (Leibold *et al.*, 2004; Cottenie, 2005; Gravel *et al.*, 2006; Massol *et al.*, 2011). In the metacommunity context, local processes account for the niche-based processes and is included on the species-sorting perspective, while regional processes are also designed as dispersal-based processes and constitutes the patch dynamics perspective (Leibold *et al.*, 2004).

Ecologists typically measure scale in terms of grain and extension (Nekola & White, 1999; Whittaker *et al.*, 2001). Beyond the local and regional scales, which are covered on the metacommunity approach, there are processes acting at biogeographic scale, which defines patterns of species distribution at larger temporal and spatial scales. Within biogeography, there is extensive evidence for variation in the spatial patterns and processes driving alpha and beta diversity at different spatial grains and extents (Palmer & White, 1994; Rosenzweig, 1995; Whittaker *et al.*, 2001; Field *et al.*, 2009). Once dispersal and niche-based processes are either considered to explain structures at metacommunity and biogeography scales, some confusion may arise since there is no single natural scale at which ecological processes occur (Levin 1992). Indeed, the recognition of the most relevant processes that account for compositional variation and model species–environment interactions is not clear, and may change with the scale of observation (Dungan *et al.*, 2002; Legendre *et al.*, 2009). It is well established that different factors affect community assembly at different scales. For example, climate and historical factors can act as large-scale filters, whereas habitat structure and dispersal can act as local filters on community assembly (see Table 1, modified from Barton *et al.*, 2013).

For the study of processes and mechanisms assembling communities at broad scale, we are based on metacommunities of mites associated to rubber trees in Brazil. Our study system properly fits on the conceptual model of briogeographic studies, given that the range of sampled patches varies from -2.6 to -24.5 in latitude, and from -39.16 to -67.87 in longitude, being distributed at different vegetation biomes. The rubber tree cultivation was implemented during the last century in several parts of Brazil, and as consequence, an associated mite fauna was also established in conjunction with its host.

The colonization of the crop areas may have occurred by the species of mites which were carried with the seedlings, and also by dispersion of individuals from local species pool. Moreover, we suppose that events of species dispersion among crop areas, favored by possible human manipulation, also contributed to assemble the mite community observed. In summary, we consider that the mite community from each patch might have been resulting from colonization of native species carried out with the seedlings, by species from the regional pool from other plants, and also by dispersion from other crops. Local environmental filters, species interaction, and differential rate of dispersion, are the possible mechanisms modeling the mite communities on rubber trees.

Based on the factors above discriminated, we suppose that local climate and species interaction may negatively influence the establishment of some species, mainly predators. As a result, predatory species from surrounding areas (regional pool) may have had more chances to successfully colonize the new *Hevea* leaves than those carried with the seedling. On the other hand, phytophagous species have intrinsic association with their hosts, so we believe that local-based processes had a small influence on the species composition, whereas the distance, or dispersal-based processes would have affected more this group of mites. In summary, we predict that: (1) dispersal-based processes are the main structuring force acting on the communities of mites at biogeographic scale, being more important for phytophagous species; (2) the distribution Phytoseiidae (predatory mites) species will be less spatially structured than phytophagous, with a higher importance of the environmental component factors, or niche-based processes on the species composition.

Considering this, we intend to investigate the partial importance of the mechanisms driving the patterns of distribution of the species in rubber trees in Brazil. More specifically, we will test the relative importance of the spatial- and environmental-based process on the distribution of the species of mites in each patch, and also how these processes acts in two particular groups formed by Phytoseiidae and phytophagous species.

Methods

Study system

The database assembled on the Chapter I (Table 1) was used as basis for the present study. Thus, despite the database constitute the most recent source of information about the occurrence of mites in rubber trees in Brazil, it is comprised by heterogeneous surveys, which in turn have applied different methods of sampling for distinct objectives. So, in order to standardize the dataset and make it suitable to test our predictions, we excluded some patches (or surveys) whose do not attempt for the following criteria: the samples must have been performed targeting to inventory the whole community of mites on rubber trees instead of one or another group or species; a minimal number of three rubber trees must have been sampled by plot; the species recorded must have been identified nominally, or in case of morphospecies only if deposited at the Acari Collection of DZSJRP; at least 10 species must have been recorded in the patch.

Following these criteria, from the 60 localities initially constrained in the dataset, only 42 patches were retained for the current study (Table 1, Chapter I). The sites are distributed along diverse Brazilian biomes (Amazonian, Coastal Atlantic Rainforest, Semidecidual Atlantic Rainforest, Cerrado, and transition areas among them), and their location range between -2.6 to -24.5 in latitude, and from -39.16 to -67.87 in longitude. Details about sampling methodology, mite extraction and mounting procedures from each patch can be found on the Chapter 1.

We considered each site as a metacommunity, with trees acting as local assemblages with hundreds of leaves that are habitat for the mites. Species passively disperse among trees and over long distances by wind or phoresis, and actively disperse within trees and over short distances. Since we are interest in to determine the prevalence of dispersal or niche-based processes on the composition of rubber trees mites at a biogeographical scale, we assembled the data from the trees constrained in a metacommunity into a single matrix that summarizes all the species found in a particular site.

Environmental variables

Climatic data were obtained from local meteorological stations, and provided by the authors of surveys. In case which authors do not provide the climatic data, or the data is not complete, the information were retrieved from “Instituto Nacional de Meteorologia” (http://www.inmet.gov.br/projetos/rede/pesquisa/), and from “Centro Integrado de Informações Agrometeorológicas” CIIAGRO (http://www.ciiagro.sp.gov.br/ciiagroonline/). The variables were taken monthly, during the year that the survey was carried out, and an average mean of each variable were estimated corresponding to the whole period. A total of 15 variables were included: mean temperature (°C), minimum mean temperature (°C), minimum temperature on the coldest month (°C), maximum average temperature (°C), maximum temperature on the hottest month(°C), temperature seasonality (°C), mean relative humidity “rh” (%), minimum rh of the driest month (%), maximum rh of the wettest month (%), annual precipitation (mm), mean monthly precipitation (mm), precipitation on the driest month (mm), precipitation on the wettest month (mm), number of rainy days (days), and mean sunlight duration (h). We tested all the climatic variables for correlation, and removed those which variance inflation factor (VIF) higher than 10. According to the analysis, were retained 10 from 15 variables (Mean Temp., Max. Temp., Seasonal Temp., Minim. rh, Max. rh, Minim. Rain, Max. Rain, Number of Rainy

Days, and Sunligh duration). The variables were standardized, using the method “deconstand” (vegan package), and then, we performed a Principal Component Analysis (PCA) for extraction of the first four orthogonal axes (cumulative proportion of 92%) to be used as environmental predictor variables in the redundancy analysis (RDA) (Table 2).

Spatial variables

We built a matrix of plot coordinates with the latitude and longitude references by site. Since the studied areas vary in size, we established the center point of each site as our correspondent coordinates. The raw matrix containing the coordinates of 42 sites were transformed in a spatial eigenvector map, using the “Moran’s eigenvector maps” (MEMs) based on Gabriel graphs (Dray *et al.*, 2012; Legendre & Legendre, 2012). A total of 41 MEMs were generated, and represents a new display of the prior coordinates (latitude and longitude) into spatial predictors, which can be used as explanatory variables. From those MEMs, only seven contributed significantly to the explanation of the species response data (tested by forward selection “$p<0.05$”), so they were retained and assembled into broad (positive autocorrelation) and fine (negative autocorrelation) spatial scales (Blanchet *et al.*, 2008). A scalogram was constructed showing how well each MEM eigenfunction explains the variability of the response data (Legendre & Legendre, 2012).

According to (Dray *et al.*, 2012) the use of submodels of MEMs (broad and fine scales) as spatial predictors in RDA analysis allows one to determine how much of the species variation is spatially structured, and within that, how much variation can be related to the influence of the measured environmental variables (see Legendre *et al.* 2009; Peres-Neto & Legendre 2010).

The previous procedure was carried out considering the whole set of species, constrained for the 42 sites (Figure 1). The same method was performed considering only the phytophagous species belonging to Eriophyidae, Tenuipalpidae and Tetranychidae (Figure 2), and also for the species of Phytoseiidae (predators) (Figures 3-4).

Data analyses

The original data set was assembled based on mite abundances, but for all analysis we converted abundances to presence-absence data in order to diminish the possible bias resulting from differences on the sampling procedures. In order to understand the general pattern of shared species among all the sites, we performed a cluster analysis, based on the UPGMA method (Unweighted Pair-Group Method) and Sorensen’s distance. An analysis of similarity (ANOSIM) was performed in complement.

To test our predictions, we estimated the relative importance of macroclimatic and spatial variables (broad and fine-scale MEMs) on the mite species composition of all the sites with a Redundancy analysis (RDA) coupled with the unbiased Variation Partitioning analysis, following Peres-Neto et al. 2006. The total variation in the species composition can be decompounded into environmental and spatial components, and then partitioned into the total variation explained exclusively by environmental and spatial variables. Using this method we can access the variation explained by each component of the analysis and their interaction.

Using another RDA analysis, we also tested the influence of macroclimatic variables on the spatial processes. The variation explained by the pure spatial component was tested against the four scores of the macroclimatic PCA, in order to understand which and whether climatic factors are associated with the variation in the species composition.

The scores of macroclimatic PCA were also regressed with the species richness values of each locality, with the intention to test which and if the climatic variation can predict the number of mite species associated with rubber trees. All the analysis were performed on R software (R Core Team 2014), using the packages ade4, packfor, spacemakeR, and vegan.

Results

Considering the current dataset, a total amount of 270 species of mites was recorded from 42 localities and nine states. The average richness by site was about 40±15.9 SD, ranging from 15 to 60 species per site. About 50% of the species had the occurrence constrained to one or two sites, whereas only five of them had a wide distribution, being recorded on more than 70% of the sites. These species correspond to the phytophagous *C. heveae, S. petiolula, P. seringueirae, T. heveae,* and *B. phoenicis.* The composition of species largely vary among sites (R^2=0.62, p<0.001), and according to the clustering analysis the dissimilarity in species composition trend to increase with the distance among sites. As a result, the sites were roughly assembled into two major groups, one comprising the patches from Bahia, Acre, Maranhão, and some sites from Amazonas, and other basically formed by the sites located on Mato Grosso, São Paulo, Rondônia, Minas Gerais, and those remaining from Amazonas (Figure 5).

The variation on the composition of the whole set of mites was mainly explained by the broad spatial scale that account for about 20% of variation, considering both spatially-structured environment [$E \cap S_b$] (R_{adj}^2= 0.117), and the pure broad spatial component [$S_b|E$] (R_{adj}^2= 0.086). Complementary, both the pure environment component [$E|S$] (R_{adj}^2= 0.029), and fine spatial scale [$S_f|E$] (R_{adj}^2=0.031) were also partially important underlying the structure composition of the communities (Figure 6A). Considering only the composition of phytophagous mites, the spatially-structured environment component [$E \cap S_b$] (R_{adj}^2= 0.107) was the main underlying component, followed by the pure broad [$S_b|E$] (R_{adj}^2= 0.056) and fine [$S_f|E$] (R_{adj}^2= 0.016) spatial scales. The pure environmental factors did not account a significant explanation in this case. Similarly, for the predatory mites, in particular the species of Phytoseiidae, the composition of species were once again driven by the spatially-structured environment component [$E \cap S_b$] (R_{adj}^2= 0.211), being the pure fine spatial scale structure another factor that explained part of the variation [$S_f|E$] (R_{adj}^2= 0.178).

Considering the possible factors driving the species richness, we found that the environmental component, in particular those which represent the dry season (PCA1), performs a strong and negative influence on the number of species at the biogeographical scale (R^2=0.22, $p<0.001$). In complement, the spatial component associated with the composition of species was related with the first three axis of the PCA of the bioclimatic variables (PCA1 [F= 7.045, p= 0.001], PCA2 [F=3.914, p= 0.001], and PCA3 [F=3.363, p= 0.001]) (Table 1). The spatial component associated to the species of Phytoseiidae was positively related to the rainy season (PCA3, F= 2.387, p= 0.036) (Table 1). On the other hand, for phytophagous mites the spatial component was related either to the dry season (PCA1) and to the temperature variation (PCA2) (Table 1).

The PCA1 was negatively related to the number of rainy days during the year, and to the minimum relative humidity and rain, the PCA2 had a negative relation with the mean temperature, maximum absolute temperature and with the maximum rain, and PCA3 had a positive relation with hours of sun, and with maximum relative humidity and was negatively related to maximum rain (Table 2).

Discussion

In summary, our results sum evidences for the dominance of dispersal-based processes driving the patterns of species distribution at larger scales, although pure environmental component also had a small, but significant, contribution. Most of variation accounted for the environment, or niche-based processes, was spatially structured. Meanwhile the spatial variation tracked for the whole set of species, and phytophagous rely on the broad-scale elements, for Phytoseiidae mites the fine-scale elements had bigger importance.

The number of species greatly varies among sites, and part of variation could be tracked by our study, which reveals a high and negative relation between number of species and dry season. The climatic variables constrained on the PCA1, minimum relative humidity, number of rainy days, and minimum rain, negatively affect the number of species. As a result, sites subjected to more severe dry season trend to present lower number of mite species, in such case the local weather are acting as local filter to some species. Relative humidity is usually a limiting parameter for the occurrence of plant and soil mites, or arthropods in general, since values of RH lower of 50% are not tolerable for many species (Krantz & Walter, 2009). Other factors, such as environmental heterogeneity (Altieri, 1999; Sunderland & Samu, 2000; Benton *et al.*, 2003), and type of crop management (Östman *et al.*, 2001) also heavily influence the local and regional richness and was not considered in the current analysis.

Partially as we predicted, the spatial component was the most important factor structuring the communities of mites at large scale. Our first prediction that the composition of the mite communities, and also the phytophagous species were spatially structured, was corroborated. Unlike predicted to Phytoseiidae, the pure environmental component did not play an important role structuring the species composition, being the variance explained either by the spatial components or by the autocorrelation of space and environment, the structuring mechanisms of Phytoseiidae composition. Our outcomes are in agreement with previous studies on diversity patterns at large, in which the spatial component is constraining the distribution of species (Meynard *et al.*, 2013; Gonçalves-Souza *et al.*, 2014). Although the variance-partitioning test has shown the higher influence of dispersal processes supporting the species composition of the mite communities, such as highlighted by Gilbert & Bennett (2010) our conclusion might be taken carefully. According to them, most of variation-partitioning tests fail to accurately represent environmental and spatial components of community variation, essentially due to poor environmental and/or spatial models. As a consequence, frequently the dispersal-based processes are overestimated rather niche-based processes. Concerning about this criticism, we believe that the large spatial scale in which our data if comprised was actually a limiting factor for the species dispersion, moreover we also applied standardization procedures to control possible sampling bias, improving the reliability of our findings.

Dispersion on rubber tree mites may be difficult to detect or to estimate, but we assume that it may occurs passively by wind, being more likely to be succeeded from small to medium scales (1.000km). Moreover, considering the recent history of rubber tree cultivation, it is more plausible that human transportation of the seedlings between crop areas may have deeply influenced dispersion rate of the species, and as consequence the observed pattern of species distribution. Nonetheless, the spatial autocorrelation structure that arise from the studied system may be a result of dispersal limitation or due to species response to spatially structured environmental variables, or even a combination of both (Shurin *et al.*, 2009).

Partitioning the spatial structure into broad and fine-scale components, we noticed that the whole community and the phytophagous species presented a domain of broad scale elements, while the Phytoseiidae species presented an important fine-scale component. It is generally assumed that broad-scaled spatial structures in the species response data correspond to the scale (sometimes referred to as wavelength) of environmental drivers, whereas spatial autocorrelation generated by community dynamics is usually finer scaled (Dray *et al.*, 2012; Legendre & Legendre, 2012). Although, identifying the characteristic spatial scales of variation displayed by the response variables that are explained (or not) by the measured environmental variables is a first step toward disentangling the various processes that might act to structure the spatial distributions of species (Smith & Lundholm, 2010). In fact, given that in our study system the climatic variables account for large-scale environmental drivers on the spatial structure of the communities, the fine-scale structures could be generated by local dispersal processes (Condit *et al.*, 2002), biotic interactions, or micro-site effects of unmeasured environmental factors. Noteworthy, we believe that local factors not accounted in the study, such as microclimatic variables, or even the local heterogeneity and presence of native plants in the crop, might correspond to the fine-elements determining the species composition of Phytoseiidae mites.

The spatial component associated with the communities of mites was related to the first three axis of the PCA, however this result raises more questions than clarifies the relation between dispersion limitations of the communities and the environmental components. Due to differences in the dispersion rate among species, makes more sense explaining the differential effects of climate on the spatial structure of each group of species instead of the whole community. In this case, we could clearer access that the spatial component driven the phytophagous dispersal were associated with the PCA1 and PCA2, which constrain the variables related to the dry season, and weather seasonality, respectively. The group of phytophagous species encompasses species of the family Eriophyidae, Tenuipalpidae and Tetranychidae, which in turn have shown the same feeding habit, although they greatly vary in terms of body size and shape, resulting in distinct dispersal abilities (Krantz & Walter, 2009) Furthermore, such as highlighted on previous studies, species of Eriophyidae, represented by *Calacarus heveae* and *P. seringueirae* seem to be negatively influenced by the dry season, whereas Tetranychidae species are usually favored under the same conditions. On the other hand Phytoseiidae species comprises a more homogeneous group in terms of body size and shape, and as consequence, only the PCA3 was associated with the spatial component of this group. This orthogonal axis resume the rain season, grouping the variables maximum relative humidity, maximum rain and sunlight hours.

In conclusion, our study reveals that at large scales the dispersal-based processes are the main forces structuring the distribution of species of mites on rubber trees. Patterns of diversity and composition are spatially structured as well as the most important environmental processes that operating the mite community. Broad-scale elements of space are possibly the main drivers of the whole community of mites, and mainly phytophagous species, while fine-scale elements determine the distribution of Phytoseiidae species. As far as we are aware, our study correspond to the first survey which goal was to understand the distribution of species associated to a crop plant in a continental scale. Future works must spend more efforts in order to understand how local elements (at fine-spatial scale) may operate the species diversity, and how different groups or species respond to them.

References

Altieri, M. a. (1999) The ecological role of biodiversity in agroecosystems. *Agriculture, Ecosystems & Environment*, **74**, 19–31.

Barton, P.S., Cunningham, S. a., Manning, A.D., Gibb, H., Lindenmayer, D.B. & Didham, R.K. (2013) The spatial scaling of beta diversity. *Global Ecology and Biogeography*, **22**, 639–647.

Benton, T.G., Vickery, J. a. & Wilson, J.D. (2003) Farmland biodiversity: is habitat heterogeneity the key? *Trends in Ecology & Evolution*, **18**, 182–188.

Blanchet, F.G., Legendre, P. & Borcard, D. (2008) Modelling directional spatial processes in ecological data. *Ecological Modelling*, **215**, 325–336.

Chesson, P. (2000) Mechanisms of Maintenance of Species Diversity. *Annual Review of Ecology and Systematics*, **31**, 343–366.

Condit, R., Pitman, N., Leigh, E.G., Chave, J., Terborgh, J., Foster, R.B., *et al.* (2002) Beta-diversity in tropical forest trees. *Science*, **295**, 666–669.

Cottenie, K. (2005) Integrating environmental and spatial processes in ecological community dynamics. *Ecology letters*, **8**, 1175–82.

Dray, S., Pélissier, R., Couteron, P., Fortin, M.-J., Legendre, P., Peres-Neto, P.R., *et al.* (2012) Community ecology in the age of multivariate multiscale spatial analysis ´. *Ecological Monographs*, **82**, 257–275.

Dungan, J.L., Perry, J.N., Dale, M.R.T., Legendre, P., Citron-Pousty, S., Fortin, M.-J., *et al.* (2002) A balanced view of scale in spatial statistical analysis. *Ecography*, **25**, 626–640.

Field, R., Hawkins, B.A., Cornell, H.V., Currie, D.J., Diniz-Filho, J.A.F., Guégan, J.F., *et al.* (2009) Spatial species-richness gradients across scales: a meta-analysis. *Journal of Biogeography*, **36**, 132–147.

Gilbert, B. & Bennett, J.R. (2010) Partitioning variation in ecological communities: do the numbers add up? *Journal of Applied Ecology*, **47**, 1071–1082.

Gonçalves-Souza, T., Romero, G.Q. & Cottenie, K. (2014) Metacommunity versus Biogeography: A Case Study of Two Groups of Neotropical Vegetation-Dwelling Arthropods. *PloS one*, **9**, e115137.

Gravel, D., Canham, C.D., Beaudet, M. & Messier, C. (2006) Reconciling niche and neutrality: the continuum hypothesis. *Ecology letters*, **9**, 399–409.

Hortal, J., Sanders, N.J. & Rahbek, C. (2010) Understanding (insect) species distributions across spatial scales. *Ecography*, **33**, 2009–2011.

Hubbel, S.P. (2001) *The unified neutral theory of biodiversity and biogeography*. Princeton University Press, Princeton, New Jersey, USA.

Krantz, W. & Walter, D.E. (2009) *A manual of Acarology*. Third Edit. Texas Tech University Press, Lubbock, Texas.

Legendre, L. & Legendre, P. (2012) *Numerical Ecology*. *Ecology*. Elsevier, Amsterdan.

Legendre, P. (1993) Spatial Autocorrelation: Trouble or New paradigm? *Ecology*, **74**, 1659–1673.

Legendre, P., Mi, X., Ren, H., Ma, K., Yu, M., Sun, I.-F., *et al.* (2009) Partitioning beta diversity in a subtropical broad-leaved forest of China. *Ecology*, **90**, 663–674.

Leibold, M. a., Holyoak, M., Mouquet, N., Amarasekare, P., Chase, J.M., Hoopes, M.F., *et al.* (2004) The metacommunity concept: a framework for multi-scale community ecology. *Ecology Letters*, **7**, 601–613.

Levin, S.A. (1992) The problem of pattern and scale in ecology. *Ecology*, **73**, 1943–1967.

Massol, F., Gravel, D., Mouquet, N., Cadotte, M.W., Fukami, T. & Leibold, M. a. (2011) Linking community and ecosystem dynamics through spatial ecology. *Ecology letters*, **14**, 313–23.

Meynard, C.N., Lavergne, S., Boulangeat, I., Garraud, L., Es, J. Van, Mouquet, N., *et al.* (2013) Disentangling the drivers of metacommunity structure across spatial scales. *Journal of biogeography*, **40**, 1560–1571.

Nekola, J.C. & White, P.S. (1999) The distance decay of similarity in biogeography and ecology. *Journal of Biogeography*, **26**, 867–878.

Östman, Ö., Ekbom, B. & Bengtsson, J. (2001) Farmland biodiversity: is habitat heterogeneity the key? *Basic and Applied Ecology*, **2**, 365–371.

Palmer, M.W. & White, P.S. (1994) Scale dependence and the species-area relationship. *American Naturalist*, **144**, 717–740.

Peres-Neto, P.R. & Legendre, P. (2010) Estimating and controlling for spatial structure in the study of Edited by Foxit Reader. *Ecology*, **19**, 174–184.

R Development Core Team. (2014) A language and environment for statistical Computing.

Ricklefs, R.E. (2004) A comprehensive framework for global patterns in biodiversity. *Ecology letters*, **7**, 1–15.

Rosenzweig, M.L. (1995) *Species diversity in space and time*. Cambridge University Press, New York, NY.

Shurin, J.B., Cottenie, K. & Hillebrand, H. (2009) Spatial autocorrelation and dispersal limitation in freshwater organisms. *BioScience*, 151–159.

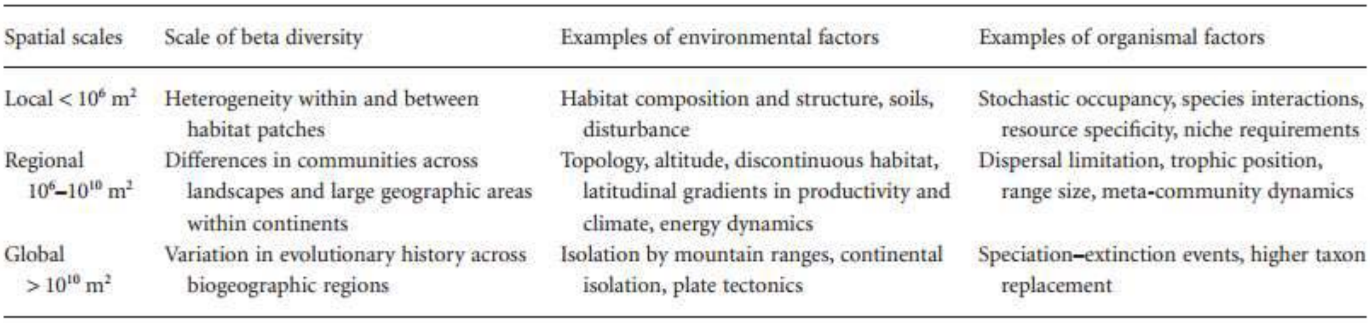
Smith, T.W. & Lundholm, J.T. (2010) Variation partitioning as a tool to distinguish between niche and neutral processes. *Ecography*, **33**, 648–655.

Sunderland, K. & Samu, F. (2000) Effects of agricultural diversifica-tion on the abundance, distribution, and pest control potential of spiders: a review. *Entomologia Experimentalis et Applicata*, **95**, 1–13.

Tilman, D. (2004) Niche tradeoffs, neutrality, and community structure: a stochastic theory of resource competition, invasion, and community assembly. *Proceedings of the National Academy of Sciences of the United States of America*, **101**, 10854–61.

Whittaker, R.J., Willis, K.J. & Field, R. (2001) Scale and species richness: towards a general, hierarchical theory of species diversity. *Journal of Biogeography*, **28**, 453–470.

Table 1. A variety of different occupancy, bionomic and biogeographic factors are suggested to drive beta diversity at different spatial scales (see Whittaker *et al.*, 2001; Ricklefs, 2004; Hortal *et al.*, 2010). **Modified from Barton et al 2011.**



Spatial scales	Scale of beta diversity	Examples of environmental factors	Examples of organismal factors
Local < 10^6 m^2	Heterogeneity within and between habitat patches	Habitat composition and structure, soils, disturbance	Stochastic occupancy, species interactions, resource specificity, niche requirements
Regional 10^6–10^{10} m^2	Differences in communities across landscapes and large geographic areas within continents	Topology, altitude, discontinuous habitat, latitudinal gradients in productivity and climate, energy dynamics	Dispersal limitation, trophic position, range size, meta-community dynamics
Global > 10^{10} m^2	Variation in evolutionary history across biogeographic regions	Isolation by mountain ranges, continental isolation, plate tectonics	Speciation–extinction events, higher taxon replacement

Table 2. Linear regression used to test the effect of bioclimatic variables (i.e., scores of the PCA analysis) on the pure spatial components (broad and fine scales) for the set of all communities of mites, for the phytophagous and Phytoseiidae mites**.**

	F	***P***
Mite communities		
PCA1	7.045	**0.001**
PCA2	3.915	**0.001**
PCA3	3.363	**0.001**
Phytophagous species		
PCA1	12.424	**0.001**
PCA2	7.241	**0.001**
PCA3	2.612	0.560
Phytoseiidae species		
PCA1	1.381	0.179
PCA2	0.831	0.584
PCA3	2.387	**0.036**

Table 3. PCA loadings of climatic variables associated with the first four PCA axis.

Variables	PCA1	PCA2	PCA3	PCA4
Temp. Med.	-0.20537	-0.42979	-0.27286	0.670098
Temp. Max.	0.067743	-0.6059	0.150575	0.239857
RH Min.	-0.43992	0.25748	-0.27961	0.097402
RH Max.	-0.42065	-0.26116	0.217119	-0.24472
Rain Min.	-0.46002	0.227618	-0.03517	0.169763
Rain Max.	-0.07238	-0.45493	-0.57863	-0.59698
Rainy days	-0.48949	0.097521	-0.15112	-0.06016
Sunligh time	-0.35539	-0.21302	0.647039	-0.18771

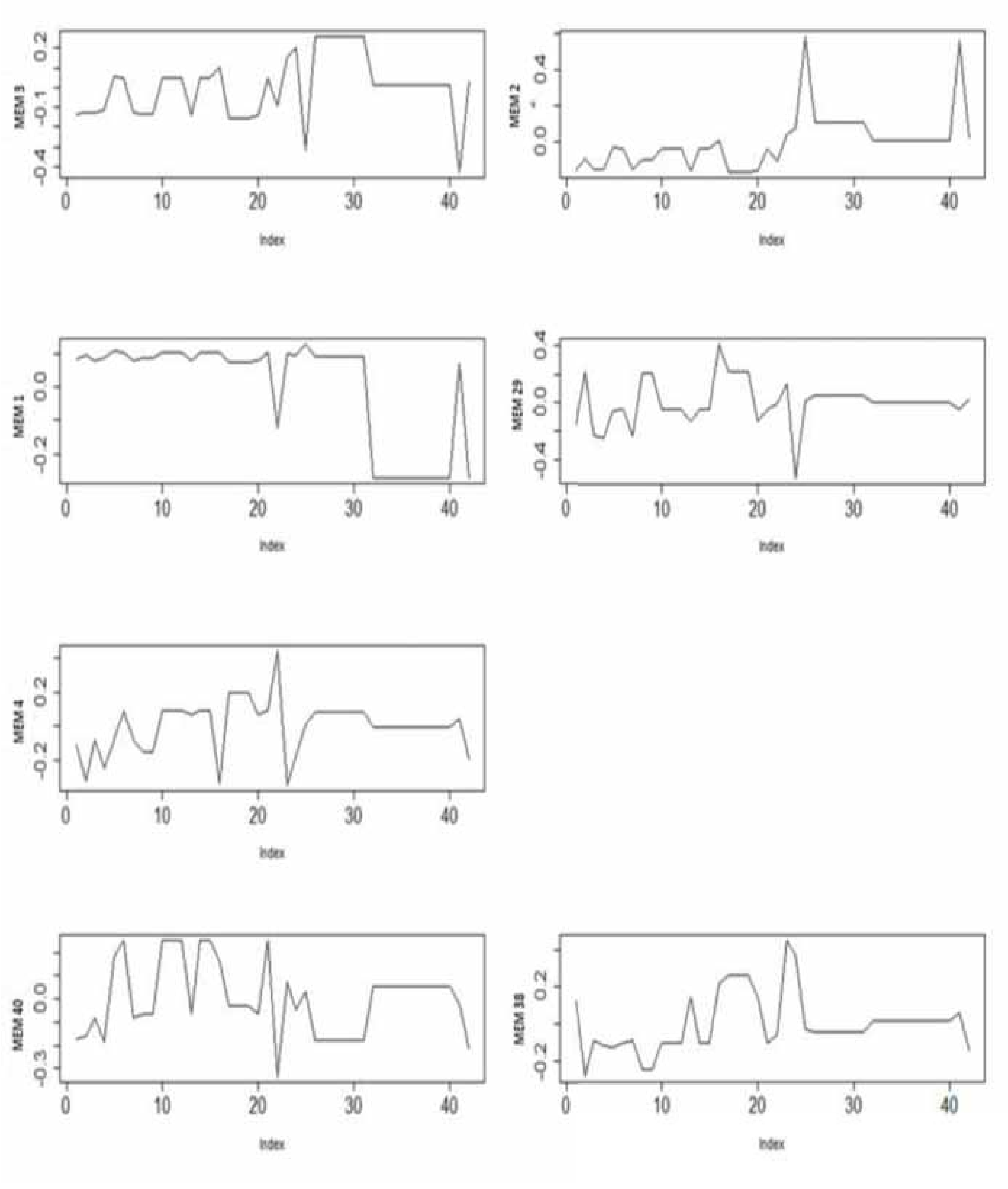


Fig 1. Broad and fine scale spatial predictors of the communities of mites. The y axis (index) presents the raw data (replicates – patches – within each locality) of the matrix of coordinates. Broad-scale MEMs: 3, 2, 1, 29, 4; Fine-scale MEMs: 40, 38.

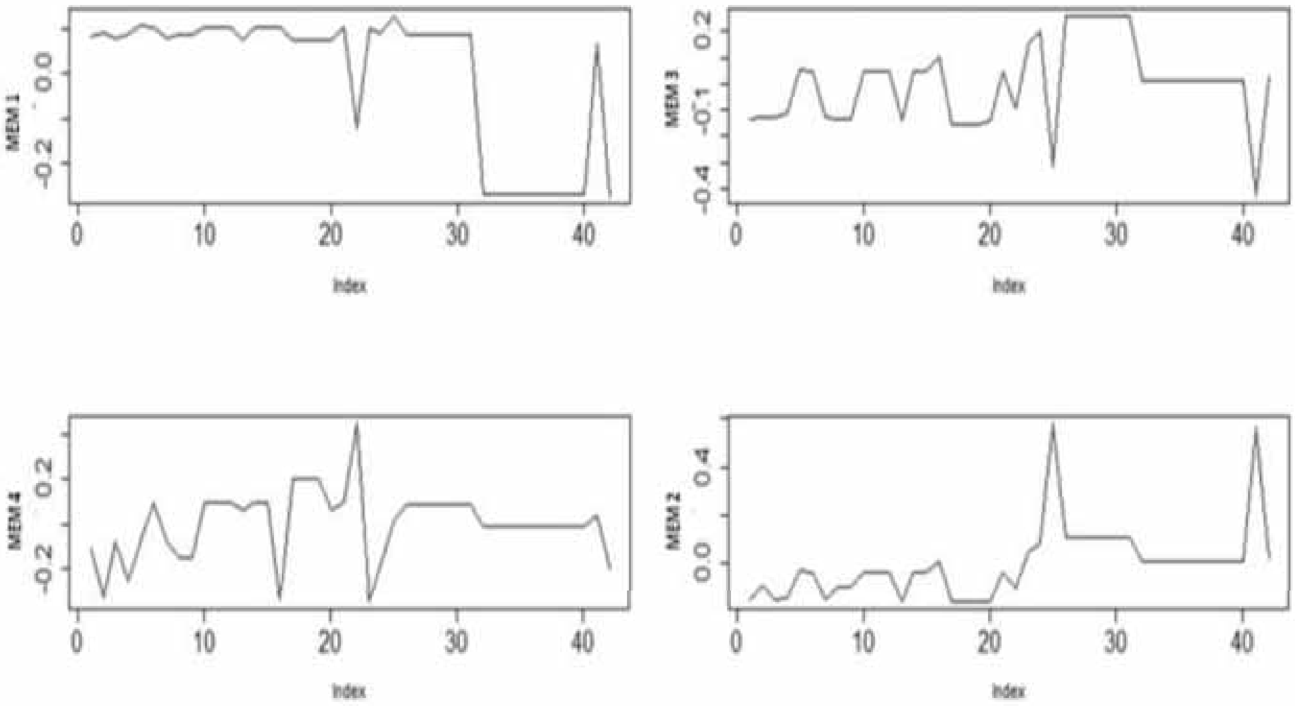


Fig 2. Broad scale spatial predictors of the phytophagous species of mites. The y axis (index) presents the raw data (replicates – patches – within each locality) of the matrix of coordinates

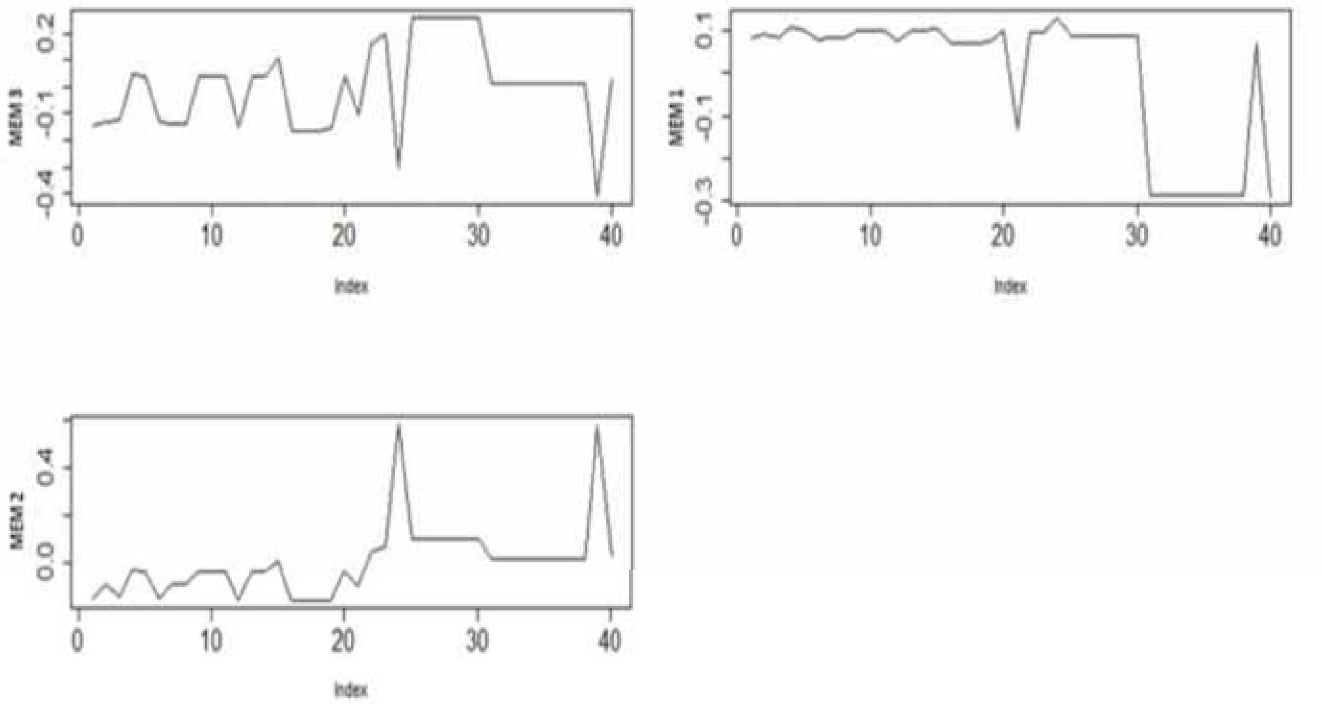


Fig 3. Broad scale spatial predictors of the Phytoseiidae mites. The y axis (index) presents the raw data (replicates – patches – within each locality) of the matrix of coordinates.

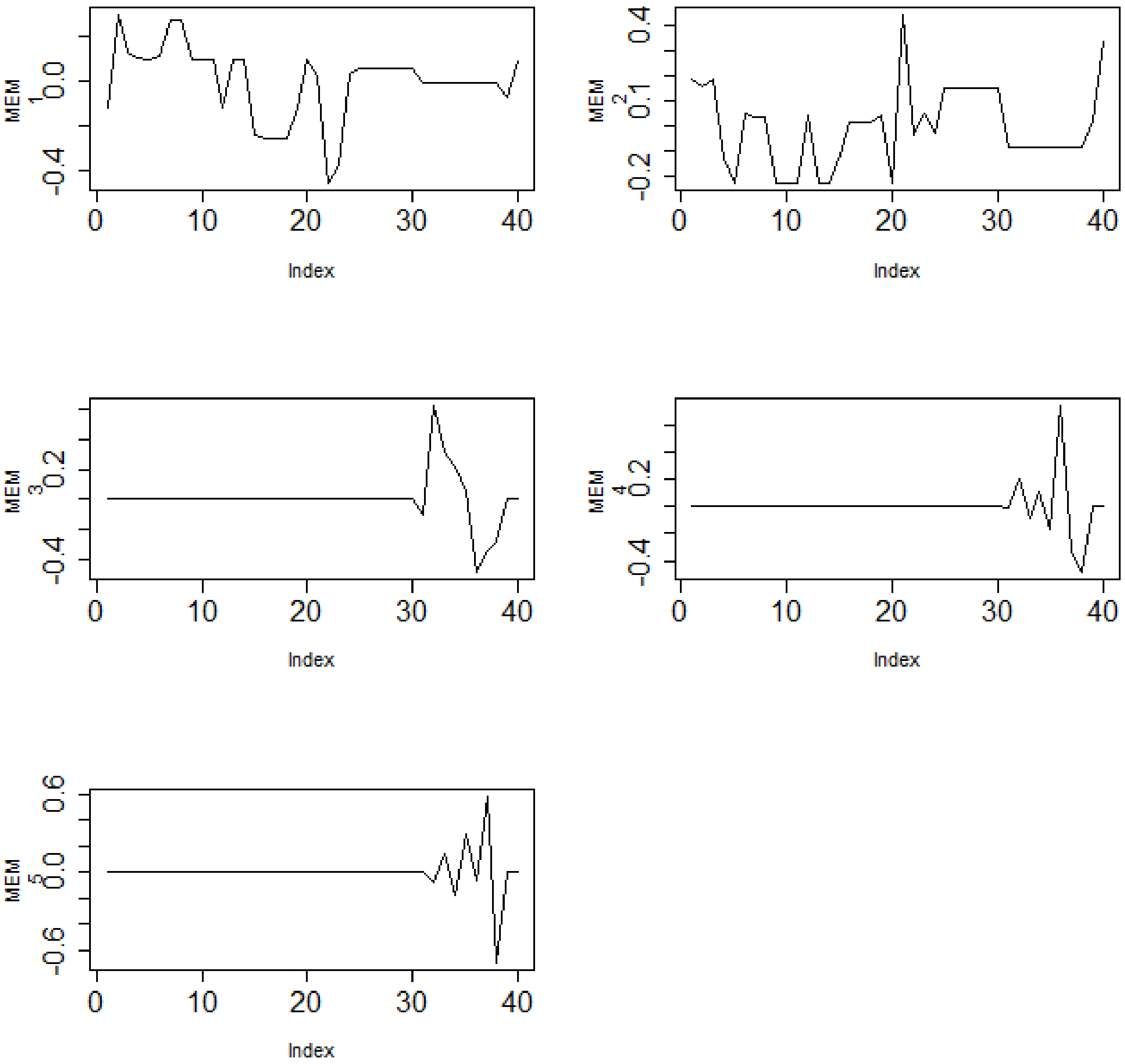


Fig 4. Fine scale spatial predictors of the Phytoseiidae mites. The y axis (index) presents the raw data (replicates – patches – within each locality) of the matrix of coordinate

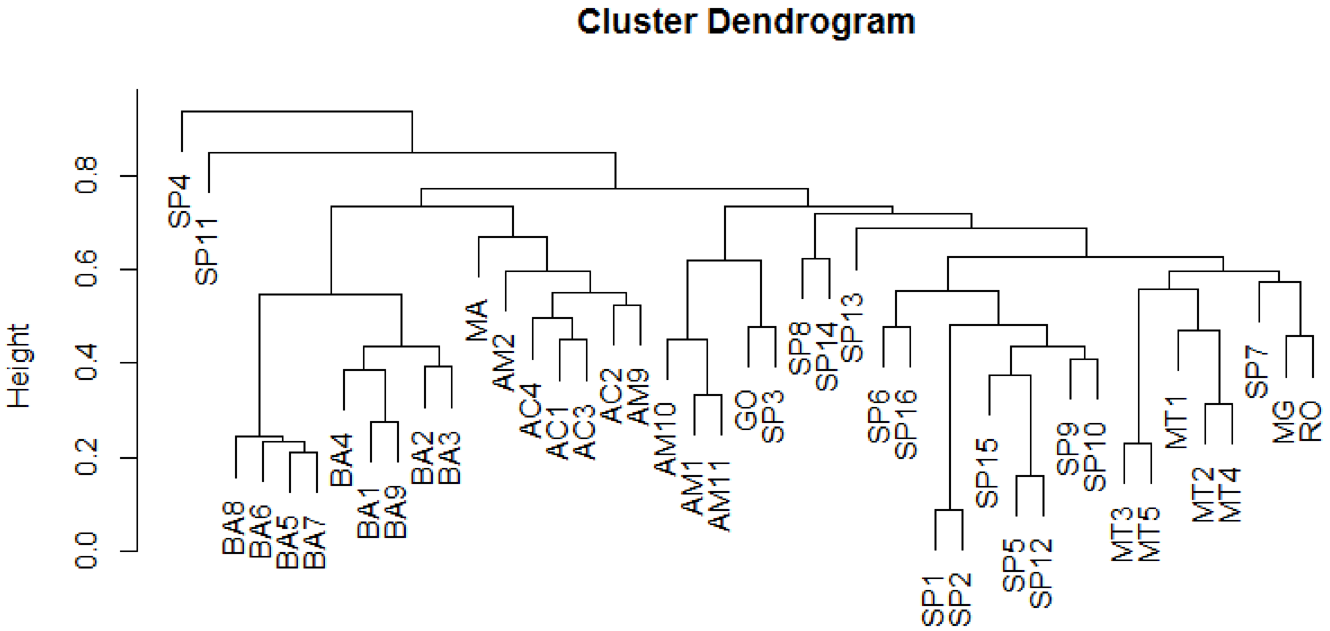


Fig 5. UPGMA analysis (cluster dendrogram) based on the Sorensen's distance, with the dissimilarity index among sites. Letters and numbers represent a code for the origin of each site.

* AC= Acre, AM= Amazonas, BA= Bahia, GO= Goiás, MT= Mato Grosso, RO= Rondônia, SP= São Paulo, MA= Maranhão.

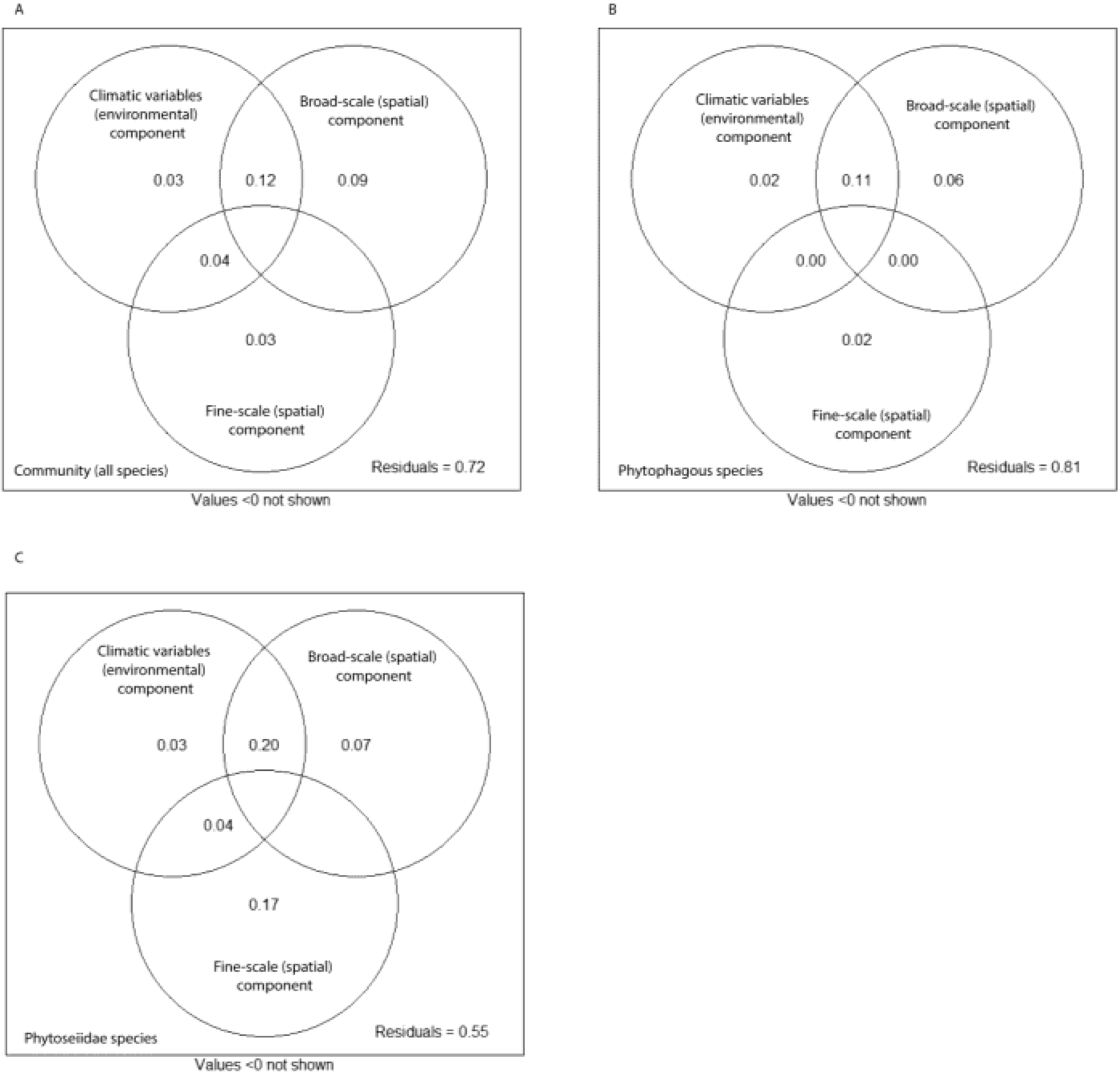


Fig 6. Results of variation partition with partial Redundancy Analysis showing the pure and shared influences of climatic variables, broad- and fine-scale spatial components on the mite communities (A), the phytophagous species (B), and Phytoseiidae mites (C). Numbers represent adjusted canonical R^2 values. Complementary values are shown on the text.

Considerações Finais

Diversidade de ácaros em seringueira

Nossos resultados ressaltam que a seringueira pode abrigar uma elevada diversidade de espécies, visto que mais de 250 espécies foram registradas em nosso estudo. A maioria destas espécies teve sua ocorrência restrita a poucas localidades, exceto pelos principais fitófagos, *Calacarus heveae, Tenuipalpus heveae, Phyllocoptruta seringueirae,* que foram registrados na maioria dos pontos estudados. Estas espécies tiveram seus picos populacionais compreendidos entre os meses de fevereiro e maio, e sua importância relativa variou de acordo com a região amostrada, por exemplo, *C. heveae* foi a espécie mais abundante registrada nos estados de São Paulo, Bahia e em alguns clones cultivados em Mato Grosso, enquanto *T. heveae* a espécie dominante nos estados da região Norte e Minas Gerais, por outro lado *P. seringueira* foi registrado apenas em elevadas abundâncias apenas em Mato Grosso. *Eutetranychus banksi,* e *Brevipalpus phoenicis* aparecem como pragas secundárias nesta cultura.

As seringueiras nativas foram pela primeira vez amostradas, e pudemos confirmar que os principais fitófagos também ocorrem nestas plantas. Além disso, elas abrigam uma enorme diversidade de ácaros Phytoseiidae, visto que sete novas espécies foram descritas associadas à *Hevea* nativa Amazônica. Novas espécies de Phytoseiidae também foram registradas em seringais do estado da Bahia.

Também verificamos que a diversidade de alguns táxons que são normalmente negligenciados e pouco estudados, é muito maior do que se imaginava. Espécimes de *Brachytydeus* por exemplo, são comumente relatadas nos estudos com seringueiras, entretanto apenas uma espécie havia sido formalmente registrada, *B. formosus.* Em um estudo mais minucioso destes indivíduos, descobrimos que na verdade o número de espécies sobe para 10, sendo que cinco delas representam espécies novas.

Padrões de distribuição espacial e temporal

Baseando-se nos estudos de dinâmica anual das comunidades de ácaros, verificamos que a abordagem tradicional ("species-time-relationship", STR) não pode ser aplicada ao nosso sistema de estudo, visto que há um fator determinístico atuando temporalmente no modelo de estudo (forte sazonalidade). Da mesma forma a substituição do espaço pelo tempo (proposta por Adler & Laurenroth 2003) também é falha nesse caso. Além disso, para o estudo da relação espécies-tempo elaboramos uma nova abordagem baseada na taxa de *turnover* temporal, a partir do desmembramento dos componentes de Colonização e Extinção da métrica de *turnover* (Sorensen, no nosso caso). Dessa forma podemos verificar que variáveis ambientais distintas modelam o aumento do *turnover* (p. ex. umidade relativa) e da colonização de espécies (p. ex diferença de temperatura, e temperatura absoluta), e consequentemente o aumento da diversidade de espécies.

Considerando-se a estruturação das comunidades no espaço, nossos resultados apontam que os processos baseados na dispersão das espécies, e o componente ambiental autocorrelacionado com o espaço, são os principais fatores determinando a montagem das comunidades em uma escala biogeográfica. Por outro lado, o efeito destes componentes também é variável de acordo com o táxon estudado. Por fim, verificamos que a riqueza de espécies também é modelada negativamente por fatores climáticos relacionados ao clima seco (p. ex. baixa umidade relativa, e baixa precipitação mensal).