Aspectos Florísticos da Estação Ecológica de Itapeva, SP: uma Unidade de Conservação no Limite Meridional do Bioma Cerrado

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Abstract: The Itapeva Ecological Station – EEcI (24° 04' S and 49° 04' W, altitude 750 m), Itapeva, São Paulo State, is a Protected Area (PA) predominantly covered by cerrado denso and cerradão, whose occurrence in the region represents the southern limit of distribution of cerrado *sensu lato*. Aiming to know the regional flora and assuming the existence of floristic peculiarities due to the local weather conditions (incidence of frosts and absence of water deficit), we conducted a floristic survey in this PA from February 2008 to May 2010 and recorded 437 species in seven different physiognomies. In the cerrado *sensu lato* physiognomies, 346 species, distributed among 87 families and 220 genera, were found. The richest families were Asteraceae (31 species), Fabaceae (27), Myrtaceae (26), Melastomataceae (21), Rubiaceae (15), Lauraceae (12), Bignoniaceae (11) and Poaceae (10). Concerning richness and family representativeness, the EEcI flora does not differ from that of other cerrado *sensu lato* remnants at lower latitudes. However, frequent species in those remnants - *Dimorphandra mollis*, *Xylopia aromatica*, *Eugenia aurata* and *Tocoyena formosa* - were not found in the study area region, probably due to frost effects and other limiting climatic factors. On the other hand, geographical distribution models did not predict the occurrence of *Annona dioica*, *Brosimum gaudichaudii*, *Duguetia furfuracea*, *Anadenanthera peregrina* var. *falcata*, *Caryocar brasiliense* and *Schefflera vinosa* for the region of Itapeva, possibly due to the absence of water deficit. The floristic data obtained in this study may assist in the parameterization of these models. The floristic similarity observed between the physiognomic extremes of the cerrado *sensu lato* in the EEcI: cerradão and cerrado ralo, 26%, was smaller than the floristic similarity between the swamp grassland physiognomy and the cerrado ralo (27%), and between the former and the cerrado denso (30%). Therefore, considering floristic composition as one of the defining aspects of vegetation type, the swamp grassland can be included in the delimitation of cerrado *sensu lato* in the EEcI. We recorded eight species threatened with extinction. Due to the PA's small dimensions, we suggest the expansion of its area for a more effective conservation of these species' populations.
Keywords: *Cerrado concept, geographic distribution, Cerrado physiognomies, collecting effort, threatened species.*

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Resumo: A Estação Ecológica de Itapeva – EEcI (24° 04' S e 49° 04' W, altitude 750 m), Itapeva, SP, é uma Unidade de Conservação (UC) de proteção integral com cobertura vegetal predominante de cerrado denso e cerradão, cuja ocorrência na região representa o limite meridional de distribuição do cerrado *sensu lato*. Buscando conhecer a flora regional e supondo a existência de particularidades florísticas devido às condições climáticas locais (ausência de déficit hídrico e incidência de geadas), realizamos um levantamento florístico nesta UC entre fevereiro de 2008 a maio de 2010 e registramos 437 espécies em sete diferentes fisionomias. Nas fisionomias de cerrado *sensu lato* foram encontradas 346 espécies distribuídas em 87 famílias e 220 gêneros. As famílias mais ricas foram Asteraceae (31 espécies), Fabaceae (27), Myrtaceae (26), Melastomataceae (21), Rubiaceae (15), Lauraceae (12), Bignoniaceae (11) e Poaceae (10). Em relação à riqueza e famílias mais representativas, a flora da EEcI não difere de outros remanescentes de cerrado *sensu lato* em latitudes mais baixas. Contudo, espécies frequentes naqueles remanescentes - *Dimorphandra mollis*, *Xylopia aromatica*, *Eugenia aurata* e *Tocoyena formosa* - não foram encontradas na região da área de estudo, provavelmente devido ao efeito de geadas e outros fatores climáticos limitantes. Por outro lado, *Annona dioica*, *Brosimum gaudichaudii*, *Duguetia furfuracea*, *Anadenanthera peregrina* var. *falcata*, *Caryocar brasiliense* e *Schefflera vinosa* não tinham ocorrência prevista na região de Itapeva por modelos de distribuição geográfica, possivelmente devido à ausência de déficit hídrico. As informações florísticas obtidas neste estudo poderão auxiliar na parametrização desses modelos. A similaridade florística observada entre os extremos fisionômicos de cerrado *sensu lato* de interflúvio na EEcI: cerradão e cerrado ralo, 26%, foi menor do que a similaridade florística entre a fisionomia campestre úmida e o cerrado ralo (27%), e entre a primeira e o cerrado denso (30%). Portanto, considerando a composição florística como um dos aspectos definidores do tipo de vegetação, a fisionomia campestre úmida pode ser incluída na delimitação de cerrado *sensu lato* na EEcI. Foram registradas oito espécies ameaçadas de extinção. Devido às dimensões reduzidas da UC, sugerimos a sua ampliação visando maior efetividade na conservação das populações dessas espécies.

Palavras-chave: *conceito de Cerrado, distribuição geográfica, fisionomias de Cerrado, esforço de coleta, espécies ameaçadas.*

Introdução

O Cerrado pode ser considerado como um bioma de savana, uma grande área geográfica marcada por um ambiente relativamente uniforme e pela predominância das fitofisionomias savânicas campo sujo, campo cerrado e cerrado *sensu stricto* (Coutinho 2006). Acrescidas das fisionomias florestal e campestre, cerradão e campo limpo, aquelas fisionomias constituem, segundo o conceito floresta-ecótono-campo de Coutinho (1978), o cerrado *sensu lato* (*s.l.*), ou simplesmente Cerrado, termo utilizado para designar tanto o Bioma quanto o tipo de vegetação que o caracteriza (Coutinho 2002, 2006). Diferentemente de Coutinho (2006), Ribeiro & Walter (2008) não restringem o bioma Cerrado ao cerrado (*s.l.*), mas incluem outras fisionomias florestais e savânicas que ocorrem na região. Além disso, na delimitação de cerrado (*s.l.*), aqueles autores admitem três subtipos para os campos sujo e limpo: úmido, seco e com murundus (Ribeiro & Walter 2008). Neste trabalho, usaremos o termo Cerrado para nos referir ao Bioma conforme definido acima, com base em Coutinho (2006), mas admitiremos a existência de variantes úmidas para os campos sujo e limpo, com base em Ribeiro & Walter (2008). O Cerrado também pode ser considerado como um conjunto de biomas (Coutinho 2002, Ribeiro & Walter 2008, Batalha 2011), contudo, o conceito de bioma de savana é amplamente aceito na literatura nacional e internacional (Coutinho 2006) e sob tal conceituação, o mapeamento do Cerrado, em conjunto com outros biomas nacionais, torna-se mais simples.

A inclusão das fisionomias campestres úmidas constitui a principal diferença entre a delimitação de cerrado (*s.l.*) proposta por Ribeiro & Walter (2008) e aquela sugerida por Coutinho (1978). Este autor entende o cerrado (*s.l.*) como vegetação de interflúvio, sobre solo bem drenado, mesma acepção encontrada em Oliveira-Filho & Ratter (2002). Almeida et al. (2010) consideraram o campo sujo úmido da Estação Ecológica de Itapeva (EEcI) como fisionomia de cerrado (*s.l.*) admitindo que a composição florística constitui um dos aspectos que podem ser considerados na delimitação do tipo de vegetação, juntamente com a fisionomia e as condições ecológicas (Eiten 1979, Rizzini 1997). No entanto, Almeida et al. (2010) não avaliaram formalmente as relações florísticas entre as diferentes fitofisionomias da EEcI. A análise dessas relações envolvendo a fisionomia campestre úmida (campos limpo e sujo úmidos) e as fisionomias de cerrado (*s.l.*) sobre solos bem drenados pode auxiliar na delimitação do cerrado (*s.l.*) na área de estudo.

Segundo Coutinho (2002), a área de abrangência do Cerrado compreende entre 1,8 a 2 milhões de km^2. Tem como área *core* o Planalto Central, estendendo-se em seu limite meridional de distribuição, até o estado do Paraná (Brasil 2008a). Na história recente da ocupação do território nacional, foi o Bioma que mais cedeu espaço para a implantação de áreas destinadas a atividades agrícolas, silviculturais, pecuárias e para a urbanização (Klink & Machado 2005). Em São Paulo, entre 1962 e 2001, a área ocupada por cerrado (*s.l.*) foi reduzida em 88,5% de sua extensão (Kronka et al. 2005). A importância biológica do Cerrado vem sendo enfatizada recentemente (Mittermeier et al. 1999, Aguiar & Camargo 2004, Klink & Machado 2005, Sano et al. 2008), e embora seja considerável o número de espécies ameaçadas de extinção no Bioma (São Paulo 2004, Fundação Biodiversitas 2008), o percentual de sua área ocupada por unidades de conservação (UC) de proteção integral é de apenas 2,48% (Arruda et al. 2008).

A EEcI é uma dessas unidades, localizada no limite meridional de distribuição do Cerrado. Tal localização acentua a importância da UC como área protegida devido a possíveis peculiaridades florísticas inerentes a condições climáticas diferentes daquelas que predominam na área *core* do Bioma. Ratter et al. (2003), considerando apenas espécies lenhosas de cerrado (*s.l.*), reconheceram cinco províncias florísticas, sendo que uma delas abrange remanescentes situados no estado de São Paulo. Por outro lado, considerando apenas os remanescentes paulistas, verificou-se uma diferenciação na flora lenhosa entre áreas situadas ao norte e ao sul do Estado (Durigan et al. 2003). Essas diferenças estariam relacionadas a variações climáticas, especialmente a duração do período seco e a temperatura, resultando em diferenciações florísticas dentro de um mesmo tipo fisionômico (Durigan et al. 2003).

De acordo com Leitão-Filho (1992), no estado de São Paulo existiria um gradiente latitudinal na flora arbórea do cerrado (*s.l.*), sendo os remanescentes do sul desprovidos de algumas espécies encontradas nos remanescentes do norte, provavelmente devido a geadas que atuariam como fator restritivo à ocorrência dessas espécies. A ausência de algumas espécies típicas de cerrado foi relatada para áreas no Paraná, sugerindo que este Estado constituiria o limite meridional de distribuição dessas espécies (Linsingen et al. 2006, Ritter et al. 2010). Contudo, considerando o gradiente latitudinal, é possível que tal limite ocorra no estado de São Paulo, o que pode ser aferido por meio do estudo da flora de remanescentes de cerrado (*s.l.*) no extremo meridional de distribuição do Bioma no Estado. Tais estudos são ainda escassos (Scaramuzza 2006), assim, o estudo florístico da EEcI pode ajudar a preencher essa lacuna e auxiliar no reconhecimento dos limites meridionais de distribuição geográfica de espécies de cerrado (*s.l.*).

Adicionalmente, a disponibilidade de dados florísticos contribui para aumentar a precisão de modelos de distribuição geográfica dos taxons, que podem ser úteis como ferramentas de apoio ao planejamento de ações de conservação da biodiversidade (Peterson 2001, Stockwell & Peterson 2002). Em revisão recente sobre o tema, Feeley & Silman (2011) consideraram que a coleta de novos espécimes é fundamental para o desenvolvimento de modelos que possam prever acuradamente a distribuição das espécies de plantas tropicais e as possíveis alterações na distribuição geográfica dessas espécies frente às mudanças climáticas globais. Assim, a inclusão de estudos florísticos realizados na região climática da área de estudo poderia ajudar a melhorar os modelos de distribuição geográfica de espécies de cerrado (*s.l.*) no estado de São Paulo (Siqueira & Durigan 2007). É possível abordar essa questão indiretamente por meio da comparação entre as previsões de incidência de espécies dos modelos e os dados obtidos no presente trabalho.

O objetivo geral deste estudo foi caracterizar a flora vascular da Estação Ecológica de Itapeva, especialmente a flora de cerrado (*s.l.*). Os objetivos específicos foram: (a) avaliar se a fisionomia campestre úmida da Estação pode ser incluída no tipo de vegetação cerrado (*s.l.*), considerando a composição florística; (b) identificar espécies ameaçadas de extinção na Unidade; (c) verificar se a região da área de estudo representa o limite meridional de distribuição de espécies lenhosas típicas de cerrado (*s.l.*); e (d) comparar os dados de incidência de espécies obtidos a partir do levantamento florístico com a incidência prevista por modelos de distribuição geográfica no estado de São Paulo.

Material e Métodos

1. *Localização, clima, relevo, solo e tipos de vegetação*

A Estação Ecológica de Itapeva, criada pelo Decreto Estadual nº 7.692/76, está situada no município de Itapeva, na região sudoeste do estado de São Paulo, na microbacia do rio Pirituba, bacia do Alto Paranapanema (24° 04' S e 49° 04' W, altitude 750 m). A EEcI possui 107 ha, sendo delimitada ao norte pela Rodovia Francisco Alves Negrão (SP 258); ao sul, pelo assentamento rural Pirituba II área IV; a leste, pelo rio Pirituba e, a oeste, pelo córrego do Banhado. Encontra-se em região caracterizada por colinas de topos convexos com declives de 10 a 20%, na Depressão Periférica Paulista, zona do Paranapanema (Ross & Moroz 1997). O clima na região é classificado como Cfb na classificação de Koeppen, com 18 a 20 °C de temperatura média anual, variando de 26 a 28° C a temperatura média do mês de janeiro, e de 8 a 16° C a média do mês de julho. A precipitação anual varia entre 1.200 a 1.400 mm (Instituto de Pesquisas Tecnológicas 2001).

Na EEcI predominam o Latossolo Vermelho Amarelo e o Argissolo Amarelo, mas ocorrem também associações de Argissolo Amarelo + Neossolo Litólico e Gleissolo Melânico + Gleissolo Háplico (Novais et al. 2009). Possui 100,42 ha de vegetação natural, distribuídos em sete categorias fisionômicas (Cielo-Filho et al. 2011). As categorias de cerrado (*s.l.*) foram definidas de acordo com o sistema de classificação de Ribeiro & Walter (2008), incluindo campo limpo e sujo úmidos (2,44 ha), cerrado ralo (3,10 ha), cerrado denso (42,88 ha) e cerradão (44,15 ha). Utilizamos o sistema de Veloso et al. (1991) para classificar as fisionomias extra cerrado (*s.l.*), que na EEcI consistem de Floresta Estacional Semidecidual Montana (6,92 ha) e Floresta Estacional Semidecidual Aluvial (0,93 ha). Assim, dois biomas estão representados na Estação por fisionomias pertencentes aos seus respectivos tipos de vegetação sentido amplo: o Cerrado (Coutinho 2006) e a Mata Atlântica (Oliveira-Filho & Fontes 2000).

2. *Amostragem florística e análise de dados*

Todas as categorias fisionômicas e formas de vida de plantas vasculares foram consideradas na amostragem florística. No entanto, por predominarem na área, as fisionomias de cerrado (*s.l.*) receberam maior ênfase no detalhamento dos resultados e na discussão. A listagem florística do campo sujo úmido foi publicada em trabalho à parte (Almeida et al. 2010) e não é apresentada aqui. Contudo, os dados referentes ao número de espécies, espécies ameaçadas e distribuição de riqueza entre hábitos e famílias naquela fisionomia também foram considerados para compor os valores totais dessas variáveis para o cerrado (*s.l.*).

O método adotado teve como base o caminhamento (Filgueiras et al. 1994). Foram percorridas as trilhas existentes e as abertas para a elaboração deste trabalho, bem como as bordas da Estação em seus limites norte e sul, no período compreendido entre os meses de fevereiro de 2008 e maio de 2010. As visitas a campo tiveram duração de três dias e periodicidade mensal. A coleta e a herborização do material botânico seguiram as recomendações de Fidalgo & Bononi (1989). A identificação de materiais férteis e estéreis foi feita por meio de comparação com exsicatas depositadas nos herbários Dom Bento Pickel (SPSF) e Maria Eneyda P. K. Fidalgo (SP) e de consulta à bibliografia e a especialistas.

Materiais férteis foram tombados e depositados no Herbário SPSF e os respectivos registros estão disponíveis para consulta *online* (Species Link 2010). As espécies foram ordenadas em gêneros e famílias de acordo com o sistema APG III (Judd et al. 2002, Souza & Lorenzi 2008, Angiosperm Phylogeny Group 2009). Para verificação de sinonímias botânicas e grafias foram consultados os bancos de dados W3 Tropicos (Missouri Botanical Garden 2010), *International Plant Names Index* (International Plant Names Index 2010) e Lista de Espécies da Flora do Brasil (Jardim Botânico do Rio de Janeiro 2010). Na lista de espécies foram indicados o nome popular, o hábito, a fisionomia em que a espécie foi coletada e o número de tombo SPSF. Devido às pequenas dimensões da Estação, não foram apresentadas as coordenadas geográficas para as coletas individuais, mas essas coordenadas podem ser obtidas no sistema de busca do Species Link escolhendo a coleção SPSF e utilizando o número de tombo como filtro.

Para avaliar se a fisionomia campestre úmida da EEcI pode ser considerada como cerrado (*s.l.*), as espécies do campo sujo úmido (Almeida et al. 2010) e campo limpo úmido foram agrupadas em uma única lista para representar a fisionomia campestre úmida. Esta lista foi comparada, considerando apenas o estrato herbáceo-arbustivo, com a lista geral das fisionomias de cerrado (*s.l.*) de interflúvio, que na EEcI inclui cerradão, cerrado denso e cerrado ralo, e com a lista da Floresta Estacional Semidecidual Montana. Devido à área relativamente pequena ocupada pela Floresta Estacional Semidecidual Montana, adicionamos à respectiva lista as espécies do mesmo estrato e fisionomia encontradas na Estação Experimental de Itapeva, que é contígua à EEcI (Souza et al. *in prep.*). As comparações foram feitas por meio do índice de similaridade de Sorensen (Legendre & Legendre 1998). Também comparamos, por meio do mesmo índice, mas considerando todos os estratos, cada uma das listas individuais das fisionomias de cerrado (*s.l.*) de interflúvio entre si e com a lista da fisionomia campestre úmida. Assumimos que a delimitação de cerrado (*s.l.*) deveria incluir a fisionomia campestre úmida se: (1) a similaridade entre a lista dessa fisionomia fosse maior em relação à lista geral de cerrado (*s.l.*) do que em relação à lista da Floresta Estacional Semidecidual Montana; e (2) as similaridades obtidas nas comparações das listas individuais das fisionomias que compõem o cerrado (*s.l.*) de interflúvio entre si fossem comparáveis às similaridades obtidas nas comparações entre aquelas listas e a lista da fisionomia campestre úmida.

Consultamos as seguintes fontes para verificação do nível de ameaça de extinção das espécies encontradas:

Lista Oficial de Espécies Ameaçadas de Extinção no Estado de São Paulo – SMA-SP (São Paulo 2004);

Revisão da Lista de Espécies da Flora Brasileira Ameaçada de Extinção - FB (Fundação Biodiversitas 2008);

Lista Oficial das Espécies da Flora Brasileira Ameaçadas de Extinção – MMA (Brasil 2008b);

Lista Vermelha de Espécies Ameaçadas de Extinção da União Internacional para a Conservação da Natureza – IUCN (International Union for Conservation of Nature 2010).

A lista da Fundação Biodiversitas foi utilizada, juntamente com a lista do Ministério do Meio Ambiente, para a análise das espécies ameaçadas em escala nacional, por ser mais abrangente do que esta última. Como a lista MMA não apresenta as categorias de ameaça das espécies, os resultados obtidos a partir dessa lista são apenas de presença ou ausência, indicadas pelos números 1 ou 0, respectivamente. As categorias de ameaça adotadas nas listas SMA-SP e FB são baseadas nas categorias adotadas na lista IUCN, as quais apresentam a seguinte ordenação de acordo com o grau decrescente de ameaça (International Union for Conservation of Nature 2001): Extinta (EX), Extinta na Natureza (EW), Criticamente Ameaçada (CR), Ameaçada (EN), Vulnerável (VU), Baixo Risco (LR). Informações sobre os tipos de ameaça foram obtidas em Souza et al. (2007) e nos sítios eletrônicos da Fundação Biodiversitas (Fundação Biodiversitas 2008) e da União Internacional para a Conservação da Natureza – IUCN (International Union for Conservation of Nature 2010).

Para verificar se a região da área de estudo representa o limite meridional de distribuição geográfica para espécies arbóreas típicas do cerrado (*s.l.*) utilizamos dois conjuntos de espécies como parâmetro. O primeiro envolve as 25 espécies consideradas frequentes (frequência superior a 70%) na província florística do extremo sul do Bioma (Bridgewater et al. 2004), que inclui predominantemente remanescentes de Cerrado paulistas (Ratter et al. 2003). O segundo grupo abrange as 17 espécies mais frequentes em remanescentes de Cerrado paulistas apontadas por Siqueira & Durigan (2007). Na análise destas autoras não foram incluídos levantamentos florísticos em latitudes semelhantes ou superiores à da EEcI e, em Ratter et al. (2003), apenas uma das áreas incluídas nas comparações situa-se em posição mais meridional do que a EEcI. Assim, consideramos que a ausência na EEcI de espécies dos dois conjuntos mencionados acima pode indicar o limite meridional de distribuição para essas espécies.

A comparação dos dados de incidência de espécies obtidos a partir do levantamento florístico com a incidência prevista por modelos de distribuição geográfica no estado de São Paulo considerou os modelos gerados por algoritmo genético apresentados em Siqueira & Durigan (2007). Esses modelos foram gerados a partir de um conjunto de levantamentos florísticos de áreas situadas em latitudes mais baixas do que a da EEcI e foram usados para prever a distribuição do bioma Cerrado bem como de algumas de suas espécies mais importantes no estado de São Paulo.

Resultados

A lista florística apresentada aqui (Tabela 1) totalizou 399 espécies de plantas vasculares, sendo que 99 foram identificadas por meio do exame de material vegetativo, pois não foram coletadas em período reprodutivo (essas espécies não apresentam número de tombo na tabela 1). Dentre as 106 espécies citadas por Almeida et al. (2010) para o campo sujo úmido, 38 não foram encontradas nas outras fisionomias. Assim, o número total estimado de espécies de plantas vasculares para a Estação é de 437 (399 + 38 exclusivas de campo sujo úmido).

1. *Caracterização da flora de cerrado (s.l.)*

Considerando apenas espécies de cerrado (*s.l.*), foram encontradas 346 espécies distribuídas em 220 gêneros e 87 famílias botânicas, sendo as de maior riqueza Asteraceae (31 espécies), Fabaceae (27), Myrtaceae (26), Melastomataceae (21), Rubiaceae (15), Lauraceae (12), Bignoniaceae (11) e Poaceae (10), que reuniram 153 espécies ou 44,2% do total.

Em relação ao hábito, 133 espécies são árvores, 100 são ervas, 84 são arbustos, 18 são lianas e 9 são epífitas. Apenas uma espécie de saprófita e uma espécie hemiparasita foram encontradas. As espécies do componente arbóreo estão distribuídas em 88 gêneros e 46 famílias sendo as famílias mais ricas Myrtaceae (19 espécies), Fabaceae (14), Lauraceae (9), Annonaceae (6), Asteraceae e Melastomataceae (5 cada). Já o componente não-arbóreo reuniu 213 espécies de 150 gêneros e 64 famílias, as mais ricas sendo Asteraceae (26 espécies), Melastomataceae (16), Fabaceae (14), Rubiaceae (12), Poaceae (10), Bromeliaceae (8), Malpighiaceae, Myrtaceae (7 espécies cada), Cyperaceae (6), Apocynaceae, Orchidaceae e Solanaceae (5 espécies cada).

2. *Delimitação do cerrado (s.l.) na EEcI*

O cerrado denso apresentou o maior número de espécies (178), seguido pelo cerrado ralo (158), campo sujo úmido (100), cerradão (104) e campo limpo úmido (20). A fisionomia campestre úmida (campo sujo úmido + campo limpo úmido) totalizou 101 espécies. Considerando apenas o estrato herbáceo-arbustivo, a riqueza nesta fisionomia foi de 86 espécies. No conjunto das fisionomias de cerrado (*s.l.*) de interflúvio e na Floresta Estacional Semidecidual Montana (incluindo dados da Estação Experimental) foram encontradas 148 e 143 espécies herbáceo-arbustivas, respectivamente. O número de espécies herbáceo-arbustivas compartilhadas entre a fisionomia campestre úmida e o cerrado (*s.l.*) de interflúvio foi de 35. O número correspondente para a Floresta Estacional Semidecidual Montana foi de apenas 11. As similaridades obtidas com o índice de Sorensen foram de 0,3 entre a fisionomia campestre úmida e o cerrado (*s.l.*) de interflúvio e de 0,1 entre aquela e a Floresta Estacional Semidecidual Montana. Considerando as fisionomias de cerrado (*s.l.*) de interflúvio separadamente e a campestre úmida, a menor similaridade foi entre esta e o cerradão e a maior, entre o cerrado ralo e o cerrado denso (Tabela 2). Contudo, as similaridades entre a fisionomia campestre úmida e o cerrado ralo e especialmente, entre a primeira e o cerrado denso, foram maiores do que a similaridade observada entre os extremos fisionômicos de cerrado (*s.l.*) de interflúvio na EEcI: cerradão e cerrado ralo.

3. *Espécies ameaçadas*

Dentre as 437 espécies registradas em todas as fisionomias da EEcI, oito estão ameaçadas de extinção de acordo com as fontes consultadas (Tabela 3). A distribuição geográfica restrita e a ocorrência desconhecida em unidade de conservação são as causas de ameaça mais frequentes, afetando quatro das oito espécies ameaçadas. Apenas uma espécie, *Araucaria angustifolia* (Bert.) Kuntze, consta como ameaçada simultaneamente nas listas que consideram os níveis mundial, nacional e estadual. Considerando apenas o nível estadual, são três espécies na categoria "Ameaçada" e três na categoria "Vulnerável".

4. *Limites de distribuição de espécies lenhosas típicas de cerrado (s.l.)*

Dentre espécies apontadas por Bridgewater et al. (2004) como frequentes no cerrado (*s.l.*) na província florística do extremo sul do Bioma, não foram encontradas na EEcI:

Tabela 1. Espécies de plantas vasculares da Estação Ecológica de Itapeva. Fisionomias: C, cerradão; CD, cerrado denso; CLU, campo limpo úmido, CR, cerrado ralo; FESM, Floresta Estacional Semidecidual Montana; FESA, Floresta Estacional Semidecidual Aluvial. SPSF, número de tombo no Herbário Dom Bento Pickel. Asterisco, mata ciliar do rio Pirituba.

Table 1. Vascular plant species of the Ecological Station of Itapeva. Physiognomy, C, woody savanna taller than CD; CD, woody savanna; CLU, grassland swamp savanna; CR, grassland savanna with scattered trees; FESM, Montane Semideciduous Seasonal Forest; FESA, Alluvial Semideciduous Seasonal Forest. SPSF, specimen record number at the Dom Bento Pickel Herbarium. Asterisk, Pirituba riverine forest.

Família/Espécie	Nome popular	Hábito	Fisionomia	SPSF
ACANTHACEAE				
Justicia carnea Lindl.	Justícia	Erva	FESM*	41146
Ruellia geminiflora Kunth	Ipecaconha	Erva	CR	
ANACARDIACEAE				
Lithraea molleoides (Vell.) Engl.	aroeira-brava	Árvore	CD, CR, FESM	39591, 41513
Schinus terebinthifolius Raddi	aroeira-pimenteira	Árvore	CD	41254
Tapirira guianensis Aubl.	peito-de-pombo	Árvore	C, CD, FESA	39621, 41252
ANNONACEAE				
Annona cacans Warm.	araticum-cagão	Árvore	C	
Annona coriacea Mart.	araticum-do-campo	Árvore	C	
Annona crassiflora Mart.	araticum	Árvore	C, CD	39697
Annona dioica A.St.-Hil.	araticum	Árvore	C	
Duguetia furfuracea (A.St.-Hil.) Saff.	marolinho	Arbusto	CLU, CD, FESA	39738, 41466
Duguetia lanceolata A.St.-Hil.	pindaíba	Árvore	C	
Guatteria australis A.St.-Hil.	pindaúva-preta	Árvore	C, CD, FESM*, FESA	39767, 41130
APIACEAE				
Eryngium canaliculatum Cham. & Schltdl.	língua-de-tucano	Erva	CR, CD	
Eryngium elegans Cham. & Schltdl.	caraguatá-elegante	Erva	CR	41572
Eryngium eriophorum Cham. & Schltdl.	azulzinha	Erva	CR	39721
APOCYNACEAE				
Aspidosperma cylindrocarpon Müll. Arg.	peroba-poca	Árvore	FESM	
Aspidosperma subincanum Mart.	guatambu-vermelho	Árvore	C	
Aspidosperma tomentosum Mart.	guatambu-do-cerrado	Árvore	CLU, C, CD	39595, 39627
Ditassa warmingii E.Fourn.		Liana	CD	39859
Gonioanthela axillaris (Vell.) Fontella & E.A.Schwarz		Liana	FESA	
Mandevilla pohliana (Stadelm.) A.H.Gentry	jalapa-do-campo	Erva	CD	41247, 41249
Oxypetalum appendiculatum Mart.	cipó-leite	Erva	CD	39770
Tabernaemontana laeta Mart.	leiteiro	Árvore	FESM	41511
Temnadenia violacea (Vell.) Miers	cipó-da-flor-lilás	Liana	CLU, C, CD, FESM	39566, 41515
AQUIFOLIACEAE				
Ilex brasiliensis (Spreng.) Loes.	mate-falso	Árvore	FESM*, FESA	40120, 41128
Ilex paraguariensis A.St.-Hil.	erva-mate	Árvore	CD	39580, 41115
Ilex theaezans Mart.	caúna	Arbusto	CD	41120
ARALIACEAE				
Dendropanax cuneatus (DC.) Decne. & Planch.	maria-mole	Árvore	FESM	
Schefflera morototoni (Aubl.) Decne. & Planch.	morototó	Árvore	FESM	
Schefflera vinosa (Cham. & Schltdl.) Frodin & Fiaschi	mandioqueiro	Árvore	C, CD, CR	39607, 40514
ARAUCARIACEAE				
Araucaria angustifolia (Bert.) Kuntze	araucária	Árvore	FESM*	
ARECACEAE				
Attalea geraensis Barb. Rodr.	palmeira-indaiá-do-cerrado	Arbusto	CD	39727
Geonoma schottiana Drude	gamiova	Arbusto	FESM*, FESA	40130, 40173
Syagrus romanzoffiana (Cham.) Glassm.	jerivá	Árvore	CD	
ASTERACEAE				
Achyrocline satureioides (Lam.) DC.	macela	Arbusto	CR	39702
Aspilia heringeriana H.Rob.	margarida-do-campo	Erva	CR	41240
Baccharis dentata (Vell.) G.M.Barroso	alecrim-do-campo	Árvore	FESM*	
Baccharis dracunculifolia DC.	alecrim	Arbusto	CR	39760

Tabela 1. Continuação...

Família/Espécie	Nome popular	Hábito	Fisionomia	SPSF
Baccharis genistelloides (Lam.) Pers.	carqueja	Erva	FESM*	40562
Baccharis pentziifolia Sch.Bip. ex Baker	vassourão-do-campo	Arbusto	CD	39740
Baccharis trimera (Less.) DC.	carqueja-amarga	Arbusto	CLU, CD, CR	40466, 41477
Calea cymosa Less.	margarida-branca	Erva	CR	41533
Calea pinnatifida (R.Br.) Baker	erva-de-lagarto	Erva	FESM	
Calea triantha (Velloso) Pruski		Erva	CR	39689
Chresta sphaerocephala DC.	chapéu-de-couro	Arbusto	CD, CR	40154, 40476
Chromolaena congesta (Hook. & Arn.) R.M.King & H.Rob.		Arbusto	CR	39761
Chromolaena odorata (L.) King & H.E. Robins.	cromolena	Liana	C	39684
Chromolaena subvelutina (DC.) R.I.Esteves		Arbusto	CD	39677
Chrysolaena platensis (Spreng.) H. Rob.	assa-peixe-roxo	Arbusto	CD, CR	39686, 41579
Eupatorium sp.		Erva	CD	41467
Gochnatia paniculata (Less.) Cabrera	cambará	Arbusto	CD, CR	40281, 40467
Gochnatia polymorpha (Less.) Cabrera	cambará	Árvore	CD, CR	39763, 39765
Grazielia multifida (DC.) King & Robins	eupatório	Erva	CR	41161
Mikania oblongifolia DC.		Arbusto	CD	41122
Mikania sessilifolia DC.		Arbusto	CR	39691
Neocabreria aff. *malacophylla* (Klatt) R.M.King & H.Rob.		Erva	C, FESM*	40512, 40524
Piptocarpha axillaris (Less.) Baker	vassourão	Árvore	C, CR, FESM*	40295, 40480
Piptocarpha macropoda (DC.) Baker	casca-preta-da-folha-larga	Árvore	C	
Piptocarpha regnellii (Sch.Bip.) Cabrera	vassourãozinho	Árvore	C	
Senecio brasiliensis (Spreng.) Less.	maria-mole	Erva	CR	41532
Symphyopappus cuneatus (DC.) Sch.Bip. ex Baker	eupatório	Arbusto	CD, CR	
Trixis verbasciformis Less.	arnica-docampo	Erva	CD	41469
Vernonia diffusa Less.	cambará-de-casca-preta	Árvore	C	
Vernonia nitidula Less.	cambarazinho	Arbusto	CD	39687
Viguiera aff. *gardneri* Barker		Erva	CR	41166, 41587
BIGNONIACEAE				
Cybistax antisyphilitica (Mart.) Mart.	ipê-verde	Árvore	CD	
Fridericia speciosa Mart.	cipó-vermelho	Liana	CD	41160
Handroanthus chrysotrichus (Mart. ex A.DC.) Mattos	ipê-amarelo	Árvore	CD	
Handroanthus ochraceus (Cham.) Mattos	ipê-amarelo	Árvore	CLU, C, CD, CR	40478
Jacaranda aff. *macrantha* Cham.	caroba	Árvore	C	
Jacaranda caroba (Vell.) A.DC.	caroba-do-campo	Arbusto	CR, FESA	41248, 41257
Jacaranda cuspidifolia Mart. ex DC.	carobinha	Árvore	CR	41245
Jacaranda oxyphylla Cham.	caroba-de-são-paulo	Arbusto	CD, CR	39711, 40464
Tabebuia aurea (Silva Manso) Bent. & Hook.f. ex S.Moore	cinco-folhas	Árvore	C	
Zeyheria montana Mart.	bolsa-de-pastor	Árvore	CR	39610, 39633
BORAGINACEAE				
Cordia trichotoma (Vell.) Arrab. ex Steud.	louro-pardo	Árvore	C	
Euploca salicoides (Cham.) J.I.M. Melo & Semir	crisa-de-galo	Erva	CR	41578
BROMELIACEAE				
Aechmea distichantha Lem.	caraguatá	Erva	CR	40472, 40475
Ananas ananassoides (Baker) L.B.Sm.	abacaxi-do-cerrado	Erva	C	
Billbergia distachia (Vell) Mez	gravatá	Epífita	FESM*	41132
Billbergia zebrina (Herb.) Lindl.	bromélia	Epífita	C	39748
Bromelia balansae Mez	caraguatá	Erva	CD	
Dyckia linearifolia Baker	gravatá	Erva	CR, CD	40469, 41123
Tillandsia stricta Sol.	gravatazinho	Epífita	CLU, CD	39628, 40156

Tabela 1. Continuação...

Família/Espécie	Nome popular	Hábito	Fisionomia	SPSF
Tillandsia tenuifolia L.	tilandsia	Epífita	C, CR	40468, 41098
Vriesea procera (Mart. ex Schult. & Schult.f.) Wittm.		Erva	C	40580
CACTACEAE				
Cereus hildmannianus K.Schum.	mandacaru	Árvore	C	
CANNABACEAE				
Trema micrantha (L.) Blume	crindiúva	Árvore	FESM	41508
CARYOCARACEAE				
Caryocar brasiliense Cambess.	pequi	Arbusto	CD	39626, 41117
CELASTRACEAE				
Maytenus evonymoides Reissek	laranjinha	Árvore	CD, FESA	40298
Maytenus gonoclada Mart.	maytenus	Árvore	C	39701
Peritassa campestris (Cambess.) A.C.Sm.	bacupari	Arbusto	CD	40513
Peritassa hatschbachii Lombardi	bacupari	Liana	FESM*	41149
Plenckia populnea Reissek	mangabeira-brava	Árvore	CD	41251
CHLORANTHACEAE				
Hedyosmum brasiliense Miq.	chá-de-soldado	Árvore	FESA	41205
CHRYSOBALANACEAE				
Hirtella hebeclada Moric. ex DC.	macucurana	Árvore	C	
CLETHRACEAE				
Clethra scabra Pers.	guaperê	Árvore	CR	39636
CLUSIACEAE				
Clusia criuva Cambess.	folha-dura-da-pedra-grande	Árvore	FESM*	41213
Kielmeyera coriacea Mart.	para-tudo	Árvore	C, CD, CR	39745, 41234
Kielmeyera variabilis Mart.& Zucc.	pau-santo	Árvore	CD	
COMBRETACEAE				
Terminalia triflora (Griseb.) Lillo	amarelinho	Árvore	FESM*	
COMMELINACEAE				
Commelina erecta L.	trapoeraba-azul	Erva	CD, FESA	40270, 41560
CONVOLVULACEAE				
Ipomoea delphinioides Choisy	ipoméia	Liana	CD, CR	41106, 41577
Jacquemontia ferruginea Choisy		Erva	C, CR	39714, 41529
Merremia contorquens (Choisy) Hallier f.		Erva	CD, CR	39681, 39750
CUCURBITACEAE				
Cayaponia espelina (Silva Manso) Cogn.	espelina-verdadeira	Erva	C, CD, CR	39620, 41574
Melancium campestre Naudin	melancia-do-campo	Erva	CD	
CUNONIACEAE				
Lamanonia ternata Vell.	cangalheiro	Árvore	C, FESM*	40180, 41140
CYPERACEAE				
Lagenocarpus sp.		Erva	FESA	41557
Rhynchospora consanguinea (Kunth) Boeck.		Erva	CR, FESA	41552
Rhynchospora corymbosa (L.) Britton	capituva	Erva	CD, FESA	40146
Rhynchospora exaltata Kunth	periperi	Erva	CD	41108
Rhynchospora globosa (Kunth) Roem. & Schult.	espeta-nariz	Erva	FESA	41554
Rhynchospora splendens Lindm.	capim-navalha	Erva	FESA	40128
DENNSTAEDTIACEAE				
Pteridium aquilinum (L.) Kuhn	samambaia-das-taperas	Erva	CD	
DILLENIACEAE				
Davilla elliptica A.St.-Hil.	cipó-caboclo	Liana	CD	39612
Davilla rugosa Poir.	cipó-caboclo	Liana	C	39564
DIOSCOREACEAE				

Tabela 1. Continuação...

Família/Espécie	Nome popular	Hábito	Fisionomia	SPSF
Dioscorea amaranthoides C.Presl	cará	Liana	C	39762
EBENACEAE				
Diospyros hispida A.DC.	caqui-do-cerrado	Árvore	CD, CR	
ERICACEAE				
Gaylussacia brasiliensis (Spreng.) Meisn.	camarinha	Arbusto	CR	39616
ERIOCAULACEAE				
Eriocaulon gomphrenoides Kunt		Erva	CLU	40497
Syngonanthus xeranthemoides (Boing.) Ruhland	jazida-do-brejo	Erva	CLU, FESA	41553
ERYTHROXYLACEAE				
Erythroxylum cuneifolium (Mart.) O.E.Schulz	mercúrio	Arbusto	CD	39769, 41238
Erythroxylum deciduum A.St.-Hil.	cocão	Árvore	CD, CR	40485, 41242
Erythroxylum suberosum A.St.-Hil.	galinha-choca	Arbusto	CD	
ESCALLONIACEAE				
Escallonia farinacea A.St.-Hil. var. *farinacea*	esponja-do-mato	Arbusto	CD	41573
EUPHORBIACEAE				
Alchornea triplinervia (Spreng.) Müll.Arg.	tapiá	Árvore	FESM	
Croton serpyllifolius Baill.		Arbusto	CR	41168
Microstachys daphnoides (Mart) Müll.Arg.		Erva	CR	39749
Pera glabrata (Schott) Poepp. ex Baill	tamanqueira	Árvore	CD, FESA	
Sebastiania brasiliensis Spreng.	branquilho	Árvore	FESM	
Sebastiania commersoniana (Baill.) L.B.Sm. & Downs	branquilha	Arbusto	FESM*	41137, 41144
FABACEAE-CAESALPINIOIDEAE				
Cassia ferruginea (Schrad.) Schrad. ex DC.	chuva-de-ouro	Árvore	CD, FESM	
Chamaecrista cathartica (Mart.) H.S.Irwin & Barneby	sene-do-campo	Arbusto	CLU, CD	39602, 41547
Chamaecrista desvauxii (Collad.) Killip	sene	Arbusto	CD	39569
Chamaecrista desvauxii (Collad.) Killip var. *langsdorffii* (Kunth ex Vogel) Irwin & Barneby	sene	Erva	CR	41173
Copaifera langsdorffii Desf.	copaíba	Árvore	CD	
Senna rugosa (G.Don) H.S.Irwin & Barneby	manduirana-do-cerrado	Arbusto	CD, CR	39615, 40152
Senna splendida (Vogel) H.S.Irwin & Barneby	manduirana	Arbusto	C, CD	39724, 39812
Tachigali denudata (Vogel) Oliveira-Filho	angá	Árvore	FESM*	40177
FABACEAE-CERCIDEAE				
Bauhinia longifolia (Bong.) Steud.	pata-de-vaca-do-campo	Árvore	C, CD, FESM*, FESM	
Bauhinia rufa (Bong.) Steud.	pata-de-vaca	Árvore	C, CR	39752, 41544
FABACEAE-FABOIDEAE				
Acosmium subelegans (Mohlenbr.) Yakovlev	amendoim-falso	Árvore	CD	41195
Andira humilis Mart. ex Benth.	angelim-do-campo	Árvore	CR	39583
Camptosema scarlatinum (Mart. ex Benth.) Burkart	bico-de-papagaio	Liana	C, CR, FESM	39718, 41517
Centrosema bracteosum Benth.	rabo-de-tatu	Arbusto	FESA	41541
Crotalaria micans Link	guizo-de-cascavel	Erva	CR	39707
Dalbergia miscolobium Benth.	caviúna-do-campo	Árvore	CD, CR	39618, 39698
Eriosema heterophyllum Benth.	feijão-bravo	Erva	CR	40477, 41200
Machaerium acutifolium Benth.	jacarandá-do-campo	Árvore	C, CD, CR	39630, 41092
Machaerium brasiliense Hoehne	sapuva	Árvore	CLU, C, FESM*	39603
Machaerium hirtum (Vell.) Stellfeld	barreiro	Árvore	FESM	
Machaerium nictitans (Vell.) Benth.	bico-de-andorinha	Árvore	C, CD, FESM*	
Ormosia arborea (Vell.) Harms	olho-de-cabra	Árvore	FESM*	
Periandra mediterranea (Vell.) Taub.	alcaçuz-do-cerrado	Arbusto	C, CD	39619, 39625
Vigna peduncularis Kunth	feijão-do-mato	Liana	CD	40110
FABACEAE-MIMOSOIDEAE				

Tabela 1. Continuação...

Família/Espécie	Nome popular	Hábito	Fisionomia	SPSF
Anadenanthera colubrina (Vell.) Brenan	angico-branco	Árvore	FESM*	41129, 41141
Anadenanthera peregrina var. *falcata* (Benth.) Altschul	angico-do-cerrado	Árvore	CD, CR	39609, 40455
Calliandra dysantha Benth.	flor-de-caboclo	Arbusto	CD, CR	39731, 40488
Inga marginata Willd.	ingá-feijão	Árvore	FESM*	40540
Leucochlorom incuriale (Vell.) Barneby & J.W.Grimes	angico-rajado	Árvore	FESM*	
Mimosa debilis Humb. & Bonpl. ex Willd. var. debilis	juquiri	Arbusto	CD	41474
Mimosa dolens Vell.	juquiri	Arbusto	CLU, CR	39564, 39699
Mimosa furfuracea Benth.		Árvore	CR	40474
Mimosa micropteris Benth.		Arbusto	CD	41471, 41538
Piptadenia gonoacantha (Mart.) J.F.Macbr.	pau-jacaré	Árvore	FESM	
Stryphnodendron adstringens (Mart.) J.F.Macbr.	barbatimão-verdadeiro	Árvore	CD, CR	40481, 41253
Stryphnodendron obovatum Benth.	barbatimão	Árvore	CR	39631
GENTIANACEAE				
Adenolisianthus arboreus (Spruce ex Progel) Gilg	genciana-da-terra	Erva	CR	41539
Irlbachia oblongifolia (Mart.) Maas	genciana-do-campo	Erva	FESA	41311
Voyria aphylla (Jacq.) Pers.	angélica-do-mato	Saprófita	C	39757
Voyria tenella Hook.	angélica-lilás	Saprófita	FESA	40277
GESNERIACEAE				
Sinningia allagophylla (Mart.) Wiehler	cravo-do-campo	Erva	FESM	
HYPERICACEAE				
Hypericum brasiliense Choisy	alecrim-bravo	Erva	CD	40165
IRIDACEAE				
Alophia sellowiana Klatt	lírio-branco-do-brasil	Erva	CD	40462
Neomarica rigida (Ravenna) Capellari Jr.	neomarica-espetada	Erva	FESM*	41142
Sisyrinchium vaginatum Spreng.	capim-reis	Erva	CD	40169
Trimezia juncifolia (Klatt) Benth. & Hook.	ruibarbo-amarelo	Erva	CD, CR	41116, 41545
LAMIACEAE				
Aegiphila lhotskiana Cham.	tamanqueira	Árvore	CLU, C, CD	39601, 41118
Aegiphila verticillata Vell.	papagaio	Árvore	CR	
Hyptis caespitosa A.St.-Hil. ex Benth.		Erva	CR, FESA	41535, 41555
Rhabdocaulon lavanduloides (Benth.) Epling		Erva	CD	40167
Vitex megapotamica (Spreng.) Moldenke	azeitona-do-mato	Árvore	FESM*	
Vitex polygama Cham.	maria-preta	Árvore	C, CD, FESM*	
LAURACEAE				
Cinnamomum sellowianum (Nees & Mart.) Kosterm.	canela	Árvore	C, CR, FESM*	
Endlicheria paniculata (Spreng.) J.F.Macbr.	canela-do-brejo	Árvore	FESM	
Nectandra lanceolata Nees	canelão-amarelo	Árvore	FESM	41216
Nectandra megapotamica (Spreng.) Mez	canelinha-de-cheiro	Árvore	CD	
Nectandra oppositifolia Nees	canela-ferrugem	Árvore	FESM	
Ocotea bicolor Vattimo-Gil	canela	Árvore	C, CD, FESM*	40170
Ocotea corymbosa (Meisn.)Mez	canelinha-do-cerrado	Árvore	C, CD, CR	39605, 42500
Ocotea lancifolia (Schott) Mez	canela-sabão	Árvore	CD, FESA	40123, 40162
Ocotea odorifera (Vell.) Rohwer	canela-sassafras	Árvore	FESM	
Ocotea pulchella (Nees & Mart.) Mez	canela-do-cerrado	Árvore	C, CD, CR	39604, 41244
Ocotea tristis (Nees & Mart.) Mez	canelinha	Arbusto	CD, CR	39606, 41473
Persea alba Nees		Árvore	C, CD, CR	41111
Persea fulva var. *strigosifolia* L.E.Kopp		Árvore	CD, CR	40134, 40161
Persea venosa Nees & Mart.	pau-andrade	Arbusto	CD	41255
Persea willdenovii Kosterm.	abacateiro-do-mato	Árvore	C, CD, FESM	41476, 42501
LENTIBULARIACEAE				

Tabela 1. Continuação...

Família/Espécie	Nome popular	Hábito	Fisionomia	SPSF
Utricularia tricolor A.St.-Hil.	utricularia	Erva	FESA	41558
LORANTHACEAE				
Struthanthus vulgaris Mart.	erva-de-passarinho	Hemiparasita	C	41089
LYCOPODIACEAE				
Lycopodiella camporum B. Øllg. & P.G.Windisch	pinheirinho	Erva	CLU	
Lycopodium clavatum L.	licopódio	Erva	CR	40223
LYTHRACEAE				
Cuphea calophylla Cham. & Schltdl. ssp. *mesostemon* (Koehne) Lourteig	erva-de-bicho	Erva	CD	39831
Cuphea racemosa (L.f.) Spreng.	sete-sangrias	Erva	FESM*	41139
Lafoensia nummularifolia A.St.-Hil.	dedaleira-branca	Arbusto	CLU, CD, CR	39572, 41472
Lafoensia pacari A.St.-Hil.	dedaleiro	Árvore	CD	
MAGNOLIACEAE				
Magnolia ovata (A.St.-Hil.) Spreng.	magnólia-do-brejo	Árvore	CD, FESA	
MALPIGHIACEAE				
Banisteriopsis laevifolia (A.Juss.) B.Gates	cipó-prata	Arbusto	CR	39730, 39732
Byrsonima coccolobifolia Kunth	murici	Arbusto	C, CD, CR	39579, 41528
Byrsonima intermedia A.Juss.	canjica	Arbusto	CD, CR	39768, 41110
Byrsonima verbascifolia (L) DC.	murici	Arbusto	CR	41542
Heteropterys dumetorum Nied.		Arbusto	CR	41534
Heteropterys umbellata A.Juss.	pedra-única	Arbusto	CD, CR	41159, 41169
Hiraea cf. *fagifolia* (DC.) A.Juss.		Liana	FESM*	41150
Peixotoa parviflora A.Juss.		Liana	C, CD, CR	39739, 41575
MALVACEAE				
Abutilon costicalyx K. Schum. ex. Bakerf.		Arbusto	FESM*	41147
Guazuma ulmifolia Lam.	mutambo	Árvore	FESM	
Helicteres ovata Lam.	sebastião-da-arruda	Árvore	C, FESM	41103, 41521
Peltaea edouardii (Hochr.) Krapov.& Cristóbal		Erva	CD	41464
Pseudobombax grandiflorum (Cav.) A.Robyns	embiruçu	Árvore	FESM*	
Sida linifolia Cav.	linho-do-campo	Erva	CD	39700, 40279
Sida urens L.		Erva	CD	39679
Waltheria carpinifolia A.St.-Hil. e Naudin	malva	Arbusto	CR	41174, 41580
Luehea candicans Mart.	açoita-cavalo	Árvore	C	
Luehea divaricata Mart.	açoita-cavalo	Árvore	FESM	
Luehea grandiflora Mart.	açoita-cavalo-do-cerrado	Árvore	CD	39613
MELASTOMATACEAE				
Acisanthera alsinaefolia (DC.) Triana	quaresmeira-do-brejo	Erva	CR	41163
Leandra aurea (Cham.) Cogn.		Arbusto	C, CD, CR	39744, 41109
Leandra melastomoides Raddi		Árvore	C, CD	39728, 41157
Leandra purpurascens (DC.) Cogn.	pixirica	Arbusto	C, CD	40511, 41124
Miconia albicans Steud.	quaresmeira-branca	Árvore	CD	40516, 41551
Miconia hyemalis A.St.-Hil. & Naudin ex Naudin	pixirica-branca	Arbusto	CD	40157, 41105
Miconia ligustroides (DC.) Naudin	jacatirão-do-brejo	Arbusto	C, CD, CR	39726, 41203
Miconia sellowiana Naudin	jacatirão	Árvore	C, CD, FESM*	40456, 41527
Miconia theaezans Cogn.	jacatirão-branco	Arbusto	CLU, C, FESA	39734, 40310
Microlepis oleifolia (DC.) Triana		Arbusto	CR	39674
Microlicia isophylla DC.		Erva	CLU	
Rhynchanthera dichotoma DC.	são-joãozinho	Erva	CD	39819
Tibouchina sebastianopolitana (Raddi) Cogn	quaresmeira-do-campo	Arbusto	CR	39693
Tibouchina gracilis (Bonpl.) Cogn.	quaresmeira-do-brejo	Erva	CR, FESA	41162, 41531
Tibouchina granulosa (Desf.) Cogn.	quaresmeira-rosa	Árvore	C	

Tabela 1. Continuação...

Família/Espécie	Nome popular	Hábito	Fisionomia	SPSF
Tibouchina martialis Cogn.	quaresmeira	Arbusto	CR	41537
Tibouchina stenocarpa Cogn.	quaresmeira	Árvore	C, CR	39567, 39712
MELIACEAE				
Cedrela odorata L.	cedro-do-brejo	Árvore	FESA	
Guarea macrophylla Vahl ssp. *tuberculata* (Vell.) Penn.	marinheiro	Árvore	FESM*, FESA	40300, 40499
MENISPERMACEAE				
Cissampelos ovalifolia DC.	orelha-de-onça	Arbusto	CD	41256
MONIMIACEAE				
Mollinedia micrantha Perkins	pimentinha	Arbusto	C	41102
Mollinedia schottiana (Spreng.) Perkins	pimenteira	Arbusto	C	41100
MORACEAE				
Brosimum gaudichaudii Trécul	mama-de-cadela	Árvore	CD	40487, 41468
Ficus enormis (Mart. Ex Miq.) Mart.	figueira-vermelha	Árvore	C, CD, FESM*	40175
Maclura tinctoria (L.) D.Don ex Steud. subsp. *tinctoria*	taiúva	Árvore	FESM	
Sorocea bonplandii (Baill.) W.C.Burger	canxim	Árvore	FESM*	40558
MYRTACEAE				
Blepharocalyx salicifolius (Kunth) O.Berg	murta-brasileira	Árvore	FESM	
Calycorectes psidiiflorus (O.Berg) Sobral	cambuí	Árvore	FESM*	41865, 41866
Calyptranthes concinna DC.	guamirim-facho	Árvore	CD, CR, FESM*	41826, 41927
Campomanesia guaviroba Kiaersk.	gabiroba	Árvore	CD, FESM	41832
Campomanesia pubescens (DC.) O.Berg	gabiroba-do-campo	Árvore	CD	41853, 41910
Eugenia bimarginata DC.	falsa-cagaita	Árvore	C, CD	41846, 41849
Eugenia calycina Cambess.		Arbusto	CD, CR	41576, 41856
Eugenia hiemalis Cambess.	cambuí-do-campo	Árvore	FESM*	41934
Eugenia involucrata DC.	cerejereira	Árvore	FESM*	41827
Eugenia ligustrina (Sw.) Willd.	eugenia	Árvore	FESM*	41818
Eugenia livida O.Berg	eugenia	Arbusto	CD	41933
Eugenia pitanga (O.Berg) Kiaersk.	pitanga-do-cerrado	Arbusto	C, CD, CR	41851, 41928
Eugenia punicifolia (Kunth) DC.	cereja-do-cerrado	Árvore	CD	
Eugenia suberosa Cambess.		Arbusto	CD	
Hexachlamys edulis (O.Berg) Kausel & D.Legrand	uvaia-do-cerrado	Árvore	C	
Myrcia albotomentosa Cambess.	myrcia	Árvore	C, CD, FESM*	41886, 41911
Myrcia guianensis (Aubl.) DC.	guamirim-vermelho	Árvore	C, CR	41843, 41901
Myrcia hartwegiana (O.Berg) Kiaersk.		Árvore	CD, FESA	41840, 41864
Myrcia laruotteana Cambess.	cambuí	Arbusto	FESM*, FESA	41829, 41863
Myrcia multiflora (Lam.) DC.	cambuí	Árvore	CD, CR, FESM*	41900
Myrcia obtecta (O.Berg) Kiaersk.	guamirim-branco	Árvore	CD	
Myrcia pulchra Kiaersk.		Árvore	C, CR	41831, 41897
Myrcia tomentosa (Aublet) DC.	goiabeira-brava	Árvore	CD	
Myrcia venulosa DC.	guamirim	Árvore	CD, CR, FESM*	41837, 41892
Myrciaria tenella (DC.) O.Berg	cambuí	Árvore	CR, FESM*	41828, 41902
Psidium australe Cambess.	araça	Arbusto	CD, CR	41855, 41912
Psidium cupreum O.Berg		Árvore	FESM*	41825
Psidium grandifolium DC.	araçá	Arbusto	CD, CR, FESA, FESM	41859, 41908
Psidium guianense Pers.	araçá	Arbusto	CR	41860
Psidium laruotteanum Cambess.		Árvore	C, CD, CR, FESM*	41830, 41932
Psidium rufum O.Berg	araçá-roxo	Árvore	C	
NYCTAGINACEAE				
Guapira opposita (Vell.) Reitz	maria-mole	Árvore	C	
OCHNACEAE				

Tabela 1. Continuação...

Família/Espécie	Nome popular	Hábito	Fisionomia	SPSF
Ouratea cf. *salicifolia* (A.St.-Hil. & Tull.) Engler	guaraparim	Arbusto	CD	39845
Ouratea spectabilis Engl.	batiputá	Árvore	CLU, C, CD	39592, 41097
OLEACEAE				
Chionanthus filiformis (Vell.) P.S.Green	carne-de-vaca	Árvore	FESM*	
ONAGRACEAE				
Ludwigia nervosa (Poir.) H.Hara	cruz-de-malta	Erva	CD	40271
Ludwigia sericea (Cambess.) H.Hara	cruz-de-malta	Arbusto	CD	40269, 41548
ORCHIDACEAE				
Epidendrum denticulatum Barb.Rodr.	epidendro	Erva	C, CR	39751, 40495
Gomesa flexuosa (Sims) M.W.Chase & N.H.Williams		Epífita	C	40494
Gomesa paranapiacabensis (Hoehne) M.W.Chase & N.H.Williams		Epífita	CR	39600
Leptotes bicolor Lindl.		Epífita	FESA	40275
Pelexia orthosepala (Rchb.f.& Warm.) Schltr.		Erva	CD	43802
Polystachya cf. *bradei* Schltr.		Epífita	FESA	40503
OXALIDACEAE				
Oxalis cytisoides Zucc.		Erva	FESM*	41136
PASSIFLORACEAE				
Piriqueta rosea (Camb.) Urb.	piriqueta	Erva	CD	40150
Piriqueta taubatensis (Urb.) Arbo		Erva	CR	41581
PHYLLANTHACEAE				
Hyeronima alchorneoides Allemão	urucurana	Árvore	FESM	
PIPERACEAE				
Piper gaudichaudianum Kunth	jaborandi	Arbusto	FESM	
PLANTAGINACEAE				
Mecardonia procumbens (Mill). Small var. *cespitosa* (Cham) V.C.Sousa		Erva	CD	40515
POACEAE				
Andropogon glaziovii Hack		Erva	CD	39673
Axonopus brasiliensis Kuhlm		Erva	CR	41170
Ctenium polystachyum Balansa		Erva	CD	39688
Eustachys retusa (Lag.) Kunth		Erva	CD	41373
Ichnanthus calvescens (Ness ex Trin.) Döll		Erva	FESM*	41133
Ichnanthus procurrens (Ness ex Trin.) Swallen		Erva	FESM*	41374
Setaria scabrifolia Kunth		Erva	CD	39676
PODOCARPACEAE				
Podocarpus sellowii Klotzsch ex Endl.	podocarpo	Árvore	CD, CR	40473
POLYGALACEAE				
Monnina richardiana A.St.-Hil. & Moq.		Erva	FESA	40278
POLYPODIACEAE				
Microgramma squamulosa (Kaulf.) de la Sota	cipó-cabeludo	Epífita	CD, FESM	40579, 41523
Pleopeltis hirsutissima (Raddi) de la Sota	polipódio-hirsutíssimo	Epífita	C, CD	40509, 40537
Pleopeltis pleopeltifolia (Raddi) Alston	samambaia	Epífita	C	40508
PRIMULACEAE				
Cybianthus densicomus Mart.	tintarana	Arbusto	CD, FESM*	40290, 41127
Myrsine balansae (Mez) Arechav.	capororoca	Árvore	FESM	
Myrsine coriacea (Sw.) R. Br. ex Roem. & Schult.	capororoca	Árvore	C, CD, CR, FESA	39629, 41114
Myrsine gardneriana A.DC.	capororoca	Árvore	C, CD, FESA	40274
Myrsine lancifolia Mart.	capororoca	Árvore	C, FESM	
Myrsine umbellata Mart.	capororoca	Árvore	C, CD, CR, FESA, FESM	9634, 40149
PROTEACEAE				

Tabela 1. Continuação...

Família/Espécie	Nome popular	Hábito	Fisionomia	SPSF
Roupala montana Aubl.	carne-de-vaca	Árvore	CD	
Colubrina glandulosa Perkins	saraguagi-vermelho	Árvore	FESM	
RHAMNACEAE				
Rhamnus sphaerosperma Sw.	canjica	Arbusto	C, CD, CR	39741, 41243
ROSACEAE				
Prunus myrtifolia L.	pessegueiro-bravo	Árvore	CD	
Rubus brasiliensis Mart.	amora-branca	Arbusto	CD, CR	39708, 40458
RUBIACEAE				
Alibertia myrciifolia Spruce ex K.Schum.	marmelinho	Arbusto	FESM	
Amaioua intermedia Mart.	café-do-mato	Árvore	C	
Coccocypselum glabrifolium Standl.		Erva	C	39715
Coccocypselum lanceolatum Pers.	piririca	Erva	C, FESM*	39716, 41135
Cordiera concolor (Cham.) Kuntze	marmelada	Arbusto	C, CD, CR, FESA	39565, 40151
Declieuxia cordigera Mart. & Zucc.		Erva	CR	39704
Diodella radula (Willd. ex Roem. & Schult.) Delprete	erva-de-lagarto	Erva	CR	41530
Guettarda viburnoides Cham. & Schltdl.	jangada	Árvore	CD	40147
Ixora venulosa Benth.	ixora	Arbusto	FESM	
Manettia cordifolia Mart.	cipó-de-santo-antonio	Liana	FESM*	40179, 41134
Margaritopsis cephalantha (Müll. Arg.) C.M.Taylor	cravo-selvagem	Arbusto	C	
Palicourea croceoides Ham.		Erva	C, FESA	39690, 40143
Palicourea rigida H.B.K.	douradinha	Arbusto	CD	41121, 41199
Posoqueria acutifolia Mart.	baga-de-macaco	Árvore	FESM*	40174
Psychotria cf. *carthagenensis* Jacq.	erva-de-gralha	Arbusto	FESM*	41145
Psychotria leiocarpa Cham. & Schltdl.	grandiúva-d'anta	Arbusto	C, FESM	40510, 41522
Psychotria vellosiana Benth.	erva-de-rato-de-folha-estreita	Árvore	C	39756, 41090
Randia armata (Sw.) DC.	fruto-de-jacaré	Arbusto	FESM	
Rudgea jasminoides (Cham.) Müll.Arg.	rudgea	Erva	C	41155
RUTACEAE				
Esenbeckia grandiflora Mart.	pau-de-cotia	Árvore	FESM*	41212
Helietta apiculata Benth.	amarelinho	Árvore	CD, FESM	41099, 41510
SALICACEAE				
Casearia lasiophylla Eichl.	cambroé	Árvore	C, CD	
Casearia obliqua Spreng.	guaçatonga	Árvore	FESM	
Casearia sylvestris Sw.	guaçatonga	Árvore	FESA	40506
SANTALACEAE				
Phoradendron craspedophyllum Enchl.	erva-de-passarinho	Hemiparasita	FESM*	41143
SAPINDACEAE				
Allophylus semidentatus (Miq.) Radlk.	camboatã	Árvore	FESM	41509
Cupania vernalis Cambess.	arco-de-peneira	Árvore	C, CD	39754, 40459
Cupania zanthoxyloides Cambess.	cupania-veludo	Árvore	C	41154
Matayba elaeagnoides Radlk.	cuvantã	Árvore	CD	
Serjania acoma Radlk.		Liana	C	39722
Serjania erecta Radlk.	cipó-de-timbó	Liana	CD, CR	39703, 41543
Serjania gracilis Radlk	timbó	Liana	CD	40171
Serjania meridionalis Cambess.	timbó	Liana	C	39685
SAPOTACEAE				
Chrysophyllum inornatum Mart.	aleixo	Árvore	CD	
Chrysophyllum marginatum (Hook. & Arn.) Radlk.	aguaí	Árvore	C, FESM*	39717
Pouteria gardneri (Mart. & Miq.) Baehni	sapoti-vermelho	Árvore	FESM	
Pradosia brevipes T.D.Penn.	fruta-de-tatu	Arbusto	CLU, CD	41119

Tabela 1. Continuação...

Família/Espécie	Nome popular	Hábito	Fisionomia	SPSF
SCHIZAEACEAE				
Anemia ferruginea Kunth	avenca-docampo	Erva	CD	40280
Anemia phyllitidis (L.) Sw.	avenca-de-cacho	Epífita	CD	40291
SMILACACEAE				
Smilax elastica Griseb.	japecanga	Liana	C, CD, CR, FESA	39705, 40463
Smilax fluminensis Steud.	japecanga	Liana	C, CD	39725, 40461
SOLANACEAE				
Calibrachoa micrantha Stehmann & Semir	petunia	Erva	CLU, CR	39599, 39680
Cestrum intermedium Sendtn.	coerana-preta	Arbusto	FESA	40132
Dyssochroma viridiflora (Sims) Miers	solandra	Árvore	CD	41113
Solandra grandiflora Sw.	copo-de-ouro	Arbusto	C	
Solanum campaniforme Roem & Schult.	joá -manso	Árvore	CD	41156
Solanum corymbiflorum (Sendtn.) Bohs	coerana-amarela	Arbusto	CD, FESA	39846, 40116
Solanum gemellum Mart. ex. Sendtn.	juá-velame	Arbusto	FESM	41518
Solanum leucodendron Sendtn.	capoeira-branca	Árvore	FESM	41519
Solanum lycocarpum A.St.-Hil.	fruta-de-lobo	Arbusto	CD, CR	39695, 41250
Solanum sanctaecatharinae Dunal	joá-manso	Árvore	C	
Solanum variabile Mart.	jurubeba-velame	Arbusto	CD	41550
STYRACACEAE	estoraque-do-campo			
Styrax camporum Pohl	estoraque	Árvore	CLU, C, CD, CR	39571, 41152
Styrax ferrugineus Nees & Mart.	estoraque	Árvore	FESM	41520
Styrax longiflorum A.DC.	estoraque	Árvore	C	
Styrax pohlii A.DC.	estoraque	Árvore	C	
SYMPLOCACEAE				
Symplocos lanceolata A.DC.	capororoca-falsa	Árvore	CR	
Symplocos pubescens Klotzsch ex Benth.	sete-sangrias	Árvore	CD, CR	39584, 39632
Symplocos tenuifolia Brand.	cangalha	Árvore	C, CR, FESM*	39682, 41241
THYMELAEACEAE				
Daphnopsis brasiliensis Mart.	embira-branca	Árvore	FESM	41507
Daphnopsis fasciculata (Meisn.) Nevling	embira	Árvore	FESM	
Daphnopsis utilis Warm.	embira-branca	Árvore	C	39709
URTICACEAE				
Cecropia pachystachya Trécul	embaúba-branca	Árvore	CD	
VERBENACEAE				
Lantana fucata Lindl.	lantana-roxa	Arbusto	CD	
Lippia brasiliensis (Link) T.Silva	cambará	Erva	FESM	41516
Lippia lupulina Cham.	rosa-do-campo	Erva	CD, CR	41475, 41536
Lippia velutina Schauer		Arbusto	CR	39764
Verbena rigida Spreng	verbena-perene	Erva	FESA	41559
VIOLACEAE				
Anchietea pyrifolia A. St.-Hil.	suma-roxa	Liana	FESM*	41148
VOCHYSIACEAE				
Callisthene castellanosi H.F.Martins		Árvore	CR, FESM*	39743, 40184
Qualea cordata (Mart.) Spreng.	carvãozinho	Árvore	C, CD	39771, 39807
Qualea grandiflora Mart.	pau-terra	Árvore	C	39622
Vochysia tucanorum Mart.	cinzeiro	Árvore	CR, FESM*, FESM	39614, 41514
WINTERACEAE				
Drimys brasiliensis Miers	casca-d'anta	Árvore	CD, CR, FESM*, FESA	39815, 41556
XYRIDACEAE				
Xyris savanensis Miq.		Erva	CD	41198

Piptocarpha rotundifolia (Less.) Baker, *Dimorphandra mollis* Benth., *Couepia grandiflora* (Mart.) Benth, *Eriotheca gracilipes* (Schum.) A. Robyns, *Xylopia aromatica* Lam., *Eugenia aurata* O. Berg e *Qualea multiflora* Mart. Em relação ao conjunto das 17 espécies consideradas mais frequentes nos cerrados paulistas apontadas por Siqueira & Durigan (2007), estão ausentes na EEcI *D. mollis*, *Miconia stenostachya* DC. e *Tocoyena formosa* (Cham. & Schltdl.) K. Schum..

5. *Incidência de espécies*

A comparação entre os dados de incidência de espécies gerados no presente estudo com dados derivados de modelos de distribuição geográfica revelou que *Annona dioica* A.St.-Hil., *Brosimum gaudichaudii* Trécul, *Duguetia furfuracea* (A.St.-Hil.) Saff., *Caryocar brasiliense* Cambess., *Anadenanthera peregrina* var. *falcata* (Benth.) Altschul e *Schefflera vinosa* (Cham. & Schltdl.) Frodin & Fiaschi não foram previstas para a região da área de estudo (Siqueira & Durigan 2007), no entanto, foram encontradas no presente levantamento. As duas últimas são, inclusive, visualmente bastante abundantes na Estação. Outras sete espécies com distribuição espacial modelada, e encontradas em Itapeva neste estudo, foram previstas para a região aparentemente por apenas um dos modelos gerados pelo algoritmo genético (Siqueira & Durigan 2007).

Tabela 2. Similaridade florística (Sorensen) entre fisionomias de cerrado (*s.l.*) e campestre úmida na Estação Ecológica de Itapeva.

Table 2. Floristic similarity (Sorensen) among cerrado (*s.l.*) and Swamp Grassland physiognomies in the Ecological Station of Itapeva.

	Cerradão	Cerrado denso	Cerrado ralo
Cerrado denso	0,31		
Cerrado ralo	0,26	0,38	
Campestre úmida	0,18	0,30	0,27

Discussão

Considerando a flora da EEcI como um todo, observa-se que a riqueza estimada de espécies (437) aproxima-se da obtida por Durigan et al. (1999), que registraram 486 espécies em inventário semelhante na Estação Ecológica de Assis, SP. Outros levantamentos amplos que consideraram a variedade de fisionomias e formas de vida em áreas de Cerrado reportaram a ocorrência de 458 espécies no Parque Estadual do cerrado, em Jaguariaíva, PR (Linsingen et al. 2006) e 314 espécies na Estação Ecológica de Santa Bárbara, SP (Meira-Neto et al. 2007). Embora devam ser consideradas as diferenças de tamanho das áreas de vegetação natural estudadas, as variações no esforço amostral e nos critérios de inclusão, além de particularidades de cada localidade, evidencia-se a riqueza de espécies relativamente elevada para a EEcI, sendo causas prováveis: a sua condição de área protegida na forma de Unidade de Conservação, resultando em ausência de pastoreio e de incêndios recentes; a sua localização em uma região de interface entre várias formações vegetais que ocorrem no estado de São Paulo (Kronka et al. 2005); a variedade fisionômica; e as particularidades climáticas da região.

Restringindo a análise à flora das fisionomias que ocorrem no cerrado (*s.l.*), verifica-se que a riqueza estimada (346) encontra-se no intervalo de variação de outros estudos realizados no estado de

Tabela 3. Espécies ameaçadas de extinção registradas na Estação Ecológica de Itapeva, segundo as listas da União Internacional para a Conservação da Natureza (IUCN), Fundação Biodiversitas (FB), Ministério do Meio Ambiente (MMA) e Secretaria do Meio Ambiente do estado de São Paulo (SMA–SP). CR, Em Perigo Crítico; EN, Em Perigo; VU, Vulnerável. As espécies ameaçadas de acordo com o MMA estão indicadas por “1”.

Table 3. Threatened species recorded in the Ecological Station of Itapeva according to the lists of the International Union for Conservation of Nature (IUCN), Biodiversitas Foundation (FB), Brazilian Environmental Agency (MMA) and Environmental Bureau of the São Paulo State (SMA-SP). CR, Critically Endangered; EN, Endangered; VU, Vulnerable. Threatened species according to MMA are indicated by “1”.

Família/Espécie	IUCN	FB	MMA	SMA-SP	Tipo de ameaça
Apiaceae					
Eryngium eriophorum			0	EN	Distribuição geográfica restrita, ocorrência desconhecida em unidade de conservação e ocorrência em um único tipo de formação vegetal.
Araucariaceae					
Araucaria angustifolia	CR	EN	1	VU	Espécie com histórico de exploração intensiva.
Asteraceae					
Calea cymosa			0	EN	Distribuição geográfica restrita, ocorrência desconhecida em unidade de conservação e ocorrência em um único tipo de formação vegetal.
Neocabreria malacophylla			0	VU	Distribuição geográfica restrita e ocorrência desconhecida em unidade de conservação.
Lauraceae					
Ocotea odorifera		VU	1		Baixa densidade populacional e exploração.
Malvaceae					
Abutilon costicalyx			0	EN	Distribuição geográfica restrita, ocorrência desconhecida em unidade de conservação e ocorrência em um único tipo de formação vegetal.
Meliaceae					
Cedrela odorata	VU		0		Desmatamento e exploração.
Sapindaceae					
Allophylus semidentatus			0	VU	Distribuição geográfica restrita e ocorrência exclusiva em unidade de conservação.

São Paulo: entre 75 e 443 espécies (Batalha & Mantovani 2000, Weiser & Godoy 2001, Durigan et al. 2002, Fidelis & Godoy 2003, Meira-Neto et al. 2007, Ishara et al. 2008, Sasaki & Melo-Silva 2008). Os fatores que possivelmente contribuem para essa elevada riqueza são os mesmos considerados acima com respeito à flora da Estação como um todo. Linsingen et al. (2006) também mostraram uma elevada riqueza de espécies de plantas vasculares em área de cerrado (*s.l.*) localizada no limite meridional de distribuição do Bioma e comentaram que a riqueza poderia ser maior, não fosse o rigoroso inverno restringindo a ocorrência de algumas espécies. Portanto, mesmo com as possíveis restrições impostas pelo clima, os remanescentes localizados no extremo sul do Bioma apresentam riqueza comparável à de remanescentes mais próximos à sua área *core*.

Levantamentos em cerrado (*s.l.*) apontaram as famílias Asteraceae, Myrtaceae, Fabaceae, Malpighiaceae, Bignoniaceae, Melastomataceae, Rubiaceae, Vochysiaceae, Poaceae e Annonaceae como as mais ricas (Durigan et al. 1999, Batalha & Mantovani 2000, Weiser & Godoy 2001, Durigan et al. 2002, Fidelis & Godoy 2003, Meira-Neto et al. 2007, Ishara et al. 2008, Sasaki e Melo-Silva 2008). Das famílias supracitadas, a maioria é bem representada em número de espécies na EEcI. As famílias mais ricas do componente não-arbóreo da Estação foram mencionadas entre as mais representativas nos levantamentos de cerrado (*s.l.*) que consideraram esse componente individualmente (Christianini & Cavassan 1998, Batalha & Mantovani 2001, Weiser & Godoy 2001, Tannus & Assis 2004, Ishara et al. 2008, Rossatto et al. 2008). Da mesma forma, a distribuição da riqueza de espécies arbóreas entre as famílias concorda em geral com as informações da literatura sobre o cerrado (*s.l.*) no Brasil (Oliveira-Filho & Ratter 2002) e no estado de São Paulo (Cavassan 2002). Por outro lado, o destaque mostrado por Lauraceae no cerrado (*s.l.*) da EEcI pode ser uma peculiaridade regional em função da importância dessa família para florestas da região Sul do país (Souza & Lorenzi 2008).

O número de espécies arbóreas (133) superou o número de espécies herbáceas (100) no cerrado (*s.l.*) da EEcI, assim como a área ocupada por cerradão e cerrado denso (87 ha) supera consideravelmente a área ocupada por cerrado ralo, campo sujo úmido e campo limpo úmido (5,5 ha). De maneira geral, a flora herbácea do cerrado é considerada mais rica do que a flora arbórea (Goodland & Ferri 1979). Em sua análise sobre as comunidades herbáceas do Cerrado, Filgueiras (2002) informa que a razão entre ervas e árvores varia de 3:1 (Felfili et al. 1994) a 4,5:1 (Mendonça et al. 1998). Por outro lado, dados apresentados por Goodland & Ferri (1979), mostram que o número de espécies herbáceas diminui e o número de arbóreas aumenta das fisionomias mais abertas para as mais fechadas e que, no cerradão, o número de espécies arbóreas supera o número de herbáceas. No presente trabalho, o maior número de espécies arbóreas relativamente ao de herbáceas pode ser explicado, em parte, pelo predomínio das fisionomias cerradão e cerrado denso. Resultado semelhante foi encontrado no cerrado (*s.l.*) da Estação Ecológica de Santa Bárbara (Meira-Neto et al. 2007), onde o número de espécies arbóreas (149) superou o número de herbáceas (119) e a área ocupada por cerradão, cerrado denso e cerrado típico (1.819 ha) é maior que a área ocupada por campo cerrado e campo úmido (435 ha) (Durigan et al. dados não publicados). Por outro lado, no Parque Estadual do Cerrado, onde não foram registradas as fisionomias cerradão e cerrado denso, o número de espécies de árvores (27) foi menor que o número de ervas (81) e a área ocupada por formações campestres (188 ha) superou a área ocupada por cerrado típico (83 ha) (Linsingen et al. 2006). Portanto, a relação entre o número de árvores e ervas em dada localidade depende da representatividade das diferentes fisionomias de cerrado (*s.l.*) que aí ocorrem, embora uma relação entre 3:1 e 4,5:1 possa se manter para a flora do Cerrado como um todo (Filgueiras 2002).

A inclusão da fisionomia campestre úmida na delimitação de cerrado (*s.l.*) adotada neste trabalho foi suportada pelos dados de similaridade florística (ver critérios em Material e Métodos). O mesmo tratamento pode ser encontrado em Meira-Neto et al. (2007) para o campo limpo úmido. Por outro lado, Batalha (1997), Tannus & Assis (2004) e Linsingen et al. (2006) não consideraram o campo limpo úmido como fisionomia de cerrado (*s.l.*). Batalha (1997) reportou similaridade florística (Sorensen) de 0,41 entre o campo úmido e campo cerrado. Os dados de Tannus & Assis (2004) permitem calcular uma similaridade de 0,05 entre campo limpo úmido e campo sujo de interflúvio. A maior intensidade de perturbação poderia ser responsável pela diferença de similaridade entre fisionomias campestres úmidas e aquelas de cerrado (*s.l.*) de interflúvio reportadas nesses dois estudos, resultando na ocorrência generalizada de espécies ruderais em diferentes fisionomias. Porém, Tannus & Assis (2004) encontraram 60 espécies ruderais em um total de 284 e apenas duas ocorreram simultaneamente nas duas fisionomias estudadas pelos autores. Verifica-se, portanto, que a similaridade florística entre fisionomias campestres úmidas e fisionomias de cerrado (*s.l.*) no conceito de Coutinho (1978) pode variar bastante entre localidades, podendo atingir níveis que justificariam o tratamento adotado para a vegetação da EEcI.

Dentre os principais fatores de ameaça de extinção verificados, a distribuição geográfica restrita e a ocorrência desconhecida em unidade de conservação se destacam. O primeiro fator é uma característica natural da espécie, que a torna mais propensa à extinção em virtude do processo histórico de eliminação de áreas de Cerrado no estado de São Paulo (Kronka et al. 2005). O segundo fator é mais dinâmico, podendo sua aplicação ser alterada em função do avanço do conhecimento sobre a biodiversidade. Assim, as quatro espécies consideradas ameaçadas em função de ocorrência desconhecida em unidade de conservação não mais poderiam ser enquadradas nas categorias de ameaça definidas em Souza et al. (2007). A contribuição da EEcI para a conservação dessas espécies fica evidente com essa mudança de nível de ameaça. A proteção dessas espécies poderá ser enfatizada em programas de educação ambiental e na captação de recursos para o manejo da UC.

A espécie com nível de ameaça mais preocupante é *Araucaria angustifolia* (Bert.) Kuntze, não apenas em função das categorias de ameaça atribuídas nas diferentes listas, mas também devido à sua presença em todas as listas, ou seja, nas escalas geográficas estadual, nacional e mundial. Apenas um indivíduo da espécie foi observado na EEcI, na Floresta Estacional Semidecidual Montana. De acordo com Garcia (2002) indivíduos isolados da espécie podem ser encontrados na Floresta Estacional Semidecidual, entre as faces ocidental das serras do Mar e de Paranapiacaba e a Depressão Periférica. A importância da EEcI para a conservação dessa espécie certamente é menor do que a da Estação Experimental de Itapeva que lhe é contígua e abriga 324 ha de remanescentes de Floresta Estacional Semidecidual Montana (Instituto Florestal 2010) com ocorrência de indivíduos de araucária (Souza et al. *in prep.*), enquanto a EEcI apresenta apenas 6,92 ha ocupados por essa fisionomia. A Estação Experimental abriga também remanescentes de cerrado (*s.l.*). Portanto, a conservação da vegetação natural na Estação Experimental de Itapeva pode contribuir para a conservação das espécies ameaçadas presentes na EEcI.

Dentre as espécies consideradas típicas do cerrado (*s.l.*) paulista (Bridgewater et al. 2004, Siqueira & Durigan 2007), mas que estiveram ausentes na EEcI, Scaramuzza (2006) citou *Miconia stenostachya e Piptocarpha rotundifolia* para os campos de Itararé, ao sul de Itapeva. Linsingen et al. (2006) e Ritter et al. (2010)

citaram *Couepia grandiflora*, *Qualea multiflora* e *Eriotheca gracilipes* para áreas de cerrado (*s.l.*) no Paraná. É possível que as demais espécies - *Dimorphandra mollis*, *Xylopia aromatica*, *Eugenia aurata* e *Tocoyena formosa* – sejam encontradas em futuros levantamentos em porções tão ou mais meridionais do que a área de estudo, mas também é provável que essas espécies apresentem restrições ecológicas que comprometam seu desenvolvimento ou sobrevivência no limite meridional do bioma Cerrado. Corroborando essa afirmação, Ritter et al. (2010) compilaram uma lista geral para 30 remanescentes de cerrado (*s.l.*) no Paraná, totalizando 1.782 espécies, mas não encontraram *D. mollis*, *X. aromatica*, *E. aurata* e *T. formosa*. É provável que o limite meridional de distribuição geográfica dessas espécies encontre-se em latitudes inferiores à da área de estudo, sendo o seu plantio na região desaconselhável.

Dentre as possíveis restrições ecológicas, o dano aos tecidos vegetais provocados por geadas é enfatizado na literatura (Leitão-Filho 1992, Silberbauer-Gottsberger et al. 1977). A ocorrência de geadas não é fato incomum no limite meridional do cerrado (Coutinho 2002), algumas inclusive se destacaram historicamente por sua intensidade e pelos prejuízos econômicos causados, tais como as geadas de 1975 e 1994. Em função da posição latitudinal, verifica-se diminuição da temperatura e aumento na frequência de geadas na região de Itapeva em comparação com o restante do estado de São Paulo (Eiten 1970). Em relação à sensibilidade das espécies lenhosas do cerrado (*s.l.*), as informações são escassas, porém é sabido que *Miconia albicans* e *Xylopia aromatica* foram mencionadas como as mais prejudicadas em Botucatu, após a geada de 1975 (Silberbauer-Gottsberger et al. 1977), e também foram citadas como espécies susceptíveis após a geada de 1994 em Agudos (Bertoncini 1996). *X. aromatica* é uma das espécies típicas ausentes na EEcI, mas *M. albicans* é visualmente bastante conspícua, sugerindo que a susceptibilidade à geadas não deve ser o único fator limitador da distribuição geográfica das espécies de cerrado (*s.l.*) em climas mais frios.

A região de Itapeva apresenta duas peculiaridades que a credenciam como prioritária para a realização de estudos florísticos no Cerrado: a posição no limite meridional de distribuição do Bioma (Brasil 2008a) e a ausência de déficit hídrico (Instituto Brasileiro de Geografia e Estatística 1990). Esta última característica destoa das condições predominantes na área *core* do Cerrado, que apresenta forte estacionalidade climática e déficit hídrico (Silva et al. 2008), e mesmo do restante da área ocupada pelo Cerrado no estado de São Paulo (Eiten 1970). A presença de Cerrado em uma região sem déficit hídrico pode ser considerada como relictual, tendo em vista as flutuações climáticas do período Quaternário, que possibilitaram a expansão do Cerrado sobre áreas florestais (Pessenda et al. 2009). Após o término do período seco, mesmo em regiões com forte estacionalidade climática, as florestas teriam avançado sobre o Cerrado, mas essa substituição teria sido prejudicada por incêndios provocados pelo homem desde o meio Holoceno (Oliveira-Filho & Ratter 1995). Esses autores argumentam que a ocorrência de Florestas Estacionais Semideciduais sobre solos secos e pobres na região do Cerrado sugere que as condições climáticas atuais são favoráveis ao estabelecimento de florestas na maior parte do Bioma. Se tal argumento é válido para a área *core* do Cerrado, tanto mais o será para a região de Itapeva, devido à ausência de déficit hídrico. As mesmas considerações sobre o clima atual e flutuações climáticas do Holoceno sugerem que a ocorrência de Cerrado no Paraná também seria relictual (Straube 1998).

Algumas espécies encontradas neste estudo, embora consideradas características de Cerrado em outras regiões do estado de São Paulo, não tiveram sua ocorrência prevista para a região de Itapeva por modelagem de distribuição geográfica em escala estadual (Siqueira & Durigan 2007). Provavelmente, contribuíram para esses resultados as peculiaridades geográfica e climática mencionadas acima, aliadas ao fato de que a amostragem de Siqueira & Durigan (2007) não incluiu áreas de Cerrado em posição geográfica semelhante ou na mesma zona climática verificada para Itapeva (Instituto Brasileiro de Geografia e Estatística 1990). Uma das principais limitações encontradas no uso de ferramentas de modelagem de distribuição geográfica diz respeito aos problemas de comissão ou de omissão com a diminuição ou ampliação, respectivamente, da escala geográfica de trabalho (Peterjohn 2001). A omissão de algumas espécies para a região de Itapeva pelos modelos apresentados em Siqueira & Durigan (2007) pode estar relacionada à ampliação da escala para regiões com parâmetros climáticos diferentes daqueles incluídos nos modelos. A inclusão de levantamentos efetuados na região de Itapeva poderá gerar predições mais acuradas tanto para as espécies como para o bioma Cerrado no estado de São Paulo. Por outro lado, é possível questionar a uso de dados florísticos de áreas consideradas relictuais para a geração de modelos preditivos de distribuição geográfica de um bioma e suas espécies, pois, assim, obter-se-iam predições mais relacionadas a fatores históricos do que ecológicos.

Conclusões

De maneira geral, observa-se que tanto a riqueza em espécies como a distribuição da riqueza entre as famílias não evidenciaram diferenças marcantes entre a flora do cerrado (*s.l.*) da EEcI e de outras áreas de Cerrado localizadas em regiões mais setentrionais. Contudo, análises em nível de espécie evidenciaram, como uma particularidade da flora da região deste estudo, a ausência de espécies arbóreas consideradas típicas do cerrado (*s.l.*) paulista, possivelmente em decorrência dos efeitos de geadas e outros fatores climáticos restritivos.

Por outro lado, constatamos na EEcI a presença de espécies não previstas para a região por modelagem de distribuição geográfica, provavelmente em decorrência da não inclusão de levantamentos florísticos realizados na região de Itapeva na base de dados utilizada para gerar os modelos (Siqueira & Durigan 2007), reforçando a necessidade de ampliação do esforço de coleta em certas regiões do estado de São Paulo, como a bacia hidrográfica do Alto Paranapanema, onde a área de estudo está inserida (Cielo-Filho et al. 2009).

Análises comparativas da similaridade florística entre o cerradão, cerrado denso, cerrado ralo, campo sujo úmido e campo limpo úmido da EEcI, permitiram incluir todas essas fisionomias dentro de uma delimitação de cerrado (*s.l.*) mais abrangente do que a adotada por Coutinho (1978), que considera apenas vegetação de interflúvio sobre solo bem drenado. Sugerimos que a inclusão de fisionomias úmidas no cerrado (*s.l.*) deva ser considerada separadamente para cada localidade tendo em vista as relações florísticas entre as fisionomias.

Dentre as oito espécies ameaçadas de extinção na EEcI, quatro poderiam perder esse *status* se uma reavaliação considerasse sua ocorrência naquela Unidade de Conservação. Contudo, as pequenas dimensões da EEcI enfraquecem a sua importância na conservação das espécies ameaçadas, o que demonstra a necessidade de ampliação de seus limites territoriais bem como de conservação de remanescentes de vegetação natural situados na contígua Estação Experimental de Itapeva. Tal constatação é particularmente pertinente para a conservação de *Araucaria angustifolia*, tendo em vista a ocorrência dessa espécie em áreas florestais adjacentes à EEcI.

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Referências Bibliográficas

AGUIAR, L.M.S. & CAMARGO, A.J.A. 2004. Cerrado: ecologia e caracterização. Embrapa, Brasília.

ALMEIDA, R.S., SOUZA, S.C.P.M., BAITELLO, J.B., PASTORE, J.A., AGUIAR, O.T., KANASHIRO, M.M., MATTOS, I.F.A., LIMA, C.R. & CIELO-FILHO, R. 2010. campo sujo úmido: Fisionomia de cerrado ameaçada pela contaminação biológica de *Pinus elliottii* Engelm. na Estação Ecológica de Itapeva, Estado de São Paulo. Rev. Inst. Florest. 22(1):71-91.

ANGIOSPERM PHYLOGENY GROUP – APG. 2009. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. Bot. J. Linn. Soc. 161:105-121. http://dx.doi.org/10.1111/j.1095-8339.2009.00996.x

ARRUDA, M.B., PROENÇA, C.E.B., RODRIGUES, S.C., CAMPOS, R.N., MARTINS, R.C. & MARTINS, E.S. 2008. Ecorregiões, unidades de conservação e representatividade ecológica do bioma cerrado. In Cerrado: ecologia e flora (S.M. Sano, S.P. Almeida & J.F. Ribeiro, orgs.). Embrapa cerrados, Brasília, p.229-272.

BATALHA, M.A. 1997. Análise da vegetação da ARIE cerrado Pé-de-Gigante (Santa Rita do Passa Quatro, SP). Dissertação de Mestrado, Universidade de São Paulo, São Paulo.

BATALHA, M.A. 2011. O cerrado não é um bioma. Biota Neotrop. 11(1): http://www.biotaneotropica.org.br/v11n1/pt/abstract?inventory+bn00111012011.

BATALHA, M.A. & MANTOVANI, W. 2000. Reproductive phenological patterns of cerrado plant species at the Pé-de-Gigante Reserve (Santa Rita do Passa Quatro, SP, Brazil): a comparison between the herbaceous and woody floras. Rev. Bras. Biol. 60(1):129-145. PMid:10838932. http://dx.doi.org/10.1590/S0034-71082000000100016

BATALHA, M.A. & MANTOVANI, W. 2001. Floristic composition of the cerrado in the Pé-de-Gigante Reserve (Santa Rita do Passa Quatro, Southeastern Brazil). Acta Bot. Bras. 15(3):289-304. http://dx.doi.org/10.1590/S0102-33062001000300001

BERTONCINI, A.P. 1996. Composição floristica e estrutura fitossociológica de uma área de cerrado no município de Agudos, SP. Dissertação de Mestrado, Universidade Estadual Paulista, Botucatu.

BRASIL. 2008a. Monitoramento do desmatamento dos biomas brasileiros por satélite: monitoramento do bioma cerrado 2002 a 2008. Ministério do Meio Ambiente, Brasília, p.68.

BRASIL. Ministério do Meio Ambiente. 2008b. Instrução Normativa nº 06, de 26 de setembro de 2008. Diário Oficial da República Federativa do Brasil, Brasília, DF, set. 2008. http://www.mma.gov.br (último acesso em 05/12/2008).

BRIDGEWATER, S., RATTER, J.A. & RIBEIRO, J.F. 2004. Biogeographic patterns, b-diversity and dominance in the cerrado biome of Brazil. Biodivers. Conserv. 13:2295-2318. http://dx.doi.org/10.1023/B:BIOC.0000047903.37608.4c

CAVASSAN, O. 2002. O cerrado no Estado de São Paulo. In Eugen Warming e o cerrado brasileiro: um século depois (A.L. Klein, org.). Editora UNESP, São Paulo, p.93-106.

CHRISTIANINI, S.R. & CAVASSAN, O. 1998. O estrato herbáceo-subarbustivo de um fragmento de cerradão em Bauru-SP. Salusvita 17:9-16.

CIELO-FILHO, R., BAITELLO, J.B., PASTORE, J.A., AGUIAR, O.T., SOUZA, S.C.P.M., TONIATO, M.T.Z., LIMA, C.R. & RIBEIRO, A.P. 2009. Ampliando a densidade de coletas botânicas na região da bacia hidrográfica do Alto Paranapanema: Caracterização florística da Floresta Estadual e da Estação Ecológica de Paranapanema. Biota Neotrop. 9(3): http://www.biotaneotropica.org.br/v9n3/en/abstract?inventory+bn02009032009 (ultimo acesso em 29/11/2010).

CIELO-FILHO, R., AGUIAR, O.T., BAITELLO, J.B., PASTORE, J.A., SOUZA, S.C.P.M., LIMA, C.R., KANASHIRO, M.M., MATTOS, I.F.A., DURIGAN, G., IVANAUSKAS, N.M., BERTANI, D.F., SOUZA, F.M., TONIATO, M.T.Z., FRANCO, G.A.D.C., RIBEIRO, A.P., ALMEIDA, R.S., COSTA, N.O. & CARMONA, M. 2011. A vegetação da Estação Ecológica de Itapeva: subsídios para o Plano de Manejo. IF Sér. Reg. 46:1-82.

COUTINHO, L.M. 1978. O conceito de cerrado. Rev. Bras. Bot. 1(1):17-23.

COUTINHO, L.M. 2002. O bioma do cerrado. In Eugen Warming e o cerrado brasileiro: um século depois (A.L. Klein, org.). Editora UNESP, São Paulo, p.77-91.

COUTINHO, L.M. 2006. O conceito de bioma. Acta Bot. Bras. 20(1):13-23. http://dx.doi.org/10.1590/S0102-33062006000100002

DURIGAN, G., BACIC, M.C., FRANCO, G.A.D.C. & SIQUEIRA, M.F. 1999. Inventário florístico do cerrado da Estação Ecológica de Assis, SP. Hoehnea 26(2):149-172.

DURIGAN, G., NISHIKAWA, D.L.L., ROCHA, E., SILVEIRA, E.R., PULITANO, F.M., REGALADO, L.B., CARVALHAES, M.A., PARANAGUÁ, P.A. & RANIERI, V.E.L. 2002. Caracterização de dois estratos da vegetação em uma área de cerrado no município de Brotas, SP, Brasil. Acta bot. bras. 16(3):251-262.

DURIGAN, G., SIQUEIRA, M.F., FRANCO, D.C., BRIDGEWATER, S. & RATTER, J.A. 2003. The vegetation of priority areas for cerrado conservation in São Paulo State, Brazil. Edinb. J. Bot. 60(2):217-241.

EITEN, G. 1970. A vegetação do Estado de São Paulo. Bol. Inst. Bot. 7:1-147.

EITEN, G. 1979. Formas fisionômicas do cerrado. Rev. Bras. Bot. 2:139-148.

FEELEY, K.J., SILMAN, M.R. 2011. The data void in modeling current and future distributions of tropical species. Glob. Change Biol. 17:626-630 http://dx.doi.org/10.1111/j.1365-2486.2010.02239.x

FELFILI, J.M., FILGUEIRAS, T.S., HARIDASAN, M., SILVA JUNIOR, M.C., MENDONÇA, R.C. & REZENDE, A.V. 1994. Projeto biogeografia do bioma cerrado: vegetação e solos. Cad. Geocienc. 12:75-166.

FIDALGO, O. & BONONI, V.L.R. 1989. Técnicas de coleta, preservação e herborização de material botânico. Instituto de Botânica, Imprensa Oficial do Estado de São Paulo, São Paulo.

FIDELIS, A.T. & GODOY, S.A.P. 2003. Estrutura de um cerrado *stricto sensu* na gleba cerrado Pé-de-Gigante, Santa Rita do Passa Quatro, SP. Acta Bot. Bras. 17(4):531-539. http://dx.doi.org/10.1590/S0102-33062003000400006

FILGUEIRAS, T.S. 2002. Herbaceous plant communities. In The cerrados of Brazil: Ecology and Natural History of a Neotropical Savanna (P.S. Oliveira & R.J. Marquis, orgs.). Columbia University Press, New York, p.121-139.

FILGUEIRAS, T.S., NOGUEIRA, P.E., BROCHADO, A.L. & GUALA II, G.F. 1994. Caminhamento - um método expedito para levantamentos florísticos qualitativos. Cad. Geocienc. 12:39-43.

FUNDAÇÃO BIODIVERSITAS. Lista oficial de espécies ameaçadas de extinção no Brasil. http://www.biodiversitas.org.br./florabr/grupo3fim.asp (último acesso em 10/12/2008).

GARCIA, R.J.F. 2002. Araucariaceae. In Flora Fanerogâmica do Estado de São Paulo (M.G.L. Wanderley, G.J. Shepherd & A.M. Giulietti, orgs.). FAPESP/HUCITEC, São Paulo, v.2, p.1-2.

GOODLAND, R. & FERRI, M.G. 1979. Ecologia do cerrado. Editora da Universidade de São Paulo, São Paulo, p.1-178.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA - IBGE. 1990. Diagnóstico. Brasil. A Ocupação do Território e do Meio Ambiente e uma Avaliação da Ocupação do Território. IBGE, Rio de Janeiro.

INTERNATIONAL PLANT NAMES INDEX - IPNI. 2010. http://www.ipni.org/ipni/plantnamesearchpage.do (último acesso em 15/09/2010).

INTERNATIONAL UNION FOR CONSERVATION OF NATURE - IUCN. 2001. Red List categories and criteria version. 3.1. IUCN Species Survival Commission, Gland, 35 p.

INTERNATIONAL UNION FOR CONSERVATION OF NATURE - IUCN. 2010. Lista Vermelha de Espécies Ameaçadas de Extinção da União Internacional para a Conservação da Natureza. http://www.iucnredlist.org (último acesso em 26/08/2010).

INSTITUTO DE PESQUISAS TECNOLÓGICAS - IPT. 2001. Estudos do meio físico para implantação de Distritos Agrícolas Irrigados na zona rural do município de Itapeva, SP. São Paulo. (Relatório Técnico, n.50725).

INSTITUTO FLORESTAL. Sistema de Informações Florestais do Estado de São Paulo - SiFESP. http://www.iflorestal.sp.gov.br/sifesp/ (último acesso em 25/09/2010).

ISHARA, K.L., DÉSTRO, G.F.G., MAIMONI-RODELLA, R.C.S. & YANAGIZAWA, Y.A.N.P. 2008. Composição florística de remanescente de cerrado *sensu stricto* em Botucatu, SP. Rev. Bras. Bot. 31(4):575-586. http://dx.doi.org/10.1590/S0100-84042008000400004

JARDIM BOTÂNICO DO RIO DE JANEIRO – JBRJ. 2010. Lista de Espécies da Flora do Brasil. http://floradobrasil.jbrj.gov.br/2010 (último acesso em 29/11/2010).

JUDD, W.S., CAMPBELL, C.S., KELLOG, E.A., STEVENS, P.F. & DONOGHUE, M.J. 2002. Plant Systematics: A Phylogenetic Approach. Sinauer Associates Inc., Sunderland.

KLINK, C.A. & MACHADO, R.B. 2005. A conservação do cerrado brasileiro. Megadiversidade 1(1):147-155.

KRONKA, F.J.N., NALON, M.A., MATSUKUMA, C.K., KANASHIRO, M.M., YWANE, M.S.S., PAVAO, M., DURIGAN, G., LIMA, L.M.P.R., GUILLAUMON, J.R., BAITELLO, J.B. & BARRADAS, A.M.F. 2005. Inventário florestal da vegetação natural do Estado de São Paulo. Secretaria do Meio Ambiente, Instituto Florestal, Imprensa Oficial, São Paulo.

LEGENDRE, P. & LEGENDRE, L. 1998. Numerical ecology. Elsevier, New York.

LEITÃO-FILHO, H.F. 1992. A flora arbórea dos cerrados do estado de São Paulo. Hoehnea 19(1-2):151-163.

LINSINGEN, L., SONEHARA, J.S., UHLMANN, A. & CERVI, A. 2006. Composição florística do Parque Estadual de Jaguariaíva, Paraná, Brasil. Acta Biol. Parana 35(3-4):197-232.

MEIRA-NETO, J.A.A., MARTINS, F.R. & VALENTE, G.E. 2007. Composição florística e espectro biológico na Estação Ecológica de Santa Bárbara, estado de São Paulo, Brasil. Rev. Arvore 31(5):907-922.

MENDONÇA, R.C., FELFILI, J.M., WALTER, B.M.T., SILVA JUNIOR, M.C., REZENDE, A.V., FILGUEIRAS, T.S. & NOGUEIRA, P.E. 1998. Flora vascular do Cerrado. In Cerrado: Ambiente e Flora. (S.M. Sano & S.P. de Almeira, orgs.). Empresa Brasileira de Pesquisa Agropecuária, Planaltina, p.289-556.

MISSOURI BOTANICAL GARDEN - MOBOT. http://www.tropicos.org/ (último acesso em 15/09/2010).

MITTERMEIER, R.A., MYERS, N., ROBLES, GIL, P. & MITTERMEIER, C.G. 1999. Hotspots: earth's biologically richest and most endangered terrestrial ecoregions. CEMEX, Mexico City.

NOVAIS, P.S., ROSSI, M., MATTOS, I.F.A. & KANASHIRO, M.M. 2009. Os solos da Estação Ecológica de Itapeva: caracterização e mapeamento. IF Sér. Regist. 40:217-222.

OLIVEIRA-FILHO, A.T. & RATTER, J.A. 1995. A study of the origin of central Brazilian forests by the analysis of plant species distribution patterns. Edinb. J. Bot. 52(2):141-194. http://dx.doi.org/10.1017/S0960428600000949

OLIVEIRA-FILHO, A.T. & FONTES, M.A.L. 2000. Patterns of floristic differentiation among Atlantic Forests in Southeastern Brazil and the influence of climate. Biotropica 32:793-810.

OLIVEIRA-FILHO, A.T. & RATTER, J.A. 2002. Vegetation physiognomies and woody flora of the cerrado Biome. In The cerrados of Brazil: Ecology and Natural History of a Neotropical Savanna (P.S. Oliveira & R.J. Marquis, orgs). Columbia University Press, New York, p.91-120.

PESSENDA, L.C.R., DE OLIVEIRA, P.E., MOFATTO, M., DE MEDEIROS, V.B., GARCIA, R.J.F., ARAVENA, R., BENDASSOLI, J.A., LEITE, A.Z., SAAD, A.R. & ETCHEBEHERE, M.L. 2009. The evolution of a tropical rainforest/grassland mosaic in southeastern Brazil since 28,000 14C yr based on carbon isotopes and pollen records. Quaternary Res. 71:437-452. http://dx.doi.org/10.1016/j.yqres.2009.01.008

PETERJOHN, B.G. 2001. Some considerations on the use of ecological models to predict species' geographic distributions. The Condor 103:661-663. http://dx.doi.org/10.1650/0010-5422(2001)103[0661:SCOTUO]2.0.CO;2

PETERSON, A.T. 2001. Predicting species' geographic distributions based on ecological niche modeling. The Condor 103:599-605. http://dx.doi.org/10.1650/0010-5422(2001)103[0599:PSGDBO]2.0.CO;2

RATTER, J.A., BRIDGEWATER, S. & RIBEIRO, J.F. 2003. Analysis of the floristic composition of the Brazilian cerrado vegetation III: Comparison of the woody vegetation of 376 areas. Edinb. J. Bot. 60:57-109. http://dx.doi.org/10.1017/S0960428603000064

RIBEIRO, J.F. & WALTER, B.M.T. 2008. As principais fitofisionomias do bioma cerrado. In cerrado: ecologia e flora (S.M. Sano, S.P. Almeida & J.F. Ribeiro, orgs.). Embrapa cerrados, Brasília, p.151-212.

RITTER, L.M.O., RIBEIRO, M.C. & MORO, R.S. 2010. Composição florística e fitofisionomia de remanescentes disjuntos de Cerrado nos Campos Gerais, PR, Brasil - limite austral do bioma. Biota Neotrop. 10(3): http://www.biotaneotropica.org.br/v10n3/en/abstract?inventory+bn04010032010. (último acesso em 28/03/2011)

RIZZINI, C.T. 1997. Tratado de fitogeografia do Brasil. 2. ed. Âmbito Cultural, Rio de Janeiro.

ROSS, J.L.S. & MOROZ, I.C. 1997. Mapa Geomorfológico do Estado de São Paulo. Instituto de Pesquisas Tecnológicas e Departamento de Ciências Tecnológicas, USP, FAPESP, São Paulo, v.1-2, Escala 1: 500.000.

ROSSATTO, D.R., TONIATO, M.T.Z. & DURIGAN, G. 2008. Flora fanerogâmica não-arbórea do cerrado na Estação Ecológica de Assis, Estado de São Paulo. Rev. Bras. Bot. 31(3):409-424. http://dx.doi.org/10.1590/S0100-84042008000300005

SANO, S.M., ALMEIDA S.P. & RIBEIRO, J.F. 2008. Cerrado: ecologia e flora. Embrapa cerrados, Brasília.

SÃO PAULO (Estado). Resolução SMA nº 48, de 21 de setembro de 2004. Lista Oficial das Espécies da Flora do Estado de São Paulo. http://www.ibot.sp.gov.br (último acesso em 10/12/2008).

SASAKI, D. & MELLO-SILVA, R. 2008. Levantamento florístico no cerrado de Pedregulho, SP, Brasil. Acta Bot. Bras. 22(1):187-202. http://dx.doi.org/10.1590/S0102-33062008000100019

SCARAMUZZA, C.A.M. 2006. Flora e ecologia dos campos de Itararé, São Paulo, Brasil. Tese de Doutorado, Universidade de São Paulo, São Paulo.

SILBERBAUER-GOTTSBERGER, L, MORAWETZ, W. & GOTTSBERGER, G. 1977. Frost damage of cerrado plants in Botucatu, Brazil, as related to the geographical distribution of the species. Biotropica 9:253-261. http://dx.doi.org/10.2307/2388143

SILVA, F.A.M., ASSAD, E.D. & EVANGELISTA, B.A. 2008. Caracterização climática do Bioma cerrado. In: cerrado: ecologia e flora (S.M. Sano, S.P. Almeida & J.F. Ribeiro, orgs). Embrapa cerrados, Brasília, p.151-212.

SIQUEIRA, M.F. & DURIGAN, G. 2007. Modelagem da distribuição geográfica de espécies lenhosas de cerrado no Estado de São Paulo Rev. Bras. Bot. 30(2):233-243.

SOUZA, V.C. & LORENZI, H. 2008. Botânica sistemática: guia ilustrado para a identificação das famílias de Fanerógamas nativas e exóticas no Brasil, baseado em APG II. 2. ed. Instituto Plantarum, Nova Odessa.

SOUZA, V.C., MAMEDE, M.C.H., CORDEIRO, I., PRADO, J., BARROS, F., WANDERLEY, M.G.L., KAGEYAMA, P.Y., CECCANTINI, G. & RANDO, J.G. 2007. Critérios utilizados na elaboração da Lista Oficial de Espécies da Flora Ameaçada de Extinção no Estado de São Paulo. In Livro vermelho das espécies vegetais ameaçadas do estado de São Paulo (M.C.H. Mamede, V.C. Souza, J. Prado, F. Barros, M.G.L. Wanderley & J.G. Rando, orgs.). Instituto de Botânica, São Paulo, p.15-20.

SPECIES LINK. http://www.splink.cria.org.br (último acesso em 12/11/2010).

STOCKWELL, D.R.B. & PETERSON, A.T. 2002. Effects of sample size on accuracy of species distribution models. Ecol. Model. 148:1-13. http://dx.doi.org/10.1016/S0304-3800(01)00388-X

STRAUBE, F.C. 1998. O cerrado no Paraná: ocorrência original e atual e subsídios para sua conservação. Instituto Ambiental do Paraná, Curitiba. Cadernos de Biodiversidade.

TANNUS, J.L.S. & ASSIS, M.A.A. 2004. Composição de espécies vasculares de campo sujo e campo úmido em área de cerrado, Itirapina - SP, Brasil. Rev. Bras. Bot. 27:489-509. http://dx.doi.org/10.1590/S0100-84042004000300009

VELOSO, H.P., RANGEL-FILHO, A.L.R. & LIMA, J.C.A. 1991. Classificação da Vegetação Brasileira, adaptada a um sistema universal. IBGE, Rio de Janeiro.

WEISER, V.L. & GODOY, S.A.P. 2001. Florística em um hectare de cerrado *stricto sensu* na ARIE - cerrado Pé-de-Gigante, Santa Rita do Passa Quatro, SP. Acta Bot. Bras. 15(2):201-212.

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Crustáceos decápodos associados às cordas de cultivo do mexilhão *Perna perna* (Linnaeus, 1758) (Mollusca, Bivalvia, Mytilidae) na Enseada da Armação do Itapocoroy, Penha – SC

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MACEDO, P.P.B., MASUNARI, S. & CORBETTA, R. **Decapod crustaceans associated with farming ropes of the mussel *Perna perna* (Linnaeus, 1758) (Mollusca, Bivalvia, Mytilidae) from Armacao do Itapocoroy Bay, Penha – SC**. Biota Neotrop. 12(2): http://www.biotaneotropica.org.br/v12n2/en/abstract?inventory+bn01812022012

Abstract: This study aimed to describe the assemblage of decapod crustaceans associated with the mussel farming ropes located in the Armação do Itapocoroy Bay, in the municipality of Penha, Santa Catarina State, southern Brazil. The following aspects were assessed: species composition and total weight, succession of species and temporal oscillation of abundance, species richness and Shannon's diversity. The growth data (height and weight of the shells) of the biological substrate (mussels) are also presented. During the nine months of the experiment, associated decapods were collected from 15 ropes (three ropes every other month). A total of 501 decapods were collected that belonged to nine families, 15 genera and 21 species. The most dominant family was Porcellanidae, with seven species, followed by Panopeidae (five) and Pilumnidae (three), while the remaining families were represented by one species each. The most abundant species was Pilumnus dasypodus (n = 244) that together with *Synalpheus fritzmuelleri*, *Pachycheles laevidactylus*, *Pisidia brasiliensis*, *Menippe nodifrons*, *Pachycheles monilifer* and *Petrolisthes galathinus* summed up 88% of decapod. Species richness increased from three to 15 during the experiment and species diversity showed its maximum in the fifth and ninth month, due to increased availability of shelters within biological substrate composed of living mussels. The total weight of decapods represented only 3% of the total weight of the farming ropes, due to the smallness of them. This indicates that these animals cannot be considered harmful for the mussel farming. The ropes play a role of shelter and as food resource, since most of these decapods spend all their bentic life in this biotope.
Keywords: *mytiliculture, associated fauna, richness and species diversity.*

MACEDO, P.P.B., MASUNARI, S. & CORBETTA, R. **Crustáceos decápodos associados às cordas de cultivo do mexilhão *Perna perna* (Linnaeus, 1758) (Mollusca, Bivalvia, Mytilidae) na Enseada da Armação do Itapocoroy, Penha – SC**. Biota Neotrop. 12(2): http://www.biotaneotropica.org.br/v12n2/pt/abstract?inventory+bn01812022012

Resumo: Este estudo teve por objetivo descrever a assembleia de crustáceos decápodos associados às cordas de cultivo de mexilhões em uma fazenda marinha localizada na Enseada da Armação do Itapocoroy, no Município de Penha, Santa Catarina, sul do Brasil. Os seguintes aspectos foram tratados: composição de espécies e peso total, sucessão de espécies e oscilação temporal da abundância, riqueza de espécies e diversidade (Shannon). O crescimento do mexilhão em (altura da concha e peso dos indivíduos) também, foram apresentados. Os decápodos foram amostrados de 15 cordas amostradas bimensalmente (três cordas a cada dois meses). Um total de 501 decápodos foram capturados, pertencentes a nove famílias, 15 gêneros e 21 espécies. A família dominante foi Porcellanidae, com sete espécies, seguida de Panopeidae (cinco) e de Pilumnidae (três), enquanto as demais foram representadas por uma espécie. A espécie mais abundante foi *Pilumnus dasypodus* (n = 244) que, junto com *Synalpheus fritzmuelleri, Pachycheles laevidactylus, Pisidia brasiliensis, Menippe nodifrons, Pachycheles monilifer e Petrolisthes galathinus*, somou 88% das ocorrências. A riqueza de espécies aumentou de três para 15 durante o experimento e a diversidade de espécies mostrou seu máximo no quinto mês seguido pelo nono, devido ao aumento da disponibilidade de refúgios no interior do substrato biológico composto por mexilhões vivos. O peso total dos decápodos representou apenas 3% do peso total das cordas de cultivo, devido ao seu tamanho reduzido. Isto indica que estes animais não podem ser considerados prejudiciais para o cultivou mexilhões. As cordas desempenham o papel de fornecer abrigo e fonte de alimento, já que a maioria destes decápodos passa todo o período bentônico do seu ciclo de vida neste biótopo.
Palavras-chave: *mitilicultura, fauna associada, riqueza e diversidade das espécies.*

Introdução

A mitilicultura é uma atividade que tem crescido mundialmente, fato que também vem sendo observado no Brasil nos últimos anos (Marenzi 1999). A sobre-explotação da pesca devido à falta de cuidado no manejo dos estoques naturais de pescado propiciou o sucesso da aquicultura nas últimas décadas (Young et al. 1999). Dessa forma, a mitilicultura, surgiu como uma fonte alternativa de renda para os pescadores artesanais do litoral do Estado de Santa Catarina, onde se difundiu em praticamente todas as enseadas e baías da costa centro-norte deste Estado que, na última década, tornou-se o segundo maior produtor de mexilhões da América Latina. A vasta maioria das fazendas marinhas cultiva o mexilhão *Perna perna* (Linnaeus, 1758) (Mollusca, Bivalvia, Mytilidae), em função das condições oceanográficas propícias ao desenvolvimento desta espécie, a qual possui boas qualidades para o cultivo em escala comercial como ampla distribuição geográfica, forte resistência às variações ambientais de temperatura e salinidade, grande capacidade adaptativa, alta taxa de crescimento e elevado valor protéico (Ferreira & Magalhães 2004).

A primeira referência de cultivo de mexilhões *Perna perna* para o Estado de Santa Catarina data de 1985, na Enseada da Armação do Itapocoroy, Penha (Marenzi 1999), onde, está localizado atualmente um dos maiores parques de cultivo da América Latina. Nessa enseada, a mitilicultura é realizada em estruturas do tipo "*long-line*" ou espinhel de meia água, compostas por um cabo horizontal de náilon ou poliamida com 100 metros de comprimento, no qual ficam amarradas verticalmente as cordas de cultivo de mexilhões, que são conhecidas popularmente como pencas de mariscos. A mitilicultura é desenvolvida totalmente no ambiente natural, sem a utilização de rações ou de energia exógena para a circulação de água, tampouco a retirada dos resíduos (Kautsky & Folke 1991). Contudo, esta produção de mexilhões em interação com sua fauna associada e o meio ambiente traz como consequência mudanças tanto nas características do ecossistema como no aspecto da paisagem. Nos locais onde a mitilicultura é conduzida de forma correta, observa-se um aumento na abundância e na diversidade de espécies de organismos marinhos, proporcionando uma inter-relação trófica dinâmica das espécies neste novo ecossistema (Marenzi & Manzoni 1998). Por outro lado, nos locais de alta concentração de cultivos, observa-se um enriquecimento orgânico das águas de tal intensidade que apenas espécies tolerantes e com ciclo de vida rápido sobrevivem, determinando a sucessão ecológica local (Tsutsumi et al. 1991, Marenzi & Manzoni 1998), uma ocorrência típica após um distúrbio ambiental (Connell & Slatyer 1977).

O cultivo resulta na introdução artificial de espécies e variedades para essas novas áreas e, frequentemente, desloca variedades nativas que tem evoluído em relativo isolamento (Tisdell 1991).A quantidade e o tipo de organismos incrustantes ou vágeis associados às cordas pode se tornar um problema para o cultivo de mexilhões. Essas comunidades incrustantes podem causar mortalidade principalmente nas sementes (juvenis), devido à limitação da superfície disponível para a fixação das larvas (Waterstrat et al. 1980). Podem também reduzir a razão de crescimento pela dificuldade na abertura das valvas, impedindo a entrada de água e alimento (Witman & Suchanek 1984), causar problemas de flutuação ou romper as estruturas de cultivo suspenso devido ao excesso de peso, ocasionando perdas de estruturas e grandes prejuízos.

Dentre os organismos associados às cordas de mexilhões são conhecidos os hidrozoários, briozoários, ascídias, moluscos, crustáceos e outros animais que também passam ali parte importante de suas vidas (Santos 2006). Seed (1976) relatou que um dos principais fatores responsáveis pela mortalidade dos mexilhões é a predação. Os gastrópodes predadores mais comuns são *Stramonita brasiliensis* Claremont & Reid, 2011 (vulgarmente conhecido como "búzio") e *Cymatium parthenopeum* (Salis, 1793) (também chamado de "caramujo peludo") que são capazes de abrir a concha e consumir a carne desses bivalves (Manzoni & Lacava 1998). Outros predadores importantes são algumas espécies de estrelas-do-mar (Inglis & Gust 2003), caranguejos e siris (DeGraaf & Tyrrell 2004), pássaros (Hamilton & Nuds 2003) e peixes (Lappalainen et al. 2004). Alguns parasitas também podem ser encontrados, como o poliqueta *Polydora* sp., que perfura galerias nas conchas e o caranguejo *Pinnotheres maculatus*, danificando as brânquias (Marques 1998).

Segundo Seed (1976), os mexilhões em cultivo possuem grande importância ecológica pela criação de um novo substrato sólido em disponibilidade para o estabelecimento de várias espécies associadas, pela remoção de material em suspensão presente em grande quantidade na coluna de água e por atuarem como bioindicadores de poluição costeira.

No Brasil, a fauna associada às cordas de cultivo de mexilhões foi tratada por Marenzi & Branco (2006) na Enseada da Armação do Itapocoroy, Santa Catarina (SC) e por Camargo (2011) no litoral do Estado de São Paulo. Este estudo tem como objetivos listar as espécies de crustáceos decápodos associados às cordas de mexilhões e caracterizar temporalmente as variações de riqueza, abundância e biomassa desta assembléia ocorrente na Enseada da Armação do Itapocoroy, Penha, SC.

Material e Métodos

O presente estudo foi desenvolvido na Enseada da Armação do Itapocoroy, no município de Penha, Santa Catarina (Figura 1a), na área de cultivo do Centro Experimental de Maricultura da Universidade do Vale do Itajaí – UNIVALI (Figura 1b). Este município está localizado no litoral centro-norte de Santa Catarina, (26° 46' 56" S e 48° 38' 42" O), e possui uma área de 60,3 km² fazendo divisa com Navegantes (Sul), Balneário Piçarras (Oeste) e com o Oceano Atlântico (Leste e Norte). As estruturas de cultivo utilizadas são denominadas cordas de mexilhões (Figura 1c).

O cultivo foi iniciado a partir de mexilhões juvenis (sementes) de *Perna perna*, com altura média de concha de cerca de 25 mm obtidos dos maricultores e de coletores. As sementes foram introduzidas em sacos de redes de algodão com auxílio de um cano de PVC, que, por sua vez foram inseridos dentro de outro saco de rede de náilon. Nesta etapa, o cano de PVC é subtraído. Essa técnica denomina-se "Francês" devido à sua origem (Marenzi & Branco 2006) e este conjunto de sacos com sementes constitui uma corda. O saco de rede de algodão decompõe-se rapidamente, porém não antes dos mexilhões juvenis se fixarem uns sobre os outros por meio do crescimento do bisso, formando um longo e firme agregado. Em seguida, os mexilhões transpõem o saco de rede de náilon, assentando-se na face externa do mesmo, onde crescem até atingir o tamanho comercial. No dia 18 de setembro de 2006 foram imersas 41 cordas de cultivo de mexilhões, cada uma medindo 1 metro de comprimento e pesando aproximadamente 1 kg. O experimento teve duração de nove meses e a primeira amostragem foi realizada em novembro, após um mês do início do experimento e as restantes com freqüência bimestral (dezembro, fevereiro, abril e junho de 2006), num total de cinco amostragens. Em cada amostragem, três cordas foram retiradas da água, com auxílio de um guincho da embarcação, totalizando 15 cordas amostradas. Após o período de nove meses o peso em demasia das 26 cordas de mexilhões restantes, causou o rompimento da estrutura de cultivo "*long-line*" inviabilizando a continuidade do estudo. Nesse período, ocorreram colonizações de outros organismos por meio de migração e/ou de transporte de ovos e larvas.

Figura 1. (a) Mapa do litoral do Município de Penha, SC (Fonte: Laboratório de Geoprocessamento Costeiro da UNIVALI) com a indicação da área de cultivo de mexilhões na Enseada da Armação do Itapocoroy; (b) Vista parcial da área de cultivo dentro da enseada e (c) Duas cordas de cultivo submersas e ainda amarradas ao *long-line*.

Figure 1. (a) Map of the coast of municipality of Penha, SC (Source: GIS Laboratory of Coastal UNIVALI) with the indication of the mussel farming area at Armação do Itapocoroy Bay; (b) Parcial landscape of farming area inside the bay and (c) two submerged cultivation ropes tied to the *long-line*.

No barco, cada uma das três cordas de cultivo de mexilhões foi acomodada em uma caixa plástica distinta para que os organismos de uma corda não se misturassem com os das outras cordas. Em terra, as cordas foram embaladas em sacos plásticos, transportadas para o Laboratório de Ciências Ambientais na UNIVALI de Itajaí e armazenadas em freezer até seu processamento. De cada amostragem, um lote de 60 mexilhões foi separado aleatoriamente, os quais foram pesados com auxílio de uma balança de precisão e a altura das conchas medidas com paquímetro digital para verificar o aumento de biomassa e tamanho dos mexilhões. As triagens dos crustáceos decápodos foram realizadas após o descongelamento das amostras; estes foram identificados, contados e pesados com os equipamentos acima citados, fixados em formol 4% e conservados em álcool 70%. A classificação dos decápodos do presente estudo seguiu a proposta de Melo (1996, 1999), Ng et al. (2008) e De Grave et al. (2009). Os crustáceos decápodos do presente estudo estão depositados na Coleção Crustacea, no Laboratório de Invertebrados do Museu de História Natural Capão da Imbuia (MHNCI) sob os lotes: MHNCI 2866; MHNCI 2851; MHNCI 2853 – 2857; MHNCI 2848 – 2849; MHNCI 2850; MHNCI 2859 – 2865; MHNCI 2858 e MHNCI 2852.

Análise dos Dados

A estrutura da assembleia de decápodos associados às cordas de cultivo de mexilhões foi examinada com base em dois aspectos importantes da sua organização: o número de espécies e as respectivas abundâncias relativas (Giller 1984). A partir desses dados foram calculados os índices biológicos de riqueza e diversidade de Shannon (H’) (log e), na tentativa de resumir as informações e facilitar futuramente a comparação entre este habitat e outros naturais ou artificiais. Foram utilizadas as médias de abundância total e relativa de cada espécie ao longo do tempo de cultivo. As análises foram realizadas através do programa PRIMER 6. Foi utilizada a análise de variância unifatorial (ANOVA) para comparar as médias da altura e peso dos mexilhões cultivados. No caso de existência de diferença significativa (p = 0,05), realizou-se o teste “*a posteriori*” de Tukey HSD para saber qual média apresentou a diferença entre os meses. As análises foram realizadas utilizando o programa computacional R.

Resultados

1. *O substrato biológico Perna perna:*

Os mexilhões cultivados atingiram uma altura média da concha de 70,07 ± 25,26 mm no final de nove meses. Como as sementes (juvenis) mediram 25 ± 0,25 mm; isto equivale a um incremento médio mensal de 4,74 mm. Houve, entretanto, maior velocidade de crescimento das conchas entre o mês um ao três e do quinto ao nono (Figura 2). Entre o terceiro e quinto mês de amostragem não houve diferença significativa em relação à altura (F = 285,58; p < 2,2e-16). O peso médio de cada mexilhão ao final do estudo foi de 25,25 ± 11,59 g, resultado de um incremento médio mensal de 1,6 g; entre os meses três e cinco não houve diferença significativa no peso (F = 158,68; p = 2,2e-16) ocorrendo um declínio no peso médio total, porém no restante do período de cultivo, não houve diferença significativa entre os meses, havendo sucessivos incrementos de peso (Figura 2). As cordas que pesavam aproximadamente 1 kg no início do cultivo atingiram o peso médio de 6,220 kg cada uma, num incremento médio mensal de aproximadamente 580 g por corda em nove meses de cultivo.

2. *A fauna de decápodos associados às cordas de cultivo de mexilhões:*

Um total de 501 exemplares foi registrado, sendo representados por 21 espécies de decápodos pertencentes a 15 gêneros e nove famílias (Tabela 1). Destas, 12 foram braquiúros, sete anomuros e uma de cada camarão carídeo e peneídeo.

A riqueza da assembléia aumentou de três a 15 espécies e a diversidade de espécies, de 0,36 ± (0,36) a 1,31 ± (0,15) ao longo dos meses de cultivo. Por outro lado, a abundância aumentou de três até 262 indivíduos no sétimo mês e diminuiu para 164 no último mês (Tabela 2).

As seguintes espécies perfizeram 88% de abundância total: *Pilumnus dasypodus*, *Synalpheus* cf. *fritzmuelleri*, *Pachycheles laevidactylus*, *Pisidia brasiliensis*, *Menippe nodifrons*, *Pachycheles monilifer e Petrolisthes galathinus*. As demais espécies (14) representaram em conjunto apenas 12% da abundância total (Tabela 3).

Nenhuma espécie foi de ocorrência constante durante todo o período de estudo. A mais frequente e abundante foi *Pilumnus dasypodus*, que ocorreu em quatro dos cinco meses amostrados, totalizando 244 indivíduos. *Pachycheles laevidactylus*, *Psidia brasiliensis*, *Pachycheles monilifer*, *Petrolisthes galathinus* ocorreram em três dos cinco meses amostrados, com abundância de 43, 33, 18 e 16 indivíduos, respectivamente. *Pilumnus reticulatus* apesar da baixa abundância (8) nas amostragens, também ocorreu em três dos cinco meses de amostragens, de modo descontínuo. *Pachygrapsus transversus*, *Petrolisthes armatus*, *Menippe nodifrons* e *Hexapanopeus paulensis* ocorreram em duas das cinco amostragens. *Synalpheus* cf. *fritzmuelleri* foi a segunda espécie mais abundante (62 indivíduos), apesar de sua ocorrência restrita às duas últimas amostragens. *Porcellana platycheles*, *Panopeus lacustris* e *P. rugosus* foram registradas apenas uma vez, mas cada uma dessas espécies representou mais de 1% da amostragem. As demais espécies tiveram ocorrência rara, ou seja, baixa freqüência e abundância, representando cada espécie menos de 1% do total de decápodos: *Panopeus austrobesus*, *Porcellana sayana*, *Pilumnoides coelhoi*, *Callinectes danae*, *Pleoticus mueller*, *Libinia spinosa e Acantholobulus schmitti* (antigo *Hexapanopeus schmitti*) (Tabela 3)

Tabela 1. Lista das espécies dos decápodos associados às cordas de cultivo de mexilhões na Enseada da Armação do Itapocoroy.

Table 1. List of species of decapods associated with strings of growing mussels in the Bay of Armacao Itapocoroy.

Filo Arthropoda Latreille, 1829
Classe Malacostraca Latreille, 1802
Ordem Decapoda Latreille, 1802
Subordem Dendrobranchiata Bate, 1802
Infraordem Penaeidea (Calazans, 1993)
Família Solenoceridae Wood-Mason & Alcock, 1891
Pleoticus muelleri (Bate, 1888)
Subordem Pleocyemata Burkenroad, 1963
Infraordem Anomura MacLeay, 1838
Família Porcellanidae Haworth, 1825
Pachycheles laevidactylus Ortmann, 1892
Pachycheles monilifer (Dana, 1852)
Petrolisthes armatus (Gibbes, 1850)
Petrolisthes galathinus (Boch, 1802)
Pisidia brasiliensis Haig *in* Rodrigues da Costa, 1968
Porcellana platycheles (Pennant, 1777)
Porcellana sayana (Leach, 1820)
Infraordem Brachyura Linnaeus, 1758
Família Pilumnidae Samouelle, 1819
Pilumnoides coelhoi Guinot & Macpherson, 1987
Pilumnus dasypodus Kingsley, 1879
Pilumnus reticulatus Stimpson, 1860
Família Panopeidae Ortmann, 1893
Acantholobulus schmitti (Rathbun, 1930)
Panopeus rugosus A. Milne Edwards, 1880
Panopeus lacustris Desbonne, 1867
Panopeus austrobesus Williams, 1983
Hexapanopeus paulensis Rathbun, 1930
Família Menippidae Ortmann, 1893
Menippe nodifrons Stimpson, 1859
Família Portunidae Rafinesque, 1815
Callinectes danae (Smith, 1869)
Família Epialtidae MacLeay, 1838
Libinia spinosa H. Milne Edwards, 1834
Família Grapsidae MacLeay, 1838
Pachygrapsus transversus Gibbes, 1850
Infraordem Caridea Dana, 1852
Família Alpheidae Rafinesque, 1815
Synalpheus frizmuelleri Coutière, 1901

A biomassa média do conjunto das espécies de decápodos associados variou de 0,2 g (mês 1) a 38,77 g (mês 7); o peso médio dos mesmos ao longo dos meses foi crescente até o sétimo mês (38,77 g), e houve uma leve diminuição no nono mês (22,16 g) (Tabela 2). A biomassa total de decápodos nos nove meses de amostragem foi de apenas 207,3 g. As cinco espécies que mostraram maior contribuição na biomassa total foram: *Pilumnus dasypodus*, *Menippe nodifrons*, *Pachycheles laevidactylus*, *Synalpheus* cf. *fritzmuelleri* e *Pisidia brasiliensis*. Embora *Menippe nodifrons* tenha sido representado por somente 24 indivíduos aparentemente juvenis, estes foram os de maior contribuição na biomasssa total, em função do maior porte atingido pela espécie. Por outro lado, *Pilumnus dasypodus* apresentou maior biomassa total (123,28 g), com a contribuição de 183 indivíduos adultos no mês sete e 45 no mês nove.

Discussão

O crescimento médio dos mexilhões do presente estudo (70,07 ± 25,26 mm em altura da concha em nove meses) apresentou-se inferior ao encontrado por Marenzi & Branco (2006) que, em oito meses de cultivo obtiveram uma altura de concha média de 70,7 mm. Isto pode ser explicado devido à diferença no tamanho das sementes. Marenzi & Branco (2006) iniciaram seu estudo com sementes de

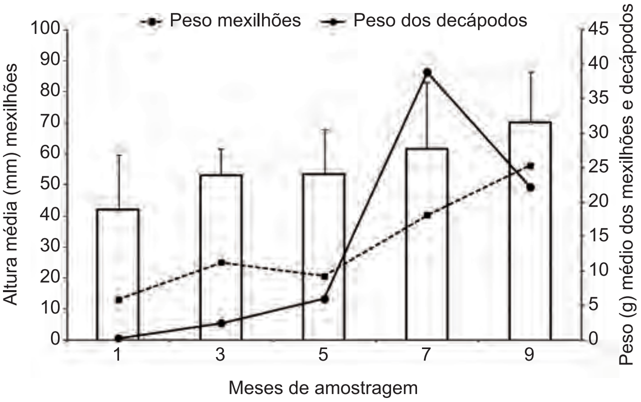

Figura 2. Cordas de cultivo de mexilhão *Perna perna*. Altura média (mm) e peso médio (g) individual das conchas dos mexilhões (média de 180 mexilhões por mês de amostragem) e peso médio total dos decápodos associados às cordas (média das três cordas), ao longo do experimento.

Figure 2. Rope cultivation of mussels *Perna perna*. The average height (mm) and weight (g) of individual shells of mussels (average of 180 mussels per month of sampling) and total weight of decapods associated with ropes (average of three ropes), along the experiment.

Tabela 2. Decápodos associados às cordas de cultivo de mexilhões na Enseada da Armação do Itapocoroy. Abundância, riqueza, riqueza acumulada, biomassa e diversidade de Shannon das espécies ao longo do experimento.

Table 2. Decapods associated with ropes of mussel cultivated in the Bay of Armação of Itapocoroy. Abundance, specie richness, accumulatet specie richness, biomass and Shannon diversity of species throughout the experiment.

Meses	**1**	**3**	**5**	**7**	**9**	**∑**
espécies	**Abundância das espécies nos meses**					
Pilumnus dasypodus	0	3	13	183	45	244
Synalpheus fritzmuelleri	0	0	0	21	41	62
Pachycheles laevidactylus	0	3	3	37	0	43
Psidia brasiliensis	0	0	21	10	2	33
Menippe nodifrons	0	0	0	2	22	24
Pachycheles monilifer	0	0	6	2	10	18
Petrolisthes galathinus	0	0	12	3	1	16
Porcellana platycheles	0	0	0	0	9	9
Hexapanopeus paulensis	0	0	0	1	8	9
Pachygrapsus tranversus	1	8	0	0	0	9
Panopeus lacustres	0	0	0	0	8	8
Pilumnus reticulatus	0	1	0	2	5	8
Panopeus rugosus	0	0	0	0	5	5
Panopeus austrobesus	0	0	0	0	3	3
Petrolisthes armatus	1	1	0	0	0	2
Porcellana sayana	0	0	0	0	2	2
Pilumnoides coelhoi	0	0	0	0	2	2
Libinia spinosa	0	0	0	1	0	1
Callinectes danae	1	0	0	0	0	1
Acantholobulus schmitti	0	0	0	0	1	1
Pleoticus muelleri	0	0	0	1	0	1
Abundância	3	16	55	262	164	501
Riqueza de espécies	3	5	5	11	15	
Riqueza acumulada	3	6	9	14	21	
Peso (média) total dos decápodes	0,2	2,04	5,93	38,77	22,16	
Diversidade (Shannon_H)	0,36 (±0,36)	0,96(±0,22)	1,37(±0,02)	0,58(±0,49)	1,31 (±0,15)	

30,0 mm em média, um valor relativamente maior do que as sementes usadas neste experimento (25,0 mm em média). Henriques et al. (2004) recomenda iniciar um cultivo com sementes superiores a 40,0 mm para atingir tamanho comercial em menos tempo. Entretanto, devido à dificuldade na obtenção das sementes nem sempre é possível manter esse tamanho mínimo sugerido.

Outro fator que pode ter influenciado essa diferença no crescimento foi o aumento desordenado das áreas de cultivo na região. Segundo Suplicy (2000), o conceito de capacidade de suporte de um ecossistema é derivado de um estudo da ecologia de populações. Outros autores consideram ainda a capacidade suporte como sendo o ponto onde a biomassa de uma determinada população para de crescer, e o montante de biomassa mantida nestas condições é considerado como capacidade de suporte máxima. Além disso, o referido autor afirma que, em casos de elevadas densidades de cordas de cultivo, estas funcionam como "paredes submersas", retendo e causando uma sedimentação excessiva de materiais em suspensão na água. Se as estruturas de cultivo estiverem localizadas em áreas de pequena profundidade e de circulação restrita, os biodepósitos (fezes e pseudofezes) e animais que caem do cultivo causam impactos negativos no sedimento podendo provocar eutrofização do biótopo prejudicando o cultivo de forma geral.

Cultivos densos como na Enseada do Brito (Palhoça, Santa Catarina), onde os mexilhões atingiam o tamanho comercial de 80,0 mm em seis a sete meses, atualmente somente o atingem em 12 a 13 meses Suplicy (2000).

Entre o primeiro e o terceiro mês de cultivo, houve grande crescimento dos mexilhões. Isto pode estar relacionado com o período de amostragem (verão), período no qual a enseada é fortemente influenciada pelo aporte de águas continentais, principalmente do Rio Itajaí-Açu o qual é incrementado pelas precipitações que ocorreram nas áreas continentais, além daquela precipitação ocorrida no próprio local de cultivo (Schettini et al. 1999, Carvalho et al. 1999). Esse aporte traz como conseqüência todas as substâncias lançadas neste rio: nutrientes inorgânicos e orgânicos, metais traço e compostos orgânicos persistentes (Schettini et al. 1997). Essa maior quantidade de nutrientes, nesse período, promove alimento para esses bivalves, explicando esse maior crescimento nesse período, em contra partida, esse aporte é caracterizado por uma salinidade extremamente baixa (Schettini et al. 1999), aliado aos maiores valores de temperaturas da água, (de 28 °C a 30 °C) que ocorrem nos meses de janeiro e fevereiro nessa enseada (Marenzi & Branco 2006) e, segundo Loo & Rosenberg (1983), essa alta temperatura diminui a capacidade de filtração dos mexilhões, influenciando negativamente o seu crescimento nesse período de temperaturas elevadas promovendo estresse para esses organismos. Esse estresse gerado pelo aumento da temperatura provoca ainda a desova dos organismos, que no caso da espécie do mexilhão *Perna perna* pode apresentar desovas ao longo de todo ano,

Tabela 3. Decápodos associados às cordas de mexilhões cultivados na Enseada da Armação do Itapocoroy. Ocorrência das espécies (barras horizontais) e oscilação da abundância dos decápodos (número acima das barras horizontais) durante o experimento.

Table 3. Decapods associated with ropes of mussel cultivated in the Bay of Armação of Itapocoroy. Occurrence of species (horizontal bars) and oscillation of the abundance of decapods (number above the horizontal bars) during the experiment.

Espécies	**Meses**	**1**	**3**	**5**	**7**	**9**
	Data	**18/10/06**	**12/12/06**	**21/02/07**	**06/04/07**	**14/06/07**
1 *Pilumnus dasypodus* 			3	13	183	45
2 *Pachycheles laevidactylus* 			3	3	37	
3 *Pisidia brasiliensis* 				21	10	2
4 *Pachycheles monilifer* 				6	2	10
5 *Petrolisthes galathinus* 				12	3	1
6 *Pilumnus reticulatus* 			1		2	5
7 *Pachygrapsus transversus* 		1	8			
8 *Petrolisthes armatus* 		1	1			
9 *Synalpheus fritzmuelleri* 					21	41
10 *Menippe nodifrons* 					2	22
11 *Hexapanopeus paulensis* 					1	8

Tabela 3. Continuação...

Espécies	Meses	1	3	5	7	9
	Data	**18/10/06**	**12/12/06**	**21/02/07**	**06/04/07**	**14/06/07**
12 *Callinectes danae* 		1				
13 *Pleoticus muelleri* 					1	
14 *Libinia spinosa* 					1	
15 *Porcellana platycheles* 						9
16 *Panopeus lacustris* 						8
17 *Panopeus rugosus* 						5
18 *Panopeus austrobesus* 						3
19 *Porcellana sayana* 						2
20 *Pilumnoides coelhoi* 						2
21 *Acantholobulus schmitti* 						1

estando dependente da variação da temperatura (Ferreira et al. 2006). A eliminação de gametas (desova) promove perdas significativas no peso dos mexilhões (Marenzi & Branco 2006). Esses fatores podem explicar a redução na velocidade de crescimento e diminuição do peso que ocorreu do terceiro para o quinto mês neste estudo. Além destes fatores, um causador de grande estresse para esses organismos é a predação por platelmintos, gastrópodes, equinodermos, peixes e aves que ocorre em maior intensidade nos meses mais quentes (Freitas 1997, Cochôa & Magalhães 2008).

A produtividade média por metro de corda de cultivo é de 13 kg de mexilhões, e a fauna associada pode representar até 30% do peso total das cordas (Marenzi & Branco 2006). Em contraste, no presente estudo, os crustáceos representaram apenas 0,62% (38,77 g no mês de maior peso). Nenhuma espécie apresentou grande contribuição em peso, embora a maioria tenha sido abundante numericamente. Os epibiontes embora constituam os competidores mais sérios dos mexilhões (Marques & Pereira 1989) na Enseada da Armação do Itapocoroy, os crustáceos decápodos não constituem ameaça no que concerne ao peso como mencionado em outros cultivos (Choncheunchob 1980, Mattsson & Lindén 1983). O elevado peso da fauna associada registrada pelos referidos autores se deve à presença de cirripédios, poliquetos tubícolas e outros animais coloniais que contribuem de maneira significativa para o peso total das cordas.

A biomassa da fauna de decápodos associados acompanhou o crescimento dos mexilhões até o sétimo mês, quando o seu valor atingiu o máximo; após, houve um significativo decréscimo juntamente com a sua abundância. Os epibiontes são competidores mais sérios dos mexilhões (Marques & Pereira 1989). Cirripédios e ascídias sobre as valvas dos mexilhões dificultam o crescimento e, consequentemente, afetam a fauna associada (Marenzi & Branco 2006). Estes observaram que a partir de 70 mm de altura de concha, os mexilhões tendem a reduzir o seu crescimento, certamente pela diminuição da eficiência na limpeza da concha com o pé (Loo & Rosembreg 1983), facilitando a fixação de epibiontes (Andreu 1976). Embora os mexilhões deste estudo tenham atingido uma altura de concha próxima de 70 mm apenas no nono mês (junho), a súbita redução dos decápodos em abundância e biomassa, provavelmente se deu devido aos fortes ventos de leste que normalmente atingem diretamente a Armação do Itapocoroy nos meses de inverno e primavera (Marenzi & Branco 2006), um fato largamente conhecido em outros cultivos (Choncheunchob 1980, Mattsson & Lindén 1983), e que provavelmente desalojaram os mexilhões ou tornaram as cordas locais não estáveis para os decápodos habitarem. Desta forma, o tamanho dos mexilhões teve influência sobre a fauna de decápodos associada, porém as condições adversas de tempo que ocorreram durante esse mês de amostragem também tiveram importância na alteração do número de organismos.

Os estudos sobre fauna e flora associadas às cordas de cultivo de mexilhões realizada no Estado de Santa Catarina trataram parte considerável dos crustáceos decápodos ao nível de família ou superfamília (Marenzi & Branco 2006), tornando difícil uma comparação com o presente estudo. Um total de 38 espécies de crustáceos associadas às cordas de mexilhões foi registrado neste Estado, além daquelas não identificadas ao nível específico (Freitas 1997, Marenzi & Branco 2006, Leite 2007 e o presente estudo). Destas apenas três (Freitas 1997 e Marenzi & Branco 2006), e duas (Leite 2007) espécies de decápodos foram registradas neste biótopo. Marenzi & Branco (2006) encontraram ainda representantes da família Xanthidae MacLeay, 1838 (*sensu lato*). Certamente, esta baixa riqueza de espécies comparativamente ao presente estudo (21 espécies) está relacionada com a identificação ao nível taxonômico mais elevado nos trabalhos anteriores. Deste litoral, as seguintes cinco espécies foram comuns com o presente estudo: *Pachygrapsus transversus*, *Callinectes danae*, *Menippe nodifrons*, *Petrolisthes armatus*, *P. galathinus*, perfazendo menos de 25% de similaridade de espécies. Outras espécies identificadas ao nível de gênero pelos referidos autores como *Hexapanopeus* sp. e *Petrolisthes* sp. poderiam também serem comuns com o presente estudo.

No estudo restrito aos decápodos braquiúros no litoral norte do Estado de São Paulo, Camargo (2011) encontrou 16 espécies, ou seja, quatro a mais do que no presente estudo (12 espécies de braquiúros). Sete espécies foram comuns no litoral do dois estados: *Libinia spinosa*, *Hexapanopeus paulensis*, *Acantholobulus schmitti*, *Menippe nodifrons*, *Panopeus austrobesus*, *Pilumnus reticulatus* e *Pachygrapsus transversus*, perfazendo 50% de similaridade de espécies de braquiúros. A espécie mais abundante naquele Estado foi *Panopeus austrobesus* com 711 indivíduos, ao passo que no presente estudo foi *Pilumnus dasypodus* com 244 indivíduos (total registrado em nove meses de cultivo). Estas diferenças na riqueza, composição e abundância das espécies em biótopos similares de litorais com clima distintos ressaltam a importância das variáveis abióticas reinantes nos respectivos ecossistemas.

Ricklefs (2003) afirma que substratos mais homogêneos abrigam uma riqueza de espécies menor do que aquelas verificadas para substratos mais heterogêneos. Neste contexto, as cordas de cultivo de mexilhões podem ser consideradas os substratos mais heterogêneos conhecidos. Corroboram esta hipótese as riquezas de espécies de decápodos braquiúros registradas em outros substratos biológicos: 14 espécies sobre as colônias do briozoário *Schizoporella unicornis* (Johnston, 1847); (Mantelato & Souza-Carey 1998) e 12 espécies sobre as comunidades fitobentônicas de um costão rochoso (Széchy et al. 2001).

As espécies encontradas nesse estudo pertencem a nove famílias, sendo Porcellanidae a mais rica e abundante, apresentando sete espécies. Esta família, apesar de pouco citada em outras pesquisas, pode ter sua elevada abundância nas cordas de mexilhões explicada pela plasticidade adaptativa de suas 230 espécies que habitam uma grande variedade de habitats, entre-marés e sublitorais, como bancos algas, corais, esponjas, fissuras das rochas, embaixo de pedras, incluindo os bancos naturais de mexilhões (Rodriguez 1980). Além disso, apesar destes animais serem primariamente filtradores, podem manipular pedaços de alimento com os quelípodos e aproveitar detritos depositados no substrato (Kropp 1981), podendo ainda ocorrer como comensais de algumas espécies de fundos duros (anêmonas-do-mar) e moles (estrelas-do-mar) (Silva et al. 1989). Os porcelanídeos *Pachycheles laevidactylus* e *Petrolisthes armatus* são encontrados em bancos naturais de mexilhões; *Porcellana sayana* em fundos de lama, substrato característico da região de Enseada da Armação do Itapocoroy e sobre conchas e como comensais de paguros e gastrópodes; *Pachycheles monilifer*, *Porcellana platycheles* e *Pisidia brasiliensis* são mais comuns em substratos rochosos de ambientes naturais (Melo 1999).

Marenzi & Branco (2006) na Enseada da Armação do Itapocoroy, SC registraram maior abundância de representantes da antiga família Xanthidae MacLeay, 1838 nas cordas de mexilhões. Estes dados coincidem com o presente estudo, pois nove espécies desta superfamília totalizaram 304 indivíduos, perfazendo 60,67% do total. Além de serem importantes numericamente, muitos Xanthidaes são predadores bentônicos, mas frequentemente desprezados devido ao seu pequeno tamanho e comportamento críptico.

Silliman et al. (2004) sugeriram que estes caranguejos quebradores de conchas atuam como forças importantes na estruturação das comunidades. Entretanto, com exceção de *Menippe nodifrons*, os representantes desta supefamília do presente estudo foram de pequeno a médio porte (Marochi & Masunari 2011) e, portanto, quebras de conchas de mexilhões por estes caranguejos não seriam possíveis. Mesmo os *Menippe nodifrons* potencialmente predadores de moluscos registrados no presente estudo foram juvenis de pequeno porte e não atingiram tamanhos maiores do que 2 cm de largura de carapaça (os adultos desta espécie podem atingir até 78,82 cm (Marochi & Masunari 2011), sendo portanto incapazes de realizar tal atividade. Como a colonização por estes caranguejos aconteceu apenas no sétimo mês (com aumento significativo de abundância no último mês, quando os mexilhões já haviam atingido cerca de 6 cm de altura de concha, é muito provável que estes animais estariam predando exclusivamente os componentes da fauna associada de porte compatível com o tamanho dos mesmos. No início do cultivo, quando os mexilhões tinham apenas 25 mm de concha, e portanto passíveis de serem predados, estes caranguejos estavam ausentes. Com o mesmo raciocínio, as demais espécies de decápodos utilizaram as cordas de cultivo dos mexilhões como um substrato alternativo de moradia e fonte de alimento diferente da carne do mexilhão adulto. Entretanto, como a desova dos mexilhões *Perna perna* em Santa Catarina ocorre principalmente nos meses de abril e maio, e estes juvenis encontram local adequado para seu desenvolvimento nas próprias cordas de mexilhões (Cochôa & Magalhães 2008), este pode ser mais um dos fatores do aparecimento de *Menippe nodifrons*, potenciais predadores no sétimo e nono mês de amostragem (abril e junho), em busca dos mexilhões juvenis que nasceram das referidas desovas e se fixaram aos mexilhões adultos.

Segundo Tenore & Gonzales (1975), o abrigo disponibilizado pelas cordas de mexilhões é um dos principais fatores que regulam o estabelecimento de crustáceos nos cultivos de mexilhões em Ría de Arosa, Espanha. Por outro lado, Mantelatto & Souza-Carey (1998) concluíram que o abrigo para caranguejos braquiúros disponibilizado pelo briozoário *Schizoporella unicornis* (Johnston, 1847) foi o principal recurso que atraiu estes organismos; recurso este que foi incrementado à medida que o substrato biológico foi crescendo em tamanho e complexidade. Além disso, Széchy et al. (2001) ressaltaram que as espécies associadas aos mexilhões apresentam dimensões compatíveis ao espaço oferecido como abrigo entre as conchas: estas são de pequeno porte durante as fases iniciais do desenvolvimento juvenil do substrato, o que demonstra a importância do abrigo como recurso para estes animais. O registro de uma relação diretamente proporcional entre a abundância de caranguejos e o crescimento do substrato dos mexilhões do presente estudo permite inferir que ambos os fatores devem estar atuando nas cordas de cultivo. Com o crescimento das conchas dos mexilhões, houve um incremento de espaços entre as mesmas e, portanto, maior oferta de abrigos para a colonização dentre as conchas de maiores dimensões.

Não houve relação entre o número e o peso das espécies mais abundantes. Em uma corda pode haver espécies abundantes, mas com pouca biomassa e outras raras, mas com muita biomassa, contribuindo de maneira semelhante para o peso final da corda de mexilhões. Destaca-se como exemplo *Menippe nodifrons*, que apresentou poucos indivíduos, porém com maior biomassa. Por outro lado, a espécie com maior biomassa total foi *Pilumnus dasypodus*, cujos indivíduos são de muito menor porte do que os de *Menippe nodifrons*, porém numericamente superior (total de 183 indivíduos somente no mês sete). Assim, a espécie que apresentou maior biomassa foi *Menippe nodifrons* e a espécie mais abundante e frequente foi *Pilumnus dasypodus*.

Não se conhecem estudos que tratem especificamente da sucessão de crustáceos decápodos associados às cordas de mexilhões, mas pode-se afirmar que houve substituição e acréscimo de espécies no decorrer do tempo do cultivo. Entretanto, espécies que foram registradas no 1º mês- *Callinectes danae*, *Pachygrapsus transversus* e *Petrolisthes armatus* devem ser consideradas ocasionais mais do que pioneiras, em função das frequências muito baixas. Foi observado que a rede de algodão ainda estava presente no primeiro mês em duas das três cordas amostradas, onde não foi registrado qualquer crustáceo decápodo. A terceira corda apresentou as três espécies citadas, com um representante cada uma. A malha de algodão pode ter interferido na entrada e colonização dos braquiúros. Outro fator para a baixa riqueza de espécies no primeiro mês de amostragem foi o tamanho abaixo do ideal das sementes, que propiciou o aumento da densidade e, portanto, pouco espaço disponível para os organismos associados.

De uma forma geral, o aumento na abundância e na diversidade de espécies com o passar do tempo indica que a comunidade se tornou mais complexa em termos de arquitetura e de composição trófica. A diversidade máxima registrada no último mês (1,31) pode indicar uma tendência ao aumento deste índice em direção à estabilidade da assembleia. A colonização da espécie mais abundante, *Pilumnus dasypodus*, teve início somente após três meses do início do cultivo. A queda acentuada na abundância desta espécie no nono mês pode indicar fuga para outros habitats, pois, a temperatura da água tende a cair significativamente em junho (nono mês). Outras espécies como *P. reticulatus, P. laevidactylus, P. galathinus, P. brasiliensis* e *S. fritzmuelleri* mostraram indícios de colonização e estabelecimento das populações. *M. nodifrons* também pertenceria a esta categoria, porém, como esta espécie foi representada exclusivamente por juvenis, uma migração para outras áreas naturais deve certamente ter ocorrido. Por outro lado, espécies que surgiram tardiamente (somente no último mês) como todos os *Panopeus, H. paulensis, Porcellana sayana e P. platycheles* indica que as mesmas necessitam de habitats mais complexos para iniciar a sua colonização.

Algumas espécies tiveram uma ocorrência rara neste trabalho, como *Callinectes danae*, o único siri dessa amostragem, e animal típico de substratos não-consolidados (Calado & Souza 2003) de hábito predador e oportunista (Leite 2007), porém sua presença em cordas de cultivo de mexilhões já foi registrada anteriormente por e Freitas (1997). Sua captura deve ter sido acidental, pelo fato de possuir capacidade de natação e de explorar a coluna d’água. Entretanto, a julgar pela dieta constituída de moluscos, poliquetos e crustáceos (Branco & Verani 1997), a possibilidade destes siris explorarem a fauna associada às cordas em busca de alimento não pode ser descartada. Juntamente com *P. transversus* e *P. armatus*, este siri constitui um grupo de braquiúros que visitou as cordas no início do cultivo, mas não estabeleu populações nas mesmas. Outras espécies raras, como *L. spinosa*. *A. schimitti* e *P. muelleri*, certamente exploram as cordas de cultivo, mas não conseguem se estabelecer como populações.

O predomínio dos moluscos na dieta dos braquiúros foi registrado por vários autores: Ropes (1968), Laughlin (1982), Wear & Haddon (1987) e Haefner (1990). Elner (1978) e Seed (1980) relatam a versatilidade dos braquiúros em capturar suas presas que vivem associadas aos mexilhões. Elner & Lavoie (1983) verificam o mesmo nos cultivos de ostras, Stevens et al. (1982) de outros moluscos e Kneib (1982) de peixes.

Os camarões da família Alpheidae são comuns e ocupam cavidades naturais em diferentes substratos, por isso também podem ser encontrados em cordas de mexilhões (Calado & Souza 2003). As três espécies registradas de *Panopeus* são bem diferentes entre si em relação ao hábito alimentar e ao habitat: *P. austrobesus* e *P. rugosus* vivem em substrato não-consolidado (Melo 1996), enquanto, *P. lacustris*, em costões e outros locais de substrato consolidado. Essas espécies podem ser observadas junto às ostras (Melo 1996) e, segundo Calado & Souza (2003), possuem importância na teia trófica de vertebrados. Sua ocorrência nos meses finais de amostragem pode ser explicada pela maior complexidade de habitat com disponibilidade suficiente de alimento e abrigo para fuga dos vertebrados. Do litoral de Santa Catarina são conhecidas 38 espécies de crustáceos decápodos associados aos cultivos de mexilhões, das quais 21 foram registradas para as cordas de mexilhões do presente estudo, indicando que este biótopo contribui significativamente para o incremento da biodiversidade carcinológica. Certamente, maiores esforços amostrais poderão elevar o valor em relação ao obtido, pois, espécies raras podem estar subestimadas devido às suas baixas abundâncias.

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Referências Bibliográficas

ANDREU, B. 1976. El cultivo del mejillon en Europa. An. Acad. Bras. Cienc. 45(Supl.):1-32.

BRANCO, J.O. & VERANI, J.R. 1997. Dinâmica da alimentação natural de *Callinectes danae* Smith, (Decapoda, Portunidae) na Lagoa da Conceição, Florianópolis, Santa Catarina, Brasil. Rev. Bras. Zool. 14(4):1003-1018.

CALADO, T.C.S. & SOUSA, E.C. 2003. Crustáceos do complexo estuarino-lagunar Mundaú/Manguaba Alagoas. Fundação de Amparo a Pesquisa de Alagoas - FAPEAL, Maceió.

CAMARGO, F.V. 2011. Biodiversidade de caranguejos braquiúros (Crustacea: Decapoda) associados ao cultivo comercial de mexilhão *Perna perna* (Linnaeus, 1758) (Molusca, Bivalvia) no Litoral Norte do Estado de São Paulo. Dissertação de mestrado, Universidade Estadual Paulista, Botucatu.

CARVALHO, J.L.B., SCHETTINI, C.A.F. & TRUCCOLO, E.C. 1999. Aspectos hidrodinâmicos da Enseada da Armação do Itapocoróy, SC. Notas téc. FACIMAR 3:99-109.

CHONCHEUNCHOB, P. 1980. Handing culture of the green mussel (*Mytilus smarangdinus* (Chemnatz) in Thailand. Editora ICLARM, Manila.

COCHÔA, A.R. & MAGALHÃES, A.R.M. 2008. Perdas de sementes de mexilhão *Perna perna* (L., 1758), cultivado na Baía Norte - Ilha de Santa Catarina/SC. Bol. Inst. Pesca 34(1):1-10.

CONNELL, J.H. & SLATYER, R.O. 1977. Mechanisms of succession in natural communities and their role in community stability and organization. Am. Nat. 111:1119-1144.

DeGRAAF, J.D. & TYRRELL, M.C. 2004. Comparison of the feeding rates of two introduced crab species, *Carcinus maenas* and *Hemigrapsus sanguineus*, on the blue mussel, *Mytilus edulis*. Northeast. Nat. 11(2):163-166.

DE GRAVE, S., PENTCHEFF, N.D., AHYONG, S.T., CHAN, T-Y., CRANDALL, K.A., DWORSCHAK, P.C., FELDER, D.L., FELDMANN, R.M., FRANSEN, C.H.J.M., GOULDING, L.Y.D., LEMAITRE, R., LOW, M.E.Y., MARTIN, J.W., NG, P.K.L., SCHWEITZER, C.E., TAN, S.H., TSHUDY, D. & WETZER, R. 2009. A classification of living and fossil genera of decapod crustaceans. Raffles Bull. of Zoo. Supplement 21:1-109.

ELNER, R.W. 1978. The mechanics of predation by the shore crab, *Carcinus maenas* (L.), on the edible mussel, *Mytilus edulis* L. Oecologia. 36(3):333-344.

ELNER, R.W. & LAVOIE, R.E. 1983. Predation on American oysters (*Crassostrea virginica* (Gmelin)) by American lobsters (*Homarus americanus* Say), and mud crabs (*Neopanopesayi* (Smith)). J. Shellfish Res. 3(2):129-134.

FERREIRA, J.F & MAGALHÃES, A.R.M. 2004. Cultivo de mexilhões. In Aqüicultura - experiências brasileiras (C.R Poli, A.T.B. Poli, E. Andreatta, & E. Beltrame, eds.). Multitarefa, Florianópolis.

FERREIRA, J.F., OLIVEIRA-NETO, F.M., MARENZZI, A.C., TUREK, C. & SILVA, R.T. 2006. Coletores de sementes de mexilhões - a opção do mitilicultor catarinense para retomar o crescimento da produção. Panor. Aquic. 43-48.

FREITAS, M. 1997. Incrustações biológicas no mexilhão *Perna perna* (Mollusca, Bivalvia), cultivado na Ilha de Ratones, SC: efeito da exposição ao ar. Dissertação de mestrado, Universidade Federal de Santa Catarina, Florianópolis.

GILLER, P.S. 1984. Community structure and niche. Chapman & Hall, London. http://dx.doi.org/10.1007/978-94-009-5558-5_2

HAEFNER, P.A.J.R. 1990. Natural diet of *Callinectes ornatus* (Brachyura: Portunidae) in Bermuda. J. Crustacean Biol. 10(2):236-246.

HAMILTON, D.J. & NUDDS, T.D. 2003. Effects of predation by common eiders (*Somateria mollissima*) in an intertidal rockweed bed relative to an adjacent mussel bed. Mar. Biol. 142(1):1-12.

HENRIQUES, M.B., MARQUES, H.L.A., PEREIRA, O.M. & BASTOS, G.C. 2004. Aspectos da estrutura populacional do mexilhão Perna perna, relacionados à extração em bancos naturais da baía de santos, Estado de São Paulo, Brasil. Bol. Inst. Pesca 30(2):117-126.

INGLIS, G.J. & GUST, N. 2003. Potential indirect effects of shellfish culture on the reproductive success of benthic predators. J. Appl. Ecol. 40(6):1077-1089.

KAUTSKY, N. & FOLKE, C. 1991. Ecological economic principles for aquaculture development. In Nutritional Strategies and Aquaculture Waste (C.B. Cowey & C.Y. Cho, eds.). University of Guelph, Ontario.

KNEIB, R.T. 1982. The effects of predation by wading birds (Ardeidae) and blue crab (*Callinectes sapidus*) on the population size structure of the common mummichog, *Fundulus heteroclitus*. Estuar. Coast. Shelf Sci. 14:159-163. http://dx.doi.org/10.1016/S0302-3524(82)80042-X

KROPP, R.K. 1981. Additional porcdain crah feeding methods (Decapoda, Porcelanidae). Crustaceana 40(3):307-310. http://dx.doi.org/10.1163/156854081X00778

LAPPALAINEN, A., WESTERBOM, M. & VESALA, S. 2004. Blue mussels (*Mytilus edulis*) in the diet of roach (*Rutilus rutilus*) in outer archipelago areas of the western Gulf of Finland, Baltic Sea. Hidrobiologia. 514(1-3):87-92. http://dx.doi.org/10.1023/B:hydr.0000018209.10032.0c

LAUGHLIN, R.A. 1982. Feeding habits of the blue crab, *Callinectes sapidus* Rathbun, in the Apalachicola estuary, Florida. Bull. Mar. Sci. 32:807-822.

LEITE, L.A. 2007. Influência da predação, parasitismo e densidade de sementes nas perdas de mexilhões *Perna perna* (L., 1758) cultivados na Baía Norte da Ilha de Santa Catarina. Dissertação de mestrado, Universidade Federal de Santa Catarina, Florianópolis.

LOO, L.O. & ROSENBERG, R. 1983. *Mytilus edulis* culture: growth and production in Western Sweden. Aquaculture. 35:137-150.

MANTELATTO, F.L.M. & SOUZA-CAREY, M.M. 1998. Brachyura (Crustacea, Decapoda) associated to *Schizoporella unicornis* (Bryozoa, Gymnolaemata) in Ubatuba Bay (SP), Brazil. Braz. Arch. Biol. Techn. 41(2):212-217.

MANZONI, G.C. & LACAVA, L.A. 1998. Crescimento doa gastrópodes Thais (Stramonita) haemastoma e Cymatium parthenopeum parthenopeum em cultivo experimental na Enseada da Armação do Itapocoróy (26°47'S - 48°36'W)(Penha - SC). Notas téc. FACIMAR 2: 167-173.

MARENZI, A.W.C. 1999. O uso de mecanização nos cultivos de mexilhões *Perna perna* em Santa Catarina. Agrárias 18(1-2):155-163.

MARENZI, A.W.C. & BRANCO, J.O. 2006. O cultivo do mexilhão *Perna perna* no Município de Penha - SC. In Bases ecológicas para um desenvolvimento sustentável: estudos de caso em Penha - SC. (J.O. Branco & A.W.C. Marenzi, eds.). Editora da UNIVALI, Itajaí, p.227-244.

MARENZI, A.W.C. & MANZONI, G.C.M. 1998. Cultivo de moluscos marinhos: estabelecimento de novo ecossistema em regiões costeiras de Santa Catarina. In IV Simpósio de Ecossistemas Brasileiros. Águas de Lindóia, v.3, p.438- 442.

MAROCHI, M.Z. & MASUNARI, S. 2011. Os caranguejos Eriphiidae, Menippidae, Panopeidae e Pilumnidae (Crustacea Brachyura) de águas rasas do litoral do Paraná, com chave pictórica de identificação para as espécies. Biota Neotrop. 11(3): http://www.biotaneotropica.org.br/v11n3/pt/abstract?inventory+bn00211032011 http://dx.doi.org/10.1590/S1676-06032011000300001

MARQUES, H.L.A. 1998. Criação comercial de mexilhões. Editora Nobel, São Paulo.

MARQUES, H.L.A. & PEREIRA, R.T.L. 1989. Levantamento e dimensionamento preliminares das áreas mais favoráveis para a prática da mitilicultura no litoral do Município de Ubatuba, Estado de São Paulo (23° 26’ S, 045° 04’ W). Bol. tec. - Inst. Pesca 13.

MATTSSON, J.C. & LINDÉN, O. 1983. Benthic macrofauna succession under mussels *Mytilus edulis* L. (Bivalvia) cultured on hanging long-lines. Sarsia 68:97-102.

MELO, G.A.S. 1996. Manual de identificação dos Brachyura (caranguejos e siris) do litoral brasileiro. Plêiade/FAPESP, São Paulo.

MELO, G.A.S. 1999. Manual de identificação dos Crustacea Decapoda do litoral brasileiro: Anomura, Thalassinidea, Palinuridea, Atacidea. Plêiade; FAPESP, São Paulo.

NG, P.K.L., GUINOT, D. & DAVIE, P.J.F. 2008. Systema Brachyurorum: part I. An annotated checklist of extant brachyuran crabs of the world. Raffles Bull. Zool. 17:1-286.

RICKLEFS, R.E. 2003. Economia da Natureza. 6. ed. Editora Guanabara Koogan, São Paulo.

RODRIGUEZ, G. 1980. Los crustaceos decapodos de Venezuela. Instituto Venezodano de Investigaciones Cientíticas, Caracas, 494p.

ROPES, J.W. 1968. The feeding habits of the green crab, *Carcinus maenas* (L.). Fishery Bull. Fish Wildl. Serv. U.S. 67(2):183-203.

SANTOS, W.A. 2006. Importância econômica dos costões rochosos. Saúde & Amb. Rev. 1(2):51-59.

SCHETTINI, C.A.F., CARVALHO, J.L.B. & TRUCCOLO, E.C. 1999. Aspectos hidrodinâmicos da enseada da Armação do Itapocoroy, SC. Notas téc. FACIMAR 3:99-109.

SCHETTINI, C.A.F., RESGALLA JUNIOR, C. & KUROSHIMA, K.N. 1997. Avaliação preliminar da taxa sedimentar na região de cultivo de moluscos (Perna perna) na enseada da Armação-SC. Notas téc. FACIMAR 1: 1-8.

SEED, R. 1976. Ecology. In Marine Mussels: their ecology and physiology. (B.L. Bayne, ed). Cambridge University Press, Cambridge.

SEED, R. 1980. Predatior-prey relationships between the mud crab *Panopeus herbstii*, the blue crab, *Callinectes sapidus* and the Atlantic ribbed mussel *Geukensia* (=*Modiolus*) *demissa*. Estuar. Coast. Mar. Sci. 11:445-448. http://dx.doi.org/10.1016/S0302-3524(80)80067-3

SILLIMAN, B.R., LAYMAN, C.A., GEYER, K. & ZIEMAN, J.C. 2004. Predation by the black-clawed mud crab, *Panopeus herbstii*, in Mid-Atlantic salt marshes: further evidence for top-down control of marsh grass production. Estuaries. 27(2):188-196.

SILVA, B.M.G., BRAGA, A.C. & D’INCAO, F. 1989. Porcellanidae (Decapoda Anomura) de Santa Catarina e Rio Grande do Sul, Brasil. Iheringia, Série Zool. 69:131-146.

STEVENS, B.G., ARMSTRONG, D.A. & CUSIMANO, R. 1982. Feeding habits of the dungeness crab *Cancer magister* as determined by the index of relative importance. Mar. Biol. 72:135-145.

SUPLICY, F.M. 2000. Capacidade de suporte nos cultivos de moluscos. Panor. Aquic. 10(57):21-4.

SZÉCHY, M.T.M., VELOSO, V.G. & PAULA, E.J. 2001. Brachyura (Decapoda Crustacea) of phytobenthic communities of the sublittoral region of rocky shores of Rio de Janeiro and São Paulo, Brazil. J. Trop. Ecol. 42(2):231-242.

TENORE K.R. & GONZALES, N. 1975. Food chain patterns in the Ría de Arosa, Spain; an area of intense mussel aquaculture. In European Symposium on Marine Biology (G. Persoone & E. Jaspers, eds.). Universa Press, Wetteren, v.2, p.601-619.

TISDELL, C. 1991. Development of aquaculture and the environment: coastal conflicts, and giant clam farming as a case. Int. J. Environ. Stud. 39:35-44. http://dx.doi.org/10.1080/00207239108710679

TSUTSUMI, H., KIKUCHI, T., TANAKA, M., HIGASHI, T., IMASAKA, K. & MYASAKI, M. 1991. Benthic faunal sucession in a cove organically polluted by fish farming. Mar. Pollut. Bull. 23:233-238.

WATERSTRAT, P., CHEW, K., JOHNSON, K. & BATTIE, J.H. 1980. Mussel culture: a West Coast perspective. In Mussel culture and harvest: a north american perspective (R.A. Lutz, & I.C.D. Center, eds.). New York, v.1, p.141-163.

WEAR, R.G. & HADDON, M. 1987. Natural diet of the crab *Ovalipes catharus* (Crustacea, Portunidae) around central and northen New Zealand. Mar. Ecol. Prog. Ser. 35:39-49.

WITMAN, J.D. & SUCHANEK, T.H. 1984. Mussels in flow: drag and dislodgment by epibionts. Mar. Ecol. Prog. Ser. 16:259-262.

YOUNG, J.A., BRUGERE, C. & MUIR, J.F. 1999. Green grow the fishies-Oh? Environmental attributes in marketing aquaculture products. Aquac. Economics Manag. 3(1):7-17.

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Zooplankton richness, abundance and biomass of two hypertrophic shallow lakes with different salinity in central Argentina

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Abstract: The zooplankton of lakes is controlled by biological and physico-chemical parameters. Among the former, predation by fish can determine the replacement of large-sized species by small-sized ones and among the latter, salinity exerts negative effects on richness and abundance. Since it has been suggested that saline lakes without fishes have higher zooplankton biomass than low salinity ones, the aim of this study was to determine the richness, abundance and biomass of zooplankton in two lakes with different salinity and test the hypothesis that in the presence of zooplanktivorous fishes and at equal concentrations of nutrients and chlorophyll-*a,* saline lakes have higher biomass than those with low salinity. The study was conducted in two shallow lakes of the Province of La Pampa (central Argentina): a subsaline lake and a hyposaline lake, which shared high concentrations of chlorophyll-*a* and total phosphorus, reduced transparency and presence of planktivorous fish. Zooplankton richness was different and higher in the subsaline lake, whereas abundance and total biomass were similar, even when the taxonomic groups were considered separately. It is suggested that the presence of a halotolerant planktivorous fish controlled the size of zooplankton due to the predation on larger species and prevented the development of higher biomass in the saline lake, which is an important difference from previously recorded situations. This study shows that, regardless of the differences in salinity, the top-down effect in the food chain may have been a factor that equalized the zooplankton biomass by allowing only the development of small species and highlights the possible importance of fish predation in determining chlorophyll-*a* concentrations and water transparency.
Keywords: *shallow saline lakes, zooplankton biomass, fish predation, top down.*

ECHANIZ, S.A., VIGNATTI, A.M., CABRERA, G.C. & PAGGI, S.B.J. **Riqueza, abundancia y biomasa zooplanctónica de dos lagos someros hipertróficos de distinta salinidad de la región central de Argentina.** Biota Neotrop. v. 12 (1): http://www.biotaneotropica.org.br/v12n2/pt/abstract?article+bn00712022012

Resumen: El zooplancton lacustre es controlado por parámetros biológicos y fisicoquímicos. Entre los primeros, la depredación por peces puede determinar el reemplazo de especies de talla grande por pequeñas y entre los segundos la salinidad ejerce efectos negativos sobre la riqueza y abundancia. Dado que se ha indicado que los lagos salinos sin peces tienen mayores biomasas zooplanctónicas que los de baja salinidad, el objetivo de este trabajo es conocer la riqueza, abundancia y biomasa del zooplancton de dos lagos de diferente salinidad y probar la hipótesis de que a iguales concentraciones de nutrientes y clorofila "a" los lagos salinos tienen mayor biomasa que los de baja salinidad. El estudio se desarrolló en dos lagos de la provincia de La Pampa, en el centro de Argentina, uno subsalino y otro hiposalino, que compartieron elevadas concentraciones de clorofila *a* y fósforo total, reducida transparencia y presencia de un pez planctófago. Aunque la riqueza resultó diferente y más elevada en el lago subsalino, no ocurrió lo mismo con la abundancia y biomasa totales, ni al considerar los grupos taxonómicos por separado. La presencia de un pez planctívoro halotolerante controló la talla del zooplancton debido a la depredación sobre las especies de mayor tamaño e impidió el desarrollo de mayor biomasa en el lago salino, lo que constituye una importante diferencia con situaciones registradas anteriormente. Este estudio mostró que a pesar de la diferencia en la salinidad, el efecto en cascada en la cadena trófica (top down) es un factor que iguala la biomasa zooplanctónica al permitir sólo el desarrollo de especies pequeñas y pone en evidencia la importancia de la depredación por peces en la determinación de las concentraciones de clorofila y transparencia del agua.
Palabras clave*: lagos someros salinos, biomasa zooplanctónica, depredación, cascada trófica.*

Introduction

The zooplankton of lakes is a key component of the ecology of water bodies because these organisms feed on phytoplankton, recycle the nutrients through excretion, and represent an important prey to many predators. Their composition, abundance and biomass are controlled by biotic and abiotic parameters. The former include the availability and quality of food resources, interspecific competition and predation by vertebrates and invertebrates (Lampert & Sommer 1997, Khan et al. 2003, Chang et al. 2004, Boveri & Quirós 2007, Manca et al. 2008). The negative effects of poor quality food supply are known (DeMott et al. 2001, Wilson & Hay 2007) as is the fact that the predation by zooplanktivorous fish produces the replacement of larger species by smaller ones is also known (Brooks & Dodson 1965). This, in turn, leads to changes in grazing pressure and phytoplankton biomass (top-down effect) (Bertolo et al. 2000, Kalff 2002, Boveri & Quirós 2007, Manca et al. 2008).

Among the abiotic parameters, the structure of zooplankton is affected by the concentration of dissolved solids, the temperature, the size and land use of the basins, and environmental heterogeneity, because the higher number of habitats offered by larger lake environments exerting positive effects on the richness and abundance of zooplankton (Kobayashi 1997, Hobæk et al. 2002, Kalff 2002, Hall & Burns 2003, Dodson et al. 2007). In addition, it is known that an increase in salinity may exert negative effects on the richness and abundance of zooplankton (Herbst 2001, Ivanova & Kazantseva 2006). It has also been reported that salinity favors indirectly the secondary production of zooplankton, because saline lakes tend to lack fish fauna, which allows the development of larger zooplankton species and therefore to have higher biomass of zooplankton than low salinity lakes, although they have lower phytoplankton biomass and chlorophyll-*a* concentrations (Campbell & Prepas 1986, Evans et al. 1996).

Shallow lakes, in general, do not exceed three meters in depth, and are not stratified because of the mixing effect of the wind. Such water-bodies usually have a high trophic state (Scheffer 1998, Quirós et al. 2002, Scheffer & Jeppesen 2007, Grosman 2008) and those with total dissolved solids concentrations greater than 3 g.L^{-1} are classified as saline (Hammer 1986).

In the central semiarid region of Argentina (Province of La Pampa), there are many shallow lakes with a wide range of concentrations of dissolved solids, ranging from subsaline to hypersaline (Echaniz et al. 2006, Vignatti et al. 2007). Many of these lakes have suffered marked deterioration due to the human activities carried out in their basins, such as livestock breeding, growing of cereal and oilseed crops and development of urbanized areas of increasing size. Although most are temporary and clear, anthropogenic influence has led many lakes become permanent, or to become turbid due to the introduction of fish, particularly the zooplanktivorous *Odontesthes bonariensis* (Cuvier and Valenciennes 1835) (Echaniz et al. 2008, 2009, 2010a,b).

We have previously carried out several studies on the composition and density of zooplankton in several shallow lakes of La Pampa (Echaniz et al. 2006, 2008, 2009, 2010b, Vignatti et al. 2007), but not compared the zooplankton biomass in the studied environments. Therefore, the aim of this study was to determine the taxonomic composition, abundance and biomass of zooplankton in two shallow lakes of La Pampa with different salinity and test the hypothesis that in presence of zooplanktivorous fishes and at equal concentrations of nutrients and chlorophyll-*a*, saline lakes have higher biomass of zooplankton than lakes of low salinity.

Material and Methods

1. Study area

The study was conducted in two permanent shallow lakes located in the vicinity of the city of Santa Rosa, La Pampa Province, Argentina: the Bajo de Giuliani and Don Tomás (Figure 1).

The Bajo de Giuliani lake (64° 15' W and 36° 41' S) is hyposaline (Hammer 1986) and has a surface of 1171.3 ha and a maximum depth of 2.8 m. It is located 10 km south of the city of Santa Rosa, in a deep arheic depression. Most of its perimeter is surrounded by fields

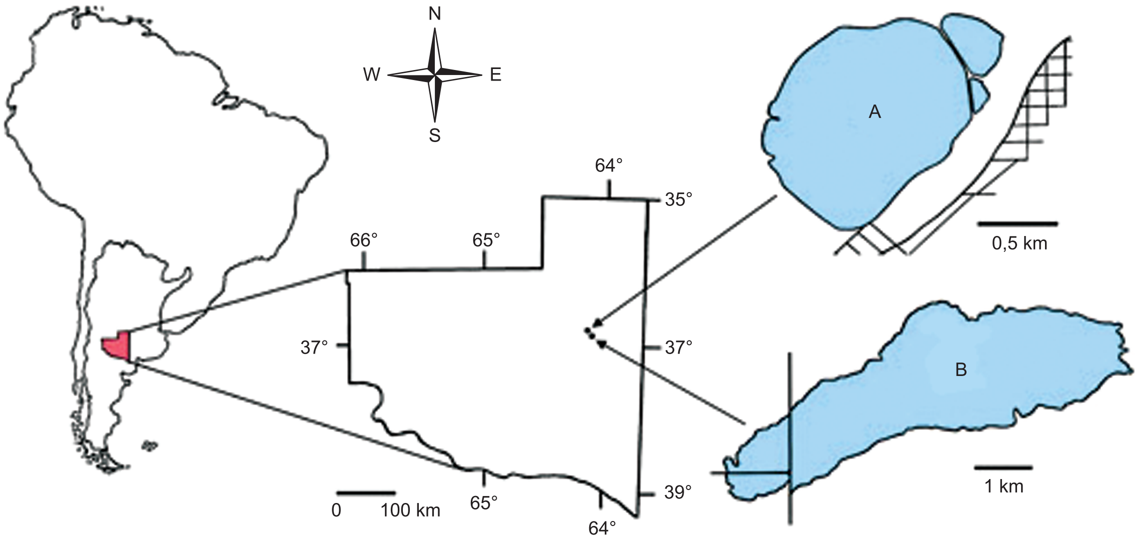

Figure 1. Geographical location and sketch of studied lakes. A: Don Tomás. B: Bajo de Giuliani.

Figura 1. Ubicación geográfica de los lagos estudiados. A: Don Tomás. B: Bajo de Giuliani.

used for farming, especially cattle breeding. In addition, it is the final recipient of the sewage treatment plant of the city.

Don Tomás Lake (64° 19' W and 36° 37' S) is subsaline (Hammer 1986) and has a surface of 148.3 ha and a maximum depth of 2.3 m. It is near the city of Santa Rosa and receives the input from storm drains. Under normal conditions, it does not receive sewage, although this may occur when heavy rains fill and overflow pipes. Since its perimeter has been rectified and dredged, it is very regular, almost circular.

Both environments have high organic turbidity, absence of aquatic vegetation, and presence of the planktivorous species *Odontesthes bonariensis* (Rosso 2006, Boveri & Quirós 2007).

2. *Field work*

Samplings were carried out at three sites in the limnetic region in each lake during each season of 2006 and 2007 (January, April, July and October). Water temperature, dissolved oxygen (oximeter Lutron OD 5510), and water transparency (Secchi disk) were determined in situ. Water samples were collected and refrigerated for physical and chemical analysis and determination of chlorophyll-*a* concentrations. Since no significant differences were found between the values of the environmental variables measured at each site of the two lakes, the mean values were used for the analysis.

Quantitative zooplankton samples were collected at each site, with a 10 L capacity Schindler-Patalas trap equipped with a 0.04 mm mesh size, at three depths that were integrated into a single sample which represented a total filtrate volume of 30 L. Qualitative samples also were taken by vertical and horizontal drags with a net of 22 cm mouth diameter and 0.04 mm mesh size. All the samples were anesthetized with CO_2 and kept refrigerated until measurements, with the aim of avoiding contractions that may deform the individuals collected. The samples were fixed with formalin 5-8% and deposited in the plankton collection of the Facultad de Ciencias Exactas y Naturales de la Universidad Nacional de La Pampa, La Pampa Province, Argentina.

3. *Laboratory Work and Data Analysis*

The pH was determined by means of a Cornning PS 15 pH meter, the conductivity with an Oakton TDSTestr 20 conductivity meter, and the concentration of dissolved solids by the method of solid residue. Chlorophyll-*a* concentration was estimated by extraction with aqueous acetone with Microclar FFG047WPH filters and spectrophotometry (Metrolab 1700 spectrophotometer) (APHA 1992, Arar 1997), total nitrogen by the Kjeldahl method and total phosphorus by digestion of the sample with potassium persulfate in acidic medium and spectrophotometry (APHA 1992).

The content of organic and inorganic suspended solids was determined by filtering a known volume of water through Microclar FFG047WPH filters, dried at 103 to 105 °C to constant weight and then calcined at 550 °C (EPA 1993).

The density of macro and microzooplankton (Kalff 2002) was estimated with a stereomicroscope and conventional optical microscope in Bogorov and Sedgwick-Rafter chambers respectively. To determine the biomass of zooplankton, a minimum of 30 specimens of all species were measured with a Carl Zeiss ocular micrometer and formulas that relate the total length with the dry weight of the specimens were used (Ruttner-Kolisko 1977, Dumont et al. 1975, Rosen 1981, McCauley 1984, Culver et al. 1985).

The physical, chemical and biological differences were tested by nonparametric Kruskal-Wallis analysis of variance and the relationships between the environmental factors and the zooplankton features were assessed by Spearman correlation (r_s) (Sokal & Rohlf 1995, Zar 1996) and Principal Components Analysis (PCA) (Pérez 2004, Mangeaud 2004), using Past (Hammer et al. 2001) and Infostat (Di Rienzo et al. 2010) softwares.

Results

1. *Abiotic parameters*

Water temperature followed a similar seasonal pattern in both lakes, and although the mean was slightly lower in Don Tomás, the differences were not significant (Table 1).

The concentration of dissolved solids ranged between 0.64 and 1.16 $g.L^{-1}$ in Don Tomás, and between 9.64 and 11.2 $g.L^{-1}$ in Bajo de Giuliani (Figure 2), being this a significant difference (Table 1).

Water transparency in both lakes was low and ranged between 0.11 and 0.22 m, but there were no significant differences between the values (Table 1). No significant correlations were found between transparency and chlorophyll-*a* or suspended solids concentrations.

The average concentration of nutrients was very high in both water bodies and there were significant differences only in total nitrogen (Table 1). No significant correlation was found between the concentrations of both nutrients. The pH and dissolved oxygen concentration were different and higher in Bajo de Giuliani (Table 1).

The concentrations of inorganic and organic suspended solids in both lakes were different (Table 1) and correlation was found only between the latter parameter and dissolved solids ($r_s = 0.69$, $p = 0.0033$).

2. *Chlorophyll-a concentrations and zooplankton*

The phytoplanktonic chlorophyll-*a* concentration was high in both lakes, and fluctuated between 88.8 $mg.m^{-3}$ (Don Tomás) and 352.4 $mg.m^{-3}$ (Bajo de Giuliani), although the differences were not significant (Table 1, Figure 3). A significant correlation was found only between chlorophyll-*a* and TN concentrations ($r_s = 0.65$, $p = 0.0063$).

A total of 33 taxa were recorded: 7 cladocerans, 6 copepods and 20 rotifers. The number of species was significantly different ($H = 8.91$, $p = 0.0028$) between the lakes: 26 were found in Don Tomás and 17 in Bajo de Giuliani (Table 2). While seven taxa were recorded only in Bajo de Giuliani and 16 only in Don Tomás, two cladocerans, one copepod and seven rotifers were recorded in both water bodies (Table 2).

The (PCA), whose first two components explained almost 50% of the total variance, showed the negative influences of the concentration of total dissolved solids and suspended solids on the cladocerans

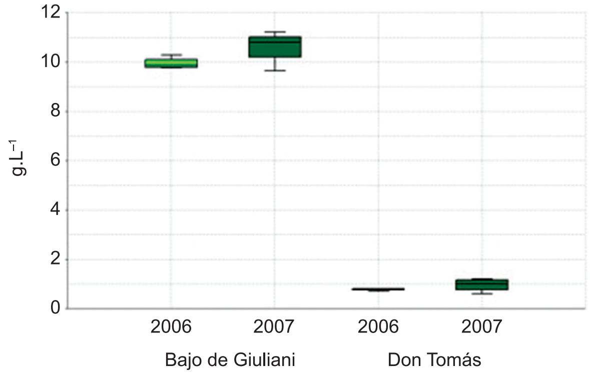

Figure 2. Dissolved solids concentrations in the water of both studied lakes.

Figura 2. Concentración de sólidos disueltos en el agua de las dos lagunas estudiadas.

Table 1. Main limnological parameters of the studied lakes (means and standard deviations) and results of Kruskal Wallis test (K.W.) (*indicates significative differences).

Tabla 1. Principales parámetros limnológicos medidos en los lagos someros estudiados (promedios y desviaciones estándar) y resultados del test de Kruskal Wallis (K.W.) (*indica diferencias significativas).

	Bajo de Giuliani	Don Tomás	K.W.
Water temperature	**17.6** ± 8.1	**16.7** ± 7.3	H = 0.01 p = 0.9164
Transparency (m)	**0.17** ± 0.04	**0.16** ± 0.04	H = 0.34 p = 0.5603
Total dissolv. solids (g.L^{-1})*	**10.27** ± 0.58	**0.87** ± 0.18	H = 11.29 p = 0.0008
Conductivity (mS.cm^{-1})*	**16.9** ± 1.04	**1.48** ± 0.23	H =11.31 p = 0.0008
pH*	**9.1** ± 0.15	**8.4** ± 0.50	H = 9.83 p = 0.0201
Total phosphorus (mg.L^{-1})	**8.91** ± 2.81	**6.57** ± 4.50	H =7.12 p = 0.0682
Total nitrogen (mg.L^{-1})*	**18.77** ± 4.91	**10.16** ± 2.13	H =8.46 p = 0.0375
Dissolved oxigen (mg.L^{-1})*	**12.41** ± 3.10	**8.79** ± 1.35	H = 9.71 p = 0.0212
Inorg. susp. solids (mg.L^{-1})*	**38.05** ± 27.3	**4.03** ± 4.6	H = 6.35 p = 0.0117
Org. susp. solids (mg.L^{-1})*	**89.33** ± 14.83	**52.05** ± 13.15	H = 9.94 p = 0.0016
Chl *a* (mg.m^{-3})	**201.16** ± 69.74	**143.5** ± 45.02	H = 5.28 p = 0.1524

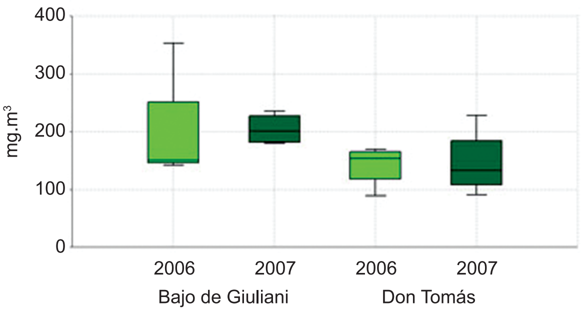

Figure 3. Phytoplanktonic chlorophyll-*a* concentration in both studied lakes.

Figura 3. Concentración de clorofila-*a* fitoplanctónica de las dos lagunas estudiadas.

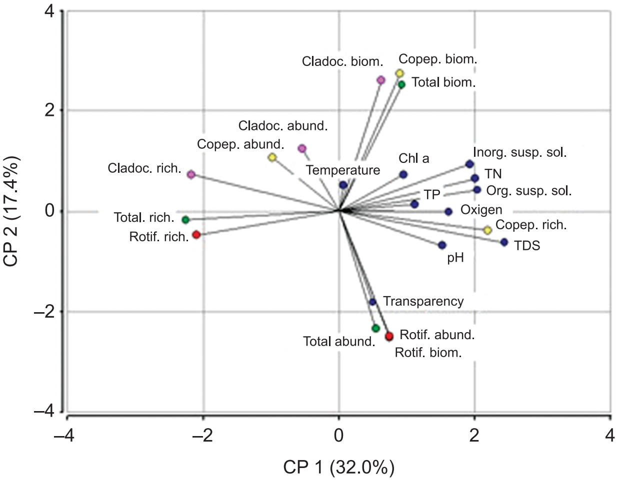

Figure 4. Biplot of the Principal Component Analysis (PCA).

Figura 4. Resultados del análisis de componentes principales (ACP).

and rotifers richness. In contrast, both parameters showed a positive influence on the number of copepod species (Figure 4).

The most common crustaceans in Don Tomás were *Eubosmina huaronensis* (Delachaux, 1918), *Acanthocyclops robustus* (G.O. Sars, 1863) and *Microcyclops anceps* (Richard, 1897), the latter was the most abundant species (mean = 707.5 ± 1051.1 ind.L^{-1}). The crustaceans most frequently recorded in Bajo de Giuliani were *Cletocamptus deitersi* (Richard, 1897), *Boeckella poopoensis* Marsh, 1906 and *Metacyclops mendocinus* (Wierzejski, 1892); the latter reached the highest density (mean = 159.9 ± 300.5 ind.L^{-1}).

The rotifers that predominated in both lakes belonged to the genus *Brachionus*. *B. angularis* Gosse, 1851 and *B. dimidiatus* Bryce, 1931 were the most frequent species in Don Tomás, although the most abundant species was *B. plicatilis* Müller, 1786 (mean = 208.7 ± 586.4 ind.L^{-1}). In Bajo de Giuliani, the most frequent were *B. ibericus* Ciros-Pérez, Gómez & Serra, 2001 and *B. dimidiatus* (Table 2), the latter being the one which reached the highest density (mean = 2114.4 ± 4934.7 ind.L^{-1}).

No significant differences were found in zooplankton total abundance in both lakes, even when the taxonomic groups were considered separately (Table 3, Figure 5). The PCA showed that the total density was determined especially by the high abundances

Table 2. Taxa registered in the studied shallow lakes and frequency in samples.

Tabla 2. Taxones registrados en los lagos someros estudiados y frecuencia de aparición en las muestras.

Taxa	Bajo de Giuliani	Don Tomás
Cladocera		
Diaphanosoma birgei Korinek, 1981		37.5
Moina micrura Kurz, 1874	12.5	50
Moina eugeniae Olivier, 1954	12.5	
Eubosmina huaronensis (Delachaux, 1918)		100
Daphnia menucoensis Paggi, 1996	25	
Daphnia spinulata Birabén, 1917	12.5	12.5
Alona sp.		37.5
Copepoda		
Boeckella gracilis (Daday, 1902)		12.5
Boeckella poopoensis Marsh, 1906	87.5	
Microcyclops anceps (Richard, 1897)		100
Acanthocyclops robustus (G.O. Sars, 1863)		100
Metacyclops mendocinus (Wierzejski,1892)	87.5	
Cletocamptus deitersi (Richard, 1897)	100	12.5
Rotifera		
Brachionus plicatilis Müller, 1786		50
Brachionus ibericus Ciros-Pérez, Gómez & Serra, 2001	62.5	
Brachionus havanaensis Rousselet, 1913	12.5	25
Brachionus angularis Gosse, 1851	37.5	62.5
Brachionus dimidiatus Bryce, 1931	62.5	50
Brachionus calyciflorus (Pallas, 1766)		12.5
Brachionus pterodinoides Rousselet, 1913	50	25
Brachionus caudatus Barrois & Daday, 1894		25
Brachionus quadridentatus Hermann, 1783		25
Keratella tropica (Apstein, 1907)	12.5	75
Keratella cochlearis (Gosse, 1851)	12.5	37.5
Hexarthra intermedia (Wiszniewski, 1929)		25
Hexarthra fennica (Levander, 1892)	12.5	
Polyarthra dolichoptera Idelson, 1925		50
Lepadella acuminata (Ehrenberg, 1834)		12.5
Lecane sp.		25
Lecane lunaris (Ehrenberg, 1832)	12.5	12.5
Lecane bulla (Gosse, 1851)		25
Anuraeopsis fissa (Gosse, 1851)	12.5	
Pompholyx complanata Gosse, 1851		25
Richness	**17**	**26**

of rotifers and that it was positively affected by water transparency (Figure 4).

When analyzing the abundance of the taxonomic groups separately, the PCA showed a positive relationship between the abundance of cladocerans and copepods and water temperature, but a negative relationship with the concentration of dissolved solids (Figure 4).

The average size of zooplankton in Bajo de Giuliani was 413.5 µm ± 286.3, whereas in Don Tomás this value was slightly lower (295.74 µm ± 109.4), but the difference was not significant.

The biomass of zooplankton in both lakes was similar (Figure 6), since no significant differences were found in total biomass or when considering the taxonomic groups separately (Table 3).

Zooplankton biomass was not influenced by the concentration of dissolved solids, but was positively influenced by the concentrations of chlorophyll-*a* and inorganic suspended solids (Figure 4). Copepods and cladocerans were the ones that contributed most to the total biomass in both lakes.

Among the crustaceans of Bajo de Giuliani, the greatest mean biomass was provided by *B. poopoensis* (1510.6 ± 2234.5 µg.L^{-1}) followed by *M. mendocinus* (511.4 ± 1034.2 µg.L^{-1}), and, among the rotifers, by *B. ibericus* (258.8 ± 435.8 µg. L^{-1}). In Don Tomás, *M. anceps* contributed with the highest mean crustacean biomass (1505.7 ± 1212.9 µg. L^{-1}) and *B. plicatilis* with the highest mean rotifer biomass (49.9 ± 125.7 µg.L^{-1}).

In Bajo de Giuliani, the zooplankton biomass presented its peaks in spring (3375.6 and 8375.6 in 2006 and 2007 respectively),

Table 3. Mean abundance and biomass (in bold), minimum and maximum (in italics) by taxonomic group and total zooplankton in both lakes and results of Kruskal Wallis test. (BG: Bajo de Giuliani, DT: Don Tomás).

Tabla 3. Abundancia y biomasa medias (en negritas), mínimas y máximas (en cursivas) por grupo taxonómico y del total del zooplancton de ambas lagunas y resultados del test de Kruskal Wallis. (BG: Bajo de Giuliani, DT: Don Tomás).

	Abundance (ind.L^{-1})			**Biomass (μg.L^{-1})**		
	BG	**DT**	**K.W.**	**BG**	**DT**	**K.W.**
Cladocera	**11**	**130.6**	H = 2.84	**298**	**257**	H = 0.89
	0 – 70.5	*1.4 – 771.6*	p = 0.0919	*0 – 2246*	*1.4 – 1071.7*	p = 0.3431
Copepoda	**295.4**	**758.6**	H = 0.54	**2030.6**	**1547.7**	H = 0.11
	23 - 892	*15.2 – 3813*	p = 0.4623	*180.7 – 6119*	*38.9 - 3834*	p = 0.7527
Rotifera	**7060.3**	**510.6**	H = 0.89	**390.2**	**87.9**	H = 0.39
	47 – 3399	*10 - 1840*	p = 0.3446	*5.9 – 1549*	*1.2 – 388.4*	p = 0.5286
Total	**7768.4**	**2174.3**	H = 0.54	**2850.2**	**2120.9**	H = 0.18
	261.1 – 34495	*87 - 8291*	p = 0.4623	*341.3 – 8376*	*48.6 – 4612.4*	p = 0.6744

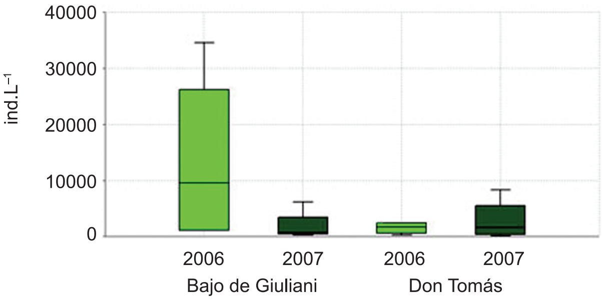

Figure 5. Annual zooplanktonic abundance in both studied lakes.

Figura 5. Densidad zooplanctónica anual de las dos lagunas estudiadas.

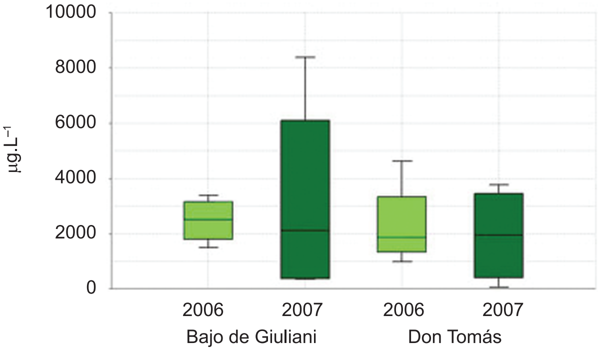

Figure 6. Zooplanktonic biomass in both studied lakes.

Figura 6. Biomasa zooplanctónica de los dos lagos someros estudiados.

whereas, in Don Tomás, peaks were in spring 2006 (4612.4 μg. L^{-1}) and in summer 2007 (3753.7 μg.L^{-1}). No correlation was found between the zooplankton biomass and the abiotic variables, and when considering the groups separately. The relationship was significant only between the biomass of cladocerans and water temperature ($r_s = 0.54$, $p = 0.0309$).

Discussion

Although the two lakes differed in their salinity, they shared features such as high concentrations of phosphorus and reduced transparency (caused by high concentrations of chlorophyll-*a* and organic and inorganic suspended solids), which allowed their categorization as hypertrophic environments (OECD 1982). According to the model of alternative states of shallow lakes, they are organic turbid environments (Torremorell et al. 2007, Allende et al. 2009) and their primary production is dominated by phytoplankton due to the absence of macrophytes.

The number of zooplankton taxa in both lakes differed because it was negatively influenced by the concentration of dissolved salts in the water. The higher zooplankton richness of Don Tomás, typical of subsaline environments, had been previously reported (Echaniz et al. 2008). In contrast, the lower number of taxa recorded in Bajo de Giuliani showed the modulating effect of the higher salt concentration, which means it can be inhabited by a smaller number of halotolerant species (Herbst 2001, Ivanova & Kazantseva 2006).

Although some species were present in both lakes, the crustaceans *E. huaronensis*, *A. robustus* and *M. anceps* predominated in Don Tomás. These species are more commonly found in other environments of low salinity of La Pampa (Vignatti et al. 2007, Echaniz et al. 2008). The species that prevailed in Bajo de Giuliani were the halotolerants *Cletocamptus deitersi*, *M. mendocinus* and *B. poopoensis* (Menu-Marque & Locascio de Mitrovich 1998, Echaniz et al. 2006, Vignatti et al. 2007). The highest number of shared species was recorded among rotifers and most of the taxa recorded were of cosmopolitan distribution (Segers & De Smet 2008) and euryhaline (Fontaneto et al. 2006). The presence of large-sized cladocerans, especially that of the genus *Daphnia*, was sporadic and never reached high densities, possibly due to the predation exerted by fish (Grosman & Sanzano 2003, Boveri & Quirós 2007, Manca et al. 2008) present in both lakes. The high standard deviation values found in the abundance and biomass of both lakes were due to the pronounced seasonality of the pampean environments, that have produced marked differences in both parameters (Echaniz et al. 2006, 2009).

In Redberry Lake, Evans et al. (1996) found that, due to its high salinity, the lake lacked fish fauna, which constitutes an important difference with the lakes included in this study, which are characterized by fish fauna dominated by *Odontesthes bonariensis*, a very tolerant species that can inhabit water bodies with salinities of up to 35.8 g.L^{-1} (Rosso 2006, Mancini & Grosman 2008). The lack of fish in Redberry Lake allowed the increased abundance of the large herbivorous zooplankton species, including *Daphnia pulicaria*

Forbes, 1893, and the diaptomid copepods *Diaptomus sicilis* (Forbes, 1882) and *Diaptomus nevadensis* (Light, 1938). This, in turn, allowed the development of a high zooplankton biomass (Evans et al. 1996). In contrast, the presence of a visual planktivorous fish such as *Odontesthes bonariensis* (Rosso 2006, Boveri & Quirós 2007) in the lakes of La Pampa prevents the development of large-sized zooplankton species (Quirós et al. 2002, Grosman & Sanzano 2003, Rosso 2006, Boveri & Quirós 2007). So, the composition of the zooplankton is dominated by rotifers and small crustaceans producing zooplanktonic communities of similar size, and resulted in no differences in biomass. The lower efficiency of the smaller zooplankton to filter the algae would have allowed the development of high phytoplankton biomass, with the consequent reduced transparency in the studied lakes.

Although it has been reported that lakes that exceed 1 $g.L^{-1}$ of salt tend to have lower phytoplanktonic biomass (expressed by the concentrations of chlorophyll-*a* and higher zooplanktonic biomass than subsaline lakes with similar nutrient concentrations (Evans et al. 1996), the present study not found higher zooplanktonic or lower phytoplanktonic biomasses in Bajo de Giuliani lake. The study showed that the taxonomic composition and biomass of zooplankton seemed to depend largely on the effect of predation, evidencing the importance of the top-down effect exerted by planktivorous fish. Despite the wide difference in the concentration of dissolved solids recorded between the two lakes, it is suggested that the trophic cascade caused both chlorophyll-*a* concentration and zooplankton abundance and biomass to show no significant differences between the two lakes.

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References

ALLENDE, L., TELL, G., ZAGARESE, H., TORREMORELL, A., PÉREZ, G., BUSTINGORRY, J., ESCARAY, R. & IZAGUIRRE, I. 2009. Phytoplankton and primary production in clear-vegetated, inorganic-turbid and algal-turbid shallow lakes from the pampa plain (Argentina). Hydrobiologia 624:45-60. http://dx.doi.org/10.1007/s10750-008-9665-9

AMERICAN PUBLIC HEALTH ASSOCIATION - APHA. 1992. Standard Methods for the Examination of Water and Wastewater. 18th ed. APHA, American Water Works Association - AWWA and Water Pollution Control Federation - WPCF, Washington.

ARAR, E.J. 1997. In Vitro Determination of Chlorophylls a, b, c1 + c2 and Pheopigments in Marine and Freshwater Algae by Visible Spectrophotometry. Method 446.0. U.S. Environmental Protection Agency. http://www.epa.gov/microbes/m446_0.pdf (último acesso em 20/04/2011).

BERTOLO, A., LACROIX, G., LESCHER-MOUTOUÉ, F. & CARDINAL-LEGRAND, C. 2000. Plankton dynamics in planktivore- and piscivore-dominated mesocosms. Arch. Hydrobiol. 147:327-349.

BOVERI, M. & QUIRÓS, R. 2007. Cascading trophic effects in pampean shallow lakes: results of a mesocosm experiment using two coexisting fish species with different feeding strategies. Hydrobiologia 584:215-222. http://dx.doi.org/10.1007/s10750-007-0581-1

BROOKS, J. & DODSON, S. 1965. Predation, body size and composition of plankton. Science 150(3692):28-35. PMid:17829740. http://dx.doi.org/10.1126/science.150.3692.28

CAMPBELL, C.E. & PREPAS, E.E. 1986. Evaluation of factors related to the unusually low chlorophyll levels in prairie saline lakes. Can. J. Fish. Aquat. Sci. 43:846-854. http://dx.doi.org/10.1139/f86-104

CHANG, K., NAGATA, T. & HANAZATO, T. 2004. Direct and indirect impacts of predation by fish on the zooplankton community: an experimental analysis using tanks. Limnology 5:121-124. http://dx.doi.org/10.1007/s10201-004-0116-7

CULVER, D.A., BOUCHERLE, M., BEAN D.J. & FLETCHER, J.W. 1985. Biomass of freshwater crustacean zooplankton from length- weight regressions. Can. J. Fish. Aquat. Sci. 42(8):1380-1390. http://dx.doi.org/10.1139/f85-173

DEMOTT, W., GULATI, R. & VAN DONK, E. 2001. *Daphnia* food limitation in three hypereutrophic Dutch lakes: Evidence for exclusion of large-bodied species by interfering filaments of cyanobacteria. Limnol. Oceanogr. 46(8):2054 -2060. http://dx.doi.org/10.4319/lo.2001.46.8.2054

DI RIENZO, J.A., CASANOVES, F., BALZARINI, M.G., GONZÁLEZ, L., TABLADA, M. & ROBLEDO, C.W. 2010. InfoStat (versión 2010). Grupo InfoStat, FCA, Universidad Nacional de Córdoba, Argentina. http://www.infostat.com.ar/ (último acesso em 20/04/2011).

DODSON, S., EVERHART, W., JANDL, A. & KRAUSKOPF, S. 2007. Effect of watershed land use and lake age on zooplankton species richness. Hydrobiologia 579:393-399. http://dx.doi.org/10.1007/s10750-006-0392-9

DUMONT, H.J., VAN DER VELDE, I. & DUMONT, S. 1975. The dry weight estimate of biomass in a selection of Cladocera, Copepoda and Rotifera from the plankton, periphyton and benthos of continental waters. Oecologia 19:75-97. http://dx.doi.org/10.1007/BF00377592

ECHANIZ, S.A., VIGNATTI, A.M., JOSÉ DE PAGGI, S., PAGGI, J.C. & PILATI, A. 2006. Zooplankton seasonal abundance of South American saline shallow lakes. Int. Rev. Hydrobiol. 91:86-100. http://dx.doi.org/10.1002/iroh.200510803

ECHANIZ, S.A., VIGNATTI A.M. & BUNINO, P.C. 2008. El zooplancton de un lago somero hipereutrófico de la región central de Argentina: Cambios después de una década. Biota Neotrop. 8(4): http://www.biotaneotropica.org.br/v8n4/pt/fullpaper?bn01008042008 (último acesso em 11/01/2012).

ECHANIZ, S.A., VIGNATTI, A.M. & CABRERA, G.C. 2009. Características limnológicas de una laguna turbia orgánica de la provincia de La Pampa y variación estacional del zooplancton. Biol. Acuat. 26:71-82.

ECHANIZ, S.A., VIGNATTI, A.M., JOSÉ DE PAGGI, S.B. & PAGGI, J.C. 2010a. Los nutrientes en los sedimentos de lagunas de La Pampa. Relación con la granulometría y uso de la tierra. In Congreso Pampeano del Agua. Gobierno de la Provincia de LA PAMPA, p.23-31. Libro de Trabajos. http://www.lapampa.gov.ar/publicacionesrechid/24625-libro-del-3er-congreso-pampeano-del-agua-ano-2010.pdf (último acesso em 11/01/2012).

ECHANIZ, S.A., VIGNATTI, A.M., JOSÉ DE PAGGI, S.B., PAGGI J.C. & CABRERA, G.C. 2010b. El modelo de estados alternativos de lagos someros en La Pampa: comparación de Bajo de Giuliani y El Carancho. In Congreso Pampeano del Agua. Gobierno de la Provincia de LA PAMPA, p.45-53. Libro de Trabajos. http://www.lapampa.gov.ar/publicacionesrechid/24625-libro-del-3er-congreso-pampeano-del-agua-ano-2010.pdf. (último acesso em 11/01/2012).

ENVIRONMENTAL PROTECTION AGENCY - EPA. 1993. ESS Method 340.2: Total Suspended Solids, Mass Balance (Dried at 103-105 °C) Volatile Suspended Solids (Ignited at 550 °C). EPA. http://www.epa.gov/glnpo/lmmb/methods/methd340.pdf. (último acesso em 20/04/2011).

EVANS, M., ARTS, M. & ROBARTS, R. 1996. Algal productivity, algal biomass, and zooplankton biomass in a phosphorus-rich saline lake: deviations from regression model predictions. Can. J. Fish. Aquat. Sci. 53:1048-1060. http://dx.doi.org/10.1139/f96-037

FONTANETO, D., DE SMET, W. & RICCI, C. 2006. Rotifers in saltwaters, re-evaluation of an inconspicuos taxon. J. Mar. Biol. Assoc. U.K. 86:623-656. http://dx.doi.org/10.1017/S0025315406013531

GROSMAN, F. 2008. Espejos en la llanura: Nuestras lagunas de la región pampeana. Editorial Universidad Nacional del Centro de la Provincia de Buenos Aires, Buenos Aires.

GROSMAN, F. & SANZANO, P. 2003. El pejerrey ¿puede causar cambios estructurales en un ecosistema? Biol. Acuat. 20:37-44.

HALL, C. & BURNS, C. 2003. Responses of crustacean zooplankton to seasonal and tidal salinity changes in the coastal Lake Waihola, New Zealand. New Zealand J. Mar. Freshw. Res. 37:31-43. http://dx.doi.org/10.1080/00288330.2003.9517144

HAMMER, Ø., HARPER, D.A.T. & RYAN, P.D. 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontol. Elect. 4(1):1-9.

HAMMER, U.T. 1986. Saline Lake Ecosystems of the World. Monographiae Biologicae 59. Dr. W. Junk Publishers, Dordrecht.

HERBST, D. 2001. Gradients of salinity stress, environmental stability and water chemistry as a templet for defining habitat types and physiological strategies in inland salt waters. Hydrobiologia 466:209-219. http://dx.doi.org/10.1023/A:1014508026349

HOBÆK, A., MANCA, M. & ANDERSEN, T. 2002. Factors influencing species richness in lacustrine zooplankton. Acta Oecol. 23:155-163. http://dx.doi.org/10.1016/S1146-609X(02)01147-5

IVANOVA, M. & KAZANTSEVA, T. 2006. Effect of Water pH and Total Dissolved Solids on the Species Diversity of Pelagic Zooplankton in Lakes: A Statistical Analysis. Russ. J. Ecol. 37(4):264-270. http://dx.doi.org/10.1134/S1067413606040084

KALFF, J. 2002. Limnology. Inland Water System. Prentice Hall, New Jersey. 592 p.

KHAN, T., WILSON, M. & KHAN, M. 2003. Evidence for invasive carp mediated trophic cascade in shallow lakes of western Victoria, Australia. Hydrobiologia 506-509:465-472. http://dx.doi.org/10.1023/B:HYDR.0000008558.48008.63

KOBAYASHI, T. 1997. Associations between environmental variables and zooplankton body masses in a regulated Australian river. Mar. Freshw. Res. 48:523-529. http://dx.doi.org/10.1071/MF96081

LAMPERT, W. & SOMMER, U. 1997. Limnoecology:The ecology of lakes and streams. Oxford University Press, London. 382 p.

MANCA, M., VIJVERBERG, J., POLISHCHUK, L. & VORONOV, D. 2008. *Daphnia* body size and population dynamics under predation by invertebrate and fish predators in Lago Maggiore: an approach based on contribution analysis. J. Limnol. 67(1):15-21. http://dx.doi.org/10.4081/jlimnol.2008.15

MANCINI, M. & GROSMAN, F. 2008. El pejerrey de las lagunas pampeanas: Análisis de casos tendientes a una gestión integral de las pesquerías. Editorial Universidad Nacional de Río Cuarto.

MANGEAUD, A. 2004. La aplicación de técnicas de ordenación multivariadas en la entomología. Rev. Soc. Entomol. Argent. 63(3-4):1-10.

McCAULEY, E. 1984. The estimation of the abundance of biomass of zooplankton in samples. In A manual on methods for the assessment of secondary productivity in freshwaters (J.A. Downing & F. Rigler, eds.). Blackwell Sci. Publishers, London, p.228-265.

MENU-MARQUE, S. & LOCASCIO DE MITROVICH, C. 1998. Distribución geográfica de las especies del género *Boeckella* (Copepoda, Calanoida, Centropagidae) en la República Argentina. Physis, B 56:1-10.

ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT - OECD. 1982. Eutrophication of waters. Monitoring, Assesment and Control. OECD, París. Final report.

PÉREZ, C. 2004. Técnicas de análisis multivariante de datos. Pearson Educación S.A., Madrid.

QUIRÓS, R., RENNELLA, A., BOVERI, M., ROSSO, J. & SOSNOVSKY, A. 2002. Factores que afectan la estructura y el funcionamiento de las lagunas pampeanas. Ecol. Aust. 12:175-185.

ROSEN, R.A. 1981. Length - dry weight relationships of some freshwaters zooplankton. J. Freshwater Ecol. 1: 225-229. http://dx.doi.org/10.1080/02705060.1981.9664034

ROSSO, J.J. 2006. Peces pampeanos: Guía y ecología. L.O.L.A. Literature of Latin America, Buenos Aires.

RUTTNER-KOLISKO, A. 1977. Suggestions for biomass calculation of plankton rotifers. Arch. Hydrobiol. 8:71-76.

SCHEFFER, M. 1998. Ecology of shallow lakes. Chapman & Hall, London.

SCHEFFER, M. & JEPPESEN, E. 2007. Regime Shifts in Shallow Lakes. Ecosystems 10:1-3. http://dx.doi.org/10.1007/s10021-006-9002-y

SEGERS, H. & DE SMET, W. 2008. Diversity and endemism in Rotifera: a review, and *Keratella* Bory de St Vincent. Biodivers. Conserv. 17:303-316. http://dx.doi.org/10.1007/s10531-007-9262-7

SOKAL, R. & ROHLF, F. 1995. Biometría. Principios y métodos estadísticos en la investigación biológica. Ed. Blume, Barcelona.

TORREMORELL, A., BUSTINGORRY, J., ESCARAY, R. & ZAGARESE, H. 2007. Seasonal dynamics of a large, shallow lake, laguna Chascomús: The role of light limitation and other physical variables. Limnologica 37:100-108. http://dx.doi.org/10.1016/j.limno.2006.09.002

VIGNATTI, A.M., ECHANIZ, S.A & MARTÍN, M.C. 2007. El zooplancton de lagos someros de diferente salinidad y estado trófico en la región semiárida pampeana (La Pampa, Argentina). Gayana 71(1):38-48.

WILSON, A.E. & HAY, M.E. 2007. A direct test of cyanobacterial chemical defense: Variable effects of microcystin-treated food on two Daphnia pulicaria clones. Limnol. Oceanogr. 52:1467-1479. http://dx.doi.org/10.4319/lo.2007.52.4.1467

ZAR, J.H. 1996. Biostatistical analysis. Prentice Hall, New Jersey.

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What can we learn from confusing *Olivella columellaris* and *O. semistriata* (Olivellidae, Gastropoda), two key species in panamic sandy beach ecosystems?

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TROOST, A.I., RUPERT, S.D., CYRUS, A.Z., PALADINO, F.V., DATTILO, B.F. & PETERS, W.S. **What can we learn from confusing *Olivella columellaris* and *O. semistriata* (Olivellidae, Gastropoda), two key species in panamic sandy beach ecosystems?** Biota Neotrop. 12(2): http://www.biotaneotropica.org.br/v12n2/en/abstract?article+bn02112022012

Abstract: *Olivella columellaris* (Sowerby 1825) and *O. semistriata* (Gray 1839) are suspension-feeding, swash-surfing snails on tropical sandy beaches of the east Pacific. While they often are the numerically dominant macrofaunal element in their habitats, their biology is poorly understood; the two species actually have been confused in all of the few publications that address their ecology. Frequent misidentifications in publications and collections contributed also to an overestimation of the geographic overlap of the two species. To provide a sound taxonomic basis for further functional, ecological, and evolutionary investigations, we evaluated the validity of diagnostic traits in wild populations and museum collections, and defined workable identification criteria. Morphometric analysis demonstrated that shell growth is allometric in *O. columellaris* but isometric in *O. semistriata*, suggesting that the species follow distinct developmental programs. The taxonomic confusion is aggravated by the existence of populations of dwarfish *O. semistriata,* which originally had been described as a separate species, *O. attenuata* (Reeve 1851). At our Costa Rican study sites, the occurrence of such dwarfish populations correlates with low wave energies but not with predation pressure and anthropogenic disturbances, indicating significant ecological plasticity in the development of *O. semistriata*.

Keywords: *Olivella, Pachyoliva, panamic faunal province, sandy beach intertidal, shell growth (allometry), suspension feeder.*

TROOST, A.I., RUPERT, S.D., CYRUS, A.Z., PALADINO, F.V., DATTILO, B.F. & PETERS, W.S. **¿Qué podemos aprender de la confusión de la *Olivella columellaris* y la *O. semistriata* (Olivellidae, Gastropoda), dos especies con un papel clave en los ecosistemas de las playas arenosas panamicas?** Biota Neotrop. 12(2): http://www.biotaneotropica.org.br/v12n2/pt/abstract?article+bn02112022012

Resumen: La *Olivella columellaris* (Sowerby 1825) y la *O. semistriata* (Gray 1839) son caracoles filtradores que navegan en la zona de vaivén de las playas arenosas tropicales del Pacífico oriental. Si bien son frecuentemente el elemento macrofáunico dominante en su habitat, su biología está insuficientemente entendida; de hecho, las dos especies han sido confundidas en las pocas publicaciones que han tratado de su ecología. La identificación equivocada tanto en las publicaciones como en las colecciones ha contribuido también a sobrestimar el solapamiento geográfico de las dos especies. Para proporcionar una base taxonómica segura para futuras investigaciones funcionales, evolutivas y ecológicas, evaluamos la validez de los rasgos diagnósticos en poblaciones silvestres y en colecciones museísticas, y definimos criterios de identificación para ser usados. El análisis morfométrico mostró que el crecimiento de la concha es alométrico en la *O. columellaris* pero isométrico en la *O. semistriata*, lo que sugiere que las dos especies siguen programas de desarrollo diferentes. La confusión taxonómica se ha visto agravada por la existencia de poblaciones de *O. semistriata* enanas, que fueron originalmente descritas como una especie separada: *O. attenuata* (Reeve 1850). En nuestro sitio de estudio en Costa Rica, la ocurrencia de tales poblaciones enanas se correlaciona con olas de baja energía, y no con la presión de depredación ni con disturbios antropogénicos, lo que indica una plasticidad ecológica considerable en el desarrollo de la *O. semistriata*.

Palabras clave: *Olivella, Pachyoliva, provincia fáunica panamica, zona intermareal de playa arenosa, crecimiento de concha (alometría), animales filtradores.*

Introduction

The macrofaunal communities on many dissipative sandy beaches of the panamic faunal province (American west coast from Baja California to north Peru) are numerically dominated by two closely related species of intertidal snails, *Olivella columellaris* (Sowerby 1825) and *O. semistriata* (Gray 1839). These very similar species must be assumed to be ecological key players due to their immense densities on those beaches (Olsson 1923/1924, 1956, Aerts et al. 2004), but our knowledge of their biology is fragmentary. According to Olsson (1956), the two species form the subgenus *Pachyoliva* in the genus *Olivella* (Olivellidae, Caenogastropoda, Gastropoda; while Olsson had included *Olivella* in the Olividae, we here follow the more recent suggestion by Bouchet & Rocroi (2005) to separate Olivellidae and Olividae). *Olivella semistriata* appears to be the more northerly species frequently found on Central American beaches, whereas *O. columellaris* seems to be common in South America (Olsson 1956). From previous casual field observations of *O. semistriata* at Playa Grande, Costa Rica, and of *O. columellaris* at Colan, Peru, we conclude that both species are swash surfers that reposition themselves in the sandy intertidal using their expanded foot as an underwater sail for rapid locomotion. Moreover, both use a pair of mucus nets suspended from unique lateral appendages of the anterior foot to filter suspended particles from the backwash in the upper beach zone. These observations are not novel, as similar reports regarding '*O. columellaris*' can be found in the older literature (Seilacher 1959). However, in all of the few papers published on the functional biology and ecology of *Pachyoliva* in peer-reviewed journals, the two species have been confused, as we will demonstrate below. Such confusion obviously hampers our understanding of the biology of the two species, and prevents the detection and analysis of any behavioral, physiological, and developmental differences that may throw light on their ecological role on panamic beaches and on the evolution of their clade. We analyzed the classical literature and conducted morphometric studies of populations in the field and of museum collections, in order to identify and resolve taxonomic and morphological issues that have caused the confusion.

Material and Methods

1. Analysis of diagnostic traits and morphometric studies

Live *Olivella columellaris* (Sowerby 1825), *O. semistriata* (Gray 1839), and *O. biplicata* (Sowerby 1825) were studied in their natural habitats, mainly at Colan, Piura, Peru (04° 59' S and 81° 05' W), at Playa Grande, Guanacaste, Costa Rica (10° 20' N and 85° 51' W), and at Bodega Bay, California, USA (38° 19' N and 123° 02' W), respectively. Shells of the former two species in the collections of the Senckenberg Museum of Natural History in Frankfurt, Germany (http://www.senckenberg.de), and of the Natural History Museum in London, UK (http://www.nhm.ac.uk), were also examined. Additional field observations from various locations along the Pacific coasts of El Salvador, Costa Rica, and Peru are included in this report. For morphometric analyses, we measured shell length, shell width, spire height, and spire base width (Figure 1) of animals in the field and in the museum collections to the nearest 0.05 mm with digital calipers.

2. Microscopy of shells

Cross sections of shells were prepared by embedding cleaned shells in plastic cylinders with epoxy resin, slicing the cylinders at 1 mm intervals, adhering the slices to glass slides with epoxy, and grinding them to approximately 30 µm thickness. The thin sections were examined under glass cover-slips with glycerine using a Leica Z16 APO Macroscope with a DFC490 digital camera and polarization equipment (Leica, Wetzlar, Germany).

3. Comparative ecological studies of Olivella semistriata populations

Eight test beaches in northwest Costa Rica (Figure 2) known from previous visits to home dense populations of *O. semistriata* were selected for investigations into the dependence of maximum body size on local ecological conditions. In Table 1, the test beaches are listed according to their exposure to wave energy. The highest degree of exposure was defined as that found in dissipative sandy beaches forming part of long linear or even convex coastlines, whereas the lowest degree was assigned to coves in the interior of complex coast geometries providing shelter from open ocean conditions. It is worth noting that the degree of wave exposure thus defined generally correlated with the type of human activity: high-exposure beaches are frequented mostly by surfers, whereas low-exposure sites typically are family-friendly bathing beaches. With respect to the extent of human utilization, the eight test beaches ranged from pristine without significant tourist infrastructure to strongly impacted by tourism and other activities due to a 'downtown location'.

Local maximum body size and predation pressure were evaluated on the test beaches between November 20 and 27, 2010 (end of the rainy season), during daylight hours following a standardized procedure. Exactly two hours before low tide, we began to screen a beach for the predatory snail *Agaronia propatula* (Conrad 1849; Olividae, Gastropoda) which feeds mostly on *O. semistriata* (Cyrus et al. 2012), by slowly walking in a zigzag pattern between the uppermost waterline occasionally reached by the highest waves

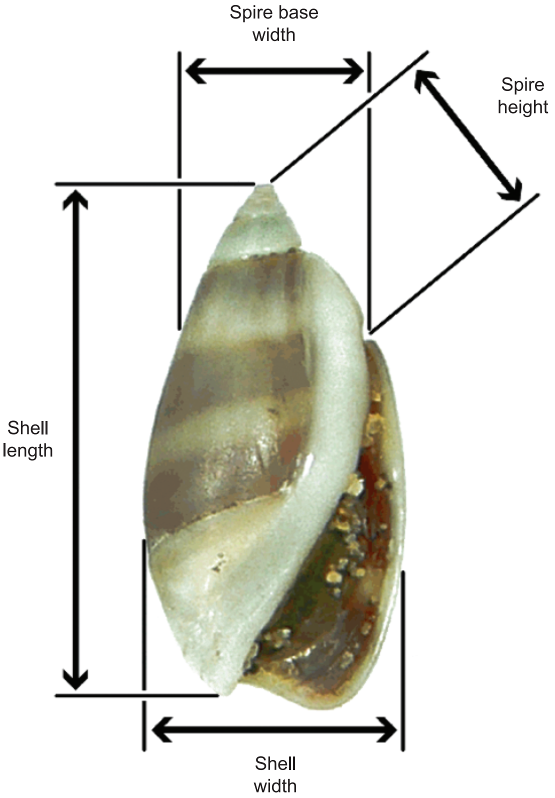

Figure 1. Definition of the measures taken on shells of *Olivella columellaris* and *O. semistriata*.

Figure 2. Locations of the eight test beaches in Northwest Costa Rica. 1) Playa Junquillal; 2) Playa Avellana; 3) Playa Grande; 4) city beach of the town of Puntarenas; 5) Playa Carrillo; 6) Playa Hermosa; 7) Playa Conchal; 8) Bahia Junquillal. For further details, see Table 1.

Table 1. Characteristics of the Costa Rican beaches on which *Olivella semistriata* populations were studied; compare map in Figure 2. Abbreviation in the last column: *A.p.*, density of the predatory snail *Agaronia propatula* in individuals per 100 m of beach.

Location	Exposure	Beach morphology	Utilization	*A.p.*
Exposed beaches:				
(1) *Playa Junquillal* 10° 10' N and 85° 49' W	Straight beach (1.9 km) in a linear coastline, fully exposed to oceanic waves	Moderately flat dissipative beach; intertidal plain flooded by the highest waves at low tide >35 m wide	Turtle breeding site; remote location but popular with surfers and other tourists	0.6
(2) *Playa Avellana* 10° 14' N and 85° 50' W	Straight beach (1.4 km) in a long linear coastline, fully exposed to oceanic waves	Flat dissipative beach; intertidal plain flooded partly by the highest waves at low tide >70 m wide	Remote location but very popular with surfers and other tourists	3.4
(3) *Playa Grande* 10° 20' N and 85° 51' W	Slightly curved beach (4.7 km); some sheltering effects by protruding coastline in the N and S, but mostly exposed to oceanic waves	Flat dissipative beach; intertidal plain that at low tide is flooded by the highest waves is >50 m wide	Turtle breeding site in national park with restricted access, but very popular with surfers	21.0
Intermediate beaches:				
(4) City beach of *Puntarenas* 9° 58' N and 84° 50' W	Part of a spit protruding into the Golfo de Nicoya; exposure to wave action limited	Moderately steep dissipative beach; backwash zone suitable for suspension feeding of *O. semistriata* is hardly ever >10 m	Adjacent to the downtown area of Puntarenas; extensively utilized by tourists and the local public, by far the most polluted site studied	14.7
(5) *Playa Carrillo* 9° 52' N and 85° 30' W	Semicircular bay of 1.8 km diameter, opens to the open ocean	Moderately flat dissipative beach; width of intertidal plain flooded by largest waves at low tide <20 m wide	Despite vicinity to the touristic city of Samara, relatively moderate utilization by tourists	0.9
Sheltered beaches:				
(6) *Playa Hermosa* 10° 35' N and 85° 41' W	Cove of 1.3 km diameter at the opening of the Bahia Culebra with several islands just off the shore	Moderately steep reflective beach; in the lower part, current ripples form at retreating tide	Small bay in 'downtown location', utilized by tourists, the local public, and local small-scale industries	10.7
(7) *Playa Conchal* 10° 24' N and 85° 49' W	Sheltered southern edge of the Bahia Brasilito, protected by the protruding Punta Sabana	Sandy beach with interspersed rocks and pebble fields. In the lower part, current ripples form at retreating tide	Unattractive for surfing and bathing, but frequented at low tide by off-road vehicles and horse-back riders; launching spot for jet skis	4.3
(8) *Bahia Junquillal* 10° 58' N and 85° 41' W	Sheltered bay of 1.6 km diameter in the interior of the Golfo de Santa Elena	Steep reflective beach; backwash zone suitable for suspension feeding of *O. semistriata* never >5 m	Remote and pristine cove; limited access and little infrastructure, very low touristic impact	0.0

and a line where the water was about ankle-deep (10 to 20 cm) during the phases of wave retreat. After two hours (that is, at low tide), the counting of *Agaronia* was stopped. The estimated density of *Agaronia* was expressed as the number of individuals per 100 m of beach. Obviously, this number provided a relatively crude minimum estimate of the true density of *Agaronia* in the intertidal zone since only actively hunting individuals that were visible on the surface were counted. In the following two hours, the same stretch of beach was screened for particularly large specimens of *O. semistriata*. Their shell lengths were measured to the nearest 0.05 mm with digital calipers; the animals were put back to their original location immediately. Up to 80 and not less than 52 individual measurements were taken on each beach; these particularly large animals represented a tiny minority of the total population present at each site. The 25 largest animals found on a given beach were selected from each dataset and their size spectrum served as an estimate of the maximum size which *O. semistriata* reached at that location. To transform shell length measurements into biomass, shell length as well as the weight of the live animals (measured to the nearest 0.01 g) were determined for a representative sample of 266 individuals from Playa Grande that was selected to cover all size classes. The relation between shell length and body mass was expressed as the geometric mean functional relationship (GMFR), a type II correlation model (Laws & Archie 1981).

Results and Discussion

1. *The subgenus Pachyoliva*

In the most recent revision of extant and extinct members of the genus *Olivella*, Olsson (1956) established a number of subgenera, mainly based on shell characteristics. However, the most obvious morphological characters that identify the subgenus *Pachyoliva* (comprising *O. columellaris* and *O. semistriata*) are found in the anterior soft body. *Olivella* generally lacks eyes and cephalic tentacles, and the most anterior portion of the foot (propodium) is set off against the main part (metapodium) by a shallow groove. The tips of the crescent-shaped propodium protrude slightly from the lateral edges of the foot in most species (Figure 3a shows *O. biplicata* as a typical example). In contrast, the lateral tips of the propodium are thickened and elongated in *O. semistriata* and *O. columellaris* (Figures 3b, c). In live animals, these enlarged propodial tips are quite conspicuous and occasionally have been confused with cephalic tentacles, for instance by Gray (1839) in the original description of *O. semistriata*. This author included the species in *Oliva* rather than in *Agaronia*, precisely because *Oliva* possesses cephalic tentacles whereas *Agaronia* does not (Gray 1839 p. 129). In fact, however, the elongated propodial tips are unknown from other Olivellidae and Olividae, and thus represent an autapomorphy of *Pachyoliva*. A smaller, less conspicuous appendage protrudes from each side of the

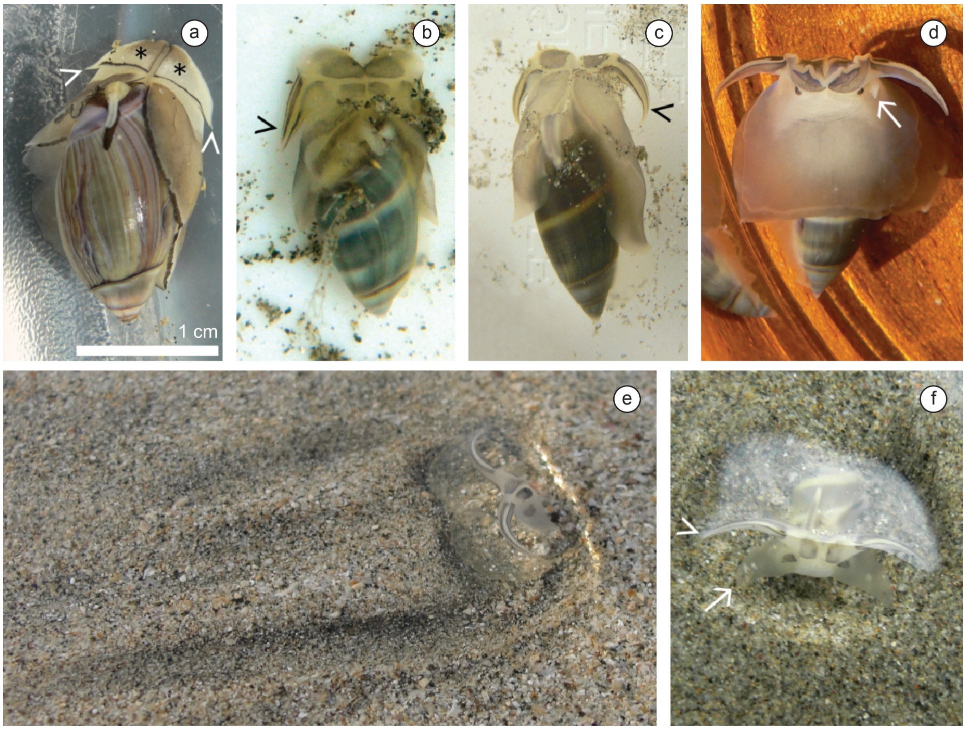

Figure 3. Morphology of *Olivella* species. a) *O. biplicata* (from Bodega Bay, California, USA) as an example of the typical morphology of the genus. Cephalic tentacles carrying eyes are absent; the left and right halves of the propodium (asterisks) are visually separated from the metapodium by transverse dark lines, and the lateral tips of the propodium (arrowheads) extend slightly beyond the lateral edges of the foot. These lateral propodial tips are greatly enlarged in the two members of the subgenus *Pachyoliva*: b) *O. columellaris* from Colan, Peru, and c) *O. semistriata* from Playa Grande, Costa Rica. d) A smaller lateral appendage is present on each side of the anterior metapodium, highlighted here by the arrow in a ventral view of an *O. semistriata* that has assumed the surf posture. e) Food acquisition by *O. semistriata* in the backwash; direction of water flow from right to left. The snail has burrowed into the sand; only the propodium and most anterior metapodium extend above the surface. The lateral propodial appendages arch outwards and support translucent mucus nets that balloon in the flow; at this late stage in the filtering cycle, the nets have accumulated suspended detritus and are clearly visible. A characteristic trident flow mark has formed downstream of the animal. f) Head-view of a filtering *O. columellaris*; direction of water flow from bottom to top. The mucus nets are suspended between the propodial (arrowhead) and the greatly expanded metapodial (arrow) appendages, but are not yet visible in this early stage of the filtering cycle. Scale bar in a) applies to all photographs.

anterior metapodium (Figure 3d, f). These metapodial appendages, which have not been described previously, appear to be absent in species with typical foot morphology such as *O. biplicata*. *Pachyoliva* snails use their foot appendages to deploy mucus nets for suspension feeding in the backwash of sandy beaches: one semispherical net is suspended on each side between the large propodial and small metapodial appendage (Figure 3e, f). As noted by Seilacher (1959), these nets are hard to see at the beginning of a filtering cycle, before they have become loaded with plankton and detritus (Figure 3f).

According to modern identification keys (Olsson 1956, Burch & Burch 1963, Keen 1971), the two species can be distinguished using two structural characters of the shells (shell coloration, a feature focused on by many classical authors, is variable and of little diagnostic value). First, while shells of both species exhibit callus on the inner lip (parietal callus) that extends beyond the posterior end of the aperture (spire callus), callus development supposedly is stronger in *O. columellaris*. Second, only *O. semistriata* is thought to possess fine, longitudinal striae that cover the upper half of the body whorl, as the species name indicates. In addition, shells of *O. columellaris* frequently were described as stockier than those of *O. semistriata*; especially the spire of the latter was claimed to be higher and more sharply pointed. Finally, it is worth noting that in the modern keys, similar sizes (14–15 mm length) are given for mature shells of both species.

2. *Critical evaluation of diagnostic shell characters and their application*

To evaluate the usefulness of the above diagnostic criteria in field studies, we examined populations of *O. columellaris* in Peru and of *O. semistriata* in Costa Rica, as well as the extensive collection of the Senckenberg Museum which houses, among others, the shells collected by the authors of the first ecological studies of *Pachyoliva* (Schuster 1952, Schuster-Dieterichs 1956, Seilacher 1959).

Callus – In 'typical' specimens of *O. columellaris* resembling those shown in identification guides (Figure 4a), the parietal and spire callus is more strongly developed than in 'typical' *O. semistriata* (Figure 4b). Strong spire callus formation in *O. columellaris* causes a characteristic kink in the outline of the shell at the suture above the body whorl (highlighted in Figure 4a), which, according to the original species description by Sowerby (1825, Appendix p. 34), "[...] gives to this shell a very extraordinary appearance, and forms the characteristic feature of the species." However, in every *O. columellaris* population that we have seen in the field, specimens without strongly developed spire callus (Figure 4c) actually were more abundant than 'typical' shells. Analysis of a representative sample ($n = 315$) of *O. columellaris* shells from our study site at Colan, Peru, indicated that the 'typical' morphology does not develop before the animals grow from 10 to 13 mm shell length (Figure 4d).

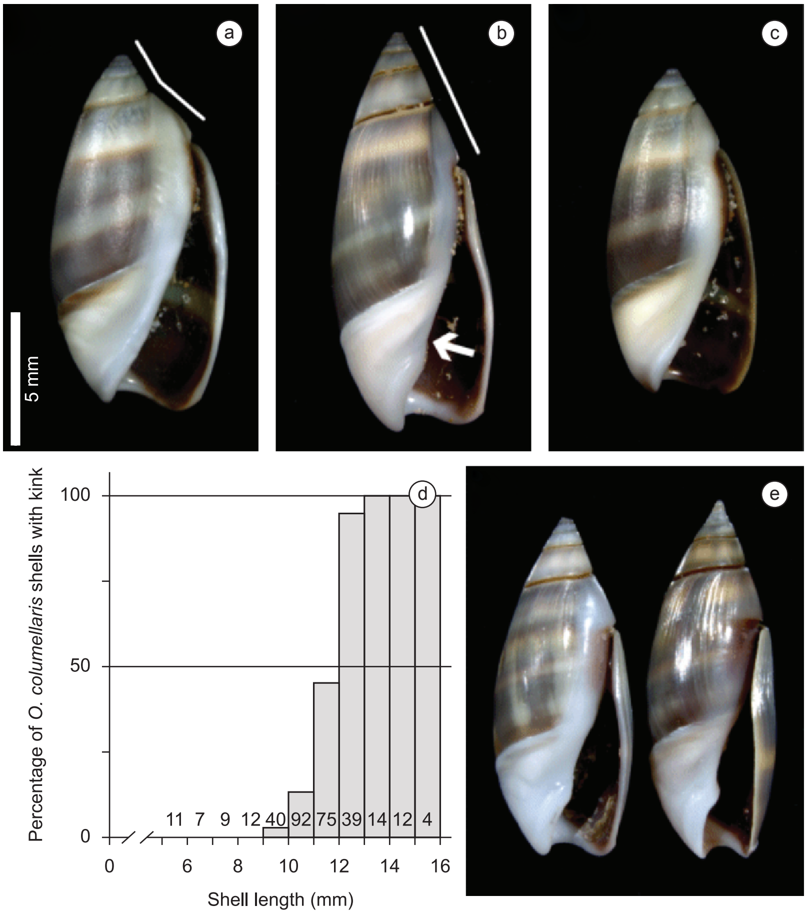

Figure 4. Callus formation in *Pachyoliva* shells. a) 'Typical' *O. columellaris* shell from Colan, Peru, showing a kink in the outline of the shell above the aperture (highlighted by white line). b) 'Typical' *O. semistriata* shell from Playa Grande, Costa Rica. The outline of the shell above the aperture is straight (highlighted by white line). Note the notch in the anterior inner lip (arrow). c) 'Atypical' specimen of *O. columellaris* from the same population as the shell in a); no kink in the outline of the shell is visible. d) Proportion of *O. columellaris* shells with kinked outline in size classes defined by shell length (1 mm class width), determined in the population of Colan, Peru. Numbers at the bases of the bars indicate the number of animals examined in that size class. e) Two *O. semistriata* from Playa de Cuco, El Salvador, demonstrating the variability of callus formation in this species. Scale bar in a) applies to all photographs.

The situation is further complicated by the significant variability of callus formation in *O. semistriata*. If the extent of spire callus were the only diagnostic criterion available, the two shells shown in Figure 4e probably would be classified as *O. columellaris* (left) and *O. semistriata* (right). In fact, the two shells come from the same *O. semistriata* population in east El Salvador, and both show the striae that are characteristic of this species (see below). We have found individuals with similarly strongly developed callus as the one on the left in numerous *O. semistriata* populations in Central America, but this always was a minority phenotype.

Striae – In the words of Keen (1971 p. 631), a "[...] faint series of vertical striae at the upper margin of the body whorl is distinctive." in *O. semistriata*. These structures were explicitly highlighted in the species description (Gray 1839 p. 130), and the name *semistriata* refers to them. The striae are unmistakable in clean and dry shells from which the light reflects (Figure 5a), but may be overlooked in the field especially under poor light. They are spaced at 230–300 µm, which corresponds to the geometry of the internal crenulation and terminations of prominent laminae within the outermost shell layer (Figure 5b, c). While the striae reflect a distinct process of routine shell accretion in *O. semistriata*, they do not resemble and must not be confused with the major growth lines that may form in response to disruptions of growth, either from trauma or during senescence, in both *Pachyoliva* species. Small *O. semistriata* shells lack striae; at our study site Playa Grande in Costa Rica, striae gradually occurred in the size classes from 7 to 12 mm shell length (Figure 5d; size of the representative sample examined, *n* = 267) and were never lacking in larger animals. In contrast, we failed to find even a single semi-striated shell among the northern Peruvian populations that we had identified as *O. columellaris* due to the presence of individuals showing the 'typical' callus (this identification was in agreement with classical studies undertaken at the same localities; Olsson 1923/1924). Intriguingly, Olsson (1956) did not even mention the characteristic striae in his description of *O. semistriata*. The *O. semistriata* shell

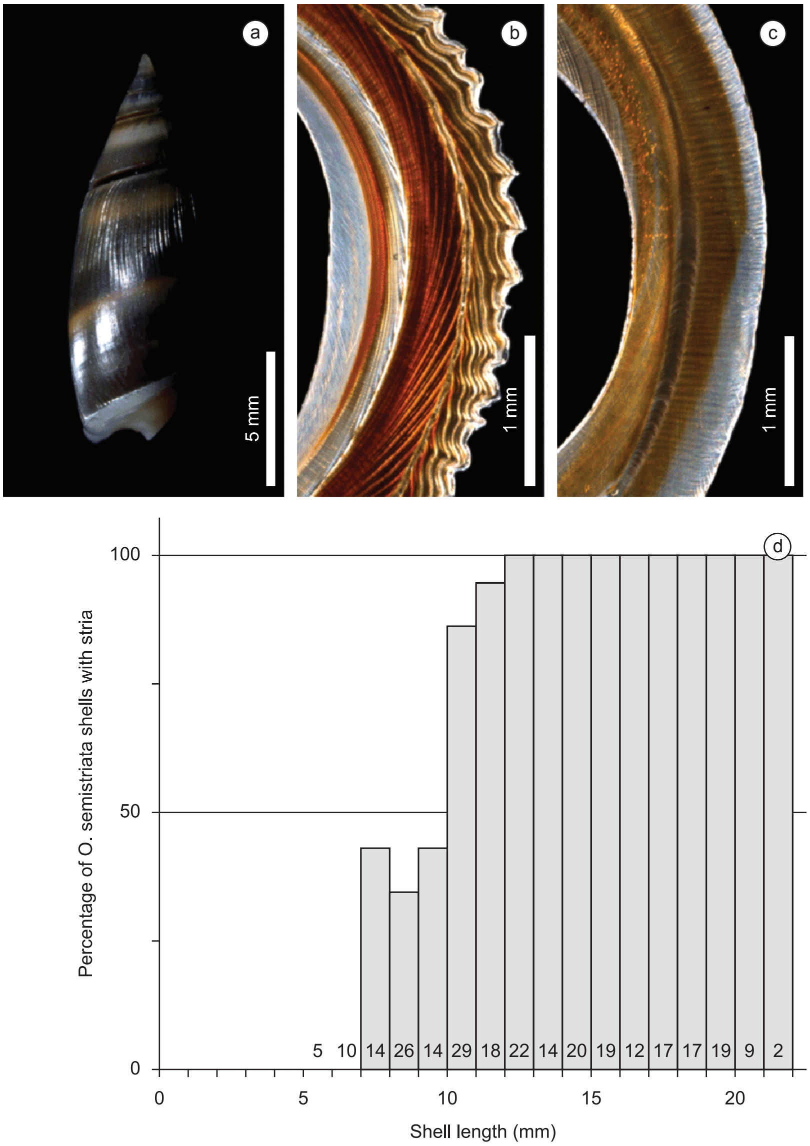

Figure 5. Striae on the shell of *Olivella semistriata*. a) Light reflections from an *O. semistriata* shell reveal the structural difference between the striated upper (posterior) part and the smooth lower (anterior) part of the body whorl. b) Cross-section of an *O. semistriata* shell, taken from the uppermost quarter of the body whorl. The striae on the surface correspond to terminations of individual laminae in the outermost shell layer. c) No striae are present in the shell of *O. columellaris*. d) Proportion of *O. semistriata* shells with visible striae in size classes defined by shell length (1 mm class width), determined in the population of Playa Grande, Costa Rica. Numbers of individuals examined in each size class are given at the bases of the bars.

shown on this author's Plate 8 was 14.2 mm long, according to the plate legend (Olsson 1956 p. 219), but the quality of the image is not sufficient to determine unambiguously whether striae were present or not. In any case, it is puzzling that Olsson ignored this defining trait, and we assume that he mainly studied immature shells too small to show this feature.

Large shells of *O. semistriata* but not of *O. columellaris* often show a notch in the anterior inner lip (Figure 4b). This character is not unambiguously expressed in small *O. semistriata* shells (data not shown), and therefore merely confirms conclusions that can be drawn from the presence or absence of striae on the posterior body whorl. Moreover, the notch, if present, frequently is covered by the foot tissue in live animals retracted into the shell, and therefore is not a suitable character for the routine identification of live specimens in ecological field studies.

From these findings we concluded that, despite all phenotypic variability, it is possible to establish the taxonomic identity of a *Pachyoliva* population based on the presence of striae in the posterior body whorls (Figure 5) and of kinks in the shell outline caused by spire callus (Figure 4), as long as a sufficient number of large animals (shell length > 12 mm) are available for examination. To establish the taxonomic validity of our conclusion, we examined the syntypes of *O. semistriata* in the Natural History Museum in London (catalogue entry: *NHMUK 20050254*). The seven shells are from 12.6 to 18.2 mm long, and are in full agreement with our above interpretation. We were unable to locate the type specimen(s) of *O. columellaris*. The oldest publication that we could link to specific specimens was Reeve (1851). The five specimens from the Cuming Collection that served as models for the *O. columellaris* drawing on Table 23 in that monograph are being held in the Natural History Museum London. The four larger shells (14.1 to 14.7 mm) show the 'typical' spire callus described above, whereas the fifth measures only 10.6 mm and lacks the strongly developed callus.

Application of the above identification criteria to published studies leads to surprising results. We are not aware of more than five articles addressing the ecology of *Pachyolivae* in peer-reviewed journals (Schuster 1952, Schuster-Dieterichs 1956, Seilacher 1959, Vanagt et al. 2008a, 2008b). Ironically, the species seems to have been misidentified in all of them. The older three of these papers (Schuster 1952, Schuster-Dieterichs 1956, Seilacher 1959) reported field work from El Salvador that established basic facts about the behavior, food acquisition, and predator-prey relations of *'O. columellaris'*. These publications were cited in more recent review articles (Declerck 1995, Davies & Hawkins 1998), and Seilacher's (1959 p. 365) beautiful and accurate drawings of a snail deploying its mucus nets were reproduced in several books (Friedrich 1969 p. 270, Hughes 1986 p. 33). However, photographs presented by Schuster-Dieterichs (1956 p. 19, 21) and Seilacher (1959 p. 359) show mature *O. semistriata*, not *O. columellaris*, and all of the hundreds of shells deposited by Schuster-Dieterichs in the Senckenberg collection that are large enough for identification are *O. semistriata*. Moreover, *O. semistriata* is the only *Pachyoliva* on the El Salvadorian beaches on which these researchers worked, as we have verified on field trips in 2010. The incorrect identifications may have been due partly to the fact that the characteristic striae on the *O. semistriata* shells had received no mention in Olsson's *Olivella* monograph (1956), to which Seilacher (1959) refers. More recently, Vanagt et al. (2008a, 2008b) scrutinized the burrowing performance of *'O. semistriata'* and its circatidal movements on beaches in Ecuador. While these authors do not comment on taxonomy, species identification is discussed in the doctoral dissertation (Vanagt 2007) on which the two papers are based. The photographs given (Vanagt 2007 p. 26 and title page) show typical *O. columellaris*, not *O. semistriata*. While the ecological and physiological conclusions drawn in all of these papers remain largely unaffected by the incorrect species identifications, our taxonomic corrections are essential for an integration of these studies in the wider contexts of biogeography, evolution, and comparative aspects of the species' physiology, ecology, and behavioral biology.

A certain degree of taxonomic confusion regarding *Pachyoliva* exists in museum collections as well. Twenty-four of the 25 items in the Senckenberg collection that bear *O. columellaris* or *O. semistriata* as species name included mature shells which could be identified unequivocally. Of these items, 11 (46%) had been misidentified. In contrast, 16 of the 17 identifiable entries in the collection of the Natural History Museum were labelled correctly, which may be due to the fact that the type specimens of *O. semistriata* were available at this institution for comparison. It is worth mentioning that in the Senckenberg collection, all of the five records of supposed *O. columellaris* from Central America in fact are *O. semistriata*, which reinforces the doubts expressed by Olsson (1956, p. 202) regarding the validity of reports of *O. columellaris* from that region. On the other hand, two of the three records in the Senckenberg collection of supposed *O. semistriata* from Ecuador and Peru in reality are *O. columellaris*. These findings, together with the misidentifications in the published literature discussed above, suggest that reports of *O. columellaris* from Central America and records of *O. semistriata* from locations south of Colombia tend to be incorrect. Therefore it appears questionable whether the overlap of the distribution ranges of the two species is as broad as suggested by standard identification guides (e.g. Nicaragua to northern Peru, according to Keen 1971 p. 631). It rather appears that *O. semistriata* is the only *Pachyoliva* north of Colombia whereas *O. columellaris* dominates more or less completely south of that country. This tentative conclusion can be tested in the field using the identification criteria validated in the present study.

3. Shell Shape and Mode of Development

Shell geometry may provide essential identification criteria in difficult taxa, such as the Olividae, if strictly quantitative morphometric approaches are followed (Tursch & German 1985). To see whether identifications of *Pachyoliva* species based on the shell characters discussed above correlate with shell shape as suggested by current identification guides, we determined simple geometric parameters (Figure 1) in several hundred individuals of each species from our study sites in Costa Rica (*O. semistriata*) and Peru (*O. columellaris*), and from the Senckenberg collection. We first plotted shell width versus shell length for the two species to determine whether shells of various populations identified as the same species fell into a common region; in fact, this was the case (Figure 6a, b). An overlay of the two clouds of data-points showed that *O. columellaris* shells actually were 'fatter' than those of *O. semistriata*, but only if they exceeded about 11 mm length (Figure 6c). This fact became even clearer in a plot of aspect ratio (shell length divided by shell width) versus shell length (Figure 6d). A similar result was obtained when we plotted spire height versus spire base width as a measure for the pointedness of the shell. Large, but not small *O. columellaris* had a smaller spire height to spire base width ratio than *O. semistriata* of comparable size (Figure 6e).

Evidently, overall shell shape is a helpful criterion in distinguishing *O. columellaris* and *O. semistriata*, but as in the cases of callus and striae, the criterion is reliable only in individuals above a certain critical size (i.e., about 12 mm shell length). Most individuals below this size cannot be identified unequivocally. Our data provided further information regarding the developmental mechanisms behind the establishment of the distinct phenotypes in larger individuals. In *O. semistriata*, simple linear relationships exist between shell length

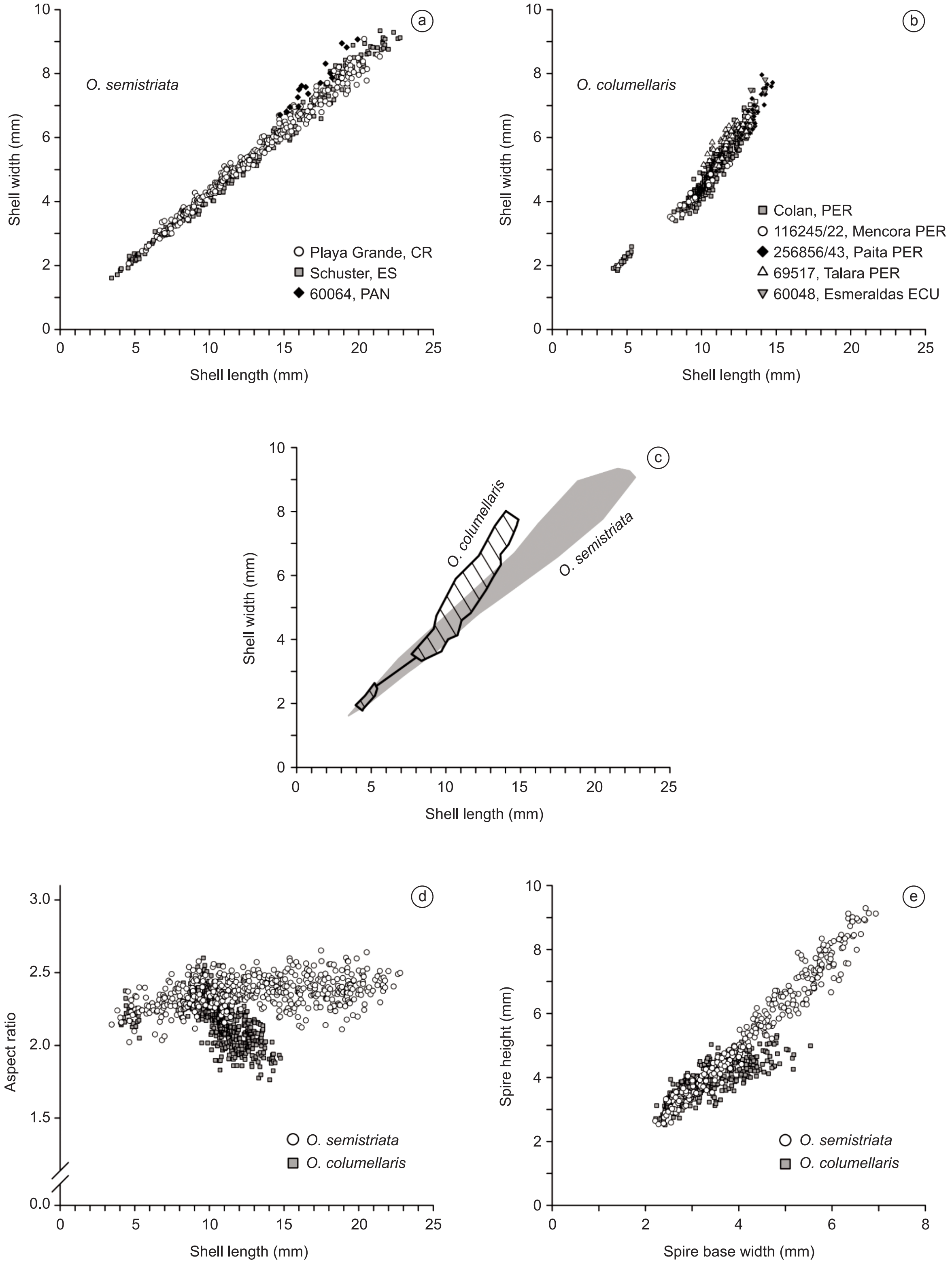

Figure 6. Shell morphometrics of *Pachyoliva* snails. a) Shell width plotted versus shell length for samples from three *O. semistriata* populations; our study population at Playa Grande, Costa Rica (*n* = 267), the population studied by O. Schuster in El Salvador (shells housed in the Senckenberg collection; *n* = 201), and a population from Panama (Senckenberg collection, catalogue number *60064*; *n* = 16). b) Analogous data from five populations of *O. columellaris*; our study population at Colan, Peru (*n* = 413), and four populations from Peru and Ecuador (Senckenberg collection, catalogue numbers indicated in the figure; *116245/22*, *n* = 22; *256856/43*, *n* = 43; *69517*, *n* = 44; *60048*, *n* = 3). c) Overlay of the data areas in a) and b); only the largest *O. columellaris* shells are wider than *O. semistriata* shells of the same length. d) The plot of shell aspect ratio (shell length divided by width, calculated from data in a) and b)) versus shell length shows that the geometry of shell growth is similar in the two species early in life, but that *O. columellaris* shells tend to become relatively wider when shell length exceeds 10–11 mm. e) Large *O. columellaris* that have spire base widths of 4 mm or more show lower ratios of spire height to spire base width than *O. semistriata* of comparable size (data from the *O. semistriata* population in Playa Grande, Costa Rica, *n* = 300, and the *O. columellaris* population in Colan, Peru, *n* = 490).

and width (Figure 6a) as well as between spire base width and spire height (Figure 6e), and the shell aspect ratio was practically constant for all shell sizes (Figure 6d). Thus, *O. semistriata* does not change its proportions as it grows; growth is isometric, and there is no geometrically defined state of maturity. In contrast, *O. columellaris* changes its mode of shell growth once it reaches 10 mm shell length; shells grow wider relative to their length (Figure 6b, d) after this stage, and the spire becomes flatter (Figure 6e). This is an allometric growth pattern with geometrically distinguishable immature and mature phases. It should be noted that growth ceases in *O. columellaris* shortly after the switch into the mature growth mode, as we never found shells of more than 15 mm length (Figure 6b). In contrast, *O. semistriata* grows isometrically up to 23 mm (Figure 6a), which significantly exceeds the size given in recent identification keys (15 mm; Burch & Burch 1963, Keen 1971).

Differences in gastropod shell shape and allometric growth can, in many cases, be explained as a function or even a direct consequence of differences and changes in shell growth rate (Kemp & Bertness 1984, Urdy et al. 2010a, 2010b). Our analysis of shell morphometrics (Figure 6) allows conclusions regarding geometric aspects of growth, but lack the temporal component required to evaluate growth rates. Growth analyses based on repeated measurements of individual snails over prolonged periods will be required to understand the morphometric relationships quantitatively in terms of temporal processes.

Allometric shell growth in marine gastropods frequently is plastic and responsive to environmental conditions (Kemp & Bertness 1984, Johnson & Black 1998, Yeap et al. 2001, Hollander et al. 2006). *Purpura columellaris* (Thaididae), an inhabitant of hard substrates in the intertidal of the tropical eastern Pacific, shows differences in growth rate leading to shell morphologies so distinct that the faster growing morph had been considered a separate species, *P. pansa* (Wellington & Kuris 1983). The occurrence of the two morphs correlated with gradients in predation risk (Wellington & Kuris 1983). Could *O. columellaris* and *semistriata* be a similar case, and represent two morphs of the same biological species? We think not, because the two taxa do not overlap geographically as broadly as previously assumed (see discussion above), because there are no intermediate adult forms with respect to the decisive trait 'semi-striation', and because the dependency of shell geometry on body size indicates two identifiable clusters of forms rather than a continuum (Figure 6c). Moreover, the distribution of the two taxa is not correlated with any obvious environmental factors that could be hypothesized to favor one over the other. Considering all available evidence, it seems more plausible that *O. columellaris* and *O. semistriata* are sister species that have diversified with respect to their genetically fixed developmental programs (isometric versus allometric growth). The occurrence of an allometric shift in shell shape at a defined developmental stage in a member of the Olivellidae is not entirely unexpected; similar cases have been reported from the closely related Olividae (Tursch 1997).

4. *Developmental and ecological plasticity in O. semistriata*

While working at Playa Grande (Costa Rica) where *O. semistriata* of over 20 mm shell length occur regularly, we also studied a population at Bahia Junquillal close to the Nicaraguan border (site 8 in Figure 2) which lacks individuals larger than 13 mm shell length. Since we consistently found this discrepancy at all times of year, it cannot be due to an annual growth cycle or a seasonal developmental pattern in *O. semistriata*. Rather, the species appears to reach different maximum body sizes at different locations. Phenotypic variability in shell size and shape that appears adaptive due to its correlation with biotic or abiotic environmental factors is common in marine gastropods (Wellington & Kuris 1983, Kemp & Bertness 1984, Johannesson 1986, Trussell 1996, Yeap et al. 2001, Hollander et al. 2006). Johnson and Black (1998, 2000, 2008) studied phenotypic variability and growth plasticity in the polymorphic *Bembicium vittatum* (Littorinidae) and reached the conclusion that "[...] the dwarf phenotype is largely a plastic stunting." (Johnson & Black 1998 p. 95) in response to specific environmental conditions. If the same holds for the 'dwarfish' populations of *O. semistriata*, their occurrence will be correlated with some environmental factor(s).

We tested this hypothesis by comparing maximum body sizes in *O. semistriata* populations at eight test sites (Figure 2). As a group, the test beaches represented ecological gradients regarding their exposure to wave energy, and with respect to the type and extent of human activities (Table 1). Finally, the test beaches varied significantly with regard to predation pressure on *O. semistriata*, with estimated minimum densities of its main predator *Agaronia propatula* (López et al. 1988, Rupert & Peters 2011, Cyrus et al. 2012) between 0 and >20 individuals per 100 m beach length. (Table 1).

Maximum shell length in *O. semistriata*, a parameter that is easily established with minimum disturbance of the animals in their natural environment, differed significantly between the sites (an example is shown in Figure 7a). However, size differences between individuals are most meaningful if expressed in terms of body mass since this reflects the different costs of generating and maintaining a given body size more directly. Therefore we determined the relationship of shell length and live body mass for the *O. semistriata* population at our primary study site, Playa Grande (site 3 in Figure 2 and Table 1). Body mass scaled with shell length to the 2.67th power (Figure 7b), close to the 3rd power that is theoretically expected for the relationship between distance- and volume-dependent parameters in bodies of similar shape.

Since the determination of the largest size class present at a given location rather than the determination of complete size spectra was sufficient to test our hypothesis, we screened each test beach for particularly large specimens following a standardized procedure (see Methods section). We used the size distribution of the largest 25 individuals found at a site as an estimate of the maximum size present at that location. The size spectra of these largest 25 animals found at each site are presented as box-plots in Figure 7c, where they are graphed versus predation pressure as represented by the estimated density of *A. propatula*. It is worth noting that the differences in maximum body size that exist between local populations may be quite substantial (Figure 7c). The estimated maximum body mass in the population with the largest snails (Playa Grande, site 3) was more than four-fold that found in the population with the smallest 'big' snails (Playa Hermosa, site 6).

The maximum size of *O. semistriata* did not correlate with predation pressure (Figure 7c). Neither did the extent of human utilization of the beaches produce any obvious effects: Bahia Junquillal (pristine, remote from settlements, no significant tourist infrastructure; site 8) and Playa Hermosa ('downtown location'; site 6) represented the extreme cases in terms of direct human impact and utilization, but at these two locations the maximum sizes of *O. semistriata* were the lowest observed. However, there was a clear correlation between maximum body size reached at a location and the exposure of that particular beach to wave energy. The three beaches fully exposed to oceanic conditions had the largest *O. semistriata* whereas the three sheltered beaches had the smallest; intermediately exposed beaches had snails of intermediate size (Figure 7c). Evidently, *O. semistriata* remains small in sheltered coves and grows to large sizes on beaches exposed to the open ocean.

Due to the variability in local maximum size, researchers familiar with specimens from only a few populations might easily

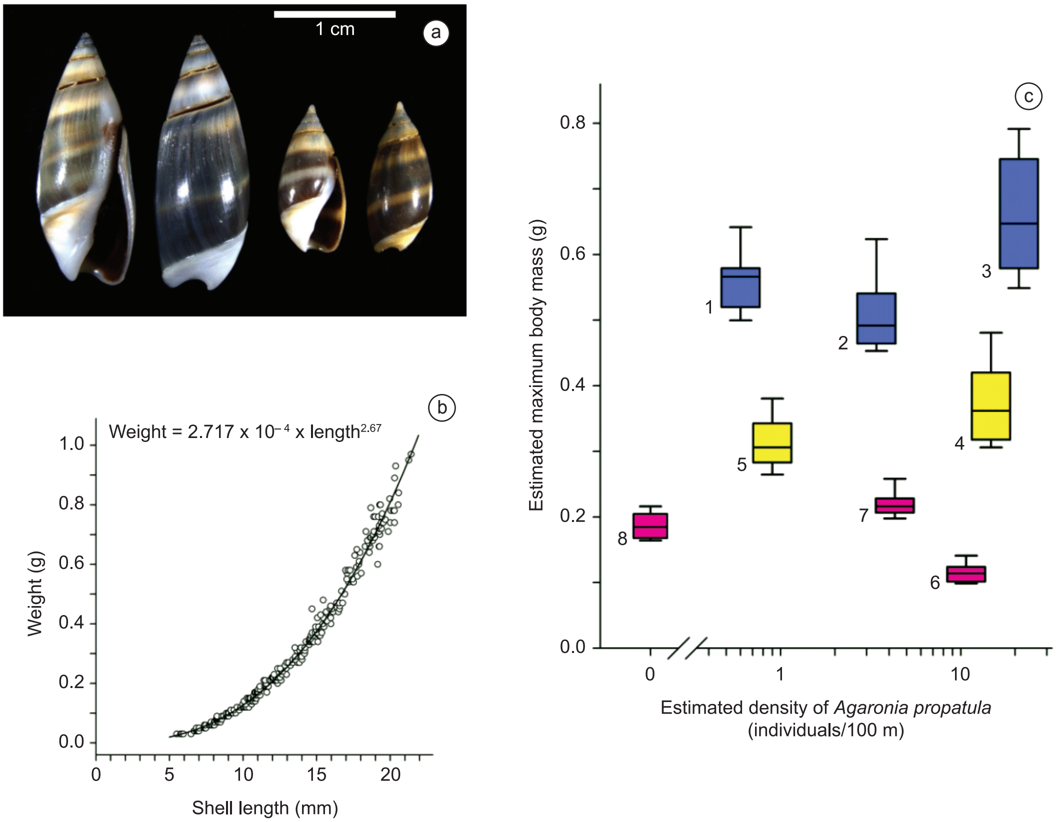

Figure 7. Dependence of maximum body mass reached by *O. semistriata* on local ecological conditions prevailing at selected test beaches (sites 1 to 8; see Table 1 and Figure 2 for details). a) Example of size differentiation; representative shells of the largest size classes found at site 2 (Playa Avellana; left) and site 8 (Bahia Junquillal; right). b) Empirical relationship between shell length and body mass established in the population at site 3 (Playa Grande; $n = 266$). c) Box plots of the body masses of the largest 25 individuals found at each test beach (boxes represent the central quartiles, and whiskers mark the 5th and 95th percentiles of these groups of 25). The abscissa represents the estimated density of the predatory gastropod *Agaronia propatula* as a measure of the predation pressure *O. semistriata* is exposed to at the test beaches. Box plots are color coded to indicate high (blue), intermediate (yellow), and low (magenta) exposure to wave energy (see Table 1 for further details).

reach invalid conclusions. For example, the maximum shell size in *O. semistriata* is understated by about one third in the current identification literature (Burch & Burch 1963 p. 5, Keen 1971 p. 632), which suggests that the authors studied specimens exclusively from populations in which only moderate body sizes were reached. In 1851, small *O. semistriata* actually were described as a separate species, *'O. attenuata'*, by Reeve, an author who obviously was familiar with the typical, large *O. semistriata*. The error was recognized first by Weinkauff in 1878 who, intriguingly, is the only classical author to report similar maximum shell lengths for *O. semistriata* as we do (22 mm). Weinkauff found that some specimens in batches of collected *'O. attenuata'* showed the striae typical of *O. semistriata*, and concluded that *'O. attenuata'* "[...] certainly is nothing but a small variety of *O. semistriata*." (Weinkauff 1878 p. 145; our translation). We infer that the specimens in which Weinkauff saw the typical striation were the very largest ones in those batches, because this is what we found in *'O. attenuata'* samples in the collection of the Natural History Museum, London. Snails classified in this collection as *'O. attenuata'* usually are below 9 mm shell length, but the few larger individuals often show faint striae on the posterior body whorl. From these facts it is evident that earlier researchers repeatedly mistook small *O. semistriata* for a different taxon, indicating that they must have encountered populations that lacked larger, semi-striated shells, which would have revealed their true identity. The observed continuation of 'dwarfish' populations over prolonged periods requires at least one of two possible mechanisms. First, the members of the population may acquire reproductive maturity and produce offspring without ever reaching the phenotypic (morphological) maturity observed in other populations. This mechanism would be in line with the open, isometric growth pattern in this species (Figure 6) that may enable the animals to mature physiologically at variable body sizes that are appropriate for different sets of environmental conditions. Alternatively, 'dwarfish' populations may be pseudopopulations, maintained solely through the continuous recruitment of individuals from other areas. Which of the two possibilities is correct in *O. semistriata* cannot be decided on the basis of the information available at this time.

Conclusions

Considering the ecological significance of *Pachyoliva* species that is suggested by their large densities, it certainly is desirable to identify them unequivocally in the field in future studies. From our analysis of diagnostic characters, we conclude that the three traits of the shell commonly listed as criteria by which *O. columellaris* and *O. semistriata* can be distinguished – development of parietal and spire callus, presence of striae on the body whorl, and shell shape – work well in large specimens but not in smaller animals which contribute the majority of individuals in all of the populations that we have studied in the field. For the field biologist attempting to establish the identity of a *Pachyoliva* population, it will be essential to examine the larger individuals of that population. Small animals are not identifiable on the basis of shell morphology and will have to be classified through their association with larger, identifiable specimens in the population. Presumably this will be unproblematic in most regions, since no mixed populations of *O. columellaris* and *O. semistriata* have been reported so far. Moreover, the geographic distributions of the two species do not seem to overlap as broadly as has been assumed in the past.

Although our comparative studies on eight test beaches utilized relatively crude measures for the potential impact of human activities and pollution, the beach character in terms of exposure to wave energy, and predation pressure, we obtained support for the idea that *O. semistriata* develops the dwarfish phenotype in response to the physical environment, more specifically low wave exposure. The clear distinction between genetic and environmental control mechanisms of morphological variability has long been considered essential for an understanding of the evolutionary significance of phenotypic variation in gastropods (Johnson & Black 1998, Trussell & Etter 2001, Conde-Padin et al. 2009), but whether this distinction is meaningful or even possible also has been doubted (Urdy et al. 2010a). At this time, it remains unclear how much, if any, of the local variability in *O. semistriata* body size is genetically fixed. However, the large differences in body size between populations that can be easily quantified, and the easily accessible, huge numbers of individuals in each local population, make *O. semistriata* a particularly convenient model for the study of the regulation of phenotypic variability. Moreover, the significance of *O. semistriata's* isometric development for this regulation as well as for the evolution of phenotypic plasticity could be addressed through studies including its allometricly growing sister species, *O. columellaris*. With the present paper we have paved the way for such comparative investigations by resolving the taxonomic ambiguities that marred the earlier literature.

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References

AERTS, K., VANAGT, T., DEGRAER, S., GUARTATANGA, S., WITTOECK, J., FOCKEDEY, N., CORNEJO-RODRIGUEZ, M.P., CALDERÓN J. & VINCX, M. 2004. Macrofaunal community structure and zonation of an Ecuadorian sandy beach. Belg. J. Zool. 134:17-24.

BOUCHET, P. & ROCROI, J.-P. 2005. Classification and nomenclator of gastropod families. Malacologia 47:1-397.

BURCH, J.Q. & BURCH, R.L. 1963. Genus *Olivella* in eastern Pacific. Nautilus 77:1-8. Plus 3 plates.

CONDE-PADIN, P., CABALLERO, A. & ROLÁN-ALVAREZ, E. 2009. Relative role of genetic determination and plastic response during ontogeny for shell-shape traits subjected to diversifying selection. Evolution 63:1356-1363.

CONRAD, T.A. 1849. The following new and interesting shells are from the coasts of lower California and Peru, and were presented to the academy by Dr. Thomas B. Wilson. Proc. Acad. Nat. Sci. Philadelphia 4:155-156.

CYRUS, A.Z., RUPERT, S.D., SILVA, A.S., GRAF, M., RAPPAPORT, J.C., PALADINO, F.V. & PETERS, W.S. 2012. The behavioral and sensory ecology of *Agaronia propatula* (Olividae, Caenogastropoda), a swash-surfing predator on sandy beaches of the panamic faunal province. J. Mollus. Stud. 78:235-245. http://dx.doi.org/10.1093/mollus/eys006

DAVIES, M.S. & HAWKINS, S.J. 1998. Mucus from marine molluscs. Adv. Mar. Biol. 34:1-71.

DECLERCK, C.H. 1995. The evolution of suspension feeding in gastropods. Biol. Rev. 70:549-569.

FRIEDRICH, H. 1969. Marine biology. University of Washington Press, Seattle.

GRAY, J.E. 1839. Molluscous animals, and their shells. In The Zoology of Captain Beechey's Voyage (J. Richardson, N.A. Vigors, G.T. Lay, E.T. Bennett, R. Owen, J.E. Gray, W. Buckland & G.B. Sowerby, eds.). Henry G. Bohn, London, p.101-155.

HOLLANDER, J., ADAMS, D.C. & JOHANNESSON, K. 2006. Evolution of adaptations through allometric shifts in a marine snail. Evolution 60:2490-2497.

HUGHES, R.N. 1986. A functional biology of marine gastropods. Johns Hopkins University Press, Baltimore.

JOHANNESSON, B. 1986. Shell morphology of *Littorina saxatilis* Olivi: the relative importance of physical factors and predation. J. Exp. Mar. Biol. Ecol. 102:183-195.

JOHNSON, M.S. & BLACK, R. 1998. Effects of habitats on growth and shape of contrasting phenotypes of *Bembicium vittatum* Philippi in the Houtman Abrolhos Islands, Western Australia. Hydrobiologia 378:95-103.

JOHNSON, M.S. & BLACK, R. 2000. Associations with habitat versus geographic cohesiveness: size and shape of *Bembicium vittatum* (Gastropoda: Littorinidae) in the Houtman Abrolhos Islands. Biol. J. Linnean Soc. 71:563-580.

JOHNSON, M.S. & BLACK, R. 2008. Adaptive responses of independent traits to the same environmental gradient in the intertidal snail *Bembicium vittatum*. Heredity 101:83-91.

KEEN, A.M. 1971. Sea shells of tropical west America. Stanford University Press, Stanford.

KEMP, P. & BERTNESS, M.D. 1984. Snail shape and growth rates: evidence for plastic shell allometry in *Littorina littorea*. Proc. Nat. Acad. Sci. USA 81:811-813.

LAWS, E.A. & ARCHIE, J.W. 1981. Appropriate use of regression analysis in marine biology. Mar. Biol. 65:13-16.

LÓPEZ, A., MONTOYA, M. & LÓPEZ, J. 1988. A review of the genus *Agaronia* (Olividae) in the panamic province and the description of two new species from Nicaragua. Veliger 30:295-304.

OLSSON, A.A. 1923-1924. Notes on marine molluscs from Peru and Ecuador. Nautilus 37:120-130.

OLSSON, A.A. 1956. Studies on the genus *Olivella*. Proc. Acad. Nat. Sci. Philadelphia 108:155-225.

REEVE, L.A. 1851. Monograph of the genus *Oliva* (Conchologia Iconica 6). L. Reeve & Co., London.

RUPERT, S.D. & PETERS, W.S. 2011. Autotomy of the posterior foot in *Agaronia* (Olividae, Caenogastropoda) occurs in animals that are fully withdrawn into their shells. J. Mollus. Stud. 77:437-440.

SCHUSTER, O. 1952. *Olivella columellaris* un caracol de la playa de Los Blancos. Comm. Inst. Tropical Invest. Cientif., Univers. El Salvador 4:10-13.

SCHUSTER-DIETERICHS, O. 1956. Die Makrofauna am sandigen Brandungsstrand von El Salvador (mittelamerikanische Pazifikküste). Senckenberg. Biol. 37:1-56.

SEILACHER, A. 1959. Schnecken im Brandungssand. Natur u. Volk 89:359-366.

SOWERBY, G.B. 1825. A catalogue of the shells contained in the collection of the late Earl of Tankerville, arranged according to the Lamarckian conchological system; together with an appendix, containing descriptions of many new species. E.J. Sterling, London.

TRUSSELL, G.C. 1996. Phenotypic plasticity in an intertidal snail: the role of a common crab predator. Evolution 50:448-454.

TRUSSELL, G.C. & ETTER, R.J. 2001. Integrating genetic and environmental forces that shape the evolution of geographic variation in a marine snail. Genetica 112-113:321-337.

TURSCH, B. 1997. Non-isometric growth and problems of species delimitation in the genus *Oliva*. Apex 12:93-100.

TURSCH, B. & GERMAIN, L. 1985. Studies on the Olividae. I. A morphometric approach to the *Oliva* problem. Indo-Malay. Zool. 2:331-352.

URDY, S., GOUDEMAND, N., BUCHER, H. & CHIRAT, R. 2010a. Growth-dependent phenotypic variation of molluscan shells: implications for allometric data interpretation. J. Exp. Zool. (Mol. Develop. Evol.) 314B:280-302. PMid:20084667. http://dx.doi.org/10.1002/jez.b.21338

URDY, S., GOUDEMAND, N., BUCHER, H. & CHIRAT, R. 2010b. Allometries and the morphogenesis of the molluscan shell: a quantitative and theoretical model. J. Exp. Zool. (Mol. Develop. Evol.) 314B:303-326. PMid:20084667. http://dx.doi.org/10.1002/jez.b.21337

VANAGT, T. 2007. The role of swash in the ecology of Ecuadorian sandy beach macrofauna, with special reference to the surfing gastropod *Olivella semistriata*. PhD thesis, Ghent University, Belgium. http://www.vliz.be/imisdocs/publications/125753.pdf (last accessed 05/11/2011).

VANAGT, T., VINCX, M. & DEGRAER, S. 2008a. Can sandy beach molluscs show an endogenously controlled circatidal migrating behaviour? Hints from a swash rig experiment. Mar. Ecol. 29 (Suppl. 1):118-125.

VANAGT, T., VINCX, M. & DEGRAER, S. 2008b. Is the burrowing performance of a sandy beach surfing gastropod limiting for its macroscale distribution? Mar. Biol. 155:387-397.

WEINKAUFF, H.C. 1878. Die Gattung *Oliva* (Systematisches Conchylien-Cabinet von Martini und Chemnitz, Vol. 5 Abt. 1). Bauer & Raspe, Nürnberg.

WELLINGTON, G.M. & KURIS, A.M. 1983. Growth and shell variation in the tropical eastern Pacific intertidal gastropod genus *Purpura*: ecological and evolutionary implications. Biol. Bull. 164:518-535.

YEAP, K.L., BLACK, R. & JOHNSON, M.S. 2001. The complexity of phenotypic plasticity in the intertidal snail *Nodilittorina australis*. Biol. J. Linnean Soc. 72:63-76.

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Errata

TROOST, A.I., RUPERT, S.D., CYRUS, A.Z., PALADINO, F.V., DATTILO, B.F. & PETERS, W.S. What can we learn from confusing *Olivella columellaris* and *O. semistriata* (Olivellidae, Gastropoda), two key species in panamic sandy beach ecosystems? Biota Neotrop. 12(2): http://www.biotaneotropica.org.br/v12n2/en/abstract?article+bn02112022012

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O. semistriata; O. columellaris; O. columellaris; Olivella columellaris

Leia-se:

O. semistriata; O. columellaris; O. columellaris Olivella columellaris

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City beach of *Puntarenas*

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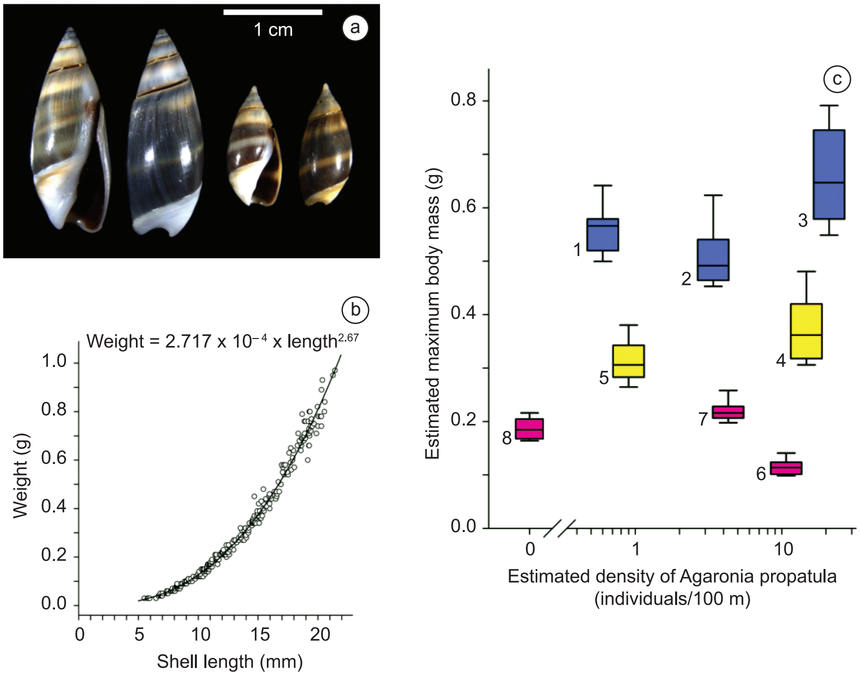

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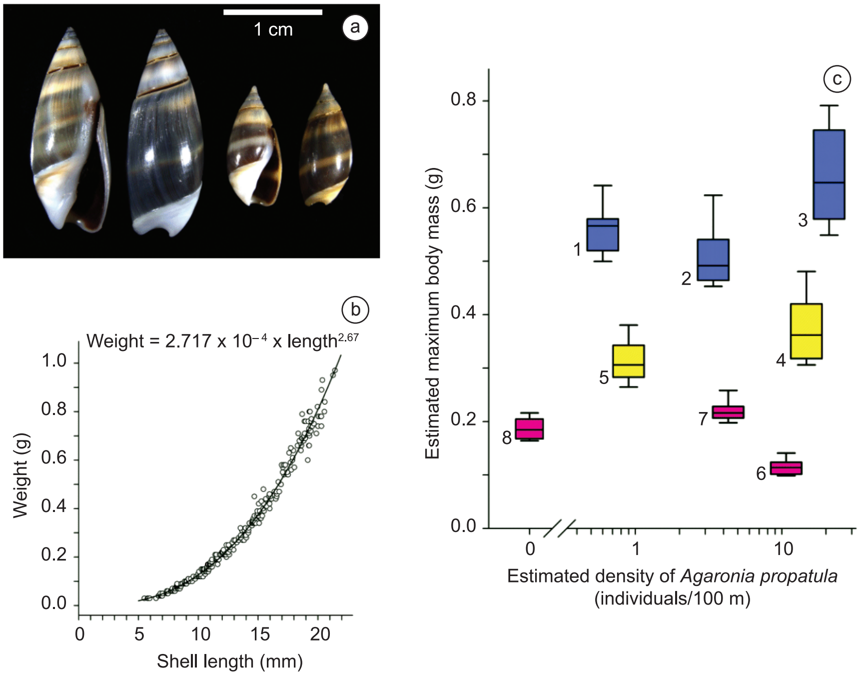

Survey of orchidaceae from the State of Sergipe, Brazil

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Abstract: The state of Sergipe, located in the Northeast Region of Brazil, covers an area of 21,994 km^2 and is the smallest state in the country. The vegetation of this region is predominantly *caatinga*, but there are also mangroves, dunes, *restinga*, fragments of original Atlantic Forest (which are intermingled with pastures, secondary growth, and agricultural land) and *cerrado*. During intensive fieldwork in Sergipe, we observed various Orchidaceae species that had not been recorded for the state, which made it necessary to update the list of species for this region. Within the state, the family is represented by 63 species and 34 genera, of which *Habenaria* (10 spp.) *Epidendrum* (4 spp.) and *Encyclia* (4 spp.) are highlights. Orchidaceae species from this region are generally terrestrial and occur in grasslands (59%, 37 of 63 spp.). The remaining species are epiphytes (21 spp.) and hemiepiphytes (3 spp.). The majority of the species flower at the beginning of the rainy season. Of the 61 species that were recorded during this study, 34 species are new records for the state of Sergipe. This work includes a list of the species of Orchidaceae from Sergipe, and provides data about the phenology and habitat for each taxon.
Keywords: *plants of the Northeast, inventory, plant biodiversity.*

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Resumo: O estado de Sergipe, localizado na região Nordeste do Brasil, abrange uma área de 21.994 km^2, sendo o menor da federação. A cobertura vegetal predominante do estado é representada pela Caatinga, mas encontra-se também vegetação de mangue, dunas, restingas, fragmentos florestais, originários da Mata Atlântica, entremeados por áreas de pastagens, capoeiras e áreas agrícolas, além de formações de Cerrado. A partir de um intenso trabalho de campo, observou-se a ocorrência de diversas Orchidaceae ainda não catalogadas para o estado, portanto, fazendo-se necessária a atualização na listagem das espécies ocorrentes em Sergipe. A família está representada no estado por 63 espécies subordinadas a 34 gêneros, dentre os quais se destacam: *Habenaria* (10 spp.) *Epidendrum* (4 spp.) e *Encyclia* (4 spp.). As espécies encontradas ocorrem principalmente nas formações campestres (59%, 37 de 63), o que explica a predominância da forma de vida terrestre. As demais espécies estão distribuídas em epífitas (21 spp.) e hemiepífitas (3 spp.). A maioria das espécies floresce no início do período chuvoso. Dentre as 63 espécies encontradas 34 são novas ocorrências para o estado de Sergipe. Este trabalho inclui listagem das espécies ocorrentes em Sergipe, assim como dados fenológicos e habitat.
Palavras-chave: *plantas do nordeste, inventário, biodiversidade vegetal.*

Introduction

Orchidaceae comprise approximately 40% of the monocotyledons, and are considered by many authors as the largest family of angiosperms (Dahlgren et al. 1985, Atwood 1986, Dressler 1993). Atwood (1986) estimates that the family possesses 24,500 species worldwide, which are mostly native to tropical regions. The most significant revision of Brazilian Orchidaceae suggests that there are 2350 species in the country (Pabst & Dungs 1975, 1977); however, a recent publication lists 2419 species (Barros et al. 2010). According to Hoehne (1949), species of Orchidaceae can be found in every vegetation type in Brazil.

The majority of the floristic works about Orchidaceae of Brazil have concentrated on the Southern and Southeast regions of the country. For the Northeast Region, there are very few studies about the occurrence and distribution of the family, and for many states the only information available is in the last Brazilian checklist of Orchidaceae (Pabst & Dungs 1975, 1977).

For the state of Sergipe, the most recent information about native orchids can be found in the *Catálogo de Plantas e Fungos do Brasil* (Barros et al. 2010). This work is based on collections from the main herbaria in the country as well as lists of Orchidaceae that were previously compiled by specialists, and, for this reason, underestimates the number of species that occur in many states.

Although Sergipe is the smallest state in Brazil (21.918 km^2), which primarily has a semi-arid climate, it possesses a diverse flora represented by different phytophysiognomies, for example, coastal vegetation, Atlantic Forest, *caatinga*, and savanna (Franco 1983). According to the checklists published by Pabst & Dungs (1975, 1977) and Barros et al. (2010), the number of orchids recorded for the state is six and 22, respectively. Besides these works, there are no other studies that include additional species.

Based on recent collections and specimens in local herbaria, it was discovered that the number of Orchidaceae species recorded for Sergipe was not accurate. Therefore, the goals of this study were to survey the Orchidaceae of Sergipe and to create an updated list of species that occur in the different vegetation types of this state.

Materials and Methods

Sergipe occupies an area of 21,918 km², and shares its border with Alagoas (to the north), Bahia (to the west and south), and the Atlantic Ocean (to the east). The vegetation cover in Sergipe is composed principally of steppe savanna (*caatinga*), seasonal semi-deciduous forest (secondary Atlantic Forest fragments), pioneer formations (*restinga* and mangroove), grasslands (*cerrado*), and areas of ecological transition (steppe savanna/seasonal forest, savanna/ seasonal forest and savanna/steppe savanna); however, the majority of the vegetation cover in the sate has been altered by agricultural activities and other human disturbances (classification based on Instituto… 1992). Although IBGE (Instituto Brasileiro de Geografia e Estatística) provides a comprehensive map of the vegetation cover of Brazil, the classification used in the map does not include some regional formations, such as open formations with white-sand soils, which occur in Parque Nacional da Serra de Itabaiana, in Sergipe, and are in transition areas with seasonal, semi-deciduous forest. The white-sand formations have sedimentary, yellowish white, sandy soils with an herb-shrub to shrub-tree vegetation that occurs at lower elevations than the grasslands (Dantas & Ribeiro 2010). In addition, the IBGE map does not include (for the sate of Sergipe) the islands of montane, seasonal, semi-deciduous forest that are in the areas of *caatinga*. In the Northeast Region of Brazil, the wet, high altitude forests are enclaves of humid Atlantic Forest that are in the middle of the semi-arid region (Tabarelli & Santos 2004), commonly known as *brejos de altitude*. This forest type is encountered in the Serra da Guia, in the municipality of Poço Redondo, in the northeastern part of the state (Machado, W. dados não publicados).

The inventory of Sergipe was conducted via random monthly samples at different times of the year, from December 2008 to December 2010, and surveyed the major vegetation types in the municipalities visited (Figure 1). As a result of human disturbance and exploitation of the land, the vegetation in Sergipe is in an advanced stage of degradation. For this reason, the municipalities selected for this study were those with remnants of original vegetation that were well preserved.

In addition, specimens were examined from herbaria at the Universidade Federal de Sergipe (ASE), Universidade Estadual de Feira de Santana (HUEFS), Universidade Federal da Bahia (ALCB), IBGE (HRB – RADAMBRASIL-BA) and Companhia Hidro-Elétrica do São Francisco (Herbário Xingó, which is not listed in Index Herbariorum), and the collections of the Universidade Federal de Minas Gerais (BHCB) and Universidade Federal do Ceará (EAC) were searched using Species-link do Centro de Referências em Informação Ambiental (CRIA). During fieldwork, plants were collected and information was recorded about their life form (according to Bechtel et al. 1998), phenology and the habitat where they grow. Sterile species were collected and cultivated (until they flowered) in the garden of the Departamento de Biologia at the Universidade Federal de Sergipe. All specimens, including those that flowered in cultivation, were deposited in ASE.

To identify the species, specialists in the family and Pabst & Dungs (1975, 1977), Cogniaux (1893-1896, 1898-1902, 1904-1906), Hoehne (1940, 1942, 1945, 1949, 1953), and Toscano-de-Brito & Cribb (2005) were consulted. The subfamilies and subtribes recognized in this work are based on Chase et al. (2003).

Results and Discussion

This inventory recorded 63 species of Orchidaceae (Table 1, Figure 2-3), distributed in three subfamilies, 11 subtribes and 34 genera. Vanilloideae, with four species in two genera, represented 7% of the total species. Orchidoideae, with 18 species in seven genera and three subtribes, represented 29% of the total species. Epidendroideae, with 41 species in 24 genera and eight subtribes, represented 64% of the total species. The main flowering periods were between January and March, and September and December, which corresponded to the beginning and end of the rainy season.

Of the species recorded, the predominant life form was terrestrial (37 spp., 59%), 37% were epiphytes (23 spp.) and 4% were hemiepiphyes (3 spp.). *Encyclia alboxanthina* Fowlie and *Brassavola tuberculata* Hook., were encountered as terrestrial/ rupicolous and epiphytic/rupicolous, respectively. The high proportion of terrestrial species is probably because of the vast field formations (grasslands) found in the state, which are natural or the result of human activity. The genus with the most species was

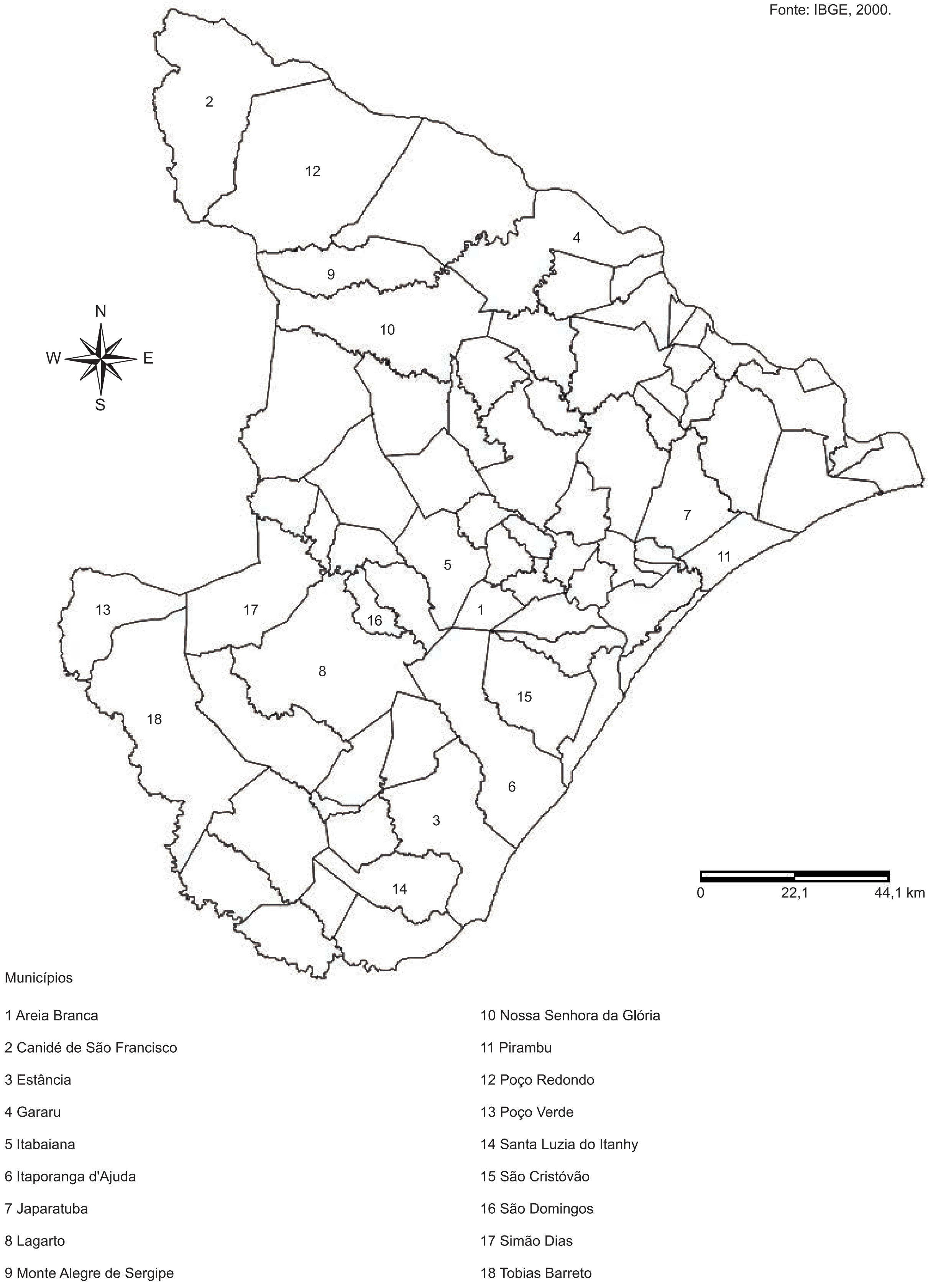

Figure 1. Map showing the municipalities visited during the Survey of Orchidaceae in Sergipe.

Table 1. Orchidaceae occurring in the state of Sergipe, Brazil.

Taxon	Life form	Habitat	Flowering	Subfamilie	Subtribe	Voucher
Brassavola tuberculata Hook	E, R	SSF	DEC	Epidendroideae	Laeliinae	Santos, L.A.S. 140 (ASE)
**Campylocentrum micranthum* (Lindl.) Rolfe	E	SSF	MAR	Epidendroideae	Angraecinae	Santos, L.A.S. 128 (ASE)
**Campylocentrum neglectum* (Rchb.f. & Warm.)	E	SSF	AUG	Epidendroideae	Angraecinae	Nascimento-Júnior, J.E. 145 (ASE)
**Catasetum* cf. *saccatum* Lindl.	E	N.I	SEP	Epidendroideae	Catasetinae	Lima, A.C. 626 (ASE)
**Catasetum hookeri* Lindl.	E	SS	MAR	Epidendroideae	Catasetinae	Santos, L.A.S. 137 (ASE)
Catasetum purum Nees & Sinning	E	SS	MAR	Epidendroideae	Catasetinae	Santos, L.A.S. 134 (ASE)
**Catasetum discolor* Lindl.	T	SSF /R	NOV	Epidendroideae	Catasetinae	Carregosa-Silva, T. 100 (ASE)
**Cattleya labiata* Lindl.	E	BA	MAR	Epidendroideae	Laeliinae	Santos, L.A.S. 139 (ASE)
**Cranichis candida* (Barb.Rodr.) Cogn.	T	BA	JUL	Orchidoideae	Cranichidinae	Machado, W.J. 454 (ASE)
**Cyrtopodium brandonianum* Barb. Rodr.	T	N.I	APR	Epidendroideae	Catasetinae	Prata, A.P. 1200 (ASE)
**Cyrtopodium flavum* Link & Otto ex Rchb.	T	WSF	JAN	Epidendroideae	Catasetinae	Santos, L.A.S. 62 (ASE)
**Cyrtopodium holstii* L.C. Menezes	T	SS	MAR	Epidendroideae	Catasetinae	Santos, L.A.S. 138 (ASE)
**Cyrtopodium parviflorum* Lindl.	T	GRA	DEC	Epidendroideae	Catasetinae	Carregosa-Silva, T. 206(ASE)
Dichaea cf. *panamensis* Lindl.	E	SSF	SEP	Epidendroideae	Zygopetalinae	M. Landim, 103 (ASE)
Dimerandra emarginata (G.Mey) Hoehne	E	SSF	SEP	Epidendroideae	Laeliinae	Silva, A.C. 65 (ASE)
Encyclia alboxanthina Fowlie	T/R	WSF	JAN	Epidendroideae	Laeliinae	Santos, L.A.S. 59 (ASE)
Encyclia dichroma (Lindl.) Schltr	T	WSF	JAN/MAR	Epidendroideae	Laeliinae	Santos, L.A.S. 64 (ASE)
Encyclia oncidioides Lindl.	T	SSF	DEC	Epidendroideae	Laeliinae	M.F. Landim, 1087 (ASE)
Encyclia patens Hook.	T	GRA	JAN	Epidendroideae	Laeliinae	Santos, L.A.S. 58 (ASE)
Epidendrum cinnabarinum Salzm.	T	WSF/R	MAY	Epidendroideae	Laeliinae	Carregosa-Silva, T. 117 (ASE)
Epidendrum orchidiflorum Salzm. ex Lindl.	T	WSF/R	FEBFEB/MAR	Epidendroideae	Laeliinae	Carregosa-Silva, T. 24 (ASE)
**Epidendrum rigidum* Jacq.	E	BA	MAR	Epidendroideae	Laeliinae	Santos, L.A.S. 129 (ASE)
Epidendrum secundum Jacq.	T	GRA	FEB	Epidendroideae	Laeliinae	Carregosa-Silva, T. 25 (ASE)
Epistephium lucidum Cogn	T	GRA	DEC	Vanilloideae	Vanillinae	Santos, L.A.S. 448 (ASE)
**Erycina pusilla* (L.) N.H.Williams & M.W.Chase	E	SS	APR	Epidendroideae	Oncidiinae	Carregosa-Silva, T. 44 (ASE)
Galeandra montana Barb. Rodr.	T	GRA	JUN	Epidendroideae	Catasetinae	Santos, L.A.S. 182 (ASE)
Gomesa barbata (Lindl.) M.W.Chase & N.H.Williams	E	APF	AUG	Epidendroideae	Oncidiinae	Santos, L.A.S. 06 (ASE)
Habenaria fluminensis Hoehne	T	GRA	JUN	Orchidoideae	Orchidinae	Santos, L.A.S. 183 (ASE)
**Habenaria depressifolia* Hoehne	T	SS	MAY	Orchidoideae	Orchidinae	Viana, G. 1443 (ASE)
Habenaria goyazensis Cogn.	T	SS	JUL	Orchidoideae	Orchidinae	Viana, G. 1530 (ASE)
Habenaria obtusa Lindl.	T	GRA	JUN	Orchidoideae	Orchidinae	Santos, L.A.S. 184 (ASE)
**Habenaria parviflora* Lindl.	T	SSF	FEB	Orchidoideae	Orchidinae	Santos, L.A.S. 170 (ASE)
Habenaria petalodes Lindl.	T	WSF/GRA	JUL	Orchidoideae	Orchidinae	Santos, L.A.S. 191 (ASE)
Habenaria pratensis (Lindl.) Rchb.f.	T	SSF	SEP	Orchidoideae	Orchidinae	Santos, L.A.S. 08 (ASE)

Life form: E = epiphyte, HE = hemiepiphytic, R = rupiculous, T = terrestrial. Habitat: BA = Brejo de altitude, SS = steppe savanna (caatinga), FES = seasonal semi-deciduous forest (secondary Atlantic Forest fragments), APF = Area of pasture to seasonal semi-deciduous forest, APS = Area of pasture to steppe savanna, GRA = grasslands (cerrado), R = Restinga, WSF = White sand field. Flowering period: JAN = January, FEB = February, MAR = March, APR = April, AUG = August, SEP = September, OCT = October, NOV = November, DEC = December. N.I. = No information. UFS=Universidade Federal de Sergipe. * = New records.

Table 1. Continued...

Taxon	Life form	Habitat	Flowering	Subfamilie	Subtribe	Voucher
**Habenaria rotundiloba* Pabst	T	APS	MAR/APR	Orchidoideae	Orchidinae	Nascimento-Júnior, J.E. 593 (ASE)
**Habenaria schenckii* Cogn.	T	BA	AUG	Orchidoideae	Orchidinae	Santos, L.A.S. 194 (ASE)
Habenaria trifida Kunth	T	APF/GRA	SEP/MAY	Orchidoideae	Orchidinae	Costa, S.M. 594 (ASE)
**Hapalorchis lineatus* (Lindl.) Schltr.	T	BA	OCT	Orchidoideae	Spiranthinae	Costa, S.M. 610 (ASE)
Jacquiniella globosa (Jacq.) Schltr.	E	GRA	JAN	Epidendroideae	Laeliinae	Mendes et al. 328 (UFP)
**Ionopsis utricularioides* (Sw.) Lindl.	E	SSF	NOV	Epidendroideae	Oncidiinae	Santos, L.A.S. 54 (ASE)
**Liparis loeselii* (L.) Rich.	T	GRA	JUL	Epidendroideae	Laeliinae	Carregosa-Silva, T. 98 (ASE)
Liparis nervosa (Thunb.) Lindl.	T	SSF /GRA	MAY	Epidendroideae	Laeliinae	Santos, L.A.S. 174 (ASE)
**Lockhartia gaoyazensis* Rchb. f.	E	SSF	FEB	Epidendroideae	Oncidiinae	G. Viana, 1680 (ASE)
**Notylia barkerii* Lindl.	E	APS	DEC	Epidendroideae	Oncidiinae	Santos, L.A.S. 11 (ASE)
Oeceoclades maculata (Lindl.) Lindl.	T	SSF	OCT	Epidendroideae	Eulophiinae	Santos, L.A.S. 23 (ASE)
**Prescottia plantaginea Lindl.*	T	SS	OCT	Orchidoideae	Cranichidinae	Machado, W. J. 784 (ASE)
**Prosthechea aemula* (Lindl.) WE Higgins	E	N.I	APR	Epidendroideae	Laeliinae	Grown in a greenhouse at the UFS
Polystachya estrellensis Rchb.f.	T	FES	OCT	Epidendroideae	Polystachyinae	Carregosa-Silva, T. 3 (ASE)
**Sacoila lanceolata* (Aubl.) Garay	T	APS	MAR	Orchidoideae	Spiranthinae	Carregosa-Silva, T. 26 (ASE)
**Sarcoglottis acaulis* (SM) Schltr.	T	APS	OCT	Orchidoideae	Spiranthinae	Carregosa-Silva, T. 2 (ASE)
**Sarcoglottis curvisepala* Szlach. & Rutk.	T	GRA	SEP	Orchidoideae	Spiranthinae	Costa, S.M. 473 (ASE)
**Sarcoglottis fasciculata* (Vell.) Schltr.	T	APS	AUG	Orchidoideae	Spiranthinae	Viana, G. 623 (ASE)
Scaphyglottis fusiformis (Griseb.) Schult.	E	SSF	JAN	Epidendroideae	Laeliinae	Mendes et al. 327 (UFP).
Scaphyglottis sickii Pabst.	E	SSF	SEP	Epidendroideae	Laeliinae	M. Landim 1029 (ASE)
Sobralia liliastrum Lindl.	T	WSF	JAN	Epidendroideae	Eulophiinae	Santos, L.A.S. 60 (ASE)
**Trichocentrum cebolleta* (Jacq.) M.W.Chase & N.H.Williams	E	SSF	NOV	Epidendroideae	Oncidiinae	Santos, L.A.S. 53 (ASE)
**Trichocentrum pulmilum* M.W.Chase & N.H.Williams	E	SSF	OCT	Epidendroideae	Oncidiinae	Carregosa-Silva, T. 01 (ASE)
Trigonidium acuminatum Batem. ex Lindl.	E	SSF	DEC	Epidendroideae	Maxillariinae	Grown in a greenhouse at the UFS
Vanilla bahiana Hoehne	HE	SSF	FEB	Vanilloideae	Vanillinae	Santos, L.A.S. 449 (ASE)
**Vanilla planifolia* Jacks. ex Andrews	HE	SSF	APR	Vanilloideae	Vanillinae	Souza, C.A.S. 21 (ASE)
**Vanilla palmarum* (Salzm. ex Lindl.) Lindl.	HE	APS	AUG	Vanilloideae	Vanillinae	Santos, L.A.S. 01 (ASE)
**Veyretia rupicola* (Barb. Rodr.) F. Barros	T	GRA	DEC	Orchidoideae	Spiranthinae	Santos, L.A.S. 447 (ASE)
**Zygostates* sp.	E	BA	MAR	Epidendroideae	Oncidiinae	Santos, L.A.S. 136 (ASE)

Life form: E = epiphyte, HE = hemiepiphytic, R = rupiculous, T = terrestrial. Habitat: BA = Brejo de altitude, SS = steppe savanna (caatinga), FES = seasonal semi-deciduous forest (secondary Atlantic Forest fragments), APF = Area of pasture to seasonal semi-deciduous forest, APS = Area of pasture to steppe savanna, GRA = grasslands (cerrado), R = Restinga, WSF = White sand field. Flowering period: JAN = January, FEB = February, MAR = March, APR = April, AUG = August, SEP = September, OCT = October, NOV = November, DEC = December. N.I. = No information. UFS=Universidade Federal de Sergipe. * = New records.

Figure 2. Some species of orchids in Sergipe. a. *Catasetum hookeri*, b. *Catasetum purum*, c. *Cattleya labiata*, d. *Cyrtopodium holstii*, e. *Cyrtopodium polyphyllum*, f. *Dimerandra emarginata*, g. *Encyclia dichroma*, h. *Encyclia oncidioides*, i. *Epidendrum cinnabarinum*, j. *Epidendrum orchidiflorum*. Photos: SHNM (a,b,e,g,h,j), LASS (c,d,i) e TCS (f).

Habenaria (10 spp.), which was very common in fields (Batista & Bianchetti 2003, Batista et al. 2005, Rocha & Waechter 2006).

Of the 63 species recorded, 29 have already been cited for the state (see Barros et al. 2010; Pessoa & Alves 2011). The remaining species (34 spp., see Table 1) are cited for the first time for Sergipe. *Encyclia advena* (Rchb.f.) Porto & Brade, *Encyclia bohnkiana* V.P.Castro & Campacci, *Encyclia osmantha* (Barb.Rodr.) Schltr., *Habenaria josephensis* Barb.Rodr., *Leochilus labiatus* (Sw.) Kuntze, *Liparis vexillifera* (Llave & Lex.) Cogn. and *Trichocentrum fuscum* Lindl., cited in Barros et al. (2010) for Sergipe, were not encountered during the fieldwork of this study, the review of specimens, or during the search for taxa in the Species Link database. This is probably because some of the species listed by Barros et al. (2010) came from misidentified collections (which was observed during the current study) based on previously compiled lists.

The 34 species that are new records for the state of Sergipe demonstrate how significant floristic work can be to our understanding of the biological diversity of a region, and how this type of work can

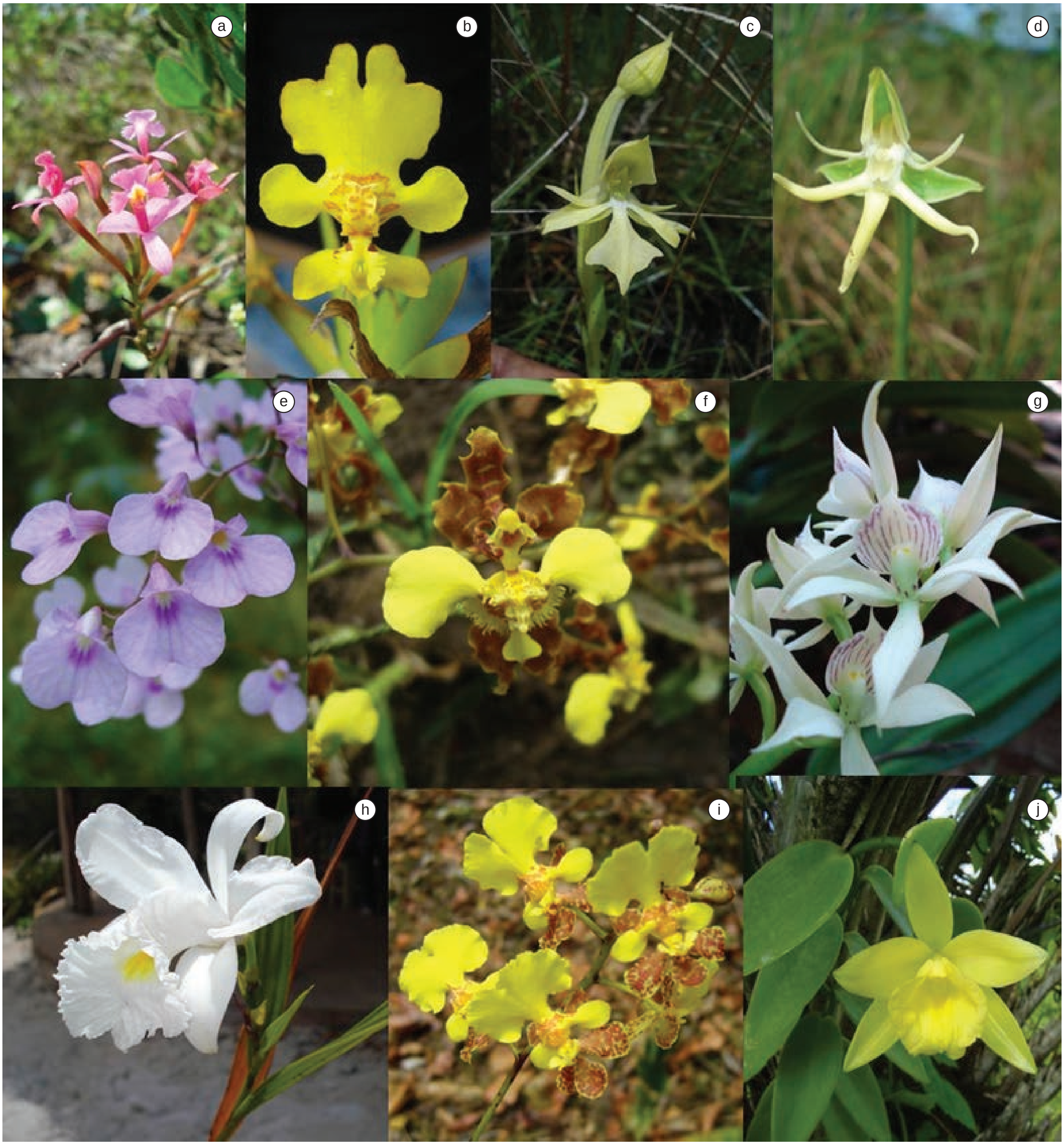

Figure 3. Some species of orchids in Sergipe. a. *Epidendrum secundum*, b. *Erycina pusilla*, c. *Habenaria pratensis*, d. *Habenaria trifida*, e. *Ionopsis utricularioides*, f. *Gomesa barbata*, g. *Prosthechea aemula*, h. *Sobralia liliastrum*, i. *Trichocentrum cebolleta*, j. *Vanilla palmarum*. (Photos: SHNM (a,c,d,g,h), LASS (e,f,i,j) e TCS (b).

contribute to our knowledge about the species and distribution of a taxonomic group.

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References

ATWOOD, J.T. 1986. The size of the Orchidaceae and the systematic distribution of epiphytic Orchids. Selbyana 9(1):171-186.

BARROS, F., VINHOS, F., RODRIGUES, V.T., BARBERENA, F.F.V.A. & FRAGA, C.N. 2010. Orchidaceae in Lista de Espécies da Flora do Brasil. Jardim Botânico do Rio de Janeiro, Rio de Janeiro. http://floradobrasil.jbrj.gov.br/2010/FB000179.

BATISTA, J.A.N. & BIANCHETTI , L.B. 2003. Lista atualizada das Orchidaceae do Distrito Federal. Acta Bot. Bras. 17(2):183-201.

BATISTA, J.A.N., BIANCHETTI, L.B. & PELLIZZARO, K.F. 2005. Orchidaceae da Reserva Ecológica do Guará, DF, Brasil. Acta Bot. Bras. 19(2):221-232.

BECHTEL, H., CRIBB, P.J. & LAUNERT, E. 1998. The manual of cultivated Orchid species. Blandford, London, 585p.

CHASE, M.W., CAMERON, K.M., BARRETT, R.L. & FREUDENSTEIN, J.V. 2003. DNA data and Orchidaceae systematics: a new phylogenetic classification. In Orchid Conservation Natural History Publications (K.W. Dixon, S.P. Kell, R.L. Barrett & P. J. Cribb, eds.). Kota Kinabalu, Sabah, p.69-89.

COGNIAUX, A. 1893-1896. Orchidaceae. In Flora brasiliensis (C.F.P. Martius, A.G. Eichler & I. Urban, eds.). F. Fleischer, Munique, v.3, parts 4, 672p.

COGNIAUX, A. 1898-1902. Orchidaceae. In Flora brasiliensis (C.F.P. Martius, A.G. Eichler & I. Urban, eds.). R. Oldenbourg, Munique, v.3, parts 5, 664p.

COGNIAUX, A. 1904-1906. Orchidaceae. In Flora brasiliensis (C.F.P. Martius, A.G. Eichler & I. Urban, eds.). R. Oldenbourg, Munique, v.3, parts 6, 604p.

DAHLGREN, R.M.T., CLIFFORD, H.T. & YEO, P.F. 1985. The families of the monocotyledons. Springer-Verlag, Berlin, 520p.

DANTAS, T.L. & RIBEIRO, A.S. 2010. Caracterização da vegetação do Parque Nacional Serra de Itabaiana, Sergipe – Brasil. Biotemas 23(4):9-18.

DRESSLER, R.L. 1993. Phylogeny and classification of the orchid family. Dioscorides Press, Portland, 314p.

HOEHNE, F.C. 1940. Flora Brasílica. Secretaria da Agricultura, Indústria e Comércio de São Paulo, São Paulo, v.12.1, fasc.1, 254p.

HOEHNE, F.C. 1942. Flora Brasílica. Secretaria da Agricultura, Indústria e Comércio de São Paulo, São Paulo, v.12.6, fasc.5, 218p.

HOEHNE, F.C. 1945. Flora Brasílica. Secretaria da Agricultura, Indústria e Comércio de São Paulo, São Paulo, v.12.2, fasc.8, 389p.

HOEHNE, F.C. 1949. Iconografia de orquidáceas do Brasil. S. A. Indústrias Graphicars-f. Lanzara, São Paulo, 601p.

HOEHNE, F.C. 1953. Flora Brasílica. Secretaria da Agricultura, Indústria e Comércio de São Paulo, São Paulo, v.12.7, fasc.10, 396p.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA – IBGE. Departamento de Recursos Naturais e estudos ambientais. Manual técnico da vegetação Brasileira. IBGE, Rio de Janeiro, 92p. Série Manuais Técnicos em Geociências, n.1.

PABST, G.F.J. & DUNGS, F. 1975. Orchidaceae Brasiliensis. Brucke-Verlag Kurt Schmersow, Hildeshein, v.1, 408p.

PABST, G.F.J. & DUNGS, F. 1977. Orchidaceae Brasiliensis. Brucke-Verlag Kurt Schmersow, Hildeshein, v.2, 418p.

PESSOA, E. & ALVES, M. 2011. Orchidaceae Juss. Na Serra de Itabaiana, Sergipe, Brasil. Rev. Caatinga 24(4):102-114.

ROCHA, F.S. & WAECHTER, J.L. 2006. Sinopse das Orchidaceae terrestres ocorrentes no litoral norte do Rio Grande do Sul, Brasil. Acta Bot. Bras. 20(1):71-86.

TABARELLI, M. & SANTOS, A.M.M. 2004. Uma breve descrição sobre a história natural dos brejos nordestinos. In Brejos de altitude em Pernambuco e Paraíba: história natural, ecologia e conservação (K.C. Porto, J.J.P. Cabral & M. Tabarelli, eds.). Brasília, Ministério do Meio Ambiente, p.17-24.

TOSCANO-DE-BRITO, A.L.V. & CRIBB, P. 2005. Orquídeas da Chapada Diamantina. Nova Fronteira, Rio de Janeiro, 400p.

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Borboletas (Lepidoptera: Papilionoidea e Hesperioidea) da porção norte da Chapada Diamantina, Bahia, Brasil

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Abstract: The knowledge of butterflies (Lepidoptera: Papilionoidea and Hesperioidea) diversity in Caatinga biome is incipient when compared to the others Brazilian's biomes. Areas considered as priorities for biodiversity conservation in the Caatinga still remain with poor knowledge about their lepidopteran fauna diversity such as the Chapada Diamantina. A study of the diversity of butterflies supported by Programa de Pesquisa em Biodiversidade to the Semiarid region (PPBio) was carried out in two areas considered as priorities for biodiversity conservation in the Caatinga from Bahia State, Morro do Chapéu and Senhor do Bonfim located in the northern portion of the Chapada Diamantina. The samples were realized in dry seasons. A total of 169 species was identified and two of them are new species. Nymphalidae was richest among others butterflies families with 82 species. Two species were registered as endemic to Caatinga.
Keywords: *biodiversity, inventory, Caatinga, Semi-arid.*

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Resumo: O conhecimento sobre a diversidade de borboletas (Lepidoptera: Papilionoidea e Hesperioidea) no bioma Caatinga é incipiente quando comparado aos demais biomas brasileiros. Áreas consideradas como prioritárias para a conservação da biodiversidade da Caatinga, ainda permanecem com conhecimento escasso acerca da diversidade da fauna de lepidópteros, como é o caso da região da Chapada Diamantina. Um estudo sobre a diversidade borboletas, financiado pelo Programa de Pesquisa em Biodiversidade do Semiárido (PPBio), foi realizado em duas áreas consideradas como prioritárias para a conservação da biodiversidade da Caatinga no estado da Bahia, Morro do Chapéu e Senhor do Bonfim, localizadas na porção norte da Chapada Diamantina. Foram registradas 169 espécies, das quais duas são espécies novas. Nymphalidae foi a família de maior riqueza, com 82 espécies. Duas espécies endêmicas para a Caatinga foram registradas.
Palavras-chave: *biodiversidade, inventário, Caatinga, Semiárido.*

Introdução

A Cadeia do Espinhaço é um conjunto montanhoso disjunto que se estende desde a porção norte do estado de Minas Gerais até a calha do Rio São Francisco, Bahia (Rocha et al. 2005). Neste último estado, a Cadeia do Espinhaço recebe a denominação de Chapada Diamantina, composta pela Serra do Rio de Contas (Pico das Almas), Serra do Sincorá, Serra do Tombador e Serra da Jacobina (Davis et al. 1997), todas inseridas no Semiárido baiano.

O bioma Caatinga é predominante no Semiárido brasileiro, sendo caracterizado por uma grande variedade de tipos vegetacionais, desde arbustos espinhosos até florestas sazonalmente secas (Eiten 1992, Giulietti et al. 2004) que se distribuem em oito estados do nordeste: Bahia, Alagoas, Sergipe, Pernambuco, Paraíba, Ceará Rio Grande do Norte e Piauí. Está inserido entre as isoetas de 280-1000 mm/ano e as chuvas são distribuídas praticamente pelo período de três a seis meses (Eiten 1992, Instituto... 1992, Velloso et al. 2002, Leal et al. 2005).

Apesar de ser um bioma exclusivamente brasileiro, a Caatinga é um dos mais ameaçados e menos protegidos, com menos de 1% destinado a unidades de conservação de proteção integral (Leal et al. 2005). Na Bahia, destacam-se o Parque Nacional da Chapada Diamantina, o Parque Estadual de Morro do Chapéu e a Área de Proteção Ambiental da Gruta dos Brejões/Vereda do Romão Gramacho (Bahia 2007). Entretanto, outras áreas ainda não preservadas da Chapada Diamantina são consideradas de extrema prioridade para a conservação da biodiversidade da Caatinga pelo Ministério do Meio Ambiente (Brasil 2002).

Ao contrário do que se acreditava (Mares et al. 1985, Willig &Mares 1989), estudos recentes com fungos e anuros tem demonstrado a importância da Caatinga para manutenção da biodiversidade (e.g. Almeida et al. 2011, São-Pedro & Feio 2011), assim como, foram reconhecidos endemismos para abelhas, plantas e aves (Martins 2002, Giulietti et al. 2004, Roos et al. 2006). Entretanto, poucos trabalhos vêm sendo realizados neste bioma quando comparado a Mata Atlântica, Cerrado e Floresta Amazônica, principalmente no que diz respeito aos lepidópteros (Brandão & Yamamoto 2003, Santos et al. 2008).

São conhecidos três trabalhos sobre a diversidade de Lepidoptera na Caatinga sobre Sphingidae nos estados da Paraíba (Gusmão & Creão-Duarte 2004), Pernambuco (Duarte Junior & Schlindwein 2005) e Rio Grande do Norte (Duarte Junior 2001), além de inventários de Papilionoidea e Hesperioidea em Pernambuco (Nobre et al. 2008, Paluch et al. 2011). Também foram publicadas listas de espécies de borboletas no Semiárido baiano, nas quais foram incluídas áreas de Caatinga (Zacca 2009) e um ecótono entre Mata Atlântica e Caatinga (Zacca et al. 2011). Nenhum inventário deste cunho foi publicado para a Chapada Diamantina, área considerada de maior prioridade para produção de inventários de borboletas (Santos et al. 2008). Para esta área são conhecidos apenas dois trabalhos, um sobre novas ocorrências de espécies de Nymphalidae na Serra do Sincorá (Cardoso 2005) e o outro com o registro de uma nova subespécie de Papilionidae no Pico das Almas (Casagrande & Mielke 2007).

Sendo assim, o presente trabalho tem como objetivo elaborar a primeira lista de espécies de borboletas para a Chapada Diamantina, visto a total escassez de dados para a região.

Material e Métodos

1. Áreas de estudo

O presente estudo foi desenvolvido em áreas de Caatinga selecionadas pelo Programa de Pesquisa em Biodiversidade (PPBio), nos municípios de Morro do Chapéu e Senhor do Bonfim, situados na porção norte da Chapada Diamantina.

Morro do Chapéu, localizado a 388 km de distância de Salvador, situa-se na ecorregião do Complexo Chapada Diamantina (Velloso et al. 2002). Possui altitudes que variam de 480 m a 1290 m e uma precipitação média anual de 726 mm, com períodos chuvosos de outubro a abril (Velloso et al. 2002). A cobertura vegetal é diversificada, variando entre florestas secas ou formações de caatinga arbórea nas encostas e vegetação de cerrado no topo dos tabuleiros (Prado 2003). Foram amostradas quatro localidades pertencentes a este município: Cachoeira do Ferro Doido, Fazenda Capão do Pinho, Lagoa Preta e Morrão (Tabela 1).

A Serra de Jacobina, situada na ecorregião da Depressão Sertaneja Meridional (Velloso et al. 2002), é formada por um complexo montanhoso que se estende por 200 km no sentido norte-sul, um prolongamento mais ao nordeste da Chapada Diamantina. De acordo com a classificação de Thronthwaite & Mater (1995), apresenta clima úmido a sub-úmido, com temperatura média anual de 24 °C e índices pluviométricos acima de 477,6 mm/ano, com dois períodos chuvosos distintos de outubro a abril (Velloso et al. 2002). Tal como indica Velloso et al. (2002), a presença de vários rios e lagoas nessa região propicia uma maior diversidade de plantas e animais. Neste complexo,

Tabela 1. Informações sobre as localidades amostradas.

Table 1. Informations about the sampled locations.

Localidades	Coordenadas geográficas	Altitude (m)	Formação vegetacional
Morro do Chapéu			
Cachoeira do Ferro Doido	11° 37' 40" S and 41° 00' 02" W	900	Campo rupestre com afloramentos rochosos associados a uma fisionomia herbáceo-arbustiva e mata ciliar
Fazenda Capão do Pinho	11° 36' 30" S and 41° 01' 06" W	850	Campo aberto com plantação de maracujá (Passiflora, Passifloraceae)
Lagoa Preta	11° 36' 84" S and 41° 09' 52" W	1099	Caatinga-Cerrado associada a solos arenosos
Morrão	11° 35' 31" S and 41° 12' 57" W	1288	Campo rupestre com afloramentos rochosos associados a uma fisionomia herbáceo-arbustiva
Senhor do Bonfim			
Serra da Maravilha	10° 23,95' S and 40° 12,49' W	700-1000	Caatinga arbustiva a arbórea de porte alto
Serra Santana	10° 21' 53,7" S and 40° 11' 45,3" W	739	Caatinga arbustiva a arbórea de porte alto
Serra da Fumaça	10° 28' 43" S and 40° 12' 27,6" W	490	Campo rupestre com afloramentos rochosos associados a uma fisionomia herbáceo-arbustiva

destacam-se as localidades amostradas no presente estudo: Serra da Fumaça, Serra da Maravilha e Serra Santana (Tabela 1).

A Serra da Maravilha e a Serra Santana pertencem ao município de Senhor do Bonfim, a 390 km de distância de Salvador. Possuem entre 700m e 1000 m de altitude, e a vegetação típica de caatinga é menos expressiva, tendo associações com a Floresta Estacional Semidecidual (Castelletti et al. 2003). A Serra da Fumaça abrange os municípios de Antônio Gonçalves, Campo Formoso, Pindobaçu e Senhor do Bonfim, sendo este último a área amostrada no presente estudo. Possui altitudes que variam entre 400m e 1100 m e vegetação predominante heterogênea, com contatos entre cerrado-Floresta Estacional Semidecidual, Cerrado-Caatinga e Campo rupestre (Castelletti et al. 2003, Brasil 2005).

2. *Amostragem*

Foram realizadas coletas não sistematizadas em todas as localidades, sendo em Morro do Chapéu nos períodos de 30.IX.2008 a 02.X.2008 e 22-25.VI.2009, e em Senhor do Bonfim nos períodos de 24-27.XI.2006, 19-22.VII.2009, 23-26.IX.2009 e 14-17.XII.2009, em áreas situadas fora de unidades de conservação.

A coleta dos indivíduos foi realizada com rede entomológica por um único coletor, seguindo trilhas pré-existentes ao longo de cada localidade, das 9 horas às 17 horas, totalizando 392 horas de esforço amostral. Também foram utilizadas armadilhas com isca de banana fermentada em caldo-de-cana, dispostas aleatoriamente na borda e no interior da vegetação, a uma altura de aproximadamente 2 m.

Os exemplares foram depositados na Coleção Entomológica Prof. Johann Becker do Museu de Zoologia da Universidade Estadual de Feira de Santana (MZUEFS), Bahia, Brasil. A classificação taxonômica segue a proposta de Lamas (2004).

Resultados e Discussão

Foram identificadas 169 espécies de borboletas (Tabela 2). Nymphalidae foi a família mais representativa, com 82 espécies (50%), seguida de Hesperiidae com 40 espécies (23%), Riodinidae com 16 espécies (10%), Lycaenidae com 14 espécies (8%), Pieridae com 13 espécies (7%) e Papilionidae com 4 espécies (2%).

A proporção da riqueza das famílias de borboletas observadas nas duas áreas manteve-se para cada uma das áreas amostradas, sendo Nymphalidae aquela com maior número de espécies registradas (Figura 1). Entretanto, a composição faunística de Morro do Chapéu e Senhor do Bonfim mostrou-se diferente, com a co-ocorrência de apenas 27 espécies e similaridade de 16% delas (Tabela 2). Tal resultado pode ser explicado pelo menor esforço amostral empregado em Morro do Chapéu (com apenas duas excursões), bem como as coletas terem sido realizadas apenas em período seco nesta localidade. Como demonstrado também no estudo de Nobre et al. (2008), a diversidade de borboletas na Caatinga parece ser maior em período chuvoso.

Algumas espécies registradas apenas em período chuvoso por Nobre et al. (2008) foram encontradas, nesse estudo, no período seco (representadas por * na Tabela 2). Os riodinídeos *Leucochimona icare mathata*, Isapis sp., *Barbicornis acroleuca bahiana*, *Melanis xenia*, *Melanis xenia*, *Juditha azan azan* e *Dynamine tithia tithia* foram encontradas exclusivamente às margens de rios na Serra Santana e Serra da Fumaça.

Do total de espécies listadas, 68% (115 espécies) da fauna de borboletas é composta por espécies com registros em áreas de Cerrado (Brown Junior & Mielke 1967a, b, Emery et al. 2006) e 56% (95 espécies) de Mata Atlântica (Brown Junior & Freitas 2000). Esse número significativo de espécies compartilhado entre os biomas pode ser explicado pelo mosaico vegetacional encontrado nas áreas amostradas, principalmente em Senhor do Bonfim (Tabela 1).

É importante ressaltar que muitas espécies podem ocorrer em hábitats específicos (Tabela 3), gerando subsídios para a utilização de borboletas como bioindicadores de hábitat. Isto pode ser exemplificado com o registro das espécies *Fountainea halice moretta* e *Hypna clymnestra forbesi* apenas para a Caatinga (Tabela 2). Por outro lado, apesar de *Adelpha iphicleola leucates* e *Pyrgus veturius* terem sido registradas apenas para a Caatinga, quando comparado com demais inventários (Tabela 2), não devem ser consideradas endêmicas devido a existência de exemplares dessas espécies, depositados na coleção entomológica Pe. Jesus Santiago Moure do Departamento de Zoologia da Universidade do Paraná (DZUP), com registros para a Mata Atlântica e Cerrado.

Quando os resultados do presente estudo são comparados com dois inventários realizados na Caatinga em Pernambuco, Parque Nacional do Catimbau (Nobre et al. 2008) e Parque Ecológico João Vasconcelos Sobrinho (Paluch et al. 2011), apenas 50% (86 espécies) das borboletas são compartilhadas entre as três áreas. O número de espécies para as áreas da Chapada Diamantina (169 espécies) é maior que o registrado para o Parque Nacional do Catimbau (121 espécies), porém menor que no Parque Ecológico João Vasconcelos Sobrinho (191 espécies). A similaridade e diferente riqueza de espécies nas distintas áreas de Caatinga devem, no futuro, ser estudadas desde um enfoque mais holístico onde sejam considerados aspectos bióticos e abióticos.

A maioria das espécies registradas na Chapada Diamantina possui ampla distribuição geográfica no Brasil, fato também corroborado em estudos realizados no Cerrado e na Caatinga (Brown Junior & Mielke 1967a, b, Nobre et al. 2008, Paluch et al. 2011). Entretanto, duas espécies novas foram encontradas, uma de *Lucida* (Hesperiidae) e outra de *Isapis* (Riodinidae), sendo a primeira amplamente distribuída até o sul do Brasil (O. Mielke com. pess.).

A porcentagem de 23% para Hesperiidae, coletadas na Chapada Diamantina, não estão de acordo com resultados de outros inventários realizados na Mata Atlântica (Mielke 1994, Carneiro et al. 2008, Dolibaina et al. 2011), nos quais os hesperídeos tem sido apontados com a maior riqueza. A sub-amostragem de Hesperiidae é comum em inventários de borboletas (Bonfantti et al. 2009, Vasconcelos et al.

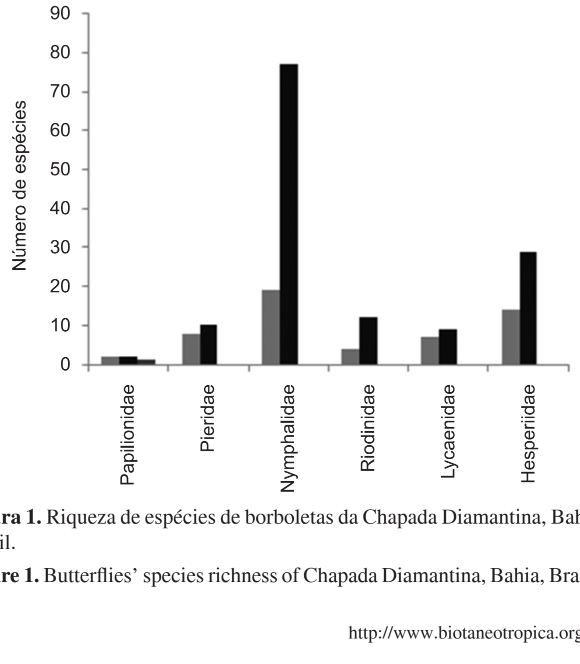

Figura 1. Riqueza de espécies de borboletas da Chapada Diamantina, Bahia, Brasil.

Figure 1. Butterflies' species richness of Chapada Diamantina, Bahia, Brazil.

Tabela 2. Borboletas da porção norte da Chapada Diamantina, Bahia, Brasil. Legendas: M = Morrão, F = Cachoeira do Ferro Doido, L = Lagoa Preta, C = Fazenda Capão do Pinho, SM = Serra da Maravilha, SS = Serra Santana e SF = Serra da Fumaça; 1 = espécies registradas para a Caatinga (Nobre et al. 2008, Paluch et al. 2011); 2 = espécies registradas para a Mata Atlântica (Brown Junior & Freitas 2000); 3 = espécies registradas para o Cerrado (Brown Junior & Mielke 1967a, b, Emery et al. 2006); * espécies registradas em períodos chuvosos na Caatinga (Nobre et al. 2008).

Table 2. Butterflies of the northern portion of the Chapada Diamantina, Bahia, Brazil. Legends: M = Morrão, F = Cachoeira do Ferro Doido, L = Lagoa Preta, C = Fazenda Capão do Pinho, SM = Serra da Maravilha, SS = Serra Santana e SF = Serra da Fumaça; 1 = species of Caatinga biome (Nobre et al. 2008, Paluch et al. 2011); 2 = species of Atlantic Rainforest (Brown Junior & Freitas 2000); 3 = species of Cerrado biome (Brown Junior & Mielke 1967a, b, Emery et al. 2006; * species presents in rain seasons in the Caatinga biome (Nobre et al. 2008).

Taxon	M	F	L	C	SM	SS	SF	1	2	3
Papilionidae (N = 4)										
Papilioninae										
Battus polydamas polydamas (Linnaeus, 1758)						X	X	●	●	●
Heraclides anchisiades capys (Hübner, [1809])						X		●*	●	●
Heraclides thoas brasiliensis Rothschild & Jordan, 1906			X					●	●	●
Protesilaus helios (Rothschild & Jordan, 1906)	X									●
PIERIDAE (N = 13)										
Coliadinae										
Anteos clorinde (Godart, [1824])			X		X		X	●	●	●
Anteos menippe (Hübner, [1818])			X					●	●	●
Eurema albula albula (Cramer, 1775)				X	X	X	X	●	●	●
Eurema arbela gracilis (Avinoff, 1926)					X	X				
Eurema elathea flavescens (Chavannes, 1850)			X	X		X		●		●
Phoebis sennae marcellina (Cramer, 1777)			X		X			●	●	●
Pyrisitia leuce leuce (Boisduval, 1836)	X					X			●	●
Pyrisitia nise tenella (Boisduval, 1836)			X			X	X	●	●	●
Pierinae										
Ascia monuste orseis (Godart, 1819)			X			X	X	●	●	●
Aphrissa statira statira (Cramer, [1777])							X	●	●	●
Ganyra phaloe endeis (Godart, 1819)		X								
Glutophrissa drusilla (Cramer, 1777)						X		●*	●	
Itaballia demophile nimietes (Fruhstorfer, 1907)						X				
NYMPHALIDAE (N = 82)										
Biblidinae										
Hamadryas amphinome amphinome (Linnaeus, 1767)							X	●	●	●
Hamadryas arete (Doubleday, 1847)							X	●	●	
Hamadryas epinome (C.Felder & R. Felder, 1867)						X		●	●	●
Hamadryas februa februa (Hübner, [1823])						X	X	●	●	●
Hamadryas feronia feronia (Linnaeus, 1758)						X	X	●	●	●
Hamadryas iphthime iphthime (Bates, 1864)						X		●	●	●
Hamadryas laodamia laodamia (Cramer, 1777)						X	X		●	●
Biblis hyperia nectanabis (Fruhstorfer, 1909)			X		X	X	X	●*		●
Temenis laothoe bahiana Fruhstorfer, 1907							X			●
Callicore sorana sorana (Godart, [1824])					X	X		●	●	●
Callicore pygas pygas (Godart, 1824])						X				
Eunica macris (Godart, [1824])		X					X			●
Eunica maja maja (Fabricius, 1775)							X		●	
Eunica tatila bellaria Fruhstorfer, 1908			X				X	●		●

Tabela 2. Continuação...

Taxon	M	F	L	C	SM	SS	SF	1	2	3
Eunica bechina magnipunctata Talbot, 1928						X				
Myscelia orsis (Drury, 1782)						X	X	●	●	
Pyrrhogyra neaerea susarion Fruhstorfer, 1909						X	X	●		
Dynamine agacles agacles (Dalman, 1823)						X		●*		●
Dynamine artemisia (Fabricius, 1793)					X	X			●	●
Dynamine coenius albidula A.G. Weeks, 1901						X	X			●
Dynamine postverta postverta (Cramer, 1779)					X			●		●
Dynamine tithia tithia (Hübner, 1823)						X		●	●	●
Mestra dorcas hypermestra Hübner, 1825				X	X	X		●*	●	●
Charaxinae										
Fountainea glycerium cratais (Hewitson, 1874)					X	X	X			●
Fountainea halice moretta (H.Druce, 1877)		X			X	X		●		
Hypna clymnestra forbesi Goldman & Salvin, 1884						X	X	●		
Memphis acidalia victoria (Druce, 1877)						X	X			●
Zaretis itys (Cramer, 1777)						X	X			●
Archaeoprepona demophon demophon (Linnaeus, 1758)						X			●	●
Prepona laertes demodice (Godart, [1824])							X	●		●
Danainae										
Danaus eresimus plexaure (Cramer, [1777])							X	●*	●	●
Danaus gilippus gilippus (Cramer, 1775)					X	X		●*	●	●
Lycoria halia discreta Haensch, 1909						X		●		●
Heliconiinae										
Euptoieta hegesia hegesia (Cramer, 1779)			X		X	X	X	●	●	
Agraulis vanillae maculosa (Stichel, [1908])					X	X	X	●	●	●
Dryas iulia iulia (Fabricius, 1775)						X	X			●
Eueides aliphera (Godart, 1819)						X			●	●
Eueides isabella dianasa (Hübner, [1806])						X		●	●	●
Melinaea ethra (Godart, 1819)							X			
Heliconius erato phyllis (Fabricius, 1775)				X	X	X	X	●	●	●
Heliconius ethilla narcaea (Godart, 1819)				X		X	X	●	●	●
Heliconius sara apseudes (Hübner, [1813])			X	X	X			●	●	
Ithomiinae										
Aeria olena olena Weymer, 1875							X		●	●
Dircenna dero rhoeo C. Felder & R. Felder, 1860						X			●	●
Episcada carcinia Schaus, 1902						X				
Episcada hymenaea hymenaea (Prittwitz, 1865)					X	X	X	●		●
Episcada sp.										
Ithomia drymo Hübner, 1816						X		●		●
Ithomia sp.					X					
Mechanitis lysimna nesaea Hübner, [1820]						X	X	●		●
Methona themisto (Hübner, 1818)							X		●	●
Scada reckia reckia (Hübner, [1808])						X	X	●		
Hypothyris ninonia daeta (Boisduval, 1836)						X		●	●	●

Tabela 2. Continuação...

Taxon	M	F	L	C	SM	SS	SF	1	2	3
Hypothyris euclea laphria (Doubleday, 1847)						X	X		●	●
Limenitidinae										
Adelpha cytherea aea (C. Felder & R. Felder, 1867)						X	X	●		●
Adelpha iphicleola leucates Fruhstorfer, 1915							X	●*		
Adelpha plesaure plesaure Hübner, 1823				X			X			
Nymphalinae										
Colobura dirce dirce (Linnaeus, 1758)							X		●	●
Anartia jatrophae jatrophae (Linnaeus, 1763)					X	X		●	●	●
Junonia evarete evarete (Cramer, [1779])		X			X	X	X	●	●	●
Historis odius dious Lamas, 1995							X	●	●	●
Smyrna blomfildia blomfildia (Fabricius, 1781)						X			●	●
Siproeta stelenes meridionalis (Fruhstorfer, 1909)							X	●	●	
Chlosyne lacinia saundersi (Doubleday, [1847])							X		●	●
Eresia lansdorfi (Godart, 1819)					X	X			●	●
Ortilia ithra (Kirby, 1900)					X	X		●*	●	●
Tegosa claudina (Eschscholtz, 1821)						X	X	●	●	●
Morphinae										
Eryphanis reevesii reevesii (Doubleday, [1849])						X		●	●	●
Satyrinae										
Hermeuptychia hermes (Fabricius, 1775)			X	X	X	X	X		●	●
Pareuptychia ocirrhoe interjecta (d'Almeida, 1952)							X	●	●	
Paryphthimoides eous (Butler, 1867)						X				●
Pharneuptychia innocentia (C. Felder & R. Felder, 1867)	X	X		X				●*		●
Pharneuptychia phares (Godart, [1824)			X		X	X		●		●
Cissia sp.						X				
Taygetis laches laches (Fabricius, 1793)						X	X	●	●	●
Taygetis tripunctata Weymer, 1907							X			●
Yphthimoides affinis (Butler, 1867)						X	X	●		●
Yphthimoides angularis (Butler, 1867)							X		●	
Yphthimoides manasses (C. Felder & R. Felder, 1867)						X		●		
Yphthimoides renata (Stoll, 1780)					X	X	X	●		●
Yphthimoides straminea (Butler, 1867)						X				●
Yphthimoides sp.						X				
RIODINIDAE (N = 16)										
Euselasiinae										
Euselasia thucydides thucydides (Fabricius, 1793)			X						●	●
Riodininae										
Aricoris campestris Bates 1868			X					●		●
Aricoris middletoni (Sharpe, 1890)			X							●
Aricoris sp.			X							
Echydna chaseba (Hewitson, 1854)						X			●	
Leucochimona icare mathata (Hewitson, 1873)					X	X			●	●
Barbicornis basilis bahiana Azzará, [1979]						X	X			

Tabela 2. Continuação...

Taxon	M	F	L	C	SM	SS	SF	1	2	3
Isapis sp.						X	X			
Juditha azan azan (Westwood, [1851])							X		●	●
Melanis xenia xenia (Hewitson, [1853])							X			
Nymphidium azanoides azanoides Butler, 1867							X			●
Calydna hiria (Godart, [1824])						X				
Calydna sturnula (Geyer, 1837)						X				
Calephelis sp.						X				
Panara jarbas (Drury, 1782)						X				
Thisbe irenea (Stoll, [1780])						X				
LYCAENIDAE (N = 14)										
Polyommatinae										
Hemiargus hanno (Stoll, 1790)			X			X		●	●	●
Celmia celmus (Cramer, [1775])							X		●	●
Evenus regalis (Cramer, [1775])							X			●
Leptotes cassius (Cramer, 1775)				X		X	X	●	●	●
Zizula cyna (Edwards, 1881)						X		●	●	●
Theclinae										
Pseudolycaena marsyas (Linnaeus, 1758)			X	X				●*	●	●
Rekoa palegon (Cramer, 1780)						X		●	●	●
Strymon astiocha (Prittwitz, 1865)			X			X		●	●	●
Strymon bazochii (Godart, [1824])		X						●*	●	●
Strymon bubastus (Stoll, 1780)						X		●		●
Strymon mulucha (Hewitson, 1867)					X	X		●*	●	●
Strymon rufofusca (Hewitson, 1877)			X			X	X	●		●
Theritas hemon (Cramer, [1775])							X	●		●
Tmolus echion (Linnaeus, 1767)						X			●	●
HESPERIIDAE (N = 40)										
Hesperiinae										
Arita arita (Schaus, 1902)						X	X		●	
Artines aquiline (Plötz, 1882)							X		●	
Callimormus saturnus (Herrich-Schäffer, 1869)						X			●	●
Cobalopsis miaba (Schaus, 1902)						X	X		●	
Cumbre belli eberti Evans 1955					X					●
Hylephila phyleus phyleus (Drury, [1773])				X				●*	●	●
Lento pyra Evans, 1955						X				
Lucida sp.						X				
Methionopsis ina (Plötz, 1882)					X			●*	●	●
Niconiades xanthaphes Hübner, [1821]						X	X		●	●
Nyctelius nyctelius nyctelius (Latreille, [1824])							X	●	●	●
Onophas columbaria distigma Bell, 1930	X								●	
Panoquina lucas (Fabricius, 1793)							X	●*	●	
Paracarystys menestries (Latreille, [1824])							X		●	
Pellicia sp.						X				

Tabela 2. Continuação...

Taxon	M	F	L	C	SM	SS	SF	1	2	3
Pompeius pompeius (Latreille, [1824])						X		●	●	●
Sodalia coler (Schaus, 1902)						X			●	
Synapte malitiosa equa Evans, 1955						X	X	●*		●
Vettius lafrenaye lafrenaye (Latreille, [1824])							X		●	
Pyrginae										
Autochton zarex (Hübner, 1818)						X	X	●	●	●
Phocides polybius phanias (Burmeister, 1880)	X									●
Polythrix octomaculata (Sepp, [1844])						X			●	●
Typhedanus undulatus (Hewitson, 1867)						X		●*	●	●
Urbanus chalco (Hübner, 1823)							X			
Urbanus dorantes dorantes (Stoll, 1790)				X			X	●	●	●
Urbanus procne (Plötz, 1880)						X		●*	●	●
Urbanus proteus proteus (Linnaeus, 1758)							X	●	●	●
Achlyodes mithridates thraso (Hübner, [1807])							X		●	
Cogia grandis Riley, 1921			X							●
Cogia sp.			X							
Gorgythion plautia (Möschler, 1877)						X	X			
Gorgythion sp						X				
Heliopetes arsalte (Linnaeus, 1758)							X	●	●	●
Heliopetes macaira (Reakirt, [1867])						X				●
Polyctor polyctor polyctor (Prittwitz, 1868)		X							●	●
Pyrgus orcus (Stoll, [1780])				X		X	X	●	●	●
Pyrgus veturius Plötz, 1884			X	X		X	X	●*		
Telemiades amphion marpesus (Hewitson, 1876)							X		●	●
Trina geometrina geometrina (C.Felder & R.Felder, 1867)						X				●

Tabela 3. Comparação da composição da fauna de borboletas do presente estudo com a Mata Atlântica (Brown Junior & Freitas 2000), Cerrado (Brown Junior & Mielke 1967a, b, Emery et al. 2006) e Caatinga (Nobre et al. 2008, Paluch et al. 2011).

Table 3. Butterflies fauna composition on present study in comparision with Atlantic Rainforest (Brown Junior & Freitas 2000), Cerrado (Brown Junior & Mielke 1967a, b, Emery et al. 2006) and Caatinga (Nobre et al. 2008, Paluch et al. 2011)

Bioma	Nº de espécies	Nº de espécies exclusivas
Mata Atlântica	95	11
Cerrado	115	19
Caatinga	86	6

2009, Ritter et al. 2011), principalmente pelos indivíduos dessa família apresentarem tamanho relativamente pequeno, padrões de coloração pouco chamativos e não serem atraídos por iscas de fruto fermentado, assim dificultando a sua coleta (Brown Junior & Freitas 1999, Caldas & Robbins 2003). Futuros estudos nas áreas de Caatinga devem por mais esforço de coleta em Hesperiidae para poder discutir se há erro de amostragem ou se nestas áreas são menos abundantes.

Por ser um estudo preliminar, há necessidade de mais coletas para melhorar o conhecimento sobre a diversidade da fauna de borboletas nesse bioma. Contudo, os dados obtidos neste estudo representam as únicas informações sobre a composição das espécies de borboletas da Chapada Diamantina, em áreas consideradas de extrema prioridade para conservação da biodiversidade, sendo primordial a sua disponibilização.

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Referências

ALMEIDA, D.A., IZABEL, T.S.S. & GUSMÃO, L.F.P. 2011. Fungos conidiais do bioma Caatinga I. Novos registros para o continente americano, Neotrópico, América do Sul e Brasil. Rodriguésia 62(1):043-053.

BAHIA (Estado). Secretaria do Meio Ambiente - SEMA. 2007. Unidades de conservação. http://www.meioambiente.ba.gov.br (último acesso em 10/2011).

BONFANTTI, D., DI MARE, R.A. & GIOVENARDI, R. 2009. Butterflies (Lepidoptera: Papilionoidea and Hesperioidea) from two forest fragments in northern Rio Grande do Sul, Brazil. Check List 5(4):819-829.

BRANDÃO, C.R.F. & YAMAMOTO, C.I. 2003. Invertebrados da Caatinga. In Biodiversidade da Caatinga: áreas e ações prioritárias para a conservação (J.M.C. Da Silva, M. Tabarelli, M.T. Fonseca & L.V. Lins, orgs). MMA, Brasilia, 382p.

BRASIL. Ministério do Meio Ambiente - MMA. 2002. Áreas prioritárias para a conservação da Caatinga. In Biodiversidade Brasileira: Avaliação e identificação de áreas e ações prioritárias para conservação, utilização sustentável e repartição dos benefícios da biodiversidade nos biomas brasileiros (Brazil. Secretaria de Biodiversidade e Florestas). MMA, Brasília, p.169-172.

BRASIL. Ministério de Minas e Energia - MME. 2005. Projeto cadastro de fontes de abastecimento por água subterrânea. Diagnóstico do município de Pindobaçu, estado da Bahia. CPRM/PRODEEM; Salvador, 14p.

BROWN JUNIOR, K.S. & FREITAS, A.V.L. 1999. Lepidoptera. In Biodiversidade do Estado de São Paulo, Brasil. Invertebrados terrestres (C.R.F. Brandão & E.M. Cancello, eds). FAPESP, São Paulo, p.227-243.

BROWN JUNIOR, K.S. & FREITAS, A.V.L. 2000. Diversidade de Lepidoptera em Santa Teresa, Espírito Santo. Bol. Mus. Biol. Mello Leitão 11-12:71-118.

BROWN JUNIOR, K.S. & MIELKE, O.H.H. 1967a. Lepidoptera of the Central Brazil Plateau. I. Preliminary list of Rophalocera: Introduction, Nymphalidae and Libytheidae. J. Lep. Soc. 21(2):77-106.

BROWN JUNIOR, K.S. & MIELKE, O.H.H. 1967b. Lepidoptera of the Central Brazil Plateau. I. Preliminary list of Rophalocera (continued): Lycaenidae, Pieridae, Papilionidae and Hesperiidae. J. Lep. Soc. 21(3):145-168.

CALDAS, A. & ROBBINS, R.K. 2003. Modified Pollard transects for assessing tropical butterfly abundance and diversity. Biol. Conserv. 110:211-219. http://dx.doi.org/10.1016/S0006-3207(02)00190-8

CARDOSO, M.Z. 2005. New localities for *Heliconius besckei* Ménétriés and *Heliconius sara* (Fabricius) (Lepidoptera: Nymphalidae) in Bahia, Brazil.. Neotrop. Entomol. 34(6):1007-1008. http://dx.doi.org/10.1590/S1519-566X2005000600018

CARNEIRO, E., MIELKE, O.H.H. & CASAGRANDE, M.M. 2008. Borboletas do sul da ilha de Santa Catarina, Florianópolis, Santa Catarina, Brasil (Lepidoptera: Hesperioidea e Papilionoidea). SHILAP 36(142):261-271.

CASAGRANDE, M.M. & MIELKE, O.H.H. 2007. Uma nova subespécie de *Parides bunichus* (Hübner) (Lepidoptera, Papilionidae, Troidini) do interior da Bahia, Brasil. Rev. Bras. Entomol. 51:301-304. http://dx.doi.org/10.1590/S0085-56262007000300008

CASTELLETTI, C.H.M., SANTOS, A.M.M., TABARELLI, M. & SILVA, J.M.C. 2003. Quanto ainda resta da Caatinga?: Uma estimativa preliminar. In Ecologia e conservação da Caatinga (I.R. Leal, M. Tabarelli & J.M.C. Silva, orgs). Editora Universitária, Universidade Federal de Pernambuco, Recife, p.719-796.

DAVIS S.D., HEYWOOD, V.H., McBRIDE, O.H., VILLA-LOBOS, J. & HAMILTON, A.C., eds. 1997. Centres of plant diversity: a guide and strategy for their conservation. WWF/IUCN, Cambridge, v.3.

DOLIBAINA, D., MIELKE, O.H.H. & CASAGRANDE, M.M. 2011. Borboletas (Papilionoidea e Hesperioidea) de Guarapuava e arredores, Paraná, Brasil: um inventário com base em 63 anos de registros. Biota Neotrop. 11(1): http://www.biotaneotropica.org.br/v11n1/pt/abstract?inventory+bn00211012011

DUARTE JUNIOR, J.A. 2001. Sphingidae (Lepidoptera) da Estação Ecológica do Seridó, Serra Negra do Norte, Rio Grande do Norte, Brasil. Entomol. Vect. 8:341-347.

DUARTE JUNIOR, J.A. & SCHLINDWEIN, C. 2005. The highly seasonal hawkmoth fauna (Lepidoptera: Sphingidae) of the Caatinga of northeast Brazil: a case study in the state of Rio Grande do Norte. J. Lep. Soc. 59(4):212-218.

EITEN, G. 1992. Natural Brazilian vegetation types and their causes. An. Acad. Bras. Ciênc. 64 (Suppl.1):35-65.

EMERY, E.O., BROWN JUNIOR, K.S. & PINHEIRO, C.E.G. 2006. As borboletas (Lepidoptera, Papilionoidea) do Distrito Federal, Brasil. Rev. Bras. Entomol. 50(1):85-92. http://dx.doi.org/10.1590/S0085-56262006000100013

GIULIETTI, A.M., BOCAGE NETA, A.L. & CASTRO, A.A.J.F. 2004. Diagnóstico da vegetação nativa do bioma da caatinga. In Biodiversidade da Caatinga: áreas e ações prioritárias para a conservação (J.M.C. Da Silva, M. Tabarelli, M.T. Fonseca & L.V. Lins, orgs). MMA-UFPE, Brasília, p.47-90.

GUSMÃO, M.A.B. & CREÃO-DUARTE, J.A. 2004. Diversidade e análise faunística de Sphingidae (Lepidoptera) em área de brejo e Caatinga no Estado da Paraíba, Brasil. Rev. Bras. Zool. 21:491-498.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA - IBGE. 1992. Manual técnico da vegetação brasileira. IBGE, Rio de Janeiro, 91p. Manuais técnicos em Geociências, n.1.

LAMAS, G. 2004. Checklist: Part 4A, Hesperioidea – Papilionoidea. In Atlas of Neotropical Lepidoptera (J. Heppner, ed.). Association for Tropical Lepidoptera, Scientific Publishers, p.479.

LEAL, I.R., SILVA, J.M.C., TABARELLI, M. & LACHER JUNIOR, T.E. 2005. Mudando o curso da conservação da biodiversidade na Caatinga do Nordeste do Brasil. Megadiversidade 1(1):139-146.

MARES, M.A., WILLIG, M.R. & LACHER, T.E. 1985. The Brazilian Caatinga in South American zoogeography: tropical mammals in dry region. J. Biogeogr. 12(1):57-69. http://dx.doi.org/10.2307/2845029

MARTINS, C.F. 2002. Diversity of the Bee Fauna of the Brazilian Caatinga. In Pollinating Bees - The Conservation Link Between Agriculture and Nature (P. Kevan & V.L. Imperatriz-Fonseca, eds). Ministry of Environment, Brasília, p.131-134.

MIELKE, C.G. 1994. Papilionoidea e Hesperioidea (Lepidoptera) de Curitiba e arredores, Paraná, Brasil, com notas taxonômicas sobre Hesperiidae. Revta. Bras. Zool. 11(4):759-776. http://dx.doi.org/10.1590/S0101-81751994000400018

NOBRE, C.E.B., SCHLINDWEIN, C. & MIELKE, O.H.H. 2008. The butterflies (Lepidoptera: Papilionoidea and Hesperioidea) of the Catimbau National Park, Pernambuco, Brazil. Zootaxa 1751:35-45.

PALUCH, M., MIELKE, O.H.H., NOBRE, C.E.B., CASAGRANDE, M.M., MELO, D.H.A. & FREITAS, A.V.L. 2011. Butterflies (Lepidoptera: Papilionoidea and Hesperioidea) of the Parque Ecológico João Vasconcelos Sobrinho, Caruaru, Pernambuco, Brazil. Biota Neotrop. 11(4): http://www.biotaneotropica.org.br/v11n4/pt/abstract?inventory+bn01911042011.

PRADO, D.E. 2003. As Caatingas da América do Sul. In Ecologia e Conservação da Caatinga (I.R. Leal, M. Tabarelli & J.M.C. Silva, eds.). Universidade Federal de Pernambuco, Recife, p.3-73.

RITTER, C.D., LEMES, R., MORAIS, A.B.B. & DAMBROS, C.S. 2011. Borboletas (Lepidoptera: Hesperioidea e Papilionoidea) de fragmentos de Floresta Ombrófila Mista, Rio Grande do Sul, Brasil. Biota Neotrop. 11(1): http://www.biotaneotropica.org.br/v11n1/pt/abstract?inventory+bn00511012011.

ROCHA, W.J.S.F., CHAVES, J.M., ROCHA, C.C., FUNCH, L. & JUNCÁ, F.A. 2005. Avaliação ecológica rápida da Chapada Diamantina. In Biodiversidade e Conservação da Chapada Diamantina (F.A. Juncá, L. Funch & W. Rocha, eds). Ministério do Meio Ambiente, Brasília, p.29-46.

SANTOS, E., MIELKE, O.H.H. & CASAGRANDE, M.M. 2008. Butterfly inventories in Brazil: the state of art and the priority-areas model research aiming at conservation. Nat. Conserv. 6:176-198.

SÃO-PEDRO, V.A. & FEIO, R.N. 2011. Anuran species composition from Serra do Ouro Branco, southernmost Espinhaço Mountain Range, state of Minas Gerais, Brazil. Check List 7(5):671-680

THORNTHWAITE, C.W. & MATTER, J.R. 1995. The Water Balance. Publications in Climatology, Centerton N.J., v.8, n.1, 104p.

VASCONCELOS, R.N., BARBOSA, E.C.C. & PERES, M.C.L. 2009. Borboletas do Parque Metropolitano de Pituaçu, Salvador, Bahia, Brasil. Sitientibus Sér. Ciên. Biol 9(2-3):158-164.

VELLOSO, A.L., SAMPAIO, E.V.S.B. & PAREYN, F.G.C., eds. 2002. Ecorregiões: Propostas para o bioma Caatinga. Associação Plantas do Nordeste; Instituto de Conservação Ambiental, The Nature Conservancy do Brasil, 76p.

ZACCA, T. 2009. Espécies de borboletas (Lepidoptera: Papilionoidea e Hesperioidea) da Coleção Entomológica Prof. Johann Becker do Museu de Zoologia da Universidade Estadual de Feira de Santana, Bahia, Brasil. Sitientibus, Sér. Ciên. Biol. 9(2-3):165-173.

ZACCA, T., BRAVO, F. & XAVIER, M.X. 2011. Butterflies (Lepidoptera: Papilionoidea and Hesperioidea) from Serra da Jibóia, Bahia State, Brazil. Entomobrasilis 4(3):139-143.

WILLIG, M.R. & MARES, M.A. 1989. Mammals from the Caatinga: an update list and summary of the recent research. Rev. Bras. Biol. 49(2):361-367. PMid:2608943.

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Reproductive phenology of *Miconia mirabilis* (Melastomataceae) within three distinct physiognomies of Atlantic Forest, Bahia, Brazil

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Abstract: Although *Miconia mirabilis* is a very common species in disturbed forest areas and is known for providing food resources for the local fauna, little is known about its reproductive phenology and other ecological aspects. The present study compares intra- and inter-annual patterns in the reproductive phenophases of that species in three distinct physiognomies of Atlantic Forest in Southeastern Bahia based on semi-quantitative observations conducted over a period of three years. We searched for possible relationships with climatic variables, differences among sites and synchrony. Both the flowering and fruiting strategies of *M. mirabilis* were classified as annual extended in all three study sites. We found no significant differences among years. Despite low seasonality of the regional climate, intensities of the different phenophases were negatively correlated with day length and temperature. In general, inter- and intra-population synchrony for flowering and fruiting was high (between 0.65 and 0.78), except for inundated forest, probably due to the stress caused by flooding. Given that *Miconia mirabilis* has the potential to be an important food resource for the local fauna due to the large quantities of flowers and fruits produced and their almost year-round availability, and its capacity for occupying impoverished areas, the species may be considered in restoration programs as a potentially interesting species capable of attracting frugivores to disturbed areas.

Keywords: *flowering, fruiting, pioneer species, secondary forest.*

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Resumo: Apesar de *Miconia mirabilis* ser uma espécie comum em áreas de floresta perturbada e conhecida por fornecer recursos alimentares para a fauna local, pouco se sabe sobre sua fenologia reprodutiva e outros aspectos ecológicos. O presente estudo teve como objetivo comparar os padrões intra e interanual das fenofases reprodutivas da espécie em três fisionomias distintas de Floresta Atlântica no sudeste da Bahia com base em observações semi-quantitativas, realizadas num período de três anos. Também procurou por possíveis relações com as variáveis climáticas, diferenças entre os locais e sincronia. Ambas as estratégias, floração e frutificação, de *M. mirabilis* foram classificadas como anuais estendidas em todos os três locais de estudo. Não houve diferenças significativas entre os anos. Apesar do clima regional apresentar baixa sazonalidade, as intensidades das diferentes fenofases foram negativamente correlacionadas com o comprimento do dia e temperatura. Em geral, a sincronia inter e intra populacional para a floração e frutificação foi alta (entre 0,65 e 0,78), exceto para a floresta inundada, provavelmente devido ao estresse causado pelo solo alagado. Assim, *Miconia mirabilis* tem potencial de ser um importante recurso alimentar para a fauna local, devido a grande quantidade de flores e frutos produzidos, sua disponibilidade quase o ano todo, e por ocupar áreas empobrecidas, a espécie pode ser considerada potencialmente interessante em programas de restauração e capaz de atrair animais frugívoros em áreas perturbadas.

Palavras-chave: *floração, frutificação, espécies pioneiras, floresta secundária.*

Introduction

Variations in the reproductive phenology of plant species are influenced by proximate environmental traits - such as precipitation, temperature and radiation - that initiate reproductive phases, and modulated by ultimate factors that select for particular reproductive phenologies, such as pollinators, seed dispersers, and predators (Adler & Kiepinski 2000, Ramos & Santos 2005). The heterogeneity of reproductive patterns within a given population may also be related, however, to differences in microhabitats (Newstrom et al. 1994), to floristic and/or edaphic variations between nearby tropical forest areas (Heideman 1989) or to periodic environmental disturbances such as flooding during the rainy season (Satake et al. 2001, Haugaasen & Peres 2005).

Reproductive patterns may further be influenced by successional stage and habitat differences both at community (Kang & Bawa 2003, Andreis et al. 2005) and population (Roos & Quinn 1977, Williams-Linera 2003) levels, and can be altered by fragmentation (Fuchs et al. 2003, Laurance et al. 2003). As such, the intensity and synchrony of reproductive phenophases may be associated with competition for light (Levey 1990, Siemann & Rogers 2003, Laurance et al. 2003, Fuchs et al. 2003, Ramos & Santos 2005) or even with limitations imposed on/by pollinators and dispersers (Rocha & Aguilar 2001, Calabrese & Fagan 2004, Borchert et al. 2005).

Synchrony of phenological events among individuals indicates their adaptation to abiotic or biotic factors (Van Schaik et al. 1993) that presumably confer adaptive advantages to these plant species (Pedroni et al. 2002). This may be a response to environmental conditions in tropical seasonal forests, which can synchronize flowering in the dry season (Muniz 2008, Coelho & Machado 2009) or in the beginning of rainfalls (Mori & Pipoly 1984, Santos et al. 2010). Also, environmental stress due to fire (Sarmiento 1992, Munhoz & Felfili 2005) or flooding (Spina et al. 2001, Aragão et al. 2005) can contribute to synchronize reproductive phenophases. Otherwise, interactions between biotic factors may lead either to the minimization or maximization of phenological overlap among plant species (Van Schaik et al. 1993), resulting in fitness advantages through cross-pollination, attracting dispersers and satiating seed predators (Augspurger 1981, Corlet 1990, Thies & Kalko 2004, Franklin & Bach 2006) or, in the case of asynchrony, by promoting “outcrossing” between distant plants (IMS 1990). Thus, the timing, duration and degree of synchrony of different phenophases within a plant population will therefore determine the availability of resources to associated fauna (Williams et al. 1999).

Melastomataceae comprises more than 4,500 species and 150 genera from tropical and subtropical areas in both Old and New Worlds (Renner 1993). This family is considered important for sustaining frugivore diversity in tropical forests (Stiles & Rosselli 1993, Manhães et al. 2003). *Miconia* Ruiz & Pavon is the largest genus in the family and probably one of the richest genera of flowering plants in the New World (Goldenberg et al. 2008). It occurs mainly in secondary areas, at forest edges and in clearings, and it comprises many pioneer species (Schupp et al. 1989, Denslow et al. 1990, Ellison et al. 1993). These plants produce large quantities of resources that are consumed by birds and mammals (Levey 1990, Poulin et al. 1999, Catenacci et al. 2009, Parrini & Pacheco 2011) and they are considered key-resources for many different frugivore species in tropical communities in Central and South America (Galetti & Stoltz 1996, Poulin et al. 1999, Peres 2000, Parrini & Pacheco 2011).

The majority of species from the genus *Miconia* present annual reproductive patterns (Snow 1965, Hilty 1980, Mori & Pipoly 1984, Mantovani et al. 2003, Pereira & Mantovani 2007), however, biannual, annually extended and continuous have also been described, (Levey 1990, Williams-Linera 2003). Some studies indicate variation in the reproductive patterns of this genus in regions with a tropical seasonal climate (Mori & Pipoly 1984, Williams-Linera 2003, Aragão et al. 2005, Kessler-Rios & Kattan 2012), with precipitation indicated as the most important influencing factor. In forests with low climatic seasonality, where water is available all year long, photoperiodic changes may induce flowering patterns (Borchert et al. 2005). Responses of plants to higher levels of light intensity can lead to increased production of resources and synchrony in different types of forests (Levey 1990, Williams-Linera 2003).

The species studied here, *Miconia mirabilis* (Aublet) L.O. Williams, is characteristic of newly regenerating forest areas in southeastern Bahia State (Martini & Santos 2007), even occurring in areas recovering from fire and pastures. It grows at high densities and dominance levels in secondary forests in intermediate stages of regeneration, and can also be found in other physiognomies, such as advanced secondary and inundated forests although in lower densities (M. S. Pessoa, unpublished). However, it is rare in mature forests (Pessoa 2008, Piotto et al. 2009). Its large production of both flowers and fruits throughout the year (Pessoa 2008) associated with its recent indication as an important food resource for the endangered golden-headed lion tamarin (*Leontopithecus chrysomelas* (Kuhl 1820)) indicate that *M. mirabilis* is important in regenerating areas (Catenacci 2008, Catenacci et al. 2009). Although the species is common in the region and may occur in distinct physiognomies providing important resources for local fauna, little is known about its reproductive patterns and whether these vary in different physiognomies.

Our study aims to investigate the potential of *Miconia mirabilis* for offering food resources in different physiognomies in a forest with low climatic seasonality. Specifically, we addressed the following questions related to both flowering and fruiting: What is the phenological reproductive pattern of the species? Does this pattern vary in the different physiognomies over different years? Which physiognomy has the higher synchrony values? Are its reproductive phenophases correlated with the climate? The answers to these questions allow for evaluating the temporal availability and spatial distribution of food resources of this species in different physiognomies.

Materials and Methods

1. *Study area*

The present study was conducted in a remnant of Atlantic Forest, within the Una Biological Reserve (Rebio Una) with nearly 19.000 ha (15° 10’ S and 39° 03’ W), located in southern Bahia, Brazil. It includes two vegetation types typically found along Brazilian coast: lowland tropical moist forest (*tabuleiro forest*) and submontane tropical moist forest (Amorim et al. 2008). In general, the study site is a regional forest mosaic composed essentially of *tabuleiro forest* in different stages of regeneration, interspersed with abandoned pastures and plantations.

We studied the reproductive patterns of *M. mirabilis* in three physiognomies; two successional stages of Atlantic Forest (advanced and medium secondary) and inundated forest. Advanced secondary forest areas suffered logging 30 years ago, and are characterized by trees generally between 15 and 20 m height, numerous species of Myrtaceae and Sapotaceae and the presence of bromeliads and vines. Medium secondary forest areas had been disturbed by slash-and-burn agriculture and pasture, at least 10 years before our study began. Tree height is generally less than 15 m height, with open canopy and lots of light entering, with predominance of the Melastomataceae family and lacking bromeliads or vines. Inundated forest occurs in areas that suffer from periodic flooding, where the soil is permanently sodden. The canopy is closed, and tree height is generally between 15 and 20 m, similar to advanced secondary forest. This physiognomy contains species typical for swamp forest, such as *Symphonia globulifera* L.f.

The regional climate is classified as type *Af* in the Köppen system: humid and hot and characterized by the absence of a defined dry period (Gouvêa et al. 1976). The annual average rainfall is approximately 2,000 mm (Mori et al. 1983) and it tends to be evenly distributed throughout the year. Average temperatures in the region are high, with values around 24 °C and little variation during the year. Average summer temperatures can reach up to 26 °C (Instituto… 1997). Day length reaches its maximum duration (12 to 13 hours) between Sep and Mar, with the shortest days occurring between May and Aug (~11 hours and 15 minutes). Although precipitation levels in southern Bahia are not as high as those observed in other regions of the Atlantic Forest, this area is notable for the absence of significant seasonal climatic variations (Martini & Santos 2007).

The amount of rainfall during the study period (Feb 2005 through Jan 2008) was generally near or above average, with the highest precipitation in 2005 (2,196 mm) and the lowest in 2006 (1,945 mm). The months with highest rainfall rates were Jun 2005 (298 mm), Mar 2006 (362 mm) and Feb, Mar and Nov 2007 (~250 mm/month). The average annual temperature was 25 °C, and the months with lowest average minimum temperatures were Jul and Aug (19 °C); the highest temperatures were recorded between Dec and Mar (33 °C) for all three study years. Climatic data were obtained from the Climatological Station of Project BioBrasil, located at the study site, where a commercial min-max thermometer and a TRU-CHEK rain gauge were installed (Figure 1).

2. Phenological study

To compare the reproductive phenological patterns of *Miconia mirabilis* among areas and with the whole community, we conducted systematic sampling using point-center quadrants along nine pre-established 200 m transects (three in each physiognomies) with central points at 15 m intervals. We included only arboreal individuals with DBH ≥ 5 cm. The entire community included 09 transects and 431 individuals, 151 in advanced secondary sites, 139 in medium secondary sites, and 141 in inundated forest site. Phenological data were collected simultaneously for community and for *M. mirabilis*. Initially, we found 74 individuals of the species along these transects, but the number of individuals observed had diminished to 70 by 2008 due to the death of four plants in the inundated forest site. Thus, seven individuals were monitored in advanced secondary forest (4.6% of the total number of individuals in this area), 56 in medium secondary forest (39.7% of the total), and eleven (years 2006 and 2007) to seven (2008) in the inundated forest site (7.1 and 5.1% of the total respectively).

The trees were visited monthly between Feb 2005 and Jan 2008 (36 months) and the following reproductive phenophases were recorded: 1) flowering: distinguishing buds and anthesis, and 2) fruiting: distinguishing unripe and ripe fruits. We used the Fournier scale (Fournier 1974) to quantify the intensity of each phenophase, both for the community and the population studied. We classified the flowering and fruiting strategies of *Miconia mirabilis* in the different physiognomies according to Newstrom et al. (1994)

3. Statistical analysis

As the data were non-parametric, we used Spearman Rank Correlations to test for correlations between the monthly activity indices of each phenophase and the different meteorological variables of the same month (rainfall, average temperature and day length) over the three year period. Since there can be a delay between changes in climatic conditions and the triggering of plant responses, we also checked for correlations between a given phenophase activity and the climatic data of the previous month. We used Kruskal-Wallis test to verify if there were significant differences in the mean annual values of intensity for each phenophase (flower buds, anthesis, unripe and ripe fruits) among sites and among the three years studied. When the Kruskal-Wallis test detected a significant difference, the Dunn test was performed to compare pairs of sites and years. All analyses were performed using the Bioestat 5.0 and Past 2.03 program.

We used the method proposed by Augspurger (1983) to determine the degree of synchrony of each phenophase, in which individual flowering and fruiting synchronies are measured as the relative overlap between the phenophase period of a given individual and all of the others in that population. Inter- and Intra-population synchrony was calculated in general and within each area of occurrence of the focal species (inundated forest, advanced and medium secondary forest).

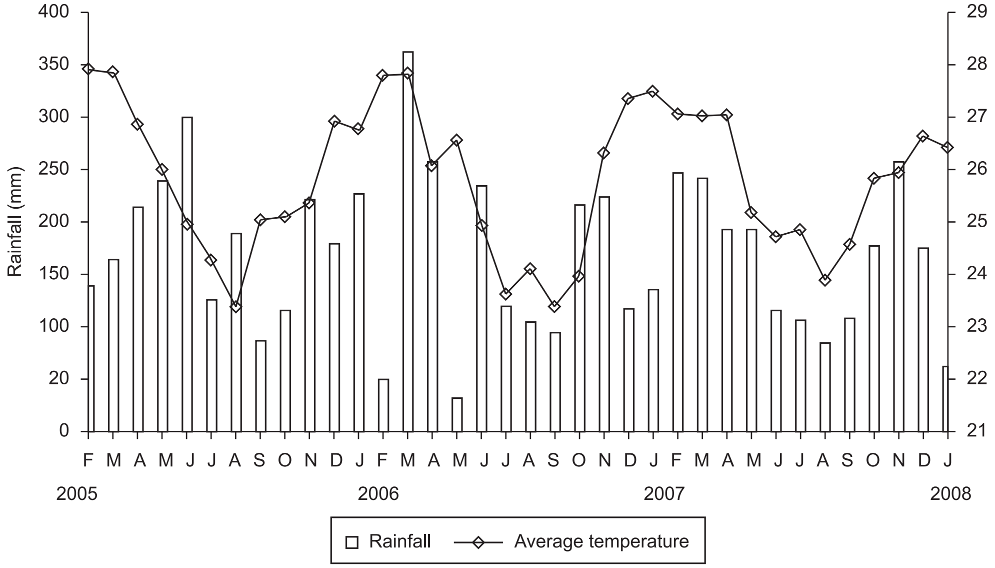

Figure 1. Precipitation and average temperature at the study site in the Una Biological Reserve, Bahia State, Brazil, from February 2005 through January 2008. Source: Project BioBrasil.

Results

1. *Spatial variation*

The resources produced by *Miconia mirabilis* (Figure 2) had a significant impact on the community as a whole, representing more than 80% of the total of flowers offered in some months, and up to 74% of fruits (Figure 2a). These high levels were typical for medium secondary forest, where the species predominated. Also, flowering and fruiting intensity was higher for the population in medium secondary (Figure 2b) as compared to the other physiognomies (Figure 2c, d), for all phenophases (Table 1). Considering the advanced secondary forest areas and inundated forest environments (where this species is less abundant) separately (Figure 2c, d), these community patterns as a whole did not show dependence on the resources produced by *M. mirabilis*, both for flowers and fruits. In the medium secondary forest (Figure 2b), however, where *M. mirabilis* predominates, the general pattern of the community is intimately linked to the abundance of the resources produced by that species.

2. *Temporal variation*

Comparisons among years showed no significant differences in flowering intensities for medium and advanced secondary forest (Table 2). The inundated forest differed from the others, showing significant differences for anthesis but no significant differences in budding. Otherwise, the comparison of fruit production among years showed no significant differences for all physiognomies (Table 2). The reproductive strategy of *M. mirabilis* was considered annual extended in the three sites (Figure 2b-d), showing a continuous pattern in 2005 and 2007 in the medium secondary forest (Figure 2b), and in 2005 in the inundated forest area (Figure 2d). The highest flowering intensities were observed between May and Aug in all three physiognomies, although with interannual variations in each area (Figure 2b-d). The flowering patterns were more similar between years in the medium secondary forest than in the other sites. The highest levels of fruiting occurred from Jul through Nov in 2005 and 2006, and from Apr to Sep in 2007, with variations in the intensities at all sites. The unripe fruit production was consistently higher than ripe fruits during the entire period in all three physiognomies.

Miconia mirabilis flowers and fruits are generally available (although at low intensities) at the medium secondary site even during months of resource scarcity. This situation was observed, for example, for flowering in Oct 2006 and for fruiting in Dec 2006 and Jan 2007 (Figure 2b). Intrapopulational synchrony was high for flowering and fruiting in the medium secondary and advanced secondary physiognomies, but not in the inundated forest. Interpopulation synchrony was high for all phenophases (Table 3).

3. *Correlation with climatic variables*

Flowering was negatively correlated to day length in all sites both for the same and the previous month, with decreasing levels of bud production and floral anthesis corresponding to increases in day length. In general, no correlations were observed between flowering with precipitation and temperature. Fruiting was also negatively related to day length of the previous month, with increasing production of unripe and ripe fruits corresponding to decreasing in day length at all sites. Only the production of ripe fruits in the medium secondary site was not correlated with the day length of the previous month. Fruiting in *M. mirabilis* was also inversely related to the average temperature for both the previous and the same months, in all sites. Thus, lower temperatures were correlated with increased productions of unripe and ripe fruits in the three physiognomies studied (Table 4).

Discussion

The predominant flowering and fruiting pattern observed for *Miconia mirabilis* was annual extended in all three physiognomies, with flower and fruit production being interrupted for only one to just a few months a year. The presence of these abundant resources throughout the year clearly influenced the general pattern of the community. Continuous and extended reproductive patterns mean year-round food availability for pollinators and frugivores, and this in turn contributes to community maintenance through the constant presence of the animals using those resources (Snow 1965, Denslow et al. 1986, Pedroni et al. 2002, Bolmgren et al. 2003, Boulter et al. 2006, Elzinga et al. 2007).

Even though *M. mirabilis* showed similar flowering and fruiting patterns in all three physiognomies it was more intense in the medium secondary site. This may have been due to the increased amount of light available in these early succession sites where tree crowns are more widely spaced. High light intensity conditions generally generate bigger flowering events (Mori & Pipoly 1984, Van Schaik et al. 1993, Wright & Van Schaik 1994) and fruit production (Denslow et al. 1986, Galetti & Stoltz 1996, Levey 1990, Elisson et al. 1993, Rocha

Table 1. Comparison of phenophase intensities among physiognomies: (AS) advanced secondary; (MS) medium secondary and (IF) inundated forest (Kruskal-Wallis H and Dunn Z tests) in the Una Biological Reserve, Bahia State, Brazil.

	Kruskal-wallis (H)	**Dunn (Z)**		
		AS × MS	**AS × IF**	**MS × IF**
Flower buds	42.94*	6.06**	0.88	5.18**
Anthesis	39.97*	5.72**	0.55	5.18**
Unripe fruits	43.74*	6.43**	1.90	4.54**
Ripe fruits	23.87*	4.88**	2.26	2.62**

*$p < 0.01$; **$p < 0.05$ significant.

Table 2. Comparison of phenophase intensities over three consecutive years for the physiognomies: (AS) advanced secondary; (MS) medium secondary and (IF) inundated forest (Kruskal-Wallis H and Dunn Z tests). The sequence of Z-values refers to the comparisons between the years 1and 2 (a); 1and 3 (b); 2 and 3 (c), respectively in the Una Biological Reserve, Bahia State, Brazil.

	Kruskal-wallis (H)			**Dunn (Z)**		
	AS	**MS**	**IF**	**a**	**b**	**c**
Flower buds	0.46	1.91	4.3			
Anthesis	1.15	2.23	9.14*	2.7**	0.3	2.4**
Unripe fruits	1.52	1.3	0.96			
Ripe fruits	0.1	0.03	0.32			

*$p < 0.01$; **$p < 0.05$ significant.

Table 3. Synchrony values within *Miconia mirabilis* populations for the phenophases examined at the three different physiognomies in the Una Biological Reserve, Bahia State, Brazil.

Phenophases	**Individuals**			
	Advanced secondary	**Medium secondary**	**Inundated forest**	**All sites**
Flower buds	0.67	0.74	0.25	0.67
Anthesis	0.70	0.72	0.23	0.65
Unripe fruits	0.65	0.78	0.38	0.73
Ripe fruits	0.65	0.71	0.23	0.72

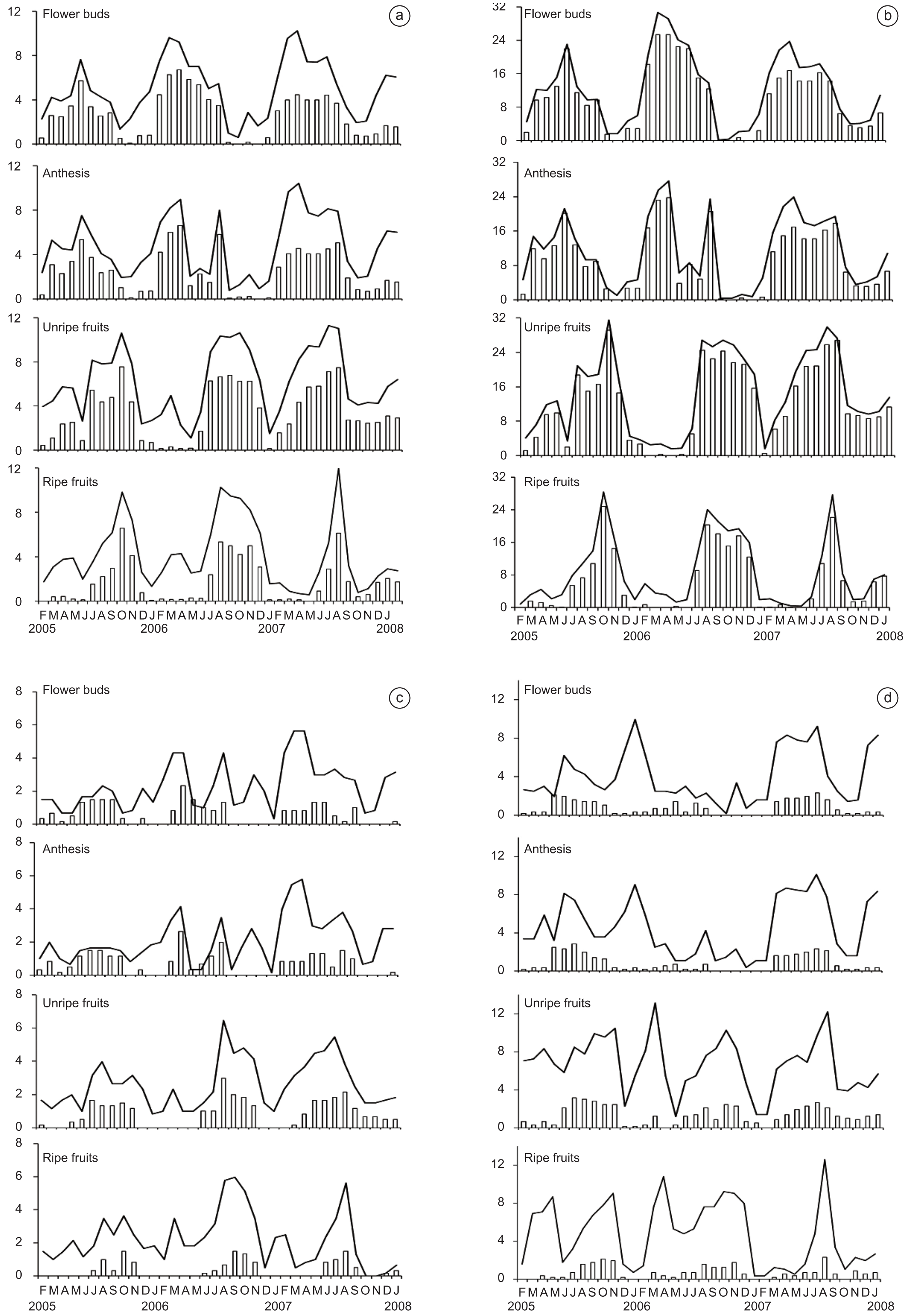

Figure 2. Intensity values of reproductive phenology of the community, compared with *Miconia mirabilis*, during three years of monthly observations, for the phenophases examined at the three different physiognomies in the Una Biological Reserve, Bahia State, Brazil. The continuous line shows the community pattern including all species surveyed, and is compared to *M. mirabilis* (bar graphs) in the following areas: (2a) all sites analyzed together; (2b) medium secondary; (2c) advanced secondary and (2d) inundated forest.

Table 4. Spearman rank correlation coefficients between the phenophases and the climatic variables average temperature, precipitation and day length, for the previous (P) and the same (S) month of occurrence in the physiognomies.

	Advanced secondary						**Medium secondary**						**Inundated forest**					
	Temperature		**Precipitation**		**Day length**		**Temperature**		**Precipitation**		**Day length**		**Temperature**		**Precipitation**		**Day length**	
	(P)	**(S)**	**(P)**	**(S)**	**(P)**	**(S)**	**(P)**	**(S)**	**(P)**	**(S)**	**(P)**	**(S)**	**(P)**	**(S)**	**(P)**	**(S)**	**(P)**	**(S)**
FB	0.00	–0.27	0.27	0.03	–0.53*	–0.67*	0.14	–0.18	0.41*	0.11	–0.51*	–0.73*	–0.11	–0.36	0.32	–0.11	–0.59*	–0.66*
AT	–0.04	–0.32	0.10	0.01	–0.52*	–0.60*	0.15	–0.16	0.30	0.15	–0.44*	–0.64*	–0.12	–0.32	0.20	–0.10	–0.51*	–0.57*
UF	–0.73*	–0.82*	–0.24	–0.31	–0.70*	–0.41	–0.60*	–0.63*	–0.11	–0.29	–0.57*	–0.29	–0.50*	–0.59*	–0.07	–0.10	–0.56*	–0.39
RF	–0.76*	–0.76*	–0.39	–0.42	–0.56*	–0.22	–0.79*	–0.57*	–0.21	–0.48*	–0.35	0.10	–0.68*	–0.71*	–0.25	–0.23	–0.55*	–0.25

Phenophases: FB- flower buds, AT- anthesis, UF- unripe fruits and RF- ripe fruits in the Una Biological Reserve, Bahia State, Brazil. $p < 0.01$ significant.

& Aguilar 2001). Thus the absence of a closed canopy may promote higher levels of flower and fruit production in disturbed environments (Laurance et al. 2003, Martini & Santos 2007), which seems to be the case for the area studied in Southern Bahia.

Similar patterns were observed in other pioneer species of the genus *Miconia* in Costa Rica at sites in early stages of succession with open canopies. The colonizing species there produced larger fruit quantities and had longer fruiting episodes than were seen in other individuals of the same species growing under shaded conditions (Levey 1990). This also appears to be the case with *M. mirabilis*, as it demonstrated more intense flower and fruit production in open areas (medium secondary sites) where more light is generally available.

The individuals demonstrated synchronous flowering and fruiting during several months of the year (although at low intensities during certain periods), except at the inundated site. In fact, flowering (Kang & Bawa 2003) and fruiting (Levey 1990) duration of early succession species have been observed to be longer than those of climax species. Synchrony in reproductive patterns is common in the genus *Miconia*, and generally associated with differences in light intensity (Williams-Linera 2003) or day length (Borchert et al. 2005), as is the case for the species in this study. In inundated areas the species showed less phenological synchronization (between 0.23 and 0.28) and intensity (5%) and the highest mortality (4 individuals, 36%), indicating that although *Miconia mirabilis* can colonize such areas, its reproduction and survival are probably affected by water stress. Plant reproduction in this environment may suffer due to stress caused by flooding, as this would limit certain physiological processes (such as root respiration) and thus reduce plant fitness (Satake et al. 2001, Haugaasen & Peres 2005), and spatial-temporal variations in the flooding regime can influence the responses of the individuals making up the plant population. As such, differences in the quantities of excess water, the duration of flooding, or the location of the individuals could generate different degrees of stress in the population and so interfere with the general reproductive pattern. It is probable that those individuals located in micro-habitats subjected to the longest periods or highest frequencies of flooding will show distinct alterations in the duration and/or intensity of their reproductive events in relation to those individuals subject to less stress - thus generating different patterns within the population and reducing synchrony in those areas.Despite the low climatic seasonality in the study region and the extended flowering and fruiting pattern, we detected a distinct increase in flowering from Mar to Aug and for fruiting from Jul to Nov, related to changes in day length and temperature. We did not find any correlations between flowering and fruiting with precipitation levels in the study areas. In fact, in seasonal tropical forests, the main factor triggering the flowering and fruiting are differences in precipitation (Mori & Pipoly 1984, Meyer 1998, Aragão et al. 2005, Santos et al. 2010), but in areas with low seasonal climate photoperiod is indicated as the only mechanism that can be attributed to synchronous flowering (Borchert et al. 2005).

The abundance of resources produced by *Miconia mirabilis* clearly influenced the fluctuations of overall resources available to the faunal community and markedly defined the pattern seen in the medium secondary forest (where it was most prominent). The importance of the resources produced by this species lie not only in the high productivity of the individuals, but also in the great abundance of these plants in altered environments, which guarantees the distribution of these food resources throughout the mosaic of forest and the presence of these resources throughout the year.

Miconia mirabilis demonstrated the greatest production of resources in the community as a whole, contributing up to 98% of the resources available in the medium secondary forest where it predominated. These regenerating areas, in turn, play an important role in determining the reproductive success of this species, as was described for *M. centrodesma* in Costa Rica (Levey 1990). Species of the genus are generally present in seed banks, and among the first species to germinate in tropical forest clearings (Ellison et al. 1993, Krijger et al. 1997). As such, a very large proportion of the individuals concentrate their reproductive efforts during the relatively brief period in which this species dominates secondary areas, attracting fauna which will disperse their seeds as they gradually shift to different sites according to the dynamics of forest regeneration.

Miconia mirabilis has the potential to be an important food resource for the local fauna due to the large quantities of flowers and fruits produced and their almost year-round availability (temporal scale), the abundance of this species in anthropogenically altered areas (spatial scale), and because these resources were present during all study years without significant variation in availability (constancy). Considering also that the species is capable of colonizing inundated areas and even areas recovering from fire or pasture, we can suggest it has a high potential to colonize impoverished areas, and may be considered for use in restoration programs as a potentially interesting species capable of attracting frugivores to disturbed areas.

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References

ADLER, G.H. & KIEPINSKI, K.A. 2000. Reproductive phenology of a tropical canopy tree, *Spondias mombin*. Biotropica 32:686-692. http://dx.doi.org/10.1646/0006-3606(2000)032[0686:RPOATC]2.0.CO;2

AMORIM, A.M., THOMAS, W.W., CARVALHO, A.M. & JARDIM, J.G. 2008. Floristics of the Una Biological Reserve, Bahia, Brazil. In The Atlantic Coastal Forest of Northeastern Brazil (W.W. Thomas, ed.). Memoirs of the New York Botanical Garden, p.67-146.

ANDREIS, C., LONGHI, S.J., BRUN, E.J., WOJCIECHOWSKI, J.C., MACHADO, A.A., VACCARO, S. & CASSAL, C.Z. 2005. Estudo fenológico em três fases sucessionais de uma floresta estacional decidual no município de Santa Tereza, RS, Brasil. Rev. Árvore 29(1):55-63. http://dx.doi.org/10.1590/S0100-67622005000100007

ARAGÃO, D.V., FORTINI, L.B., MULKEY, S.S., ZARIN, D.J., ARAUJO, M.M. & CARVALHO, C.J.R. 2005. Correlation but no causation between leaf nitrogen and maximum assimilation: the role of drought and reproduction in gas exchange in an understory tropical plant *Miconia ciliata* (Melastomataceae). Am. J. Bot. 92(3):456-461. PMid:21652422. http://dx.doi.org/10.3732/ajb.92.3.456

AUGSPURGER, C.K. 1983. Phenology, flowering synchrony, and fruit set of six neotropical shrubs. Biotropica 15(4):257-267. http://dx.doi.org/10.2307/2387650

AUGSPURGER, C.K. 1981. Reproductive synchrony of a tropical plant: experimental effects of pollinators and seed predators on *Hybanthus prunifolius* (Violaceae). Ecology 62:775-788. http://dx.doi.org/10.2307/1937745

BOLMGREN, K., ERIKSSON, O. & LINDER, H.P. 2003. Contrasting flowering phenology and species richness in abiotically and biotically pollinated angiosperms. Evolution 57:2001-2011. PMid:14575322.

BORCHERT, R., RENNER, S.S., CALLE, Z., NAVARRETE, D., TYE, A., GAUTIER, L., SPICHIGER, R. & VON HILDEBRAND, P. 2005. Photoperiodic induction of synchronous flowering near the Equator. Nature 433:627-629. PMid:15703746. http://dx.doi.org/10.1038/nature03259

BOULTER, S.L., KITCHING, R.L.R. & HOWLETT, B.G. 2006. Family, visitors and the weather: patterns of flowering in tropical rain forests of northern Australia. J. Ecol. 948:369-382.

CALABRESE, J.M. & FAGAN, W.F. 2004. Lost in time, lonely, and single: Reproductive asynchrony and the Allee effect. Amer. Nat. 164:25-37. PMid:15266368. http://dx.doi.org/10.1086/421443

CATENACCI, L.S., DE VLEESCHOUWER, K.M. & NOGUEIRA-FILHO, S.L.G. 2009. Seed Dispersal by Golden-headed Lion Tamarins *Leontopithecus chrysomelas* in Southern Bahian Atlantic Forest, Brazil. Biotropica 41:744-750. http://dx.doi.org/10.1111/j.1744-7429.2009.00530.x

CATENACCI, L.S. 2008. Ecologia alimentar do mico-leão-da-cara-dourada (Primates: Callitrichidae) em áreas degradadas da Mata Atlântica do sul da Bahia. Dissertação de mestrado, Universidade Estadual de Santa Cruz, Ilhéus, Bahia.

COELHO, A.G. & MACHADO, C.G. 2009. Fenologia reprodutiva de *Prepusa montana* Mart. (Gentianaceae) em uma área de campo rupestre da Chapada Diamantina, BA, Brasil. Rev. Bras. Bot. 32(2):405-410.

CORLET, R.T. 1990. Flora and reproductive phenology of the rain forest at Bukit Timah, Singapore. J. Tropical Ecol. 6:55-63. CROAT, T. B. 1975. Phenological behavior of habit and habitat classes on Barro Colorado Island (Panama Canal Zone). Biotropica 7:270-277.

DENSLOW, J.S., SCHULTZ, J.C., VITOUSEK, P.M. & STRAIN, B.R. 1990. Growth responses of tropical shrubs to treefall gap environments. Ecology 71:165-179. http://dx.doi.org/10.2307/1940257

DENSLOW, J.S., MOERMOND, T. & LEVEY, D.J. 1986. Spatial components of fruit display in understory trees and shrubs. In Frugivores and seed dispersal (A. Estrada & Fleming, T.H., eds). Dr. W. Junk, The Hague, The Netherlands, p.37-44. http://dx.doi.org/10.1007/978-94-009-4812-9_4

ELLISON, A.M., DENSLOW, J.S., LOISELLE, B.A. & BRÉNES, D.M. 1993. Seed and seedling ecology of Neotropical Melastomataceae. Ecology 6:1733-1749. http://dx.doi.org/10.2307/1939932

ELZINGA, J.A., ATLAN, A., BIERE, A., GIGORD, L., WEIS, A.E. & BERNASCONI, G. 2007. Time after time: flowering phenology and biotic interactions. Trends Ecol. Evol. 22:432-439. http://dx.doi.org/10.1016/j.tree.2007.05.006

FOURNIER, L.A. 1974. Un método cuantitativo para la medición de características fenológicas en arboles. Turrialba 24(4):422-423.

FRANKLIN, D.C. & BACH, C.S. 2006. Assessing intraspecific phenological synchrony in zoochorous trees from the monsoon forests of northern Australia. J. Tropical Ecol. 22(04):419-429. http://dx.doi.org/10.1017/S0266467406003300

FUCHS, E.J., LOBO, J.A. & QUESADA, M. 2003. Effects of forest fragmentation and flowering phenology on the reproductive success and mating patterns of the Tropical Dry Forest tree *Pachira quinata*. Conserv. Biol. 17(1):149-157. http://dx.doi.org/10.1046/j.1523-1739.2003.01140.x

GALETTI, M. & STOLTZ, D. 1996. *Miconia hypoleuca* (Melastomataceae) como espécie chave para aves frugívoras no Sudeste do Brasil. Rev. Bras. Biol. 56:435-439.

GOLDENBERG, R., PENNEYS, D.S., ALMEDA, F., JUDD, W.S. & MICHELANGELI, F.A. 2008. Phylogeny of *Miconia* (Melastomataceae): patterns of stamen diversification in a megadiverse neotropical genus. Int. J. Plant Sci. 169(7):963-979. http://dx.doi.org/10.1086/589697

GOUVÊA, J.B.S., SILVA, L.A.M. & HORI, M. 1976. Fitogeografia. In Diagnóstico sócio econômico da região cacaueira (Comissão Executiva do Plano da Lavoura Cacaueira e Instituto Interamericano de Ciências Agrícolas, eds.). CEPLAC; IICA, Ilhéus, p.1-10.

HAUGAASEN, T. & PERES, C.A. 2005. Tree phenology in adjacent Amazonian flooded and unflooded forests. Biotropica 4:620-630. http://dx.doi.org/10.1111/j.1744-7429.2005.00079.x

HEIDEMAN, P.D. 1989. Temporal and spatial variation in the phenology of flowering and fruiting in a tropical rainforest. J. Tropical Ecol. 77:1059-1079.

HILTY, S.L. 1980. Flowering and fruiting periodicity in a premontane rain forest in Pacific Colômbia. Biotropica 12(4):298-306.

INSTITUTO BRASILEIRO DO MEIO AMBIENTE E DOS RECURSOS NATURAIS RENOVÁVEIS - IBAMA. 1997. Plano de Manejo - Reserva Biológica de Una - Bahia. p.241.

IMS, R. 1990. The ecology and evolution of reproductive synchrony. Trends Ecol. Evol. 5:135-140. http://dx.doi.org/10.1016/0169-5347(90)90218-3

KANG, H. & BAWA, K. 2003. Effects of successional status, habitat, sexual systems, and pollinators on flowering patterns in tropical rain forest trees. Amer. J. Bot. 90:865-876. PMid:21659181. http://dx.doi.org/10.3732/ajb.90.6.865

KESSLER-RIOS, M.M. & KATTAN, G.H. 2012 Fruits of Melastomataceae: phenology in Andean forest and role as a food resource for birds. J. Tropical Ecol. 28:11-21. http://dx.doi.org/10.1017/S0266467411000642

KRIJGER, C.L., OPDAM, M., THÉRY, M. & BONGERS, F. 1997. Courtship behaviour of manakins and seed bank composition in a French Guianan rain forest. J. Tropical Ecol. 13:631-636. http://dx.doi.org/10.1017/S0266467400010774

LAURANCE, W.F., RANKIN-DE MERONA, J.M., ANDRADE, A., LAURANCE, S.G., D'ANGELO, S., LOVEJOY, T.E., HERALDO L. & VASCONCELOS, H.L. 2003. Rain-forest fragmentation and the phenology of Amazonian tree communities. J. Tropical Ecol. 3:343-347. http://dx.doi.org/10.1017/S0266467403003389

LEVEY, D.J. 1990. Habitat-Dependent fruiting behavior of an understorey tree, *Miconia centrodesma*, and tropical treefall gaps as keystone habitats for frugivores in Costa Rica. J. Tropical Ecol. 6:409-420. http://dx.doi.org/10.1017/S026646740000479X

MANHÃES, M.A., ASSIS, L.C.S. & CASTRO, R.M. 2003. Frugivoria e dispersão de sementes de *Miconia urophylla* (Melastomataceae) por aves em um fragmento de Mata Atlântica secundária em Juiz de Fora, Minas Gerais, Brasil. Ararajuba 11(2):173-180.

MANTOVANI, M., RUSCHEL, A.R., REIS, M.S., PUCHALSKI, A. & NODARI, R.O. 2003. Fenologia reprodutiva de espécies arbóreas em uma formação secundária da Floresta Atlântica. Rev. Árvore 27:451-458. http://dx.doi.org/10.1590/S0100-67622003000400005

MARTINI, A.M.Z. & SANTOS, F.A.M. 2007. Effects of distinct types of disturbance on seed rain in the Atlantic forest of NE Brazil. Plant Ecol. 190:81-95. http://dx.doi.org/10.1007/s11258-006-9192-6

MEYER, J. 1998. Observations on the reproductive biology of *Miconia calvescens* DC (Melastomataceae), an alien invasive tree on the island of Tahiti (South Pacific Ocean). Biotropica 30:609-624. http://dx.doi.org/10.1111/j.1744-7429.1998.tb00101.x

MORI, S.A. & PIPOLY, J.J. 1984. Observations on the big bang flowering of *Miconia minutiflora* (Melastomataceae). Brittonia 36:337-341. http://dx.doi.org/10.2307/2806595

MORI, S.A., BOOM, B.M., CARVALHO, A.M. & SANTOS, T.S. 1983. Southern Bahian moist forests. Botanical Rev. 49:155-232. http://dx.doi.org/10.1007/BF02861011

MUNHOZ, C.B.R. & FELFILI, J.M. 2005. Fenologia do estrato herbáceo-subarbustivo de uma comunidade de campo sujo na Fazenda Água Limpa no Distrito Federal, Brasil. Acta Bot. Bras. 19(4):979-988. http://dx.doi.org/10.1590/S0102-33062005000400031

MUNIZ, F.H. 2008. Padrões de floração e frutificação de árvores da Amazônia Maranhense. Acta Amaz. 38(4):617-626. http://dx.doi.org/10.1590/S0044-59672008000400004

NEWSTROM, L.E.F., FRANKIE, G.W. & BAKER, H.G. 1994. A new classification for plant phenology based on flowering patterns in lowland tropical rain forest trees at La Selva, Costa Rica. Biotropica 26(2):141-159. http://dx.doi.org/10.2307/2388804

PARRINI, R. & PACHECO, J.F. 2011. Frugivoria por aves em seis espécies arbóreas do gênero *Miconia* (Melastomataceae) na Mata Atlântica do Parque Nacional da Serra dos Órgãos, Região Sudeste do Brasil. Atual. Ornitol. (159):51-8.

PEDRONI, F., SANCHEZ, M. & SANTOS, F.A.M. 2002. Fenologia de copaíba (*Copaifera langsdorfii* Desf. Leguminosae, Caesalpinioideae) em uma floresta semidecídua no sudeste do Brasil. Rev. Bras. Bot. 25:183-194. http://dx.doi.org/10.1590/S0100-84042002000200007

PEREIRA, T.S. & MANTOVANI, W. 2007 Fenologia reprodutiva de *Miconia cinnamomifolia* (DC.) Naudin (Melastomataceae), em floresta submontana no Estado do Rio de Janeiro. Rev. Biol. Neotrop. 4(1): 31-45.

PERES, C.A. 2000. Identifying keystone plant resources in tropical forests: the case of gums from *Parkia* pods. J. Tropical Ecol. 16:287-317. http://dx.doi.org/10.1017/S0266467400001413

PESSOA, M.S. 2008. Comparação da comunidade arbórea e fenologia reprodutiva de duas fisionomias em Floresta Atlântica no sul da Bahia. Dissertação Mestrado, Universidade Estadual de Santa Cruz, Ilhéus, Bahia.

PIOTTO, D., MONTAGNINI, F., THOMAS, W., ASHTON, M. & OLIVER, C. 2009. Forest recovery after swidden cultivation across a 40-year chronosequence in the Atlantic forest of southern Bahia, Brazil. Plant Ecol. 205:261-272. http://dx.doi.org/10.1007/s11258-009-9615-2

POULIN, B., WRIGHT, S.J., LEFEBVRE, G. & CALDERÓN, O. 1999. Interspecific synchrony and asynchrony in the fruiting phenologies of congeneric bird-dispersed plants in Panama. J. Tropical Ecol. 15:213-227. http://dx.doi.org/10.1017/S0266467499000760

RAMOS, F.N. & SANTOS, F.A.M. 2005. Phenology of *Psychotria tenuinervis* (Rubiaceae) in Atlantic forest fragments: fragment and habitat scales. Can. J. Bot. 83:1305-1316. http://dx.doi.org/10.1139/b05-106

RENNER, S.S. 1993. Phylogeny and classification of the Melastomataceae and Memecylaceae. Nordic J. Bot. 13:519-540. http://dx.doi.org/10.1111/j.1756-1051.1993.tb00096.x

ROCHA, O.J. & AGUILAR, G. 2001. Reproductive biology of the dry forest tree *Enterolobium cyclocarpum* (Guanacaste) in Costa Rica: a comparison between trees left in pastures and trees in continuous forest. Am. J. Bot. 88:1607-1614. PMid:21669694. http://dx.doi.org/10.2307/3558405

ROOS, F.H. & QUINN, J.A. 1977. Phenology and reproductive allocation in *Andropogon scoparius* Gramineae) populations in communities of different successional stages. Am. J. Bot. 64:535-540. http://dx.doi.org/10.2307/2442001

SANTOS, A. P.M., ROMERO, R. & OLIVEIRA, P.E.A.M. 2010. Biologia reprodutiva de *Miconia angelana* (Melastomataceae), endêmica da Serra da Canastra, Minas Gerais. Rev. Bras. Bot. 33(2):333-341. http://dx.doi.org/10.1590/S0100-84042010000200014

SARMIENTO, G. 1992. Adaptive strategies of perennial grasses in South American savannas. J. Veget. Sci. 3: 325-336. http://dx.doi.org/10.2307/3235757

SATAKE, A., SASAKI, A. & IWASA, Y. 2001. Variable timing of reproduction in unpredictable environments: adaption of flood plain plants. Theor. Pop. Biol. 60:1-15. PMid:11589635. http://dx.doi.org/10.1006/tpbi.2001.1528

SCHUPP, E.W., HOWE, H.F., AUGSPURGER, C.K. & LEVEY, D.J. 1989. Arrival and Survival in Tropical Treefall Gaps. Ecology 70:562-564. http://dx.doi.org/10.2307/1940206

SIEMANN, E. & ROGERS, W.E. 2003. Changes in light and nitrogen availability under pioneer trees may indirectly facilitate tree invasions of grasslands. J. Ecol. 91:923-931. http://dx.doi.org/10.1046/j.1365-2745.2003.00822.x

SNOW, D.W. 1965. A possible selective factor in the evolution of fruiting seasons in tropical forest. Oikos 15:274-281. http://dx.doi.org/10.2307/3565124

SPINA, A.P., FERREIRA, W.M. & LEITÃO-FILHO, H.F. 2001. Floração, Frutificação e síndromes de dispersão de uma comunidade de floresta de Brejo na região de Campinas (SP). Acta Bot. Bras. 15(3):349-368. http://dx.doi.org/10.1590/S0102-33062001000300006

STILES, F.G. & ROSSELLI, L. 1993. Consumption of fruits of the Melastomataceae by birds: how diffuse is coevolution? Vegetatio 107-108(1):57-73.

THIES, W. & KALKO, E.K.V. 2004. Phenology of neotropical pepper plants (Piperaceae) and their association with their main dispersers, two short-tailed fruit bats, *Carollia perspicillata* and *C. castanea* (Phyllostomidae). Oikos 104:362-376. http://dx.doi.org/10.1111/j.0030-1299.2004.12747.x

VAN SCHAIK, C.P., TERBORGH, J.W. & WRIGHT, S.J. 1993. The phenology of tropical forests: adaptative significance and consequences for primary consumers. Ann. Rer. Ecol. Syst. 24:353-377. http://dx.doi.org/10.1146/annurev.es.24.110193.002033

WILLIAMS, R.J., MYERS, B.A., EAMUS, D. & DUFF, G.A. 1999. Reproductive phenology of woody species in a North Australian Tropical savanna. Biotropica 31:626-636. http://dx.doi.org/10.1111/j.1744-7429.1999.tb00411.x

WILLIAMS-LINERA, G. 2003. Temporal and spatial phenological variation of understory shrubs in a tropical montane cloud forest. Biotropica 35(1):28-36.

WRIGHT, S.J. & VAN SCHAIK, C.P. 1994. Light and the phenology of tropical trees. American Nat. 143:192-199. http://dx.doi.org/10.1086/285600

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First record of the fireworm *Hermodice carunculata* (Annelida, Polychaeta) preying on colonies of the fire coral *Millepora alcicornis* (Cnidaria, Hydrozoa)

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PÉREZ, C.D. & GOMES, P.B. **First record of the fireworm *Hermodice carunculata* (Annelida, Polychaeta) preying on colonies of the fire coral *Millepora alcicornis* (Cnidaria, Hydrozoa)**. Biota Neotrop. 12(2): http://www.biotaneotropica.org.br/v12n2/en/abstract?short-communication+bn01712022012

Abstract: The polychaete *Hermodice carunculata* is a voracious predator of several benthic organisms and one of the preferential groups in its diet is that of the cnidarians. This note presents the first record of a fireworm preying on the calcified hydroid *Millepora alcicornis*. The fireworm engulfs the terminal branches of the fire coral and spends several minutes scraping the surface and removing the soft tissues. Despite this being one of the most common calcified hydroids of the Brazilian northern and northeastern regions (and home to a vast associated community), this kind of association had never been recorded. This discovery points to the need of studying such associations because the damage caused by this polychaete is irreversible and depending on the amount of predators might alter reefs' health or modify the components of the reef community.
Keywords: *Amphinomidae, calcified hydroid, predation, Brazil.*

PÉREZ, C.D. & GOMES, P.B. **Primeiro registro do verme de fogo *Hermodice carunculata* (Annelida, Polychaeta) predando colônias do coral de fogo *Millepora alcicornis* (Cnidaria, Hydrozoa)**. Biota Neotrop. 12(2): http://www.biotaneotropica.org.br/v12n2/pt/abstract?short-communication+bn01712022012

Resumo: O poliqueta *Hermodice carunculata* é um voraz predador de vários organismos bentônicos e um dos grupos preferenciais na sua dieta é o dos cnidários. No presente trabalho se apresenta o primeiro registro de predação do verme de fogo sobre o hidrocoral *Millepora alcicornis*. O verme engolfa os ramos terminais do hidrocoral e fica vários minutos raspando a superfície e retirando os tecidos moles. Apesar deste hidrocoral ser um dos representantes mais comuns dos recifes do norte e nordeste brasileiros e de albergar uma vasta comunidade associada, nunca tinha sido registrada esta associação. Esta nova descoberta alerta na necessidade de se estudar esta associação já que geralmente os danos ocasionados pelo poliqueta são irreversíveis e dependendo da quantidade de predadores pode alterar a saúde dos recifes ou modificar os componentes da comunidade recifal.
Palavras-chave: *Amphinomidae, hidroide calcário, predação, Brasil.*

The amphinomid polychaete, *Hermodice carunculata* (Pallas 1776), is a widespread resident of coral reefs and littoral areas of the Caribbean and Western Atlantic Ocean (Lizama & Blanquet 1975). It is apparently omnivorous (Marsden 1963b), feeding on sedentary animals and algae. This fireworm is regarded as an important predator on coral reefs where it grazes upon zoanthids, anemones, gorgonids, hydrocorals, scleractinians and octocorals (Lizama & Blanquet 1975, Lewis & Crooks 1996, Souza et al. 2007). Of particular interest is the fact that this polychaete feeds on living hermatypic corals – more specifically *Porites porites* and *P. astreoides* (Marsden 1962, 1963b) – and on the colonial zoanthid *Palythoa mammillosa* (Marsden 1968). Witman (1988) and Lewis & Crooks (1996) studied this worm feeding on colonies of the calcified hydroid *Millepora complanata*, and such ecological relationship seems to be quite common in the Caribbean Sea.

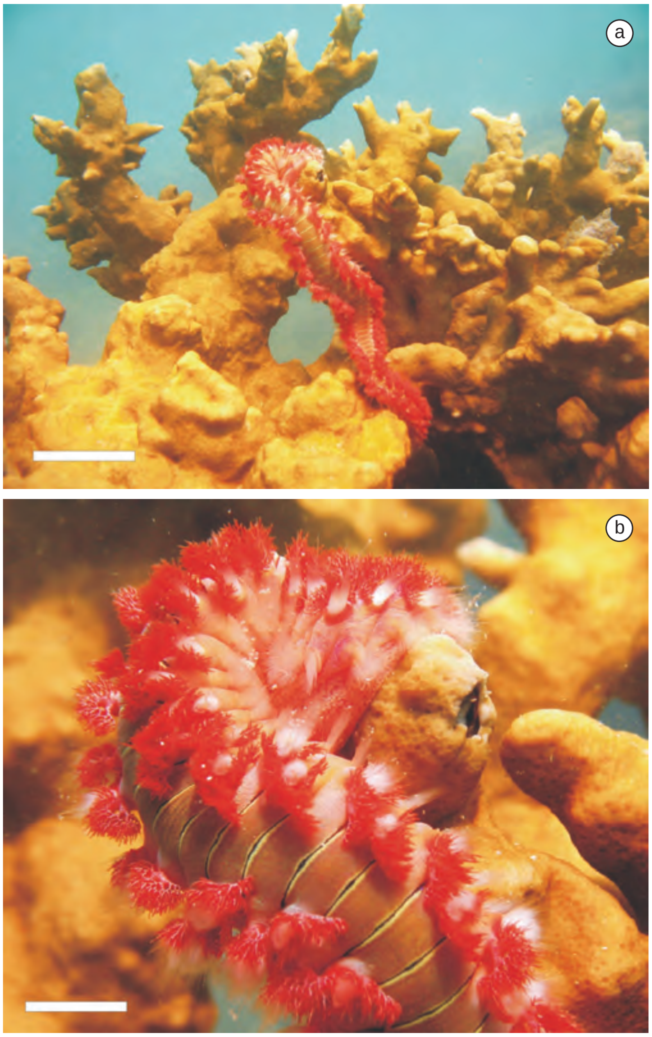

Figure 1. *Hermodice carunculata* **a** in a colony of *Millepora alcicornis* at Ponta de Mangue reef, Brazil; escale bar: 8,5 cm, and **b** engulfing a terminal branch of the fire coral; escale bar: 1,7 cm.

Figure 1. *Hermodice carunculata* **a** sobre uma colônia de *Millepora alcicornis* nos recifes de Ponta de Mangue, Brasil; escala: 8,5 cm, e **b** engolindo um ramo terminal do coral de fogo; escala: 1,7 cm.

Hermodice carunculata initiates feeding by the application and attachment to the prey of the everted buccal mass. Predigestion of the coral polyps apparently results from the liberation of digestive enzymes from the buccal cells, as extracts of this region possess lipolytic and proteolytic activity (Marsden 1963a).

In coastal reefs of Ponta de Mangue, Alagoas, Brazil, several fireworms were observed feeding on *Millepora alcicornis* Linnaeus, 1758 during the morning (Figure 1a). The polychaete engulfed the terminal branches of the colony for many minutes (between 15' and 30') and remained static while removing the tissue (Figure 1b). *Millepora alcicornis* is one of the most common calcified hydroids of tropical American reefs and provides an optimal environment for epibionts (Amaral et al. 2008). Garcia et al. (2008, 2009) found a lush macrofauna associated with the colonies of *M. alcicornis* in reefs of northeastern Brazil, yet did not record the presence of *H. carunculata*. This is the first time that such a prey-predator association is being recorded between these animals in tropical Atlantic waters.

This relationship may cause permanent damage to its prey due to excessive consumption of tissue or by initiating a sequence of algal colonization in feeding lesions (Ott & Lewis 1972, Witman 1988). Excessive damage by predators may affect the general health of reefs or alter the composition of reef communities (Witman 1988). An example is the case of the crown-of-thorns starfish *Acanthaster planci* (Linnaeus 1758) considered a major predator of corals (yet a normal member of coral communities), but widespread population explosions have caused dramatic reductions of coral cover in Indo-Pacific coral reefs (Endean 1982).

In this context, in order to estimate the extent of the damage that could be caused by *H. carunculata* to corals of northeastern Brazilian reefs, we suggest that research projects be carried out to monitor and evaluate population density, their foraging cycles and the amount of time spent feeding.

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References

AMARAL, F.M.D., STEINER, A.Q., BROADHURST, M.K. & CAIRNS, S.D. 2008. An overview of the shallow-water calcified hydroids from Brazil (Hydrozoa: Cnidaria), including the description of a new species. Zootaxa 1930:56-68.

ENDEAN, R. 1982. Crown-of-thorns starfish on the Great Barrier Reef. Endeavour 6:10-14. http://dx.doi.org/10.1016/0160-9327(82)90004-7

GARCIA, T.M., MATTHEWS-CASCON, H. & FRANKLIN-JUNIOR, W. 2008. Macrofauna associated with branching fire coral *Millepora alcicornis* (Cnidaria: Hydrozoa). Thalassas 24:11-19.

GARCIA, T.M., MATTHEWS-CASCON, H. & FRANKLIN-JUNIOR, W. 2009. *Millepora alcicornis* (Cnidaria: Hydrozoa) as substrate for benthic fauna. Braz. J. Oceanogr. 57:153-155.

LEWIS, J.B. & CROOKS, R.E. 1996. Foraging cycles of the amphinomid polychaete *Hermodice carunculata* preying on the calcareous hydrozoan *Millepora complanata*. B. Mar. Sci. 58:853-857.

LIZAMA, J. & BLANQUET, R.S. 1975. Predation on sea anemones by the amphinomid polychaete, *Hermodice carunculata*. B. Mar. Sci. 25:442-443.

MARSDEN, J.R. 1962. A coral eating polychaete. Nature 193:598. http://dx.doi.org/10.1038/193598a0

MARSDEN, J.R. 1963a. A preliminary report on digestive enzymes of *Hermodice carunculata*. Can. J. Zoolog. 41:159-164. http://dx.doi.org/10.1139/z63-019

MARSDEN, J.R. 1963b. The digestive tract of *Hermodice carunculata* (Pallas) Polychaeta: Amphinomidae. Can. J. Zoolog. 41:165-184. http://dx.doi.org/10.1139/z63-020

MARSDEN, J.R. 1968. Routes of excretion of particulate waste in the polychaete, *Hermodice carunculata*. Can. J. Zoolog. 46:619-624. http://dx.doi.org/10.1139/z68-088

OTT, B. & LEWIS, J.B. 1972. The importance of the gastropod Coralliophila abbreviata (Lamarck) and the polychaete *Hermodice carunculata* (Pallas) as coral reef predators. Can. J. Zool. 50:1651-1656. http://dx.doi.org/10.1139/z72-217

SOUZA, J.R.B., RODRIGUES, H.A, NEVES, B.M. & PÉREZ C.D. 2007. First report of bristleworm predator of the reef octocoral *Carijoa riisei*. Coral Reef. 26:1033. http://dx.doi.org/10.1007/s00338-007-0290-2

WITMAN, J.D. 1988. Effects of predation by the fireworm *Hermodice carunculata* on Milleporid hydrocorals. B. Mar. Sci. 42:446-458.

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Leguminosae-papilionoideae from the parque estadual das Várzeas do Rio Ivinhema, Mato Grosso do Sul State, Brazil*

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Abstract: This study aims to evaluate the richness of the Papilionoideae species found in the Parque Estadual das Várzeas do Rio Ivinhema (PEVRI), which is located in the southeast region of Mato Grosso do Sul, Brazil, and investigate if the habits of this Leguminosae group vary in different formations of the park. Monthly collections, including all habits, were made by walking along pre-established trails, from September 2004 to September 2009. The PEVRI includes Seasonal Semideciduous Forest, Seasonal Alluvial Semideciduous Forest and fields. Twenty-three species distributed in 16 genera and 5 tribes were recorded. Phaseoleae was noted with 7 genera, followed by Dalbergieae with 6 genera and Desmodieae, Indigofereae and Crotalarieae with only 1 genus in each species. Among the 16 recorded genera, *Crotalaria* L. (4), *Aeschynomene* L. (3), *Desmodium* Desv., and *Vigna* Savi (2) were the most representative. The Papilionoideae with herbaceous and subshrub habits were predominant in humid and pastures, while arboreous species and lianas were recorded in the Seasonal Semideciduous Forest. Nine species of Papilionoideae were recorded in humid grasslands, eight species in Seasonal Semideciduous Forest, and only one in Alluvial Semideciduous Forest. Papilionoideae found in the PEVRI have also been recorded in cerrado, Seasonal Semideciduous Forest and Pantanal, except *Andira inermis*, which does not present a reference for Seasonal Alluvial Semideciduous Forest.
Keywords: *fabaceae, leguminosae, floristic, Central-Western region, Brazil.*

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Resumo: Este estudo consiste no inventário das Leguminosae-Papilionoideae do Parque Estadual das Várzeas do Rio Ivinhema (PEVRI), localizado ao sudeste de Mato Grosso do Sul e na investigação do hábito predominante das espécies nas diferentes formações do parque. As coletas incluindo todos os hábitos foram realizadas por meio de caminhadas, entre setembro de 2004 a setembro de 2009. O PEVRI agrega remanescentes de Floresta Estacional Semidecídua, de Floresta Estacional Semidecídua Aluvial e de campos. Foram registradas 23 espécies reunidas em 16 gêneros e 5 tribos com destaque para Phaseoleae com 7 gêneros, seguida por Dalbergieae com 6 gêneros e Desmodieae, Indigofereae e Crotalarieae representadas por 1 gênero cada. Dentre os 16 gêneros registrados destacaram-se como mais representativos: *Crotalaria* L. (4), *Aeschynomene* L. (3), *Desmodium* Desv. e *Vigna* Savi (2). As Papilionoideae herbáceas e subarbustivas predominaram em campo úmido e campo com pastagens, as arbóreas e lianas em Floresta Estacional Semidecídua. Nove espécies de Papilionoideae foram registradas em campo úmido, oito em Floresta Estacional Semidecídua e apenas uma em Floresta Estacional Semidecídua Aluvial. As Papilionoideae do PEVRI também foram registradas em outros estudos no Cerrado, Floresta Estacional Semidecídua e Pantanal, exceto *Andira inermis*, sem registros para a Floresta Semidecídua Aluvial.
Palavras-chave: *fabaceae, leguminosae, florística, região Centro Oeste, Brasil.*

Introduction

Leguminosae Adans., the third largest eudicotyledon family in the world (Lewis et al. 2005) and the first in Brazil (Forzza et al. 2010), mainly occurs in tropical and subtropical regions with approximately 727 genera and 19.325 species (Lewis et al. 2005). About 2.694 native species occur in Brazil, and they are distributed among 210 genera (Lima et al. 2010). This family is important to the economy, as well as to ecological studies, and many their representatives are capable of developing nodules with N_2-fixing bacteria, while others have the potential to be used in agro forestry systems, thus having implications for the recovery of degraded areas and the maintenance of soil sustainability (Herrera et al. 1993, Franco & Faria 1997). In taxonomic terms, the subfamilies Papilionoideae and Mimosoideae are supported as monophyletic but they are sheltered in the Caesalpinioideae a subfamily which is paraphiletic (Queiroz 2009).

The Papilionoideae comprises about 13.800 species widely distributed in tropical forests in arid and cold regions (Lewis et al. 2005). In Mato Grosso do Sul, the members of this subfamily are considered important components from many plant communities, occurring in several regions and in such different formations as Planalto Residual do Urucum (Damasceno-Junior unpublished data), semideciduous forest (Sciamarelli, unpublished data), Cerrado (Pott & Pott 1994) and Chaco (Noguchi et al. 2009). Some inventories in Mato Grosso do Sul are specifically referred to *Aeschynomene* (Lima et al. 2006), *Desmodium* (Nobre et al. 2008), *Machaerium* (Polido & Sartori 2007, 2011) and *Stylosanthes* (Costas et al. 2008), but, so far, no study has specifically focused on all members of Papilionoideae occurring in a same area.

The present study aims (i) to evaluate the species richness of Papilionoideae in Parque Estadual das Várzeas do Rio Ivinhema (PEVRI), (ii) investigate the variation of the habits of this group in different formations of the park, and (iii) supply the key identification, descriptions, illustrations, taxonomic comments and information about the geographical distribution.

Material and Methods

1. Study area

The PEVRI is located in Mato Grosso do Sul, between Iguatemi and Nova Andradina micro-regions, and comprises Naviraí, Jatei and Taquarussu municipalities (Figure 1). It covers an area of 73,315 ha, (22° 55’ 14.8” S and 53° 39’ 13.1” W) at 300 m mean altitude (Mato Grosso do Sul 2001). The climate is Cwa with dry winters and rainy summers (Köppen 1948). The average annual temperature is 22 °C, and the rainfall varies from 1400 to 1700 mm. November, December and January are the wettest months (Oliveira & Luzardo 2000).

The Parque Estadual das Várzeas do Rio Ivinhema (PEVRI) is the only one located in the Paraná basin, which is located in the southeast region of the state. The PEVRI woods belong to the Atlantic Forest, and, according to Veloso et al. (1991), it may be divided into Seasonal Alluvial Semideciduous Forest, which are mixed with humid grasslands, riparian forests and secondary formation. There is also some areas represented by Cerrado (Campos & Souza 1997).

2. Collection and analysis of the botanical material

The collections were carried out from monthly April 2004 to September 2006, bimonthly July 2008 to September 2009, through non-systematic walks. During the collections, the general aspect of the plant, habitat, morphology and geographical coordinates were obtained.

The collected materials were deposited in the Herbarium CGMS of the Universidade Federal de Mato Grosso do Sul, and the duplicate were donated to the Herbarium of Dourados at UFGD/UEMS/Unigran/Anhanguera and to the Herbarium UEC at the Universidade Estadual de Campinas. The identification of specimens was achieved using taxonomic literature, experts consultation, comparisons with other herbaria material and photographic analysis of the types. When necessary morphological information was achieved using specific literature sources.

To describe the types of habit, the terminology from Guedes-Bruni et al. (2002) was adopted with some modifications, as follows: herbs, non-woody plants up to 50 cm height; subshrubs, i.e., erect plants with ramifications near the soil and whose branches are partially lignified; shrubs, i.e., ramified plants 1m in height and with woody branches; vines, defined as plants with pliable, non-woody branches that use trees or bushes for support; and lianas, i.e., various long-stemmed, woody vines, and trees which were considered as plants due to their branches are near the apex, forming a woody shaft. The terminology used to describe the vegetative and reproductive structures followed Radford et al. (1974), Harris & Harris (1994) and Barroso et al. (1999).

The taxonomic treatment was based on Lewis et al. (2005). The key and the descriptions were based on morphological variations found in individuals that were in the PEVRI. The illustrations were based on the collected material, and the floral parts were moisturized and drawn with a stereomicroscope. The classification of the biomes followed the Ministério do Meio Ambiente do Brazil (Brasil 2011).

Results

Overal, 23 species of Papilionoideae where recorded in the PEVRI (Table 1) distributed in 16 genera and five tribes. Phaseoleae was the most representative with 7 genera (*Abrus* Adans, *Canavalia* DC., *Collaea* (Loisel.) DC., *Dioclea* Kunth, *Eriosema* (DC.) Desv., *Galactia* P. Browne and *Vigna* Savi.), followed by Dalbergieae with 6 genera (*Aeschynomene* L., *Andira* Juss., *Machaerium* Pers., *Platypodium* Vogel, *Stylosanthes* SW., and *Zornia* J.F. Gmel.) and Desmodieae (*Desmodium* Desv.), Indigofereae (*Indigofera* L.) and Crotalarieae (*Crotalaria* L.) with one genus each.

The most representative genera were *Crotalaria* with four species, *Aeschynomene* with three species, *Desmodium* and *Vigna* with two species each, followed by *Abrus*, *Andira*, *Canavalia*, *Collaea*, *Dioclea*, *Eriosema*, *Galactia*, *Indigofera*, *Machaerium*, *Platypodium*, *Stylosanthes* and *Zornia* with one species each. The herbaceous habit occurred in six representatives, followed by subshrub and herbaceous in four, arboreous and climbing habit in three, liana in two and shrub in only one.

The predominance of herbaceous and subshrub species in open areas of the pasture and humid grasslands found in the PEVRI is equal to that of identical species widely distributed in Brazil. All the species of Papilionoideae found in the PEVRI have also been recorded in Cerrado, Seasonal Semideciduous Forest and Pantanal, except *Andira inermis*, which does not present a reference for Alluvial Semideciduous Forest and *Collaea speciosa* with no record in Pantanal.

1. Identification key for Papilionoideae species from PEVRI

1. Branch with leaves uni-, bi- or trifoliolate.................................2

1’. Branch with leaves plurifoliolate...16

2. Leaves 1-2-foliolate 3

2’. Leaves 1-3-foliolate 4

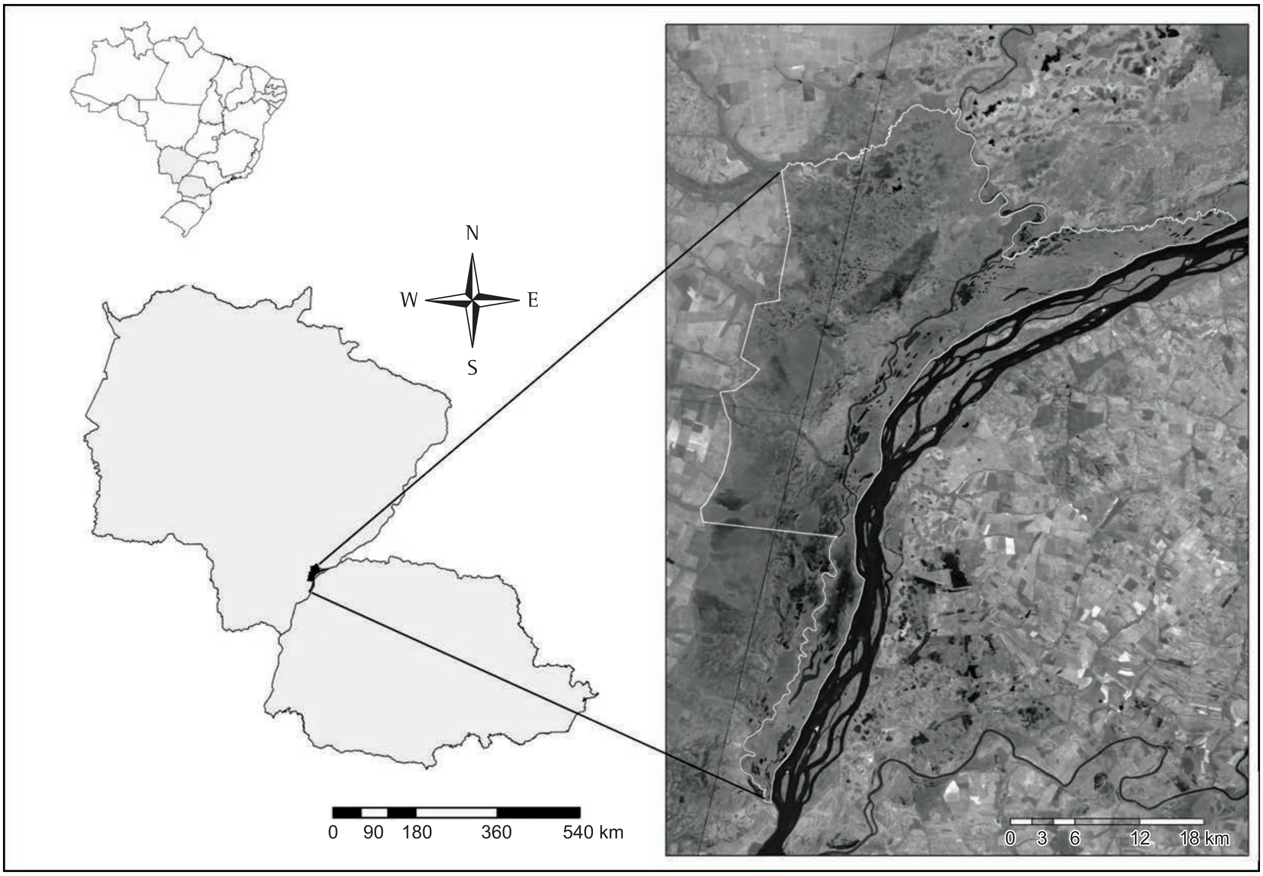

Figure 1. Location of Parque Estadual das Várzeas do Rio Ivinhema (PEVRI), Mato Grosso do Sul, Brazil.

3. Leaves 1-foliolate, the stem winged, absence of geminated bracteoles .... 11. *Crotalaria stipularia*

3’. Leaves 2-foliolate, stem without a wing, presence of two geminated bracteoles which involves each flower ....23. *Zornia latifolia*

4. Lianas or vines 5

4’. Shrubs, subshrubs or herbs 8

5. Lianas, inflorescence in panicle .... 14. *Dioclea burkatti*

5’. Vines, inflorescence in raceme 6

6. Stigma lateral, with a decurrent extension . 21. *Vigna lasiocarpa*

6’. Stigma terminal, without a decurrent extension 7

7. Inflorescence racemose with 4-18 flora; legume 5-6 cm long, 6-9-seeded .... 16. *Galactia striata*

7’. Inflorescence racemose with 4-6 flora; legume 10.5 cm long, 12-seeded .... 6. *Canavalia mattogrossensis*

8. Fruit type legume 9

8’. Fruit type loment 14

9. Legume with ovate seeds 10

9’. Legume with reniform seeds 11

10. Legume up to 1.7 cm long, 2-seeded 15. *Eriosema platycarpon*

10’. Legume longer than 2 cm, 8-20-seeded 13

11. Leaflets elliptical to lanceolate, longer than 5 cm...................8. *Crotalaria lanceolata*

11’. Leaflets elliptical to oblong, shorter than 5 cm 12

12. Legume puberulent, 12-seeded .... 9. *Crotalaria maypurensis*

12’. Legume tomentose, 28-30-seeded .... 10. *Crotalaria micans*

13. Inflorescence 2-flora calyx 5-laciniate, corolla yellow .... 22. *Vigna longifolia*

13’.Inflorescence 4-flora, calyx 4-laciniate, corolla red .... 7. *Collaea speciosa*

14. Inflorescence in capitulum, corolla yellow. ....20. *Stylosanthes guianensis*

14’. Inflorescence racemose, corolla pink or purple 15

15. Villous fruit, with 2-5 articles, 2-5-seeded ....13. *Desmodium barbatum*

15’. Fruit hirsute to glandular, with 1-2 articles, 1-2-seeded ......12. *Desmodium affine*

16. Trees, samara or drupe fruit 17

16’ Herbs, lianas, vines or subshrubs; other types of fruit...........19

17. Leaves with fewer than 10 leaflets, leaflets lanceolate or elliptical, fruit drupe type..5. *Andira inermis*

17’. Leaves with more than 15 leaflets; leaflets oblong, fruit samara type 18

18. Samara with seed-chamber distal, corolla yellow .... 19. *Platypodium elegans*

18’. Samara with seed-chamber basal, corolla lilac .... 18. *Machaerium hirtum*

19. Fruit type legume 20

19’. Fruit type loment 21

20. Leaves 5-7-foliolate, imparipinnate; both surfaces with hirsute and malpighiaceous indumentum, inflorescence multiflora, 6-9-seeded 17. *Indigofera hirsuta*

20’. Leaves 20-foliolate, paripinnate; both surfaces with a sericeous indumentum, inflorescence 4-8 flora, 4-6-seeded ....1. *Abrus praecatorius*

21. Leaves 20-40-foliolate, calyx bilabiate, externally glabrous ...4. *Aeschynomene sensitiva*

21’. Leaves 6-10-foliolate, calyx 5-laciniate, externally hispid or sericeous...22

22. Inflorescence 9-10-flora, axis 7 cm long, loment with 1-3 articles ....3. *Aeschynomene histrix*

22’. Inflorescence 2-flora, axis 0.5-1 cm long, loment with 5-6 articles ....2. *Aeschynomene falcata*

1. *Abrus praecatorius* L. Syst. Nat. (ed. 12) 2: 472. 1767. Figure 2a

Vine; branches cylindrical; stipule and stipel linear, petiole 1-2cm long, puberulent; rachis 5-10 cm long, sericeous. Leaves 20-foliate, paripinnate, symmetrical leaflet, 0.7-2 × 0.4-0.9 cm, obovate; apex mucronated; base obtuse, acute; both surfaces sericeous; entire margin; venation brochidodromous, discolorous. Inflorescence pseudo-racemose, axial, 4-8 flora; peduncle 2-10 cm long, axis 2 cm long, both sericeous. Pedicel 1mm long, sericeous; calyx 3 mm long, campanulate, 5-lacinia, 1 mm long, externally sericeous; corolla purple, standard 6-7 mm long, wing 5-6 mm long, keel 7-8 mm long. Stamens 10, diadelphous (9) + 1, 6-7 mm long. Gynoecium stipellate, stipe 8 mm long, ovary sericeous, style erect, glabrous, stigma terminal glabrous. Legume, 2.5-4.5 × 0.5-1 cm, oblong, apex aristate, sericeous; seeds 4-6 ovate, 4 × 2 mm, nut-brown.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI, 18.IV.2009, fl. and fr., *R. B. Caboco & A. Sciamarelli 28946* (CGMS), 22° 56’ 06.3” S and 53° 43’ 01.6” W.

Leaves with 20 leaflets, with mucronated apex, climbing habit and purple corolla allow the immediate identification of *Abrus praecatorius.* According to Lewis (1987), *Abrus praecatorius* was brought to South America, and there are records in both reef area and Atlantic Forest.

2. *Aeschynomene falcata* (Poir.) DC. Prodr., 2: 322. 1825. Figure 2b

Table 1. List of the sampled species of Papilionoideae in the Parque Estadual das Várzeas do Rio Ivinhema (PEVRI), Mato Grosso do Sul, Brazil, with information about the habit and the vegetation types of each species and records of occurrence in the biomes.

Species	Habit	PEVRI Phyto-physionomy	Biomes
Abrus praecatorius L.	Liana	SDF	CAAT, CE, PA e AW[30]
Aeschynomene falcata (Poir.) Prodr.	Herb/Sub	HF	CE, PA and AW [1]
Aeschynomene histrix Poir.	Herb/Sub	HF	AMA, CAAT, CE, AW and PA[1,2,3]
Aeschynomene sensitiva Sw.	Herb/Sub	SDF e HF	AMA, CAAT, CE, AW, PAMP e PA[1]
Andira inermis (W. Wringht) Kunth ex DC.	Tree	Alluvial SDF	AMA, CE e PA[4]
Canavalia mattogrossensis (Barb. Rodr.) Malme	Liana	SDF	AMA, CE, AW and PA[5]
Collaea speciosa (Loisel.) DC.	Sub	CE and HF	CAAT, CE and AW[7,8,9,10], AW and PAMP[6]
Crotalaria lanceolata E. Mey.	Sub	FI-PA	AMA, CAAT, CE, AW, PAMP and PA[11]
Crotalaria maypurensis Kuntk	Sub	HF	AMA, CAAT, CE, AW, and PA[11]
Crotalaria micans Link	Sub	HF and FI-PA	AMA, CAAT, CE, AW, PAMP and PA[1,12]
Crotalaria stipularia Desv.	Herb	HF and FI-PA	AMA, CAAT, CE, AW and PA[13,14]
Desmodium affine Schltdl.	Herb/Sub	SDF, FI-PA and HF	AMA, CAAT, CE, AW, PAMP and PA[15,16]
Desmodium barbatum (L.) Benth.	Herb	FI-PA	AMA, CAAT, CE, AW, and PA[5, 16, 17]
Dioclea burkartii R.H. Maxwell	Liana	SDF	CE, AW and PA[18]
Eriosema platycarpon Michelli	Sub	FI-PA	CE, AW and PA[19,20]
Galactia striata (jacq.) Urb.	Liana	SDF	AMA, CAAT, CE, AW, PAMP and PA[21]
Indigofera hirsuta L.	Herb/Sub	FI-PA	CE, AW and PA[21]
Machaerium hirtum (Vell.) Stellfeld	Tree	FI-PA	AMA, CAAT, CE, AW and PA[7, 22, 23, 24]
Platypodium elegans Vogel.	Tree	SDF	CE, AW, PAMP and PA[20, 25]
Stylosanthes guianensis (Aubl.) Sw.	Herb/Sub	FI-PA and SF	AMA, CAAT, CE, AW and PA[26]
Vigna lasiocarpa (Mart. Ex Benth.) Verdc.	Liana	HF	AMA, CE, AW, PAMP and PA[27]
Vigna longifolia (Benth.) Verdc.	Herb	SDF	AMA, CAAT, CE, AW, PAMP and PA[27, 28]
Zornia latifolia Sm.	Herb	FI-PA	AMA, CAAT, CE, AW and PA[7, 29]

Herbaceous Herb-; Sub- Subshrub; SDF- semideciduous forest; HF- humid field; FI-PA- Field with Pastures; AMA- Amazonia; CAAT - Caatinga; CE- Cerrado; PA- Pantanal; AW - Atlantic Forest; PAMP- Pampas; SF- secondary formations.([1]Lima et al. 2006, [2]Bentham 1862, [3]Fernandes 1996, [4]Pennington 2003, [5]Tropicos 2006, [6]Ceolin & Miotto 2009, [7]Lewis 1987, [8]Silvestre-Capellato & Melhem 1997, [9]Araújo et al. 2002, [10]Morim 2006, [11]Flores & Miotto 2001, [12]Leitão Filho et al. 1975, [13]Filliettaz 2002, [14]Flores 2004, [15]Azevedo 1981, [16]Nobre et al. 2008, [17]Ducke 1949, [18]Maxwell 1970, [19]Grear 1970, [20]Dubs 1998, [21]Burkart 1970, [21]Moreira & Azevedo-Tozzi 1997, [22]Sartori & Tozzi 1998, [23]Bortoluzzi et al. 2004, [24]Camargo 2005, [25]Mendonça-Filho 1996, [26]Brandão & Costa 1979, [27]Maréchal et al. 1978, [28]Bentham 1859, [29]Sciamarelli & Azevedo-Tozzi 1996, [30]Lewis 1987).

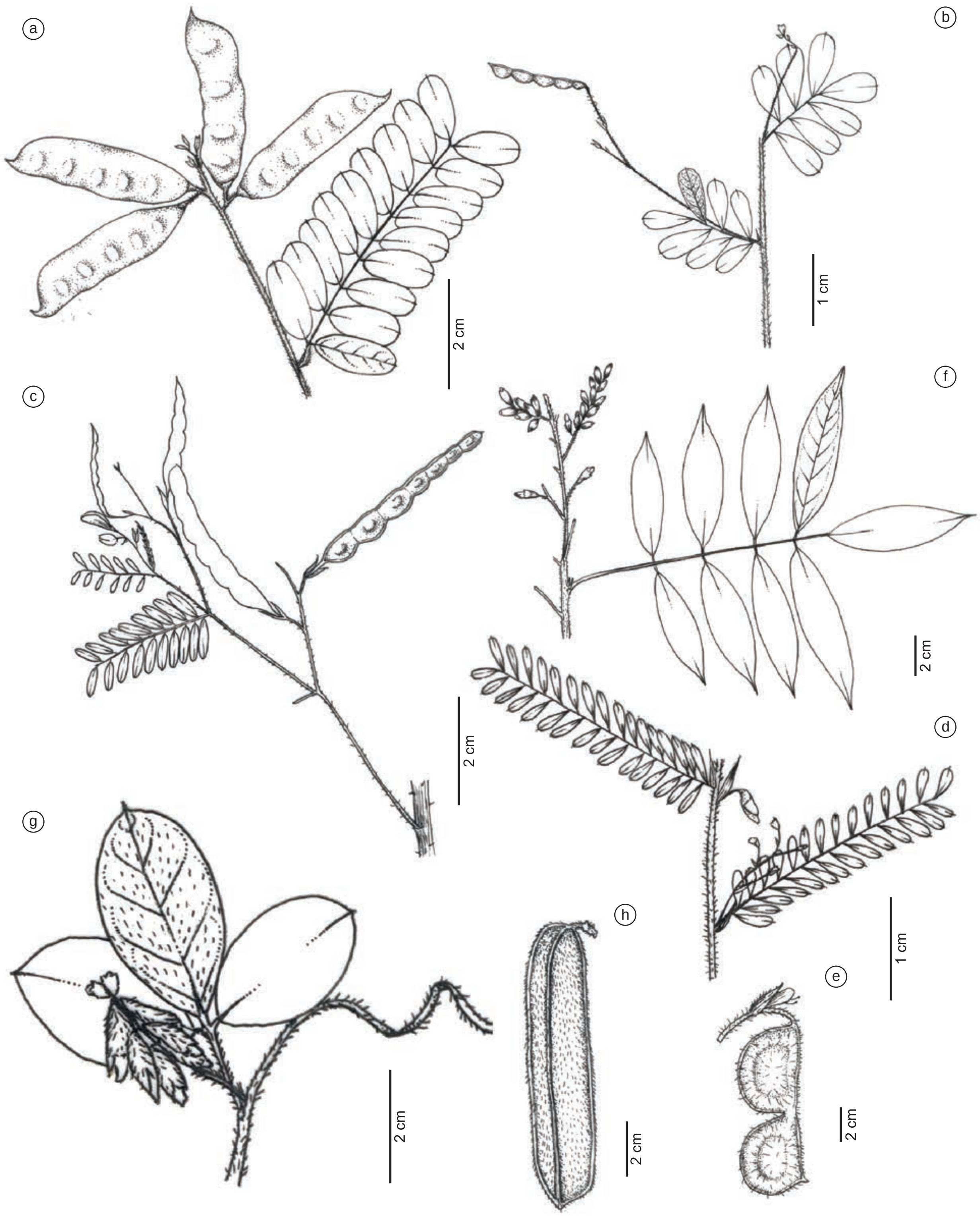

Figure 2. a. *Abrus precatorius* L. - part of the branch with fruit (*Caboco & Sciamarelli* 01); b. *Aeschynomene falcata* (Poir.) Dc. - part of the branch with fruit (*Pereira* et al. 1592); c. *Aeschynomene sensitiva* Sw. - part of the branch with fruit (*Pereira* et al. 1628); d-e. *Aeschynomene histrix* Poir.; d. part of the branch with inflorescence (*Pereira* et al. 484); e. fruit (*Pereira* et al. 484); f. *Andira inermis* (W. Wright) Kunth *ex* DC. - part of the branch with inflorescence (*Pereira* et al. s/n); g-h. *Canavalia mattogrossensis* (Barb. Rodr.) Malme - g. part of the branch with inflorescence (*Pereira* et al. 1226); h. fruit (*Pereira* et al 1226).

Prostrate herb or decumbent subshrub, branches cylindrical; stipule lanceolate, striate, stipel ovate, petiole 0.2-0.3 cm long, rachis 0.5-1 cm long, both sericeous. Leaves 6-8-foliate, paripinnate or imparipinnate, leaflet symmetrical, 0.6-0.9 × 0.3-0.4 cm, obovate; apex mucronate; base oblique, both surfaces sericeous, entire margin, venation brochidodromous, concolorous. Inflorescence racemose, axial, 2-flora; peduncle 1-2.5 cm long, axis 0.5-1 cm long, both sericeous. Pedicel 3-5 mm long, sericeous; calyx 3-4 mm long, campanulate, 5-laciniate, 1-1.5 mm long, externally sericeous; corolla yellow, standard 4 mm long, wing 3.5 mm long, keel 3.5 mm long.

Stamens 10, diadelphous (9) + 1, 2-6 mm long. Gynoecium stipellate, stipe 6-12 mm long, ovary tomentose, style curved, glabrous; stigma terminal glabrous. Loment, 3-3.3 × 2.5-3 mm, ovate, 5-6 articles, obovate, apex mucronate, tomentose; seeds 5-6 ovate to reniform, 3 × 3 mm, nut-brown.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI, 11.X.2006, fr. and fl., *Z. V. Pereira et al. 28908* (CGMS), 22° 55' 14.8" S and 53° 39' 13.1" W.

Aeschynomene falcata is distinguished by its stipule lanceolate, leaflet obovate, stipe 6-12 mm long and loment with 5-6 tomentose articles. There are records of this species in Colombia, Bolivia, Brazil, Paraguay and the savannas, fields, rocky hillsides, high altitude areas and Chaco in Argentina (Rudd 1955). It is commonly found in cerrado and closed fields, as secondary or disturbed vegetation, along lagoon shoreline, and in flooded fields (Lima et al. 2006).

3. *Aeschynomene histrix* Poir., Encycl. Suppl. 4. (1): 77. 1816....... Figure 2d, e

Prostrate herb, ascending to subshrub, branches cylindrical; stipule ovate, stipel caducous, petiole 3 mm long, rachis 1.4 cm long, both hispid. Leaves 6-10-foliate, imparipinnate, leaflets symmetrical, 0.5-1 × 0.3-0.5 cm, obovate; apex mucronate, rounded; base oblique, surfaces, adaxial glabrous and abaxial hispid, entire margin, venation brochidodromous, concolorous. Inflorescence racemose, axial, 9-10 flora; peduncle 1 cm long, axis 7 cm long, hispid. Pedicel 4-6 mm long, hispid; calyx 2 mm long, campanulate, 5-laciniate, 0.5 mm long, externally hispid; corolla yellow, standard 2.5 mm long, wing 1.2 mm long, keel 1.5 mm long. Stamens 10, diadelphous (9) + 1, 5.5 mm long. Gynoecium stipellate, stipe 1 mm long, ovary tomentose, style erect, hispid; stigma terminal glabrous. Loment, 3.5-4 × 2.5-3 mm, ovate, 1-3 articles, obovate, apex acute, thickly pilose; seeds 2-3, ovate to reniform, 2.5 × 2 mm, nut-brown.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI, 27.III.2004, fr. and fl., *Z. V. Pereira et al. 28884* (CGMS), 22° 56' 16.7" S and 53° 41' 13.3" W.

Aeschynomene histrix is distinguished by its 6-10 foliolated leaves, obovate leaflets, apex mucronate, loment with 1, 2 or 3 articles, thick pilosity (Figure 2d). According to Lima et al. (2006), this species may be collected in areas of cerrado, mountain ridge, *Elyonurus muticus* grassland (caronal), *Byrsonima orbignyana* scrub (canjiqueiral), disturbed vegetation, secondary vegetation and lagoon shoreline.

4. *Aeschynomene sensitiva* Sw., Prod. 107. 1788. .... Figure 2c

Erect herb or subshrub, branches cylindrical; stipule and stipel were not observed, petiole 3-5 cm long, hispid, rachis 30-45 mm long, glabrous. Leaves 20-40-foliate, imparipinnate, leaflets symmetrical, 0.8-1.4 × 0.2-0.3 cm, obovate; apex rounded, base oblique, both surfaces glabrous, entire margin, venation brochidodromous, concolorous. Inflorescence racemose, axial, 2-4 flora; peduncle 0.5-2 cm long, axis 1-1.5 cm long, both hispid. Pedicel 3 mm long, glabrous; calyx 5-6 mm long, bilabiate, 2-laciniate, 4-5 mm long, glabrous; corolla yellow, standard 7 mm long, wing 7 mm long, keel 8 mm long. Stamens 10, diadelphous (9) + 1, 5-6 mm long. Gynoecium stipellate, stipe 1 mm long, ovary glabrous, style erect, glabrous; stigma terminal glabrous. Loment, 6-8 × 54-5 mm, ovate, 3-7 articles, obovate, apex apiculate, seeds 3-7, ovate, 3 × 1.5 mm, brown.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI, 12.X.2006, fr. and fl., *Z. V. Pereira et al. 28907* (CGMS), 22° 55' 14.8" S and 53° 39' 13.1" W.

Aeschynomene sensitiva may be distinguished by its leaves with 20 to 40 obovate leaflets, rounded apex, calyx with 2 lacinia and loment with 3-7 glabrous articles. Lima et al. (2006) note that the bracts 3 mm long, ovate-lanceolate and flabelliform margin are important for identifying this species, but these characteristics were not observed in the material analyzed. This species occurs in flooded grasslands, swamps and disturbed vegetation (Lima et al. 2006).

5. *Andira inermis* (W. Wright) Kunth ex DC., Prodr. 2: 475. 1825. Figure 2f

Tree, branch cylindrical; stipule and stipel absent, petiole 4-6.5 cm long, rachis 7 cm long, all of them glabrous. Leaves 7-foliolate, imparipinnate, leaflets symmetrical, 3-7 × 1-2.5 cm, elliptical to lanceolate; apex acute, base diminished, surfaces glabrous, entire margin, venation brochidodromous, concolorous. Inflorescence racemose, terminal axial, multiflora; 0.5-1 cm long, tomentose, axis 5-15 cm long, tomentose. Pedicel 1-2 mm long, tomentose; calyx 5-6 mm long, campanulate, 5-laciniate, 1 mm long, tomentose; corolla yellow, standard 14 mm long, wing 14 mm long, keel 14 mm long. Stamens 10, diadelphous (9) + 1, 13-14 mm long. Gynoecium stipellate, stipe 6 mm long, ovary sericeous, style erect, sericeous; stigma terminal glabrous. Fruit drupe, 2.5-4.3 × 2-4.3 cm, ovate, glabrous (Pennington 2003).

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI, 18.IV.2009, fl., *Z. V. Pereira et al. 28947* (CGMS), 22° 55' 14.8" S and 53° 39' 13.1" W.

Andira inermis may be distinguished by its raceme inflorescence with purple flowers, standard 14 mm long, calyx thickly pilose and lacinia smaller than 1 mm in length, rounded or acute apex. There are records of this species in Seasonal Deciduous and Semideciduous Forests and cerrado (Silva 2006).

6. *Canavalia mattogrossensis* (Barb. Rodr.) Malme, Ark. Bot. 4(7): 9. 1905. .... Figure 2g, h

Vine, branches cylindrical; stipule not observed, stipel lanceolate, petiole 1-2 cm long, rachis 0.3-0.8 cm long, both tomentose. Leaves 3-foliate, imparipinnate, leaflet terminal asymmetrical, 3-6.5 × 1.6-3.5 cm, elliptical, apex acute, retuse, base obtuse, both surfaces sericeous, tomentose, entire margin, venation brochidodromous, discolorous. Leaflet lateral 3.5-5 × 1.5-3 cm. Inflorescence racemose, axial 4-6 flora; peduncle 1-2 cm long, axis 2-3 cm long, tomentose. Pedicel 0.2-0.3 cm long, tomentose; calyx 12 mm long, campanulate, 5-laciniate, 2-4 mm long, externally tomentose; corolla pink, standard 30 mm long, wing 29 mm long, keel 38 mm long. Stamens 10, monadelphous, 35 mm long. Gynoecium stipellate, stipe 1 mm long, ovary tomentose, style erect, glabrous; stigma terminal glabrous. Legume, 10.5 × 1.5 cm, oblong, apex rounded, mucronate, tomentose; seeds 12, ovate, 5 × 8 mm, brown spotted with black.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI, 22.IV.2005, fr. and fl., *Z. V. Pereira et al. 28900* (CGMS), 22° 55' 45.4" S and 53° 42' 13.9" W.

Canavalia mattogrossensis is readily distinguished by its keel petals which are bigger (38 mm long) than, or equal to, the standard length (30 mm long) and racemose inflorescences with nodules along its axis. According to Tropicos (2006), there are records in Seasonal Semideciduous Forest and cerrado.

7. *Collaea speciosa* (Loisel.) DC., Mem. Leg. 6: 245. 1825. .... Figure 3a, b

Subshrub, branches cylindrical; stipule and stipel absent, petiole 0.2 cm long, tomentose, rachis absent. Leaves 3-foliate, imparipinnate, leaflets symmetrical, 3-5.5 × 0.6-0.8 cm, lanceolate, apex acute, diminished base, entire margin, venation eucamptodromous, surfaces, adaxial glabrous and abaxial tomentose, discolorous. Inflorescence racemose, axial, 4-flora, peduncle 0.2-0.3 cm long, axis 0.1-0.2 cm long, tomentose. Pedicel 1-1.5 cm long, tomentose; calyx 16 mm

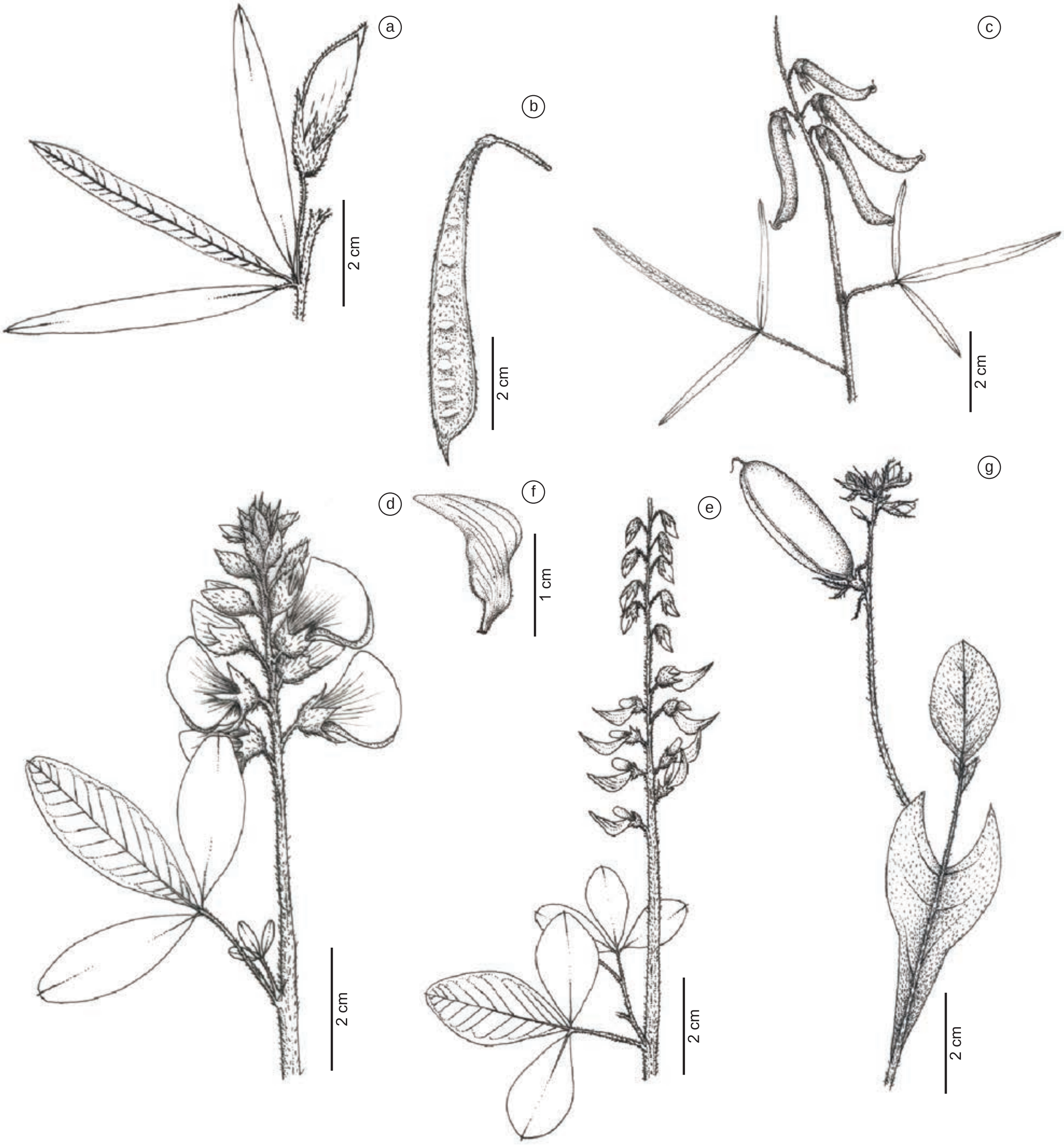

Figure 3. a-b. *Collaea speciosa* (Loisel.) DC. a. - part of the branch with flower; b. fruit (*Pereira* et al. 1197); c. *Crotalaria lanceolata* E. Mey.- part of the branch with inflorescence (Caboco & Sciamarelli 37); d. *Crotalaria maypurensis* Kunth- part of the branch with inflorescence (*Pereira* et al. 344); e-f. *Crotalaria micans* Link - branch with inflorescence; f. standard. (*Caboco & Sciamarelli 23*); g. *Crotalaria stipularia* Desv. - branch with inflorescence and fruit (*Caboco & Sciamarelli 27*).

long, campanulate, 4-laciniate, 8-10 mm long, tomentose; corolla red, standard 33 mm long, wing 30 mm long, keel 25 mm long. Stamens 10, diadelphous (9) + 1, 23-25 mm long. Gynoecium stipellate, stipe 1 mm long, ovary tomentose, style erect, glabrous; stigma terminal glabrous. Legume, 6.5 × 0.7 cm, oblong, apex apiculate, tomentose; seeds 10-20, ovate, 2 × 1 mm, nut-brown, brown.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI, 21.IV.2005, fr. and fl., *Z. V. Pereira et al. 28904* (CGMS), 22° 55' 14.8" S and 53° 39' 13.1" W.

Collaea speciosa may be noted as a subshrub by its 3-foliate leaves, lanceolate leaflets, inflorescence with short peduncle (0.3-0.2 cm long), red flowers and calyx tomentose. According to Ceolin & Miotto (2009), this species is generally isolated, occupying wooded fields, gallery forest and roadsides.

8. Crotalaria lanceolata E. Mey., Comm. Pl. Afr. Austr. 1: 24. 1836 .... Figure 3c

Subshrub, branches cylindrical; stipule and stipel not observed, petiole 1-3 cm long, puberulent, rachis 0.1 cm long, puberulent. Leaves

3-foliate, leaflet terminal asymmetrical, 1.5-6.5 × 0.4-0.5 cm long, elliptical to lanceolate, apex acute, apiculate, base acute, surfaces, adaxial glabrous and abaxial puberulent, entire margin, venation camptodromous, discolorous, leaflet lateral 5-14 × 0.4-0.5 cm long. Inflorescence racemose, terminal, multiflora; peduncle 3-6 cm long, puberulent, axis 6-10 cm long, puberulent. Pedicel 2 cm long, puberulent; calyx 3-4 mm long, campanulate, 5-laciniate, 1 mm long, externally puberulent; corolla yellow, standard 9 mm long, wing 10 mm long, with brown grooves, keel 11 mm long. Stamens 10, monadelphous, 8-9 mm long. Gynoecium stipellate, stipe 1 mm long, ovary puberulent, style curved, sericeous, stigma terminal glabrous. Legume, 3-3.5 × 0.4-0.5 cm long, oblong, apex apiculate, puberulent; seeds 16-20, reniform, 2 × 2 mm, orange or fawn.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI, 18.IV.2009, fr. and fl., *R. B. Caboco & A. Sciamarelli 28926* (CGMS), 22° 51’ 05.8” S and 53° 39’ 18.2” W.

Crotalaria lanceolata is distinguished by its leaflets lanceolate, abaxial puberulence, inflorescence axis 6-10 mm long and wing with brown grooves.

9**.** *Crotalaria maypurensis* Kunth, Nov. Gen. Sp. 6: 403. 1824. ...... Figure 3d

Subshrub, branches cylindrical; stipule linear, elliptical, stipel not observed, petiole 2-4 cm long, rachis 0.1-0.2 cm long, both puberulent. Leaf 3-foliate, leaflet terminal asymmetrical, 3.5-4 × 1.2-1.8 cm, elliptical to oblong, apex acute and apiculate, diminished base, surfaces, adaxial glabrous and abaxial puberulent, entire margin, venation camptodromous, discolorous, leaflet lateral 2-3.5 × 0.8-1.2 cm long. Inflorescence racemose, terminal, multiflora, peduncle 6-8 cm long, axis 10-32 cm long, puberulent. Pedicel 1.0 cm long, puberulent; calyx 8-10 mm long, campanulate, 5-laciniate, 5-7 mm long, sericeous; corolla yellow, standard 17-20 mm long, wing 18 mm long, with fawn grooves, keel 18 mm long. Stamens 10, monadelphous, 16 mm long. Gynoecium stipellate, stipe 1 mm long, ovary sericeous; style curved, glabrous; stigma terminal glabrous. Legume, 3.2 × 1 cm, oblanceolate, apex apiculate, puberulent; seeds 12, reniform, 3 × 3 mm, nut-brown.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI, 23.XI.2004, fr. and fl., *Z. V. Pereira et al. 28876* (CGMS), 22° 55’ 45.4” S and 53° 44’ 49.9” W.

Crotalaria maypurensis may present a variation in the shape of its leaflets, i.e., from elliptical to oblong, inflorescence axis 10-32 cm long, standard 17-20 mm long, with fawn grooves. In Brazil, it is frequently found in cerrado areas (Flores & Miotto 2001).

10. *Crotalaria micans* Link, Enum. Hort. Berol. Alt. 2: 228, 1822. Figure 3e, f

Subshrub, branches cylindrical; stipule elliptical, stipel absent, petiole 2-3 cm long, rachis 0.3 cm long, tomentose. Leaves 3-foliate, leaflets symmetrical, 2.5-5 × 1.6-2.8 cm long, oblong to elliptical, apex apiculate, cuneated base, surfaces, adaxial glabrous and abaxial sericeous, entire margin, venation camptodromous, discolorous. Inflorescence racemose, terminal, multiflora, peduncle 6-8 cm long, axis 15-35 cm long, both pubescent. Pedicel 0.4-0.5 cm long, pubescent; calyx 6-8 mm long, campanulate, 5-laciniate, 3-4 mm long, externally sericeous; corolla yellow, standard 12-13 mm long, wing 11-14 mm long, without grooves, keel 18-21 mm long. Stamens 10, monadelphous, 12-13 mm long. Gynoecium stipellate, stipe 1 mm long, ovary sericeous, style curved, sericeous, stigma terminal ciliate. Legume, 2.5-3.5 × 0.4-0.5 cm, linear to oblong, apex apiculate, tomentose in the external region of the placentation; glabrous in the opposite position; seeds 28-30, reniform, 3 × 2 mm, fawn.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI, 18.IV.2009, fr. and fl., *R. B. Caboco & A. Sciamarelli 28927* (CGMS), 22° 55’ 45.4” S and 53° 44’ 49.9” W.

The inflorescence axis of *Crotalaria micans* is longer (15-35 cm) than that of *C. maypurensis*, and it presents smaller flowers (12-13 mm long).

11. *Crotalaria stipularia* Desv., J. Bot. Agric. 3: 76. 1814. Figure3g

Erect herb, winged stem, branches cylindrical; stipule and stipel not observed, internode wing 2-6 cm long. Leaf 1-foliate, leaflet symmetrical, 2.5-4.5 × 1.5-3 cm long, elliptical to obovate, apex retuse to apiculate, diminished base, both surfaces hispid, entire margin, venation camptodromous, discolorous. Inflorescence racemose, axial, peduncle 4-6 cm long, rachis 5-12 cm long, both tomentose. Pedicel 0.1-0.4 cm long, tomentose; calyx 7-10 mm long, campanulate, 5-laciniate, lacinium 5-7 mm long, sericeous; corolla yellow, standard 5-6 mm long, wing 5 mm long, without grooves, keel 7 mm long. Stamens 10, monadelphous, 7-8 mm long. Gynoecium stipellate, stipe 1 mm long, ovary sericeous, style curved, hispid near the stigma, stigma terminal ciliate. Legume, 2-3.5 × 0.8-1 cm, oblong, apex apiculate, glabrous; seeds 21-27, reniform, 3 × 2 mm, nut-brown.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI, 18.IV.2009, fr. and fl., *R. B. Caboco & A. Sciamarelli 28880* (CGMS), 22° 52’ 50.2” S and 53° 38’ 40.7” W.

Crotalaria stipularia may be distinguished by its winged stem, unifoliate leaves, elliptical leaflet, obovate, with hispid trichomes on both surfaces. In South America, this species is found from Venezuela and Guiana to Argentina (Filliettaz 2002, Flores & Miotto 2001). It is found in “restinga”, riparian forest, cerrado, open fields, “campo rupestre” and sandy, swampy and disturbed places (Filliettaz 2002, Flores 2004).

12. *Desmodium affine* Schltdl., Linnaea 12: 312. 1838. Figure 4a, b

Prostrate herb or subshrub, branches cylindrical; stipule ovate-lanceolate, stipel lanceolate, petiole 0.6-1.8 cm long, sericeous, rachis 0.2-0.5 cm long, sericeous. Leaves 3-foliate, leaflets symmetrical 3-6.2 × 1-2 cm, elliptical, apex acute, base obtuse, cuneate, entire margin, venation brochidodromous, both surfaces sericeous, discolorous. Inflorescence racemose, terminal and axial, multiflora; peduncle 3-5 cm long, axis 6-10 cm long, both hirsute to sericeous. Pedicel 2-5 mm long, hirsute; calyx 3 mm long, campanulate, 5-laciniate, 2 mm long, hirsute; corolla pink, standard 6 mm long, wing 5 mm long, keel 5 mm long. Stamens 10, diadelphous, (9) + 1, 4 mm long. Gynoecium stipellate, stipe 1 mm long, ovary hirsute, style erect, glabrous; stigma terminal glabrous. Loment, 6 × 4 mm, oblong, 1-2 articles, obovate, apex apiculate, hirsute to glandular; seeds 1-2, ovate to reniform, 1.5 × 2 mm, white.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI, 12.IX.2006, fr. and fl., *Z. V. Pereira et al. 28910* (CGMS), 22° 55’ 59.6” S and 53° 43’ 06.9” W.

Desmodium affine is distinguished by its ovate-lanceolate stipule, elliptical leaflets, loment with 1-2 articles, obovate, with hirsute-glandular trichomes. It is found in woods, cerrado, grasslands, “campo rupestre”, but it is mainly found in humid and shadowy areas (Azevedo 1981, Nobre et al. 2008).

13. *Desmodium barbatum* (L.) Benth., Pl. Jungh. 2: 224. 1852. ..... Figure 4c, d

Prostrate herb, branches cylindrical, stipule and stipel lanceolate, petiole 5-13 mm long, rachis 1-3 cm long, both sericeous. Leaf 1-3-foliate, leaflet asymmetrical 1-2.6 × 0.5-1.8 cm, elliptical to obovate; apex obtuse to rounded, base rounded, cuneate, adaxial surface glabrous, villous, abaxial villous to sericeous, entire margin, venation brochidodromous, concolorous, lateral leaflet

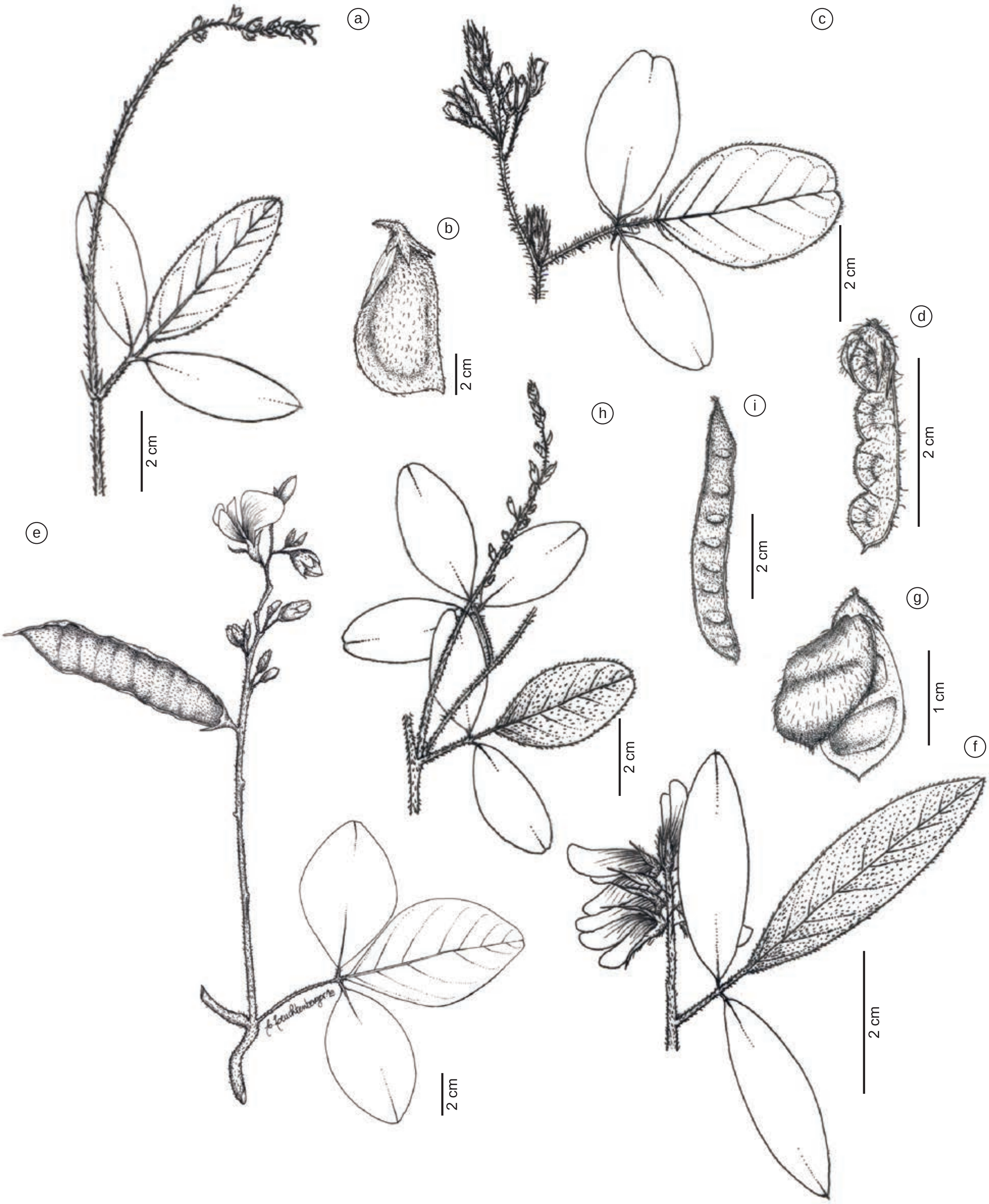

Figure 4. a-b. *Desmodium affine* Schltdl. - a. part of the branch with inflorescence; b. fruit. (*Pereira* et al. *1643*); c-d. *Desmodium barbatum* (L.) Benth. - c. part of the branch with inflorescence (*Pereira* et al. *444*); d. fruit. (*Pereira* et al. 444); e. *Dioclea burkartii* R.H. Maxwell - part of the branch with inflorescence and fruit. (*Pereira* et al. *277*); f-g. *Eriosema platycarpon* Micheli - f. part of the branch with inflorescence; g. fruit. (*Caboco & Sciamarelli 34*); h-i. *Galactia striata* (Jacq.) Urb. h- part of the branch with inflorescence; i. fruit. (*Pereira* et al. 1235).

0.9-1.9 × 0.6-1 cm. Inflorescence racemose, terminal to axial, multiflora; peduncle 1-2 cm long, villous, axis 1-3 cm long, villous. Pedicel 6-8 mm long, sericeous; calyx 4 mm long, campanulate, 5-laciniate, 3 mm long, villous; corolla purple, standard 6 mm long, wing 5 mm long, keel 5 mm long. Stamens 10, diadelphous (9) + 1, 5 mm long. Gynoecium stipellate, stipe 1 mm long, ovary tomentose, style erect, glabrous; stigma glabrous. Loment, 4-5 × 3-4 mm, oblong, 2-5 articles, ovate, apex apiculate, villous; seeds 2-5, ovate, 2 × 1 mm, black.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI, 27.III.2004, fr. and fl., *Z. V. Pereira et al. 28944* (CGMS), 22° 56’ 06.3” S and 53° 43’ 01.6” W.

Desmodium barbatum may be identified by its uni- to trifoliate leaf, elliptical and obovate leaflets present on the same plant, villous calyx and loment, which may vary from 2-5 articles. This species may be found in cerrado, swampy grasslands, dirty grasslands and degraded area (Ducke 1949, Tropicos 2006, Nobre et al. 2008).

14. *Dioclea burkartii* R.H. Maxwell, Darwiniana 16(1-2): 413. 1970. .... Figure 4e

Liana branches cylindrical; stipule ovate, stipel lanceolate, petiole 2-3 cm long, rachis 0.5 cm long, both sericeous. Leaves 3-foliate, leaflet terminal asymmetrical 6-7.5 × 4-4.5 cm long, ovate to elliptical; apex acute, base oblique, both surfaces sericeous, entire margin, venation brochidodromous, discolorous, lateral leaflet 4.5-6.5 × 3-4.5 cm. Inflorescence racemose nodose, axial, 15-26-flora; peduncle 4.5 cm long, axis of the inflorescence 20-25 cm, both sericeous. Pedicel 5-7 mm long, sericeous; calyx 14 mm long, campanulate, 5-laciniate, 5.5 mm long, sericeous; corolla lilac, standard 25 mm long, sericeous, wing 23 mm long, keel 20-23 mm long. Stamens 10, monadelphous or pseudomonadelphous, 33 mm long. Gynoecium stipellate, stipe 1 mm long, ovary tomentose, style curved, glabrous; stigma puberulent. Legume, 8.5-10 × 1.5-2.2 cm, oblong, apex apiculate, tomentose; seeds 9, ovate, 13 × 7 mm, nut-brown.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI, 06.IX.2003, fr. and fl., *Z. V. Pereira et al. 28875* (CGMS), 22° 55’ 45.4” S and 53° 44’ 49.9” W.

The main characteristics of *Dioclea burkartii* are the ovate and elliptical leaflets, acute apex, inflorescence racemose with nodes evident, lilac corolla and tomentose fruit 8 to 10 cm long. Database records of this species are few in number. It is only noted in Mato Grosso do Sul and Paraná (Maxwell 1970).

15. *Eriosema platycarpon* Micheli, Mem. Soc. Phys. Genev. 28(7): 34. 1883. ....Figure 4f, g

Subshrub, branches cylindrical; stipule and stipel lanceolate, petiole 0.5 mm long, rachis 1.5 cm long, both tomentose. Leaves 3-foliate, leaflets symmetrical 0.8-3.4 × 1.5-2.5 cm long, elliptical; apex acute, base oblique, tomentose, entire margin, venation brochidodromous, discolorous. Inflorescence racemose, axial, 8-11-flora; peduncle 2.5 cm, tomentose, axis 2.5-4 cm long, tomentose. Pedicel 6 mm long, tomentose; calyx 5 mm long, campanulate, 5-laciniate, 3 mm long, tomentose; corolla yellow, standard 15 mm long, wing 10 mm long, keel 15 mm long. Stamens 10, diadelphous (9) + 1, 15 mm long. Gynoecium stipellate, stipe 1 mm long, ovary tomentose, style erect, tomentose; stigma terminal, tomentose. Legume, 1.5-1.7 × 1-1.2 cm, oblong, apex mucronate, tomentose; seeds 2, ovate, 5-4 × 3-4 mm, greenish brown.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI, 19.IV.2009, fr. and fl., *R. B. Caboco & A. Sciamarelli 28891* (CGMS), 22° 5546.3” S and 53° 43’ 07.4” W.

Eriosema platycarpon is distinguished by its elliptical leaflets, tomentose, discolorous and relatively small fruit (1.5-1.7 × 1-1.2 cm). It is found along the cerrado edges and in the transition of woody cerrado and riparian forest and parks, as well as sandy and silty soils (Cristaldo, unpublished data).

16. *Galactia striata* (Jacq.) Urb., Symb. Antill. . 2(2): 320. 1900. .. Figure 4h, i

Vine, branches cylindrical; stipule and stipel lanceolate, petiole 0.6-3 cm long, rachis 2-5 mm long, both sericeous. Leaves 3-foliate, leaflet terminal symmetrical 2.5-6 × 1-2.4 cm, elliptical; apex apiculate, base acute, both sericeous, entire margin, venation brochidodromous, discolorous, leaflet lateral 2.2-4.5 × 0.9-2 cm. Inflorescence racemose, axial, 4-18-flora; peduncle 1-4 cm long, axis 6.5 cm long, both sericeous. Pedicel 1-2 mm long, sericeous; calyx 5 mm long, campanulate, 5-laciniate, 2-3 mm long, sericeous; corolla purple, standard 11.5 mm long, wing 9-10 mm long, keel 10 mm long. Stamens 10, diadelphous (9) + 1, 10-11 mm long. Gynoecium stipellate, stipe 1 mm long, ovary tomentose, style erect, glabrous; stigma terminal, glabrous. Legume, 5-6 × 0.6-0.7 cm, oblong, apex apiculate, sericeous; seeds 6-9, ovate, 4 × 4 mm, black.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI, 22.IV.2005, fr. and fl., *Z. V. Pereira et al. 28897* (CGMS), 22° 55’ 14.8” S and 53° 39’ 13.1” W.

Galactia striata is mainly characterized by its lanceolate stipule and stipel, venation brochidodromous, discolorous, and legume 5-6 × 0.6-0.7 cm, oblong. According to Burkart (1970), there are records of this species in the Americas, from the southeast of the United States to Argentina.

17. *Indigofera hirsuta* L., Sp. Pl. 2: 751. 1753. .... Figure 5a

Herb or subshrub, branches cylindrical; stipule lanceolate, stipel not observed, petiole 1-2 cm long, rachis 2.5-3.0 cm long, both hirsute. Leaves 5-7-foliate, imparipinnate, leaflet terminal asymmetrical, 1-2.5 × 0.6-1.5 cm, obovate; apex mucronate, diminished base, both hirsute and malpighiaceous, entire margin, venation not evident, leaflet lateral 0.9-1.4 × 0.4-0.8 cm. Inflorescence racemose, axial, multiflora; peduncle 1 mm long, axis 4-5.5 cm long; calyx 4 mm long, campanulate, 5-laciniate, 1 mm long, tomentose; corolla pink, standard 3-4 mm long, wing 4 mm long, keel 5 mm long. Stamens10, diadelphous (9) + 1, 4-4.2 mm long. Gynoecium stipellate, stipe 1 mm long, ovary glabrous, style erect, glabrous; stigma terminal glabrous. Legume, 0.2-1.6 × 0.2-1.2 cm, cylindrical, tomentose, apex acute; seeds 6-9, ovate, 1 × 1 mm, black and nut-brown.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI, 27.III.2004, fr. and fl., *Z. V. Pereira et al. 28879* (CGMS), 22° 52’ 50.2” S and 53° 38’ 40.7” W.

The peculiarities of *Indigofera hirsuta* include the hirsute and malpighiaceous indumentum on the branches, leaflets, peduncles and floral axis, leaves with 5 to 7 leaflets, lanceolate stipules and cylindrical fruit. According to Moreira & Azevedo-Tozzi (1997), it is commonly found in disturbed areas, secondary vegetation and sandy soils.

18. *Machaerium hirtum* (Vell.) Stellfeld, Tribuna Farm., Bras. 12i. 132.1944. .... Figure 5b

Tree, branches cylindrical; stipule lanceolate, rectilinear, spinescent, stipel not observed, petiole 0.5-1 cm long, rachis 8-12 cm long, both tomentose. Leaves 40-foliate, imparipinnate, leaflets symmetrical, 1-1.3 × 0.3- 0.4 cm, oblong; apex mucronate, diminished base, both surfaces glabrous, entire margin, venation craspedodromous, discolorous. Inflorescence paniculate, terminal to axial, multiflora; axis of inflorescence 11-16 cm long, villous (Polido & Sartori 2007). Pedicel 8.8-10.6 mm long, villous; calyx 2.6 mm long, campanulate, 5-laciniate; corolla lilac; standard 6.9-9.3 × 5.9-7.6 mm, wing 7.6-9 × 3.3-4.7 mm long, keel 7.1-9.6 × 4.5-5.1 mm. Stamens 10, monadelphous. Gynoecium not stipellate, ovary velutinous, style erect, stigma glabrous. Samara cultriform, 4.5-5.4 × 0.9-1.2 cm, apex obtuse, apiculate, glabrescent; seed-chamber basal, brownish, tomentose, 2-3.4 × 1-1.2 cm.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema PEVRI, 19.IV.2009, fr., *R. B. Caboco & A. Sciamarelli 28931* (CGMS), 22° 56’ 15.3” S and 53° 41’ 01.9” W.

Macherium hirtum is distinguished by its rectilinear, spinescent stipules, oblong leaflets and arboreous habit. It is found in several phyto-physyonomy of Cerrado, in sandy and clayish soils, in Seasonal Semideciduous and Deciduous Forests and dense Ombrophylous Forest (Polido & Sartori 2007).

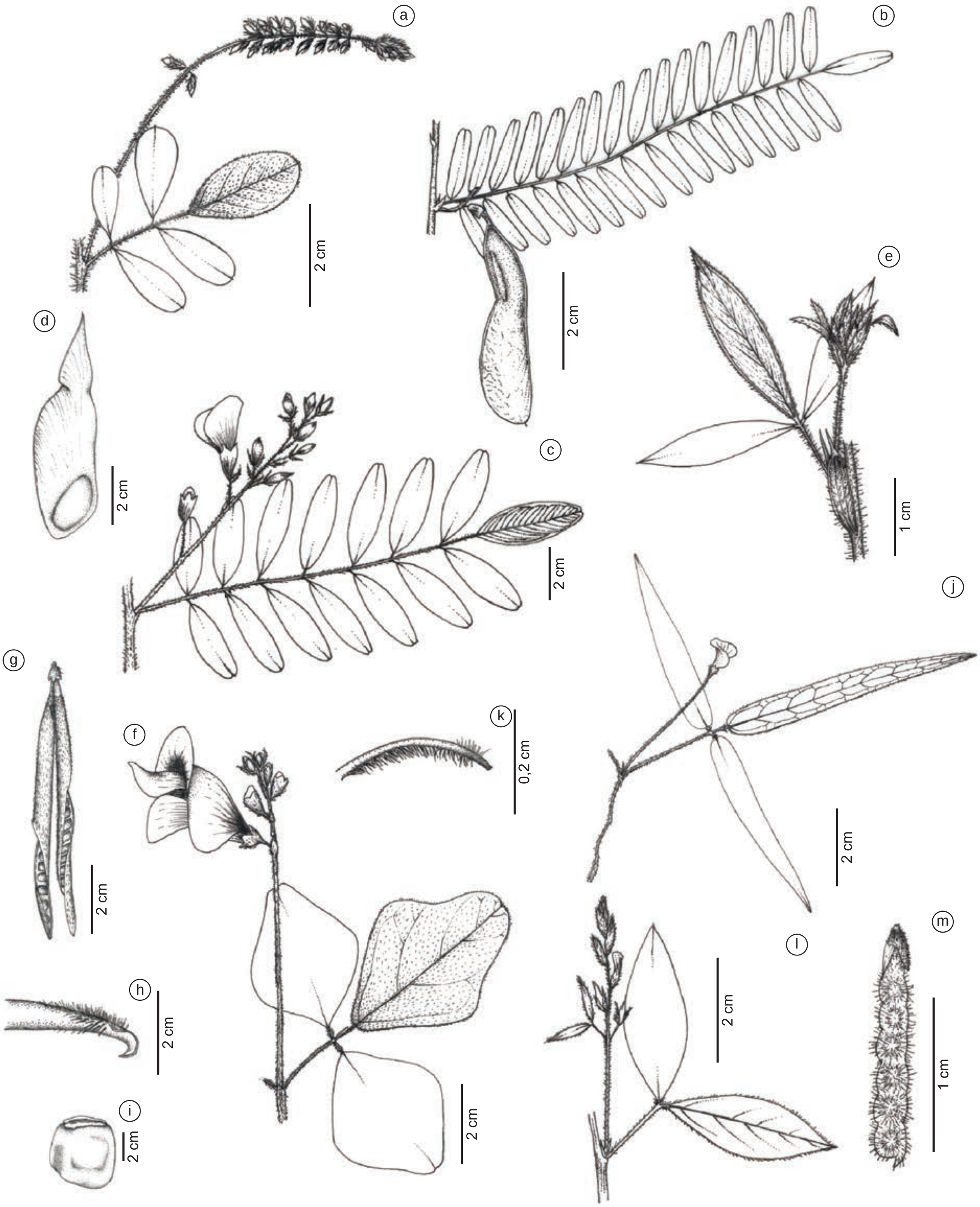

Figure 5. a. *Indigofera hirsuta* L. - part of the branch with inflorescence (*Pereira* et al. 443); b. *Machaerium hirtum* (Vell.) Stellfeld - leaf and fruit; c-d. *Platypodium elegans* Vogel. - c. part of the branch with inflorescence; d. Fruit (*Caboco & Sciamarelli 1731*); e. *Stylosanthes guianensis* (Aubl.) Sw. - branch with inflorescence (*Caboco & Sciamarelli* 39); f-i. *Vigna lasiocarpa* (Mart. former Benth.) Verdc. - f. Branch with inflorescence; g. fruit; h. style; i. seed (*Caboco & Sciamarelli 1731*); j-k. *Vigna longifolia* (Benth.) Verdc. - j. branch with flower; k. style (*Pereira et al. 1627*); l-m. *Zornia latifolia* Sm. - l. branch with inflorescence; m. fruit (*Pereira* et al. 1456).

19. *Platypodium elegans* Vogel., Linnaea 11: 420. 1837. .... Figure 5c, d

Tree, branches cylindrical, stipule and stipel caducous, petiole 1-16 cm long, sericeous, rachis 8.5-12 cm long, sericeous. Leaves 17-foliate, pinnate, leaflets symmetrical, 4.3 × 1-1.5 cm, elliptical to oblong; apex obcordate, diminished base, both surfaces sericeous, entire margin, venation eucamptodromous, discolorous. Inflorescence racemose, axial, 20-flora, peduncle 1.8-2.2 cm long, axis 8.5-9 cm long, both sericeous. Zygomorphic flower; pedicel 6 mm long, sericeous; calyx 9.5 mm long, campanulate, 5-lacinia; lacinium 2 mm long, sericeous; corolla yellow; standard 20 mm, wing 19 mm long, keel 14 mm long. Androecium heterodynamous, stamens 10, diadelphous (9) + 1, 10-12 mm long. Gynoecium stipellate, stipe 6 mm long, ovary sericeous, style curved, glabrous, stigma terminal puberulent. Samara elliptical, 6.4 × 2.3 cm, apex acute, glabrous; seed-chamber distal, fawn, glabrate, 2 × 1 cm.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI, 11.XI.2004, fl. and fr., *R. B. Caboco & A. Sciamarelli 28912*, idem, 19/IV/2009, fr., *28942* (CGMS), 22° 55' 59.6" S and 53° 40' 23.5" W.

Platypodium elegans presents 17-foliolate, pinnate leaves, obcordate apex, both surfaces sericeous, and samara 6.4 × 2.3 cm. This species has been reported to occupy areas of Seasonal Semideciduous and Deciduous Forests and cerrado (Mendonça-Filho 1996, Dubs 1998).

20. *Stylosanthes guianensis* (Aubl.) Sw., Kongl. Vetensk. Acad. Nya Handl. 10: 301. 1789. .... Figure 5e

Herb or subshrub, branches cylindrical; stipule lanceolate, stipel not observed, petiole 0.3-1 cm long, villous, rachis 1-2 mm long, tomentose. Leaf 3-foliate, leaflets symmetrical, 0.4-2.9 × 0.3-1.9 cm, lanceolate; apex acute, diminished base, both surfaces sericeous, entire margin, venation eucamptodromous, discolorous. Inflorescence in capitulum, fasciculate, terminal or axial, peduncle 3.5-5 cm long, villous, axis 0.5-1 cm long, villous. Flower without pedicel; calyx 7 mm long, villous, 5-laciniate, 1-3 mm long; corolla yellow, standard 5 mm long, wing 4 mm long, keel 4 mm long. Stamens 10, monadelphous, 8 mm long. Gynoecium stipellate, stipe 1 mm long, ovary puberulent, with terminal appendix, style erect, glabrous; stigma terminal, glabrous. Loment, 1 article, 4 × 2 mm, rounded, puberulent; seed 1, ovate, 2.4 × 1 mm, fawn.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI 23.III.2004, fl., *Z. V. Pereira et al. 28877* (CGMS); idem 19/IV/2009, fr., *R. B. Caboco & A. Sciamarelli 28921* (CGMS), 22° 55' 46.3" S and 53° 43' 07.4" W.

Stylosanthes guianensis may be identified by its striped stipules, eucamptodromous venation, discolorous leaflets, inflorescence in capitulum and fasciculate, absence of pedicel and lomentum with one article. According to Costas et al. (2008), this species may be found in cerrado, and dirty grasslands.

21. *Vigna lasiocarpa* (Mart. ex Benth.)Verdc., Kew Bull. 24(3): 539. 1970. ....Figure 5f, i

Vine, branches cylindrical; stipule elliptical to lanceolate, stipel linear, petiole 1.5-3 cm long, sericeous, glabrous, rachis 0.5-1 cm long, sericeous. Leaves 3-foliate, leaflet terminal asymmetrical 2.5-3.5 × 1-2.5 cm, trullate to elliptical; apex acute, stalked base, oblique, adaxial surface sericeous, abaxial surface glabrous, entire margin, venation brochidodromous, discolorous, leaflet lateral 2-3.5 × 1-2.2 cm. Inflorescence racemose, axial, multiflora; peduncle 3-6.5 cm long, sericeous. Pedicel 1-2 mm long, glabrous; calyx 5 mm long, campanulate, 5-laciniate, 1-2 mm long, sericeous; corolla purple, standard 13-22 mm long, wing 15-29 mm long, keel 20 mm long. Stamens 10, diadelphous (9) + 1, 25 mm long. Gynoecium stipellate, stipe 1 mm long, ovary sericeous, style curved with trichomes near the terminal stigma, glabrous. Legume, 7 × 0.5 cm, oblong, apex acute, sericeous; seeds 8-10, oblong, 4 × 3 mm, brown marbled with black and beige.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI, 19.IV.2009, fl. and fr., *R. B. Caboco & A. Sciamarelli 28940* (CGMS), 22° 55' 50.6" S and 53° 42'19.4" W.

Vigna lasiocarpa may be identified by its habit, elliptical stipule to lanceolate, multiflora inflorescence, oblong legume, and marbled seeds, both black and beige. It is associated with humid environments and flooded areas (Maréchal et al. 1978).

According to Snak et al. (2011) this species is recognized by its auriculated stipule with different lobes and sericeous indument. It is commonly confused with *V. longifolia* which is distinguished by its elongated style and a stigmatic region.

22. *Vigna longifolia* (Benth.) Verdc., Kew Bull. 24:541 (1970)....... Figure 5j, k

Prostrate herb, branches cylindrical; stipule expanded below point of insertion, basis auriculate, stipule and stipel lanceolate, petiole 1.5-3.5 cm long, strigose to tomentose, rachis 0.2-0.3 mm long, strigose. Leaf 3-foliate, leaflets symmetrical 2-6.5 × 0.3-0.6 cm, lanceolate; apex acute, base obtuse, both surfaces strigose, entire margin, venation brochidodromous, concolorous. Inflorescence racemose, axial, 2-flora; peduncle 4 cm long, axis 0.3 cm long, both strigose; calyx 3 mm long, campanulate, 5-laciniate, 1 mm long, sericeous; corolla yellow, orange, standard 16 mm long, wing 10 mm long, keel 17 mm long. Stamens 10, diadelphous (9+1), 14-15 mm long. Gynoecium stipellate, stipe 1 mm long, ovary tomentose, style erect, sericeous near the lobated lateral stigma. Legume, 6-6.6 × 0.4-0.7 cm, linear, apex acute, sericeous; seeds 12, ovate, 4 × 2 mm, nut-brown with white aril.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI, 12.IX.2006, fl. and fr., *Z. V. Pereira et al. 28909* (CGMS), 22° 51' 11.1" S and 53° 39' 18.2" W.

Vigna longifolia is distinguished by its stipules with auriculate basis and equal lobes, corolla yellow to orange, petals from the keel twisted and lateral stigma. It is frequently confused with *V. lasiocarpa*, which differs by its non-elongated style and its stigmatic region (Snak et al. 2011).

23. *Zornia latifolia* Sm., Cycl.39: 4. 1819. ....Figure 5l, m

Prostrate herb, branches cylindrical; stipule and stipel not observed, petiole 1-2 cm long, sericeous. Leaves 2-foliate, bipinnate, leaflets symmetrical 3.3-3.5 × 1-1.3 cm, elliptical to lanceolate; apex acute, base oblique, diminished, both surfaces sericeous, entire margin, venation brochidodromous, concolorous. Spike inflorescence, axial, 6-12-flora; peduncle 1-2 cm long, sericeous, rachis 2-6 cm long, sericeous. Pedicel absent; bracteoles geminated, calyx 4 mm long, bilabiate, 2-laciniate, 2-3 mm long, sericeous; corolla yellow, standard 6 mm long, wing 3 mm long, keel 4 mm long. Stamens 10, monadelphous, 5-6 mm long. Gynoecium stipellate, stipe 1 mm long, ovary tomentose, style erect, tomentose, lateral stigma, glabrous. Loment, 6-7 articles, 3 × 2 cm, ovate, uncinate; seeds 6-7, ovate and reniform, 1.5 × 1.5 mm, yellow.

Selected material: Brazil. Mato Grosso do Sul: Ivinhema, PEVRI, 16.VII.2005, fl. and fr., *Z. V. Pereira et al. 28898* (CGMS), 22° 56' 06.3" S and 53° 43' 01.6" W.

Zornia latifolia may be distinguished by its bifoliate leaves and loment with 6-7 uncinate articles, presence of two geminated bracteoles which involves each flower in the inflorescence.

Discussion

About 35% of species studied in PEVRI are distributed in Seasonal Semideciduous Forest and 26% occur only in this type of forest, which suggests the importance of preserving them for the maintenance of species richness such as the Papilonoideae. *Andira inermis* is the only species recorded in PEVRI whose habit is Alluvial Semideciduous Forest. *Dioclea burkatii* recorded only for the Pantanal has expanded its distribution since it occurs in the Seasonal Semideciduous Forest of the park. Among the 23 recorded species of Papilonoideae in PEVRI, nine of them are found in humid grasslands, and the most representatives are *Aeschynomene*, *Crotalaria*, *Desmodium* and *Vigna*. The occurrence of *Aeschynomene falcata*, *Aeschynomene histrix*, *Crotalaria maypurensis* and *Vigna lasiocarpa* denote the capacity of these species to survive in flooded soil, since they were not observed in other environments in PEVRI.

When the studies of *Aeschynomene* (Lima et al. 2006), *Desmodium* (Nobre et al. 2008), *Machaerium* (Polido & Sartori 2007, 2011) and *Stylosanthes* (Costas et al. 2008) are compared, these authors mentioned *Aeschynomene falcata*, *A. histrix*, *A. sensitiva*, *Desmodium affine*, *D. barbatum*, *Machaerium hirtum* and *Stylosanthes guianensis*, respectively, as common to those sampled in PEVRI, which occupy cerrado, flooded grasslands and disturbed areas. For Sciamarelli (unpublished data), who studied areas similar to those from PEVRI, no common species were present.

PEVRI is the second largest unit of conservation in Mato Grosso do Sul and its flora is influenced by its formations which constitutes the basins from Paraná and Paraguai rivers. Ours results are an important tool for understanding the diversity of flora in the conservation area in southern Mato Grosso do Sul, which is occupied by the westernmost border of the Atlantic biome.

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References

ARAÚJO, G.M., BARBOSA, A.A.A., AMARAL, A.F. & ARANTES, A.A. 2002. Composição florística de veredas no Município de Uberlândia, MG. Rev. Bras. Bot. 25:475-493.

AZEVEDO, A.M.G. 1981. O gênero *Desmodium* Desv. no Brasil: Considerações taxonômicas. Dissertação de mestrado, Universidade Estadual de Campinas, Campinas, 315p.

BARROSO, G.M., MORIM, M.P., PEIXOTO, A.L. & ICHASO, C.L.F. 1999. Frutos e sementes: morfologia aplicada a sistemática de dicotiledôneas. Universidade Federal de Viçosa, Viçosa, 443p.

BENTHAM, G. 1859. Leguminosae. In Flora Brasiliensis (C.F. Von Martius, S. Endlicher & I. Urban, eds.). CRIA, v.15 find. Fleischer, Monachii, Lipsiae.

BENTHAM, G. 1862. Papilionaceae. In Flora Brasiliensis (C.F. Von Martius, eds.). CRIA, v.15, n.1, p.291-9. Monachii.

BORTOLUZZI, R.L.C., CARVALHO-OKANO, R.M., GARCIA, F.C.P. & TOZZI, A.M.G.A. 2004. Leguminosae, Papilionoideae no Parque Estadual do Rio Doce, Minas Gerais, Brasil. II: árvores e arbustosescandentes. Acta Bot. Bras. 18(1):49-71.

BRANDÃO, M. & COSTA, N.M.S. 1979. O gênero *Stylosanthes* Sw. no Brasil. Epamig, Belo Horizonte.

BRASIL. Ministério Do Meio Ambiente - MMA. 2011. Geoprocessamento/ Biomas i3GEO. http://mapas.mma.gov.br/i3geo/ (último acesso em 08/03/2011).

BURKART, A. 1970. Las Leguminosas-Faseolas argentinas de los géneros *Mucuna*, *Dioclea*, y *Camptosema*. Darwiniana 16(1-2):175-218.

CAMARGO, R.A. 2005. A tribo Dalbergieae (Leguminosae-Faboideae) no estado de Santa Catarina, Brasil. Dissertação de mestrado, Universidade Federal do Rio Grande do Sul, Porto Alegre, 131p.

CAMPOS, J.B. & SOUZA, M.C. 1997. Vegetação. In A planície de inundação do alto rio Paraná: aspectos físicos, biológicos e socioeconômicos(A.E.A.M. Vazzoler, A.A. Agostinho & N.S. Hahn, eds.). Editora da Universidade Estadual de Maringá, Maringá.

CEOLIN, G.B. & MIOTTO, S.T.S. 2009. O gênero *Collaea* DC. (Leguminosae, Papilionoideae) na Região Sul do Brasil. Acta Bot. Bras. 23(4):991-998.

COSTAS, L.C., SARTORI, A.L. & POTT, A. 2008. Estudo taxonômico de *Stylosanthes* (Leguminosae- Papilionoideae- Dalbergieae) em Mato Grosso do Sul, Brasil. Rodriguésia 59(3):547-572.

DUBS, B. 1998. Leguminosae – Papilionoideae. In Prodromus florae matogrossensis (B. Dubs, ed.). Betrona Verlag, Kusnacht, p.140-148.

DUCKE, A. 1949. As leguminosas da Amazônia brasileira: notas sobre a flora neotrópica – II. Instituto Agronômico do Norte, Belém, n.18, p.200-202.

FERNANDES, A. 1996. O táxon *Aeschynomene* no Brasil. EUFC, Fortaleza.

FILLIETTAZ, A.M. 2002. Estudos taxonômicos de espécies de *Crotalaria* sect. *Calycinae* Wight & Arn. (Leguminosae-Papilionoideae-Crotalarieae) no Brasil. Dissertação de mestrado, Universidade Estadual de Campinas, Campinas.

FLORES, A.S. 2004. Taxonomia, números cromossômicos e química das espécies de *Crotalaria* L. (Leguminosae, Papilionoideae) no Brasil. Tese de doutorado, Universidade Estadual de Campinas, Campinas.

FLORES, A.S. & MIOTTO, S.T.S. 2001. O gênero *Crotalaria* L. (Leguminosae – Faboideae) na Região Sul do Brasil. Iheringia 55:189-247.

FORZZA, R.C., BAUMGRATZ, J.F., BICUDO, C.E.M., CARVALHO JÚNIOR, A.A., COSTA, A., COSTA, D.P., HOPKINS, M., LEITMAN, P.M., LOHMANN, L.G., MAIA, L.C., MARTINELLI, G., MENEZES, M., MORIM, M.P., COELHO, M.A.N., PEIXOTO, A.L., PIRANI, J.R., PRADO, J., QUEIROZ, L.P., SOUZA, V.C., STEHMANN, J.R., SYLVESTRE, L.S., WALTER, B.M.T. & ZAPPI, D., eds. 2010. Catálogo de plantas e fungos do Brasil. Andrea Jakobsson Estúdio, Jardim Botânico do Rio de Janeiro, Rio de Janeiro, v.1, 871p.

FRANCO, A.A. & FARIA, S.M. 1997.The contribution of N_2-fixing tree legumes to land reclamation and sustainability in the tropics. Soil Biol. Biochem. 29(5-6):897-903. http://dx.doi.org/10.1016/S0038-0717(96)00229-5

GREAR, J.J.W. 1970. A revision of the American species of *Eriosema* (Leguminosae-Lotoideae). Mem. New York Botanical Garden 20(3):1-98.

GUEDES-BRUNI, R.R., MORIM, M.P., LIMA, H.C. & SYLVESTRE, L.S. 2002. Inventário Florístico. In Manual Metodológico para Estudos Botânicos na Mata Atlântica (L.S. Sylvestre & M.M.T. Rosa, orgs.). Seropédica, Rio de Janeiro, p.24-49.

HARRIS, J.G. & HARRIS, M.W. 1994. Plant identification terminology: an ilustred glossary. Spring Lake Publishing, Utah, 198p.

HERRERA, M.A., SALAMANCA, C.P. & BAREA, J.M. 1993. Inoculation of woody legumes with selected arbuscular mycorrhizal fungi and rhizobia to recover desertified mediterranean ecosystems. Appl. Environ. Microbiol. 59(1):129-133.

KÖPPEN, W. 1948. Climatologia: con un estudio de los climas de la tierra. Fondo de Cultura Econômica, México, p.1-479.

LEITÃO FILHO, H.F., ARANHA, C. & BACCHI, O. 1975. Plantas invasoras de culturas no Estado de São Paulo. Hucitec, São Paulo, v.2.

LEWIS, G.P. 1987. Legumes of Bahia. Royal Botanic Gardens, Kew, 369p.

LEWIS, G.P., SCHRIRE, B., MACKINDER, B. & LOCK, M. 2005. Legumes of the World. Royal Botanic Gardens, Kew.

LIMA, L.C.P., SARTORI, A.L.B. & POTT, V.J. 2006. *Aeschynomene* L. (Leguminosae, Papilionoideae, Aeschynomeneae) no Estado de Mato Grosso do Sul. Hoehnea 33 (4):419-453.

LIMA, H.C., QUEIROZ, L.P., MORIM, M.P., SOUZA, V.C., DUTRA, V.F., BORTOLUZZI, R.L.C., IGANCI, J.R.V., FORTUNATO, R., VAZ, A.M.S., SOUZA, E.R., FILARDI, F.L., GARCIA, F.C.P., FERNANDES, J.M., MARTINS-DA-SILVA, R.C.V., FORTUNA-PEREZ, A.P., MANSANO, V.F., MIOTTO, S.T.S., TOZZI, A.M.G.A., MEIRELES, J.E., LIMA, L.C.P., FLORES, A.S., TORKE, B.M., PINTO, R.B., LEWIS, G.P., BARROS, M.J.F., RIBEIRO, R.D., RODRIGUES, R.S., PENNINGTON, T., KLITGAARD, B., SCALON, V.C., CARDOSO, D.B.O.S., COSTA, L.C., SILVA, M.J., MOURA, T.M., BARROS, L.A.V.; SILVA, M.C.R., QUEIROZ, R.T., SARTORI, Â.L.B. & CAMARGO, R.A. 2010. Fabaceae. In Catálogo de plantas e fungos do Brasil (R.C. Forzza, J.F. Baumgratz, C.E.M. Bicudo, A.A. Carvalho Júnior, A. Costa, D.P. Costa, M. Hopkins, P.M. Leitman, L.G. Lohmann, L.C. Maia, G. Martinelli, M. Menezes, M.P. Morim, M.A.N. Coelho, A.L. Peixoto, J.R. Pirani, J. Prado, L.P. Queiroz, V.C. Souza, J.R. Stehmann, L.S. Sylvestre, B.M.T. Walter & D. Zappi, eds.). Andrea Jakobsson Estúdio, Jardim Botânico do Rio de Janeiro, Rio de Janeiro, v.2, p.989-1102.

MARÉCHAL, R., MASCHERPA, J.M. & STAINER, F. 1978. Étude taxonomique d'un groupe complex d'espéces des genres *Phaseolus* et *Vigna* (Papilionaceae) sur la base de données morphologiques et polliniques, traitées par l'analyse informatique. Boissiera 28:1-273.

MATO GROSSO DO SUL (Estado). Secretaria de Estado de Meio Ambiente - SEMA. 2001. Decreto 9.278, de 17 de dezembro de 1998. Decreto de criação do Parque das Várzeas do Rio Ivinhema. Oficial de Mato Grosso do Sul (DOEMS), Campo Grande, dez. 2006.

MAXWELL, R.H. 1970. A new species of *Dioclea* (Leguminosae) from Argentina. Darwiniana 16(1-2):413-416.

MENDONÇA-FILHO, C.V. 1996. Braúna, angico, jacarandá e outras leguminosas de Mata Atlântica: Estação Biológica de Caratinga, Minas Gerais. Fundação Botânica Margaret Mee; Fundação Biodoiversitas, Belo Horizonte, 100p.

MOREIRA, J.L.A. & AZEVEDO-TOZZI, A.M.G. 1997. *Indigofera* L. (Leguminosae, Papilionoideae) no Estado de São Paulo, Brasil. Rev. Bras. Bot. 20(1):97-117.

MORIM, M.P. 2006. Leguminosae arbustivas e arbóreas da Floresta Atlântica do Parque Nacional do Itatiaia, sudeste do Brasil: padrões de distribuição. Rodriguésia 57:27-45.

NOBRE, A.V.M., SARTORI, A.L.B. & RESENDE, U.M. 2008. As espécies de *Desmodium* Desv. (Leguminosae-Papilionoideae-Desmodieae) ocorrentes no Mato Grosso do Sul. Iheringia, Sér. Bot. 63(1):37-67.

NOGUCHI, D.K., PETINE, G.N. & SARTORI, A.L.B.S. 2009. Florística e síndromes de dispersão de espécies arbóreas em remanescentes de Chaco de Porto Murtinho, Mato Grosso do Sul. Rodriguesia 60(2):353-365.

OLIVEIRA, M.J.R. & LUZARDO, R. 2000. Geologia Estrutural. In Programa Levantamentos Geológicos Básicos do Brasil: Caracaraí. (Companhia de Pesquisa de Recursos Minerais – CPRM, ed.). CPRM, Brasília. Folhas NA.20-Z-B e NA.20-Z-D (integrais), NA.20-Z-A, NA.21-Y-A, NA.20-Z-C e NA.21-Y-C (parciais). Escala 1:500.000. E.

PENNINGTON, R.T. 2003. Monograph of *Andira* (Leguminosae-Papilionoideae). Syst. Bot. Monogr. 64:1-143. http://dx.doi.org/10.2307/25027903

POLIDO, C.A. & SARTORI, A.L.B. 2007. O genêro *Machaerium* (Leguminosae-Papilionoideae-Dalbergieae) no Pantanal Brasileiro. Rodriguésia 58(2):313-329.

POLIDO, C.A. & SARTORI, A.L.B. 2011. *Machaerium* (Leguminosae, Papilionoideae, Dalbergieae) nos estados de Mato Grosso e Mato Grosso do Sul, Brasil. Rodriguésia 62(1).

POTT, A. & POTT, V.J. 1994. Plantas do Pantanal. Embrapa, Brasília, 320p.

QUEIROZ, L.P. 2009. Leguminosas da Caatinga. Universidade Estadual de Feira de Santana, 467p.

RADFORD, A.E., DICKISON, W.C., MASSEY, J.R. & BELL, C.R. 1974. Vascular plant systematics. Harper & Row, New York, 891p.

RUDD, V.E. 1955. The American species of Aeschynomene. Bul. U.S. Nat. Herb. 32:1-172.

SARTORI, A.L.B. & TOZZI, A.M.G.A. 1998. As espécies de *Machaerium* Pers. (Leguminosae - Papilionoideae - Dalbergieae) ocorrentes no estado de São Paulo. Rev. Bras. Bot. 21(3):211-246.

SCIAMARELLI, A. & AZEVEDO-TOZZI, A.M.G. 1996. Zornia J. F. GMEL. (Leguminosae - Papilionoideae - Aeschynomeneae) no estado de São Paulo. Acta Bot. Bras. 10(2).

SILVA, R.R. 2006. Leguminosae no Planalto Residual do Urucum, oeste do Pantanal de Mato Grosso do Sul, Brasil: inventário, taxonomia e similaridade florística. Tese de doutorado, Universidade Estadual de Campinas, Campinas, 318p.

SILVESTRE-CAPELLATO, M. & MELHEM, T.S. 1997. Flora polínica da Reserva do Parque Estadual das Fontes do Ipiranga (São Paulo, Brasil). Família 81 - Leguminosae. Hoehnea 24:119-167.

SNAK, C., MIOTTO, S.T.S. & GOLDENBERG, R. 2011. Phaseolinae (Leguminosae, Papilionoideae, Phaseoleae) no estado do Paraná, Brasil. Rodriguésia 62(3):695-716.

TROPICOS. http://www. tropicos.org (último acesso em 01/01/2006).

VELOSO, H.P., RANGEL FILHO, A.L.R. & LIMA, J.C.A. 1991.A classificação da vegetação brasileira adaptada a um sistema universal. IBGE, Rio de Janeiro.

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A gap analysis of ornithological research in the Brazilian state of Roraima

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Abstract: This study analyzes the ornithological data available for the Brazilian state of Roraima, focusing on sampling gaps. All ornithological data collected in Roraima up to the present were collated with the aim of answering the following questions: (a) which sites have been well sampled? (b) Are there are any geographic gaps? (c) What is the current extent of the scientific knowledge of avian diversity in Roraima? (d); Which regions and vegetation types have been well-sampled, and which should be prioritized for future surveys? Ornithological data were obtained from a total of 82 localities, including the Maracá Ecological Station (442 species), Viruá National Park (420 species), Colônia do Apiaú (320 species), Mucajaí (267 species), and Pacaráima (212 species), which were the five sites with the highest species counts. Over the past 20 years, only two localities in Roraima have been added to the list of sites with reliable samples (at least 100 bird species recorded (study skins collected, tape recordings and undocumented field observations) , the Viruá National Park and Fazenda Paraense. Five regions of the state were identified as sampling gaps, and should be prioritized in future ornithological surveys: the northwest, on the border with Venezuela and the Brazilian state of Amazonas, the lower Rio Branco between the town of Caracaraí and the mouth of the river, the *terra firme* forests of the southeast, the savannas of the northeast, on the border with Guyana, and the northern highlands, including montane forest and tepuis.
Keywords: *amazonia, birds, conservation, rio branco, sampling gaps.*

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Resumo: Neste artigo, o esforço de investigação ornitológica no estado de Roraima será investigado utilizando abordagens de análises de lacunas. Basicamente, apresentaremos uma síntese sobre todo o esforço ornitológico feito até o momento em Roraima, visando responder as seguintes questões: (a) quais os locais bem amostrados para aves? (b) quais são as lacunas geográficas de investigação? (c) em que estágio de descobertas está o inventário das espécies de aves em Roraima? (d) quais são os macro-hábitats prioritários para investigação? (e) quais os tipos de vegetação bem investigados e quais os que podem ser classificados como prioritários para investigação? Como resultados, detectamos Oitenta e duas localidades com algum tipo de informação ornitológica. Dentre essas, a Estação Ecológica de Maracá (442 sp), seguido pelo Parque Nacional do Viruá (420 sp), Colônia do Apiaú (320 sp), Mucajaí (267 sp), e Pacaráima (212 sp), são as cinco localidades com maior grau de conhecimento ornitológico dentro do estado. Nos últimos 20 anos apenas duas localidades ornitológicas em Roraima podem ser acrescidas à lista de sítios bem estudados de acordo com o critério de pelo menos 100 espécies registradas (peles, gravações de voz e observações visuais): Parque Nacional do Viruá e a Fazenda Paraense. Cinco áreas são aqui apontadas como lacunas de amostragem da avifauna de Roraima e devem receber prioridade para novos inventários e estudos sobre a avifauna dessa região, são elas: Noroeste do estado, nas áreas junto à fronteira com a Venezuela e divisa com o Estado do Amazonas; Baixo Rio Branco, desde a cidade de Caracaraí à sua foz; Florestas de terra firme no sudeste do Estado; As savanas do nordeste junto à fronteira com a Guiana e as regiões de floresta montana e os tepuis.
Palavras-chave: *amazônia, aves, conservação, Rio Branco, análise de lacunas.*

Introduction

Birds constitute one of the most visible and well-studied zoological groups. With around 9600 different species, birds are found on all continents and oceans, and are generally quite effective indicators of habitat quality (Gill 1995). While new bird species are discovered every year, these additions make up only a very small proportion of the known diversity, contrasting considerably with most other groups of zoological taxa (Marini & Garcia 2005, Peres 2005). As birds are easily recognized and identified, they constitute an extremely useful group for the quantitative assessment of the sampling effort necessary for the delineation of a region's biological diversity, providing systematic guidelines for biological inventories at national, regional, and local scales (Silva 1995a).

Despite being one of the planet's most ecologically complex and biologically richest regions, much of the Amazon basin is still largely ornithologically unexplored (Oren 2001). Oren & Albuquerque (1991) analyzed the sampling effort at sites throughout the Brazilian Amazon, considering the collection of 100 specimens as the standard minimum effort required for a reliable sample, and concluded that the vast majority of the region remains virtually unknown, from an ornithological viewpoint. While many ornithological surveys have been conducted since then, raising the total number of reliable inventories to 247, most of the areas considered then to be poorly sampled by Oren & Albuquerque (1991) remain undersampled today (Oren 2001, Aleixo 2009). Recently Vale (2007), evaluated how spatial collecting bias affects patterns of bird richness, endemism, and conservation in Amazonia and showed the bias in the location of ornithological collections has a strong effect on bird richness patterns, with the richness at collection localities being significantly higher than expected at random, demonstrating that there are still gaps in the ornithological knowledge of the region and little is known about biodiversity in the Amazon.

The avifauna of Roraima although considered relatively well studied, and the only state in the Brazilian Amazon with a well established list of birds (Santos 2005, Naka et al. 2006), the situation is nevertheless typical of the general Amazonian pattern found by Vale (2007). In fact, Santos (2005) concluded that only a very few, widely-distributed sites have been sampled adequately.

This study investigates the ornithological data available for Roraima and evaluates sampling effort and deficiencies using in a slight modification of the criterion used by Oren & Albuquerque (1991). The study provides a systematic overview of the sampling effort conducted until now, as an approach to the following questions: (a) which sites have been well sampled? (b) are there are any geographic gaps? (c) what is the current extent of the scientific knowledge of the avian diversity in Roraima? (d) which regions and vegetation types have been well-sampled, and which should be defined as priority areas for future surveys?

Material and Methods

1. *Study area*

Roraima is the northernmost state of Brazil, covering an area of 225,116 km^2 (Figure 1). The state is bounded to the north and northeast by Venezuela, and to the east by Guyana, and is located entirely within the basin of the Rio Branco. There are six distinct

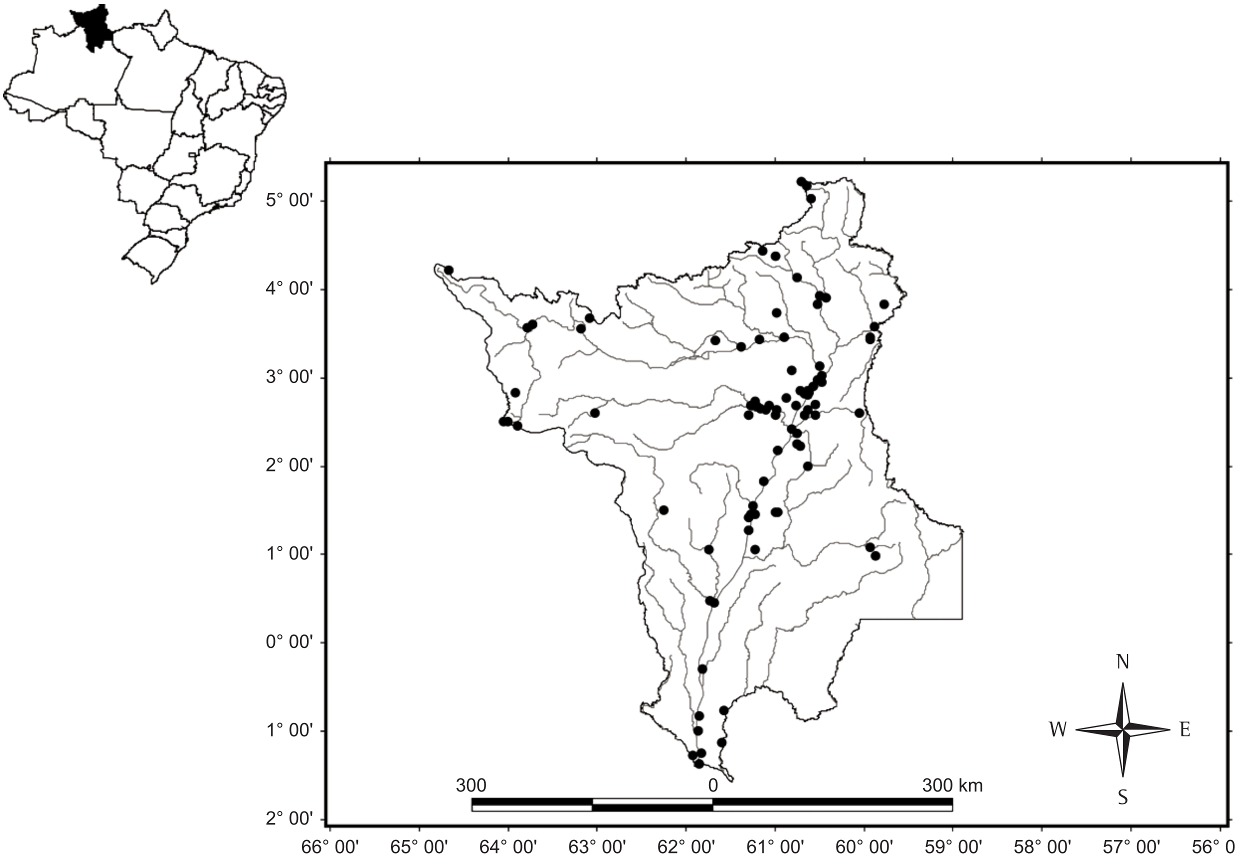

Figure 1. Geographic location of the state of Roraima within Brazil. Circles are all sites at which ornithological surveys have been conducted in the Brazilian state of Roraima.

altitudinal zones within the state, ranging from lowland areas (70 m a.s.l. at the mouth of the Rio Branco), to montane regions (2875 m a.s.l.) at the peak of Mount Roraima (Silva, 1997).

The state also encompasses three distinct climatic regions, *Af*, *Aw*, and *Am* in the Köppen classification system (Superintendência... 1984). In general terms, annual climate is divided in well-defined dry and rainy seasons, with a mean annual temperature of approximately 26 °C (Barbosa 1997).

Roraima can be divided in two principal ecological domains: the savannas and humid Amazonian *terra firme* forests. Savannas are found in areas where annual precipitation is less than 1700 mm, most of which is concentrated into a period of 100-130 days (Barbosa 1997). Within these savannas, more arid areas are covered with dry woodlands and gallery forests, while areas with more hydromorphic soil support dense corridors of buriti palms (*Mauritia flexuosa*), known as "buritizais". Rainforest is found in areas where annual precipitation is never less than 2000 mm. Grasslands ("campinas") and wetland savannas ("campinaranas") are found on sandy soils within these rainforest formations.

2. *Data analyses*

All localities where ornithological fieldwork has been conducted were identified from the database available in Santos (2005). This study includes all sites mentioned by Paynter & Traylor (1991), in addition to those identified through a bibliographic review (Appendix 1), and the localities visited by Santos (2005) and Naka et al. (2006). The geographic coordinates were obtained from Paynter & Traylor (1991), Vanzolini (1992), and Santos (2005).

Differently the criterion used by Oren & Albuquerque (1991) (100 specimens collected), we used the criterion of 100 recorded species to consider a locality as well sampled. We recognize as a valid record three basic types of information available in the literature, museums and field trips: skins, tape recordings and observations. Therefore the ornithological localities of Roraima were selected using all types of records available for each locality (skins, tape recordings, observations). Based on these data, the sites were classified in one of the following categories: (a) some ornithological data available; (b) at least 50 species recorded; and (c) more than 100 species recorded. The sites classified according to this scheme were mapped within the state of Roraima using ArcGis 9.3, in order to visualize the distribution of sampling effort within the state. This map was superimposed on the IBGE (Instituto... 1993) vegetation map for the state, to allow the visualization of sampling effort according to habitat, on which the definition of research priorities was based.

To evaluate the current level of inventory completeness of the avifauna of Roraima, cumulative species curves were prepared and analyzed using the Excell software. These curves are widely used in ecological studies, and indicate the cumulative number of species recorded over time. The curve should reach an asymptote as the number of species recorded approaches the total number existing within the area surveyed. For this analysis, a database was prepared, which included the name of each species and the year in which it was first recorded in Roraima.

Silva & Santos (2005) found that the rate at which species are recorded may vary considerably among habitat types. Therefore, separate curves were prepared for three major ecological groups, defined according to their dependence on forested habitats: (1) independent – species that are only found in open (savanna) formations; (2) semi-dependent – species that occur in both open vegetation and forest; and (3) dependent – species found essentially in forested habitats (terra firme forest, várzea, and campinarana). The objective of this analysis was to provide a more systematic baseline for the evaluation of research priorities. The three groups were based on the classifications of habitat use provided by Silva (1995b) and Sick (1997), supplemented by Field observations by the author.

The taxonomic classification of the bird species followed CBRO (Comitê... 2011).

Results

The general species accumulation curve for bird species in Roraima (Figure 2) indicates a long period of stagnation during the initial years of exploration of the region, with a first spurt of records at the beginning of the twentieth century, as a consequence of the first major expeditions along the Rio Branco. During this period, however, the curve grew in steps, coinciding with isolated surveys, rather than any continuous or prolonged research effort. A second spurt in the number of species recorded was observed only in the 1980s, and resulted from major expeditions to Maracá Island, Colônia do Apiaú, Boa Vista, and the Brazilian-Venezuelan border. Despite the increase in the number of species catalogued during recent years, the general species accumulation curve does not show a clear tendency towards stabilization (nonasymptotic), indicating that the total number of bird species occurring in Roraima is still considered to be an under-estimate (Figure 2).

The cumulative species curves for species not linked to forested habitats (independent and semi-independent) grew slowly in the first years of exploration, and continued to increase only gradually in subsequent years (Figure 2). For the forest-dependent group, by contrast, the curve has grown rapidly throughout the period, with no clear tendency for stabilization. Considering the 28 species added to the inventory of Roraima by Santos (2005), 22 (78.57%) are forest-dependent, while four (14.28%) are independent, and only two (7.14%) are semi-dependent. Of this total, 46.15% are non-passeriformes, 46.15% are suboscines passerines, and 7.70% are oscines passerines.

Ornithological data are available from 82 localities in the state of Roraima (Figure 1; Appendix 1). Of these sites, the richest in species is the Maracá Ecological Station, with a total of 442 species, followed by the Viruá National Park, with 420. The next most prominent sites are Colônia do Apiaú (320 species), Mucajaí (267 species), and Pacaráima (212 species). However, 100 or more species were recorded at only 18 (21.1%) of the 82 sites, which are mainly distributed in and around Boa Vista or Maracá Island (Figure 3). Even if the standard is set at a minimum of 50 species, the number of sites is still only 31, i.e. only 35.4% of the total number of sites (Figure 4).

Oren & Albuquerque (1991) identified only three localities in Roraima at which the avifauna had been surveyed according to their criterion of the collection of at least 100 specimens. Based on this criterion, however, seven additional sites (Forte de São Joaquim, Boa Vista, Mucajaí, Serra da Lua, Colônia do Apiaú, Maracá Ecological Station, and Vila Sorocáima) could have been included in this total. Twenty years later, only two additional localities can be added to this list, the Viruá National Park and the Fazenda Paraense, both of which were surveyed by Santos (2005) (Figure 5).

In relation to the different types of vegetation found in Roraima (Table 1), no ornithological data whatsoever are available for four of the 13 categories. These include three types of savanna, and a campinarana formation of the lower Rio Branco (Figure 6).

Discussion

The shape of the historic species accumulation curve for the avifauna of Roraima suggests that many additional species have yet to be recorded, especially in forested habitats, rather than more open environments. This conclusion is also supported by the fact that a large number of bird species with an ample

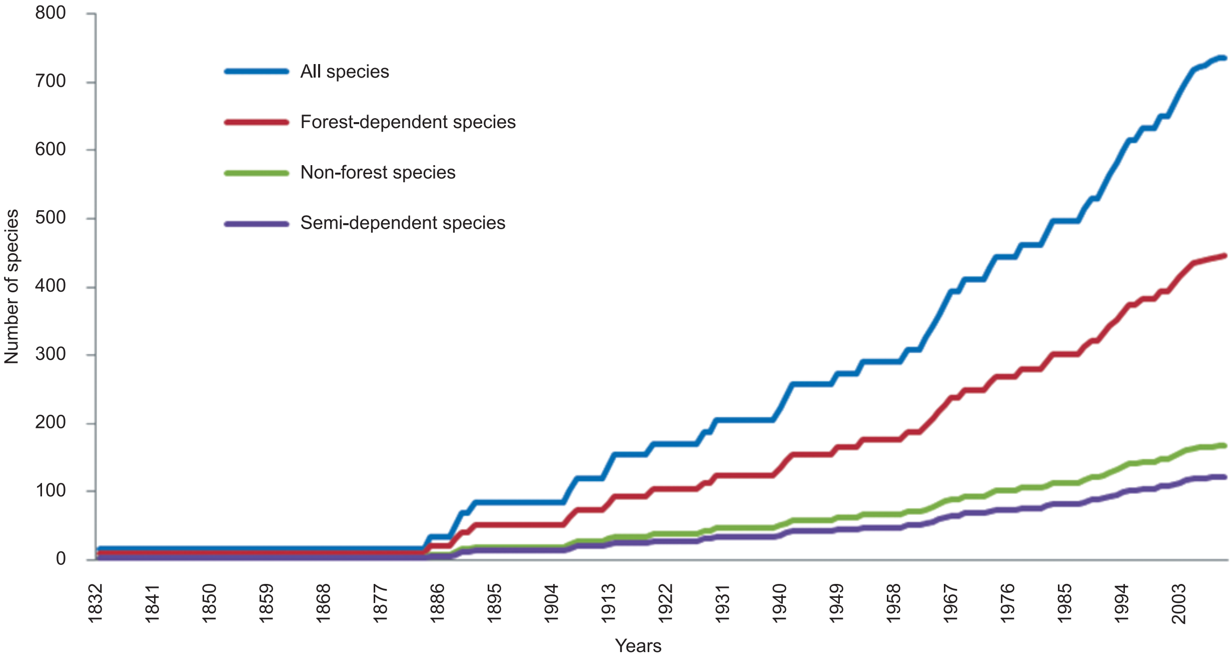

Figure 2. Historic cumulative species curves for the avifauna of the Brazilian state of Roraima.

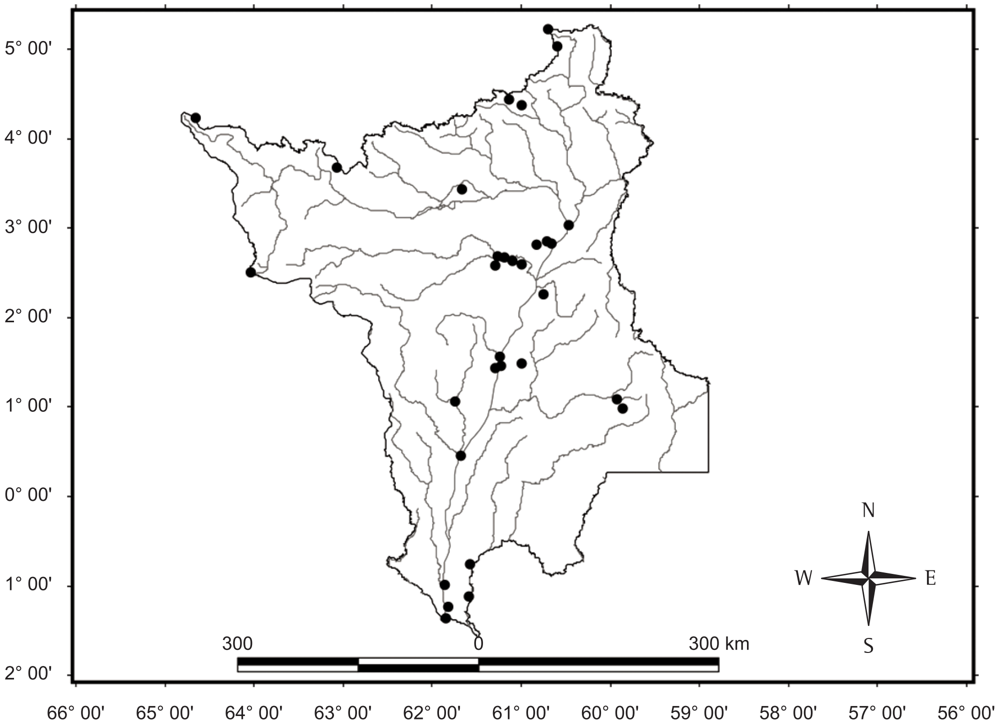

Figure 3. Sites at which at least 50 bird species have been recorded in the Brazilian state of Roraima.

distribution in northern South America and records from southern Venezuela and Guyana, have not yet been observed in Roraima (Naka et al., 2006). These species include *Amazona autumnalis, Celeus undatus, Phylloscartes virescens, Lophotriccus vitiosus, Lurocalis semitorquatus, Myrmeciza pelzelni, Neopipo cinnamomea, Dichrozona cincta, Iodopleura isabellae, Phlegopsis nigromaculata, Phoenicircus nigricollis, Certhiasomus stictolaemus, Haematoderus militaris, Lepidothrix serena, Notharchus ordii, Philydor erythrocercum, Lamprospiza melanoleuca, Malacoptila fusca, Philydor erythropterum,* and *Selenidera nattereri*.

The majority of the sites in Roraima from which ornithological data are available have been sampled in only a minimal fashion, and

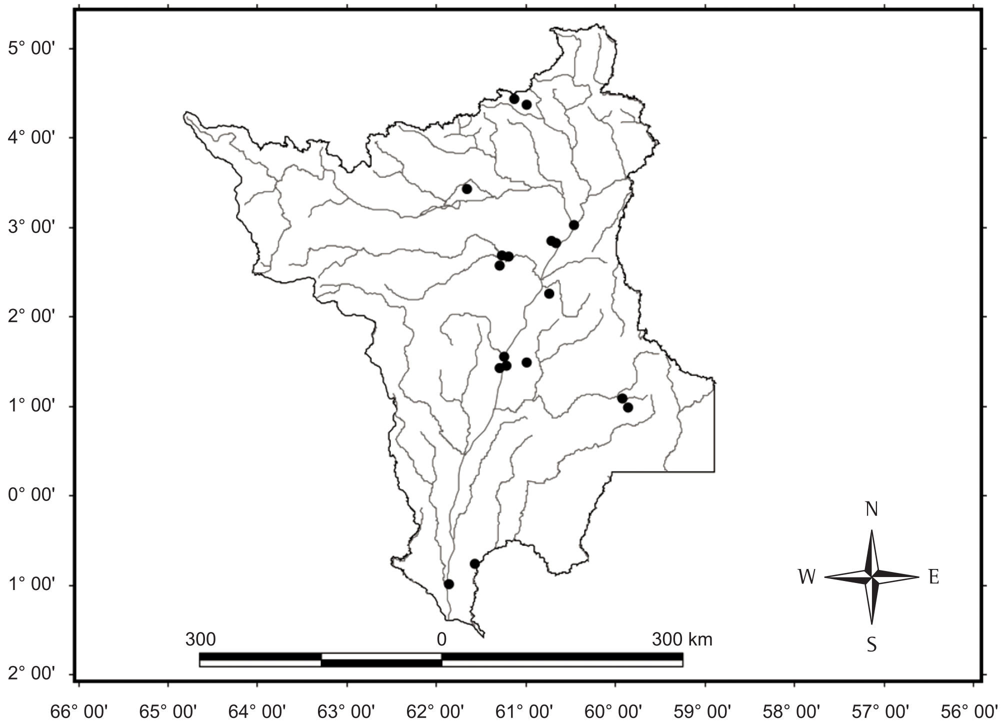

Figure 4. Sites at which at least 100 bird species have been recorded in the Brazilian state of Roraima.

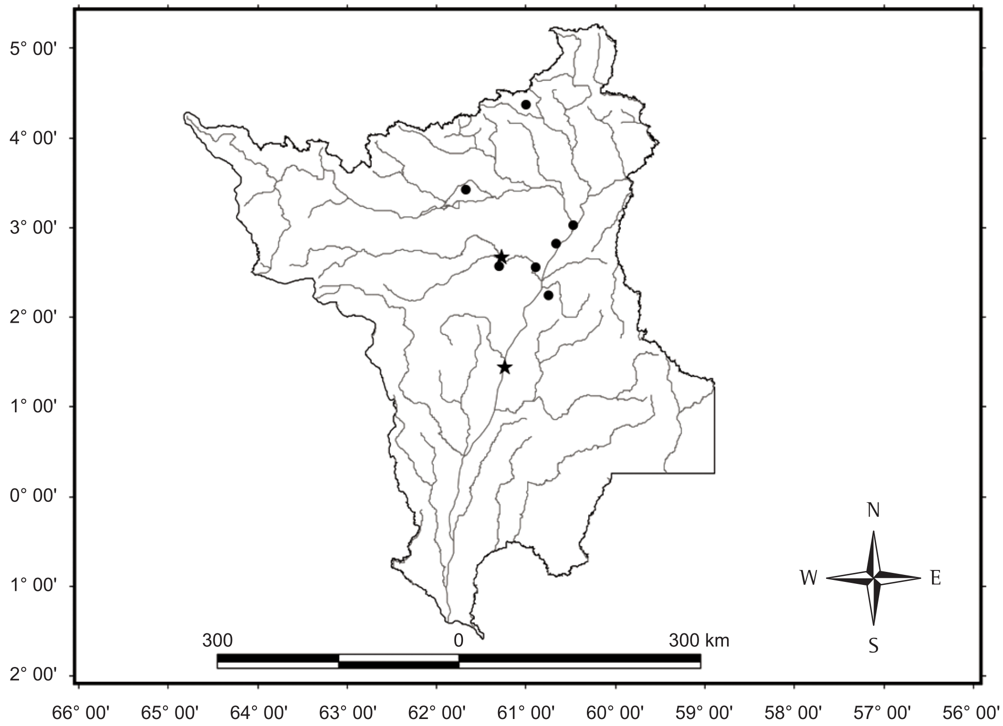

Figure 5. Sites in Roraima at which at least 100 bird specimens have been collected prior to (black circles) and after (black stars) the study of Oren & Albuquerque (1991).

considerable gaps can be observed within the state (Figure 3). Overall, only 18 of the 82 sites can be considered to have been relatively well sampled, according to the criterion adopted in the present study (at least 100 species recorded - skins, tape records and observations). Worse still, most of these sites are located in easily-accessible areas, mainly along the Rio Branco and in the vicinity of Boa Vista. This is, in fact, typical of the sites at which ornithological studies have been conducted throughout the Amazon basin (Haffer 1974, Oren &

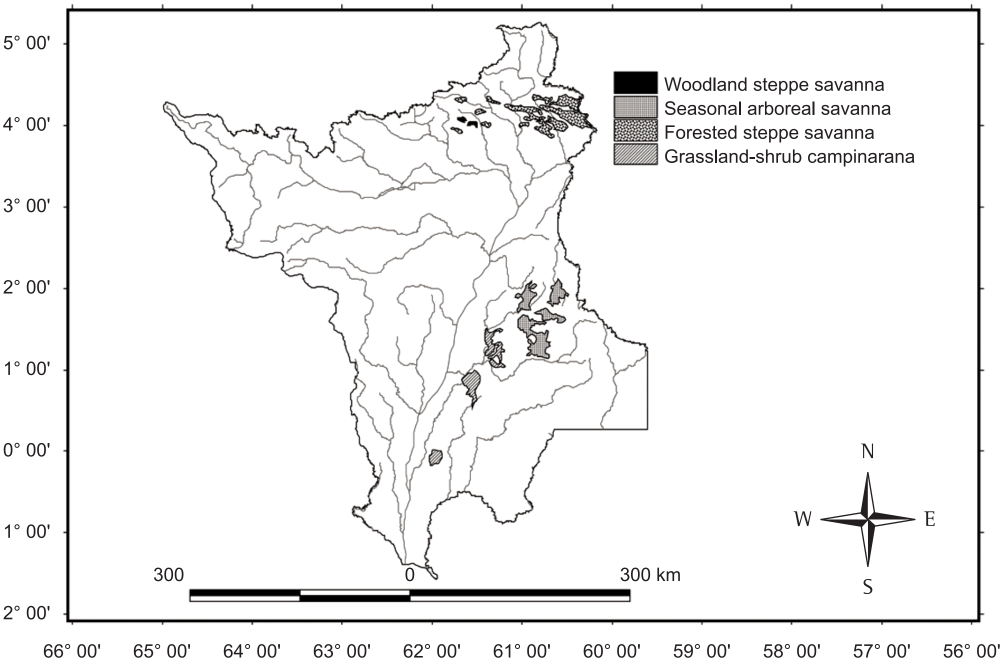

Figure 6. Vegetation types in Roraima for which no ornithological data are available.

Albuquerque 1991). Silva (1995a) recorded a similar pattern in the Cerrado savannas of central Brazil, where 70% of the region remains poorly-studied by ornithologists. Overall, then, the scenario recorded for Roraima twenty years ago by Oren & Albuquerque (1991) has changed very little, and the same lacunas in ornithological sampling are apparent in the present study.

These lacunas include five main areas, which should be given the maximum priority for future ornithological surveys:

a. Northwestern corner of the state, on the border with Venezuela and the Brazilian state of Amazonas. This region is dominated by well-preserved *terra firme* and submontane forests;

b. Lower Rio Branco, between the town of Caracaraí and the mouth of the river. The várzea forests, campinas, and campinaranas that dominate this landscape are extremely diverse in biological terms, and may have an avifauna related to those of the várzeas of the Amazon and the igapós of the Rio Negro, which would include many species not yet recorded in Roraima;

c. *Terra firme* forests of the southeast of the state, on the border with Guyana and the Brazilian state of Pará. It seems likely that many of the bird species recorded in the region of Manaus by Cohn-Haft et al. (1997) may also occur in this area, further increasing the state's species list;

d. The northeastern savannas, on the border with Guyana. While this region is relatively accessible, it is still poorly-known from and ornithological viewpoint, and probably contains many species found only in the savannas of northern South America (*Aratinga solstitialis*, *Synallaxis kollari, Campylorhynchus griseus*);

e. The montane forests and tepuis (isolated plateaus) of the northern extreme of the state on the border with Venezuela. Some areas are especially important, such as the slopes of Mount Roraima, Pacaráima, and tepuis such as Tapequén, Surucucu, and Uafaranda.

Table 1. Number of ornithological studies conducted by vegetation type in the Brazilian state of Roraima.

Type of vegetation	Number of localities (N = 82)
Seasonal arboreal savanna	0
Seasonal parkland savanna	13
Seasonal grassland-shrub savanna	9
Forested steppe savanna	0
Woodland steppe savanna	0
Parkland steppe savanna	1
Rainforest campinarana	2
Woodland campinarana	3
Grassland-shrub campinarana	0
Sub-montane rainforest	23
Montane rainforest	10
Lowland rainforest	24
Seasonal, semi-deciduous Forest	1

The least-studied vegetation types in Roraima included three savanna categories (seasonal woodland, forested steppe, and woodland steppe) and grassland-shrub campinarana (Table 1). No data whatsoever are available on the avifauna of these areas. With the exception of the forested steppe, which is located within an area dominated by conflicts between settlers and indigenous populations, the lack of data from these savannas may be due to their relatively small size, especially considering that they are all located in the vicinity of highways, and are thus relatively easily accessible. Similar factors may also account for the lack of studies in the campinarana, which is close to the BR 174 highway, but also covers a relatively small area.

Silva (1995a) has suggested that surveys in poorly-known regions should initially prioritize areas of highly anthropogenically impacted, considering the relatively high probability of local extinctions in such areas. From this perspective, the five lacunas identified above, together with the vegetation classes that lack data, can be ranked according to their relative vulnerability to anthropogenic pressures. The regions a, b, and e in the north and northwest of the state and on the lower Rio Branco are relatively well preserved and isolated from human impacts. By contrast, region c, in the southeast of the state, has suffered extensive deforestation due to the transformation of natural habitats into pastures and agricultural fields, while vast areas of the savannas and gallery forests of region d, in the northeast, have been converted into rice and soybean plantations. This situation can be even more worrying if we imagine in local extinctions caused by fragmentation.Studies with birds in the north of Manaus showed that the process of forest fragmentation produced sequential extinctions in a time interval of 20 years and that over 30% of species went extinct in 1-ha fragments, compared to about 5% in 100 ha fragments (Stouffer et al. 2009). Bird et al. (2011) observed that the incorporating projected deforestation into avian threat assessments increases the number of species qualifying as threatened on the IUCN Red List considerably and provides a more accurate reflection of the extinction risk facing species in the region. These data reinforce the need to carry out inventories in forest areas considered "bird gap" in the state of Roraima.

Overall, the lacunas identified in the present study can be grouped into two main classes of priority for ornithological inventory: (1) areas of maximum priority, with high levels of habitat alteration, and (2) areas of secondary priority, with relatively low levels of habitat modification, but few ornithological data. The first group includes the forests of the southeast of the state, and the savannas of the northeast. The second group encompasses the forests of the northwest, the campinaranas and flooded forests of the lower Rio Branco, and the highlands and tepuis of the northern border with Venezuela.

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References

ALEIXO, A. 2009. Knowledge gaps, research priorities, and future perspectives on bird conservation in the Brazilian Amazon. In Áreas importantes para a Conservação das Aves no Brasil. Parte II - Amazônia, Cerrado e Pantanal (A.C. De Luc, P.E. Devele, G.A. Benck, J.M. Goerck, orgs.). SAVE Brasil, São Paulo, p.55-69.

BARBOSA, R.I. 1997. Distribuição das chuvas em Roraima. In Homem, Ambiente e Ecologia no Estado de Roraima (R.I. Barbosa, E.J.G. Ferreira & E.G Castellón, eds.). INPA, p.325-335.

BIRD, J.P., BUCHANAN, G.M., LEES, A.C., CLAY, R.P., DEVELEY, P.F., YE'PEZ, I. & BUTCHART, S.H.M. 2011. Integrating spatially explicit habitat projections into extinction risk assessments: a reassessment of Amazonian avifauna incorporating projected deforestation. Divers. Distrib.18(3):1-9.

BORGES, S.H. 1994. Listagem e novos registros de aves para a região de Boa Vista, Roraima, Brasil. Bol. Mus. Para. Emilio Goeldi, Zool. 10(2):191-202.

COMITÊ BRASILEIRO DE REGISTROS ORNITOLÓGICOS – CBRO. 2011. Lista das aves do Brasil. 10. ed. CBRO. http://www.cbro.org.br (último acesso em 15/11/2011).

COHN-HAFT, M., WHITTAKER, A. & STOUFFER, P. 1997. A new look at the "species-poor" Central Amazon: The avifauna north of Manaus, Brazil. Ornithol. Monogr. 48:205-235.

DICKERMAN, R.W. & PHELPS, W.H.J. 1982. An annotated list of the birds of Cerro Urutaní on the border of Estado Bolívar, Venezuela, and Territorio Roraima, Brazil. Am. Mus. Novit. 2732:1-20.

FORRESTER, B.C. 1995. Brazil's northern frontier sites: in search of two Rio Branco endemics. Cotinga 3:51-53.

GILL, F.B. 1995. Ornithology. 2nd. ed. W.H. Freeman and Co, New York.

MARINI, M.A. & GARCIA, F.I. 2005. Conservação de aves no Brasil. Megadiversidade 1(1):95-102.

HAFFER, J. 1974. Avian speciation in tropical South America. With a systematic survey of the toucans (Ramphastidae) and jacamars (Galbuliae). Nuttall Ornithological Club, Cambridge, v.14, p.1-390.

HELLMAYR, C.E. & CONOVER, B. 1949. Catalogue of birds of the Americas. Publ. / Field Mus. Nat. Hist., Zool. Ser. 13(Part 1(4)):634. http://dx.doi.org/10.5962/bhl.title.2847

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA – IBGE. 1993. Mapa da vegetação brasileira. Rio de Janeiro.

NAKA, L.N., COHN-HAFT, M., MALLET-RODRIGUES, F., SANTO., M.P.D. & TORRES, M.F. 2006. The avifauna of the Brazilian state of Roraima: bird distribution and biogeography in the Rio Branco basin. Rev. Bras. Ornitol. 14:197-238.

OREN, D.C. 2001. Biogeografia e conservação de aves na região amazônica. In Biodiversidade na Amazônia Brasileira: Avaliação e ações prioritárias para a conservação, uso sustentável e repartição de benefícios (J.P.R. Capobianco, A. Veríssimo, A. Moreira, D. Sawyer, I. Santos & L.P. Pinto, eds.). Editora Instituto Socioambiental e Estação Liberdade, São Paulo, p.97-109.

OREN, D.C. & ALBUQUERQUE, G. 1991. Priority Areas for New Avian Collections in Brazilian Amazonian. Goeldiana, Zool. 6:1-11.

PAYNTER, R.A.J. & TRAYLOR, M.A. 1991. Ornithological Gazetteer of Brazil. Museum of Comparative Zoology, Cambridge, 2 v. http://dx.doi.org/10.5962/bhl.title.14635

PEBERDY, P.S. 1941. Report on the progress and field work of the Briths Guiana Museums 20th april 1939 to 31st december 1940. Carneguie Building, Georgetown. 37p. Report of the British Guiana Museum.

PELZELN, A. VON. 1868-1870. Zur Ornithologie Brasiliens. Resultate von Johann Natterers Reisen in den Jahren 1817 bis 1835. Pichler´s Witwe & Sohn, Wien, 3 v., 538p., 2 maps.

PERES, C.A. 2005. Porque precisamos de megareservas na Amazônia. Megadiversidade 1:174-180.

PHELPS, W.H.J. 1973. Adiciones a las listas de aves de sur America, Brasil Y Venezuela y notas sobre aves venezolanas. Bol. Soc. Venez. Cienc. Nat. 30:23-40.

PHELPS, W.H. & PHELPS, W.H.J. 1947. Description de seis aves nuevas de Venezuela y notas sobre veinticuatro adiciones a la avifauna del Brasil. Bol. Soc. Venez. Cienc. Nat. 71:53-74.

PHELPS, W.H. & PHELPS, W.H.J. 1962. Cuarentinueve aves nuevas para la avifauna brasilena del Cerro Uei-Tepui (Cerro del Sol). Bol. Soc. Venez. Cienc. Nat. 101(23):32-39.

PINTO, O.M.O. 1966. Estudo crítico e catálogo remissivo das aves do Território Federal de Roraima. Cad. Amazônia 8:1-176.

SANTOS, M.P.D. 2005. Avifauna do estado de Roraima: Biogeografia e Conservação. Tese de doutorado, Universidade Federal do Pará, Belém, 589p.

SHATTUCK, G.C. 1926. Observations on the Rio Branco, the Uraricoera and Parima rivers. In Medical report of the Hamilton Rice seventh expedition to the Amazon, in conjunction with the department of tropical medicine of Havard University, 1924-1925. Harvard University Press, Cambridge. Contributions from the Harvard Institute for Tropical Biology and Medicine, v.4, p.261-283.

SICK, H. 1965. Jacus (*Penelope*) da região amazônica (Aves, Cracidae). Pap. Avulsos Zool. 17:9-16.

SICK, H. 1997. Ornitologia Brasileira: uma introdução. Nova Fronteira, Rio de Janeiro.

SILVA, E.L.S. 1997. A vegetação do estado de Roraima. In Homem, Ambiente e Ecologia no Estado de Roraima (R.I. Barbosa, E.J.G. Ferreira & E.G Castellón, eds.). INPA, p.401-415.

SILVA, J.M.C. 1995a. Avian inventory of the cerrado region, South America: implication for biological conservation. Bird Conserv. Int. 5:291-304.

SILVA, J.M.C. 1995b. Biogeographic analysis of the South American Cerrado avifauna. Steenstrupia 21:49-67.

SILVA, J.M.C. 1998. Birds of the Ilha de Maracá. In Maracá: The biodiversity and environment of an Amazonia Rainforest (M. William & J. Ratter, eds.). John Wiley & Sons, Chichester, p.211-229.

SILVA, J.M.C. & SANTOS, M.P.D. 2005. A Importância relativa dos processos biogeográficos na formação da avifauna do Cerrado e de outros biomas brasileiros. In Biodiversidade: Ecologia e Conservação do Cerrado (A.O. Scariot, J.C.S. Silva & J.M. Felfili, eds.). Brasília, p.220-233.

STOTZ, D.F. 1997. Levantamento preliminar da avifauna em Roraima. In Homem, Ambiente e Ecologia no Estado de Roraima (R.I. Barbosa, E.J.G. Ferreira & E.G Castellón, eds.). INPA, p.581-608.

STOUFFER, P.C., STRONG, C. & NAKA, L.N. 2009. Twenty years of understorey bird extinctions from Amazonian rain forest fragments: consistent trends and landscape-mediated dynamics. Divers. Distrib. 15:88-97 http://dx.doi.org/10.1111/j.1472-4642.2008.00497.x

SUPERINTENDÊNCIA DO DESENVOLVIMENTO DA AMAZÔNIA – SUDAM. 1984. Atlas Climatológico da Amazônia. SUDAM, Belém. Publicação n.39.

VALE, M.M. 2007. Avian distribution patterns and conservation in Amazonia. Dissertation of doctoral, Duke University, Duke, 157p. http://dx.doi.org/10.1016/j.jradnu.2007.07.004

VANZOLINI, P.E. 1992. A supplement to the Ornithological Gazetteer of Brazil. Museu de Zoologia, Universidade de São Paulo, São Paulo.

ZIMMER, J.T. 1937a. Studies of Peruvian Birds. No. 27. Notes on the genera *Muscivora*, *Tyrannus*, *Empidonomus*, and *Sirystes*, with further notes on *Knipolegus*. Am. Mus. Novit. 962:1-28.

ZIMMER, J.T. 1937b. Studies of Peruvian Birds. No. 28. Notes on the genera *Myiodynastes*, *Conopias*, *Myiozetetes*, and *Pitangus*. Am. Mus. Novit. 963:1-28.

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Appendix

Appendix 1. Localities at which ornithological studies have been conducted in the Brazilian state of Roraima.

Localidades	Nº de spp.	Fonte	Latitude	Longitude
RR, Mun. de Alto Alegre, Uaiacás (Waica) - Rio Uraricoera	4	MPEG – Hidasi, J.	03° 33’ N	63° 11’ W
RR, Mun. de Alto Alegre, Alto Rio Parima - Posto Maranatá	6	MPEG – Mendonça, J.X. & Brigida, M.S.	02° 50’ N	63° 55’ W
RR, Mun. de Alto Alegre, Boa Esperança - Rio Uraricuera	11	Shattuck (1926)	03° 21’ N	61° 23’ W
RR, Mun. de Alto Alegre, Faz. Estrela - Rio Uraricuera	48	Santos (2005)	03° 26’ N	61° 11’ W
RR, Mun. de Alto Alegre, Faz. Kennedy - Rio Mucajaí	192	Santos (2005)	02° 40’ N	61° 12’ W
RR, Mun. de Alto Alegre, Faz. Paraense - Savana	23	Santos (2005)	02° 44’ N	61° 14’ W
RR, Mun. de Alto Alegre, Faz. Paraense - Terra Firme	180	Santos (2005)	02° 41’ N	61° 16’ W
RR, Mun. de Alto Alegre, foz do Igarapé Água Boa - Rio Mucajaí	10	Pinto (1966)	02° 49’ N	60° 40’ W
RR, Mun. de Alto Alegre, Garimpo Dicão - Rio Uraricuera	39	MPEG – Mendonça, J.X.	03° 36’ N	63° 44’ W
RR, Mun. de Alto Alegre, Serra Parima - fronteira Br-Ve - ”Frontera 2”	65	Phelps (1973)	02° 30’ N	64° 03’ W
RR, Mun. de Alto Alegre, Serra Parima - fronteira Br-Ve - ”Frontera 3”	40	Phelps (1973)	02° 27’ N	63° 54’ W
RR, Mun. de Amajari, Cerro Urutaní - fronteira Br-Ve - 1280 m	82	Dickerman & Phelps (1982)	03° 40’ N	63° 05’ W
RR, Mun. de Amajari, Estação Ecológica de Maracá - Rio Uraricoera	442	Silva (1998)	03° 25’ N	61° 40’ W
RR, Mun. de Amajari, foz do Rio Parima - Rio Uraricuera	1	Shattuck (1926)	03° 34’ N	63° 47’ W
RR, Mun. de Amajari, Ponte sobre o Rio Jauari - BR-174	1	FMNH; MZUSP – Stotz (1997).	03° 44’ N	60° 59’ W
RR, Mun. de Amajari, Rio Labarajuri - fronteira Br-Ve - (Taracuniña)	95	Phelps & Phelps (1947)	04° 13’ N	64° 40’ W
RR, Mun. de Boa Vista, foz do Igarape Água Boa - Rio Branco	5	FMNH; MZUSP – Stotz (1997).	02° 41’ N	61° 04’ W
RR, Mun. de Boa Vista, foz do Rio Cauamé - Rio Branco	5	Pelzeln (1868-70); Naterrer, J.	02° 51’ N	60° 38’ W
RR, Mun. de Boa Vista, Ilha Agua Boa - Rio Branco	5	FMNH; MZUSP – Stotz (1997).	02° 54’ N	60° 34’ W
RR, Mun. de Boa Vista, Ilha São Bento de Surrão - Rio Branco	4	FMNH; MZUSP – Stotz (1997).	02° 50’ N	60° 37’ W
RR, Mun. de Boa Vista, Ilha São José - Rio Branco	2	FMNH; MZUSP – Stotz (1997).	02° 58’ N	60° 31’ W
RR, Mun. de Boa Vista, Lago do Curirú	1	MPEG	02° 51’ N	60° 43’ W
RR, Mun. de Boa Vista, Matinha, BR 174 - Km 530	4	INPA - Conh-Haft, M. & Naka, L.N.	03° 05’ N	60° 49’ W
RR, Mun. de Boa Vista, perímetro urbano e arredores	210	MPEG; MZUSP; FMNH - Stotz (1997)	02° 49’ N	60° 40’ W
RR, Mun. de Boa Vista, Sítio Paraíso	48	Santos (2005)	02° 46’ N	60° 52’ W
RR, Mun. de Boa Vista, Vista Alegre - Rio Uraricuera	3	Shattuck (1926)	03° 08’ N	60° 30’ W
RR, Mun. de Bonfim, BR 401 - Km 53	5	INPA - Conh-Haft, M. & Naka, L.N.	03° 27’ N	59° 56’ W
RR, Mun. de Bonfim, BR 401- km100 - Rio Tacutu	32	Santos (2005)	03° 26’ N	59° 56’ W
RR, Mun. de Bonfim, Colônia Confiança	16	FMNH; MZUSP – Stotz (1997).	02° 13’ N	60° 43’ W
RR, Mun. de Bonfim, Fazenda Três Estrelas	7	FMNH; MZUSP – Stotz (1997).	02° 57’ N	60° 25’ W
RR, Mun. de Bonfim, Forte de São Joaquim	128	FMNH; MZUSP – Stotz (1997).	03° 01’ N	60° 28’ W
RR, Mun. de Cantá, BR 011 - vicinal 1	42	Santos (2005)	02° 35’ N	60° 33’ W
RR, Mun. de Cantá, Fazenda Santa Cecília	75	FMNH; MZUSP – Stotz (1997).	02° 48’ N	60° 50’ W

Appendix 1. Continued...

Localidades	Nº de spp.	Fonte	Latitude	Longitude
RR, Mun. de Cantá, Igarapé Cachorro	5	FMNH; MZUSP – Stotz (1997).	02° 22' N	60° 45' W
RR, Mun. de Cantá, Rio Quitauaú, Serra Grande de Carauamã	FMNH	MZUSP – Stotz (1997).	02° 25' N	60° 49' W
RR, Mun. de Cantá, Serra da Lua	109	FMNH – Anderson, M.P. & Becker, R.H.	02° 15' N	60° 45' W
RR, Mun. de Canta, Serra do Cantá	41	Borges (1994)	02° 38' N	60° 38' W
RR, Mun. de Cantá, Serra Grande de Caraumã - Rio Branco	49	FMNH – Anderson, M.P. & Becker, R.H.	02° 35' N	60° 40' W
RR, Mun. de Caracaraí, cidade de Caracaraí	27	Pelzeln (1868-70) – Naterrer, J.	01° 49' N	61° 08' W
RR, Mun. de Caracaraí, Estação Ecológica de Caracaraí - Rio Ajaraní	155	Santos (2005)	01° 33' N	61° 15' W
RR, Mun. de Caracaraí, Estação Ecológica de Niquiá - Rio Branco	199	Santos (2005)	01° 25' N	61° 18' W
RR, Mun. de Caracaraí, foz do Rio Amajaú - foz do Rio Branco	1	Pelzeln (1868-70) – Naterrer, J.	01° 17' S	61° 58' W
RR, Mun. de Caracaraí, PARNA Serra da Mocidade	53	INPA - Conh-Haft, M. & Naka, L.N.	01° 03' N	61° 45' W
RR, Mun. de Caracaraí, PARNA Viruá - Estrada Perdida - Campina	41	Santos (2005)	01° 28' N	60° 58' W
RR, Mun. de Caracaraí, PARNA Viruá - Igarapé Viruá - Campina	47	Santos (2005)	01° 03' N	61° 14' W
RR, Mun. de Caracaraí, PARNA Viruá - Ilha Aliança - Rio Branco	31	Santos (2005)	01° 27' N	61° 16' W
RR, Mun. de Caracaraí, PARNA Viruá - Ilha Inajatuba - Rio Branco	2	Santos (2005)	01° 16' N	61° 18' W
RR, Mun. de Caracaraí, PARNA Viruá - Posto Aliança - Rio Branco	219	Santos (2005)	01° 27' N	61° 14' W
RR, Mun. de Caracaraí, PARNA Viruá - Posto de apoio BR 174	226	Santos (2005)	01° 29' N	61° 00' W
RR, Mun. de Caracaraí, foz do Rio Catrimani - baixo Rio Branco	2	Hellmayr & Conover (1949)	00° 28' N	61° 44' W
RR, Mun. de Caracaraí, Serra do Pacú - Rio Catrimani	1	Sick (1965)	01° 30' N	62° 15' W
RR, Mun. de Iracema, Conceição - Rio Branco	38	FMNH – Anderson, M.P. & Becker, R.H.	02° 11' N	60° 58' W
RR, Mun. de Mucajaí - Vila Tamandaré - Sítio Montanha	90	Santos (2005)	02° 38' N	61° 06' W
RR, Mun. de Mucajaí - Vila Tamandaré - Sítio João Lucas	78	Santos (2005)	02° 35' N	61° 00' W
RR, Mun. de Mucajaí, foz do Rio Apiaú - Rio Mucajaí	17	Pinto (1966)	02° 39' N	61° 10' W
RR, Mun. de Mucajaí, Colônia de Apiaú	320	MPEG – Stotz (1997).; Borges (1994)	03° 34' N	61° 18' W
RR, Mun. de Mucajaí, Garimpo União - Rio Couto de Magalhães	11	MPEG – Mendonça, J.X.	02° 36' N	61° 01' W
RR, Mun. de Mucajaí, Lago da Cobra - Rio Mucajaí	26	Pinto (1966)	02° 38' N	60° 59' W
RR, Mun. de Mucajaí, perímetro urbano e arredores	267	Pinto (1966)	02° 51' N	60° 43' W
RR, Mun. de Normandia, Conceição do Maú - Rio Máu	1	Forrester (1995)	03° 35' N	59° 53' W
RR, Mun. de Normandia, Lago do Caracaranã	46	Santos (2005)	03° 50' N	59° 46' W
RR, Mun. de Normandia, Rio Maú	1	Pelzeln (1868-70) – Naterrer, J.	03° 33' N	59° 51' W
RR, Mun. de Pacaraima, BV-8, Fronteira Br-Ve	212	FMNH; MZUSP – Stotz (1997).	04° 25' N	61° 08' W
RR, Mun. de Pacaraima, Flexal - Rio Surumú	20	AMNH – Carter, T.D.	03° 50' N	60° 32' W
RR, Mun. de Pacaraima, Vila Sorocaima	210	FMNH; MZUSP – Stotz (1997).	04° 22' N	61° 00' W
RR, Mun. de Pacaraima, Vila Surumú - Rio Surumú	26	FMNH; MZUSP – Stotz (1997).	04° 08' N	60° 45' W

Appendix 1. Continued...

Localidades	Nº de spp.	Fonte	Latitude	Longitude
RR, Mun. de Rorainópolis, Castanheira Nova - foz do Rio Branco	1	Pelzeln (1868-70) J. Naterrer	01° 23’ S	61° 51’ W
RR, Mun. de Rorainópolis, Comunidade de Samaúma - Rio Jauaperí	79	INPA - Conh-Haft, M. & Naka, L.N.	01° 08’ S	61° 36’ W
RR, Mun. de Rorainópolis, foz do Rio Branco - Rio Negro	52	INPA - Conh-Haft, M. & Naka, L.N.	01° 23’ S	61° 51’ W
RR, Mun. de Rorainópolis, Ilha da Cota - Rio Branco	66	INPA - Conh-Haft, M. & Naka, L.N.	01° 15’ S	61° 50’ W
RR, Mun. de Rorainópolis, Ilha do Carmo - Rio Branco	1	Pelzeln (1868-70) – Naterrer, J.	00° 18’ S	61° 49’ W
RR, Mun. de Rorainópolis, Ilha do Castanhal - Rio Branco	2	Zimmer (1937a, 1937b)	00° 50’ S	61° 51’ W
RR, Mun. de Rorainópolis, Ilha do Passarão - Rio Branco	147	Pacheco, J.F. & Carvalhães A.	01° 00’ S	61° 52’ W
RR, Mun. de Rorainópolis, Reserva Xixuaú-Xiparina - Rio Jauaperí	124	Trolle, M. (www.amazonia.org.br)	00° 46’ S	61° 35’ W
RR, Mun. de Rorainópolis, Santa Maria do Boiaçú - Rio Branco	76	Pelzeln (1868-70) – Naterrer, J.	00° 27’ N	61° 41’ W
RR, Mun. de São João da Baliza	140	INPA - Conh-Haft, M. & Naka, L.N.	01° 05’ N	59° 56’ W
RR, Mun. de São João da Baliza - Vicinal 29	179	Santos (2005)	00° 59’ N	59° 52’ W
RR, Mun. de Uiramutã, Cerro Uei-Tepui (Cerro del Sol)	90	Phelps & Phelps (1962)	05° 02’ N	60° 36’ W
RR, Mun. de Uiramutã, Monte Roraima	51	Peberdy (1941)	05° 13’ N	60° 42’ W
RR, Mun. de Uiramutã, Rio Cotingo - nascentes	22	Peberdy (1941)	05° 10’ N	60° 30’ W
RR, Mun. de Uiramutã, Rio Cotingo - Contão	7	Forrester (1995)	03° 54’ N	60° 26’ W
RR, Mun. de Uiramutã, Rio Cotingo - Limão	8	Zimmer (1937a,1937b)	03° 56’ N	60° 30’ W

Pebapomberus, a new orthoclad genus from Brazil (Diptera: Chironomidae, Orthocladiinae)

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MENDES, H.F. & ANDERSEN, T. ***Pebapomberus*, a new orthoclad genus from Brazil (Diptera: Chironomidae, Orthocladiinae)**. Biota Neotrop. 12(2): http://www.biotaneotropica.org.br/v12n2/en/abstract?article+bn00412022012

Abstract: The genus *Pebapomberus* gen. n. is erected for *P. rugendas* sp. n. from Santa Catarina and São Paulo States and *P. euniceae* sp. n., from São Paulo State. The genus is characterized by bare eyes without dorsomedian extension; anterior simple and posterior scalpellate, weak acrostichals; bare wing membrane; squama with few setae; large, wedge-shaped anal point; and gonostylus with large, flattened apical lobe.

Keywords: *new species, Brazil, São Paulo State, Santa Catarina State, Neotropical region, Mata Atlântica.*

MENDES, H.F. & ANDERSEN, T. ***Pebapomberus*, um gênero novo de Orthocladiinae do Brasil (Diptera: Chironomidae)**. Biota Neotrop. 12(2): http://www.biotaneotropica.org.br/v12n2/pt/abstract?article+bn00412022012

Resumo: O gênero *Pebapomberus* gen. n. é descrito com base em *P. rugendas* sp. n. dos Estados de Santa Catarina e São Paulo e *P. euniceae* sp. n., de São Paulo. O gênero é caracterizado pelo olho sem microtríquios entre os omatídeos e extensão dorso-mediana do olho ausente; setas acrosticais fracas, sendo as anteriores simples e as posteriores escalpeladas; membrana alar sem setas; *squama* com poucas setas; ponta anal em forma de cunha e gonóstilo com um lobo apical grande e achatado.

Palavras-chave: *espécie nova, Brasil, São Paulo, Santa Catarina, região Neotropical, Mata Atlântica.*

Introduction

In their catalog of the Neotropical and Mexican chironomids Spies & Reiss (1996) recorded seven Orthocladiinae species from Brazil; one of these, *Ichthyocladius neotropicus* Fittkau, as uncertain, a species which later has proved not to occur in Brazil (Mendes et al. 2004). Today about 100 species of orthoclads have been described or recorded from Brazil and several new genera have been added (Mendes & Pinho 2011). However, a high number of new species still await description. When collecting in Brazil many of the orthoclads encountered do not readily fit into any described genus. Several of these might be terrestrial or semiterrestrial and the larvae and pupae might be difficult to find. Below we describe the males of two of these species and place them in a new genus. Both species were collected in Mata Atlântica in South and Southeast Brazil.

Material and Methods

The specimens were mounted on slides in Canada balsam or Euparal following the procedures outlined by Sæther (1969). The terminology follows Sæther (1980).

The types are deposited in the Museu de Zoologia da Universidade de São Paulo, São Paulo, Brazil (MZUSP).

Pebapomberus new genus

Type species: *Pebapomberus rugendas* sp. n., by present designation.

Other included species: *Pebapomberus euniceae* sp. n.

Etymology: From Tupy "*peb*", "*po*", and "*mberui*" meaning flat, hand, and midge, referring to the shape of the gostylus. The gender of the name is masculine.

Diagnostic characters: The combination of bare eyes without dorsomedian extension; anterior simple and posterior scalpellate, weak acrostichals; bare wing membrane; squama with few setae, large wedge-shaped anal point, and gonostylus with large, flattened apical lobe will separate the genus from all other Orthocladiinae

Description

Small sized species, wing length 1.1-1.3 mm.

Head. Eye bare, reniform, without dorsomedian extension. Male antenna with 13 flagellomeres; groove beginning on flagellomere 3; sensilla chaetica present on flagellomeres 2, 3 and ultimate; ultimate flagellomere slightly swollen subapically, tapering, without subapical seta; AR 0.7-0.9. Palpomeres normal, third palpomere with few sensilla clavata subapically. Temporal setae in partly double row, inner verticals weak, outer verticals and postorbitals strong. Frontal tubercle absent, but with small, pale scar. Tentorium and stipes normal. Cibarial pump with anterior margin nearly straight. Clypeus with few setae.

Thorax. Antepronotum well developed with lobes meeting medially at anterior margin of scutum, with few lateral antepronotal. Acrostichals weak, starting close to antepronotum, anterior acrostichals simple, posterior acrostichals scalpelate; dorsocentrals simple, uniserial; prealars uniserial, grouped in posterior and anterior prealars; supraalar present. Scutellum with few setae in single row.

Wing. Membrane without setae, with fine punctuation. Anal lobe normal. Costa extended; R_{2+3} running and ending midway between R_1 and R_{4+5}; R_{4+5} ending opposite to or distal to M_{3+4}; FCu distal to RM; Cu_1 slightly sinuous. Brachiolum with 1 seta, C without or with few non-marginal setae, other veins bare. Squama with few setae. Sensilla campaniformia about 8 basally, 10 apically, and 3 above seta on brachiolum; 1 on RM; and 1 basally on R_1.

Leg. Tibial spurs and comb normal. Tarsal pseudospurs and sensilla chaetica absent. Pulvilli vestigial.

Abdomen. Tergite I with few lateral setae, tergites II with anterior and posterior row of setae, tergites III-VIII with more scattered setae. Sternites I-III bare, sternites IV-V with single to few median setae, sternites VI-VII with more median setae, sternite VIII with more scattered setae.

Hypopygium. Anal point large, wedge-shaped with rounded apex, reaching below posterior margin of tergite IX, with microtrichia and weak, lateral setae. Tergite IX without seta; laterosternite IX with several setae. Phallapodeme normal; transverse sternapodeme curved, with well developed oral projections. Virga consisting of two separate, strong sclerites. Inferior volsella with anterior small bluntly rounded to larger, narrowly triangular, pointed lobe and posterior broadly rounded lobe with few marginal setae. Superior volsella barely indicated. Gonostylus broad, with large, apical, bluntly triangular to rounded, flattened lobe covered with macrotrichia and with few scattered setae; megaseta normal.

Female, *pupa* and *larva*. Unknown.

Systematics

This genus will key to dichotomy 76 in Cranston et al. (1989) where it will not key further and to *Antillocladius* Sæther in Mendes & Andersen (2008) and in Spies et al. (2009). This genus shows similarities with *Lyrocladius* Mendes *et* Andersen, from which it can be separated on the broader, wedge-shaped the anal point and the gonostylus bearing a large, flattened apical lobe.

Following the parsimony analysis presented by Mendes & Andersen (2008), the new genus is placed among the genera *Antillocladius*, *Bryophaenocladius* Thienemann, *Gymnometriocnemus* Goetghebuer, *Litocladius* Mendes, Andersen et Sæther, and *Lyrocladius*.

Pebapomberus rugendas sp. n. (Figures 1-10)

Type material: Holotype male, **Brazil: Santa Catarina State:** São Bento do Sul, 26° 19' 25.6" S and 48° 18' 26.5" W, 13-16.x.2001, 660 m a.s.l., Malaise trap (Trilha Rugendas), M. V. Yamada (MZUSP). Paratypes: 1 male, **São Paulo State:** Estação Biológica Boracéia, Salesópolis, córrego Coruja, 18.ix.2007, light trap, C. G. Froehlich et al. (MZUSP); 1 male: same data as pervious except for: córrego Venerando, 12.xii.2001.

Diagnostic characters: This species can be separated from *P. euniceae* n. sp. by the inferior volsella having a small, knob-like anterior lobe and by the subtriangular apical lobe of the gonostylus.

Etymology: Named after the path, Rugendas, where the Malaise trap was standing. The name is to be regarded as a noun in apposition.

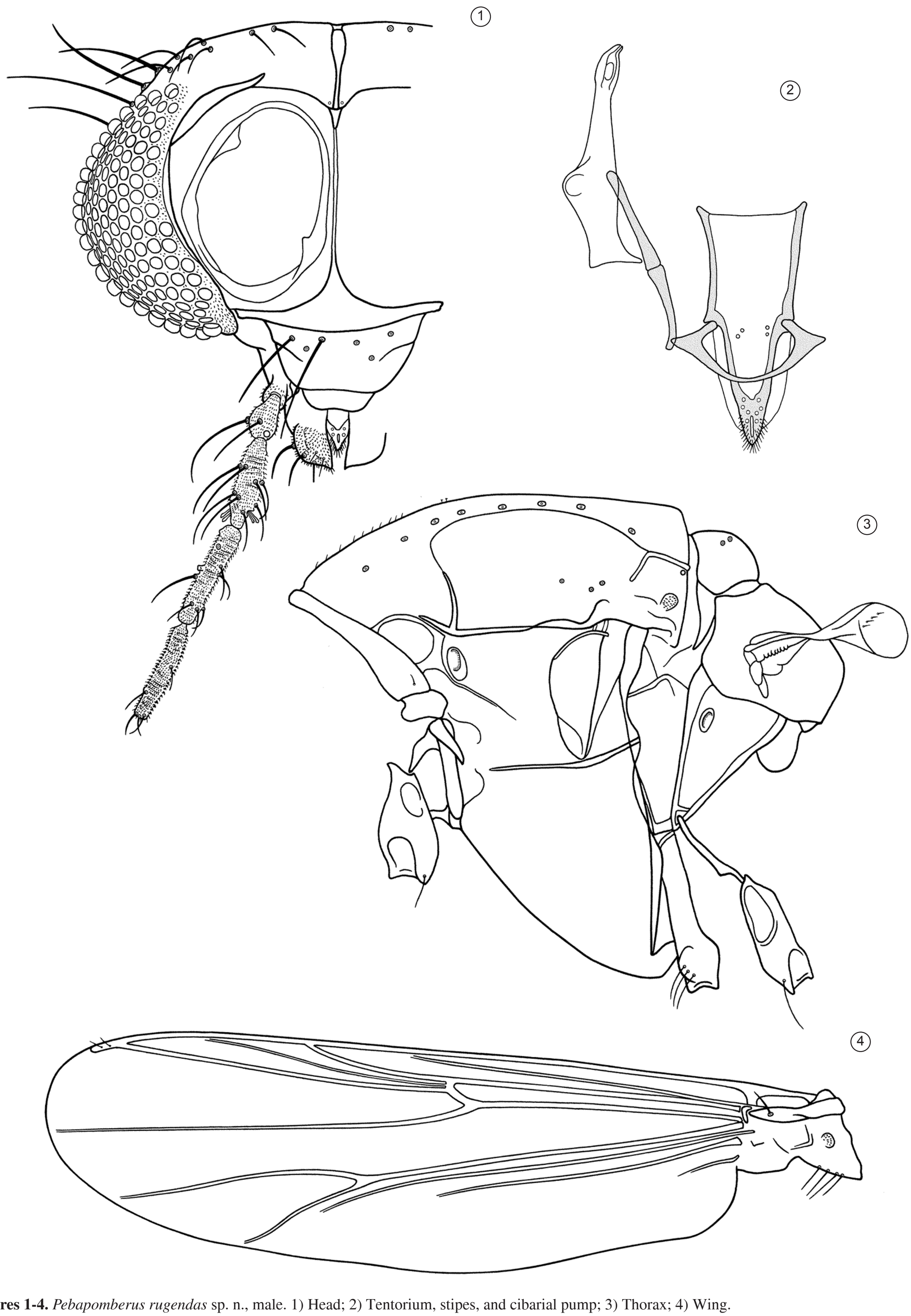
Description

Male (n = 2-3, except when otherwise stated). Total length 1.75-1.99 mm. Wing length 1.17-1.26 mm. Total length/wing length 1.44-1.70. Wing length/length of profemur 2.54-2.70.

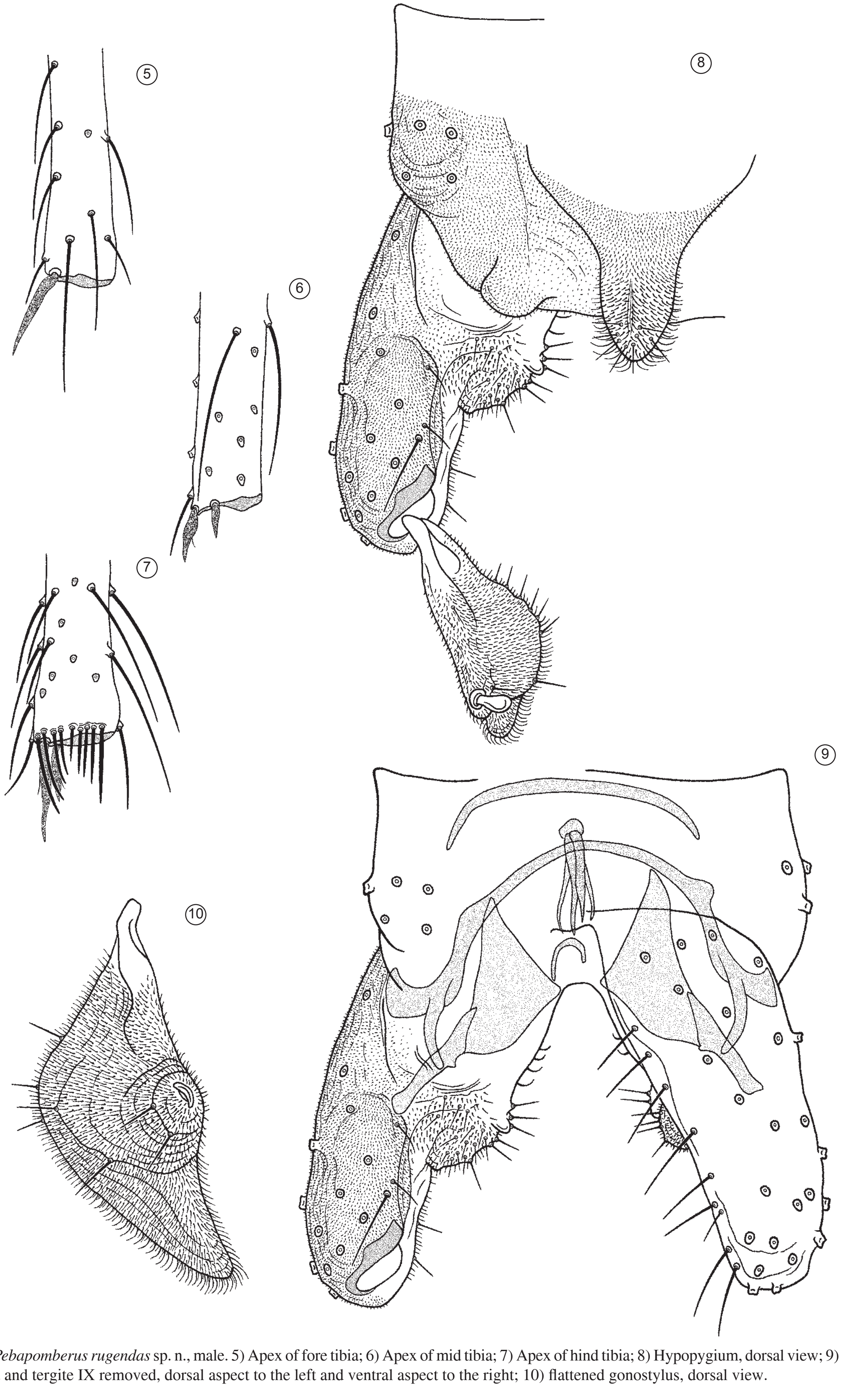
Coloration. Thorax, head, antennal flagellum, and coxae brown; abdomen and legs uniformly light brown.

Head (Figures 1-2). AR 0.74-0.78. Ultimate flagellomere 281-299 μm long. Temporal setae 8-10 including 4-5 inner verticals, 2 outer verticals, and 2-3 postorbitals. Clypeus with 6-11 setae. Tentorium, stipes, and cibarial pump as in Figure 2. Tentorium 93-109 μm long, 18-23 μm wide. Stipes 93-102 μm long. Palp segment lengths (in μm): 16-20, 29-36, 57-69, 74-84, 68-79. Third palpomere with 5 sensilla clavata in two groups subapically, longest 9-12 μm long.

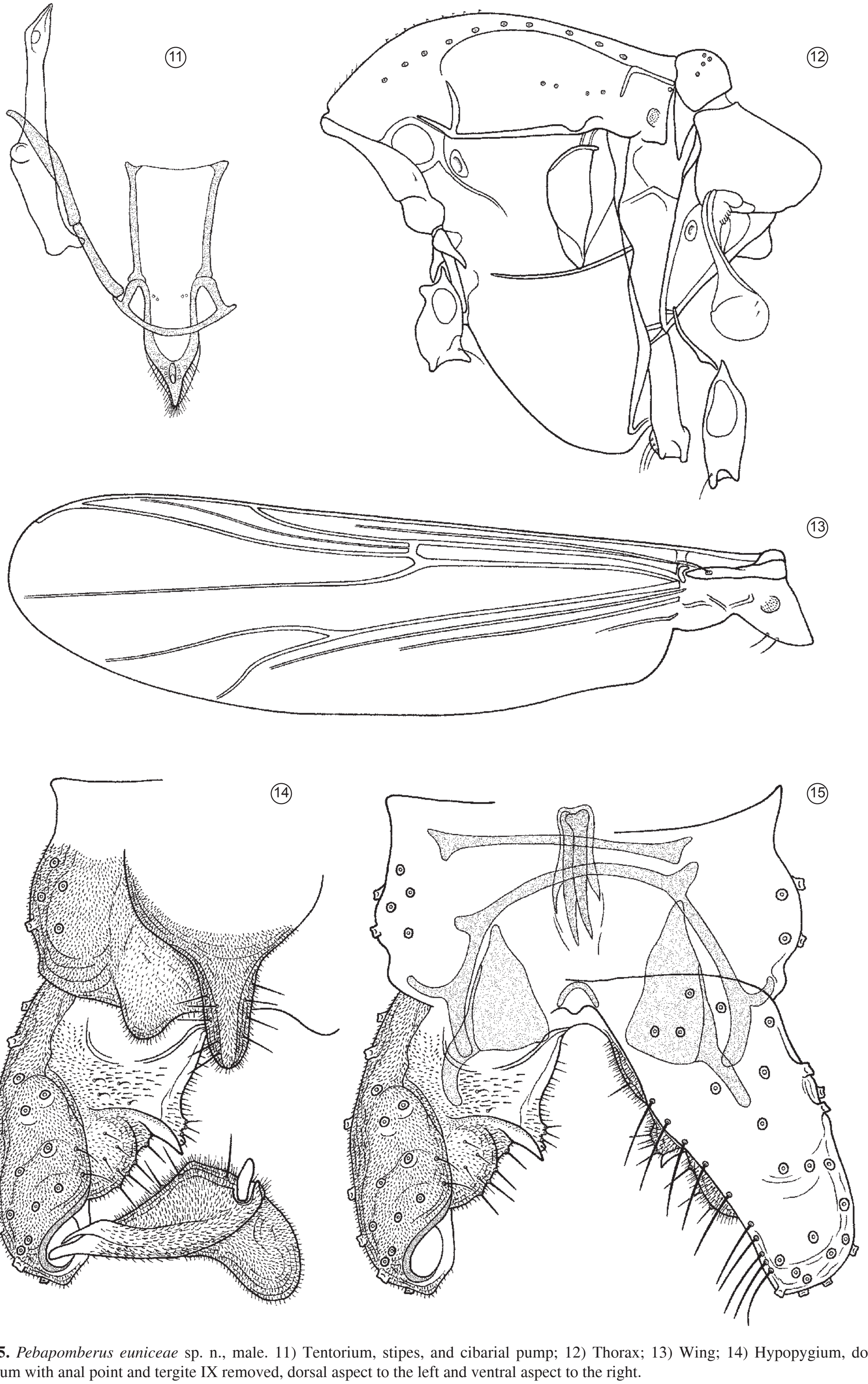
Thorax (Figure 3). Antepronotum with 1-2 seta. Dorsocentrals 7-8; acrostichals 12-13, beginning close to antepronotum, composed of 8-10 anterior simple and 2-5 posterior scalpellate; prealars 3, 2 posterior and 1 anterior; supraalar 1. Scutellum with 4 setae.



Figures 1-4. *Pebapomberus rugendas* sp. n., male. 1) Head; 2) Tentorium, stipes, and cibarial pump; 3) Thorax; 4) Wing.



Figures 5-10. *Pebapomberus rugendas* sp. n., male. 5) Apex of fore tibia; 6) Apex of mid tibia; 7) Apex of hind tibia; 8) Hypopygium, dorsal view; 9) Hypopygium with anal point and tergite IX removed, dorsal aspect to the left and ventral aspect to the right; 10) flattened gonostylus, dorsal view.



Figures 11-15. *Pebapomberus euniceae* sp. n., male. 11) Tentorium, stipes, and cibarial pump; 12) Thorax; 13) Wing; 14) Hypopygium, dorsal view; 15) Hypopygium with anal point and tergite IX removed, dorsal aspect to the left and ventral aspect to the right.

Table 1. Lengths (in µm) and proportions of legs of *Pebapomberus rugendas* sp. n., male (n = 2-3).

	fe	ti	ta$_1$	ta$_2$	ta$_3$	ta$_4$	ta$_5$	LR	BV	SV	BR
p$_1$	425-482	518-619	281-295	193-206	133-140	59-68	41-43	0.54-0.57	2.85-2.89	3.36-3.38	2.5-3.0
p$_2$	497-500	465-468	188-191	104-112	72-77	37-43	28-29	0.40-0.41	4.43-4.73	5.06-5.07	3.8-4.3
p$_3$	511-554	529-605	292-338	151-180	144-156	58-61	40-43	0.54-0.56	3.48-3.52	3.42-3.65	3.9-6.0

Table 2. Lengths (in µm) and proportions of legs of *Pebapomberus euniceae* sp. n., male (n = 1).

	fe	ti	ta$_1$	ta$_2$	ta$_3$	ta$_4$	ta$_5$	LR	BV	SV	BR
p$_1$	475	511	268	178	130	68	40	0.52	3.02	3.68	2.8
p$_2$	508	461	184	101	79	47	32	0.40	4.44	5.27	3.3
p$_3$	544	533	310	162	140	61	40	0.58	3.44	3.48	6.0

Wing (Figure 4). VR 1.43-1.44. C extension 50-70 µm long. Brachiolum with 1 seta, C with 0-2 non-marginal setae, remaining veins and cells bare. Squama with 2-4 setae.

Legs (Figures 5-7). Spur of fore tibia 25-36 µm long, spurs of mid tibia 9-11 µm and 15-23 µm, of hind tibia 14-16 µm and 36-40 µm long. Width at apex of fore tibia 24-32 µm, of mid tibia 23-25 µm, of hind tibia 35-39 µm. Hind tibia comb with 9 (1) setae, longest 27 (1) µm, shortest 14 (1) µm long. Lengths and proportions of legs as in Table 1.

Hypopygium (Figures 8-10). Tergite IX covered with microtrichia; laterosternite IX with 5-6 setae. Anal point wedge-shaped, 36-43 µm long, 20-34 µm wide at base, with 8-10 weak marginal setae. Phallapodeme 79-84 µm long; transverse sternapodeme 82 µm long. Virga 41-48 µm long. Gonocoxite 138-148 µm long. Gonostylus 73 µm long (not including apical lobe); megaseta 10-11 µm long. HR 2.00-2.03. HV 2.41-2.70.

Distribution

The species is known from Santa Catarina and São Paulo States in Brazil, where it was collected in Malaise- and light traps. Both collection sites have a humid, coastal climate with many small streams. The vegetation is a mosaic of primary and secondary forest and epiphytes are abundant.

Pebapomberus euniceae sp. n. (Figures 11-15)

Type material: Holotype male, **Brazil: São Paulo:** Parque Estadual Intervales, Iporanga, 24° 32' S and 48° 42' W, 26-27.x.2001, CDC trap, E.A.B. Galati (MZUSP).

Diagnostic characters: This species can be separated from *P. rugendas* n. sp. by the inferior volsella having a narrowly triangular, pointed anterior lobe and a broadly rounded apical lobe of the gonostylus.

Etymology: Named after Dr. Eunice A. B. Galati for making the material available to us.

Description

Male (n = 1). Total length 2.00 mm. Wing length 1.17 mm. Total length/wing length 1.71. Wing length/length of profemur 2.44.

Coloration. Thorax, head, and coxae brown; abdomen, antennal flagellum and legs uniformly light brown.

Head. AR 0.88. Ultimate flagellomere 328 µm long. Temporal setae 9 including 5 inner verticals and 4 outer verticals and 2 postorbitals. Clypeus with 7 setae. Tentorium, stipes, and cibarial pump as in Figure 11. Tentorium 118 µm long, 20 µm wide. Stipes 107 µm long. Palp segment lengths (in µm): 18, 34, 69, 79, 100. Third palpomere with 3 sensilla clavata subapically, longest 12 µm long.

Thorax (Figure 12). Antepronotum with 1 seta. Dorsocentrals 10; acrostichals 14 beginning close to antepronotum, composed of 5 anterior simple and 9 posterior scalpellate; prealars 4, 2 posterior and 2 anterior; supraalar 1. Scutellum with 7 setae.

Wing (Figure 13). VR 1.45. C extension 68 µm long. Brachiolum with 1 seta, remaining veins and cells bare. Squama with 2 setae.

Legs. Spur of fore tibia 34 µm long, spurs of mid tibia 16 µm and 23 µm long, spurs of hind tibia 14 µm and 43 µm long. Width at apex of fore tibia 25 µm, of mid tibia 27 µm, of hind tibia 36 µm. Comb with 11 setae, longest 32 µm, shortest 19 µm long. Lengths and proportions of legs as in Table 2.

Hypopygium (Figures 14-15). Tergite IX covered with microtrichia; laterosternite IX with 5 setae. Anal point wedge-shaped, 43 µm long, 20 µm wide at base, with 9 weak marginal setae. Phallapodeme 83 µm long; transverse sternapodeme 84 µm long. Virga 42 µm long. Gonocoxite 150 µm long. Gonostylus 70 µm long (not including apical lobe); megaseta 14 µm long. HR 2.13. HV 2.84.

Distribution

The species is known from southern São Paulo State in Brazil, where it was collected in a CDC trap during a project aimed at Phlebotominae. The locality is within a nature reserve with many small streams and rivulets. The vegetation is mainly pristine mountain forest with mosses and many different species of epiphytes.

Acknowledgements

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References

CRANSTON, P.S., OLIVER, D.R. & SÆTHER, O.A. 1989. The adult males of Orthocladiinae (Diptera: Chironomidae) of the Holarctic region. Keys and diagnoses. In Chironomidae of the Holarctic region: Keys and diagnoses. Part 3. Adult males. (T. Wiederholm, ed.). Ent. Scand. Suppl. 34:165-352.

MENDES, H.F. & ANDERSEN, T. 2008. A review of *Antillocladius* Sæther and *Litocladius* Mendes, Andersen et Sæther, with the description of two new Neotropical genera (Diptera, Chironomidae, Orthocladiinae). Zootaxa 1887:1-75.

MENDES, H.F. & PINHO, L.C. 2011. Taxonomy of Chironomidae (Insecta: Diptera) in Brazil. Brazilian Chironomid Home Page. http://sites.google.com/site/brazilianchironomids/ (último acesso em 22/12/2011).

MENDES, H.F., ANDERSEN, T. & SÆTHER, O.A. 2004. New species of *Ichthyocladius* Fittkau, a member of the *Corynoneura*-group (Diptera: Chironomidae: Orthocladiinae), with a review of the genus. Stud. Neotrop. Fauna Environ. 39:15-35.

SÆTHER, O.A. 1969. Some Nearctic Podonominae, Diamesinae and Orthocladiinae (Diptera: Chironomidae). Bull. Fish. Res. Board Canada 107:1-154.

SÆTHER, O.A. 1980. Glossary of Chironomid morphology terminology (Diptera: Chironomidae). Ent. Scand. Suppl. 14:1-51.

SPIES, M. & REISS, F. 1996. Catalog and bibliography of neotropical and Mexican Chironomidae (Insecta, Diptera). Spixiana, Suppl. 22:61-119.

SPIES, M., ANDERSEN, T., EPLER, J.H. & WATSON JUNIOR, C.N. 2009. Chironomidae (Non-biting midges). In Manual of Central American Diptera (B.V. Brown, A. Borkent, J.M. Cumming, D.M. Wood, N.E. Woodley & M.A. Zumbado, eds.). NRC Research Press, Ottawa, Canada, p.437-480.

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Geophagy in two parrot species in southern Pantanal, Brazil

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SEVERO-NETO, F. **Geophagy in two parrot species in southern Pantanal, Brazil**. Biota Neotrop. 12(2): http://www.biotaneotropica.org.br/v12n2/en/abstract?short-communication+bn00612022012

Abstract: Geophagy is a habit recorded for parrots, which seek earthy or soil-like substances presumably to help them in digestive functions, whether mechanical or chemical ones. Few studies are devoted to this feeding peculiarity in the Pantanal region. Here are reported two events of geophagy, for the Blue-and-yellow Macaw (*Ara ararauna*) and the Nanday Parakeet (*Aratinga nenday*) in the Pantanal subregions of the Miranda-Abobral and Nhecolândia, Mato Grosso do Sul, respectively.
Keywords: *geophagy, Pantanal, psittacines, parrots, wetland, feeding ecology.*

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Resumo: A geofagia é um hábito conhecido em psitacídeos, que se alimentam de terra ou argila supostamente por ajudar em funções digestivas, sejam mecânicas ou químicas. Poucos estudos são dedicados a essa peculiaridade alimentar na região do Pantanal. É feito aqui o registro de dois eventos de geofagia, para a arara-canindé (*Ara ararauna*) e o periquito-de-cabeça-preta (*Aratinga nenday*) nas sub-regiões pantaneiras da Nhecolândia e Miranda-Abobral, Mato Grosso do Sul, respectivamente.
Palavras-chave: *geofagia, Pantanal, psittacidae, araras, área úmida, ecologia alimentar.*

Introduction

Geophagy, the consumption of earthy or soil-like substances such as clay, silt and sand, is a habit described for several animal taxa, especially herbivorous or strictly herbivorous species (Diamond et al. 1999). Among vertebrates, most studies on geophagy are on primates, as these mammals may ingest soil from anthills, termite mounds and nests of ovenbirds (*Furnarius rufus*) (Bicca-Marques & Callegaro-Marques 1994, Krishnamani & Mahaney 2000, Mahaney & Krishnamani 2003, Sazima 2008).

The knowledge on geophagy among birds is scarce, and intensive studies on this issue are not frequent (Brightsmith 2004). Most of these studies were carried on with birds from the Peruvian Amazon, which use to cluster in flocks in hillsides with fragments of exposed soil, the so called clay licks (Burger & Gochfeld 2003, Brightsmith 2004, Brightsmith & Muñoz-Najar 2004). Geophagy is reported for Anseriformes, Columbiformes, Passeriformes, Casuariiformes, Galliformes and Psittaciformes (review in Brightsmith 2004). Among these orders, the greatest number of records is for the Psittaciformes, various species of macaws, parrots and parakeets (Mee et al. 2005, Symes et al. 2006, Lee et al. 2010).

The use of areas of moist and exposed soil is widespread among South America vertebrates and has been reported in Peru and some regions of Brazil (Vidolin et al. 2009, Tobler et al. 2009), including the Pantanal, where these clay mounds are popularly known as “barreiros”. In the northeastern Pantanal, 14 species of vertebrates were recorded ingesting soil from “barreiros” (Coelho 2006). Some birds, including a Hyacinth Macaw (*Anodorhynchus hyacinthynus* (Latham, 1790)) and other parakeets, were also spotted ingesting soil; but not from the “barreiros” (Coelho 2006). This report is on geophagy among psittacines in the Pantanal wetlands, recording this behavior for the Blue-and-yellow Macaw, *Ara ararauna* (Linnaeus, 1758), and the Nanday Parakeet, *Aratinga nenday* (Vieillot, 1823), in two subregions of the Pantanal, Mato Grosso do Sul.

Material and Methods

The Pantanal is one of the largest continuous floodplain in the world; it is located in the Upper Paraguay Basin (16-20° S and 55-58° W). This basin comprises about 496,000 km^2 in which the Pantanal area is about 160.000km^2 distributed among Paraguay, Bolivia and Brazil; being 140,000 km^2 in the Brazilian territory (Junk et al. 2006). Due to edaphic, hydrological and biogeographical variation, its ecosystem can be divided into 10 different sub-regions (Lourival et al 2000). Within these sub-regions, the observations on *A. ararauna* were made at Nhumirim Farm (18° 58’ S and 56° 38’ W), located in the Nhecolândia sub-region and those on *Aratinga nenday* were made in the Miranda-Abobral sub-region, at the Base de Estudos do Pantanal (19° 34’ S and 57° 01’ W), property of the Universidade Federal de Mato Grosso do Sul. Both geophagy events were reported trough casual observations.

Results and Discussion

The geophagic behaviour of *A. ararauna* was observed on 10 September 2010, at 8:30 AM The macaw was alone on the ground, at the edge of a “salina”, term used for the characteristic ponds of the Nhecolândia sub-region. These ponds remain isolated from other ponds during the flood and thus have sandy soil and high concentrations of sodium and potassium (Sakamoto et al. 1996). The bird scraped the ground with the beak (Figure 1) and lifted the head, as it does while swallowing, doing this repeatedly. However, as I approached to take a photograph, about100 m far from the bird, it flew. The wariness of parrots on the ground and their vulnerability to predators during geophagy are discussed by Burger & Gochfeld (2003).

Figure 1. Blue-and-yellow Macaw (*Ara ararauna*) scraping earth (geophagy) at the edge of a “salina”, a typical pond in the subregion of Nhecolândia, Mato Grosso do Sul, Brazil, in September 2010. Note mammal droppings (dark objects around the edge).

Figura 1. Arara-canindé (*Ara ararauna*) raspando terra (geofagia), na margem de uma salina, uma lagoa típica da sub-região da Nhecolândia, Mato Grosso do Sul, Brasil, em setembro de 2010. Note excrementos de mamíferos (objetos escuros ao redor da margem).

Other vertebrates, such as tapirs (*Tapirus terrestris*) and peccaries (*Pecari tajacu*, *Tayassu pecari* and *Sus scrofa*) also visit the site to lick the soil. Faeces of these and other animals that visit the same spot are visible on Figure 1. Geophagy by Hyacinth macaws and parakeets was previously observed at this site (M. Tomas pers. comm.). Additionally, *Ara ararauna* was observed feeding of cattle feces (M. Tomas pers. comm.). Other bird species also found in the “salinas” in search of the “barreiros”, include the Blue-throated Piping-Guan [*Aburria cumanensis* (Jacquin, 1784)], Bare-faced Curassow (*Crax fasciolata* Spix, 1825), Yellow-collared Macaw [*Primolius auricollis* (Cassin, 1853)], Blue-crowned Parakeet [*Aratinga acuticaudata* (Vieillot, 1818)] and the Monk Parakeet [*Myiopsitta monachus* (Boddaert, 1783)] (A.P. Nunes pers. comm.).

Aratinga nenday was observed scraping earth on 20 September 2010, at 5:30 PM Except for the work of Ragusa-Netto (2005), little is known on the biology of this species on Pantanal. The parakeet was alone on the ground, in a circle of naked soil (around 12 m^2), repeatedly making movements of scraping and swallowing similar to those described above for *A. ararauna* (Figure 2). Nanday Parakeets are frequently found alone or in couple at this site, about 50 m far from the Miranda River, where there are some tree species used as perches (*Mangifera indica, Cecropia pachystachya*) or food (fruits of *Attalea phalerata* and flowers of *Cocos nucifera*) by these birds.

Several hypotheses are postulated to explain geophagy in birds. As a mechanical function, earthy grains would be responsible for crushing the food in the gizzard (Best & Gionfriddo 1991). Biochemically, it is suggested that the ingested soil would help in the digestive processes buffering the gastric acids and providing mineral supplements. Other studies emphasize the importance of geophagy as a mean of adsorption for toxins and secondary compounds derived from the herbivorous diet and protection of gastrointestinal cells from these compounds (Gilardi et al. 1999). Diamond et al. (1999) argue that the diversity of parrots found in the western Amazon basin would be a reflection of geophagy, which allows these birds to consume a wider range of plants resources.

Figure 2. Nanday Parakeet (*Aratinga nenday*) scraping earth (geophagy) on a site of naked soil at the subregion in Pantanal known as Miranda-Abobral, in September 2010.

Figura 2. Periquito-de-cabeça-preta (*Aratinga nenday*) raspando terra (geofagia) em um local de solo nu na sub-região do Pantanal conhecido como Miranda-Abobral, em setembro de 2010.

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References

BEST, L.B. & GIONFRIDDO, J.P. 1991. Characterization of grit use by cornfield birds. Wilson Bull. 103(1):68-82.

BICCA-MARQUES, J.C. & CALEGARO-MARQUES, C. 1994. A case of geophagy in the black howling monkey Alouatta caraya. Neotrop. Primates. 2:7-9.

BRIGHTSMITH, D. 2004. Effects of Diet, Migration, and Breeding on Clay Lick Use by Parrots in Southeastern Peru. In American Federation of Aviculture Symposium. Brightsmith.

BRIGHTSMITH, D.J. & MUÑOZ-NAJAR, R.A. 2004. Avian geophagy and soil characteristics in southeastern Peru. Biotropica. 36(4):534-543.

BURGER, J. & GOCHFELD, M. 2003. Parrot behavior at a Rio Manu (Peru) clay lick: temporal patterns, associations, and antipredator responses. Acta Ethol. 6(1):23-34.

COELHO, I.P. 2006. Relações entre barreiros e a fauna de vertebrados no nordeste do Pantanal, Brasil. Dissertação de Mestrado, Universidade Federal do Rio Grande do Sul, Porto Alegre.

DIAMOND, J., BISHOP, K.D. & GILARDI, J.D. 1999. Geophagy in New Guinea birds. Ibis141(2):181-193. http://dx.doi.org/10.1111/j.1474-919X.1999.tb07540.x

GILARDI, J.D., DUFFEY, S.S., MUNN, C.A. & TELL, L.A. 1999. Biochemical functions of geophagy in parrots: detoxification of dietary toxins and cytoprotective effects. J. Chem. Ecol. 25(4):897-922. http://dx.doi.org/10.1023/A:1020857120217

JUNK, W.J., DA CUNHA, L.A., WANTZEN, K.M., PETERMANN, P., STRÜSSMANN, C., MARQUES, M.I. & ADIS, J. 2006. Biodiversity and its conservation in the Pantanal of Mato Grosso, Brazil. Aquat. Sci. 68(3):278-309. http://dx.doi.org/10.1007/s00027-006-0851-4

KRISHNAMANI, R. & MAHANEY, W.C. 2000. Geophagy among primates: adaptive significance and ecological consequences. Anim. Behav. 59(5):899-915. PMid:10860518. http://dx.doi.org/10.1006/anbe.1999.1376

LOURIVAL, R., HARRIS, M. & MONTAMBAULT, J.R. 2000. Introdução ao Pantanal, Mato Grosso do Sul, Brasil. In Uma avaliação Biológica dos Ecossistemas Aquáticos do Pantanal, Mato Grosso do Sul, Brasil (P.W. Willink, B. Chernoff, L. Alonso, J.R. Montambault & R. Lourival). Conservation International, Washington.

LEE, A.T.K., KUMAR, S., BRIGHTSMITH, D.J. & MARSDEN, S.J. 2010. Parrot claylick distribution in South America: do patterns of "where" help answer the question "why"? Ecography 33(3):503-513.

MAHANEY, W.C. & KRISHNAMANI, R. 2003. Understanding geophagy in animals: standard procedures for sampling soils. J. Chem. Ecol. 29(7):1503-1523. PMid:12921433. http://dx.doi.org/10.1023/A:1024263627606

MEE, A., DENNY, R., FAIRCLOUGH, K., PULLAN, D.M. & BOYD-WALLIS, W. 2005. Observations of parrots at a geophagy site in Bolivia. Biota Neotrop. 5(2):321-324. http://www.biotaneotropica.org.br/v5n2/pt/abstract?short-communication+bn02805022005

RAGUSA-NETTO, J. 2005. Extensive consumption of *Tabebuia aurea* (Manso) Benth. & Hook. (Bignoniaceae) nectar by parrots in a tecoma savanna in the southern Pantanal (Brazil). Braz. J. Biol. 65(2):339-344. http://dx.doi.org/10.1590/S1519-69842005000200018

SAKAMOTO, A.Y., QUEIROZ NETO, J.P., FERNANDES, E. & LUCATTI, H.M. 1996. Topografia de lagoas salinas e seus entorno no Pantanal da Nhecolândia/MS. In Simpósio Sobre Recursos Naturais e Sócio - Econômicos do Pantanal: Manejo e Conservação. EMBRAPA/CPAP-UFMS, Corumbá.

SAZIMA, I. 2008. The parrotlet *Forpus xanthopterygius* scrapes at clay nests of the ovenbird *Furnarius rufus*: tasting or testing a new home? Rev. Bras. Ornitol. 16(3):256-269.

SYMES, C.T., HUGHES, J.C., MACK, A.L. & MARSDEN, S.J. 2006. Geophagy in birds of Crater Mountain Wildlife Management Area, Papua New Guinea. J. Zool. 268(1):87-96. http://dx.doi.org/10.1111/j.1469-7998.2005.00002.x

TOBLER, M.W., CARRILLO-PERCASTEGUI, S.E. & POWELL, G. 2009. Habitat use, activity patterns and use of mineral licks by five species of ungulate in south-eastern Peru. J. Trop. Ecol. 25(3):261-270. http://dx.doi.org/10.1017/S0266467409005896

VIDOLIN, G.P., BIONDI, D. & WANDEMBRUCK, A. 2009. Seletividade de habitats pela anta (*Tapirus terrestris*) e pelo queixada (*Tayassu pecari*) na Floresta com Araucária. Sci. For. 37(84):447-458.

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The effects of bauxite/alumina waste on the composition of the macroinvertebrate community of the Rio Cobre, a major river in Jamaica

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HYSLOP, E. J. & NESBETH, D. A. **The effects of bauxite/alumina waste on the composition of the macroinvertebrate community of the Rio Cobre, a major river in Jamaica**. Biota Neotrop. 12(2): http://www.biotaneotropica.org.br/v12n2/en/abstract?article+bn00512022012

Abstract: The paper sets out the results of a one year study on the effects of bauxite waste discharge on the macroinvertebrate fauna of a Jamaican river, the Rio Cobre, based on monthly samples from four sites. Significantly higher levels of temperature and conductivity were found at the sites downstream of the point of effluent discharge. The invertebrate fauna of the two sites immediately downstream of the point of discharge was dominated by two invertebrate taxa: *Baetis* sp. (Fam. Baetidae) and *Smicridea jamaicensis* (Fam. Hydropsychidae).These taxa made up between 26 to 35% of the numbers at these two sites. Upstream of the bauxite waste input the community was dominated by cased caddis larvae of *Helicopsyche ochthephila* (Fam. Helicopsychidae) and *Cubanoptilia tridens* (Fam. Glossostomatidae), which also occurred at the site furthest downstream from the waste input. Scrapers dominated at the upstream site whereas collector gatherers were the predominant functional feeding category at the impacted sites. The constituents of the bauxite waste are discussed and it is proposed that the changes in faunal composition which have resulted from waste input may be a consequence of habitat alteration due to increased deposits of suspended material rather than the chemical nature of the waste.
Keywords: *habitat alteration, metal waste, Caribbean rivers, faunal composition, Trichoptera.*

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Resumo: O livro apresenta os resultados de um estudo de um ano sobre os efeitos das descargas de resíduos de bauxita sobre a fauna de macroinvertebra de um rio jamaicano, o Cobre de Rio, com base em amostras mensais de quatro sites. Significativamente maiores níveis de temperatura e condutividade foram encontrados nos locais a jusante do ponto de descarga de efluente. A fauna de invertebrados dos dois sites imediatamente a jusante do ponto de descarga foi dominada por dois táxons de invertebrados: Baetis SP. (Fam. Baetidae) e Smicridea jamaicensis (Fam. Hydropsychidae). Esses táxons compostas entre 26 a 35% dos números nesses dois locais. A montante da entrada de resíduos de bauxita da Comunidade foi dominada por larvas de caddis preto de Helicopsyche ochthephila (Fam. Helicopsychidae) e Cubanoptilia tridens (Fam. Glossostomatidae), que também ocorreu no local mais a jusante da entrada dos resíduos. Raspadores de dominam o site enquanto coletoras de coletores são a categoria alimentação funcional predominante.
Palavras-chave: *alteração do habitat, resíduos de metal, rios caribenhos, composição da fauna, Trichoptera.*

Introduction

There has been no significant study on the effects of anthropogenic disturbance on the invertebrate fauna of Jamaican rivers. In fact there is very little study of the basic composition and biology of this faunal component in general. Some exceptions to this are studies of the fauna of relatively uncontaminated rivers (Boon et al. 1986) and postgraduate theses (eg Fender 2001). Published information on the effects of bauxite waste on freshwater invertebrates is also sparse. Fonseca and Esteves (1999) found that sites in an Amazonian lake that had been contaminated with bauxite tailings had lower densities of oligochaetes, bivalves, ostracods and chironomid larvae when compared to unimpacted locations in the same lake. Densities of the ephemeropteran *Campsurus* were greater at bauxite waste-impacted sites. Callisto et al. (1998) also found lower densities of chironomids at bauxite waste contaminated sites in a small river in Amazonia, Brazil.

Jamaica is recognized as the third largest producer of bauxite and processed alumina in the world (Library…2011), although since 2009 three of the four major producers have scaled back operations due to a slump in global demand and the sectors' overall contribution to GDP has been declining (US Department…2010).

Extraction of aluminium from bauxite ore is achieved by digestion of the ore with hot caustic soda (Na OH) under pressure. The end product of this process is a slurry of aluminate ions which is separated by filtration from a mixture of basic iron and silicon oxides, commonly known as "red mud". During processing, the mud is washed several times to recover caustic soda and aluminates. The waste has high alkalinity and also high sodium content. Typically, highly elevated values of pH, Na^+ concentration, Al^{3+} concentration and alkalinity have been recorded from the wastewater released into the Rio Cobre, the river being studied here, from the bauxite processing plant located upstream (Parkin 1993).The waste water which is released typically has an elevated temperature greater than 30 °C since it is also used to cool the mud.

The idea that macroinvertebrate community structure reflects contamination levels in a freshwater body is a basic tenet in biomonitoring studies (Cairns & Pratt 1993). Because benthic macroinvertebrates are continuously exposed to conditions they serve to integrate the effects of contaminants over time and provide a measure of water quality. Macroinvertebrates are frequently used as bioindicators of pollution in freshwaters for a number of other reasons, (Cain et al. 1992). These include the fact that they are largely sedentary organisms whose presence or absence is often a good indication of conditions in the area. They are easily collected with the minimum of apparatus and in most cases identification to family level is all that is required (Abel 1996).

Studies which have looked at the effects of mine waste on macroinvertebrates in rivers generally show that the main effect on the community is a reduction of richness and diversity (Maret et al. 2003). Biomass and density of individual species however may be increased (Goto &Wallace 2009). Macroinvertebrates take up metals from the water or sediment or as part of their diet (Wayland & Crossley 2006). Several studies have noted a change in species composition of invertebrates at sites receiving mining effluent. (Sprague et al. 1965, Winner et al. 1980, Lynch et al. 1988) For example, mayflies which typically dominated unimpacted sites of the Arkansas river were largely replaced by Orthocladinae chironomid larvae and trichopterans such as *Hydropsyche* at sites which received contamination from mine waste (Clements 1994).

This study examines the effects of the input of waste from a bauxite processing facility on the composition of the macroinvertebrate fauna of the upper Rio Cobre, a major Jamaican river.

Method

The Rio Cobre is one of the largest rivers in Jamaica, at 30 km in length, with an extensive watershed (1256 km^2), (Andrews et al. 2001). It enters the sea at Hunt's Bay slightly to the west of Kingston Harbour, Jamaica's principal shipping port. The river receives bauxite processing waste in the upper reaches from a nearby bauxite processing plant. Four sampling sites were chosen for study, one (Black River) directly above the point of entry of the waste, located on a side stream to the main river channel, and three at varying distances downstream of effluent input in the main channel (Victoria 2.5 km, Linstead 5.5 km, and Deeside 12 km, downstream of the effluent input). The Black River site was used as the reference for comparison with the downstream sites even although it differed in certain characteristics; principally stream order and extent of bankside vegetation cover. Differences in substrate composition were thought to result from the effects of the bauxite waste. There was no site directly upstream which corresponded more closely to the bauxite waste contaminated locations.

Monthly samples were taken for a period of 13 months at all four sites between May 1999 and June 2000. The sampling technique used to estimate species composition and abundance was a combination of 2 minute kick samples using a standard bottom kick net of 500 µm mesh size and quadrat samples of 0.09 m^{-2} area and 900 µm mesh. All sampling was conducted in riffles and a total of 4 samples were collected on each sampling occasion. All invertebrates collected were preserved in 10% formalin solution for subsequent identification and enumeration in the laboratory. For purposes of analysis of taxonomic composition monthly samples were pooled as there was little seasonal variation in faunal composition at a particular site. Monthly results were used in calculation of two indices, which use different models as the basis for estimating diversity, as follows:

Simpson's Index (D) (Equation 1):

$$D = 1 - \frac{\sum n_i(n_i - 1)}{N(N-1)} \tag{1}$$

Shannon Weaver Index (H) (Equation 2):

$$H = -\Sigma \frac{n_i}{N} \ln \frac{n_i}{N} \tag{2}$$

where: N = the number of individuals in a sample from the community; n_i = the number of individuals in a species *i* of a sample from a community

Similarity indices were also used to compare macroinvertebrate composition between sites on a monthly basis (Sørensen 1957) (Equation 3):

Percentage Similarity = 2Z/(X+Y) × 100

where: X = number of taxa in community a; Y = number of taxa in community b; Z = number of taxa common to communities a and b.

Physico-chemical data were collected on each sampling occasion as follows: dissolved oxygen and water temperature using a YSI™ (Yellow Springs Instruments) 55 meter and conductivity and pH using a YSI 60 meter.

All statistical testing of data was carried out using Statistica® version 6.0, 1998. Physico-chemical data from different sites were pooled for all months of collection as no significant temporal variation in parameter values was found. Data were compared using one-way analysis of variance in conjunction with *post hoc* analysis using the Tukey test. Stepwise regression analyses were also performed to analyse the relationships between the physico-chemical parameters (dissolved oxygen, pH, temperature, and conductivity), and a) invertebrate taxonomic richness; b) invertebrate abundance/percentage frequency; and c) Simpson's diversity indices at each site.

Chi-square tests were carried out using a 2 × 2 contingency table developed in Microsoft Excel to analyze whether observed differences in the proportions of the functional feeding groups (scrapers and collectors) between Black River and the other three sites were statistically significant.

Results

Table 1 shows the mean values of the recorded physico-chemical parameters based on monthly samples. It is apparent that, while pH does not vary significantly among the four sites, the Black River site, upstream of the effluent input, has significantly lower values of temperature ($p < 0.05$), and conductivity is about 50% that of the other three sites ($p < 0.05$). Similarly dissolved oxygen levels are significantly lower ($p < 0.05$) at the Victoria site immediately downstream of the point of effluent input (All tested by one-way Analysis of Variance). Regression analyses revealed a slight positive relationship between diversity and pH ($R^2 = 0.23$ at $p = 0.032$). However, no other statistically significant associations were found between physicochemical parameters (pH, dissolved oxygen, temperature and conductivity) and biological descriptors (diversity, taxonomic richness or abundance) at the 95% probability level.

As depicted in Figure 1, overall, the macroinvertebrate assemblage at Black River was different from that found at Victoria, Linstead and Deeside. Also the proportions of the component taxa of the invertebrate fauna at the Victoria and Linstead sites were different from Black River (Table 2). *Baetis* sp., (family Baetidae) and *Smicridea jamaicensis*, (family Hydropsychidae) predominated at the impacted sites.

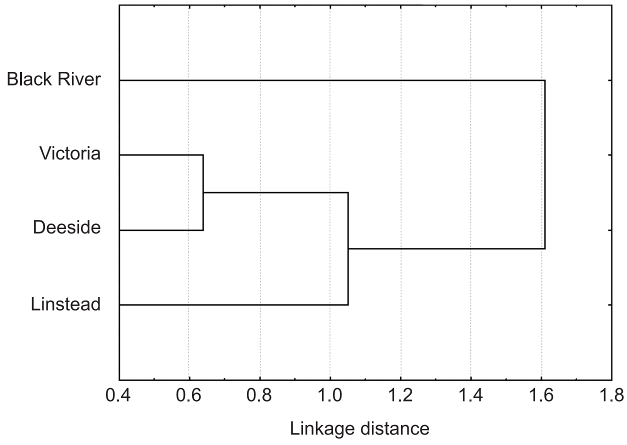


Figure 1. Tree diagram showing clustering of sites to highlight similarities in macroinvertebrate taxonomic compositions (using single linkage; Euclidean distances) across four sites on the upper Rio Cobre, Jamaica.

There was a low representation of cased Trichoptera, particularly *Helicopsyche ochthephilia* (Fam. Helicopsychidae) at these sites, and an absence of *Haegulus jamaicensis* (Fam. Leptophlebiidae), at Victoria. Among the gastropod molluscs there was replacement of *Thiara granifera* by *Melanoides tuberculata* (both Fam. Thiaridae) at the Victoria and Linstead sites and a decline in the importance of *Spilochamys* sp. (Fam. Hydrobiidae) relative to *Physella jamaicensis* (Fam. Physidae), which became increasingly abundant at the impacted sites. These trends are reversed at Deeside, 12 km below the waste input point, possibly indicating a return to a less disturbed community.

The mean monthly values for the Shannon Weaver and Simpsons diversity indices showed the highest values for Deeside whereas taxonomic richness was slightly higher at the Victoria and Linstead sites. Table 3 summarises the mean monthly similarity coefficients showing increasing similarity to the fauna of Black River with increasing distance downstream from the point of effluent input but also the greatest level of similarity between the Victoria and Linstead sites.

Functional feeding groups of invertebrates as defined by Cummins (1995) are considered important in many models of stream ecosystems. Although published information is largely lacking for neotropical species, we assigned the various taxa collected to FFG's using existing information (Merrit & Cummins 1996, Tomanova et al. 2006) and our own conclusions based upon microscopic examination of the structure of the mouthparts. The prevalence of the groups at the four sites is shown in Figure 2. Notable is the inverse relationship between scrapers and collectors at the first three sites with predominance of the former at Black River and of the latter category, particularly at the Victoria and Linstead sites. When compared with Black River, the proportion of invertebrates belonging to the collector and scraper functional feeding groups were significantly different at Victoria ($\chi^2 = 5.86 \times 10^{-18}$, $p < 0.05$, df = 1), Linstead ($\chi^2 = 1.83 \times 10^{-19}$, $p < 0.05$, df = 1), and Deeside ($\chi^2 = 3.98 \times 10^{-09}$, $p < 0.05$, df = 1).

Discussion

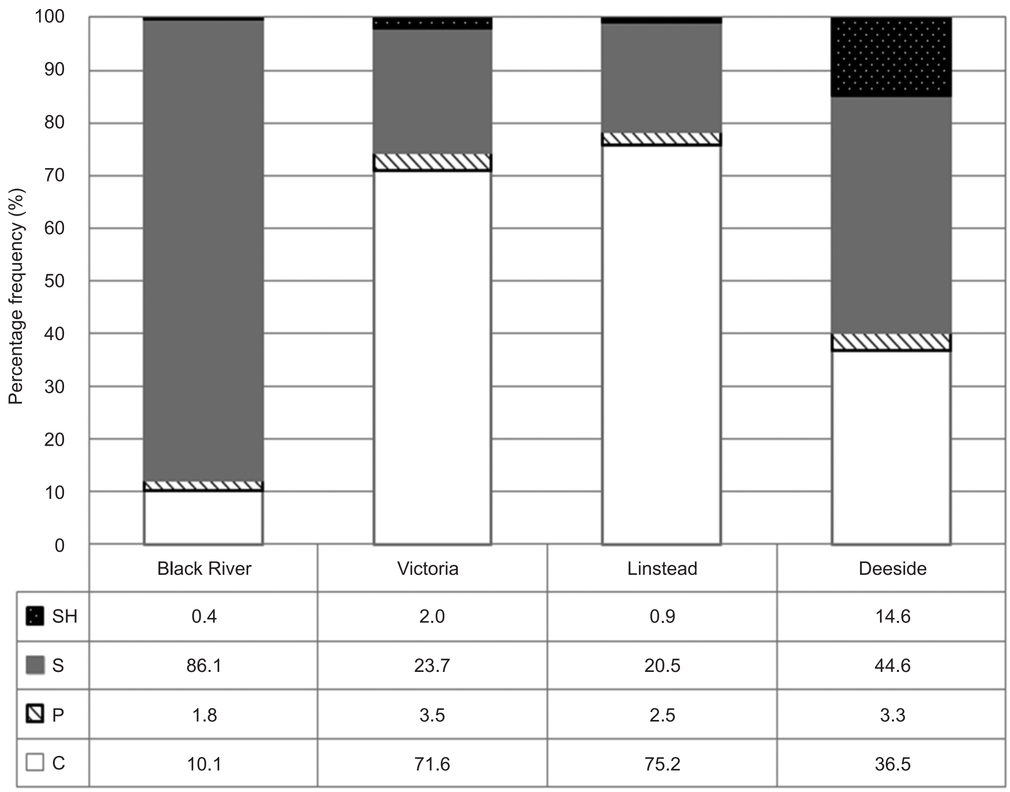
Based on physico-chemical criteria the main effects at the bauxite waste-impacted sites are significant increases in temperature and conductivity. In the former case the differences need to be interpreted with caution as the amount of bankside vegetation cover at Black River is greater and this would help maintain a lower water

Table 1. Mean values of physico-chemical parameters recorded at four sites on the upper Rio Cobre over a 13 month period. Range of recorded values is shown in parentheses (n = 12).

Parameter/Site	Black River	Victoria	Linstead	Deeside
Water Temperature °C	24.5	26.5	27.5	27
Dissolved Oxygen mgL^{-1}	(20.5-25.5)	(22.5-26.3)	(23.1-27.2)	(22.1-27.8)
	8.75	6.8	7.5	7.83
	(6.80-9.23)	(4.5-7.90)	(5.1-8.25)	(6.25-8.44)
pH	8.5	8	7.9	8
	(8.2-8.5)	(7.8-8.4)	(7.8-8.4)	(7.8-8.3)
Conductivity $\mu S.cm^{-1}$	278	434	468	432
	(210-298)	(380-796)	(342-670)	(310-543)
Distance downstream of effluent input (km)	0	2.5	5.5	12

Table 2. Percentage frequency of occurrence of various macroinvertebrate taxa collected from four sites on the upper Rio Cobre, Jamaica. Values are expressed as a percentage of the total number of organisms collected at that site over the sampling period. Also shown is the total number of invertebrates collected at each site (N), the taxonomic richness (TR), and mean values for two diversity indices. + = <0.1%. Last column shows the Functional Feeding Group (FFG) ascribed to each taxon. Key: C = collector P = predator, S = scraper, SH = shredder.

Taxon/Site			Black River	Victoria	Linstead	Deeside	FFG
Turbellaria	Dugesidae	*Girardia* sp.	1.2	2.3	1.5	2.1	P
Oligochaeta	Naididae	*Dero* sp.		1.7	1.6		C
Hirudinea	Glossiphonidae	*Helobdella* sp	0.5	0.5	0.7		C
Ephemeroptera	Baetidae	*Baetis* sp.	0.5	28.2	30.0	9.8	C
Ephemeroptera	Caenidae	*Caenis* sp.		0.1	0.1		C
Ephemeroptera	Leptophlebiidae	*Hagenulus jamaicensis* (Peters 1971)	3.2		0.1	0.1	C
Odonata	Coenagrionidae	*Enallagma coecum*		0.2	0.1		P
Odonata	Libellulidae	*Scapanea frontalis* (Burmeister 1839)	0.2	0.1	0.2	0.1	P
Odonata	Aeshnidae	*Anax junius* (Drury 1773)		0.1			P
Trichoptera	Hydropsychidae	*Smicridea jamaicensis* (Flint 1968)	0.4	25.6	37.1	14.5	C
Trichoptera	Helicopsychidae	*Helicopsyche ochthephila* (Flint 1969)	51.8	0.1	0.1	6.1	S
Trichoptera	Glossosomatidae	*Cubanoptila tridens* (Botosaneanu 1998)	22.6	0.2	5.3	11.9	S
Trichoptera	Hydroptilidae	*Oxytheria* sp.	0.1	0.8	0.2	0.1	S
Trichoptera	Hydroptilidae	*Ochrotrichia* sp.	1.5	1.1	2.3	0.6	S
Trichoptera	Hydroptilidae	*Alisotrichia* sp.				0.8	S
Trichoptera	Calaomoceratidae	*Phylloicus farri* (Flint 1968)	0.3	0.1		1.6	SH
Lepidoptera	Pyralidae	*Paraponyx* sp.	0.1	1.8	0.9	12.9	SH
Lepidoptera	Pyralidae	*Nymphula* sp.				0.1	SH
Coleoptera	Gyrinidae	*Dineutis longimanus* (Olivier 1792)	0.1	0.2	0.1		P
Coleoptera	Elminthidae	*Elmis filiformis (*Darlington 1927)	0.2	0.6	1.8	0.7	C
Coleoptera	Haliplidae				0.1		S
Coleoptera	Hydrophilidae	*Tropisternus lateralis* (Fabricius 1775)		0.1	0.1		P
Coleoptera	Dytiscidae	*Bidessonotus* sp.			0.1		P
Hemiptera	Veliidae	*Rhagovelia tayloriella* (Kirkaldy 1900)				0.1	P
Diptera	Chironomidae	*Tanytarsus* sp.	2.9	3.4	1.9	8.9	C
Diptera	Ceratopogonidae	*Bezzia* sp.	0.1	0.3	0.2	0.1	P
Diptera	Empdidae	*Clinocera* sp.	0.1	0.1	0.1	0.1	P
Diptera	Simuliidae	*Prosimulium* sp.				0.6	P
Diptera	Dolichiopodidae	*Dolichopus* sp.			0.1		P
Diptera	Hyalellidae	*Hyalella* sp.		0.1			SH
Hydracarina			0.1	0.1		0.2	P
Gastropoda	Ancylidae	*Ferrissia hendersoni* (Walker 1925)	0.1	3.8	2.2	2.9	S
	Hydrobiidae	*Spilochamys* sp.	4.0	0.4	0.5	1.6	S
	Thiaridae	*Thiara granifera* (Lamarck 1882)	5.8	1.8	2.4	15.5	S
	Thiaridae	*Melanoides tuberculata* (Muller 1774)	0.1	3.3	3.6	0.1	S
	Physidae	*Physella jamaicensis* Adams 1851	0.1	12.2	3.8	5.0	S
Bivalvia	Sphaeridae		0.2			1.4	C
Ostracoda			2.2	11.5	1.9	1.1	C
N			7331	18,577	23,819	4354	
TR			25	29	29	26	
Shannon Weaver			0.56	0.79	0.71	0.87	
Simpsons			0.58	0.73	0.67	0.79	



	Black River	Victoria	Linstead	Deeside
■ SH	0.4	2.0	0.9	14.6
■ S	86.1	23.7	20.5	44.6
▨ P	1.8	3.5	2.5	3.3
☐ C	10.1	71.6	75.2	36.5

Figure 2. Comparison of the percentage frequency of total macroinvertebrates in the four main Functional Feeding Groups at four sites on the upper Rio Cobre, Jamaica. Key: C = collector P = predator, S = scraper, SH = shredder.

Table 3. Mean monthly percentage similarity in taxonomic composition of macroinvertebrate samples from four sites on the upper Rio Cobre.

	Black river	Victoria	Linstead
Victoria	45		
Linstead	52	83	
Deeside	90	64	72

temperature. The Black River site is on a first order stream, whereas the others are on the main river which is of a higher stream order, therefore the proportion of water exposed to sunlight will be less than at the other sites. However as the temperature of the bauxite effluent frequently exceeds 30 °C (Andrews et al. 2001), the effects of this may still be apparent at the downstream sites.

Higher conductivity at the downstream sites is consistent with the elevated sodium and aluminium levels noted in the effluent (Parkin 1993) and with conductivity values recorded at the point of effluent input in this study (mean 659 μS.cm^{-1}, standard error 105 μS. cm^{-1}, range 369 to 1476 μS.cm^{-1}, n = 12), suggesting that there is a detectable downstream impact from effluent input.

Aluminium is rarely found in an active form in freshwaters. Aluminium ions are generally considered to be toxic to aquatic life but are known to form organic and inorganic complexes (Abel 1996). Much of the aluminium is released from these complexes in acidified conditions and the relationship between acidification of freshwaters and toxicity of the element to fishes at pH < 5.0 is well established. Less is known about the effects at natural pH in the alkaline range. Three "types" of aluminium species have been recognised as having biological significance (Driscoll 1984). Of these, the inorganic monomeric labile fraction is toxic to fish. (Driscoll et al. 1980) At pH's > 7.5, this exists mainly as aluminium hydroxide (Smith 1971). Solubility of aluminium and toxicity to organisms is generally considered to increase once pH exceeds 7.0 (Abel 1996). It is therefore likely that aluminium species with toxic effects on biological material would occur at the waste impacted sites in this study, although Greenway and Parkin (1993) demonstrated that increases in aluminium content in the Rio Cobre sediment did not persist far downstream below the point of effluent input.

Bauxite processing waste is a combination of the unwanted components of the bauxite ore once aluminium has been extracted from it (mainly oxides of iron, silicon, titanium, manganese and some aluminium oxide – "red mud") and waste chemicals used in the extraction process (mainly sodium hydroxide). The aluminium oxide forms a colloidal solution and is known to adsorb organic acids such as fulvic and humic acid (Davis 1980). From a biological perspective this suspension causes an increase in turbidity of the receiving river**.** Large volumes of suspended particles (red mud) are eventually deposited as flocs in regions of low turbulence. Episodic release of bauxite processing liquor results in precipitation of calcium carbonate which is deposited downstream as calcite sediment (Andrews et al. 2001). Both events lead to habitat alteration. At Victoria and Linstead sites, flocculent mud deposits are abundant and any disturbance of the substrate causes resuspension of deposited material. Large volumes of in-stream aquatic macrophytes (*Potamogeton fluvitans* and *Elodea canadiensis*, principally) become established on these mud deposits (pers. obs. E. Hyslop). These changes in conditions, flocculent mud deposits, calcite deposition and in-stream vegetation can explain the divergence in faunal composition at impacted sites when compared to Black River (Table 1 and Figure 2). For example, the odonates, *Enallagma coccum* and *Anax junius*, which occur only at Victoria and Linstead, are associated with vegetation.

Physella jamaicensis and ostracods are also largely found in plant beds. Aquatic macrophytes fulfil several important functions which may promote species richness in the invertebrate community as they form a refuge for many species and act as a trap for organic material as well as increasing habitat heterogeneity by disrupting flow patterns (Allen and Castillo 2008).

Sodium hydroxide input would be expected to increase pH, but this was not detected at impacted sites (Table 1). The water of the Rio Cobre has high levels of hardness (range 88-128 ppm $CaCO_3$) (Fender 2001).The high calcium ion concentration provides buffering capacity and any fluctuations in pH and also pH-dependent release of aluminium due to addition of bauxite waste would be minimised. It is likely that the sodium ions contribute to the elevated conductivity at impacted sites as was observed by Andrews et al. (2001).

Comparing the composition of the invertebrate fauna at the four sites, it is evident that the greatest similarity exists between Black river and Deeside, and Victoria and Linstead (Table 3). Taking into account the proportions of the component taxa (Figure 1), then Black river is clearly the outlier in relation to the other three sites. The invertebrate community at Deeside is more diverse when compared to the Victoria and Linstead sites, where there is co-dominance by *S. jamaicensis* and *Baetis*. At Black River however, using either measure of diversity, the lowest mean value for diversity was recorded. Black River is a side stream of lower habitat complexity and stream order than the other three sites which are located on the main river. This factor would undoubtedly have an impact on community composition. Unfortunately, it was not possible to locate an uncontaminated site on the main river channel above the point of entry of the bauxite waste. The dominance of two cased trichopteran larvae species at Black River contributes to the low diversity scores. The co-dominance of these two caddis families has been recognized in other tropical regions (Dudgeon 1999). Larvae of Glossosomatidae require lower water temperatures and well oxygenated conditions (Mackie 2001) which might explain their occurrence at this site. *C. tridens* is categorized as a scraper, as is *H. ochthephilia* and also *Haegulus jamaicensis* (Fam. Leptophlebiidae), (Peters 1971).

The two thiarid snails recorded from the samples are invasive species now widely established in Jamaica and throughout the wider Caribbean region (eg Pointier 2001). *T. granifera* is much more widely distributed in Jamaican freshwaters than *M. tuberculata* (Hyslop 2003). The dominance of the latter species at the Victoria and Linstead sites might be explained by greater tolerance by *M. tuberculata* of metal contamination or suspended material or both (Berry & Kadri 1974, Thompson 1984, Chaniotis et al. 1980).

There is a high level of similarity in FFG proportions between the Victoria and Linstead sites with collectors predominating, whereas the importance of scrapers is much greater at the other 2 sites, to the extent that this group predominates in the Black River invertebrate community. Scrapers are poorly represented at the other three sites (Figure 2) when compared to Black River., perhaps due to flocculent deposits limiting the growth of periphyton.

According to Jacobsen et al. (2008), the genus *Baetis* is in urgent need of taxonomic revision and subdivision. *Baetis* spp. may be regarded as collector/gatherers or scrapers (Meritt and Cummins 1996) and have been classified as a scraper/gatherer in the tropical context (Yule 2009). A similar position was taken by Shepard and Minshall (1984). Tomanova (2006), examining the functional feeding groups of several genera of Baetidae, (although not *Baetis*), in Bolivian streams, placed them in both the collector/gatherer and scraper categories. This ambiguity means that it is difficult to draw rigid conclusions on the abundance of functional feeding groups at the Victoria and Linstead sites. Examination of the mouthparts of the *Baetis* specimens collected did not reveal the existence of hardened structures which have been deemed indicative of the "scraper" category (McShafferty & McCafferty 1986). We therefore chose to classify *Baetis* as a collector/gatherer but some qualification needs to be applied to this categorization. The lack of specialized feeding habits in *Baetis* may contribute to the resilience of this taxon to disturbance and help explain its abundance at the Victoria and Linstead sites. *S. jamaicensis*, is recognized as a collector/filterer which mainly utilizes CPOM (Boon 1988). A ready supply of particulate material would be available at the Victoria and Linstead sites but this would be a poor food source. Lower levels of suspended material on the other hand, would tend to promote the growth of periphyton, a food source for scrapers, hence the abundance of this FFG at Black River. The oxygen requirements of members of the Hydropsychidae are quite low (Mackie 2001) which would help explain the predominance of *S. jamaicensis* at Victoria.

While this study does not provide evidence of a direct impact of bauxite processing waste on the macroinvertebrate community through metallic pollution, and while the results need to be interpreted with caution due to the limitations of a comparison between the impacted sites and a location which is not directly equivalent, it does seem to indicate that suspended material from the waste indirectly influences species composition at sites below the point of input by causing habitat alteration with concomitant changes in invertebrate fauna. Dominance of *S. jamaicensis* and *Baetis* at the most heavily impacted sites and an under-representation of the scraper functional feeding group appear to be the main effects

References

ABEL, P.B. 1996. Water pollution biology. Taylor and Francis, London.

ALLEN, J.D. & CASTILLO, M.M. 2008. Stream ecology: Structure and function of running waters. 2nd ed. Springer, Netherlands.

ANDREWS, J.E., GREENAWAY, A.M., DENNIS, P.F. & BARBES-LESLIE, D.A. 2001. Isotopic effects on inorganic carbon in a tropical river caused by caustic discharges from bauxite processing. Appl. Geochem. 16:197-206. http://dx.doi.org/10.1016/S0883-2927(00)00033-0

BERRY, A.J. & KADRI, A.B.H. 1974. Reproduction in the Malayan freshwater cerithiacean gastropod *Melanoides tuberculata*. J. Zool. 172:369-381. http://dx.doi.org/10.1111/j.1469-7998.1974.tb04113.x

BOON, P.J., JUPP, B.P., & LEE, D.G. 1986. The benthic ecology of rivers in the Blue Mountains (Jamaica) prior to construction of a water regulation scheme. Arch. Hydrobiol 74:315-355

BOON, P.J. 1988. Notes on the distribution and biology of *Smicridea* (Trichoptera: Hydropsychidae) in Jamaica. Arch. Hydrobiol. 111:423-433.

CAIN, D.J., LUOMA, S.N., CARTER, J.L. & FEND, S.V. 1992. Aquatic insects as bioindicators of trace element contamination in cobble-bottom rivers and streams. Can. J. Fish Aquat. Sci. 49:2141-2154 http://dx.doi.org/10.1139/f92-237

CAIRNS, J. & PRATT, J.R. 1993. A history of biological monitoring using benthic macroinvertebrates. In FreshwaterBiomonitoring and benthic Macroinvertebrates (D.M. Rosenberg & V.H. Resh, eds.). Chapman and Hall, New York

CALLISTO, M., ESTEVES, F.A., GONÇALVES, J.F. &. LEAL, J.J.F. 1998. Impact of bauxite tailings on the distribution of benthic macrofauna in a small river ('igarapé') in Central Amazonia, Brazil. J. Kans. Entomol. Soc. 71(4):447-455.

CHANIOTIS, B.N., BUTLER, J.M., FERGUSON, F.F. & JOBIN, W.R. 1980. Thermal tolerance, desiccation and humidity reactions of *Thiara (Tarebia) granifera mauiensis* (Gastropoda: Thiaridae), host of the Asiatic lung fluke disease. Caribb. J. Sci. 16:91-93.

CLEMENTS, W. 1994. Benthic Invertebrate Community Responses to Heavy Metals in the Upper Arkansas River Basin, Colorado. J. N. Am. Benthol. Soc.13:30-44. http://dx.doi.org/10.2307/1467263

CUMMINS, K.W. 1995. Invertebrates. In The rivers handbook (P. Calow & G.E. Petts, eds.). Blackwell, Oxford. p.234-250.

DAVIS, J.A. 1980. Adsorption of natural organic matter from freshwater environments by aluminium oxide. In Contaminants and sediments (R.A. Baker ed.). Ann Arbor. Sci. Publ. Inc. 2:279-303.

DRISCOLL, C.T., BAKER, J.P., BISOGNI, J.J. & SCHOFIELD, C.L. 1980. Effect of aluminium speciation on fish in dilute acidified waters. Nature 284:161-164. http://dx.doi.org/10.1038/284161a0

DRISCOLL, C.T. 1984. A procedure for the fractionation of aqueous aluminium in dilute acidic waters. Int. J. Environ. An. Ch. 16:267-283. http://dx.doi.org/10.1080/03067318408076957

DUDGEON, D. 1999. Tropical Asian streams: zoobenthos, ecology and conservation. Hong Kong University Press, Hong Kong.

FENDER, A. 2001. Evaluation of the benthic macroinvertebrate composition of the Rio Cobre and selected tributaries with special emphasis on the family Thiaridae. Master's thesis, University of the West Indies, Mona, Jamaica.

FONSECA, J.J.L. & ESTEVES, F.A. 1999. Influence of bauxite tailings on the structure of the benthic macroinvertebrate community in an Amazonian Lake (Lago Batata, Pará - Brazil). Rev. Bras. Biol. 59:397-405. http://dx.doi.org/10.1590/S0034-71081999000300004

GOTO, D. & WALLACE, W.G. 2009. Biodiversity loss in benthic macroinfaunal communities and its consequence for organic mercury trophic availability to benthivorous predators in the lower Hudson River estuary, USA. Marine Pollut. Bull. 58:1909-1915 PMid:19857879. http://dx.doi.org/10.1016/j.marpolbul.2009.09.032

GREENAWAY, A.M. & PARKIN, G.N.L. 1993. Water and sediment analyses on samples from the Rio Cobre. Jamaican J. Sci. Technol. 4:1-16

HYSLOP, E.J. 2003. Additions to the freshwater malacofauna of Jamaica. Rev. Biol. Trop. 51:262-263.

JACOBSEN, D., CRESSA, C., MATHOKO, J.M. & DUDGEON, D. 2008. Macroinvertebrates: composition, life histories and production. In Tropical stream ecology (D. Dudgeon, ed.). Elsevier, Amsterdam, p.65-105. http://dx.doi.org/10.1016/B978-012088449-0.50006-6

LIBRARY OF CONGRESS. Industry. http://countrystudies.us/caribbean-islands/30.htm (último acesso em 07/05/2011).

LYNCH, T.R., POPP, C.J. & JACOBI, G.Z. 1988. Aquatic insects as environmental monitors of trace metal contamination: Red River, New Mexico. Water, Air Soil Poll. 42:19-31. http://dx.doi.org/10.1007/BF00282388

McSHAFFERTY, D. & McCAFFERTY, W.P. 1986. Feeding behavior of *Stenonema interpunctatum* (Ephemeroptera:Heptageniidae). J. N. Am. Benthol. Soc. 22:359-370.

MACKIE, G.L. 2001. Applied aquatic ecosystem concepts. Kendall/Hunt, Iowa.

MARET, T.R., CAIN, D.J., MACCOY, D.E &. SHORT, T.M. 2003. Response of benthic invertebrate assemblages to metal exposure and bioaccumulation associated with hard-rock mining in northwestern streams, USA. J. N. Am. Benthol. Soc. 22: 598-620. http://dx.doi.org/10.2307/1468356

MERRIT, R.W. & CUMMINS, K.W. 1996. An Introduction to the Aquatic Insects of North America. Kendall/Hunt, Iowa.

PARKIN, G. 1993. Effect of bauxite/alumina waste on the Rio Cobre and its tributaries. Master's thesis, University of the West Indies, Mona, Jamaica.

PETERS, W.L. 1971. A revision of the Leptophlebiidae of the West Indies (Ephemeroptera). Smith. Contrib. Zool. 62:1-48 http://dx.doi.org/10.5479/si.00810282.62

POINTIER, J.P. 2001. Invading freshwater snails and biological control in Martinique island, French West Indies. Mem. I. Oswaldo Cruz 96:67-74. http://dx.doi.org/10.1590/S0074-02762001000900009

SHEPARD, R.B. & MINSHALL, G.W. 1984. Selection of fine-particulate foods by some stream insects under laboratory conditions. Am. Midl. Nat. 111:23-32. http://dx.doi.org/10.2307/2425538

SØRENSEN, T. 1957. A method of establishing groups of equal amplitude in plant sociology based on similarity of species and its application to analyses of the vegetation on Danish commons. Biol. Skrif. 5:1-34.

SMITH, R.W. 1971. Relations among equilibrium and non-equilibrium aqueous species of aluminium hydroxyl complexes. Adv. Chem. Ser. 106:250-269 http://dx.doi.org/10.1021/ba-1971-0106.ch010

SPRAGUE, J.B., ELSON, P.F. & SAUNDERS, R.L. 1965. Sublethal copper-zinc pollution in a salmon river – a field and laboratory study. Int. J. Air Water Poll. 9:531-543

THOMPSON, F.G. 1984. The freshwater snails of Florida: A manual for identification. University of Florida Press, Gainesville.

TOMANOVA, S., GOITIA, E. & HELESIC, J. 2006. Trophic levels and functional feeding groups of macroinvertebrates in neotropical streams. Hydrobiologia 556:252-264 http://dx.doi.org/10.1007/s10750-005-1255-5

US DEPARTMENT OF STATE. Background note: Jamaica 9th august 2010. www.state.gov/r/pa/ei/bgn/2032.htm (último acesso em 07/05/2011).

WAYLAND, M. & CROSLEY, R. 2006. Selenium and other trace elements in aquatic insects in coal mine-affected stream in the Rocky mountains of Alberta, Canada. Arch. Environ. Contam. Toxicol. 50:511-522 PMid:16446991. http://dx.doi.org/10.1007/s00244-005-0114-8

WINNER, R.W., BOESEL, M.W. & FARRELL, P.M. 1980. Insect community structure as an index of heavy-metal pollution in lotic ecosystems. Can. J. Fish. Aquat. Sci. 37:647-655. http://dx.doi.org/10.1139/f80-081

YULE, C.M. 1996. Trophic relationship and food webs of the benthic invertebrate fauna of two aseasonal tropical streams in Bougainville Island, Papua New Guinea. J. Trop. Ecol. 12:517-534. http://dx.doi.org/10.1017/S0266467400009755

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Principais conclusões do workshop conjunto dos programas FAPESP BIOTA-BIOEN-Mudanças Climáticas: ciência e políticas públicas para uma economia mais verde, no contexto da RIO+20

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JOLY, C.A., BERLINCK, R.G.S., BOLZANI, V.S., HADDAD, C.F.B., OLIVEIRA, M.C., VAN SLUYS, M-A., SOUZA, G.M., VERDADE, L.M. & VICTORIA, R.L. **Main conclusions of the joint FAPESP Programs BIOTA-BIOEN-Climate Change Workshop: Science and Policy for a Greener Economy in the context of RIO+20.** Biota Neotrop. 12(2): http://www.biotaneotropica.org.br/v12n2/en/item?point-of-view+bn00112022012

Abstract: This Point of View summarizes the conclusion of a joint workshop organized by FAPESP's Environmental Research Programs – BIOTA (The Virtual Institute of Biodiversity) – BIOEN (Bioenergy Research) – Climate Change, to discuss the scientific contribution to the RIO+20 UN Conference. Brazilian scientists gathered at FAPESP's headquarters in São Paulo City in the first week of March 2012 raised the following concerns: a) that there are very few opportunities for the scientific community to interact with Conferences like the RIO+20; b) the deficiencies of the ZeroDraft, document produced by UN's Division for Sustainable Development for the RIO+20; c) the fact that the focus of all three research programs - biodiversity, bioenergy and climate change - are not on the agenda of discussions of RIO +20; d) that little emphasis is given to the oceans in the Conference Agenda; e) regarding market mechanisms associated with the transition to a greener economy, the need to emphasize the reduction of perverse subsidies and promotion of economic incentives to activities or processes to mitigate emissions and/or carbon sequestration; f) that in Brazil we need to stimulate and consolidate research focused on Ecosystem Services Assessments and Evaluation. The workshop participants recognized the need to strengthen knowledge about international conventions, treaties and agreements signed and ratified by Brazil, as well as international institutions, programs and initiatives to promote the participation of the scientific community in global environmental policies debate. Finally, from the viewpoint of the three FAPESP programs two points were highlighted: a) that it is imperative to deepen the scientific knowledge in each of the three focal areas - biodiversity, bioenergy and climate change - because it is necessary to increase the critical mass of researchers and knowledge to reach the global forum in these strategic areas; b) it is also imperative to support and promote research projects that integrate the focal areas of the three programs, bringing together inter and transdisciplinary teams. This is a worldwide trend in the area of global environmental change, and participants of the three programs feel they can make a significant contribution to the advancement of knowledge, to the international debate and for the effective solution of problems.

Keywords: *RIO+20, sustainability, green economy, environmental research, global change.*

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Resumo: Este Ponto de Vista resume as conclusões de um Workshop conjunto, organizado pelos três Programas da FAPESP na Área Ambiental – BIOTA (O Instituto Virtual da Biodiversidade) – BIOEN (Pesquisa em

Bioenergia) – Mudanças Climáticas, para discutir a contribuição da comunidade científica para a RIO+20, a Conferência das Nações Unidas para o Desenvolvimento Sustentável. O grupo de pesquisadores brasileiros reunidos pela FAPESP no início de março de 2012 levantou as seguintes preocupações: a) o número reduzido de oportunidades para a comunidade científica interagir com Conferências como a RIO+20; b) as graves deficiências do ZeroDraft, documento produzido pela Divisão das Nações Unidas para o Desenvolvimento Sustentável para a RIO +20; c) o fato do foco de pesquisa dos três Programas de Pesquisa Ambiental da FAPESP – biodiversidade, bioenergia e mudanças climáticas – não estarem na pauta das discussões da RIO+20; d) que pouca ênfase é dada aos oceanos na Agenda da Conferência; e) em relação aos mecanismos de mercado associados com a transição para uma economia mais verde, a necessidade de enfatizar a redução de subsídios perversos e a promoção de incentivos econômicos para atividades ou processos de mitigação e/ou seqüestro de carbono; f) a necessidade de estimular o desenvolvimento e a consolidação da pesquisa na área de avaliação e valoração de serviços ambientais, no Brasil. Os participantes do Workshop reconheceram a necessidade de aprofundar o conhecimento sobre as convenções, tratados e acordos internacionais assinados e ratificados pelo Brasil, bem como as instituições internacionais, programas e iniciativas que promovem a participação da comunidade científica no debate de políticas ambientais globais. Finalmente, do ponto de vista dos três programas da FAPESP dois pontos foram destacados: a) que é imperativo aprofundar o conhecimento científico em cada uma das três áreas focais - biodiversidade, bioenergia e mudanças climáticas - porque é necessário aumentar a massa crítica de pesquisadores e do conhecimento para participar das discussões internacionais nessas áreas estratégicas; b) também é imperativo apoiar e promover projetos de pesquisa que integrem as áreas focais dos três programas, estimulando a constituição de equipes inter e transdisciplinares. Esta é uma tendência mundial na área das mudanças ambientais globais, e os participantes dos três programas sentem que podem dar uma contribuição significativa para o avanço do conhecimento, para o debate internacional e para a efetiva solução dos problemas.

Palavras-Chave: *RIO+20, sustentabilidade, economia verde, pesquisa ambiental, mudanças ambientais globais.*

Introdução

Em 2012, o Brasil hospeda a Conferência das Nações Unidas em Desenvolvimento Sustentável (UNCSD), ou RIO+20, a ser realizada de 20 a 22 de junho no Rio de Janeiro. A Secretaria-Executiva da Comissão Nacional para a Conferência das Nações Unidas sobre Desenvolvimento Sustentável é constituída pelos Ministérios das Relações Exteriores, da Fazenda, do Desenvolvimento Social e Combate à Fome, e Ministério do Meio Ambiente. A Comissão Nacional da RIO+20 propriamente dita, tem uma composição mais abrangente, envolvendo 20 ministérios, entre os quais o de Ciência, Tecnologia e Inovação, além de instituições relevantes da comunidade científica, como a ABC, SBPC e representantes da sociedade civil e empresarial (vide Decreto Nº 7.495, de 7 de junho de 2011).

A resolução das Nações Unidas estabelece que o objetivo da conferência é a **"renovação do compromisso político com o desenvolvimento sustentável, por meio da avaliação do progresso na implementação dos resultados das Cúpulas anteriores sobre Desenvolvimento Sustentável (Rio, 1992; Johanesburgo, 2002) e do tratamento de temas novos e emergentes".** Além disso, a Rio+20 tratará dos seguintes dois temas: **"economia verde no contexto do desenvolvimento sustentável e da erradicação da pobreza"** e **"estrutura institucional do desenvolvimento sustentável".**

Como parte do processo preparatório, o Brasil, assim como todos os demais países membros das Nações Unidas, encaminhou à ONU em 01/11/2011 sua contribuição para o documento síntese a ser discutido na conferência de junho. Em janeiro de 2012 a ONU publicou a primeira versão do documento síntese (denominado ZeroDraft), reunindo as contribuições de todos os países e organizações por ela reconhecidas. Desde então este documento tem balizado a preparação do documento final da RIO+20, que será subscrito pelos chefes de estado presentes no Rio.

A FAPESP, visando contribuir para o processo da RIO+20, e ampliar a possibilidade de pesquisadores brasileiros expressarem suas posições em relação a estes temas, realizou nos dia 07 e 08 de março de 2012 o **BIOTA-BIOEN-Climate Change Joint Workshop: Science and Policy for a Greener Economy in the context of RIO+20.**

Este Ponto de Vista resume as principais conclusões dos participantes deste workshop.

Resultados

1) Os participantes mostraram preocupação com as poucas oportunidades para discussões relativas à temática de desenvolvimento científico, tecnológico e inovador como estratégia para uma transição para uma economia mais verde, no âmbito da RIO+20.

2) Os participantes foram unânimes em apontar deficiências no documento ZeroDraft, produzido pela Divisão para o Desenvolvimento Sustentável da ONU. Os principais problemas apontados foram:

a) não reconhecer que há um limite natural na capacidade suporte do planeta, e que ações para equilibrar a demanda por alimentos, recursos naturais (incluindo água) e energia, até a metade do século XXI, precisam ser tomadas agora;

b) não reconhecer que o equilíbrio do pilar ambiental é condição *sine qua non* para que os outros dois pilares da sustentabilidade, o social e o econômico, possam se desenvolver;

c) a sustentabilidade ambiental é condição *sine qua non* para garantir acesso a condições dignas de vida e desenvolvimento e para erradicação da pobreza, pois a instabilidade ambiental afeta de forma distinta o planeta, prejudicando mais as populações mais pobres;

d) praticamente não há menção a um projeto de educação, peça-chave no processo de transição para uma economia mais verde, que implica em mudanças de hábitos de consumo e estilo de vida; e

e) pouca ênfase é dada ao conhecimento produzido pelo desenvolvimento científico, tecnológico e inovador, estratégico na reformulação da economia atual para uma economia mais verde.

3) Os participantes mostraram preocupação com o fato do foco de pesquisa dos três Programas de Pesquisa Ambiental da FAPESP – biodiversidade, bioenergia e mudanças climáticas – não estarem na pauta das discussões da RIO+20;

4) Identificou-se também, especificamente, o pequeno destaque dado aos oceanos, fonte de recursos essenciais para a sobrevivência de milhões de pessoas, fronteira ainda pouco conhecida em relação à biodiversidade, e reconhecida como de fundamental importância na questão das mudanças ambientais globais;

5) Na avaliação dos mecanismos de mercado associados à transição para uma economia mais verde, foi enfatizada a necessidade de redução de subsídios perversos, por exemplo, a redução da alíquota de impostos sobre automóveis sem uma exigência de contrapartida de eficiência e/ou redução na emissão de gases, bem como da possibilidade de taxação de carbono, por exemplo, a taxa de permissão de emissão de CO_2 recentemente implantada pela União Européia às companhias aéreas. Mas a ênfase maior foi dada ao favorecimento, em alguns casos através de incentivos fiscais, às atividades de mitigação de emissões e/ou sequestro de carbono.

6) Ênfase foi dada também à questão da valoração dos serviços ambientais, reconhecendo-se que esta é uma área na qual o país ainda carece de conhecimento científico. Trata-se, portanto, de uma área de pesquisa que precisa de apoio para expansão e consolidação no Brasil.

7) Avaliação dos resultados do questionário *on-line* "A participação dos pesquisadores dos programas BIOEN, BIOTA e Mudanças Climáticas na RIO+20", evidencia a necessidade dos pesquisadores dos três programas conhecerem mais profundamente convenções, tratados e acordos assinados e ratificados pelo Brasil, bem como instituições, programas e iniciativas internacionais, que promovem a participação da comunidade científica no debate internacional.

8) Finalmente, e do ponto de vista dos três Programas FAPESP, talvez o mais relevante seja destacar dois aspectos quanto à necessidade estratégica das pesquisas na área de mudanças ambientais globais:

a) de um lado é imperativo aprofundarmos o conhecimento científico em cada uma das três áreas focais – biodiversidade, bioenergia e mudanças climáticas – porque é necessário aumentar a massa crítica de pesquisadores e de conhecimento, para uma atuação mais estratégica nestas áreas;

b) por outro, considerando-se as mudanças ambientais globais, é igualmente imperativo o apoio e o incentivo a projetos de pesquisa que integrem as áreas focais dos três Programas, reunindo equipes inter e transdisciplinares. A reunião de pesquisadores, de diversas formações e áreas de atuação, em torno do equacionamento de questões ambientais concretas, é fundamental dada à multiplicidade de atores e de impactos. A necessidade do desenvolvimento de projetos com estas características segue uma tendência mundial na área de mudanças ambientais globais, e os três Programas avaliam que podem dar uma contribuição significativa para o avanço do conhecimento, para o debate internacional e para a efetiva solução de problemas.

Leituras Complementares Recomendadas

HALONEN, T., ZUMA, J., AL NAHAYAN, S.A.Z., AZ-ZUBAIR, H.A., BABACAN, A., BALSILLIE, J.L., BEDRITSKY, A., BRUNDTLAND, G.H., CALMY-REY, M., LILLO, J.C., CARLSSON, G., DIOGO, L.D., SEUNG-SOO, H., HATOYAMA, Y., HEDEGAARD, C., RUIZ, C.N., RAMESH, J., RICE, S.E., RUDD, K., STUART, F., TEIXEIRA, I.M.V. & GUOGUANG, Z. 2012. Resilient People, Resilient Planet: A Future Worth Choosing. The Secretariat for the High-level Panel on Global Sustainability, New York, United Nations. www.un.org/gsp.

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION OF UNESCO - IOC/UNESCO, INTERNATIONAL MARITIME ORGANISATION - IMO, FOOD AND AGRICULTURE ORGANIZATION OF UNITED NATIONS – FAO & UNITED NATIONS DEVELOPMENT PROGRAMME - UNDP. 2011. A Blueprint for Ocean and Coastal Sustainability. IOC/UNESCO, Paris.

INTERNATIONAL COUNCIL FOR SCIENCE - ICSU, DIVERSITAS, INTERNATIONAL GEOSPHERE-BIOSPHERE PROGRAMME - IGBP, INTERNATIONAL HUMAN DIMENSIONS PROGRAMME ON GLOBAL ENVIRONMENTAL CHANGE - IHDP, WORLD CLIMATE RESEARCH PROGRAMME - WCRP & EARTH SYSTEM SCIENCE PARTNERSHIP - ESSP. 2012. The State of the Planet Declaration. In: Planet Under Pressure: New Knowledge Towards Solutions Conference. ICSU, London. http://www.planetunderpressure2012.net/pdf/state_of_planet_declaration.pdf.

PLANET UNDER PRESSURE: New Knowledge Towards Solutions Conference. 2012. Policy Briefs. Elsevier. Titles: Water security; Food security; Biodiversity and ecosystems; Transforming governance and institutions; Interconnected risks and challenges; Energy security; Health; Well-being; Green economy. http://www.planetunderpressure2012.net/policybriefs.asp.

PROGRAMA DAS NAÇÕES UNIDAS PARA O MEIO AMBIENTE - PNUMA, 2011. Caminhos para o Desenvolvimento Sustentável e a Erradicação da Pobreza – Síntese para Tomadores de Decisão. PNUMA. www.unep.org/greeneconomy.

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O gênero *Vaucheria* D.C. (Vaucheriaceae, Xanthophyceae) no Sul do Brasil: aspectos taxonômicos e ecológicos

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TONETTO, A.F., PERES, C.K. & BRANCO, C.C.Z. **The genus *Vaucheria* D.C. (Vaucheriaceae, Xanthophyceae) in southern Brazil: taxonomic and ecological aspects**. Biota Neotrop. 12(2): http://www.biotaneotropica.org.br/v12n2/en/abstract?inventory+bn02012022012

Abstract: (The genus *Vaucheria* D.C. [Vaucheriaceae, Xanthophyceae] in Southern Brazil: taxonomic and ecology aspects). Taxonomic survey and environmental occurrence of the genus *Vaucheria* were investigated in 105 streams from Southern Brazil. Abiotic variables were correlated to species occurrence. Three species were identified according to gametangia characteristics: *V. geminata* (Vauch.) D.C., *V. taylorii* Blum and *V. sessilis* (Vauch.) D.C.; the latter is reported for the first time in Brazil. The results of this survey suggest that *Vaucheria* is influenced by environmental characteristics, occurring mainly, in neutral to slightly acidic pH, low turbidity, slow current velocity and in partly shaded streams. This combination of variables seems to be the most favorable in the *Vaucheria* population establishment in lotic habitats independently of biome.
Keywords: *distribution, taxonomy, Vaucheria, Vaucheriales, Xanthophyceae.*

TONETTO, A.F., PERES, C.K. & BRANCO, C.C.Z. **O gênero *Vaucheria* D.C. (Vaucheriaceae, Xanthophyceae) no Sul do Brasil: aspectos taxonômicos e ecológicos**. Biota Neotrop. 12(2): http://www.biotaneotropica.org.br/v12n2/pt/abstract?inventory+bn02012022012

Resumo: (O gênero *Vaucheria* D.C. [Vaucheriaceae, Xanthophyceae] no Sul do Brasil: aspectos taxonômicos e ecológicos). O levantamento taxonômico e ocorrência ambiental do gênero *Vaucheria* foram investigados em 105 riachos do sul do Brasil. As variáveis abióticas foram correlacionadas com a ocorrência das espécies. Três espécies foram identificadas de acordo com as características do gametângio: *V. geminata* (Vauch.) D.C., *V. taylorii* Blum e *V. sessilis* (Vauch.) D.C., este último sendo relatado pela primeira vez no Brasil. Os resultados deste estudo sugerem que *Vaucheria* é influenciada pelas características ambientais, ocorrendo principalmente em pH neutro a levemente ácido, baixa turbidez, velocidade da correnteza lenta e em riachos parcialmente sombreados. Esta combinação de variáveis parece ser a mais favorável para o estabelecimento da população de *Vaucheria* em ambientes lóticos, independentemente do bioma.
Palavras-chave: *distribuição, taxonomia, Vaucheria, Vaucheriales, Xanthophyceae.*

Introdução

O gênero *Vaucheria* D.C. reúne organismos algais com talo filamentoso simples ou ramificado, jamais divididos em células por septos transversais (Bicudo & Menezes 2006, Lee 2008). O gênero é o mais amplamente distribuído e com maior número de espécies dentre aqueles da ordem Vaucheriales. Neste contexto, representantes do gênero *Vaucheria* são encontrados em diversos ambientes desde nascentes, riachos, rios, lagos, e até mesmo habitats marinhos (Rieth 1980, Entwisle 1988). As aproximadamente 70 espécies reconhecidas para o gênero são diferenciadas pela morfologia dos órgãos reprodutores sexuados (anterídeo e oogônio), um sistema estabelecido por Vaucher (1803). Rieth (1980) e Entwisle (1988), por sua vez, propuseram a subdivisão do gênero em várias seções. Tais propostas, especialmente a de Entwisle (1988), foram corroboradas por Andersen & Bailey (2002) que estudaram a filogenia do grupo através da análise de sequências de DNA (gene *rbc*L e espaçadores *psb*A-*rbc*L e RUBISCO entre *rbc*L e *rbc*S).

No Brasil, diversos trabalhos têm registrado a ocorrência de espécies de *Vaucheria*, porém, grande parte destes registros recentes insere-se no contexto da descrição da diversidade e de aspectos ecológicos da comunidade de macroalgas lóticas (Necchi Junior & Pascoaloto 1993, Branco & Necchi Junior 1996a, b, Necchi Junior et al. 1995, 1997, 2000, Krupek et al. 2008, Peres et al. 2008). Em adição, há outros registros mais antigos. Martius (1833), por exemplo, relatou a ocorrência de *V. terrestris* (Vaucher) D.C. para os estados de São Paulo e Minas Gerais e de *V. dichotoma* (L.) Mart. para o estado de São Paulo. Zeller (1876), por sua vez, registrou *V. sessilis* (Vauch.) DC. in Lam. *et* DC. para o estado do Rio de Janeiro.

O gênero, para ambientes continentais, possui caráter cosmopolita, com registros de ocorrência em praticamente todas as regiões do mundo (Hoppaugh 1930, Christensen 1956, 1969, Blum 1971, 1972, Entwisle 1988, Aboal 1989, Sarma & Rattan 1990, Branco & Necchi Junior 1996a, Necchi Junior et al. 1997, 2000, Schagerl & Kerschbaumer 2008).

No Brasil, existe somente um estudo no estado de São Paulo abordando especificamente aspectos taxonômicos e ecológicos deste grupo (Necchi Junior et al. 2001). Assim, em vista do conhecimento relativamente escasso, o principal objetivo deste estudo foi contribuir sobre os aspectos da taxonomia e da distribuição ecológica das espécies do gênero *Vaucheria* ocorrentes em ambientes lóticos, com base em um amplo programa amostral desenvolvido nos biomas mais representativos da região Sul do Brasil. Em adição, procurou-se investigar a influência das variáveis abióticas típicas de cada bioma sobre a ocorrência e distribuição das espécies deste gênero.

Material e Métodos

As amostragens foram realizadas em 105 segmentos de riachos distribuídos na região Sul do Brasil (Figura 1). A ocorrência de espécies do gênero *Vaucheria* nos ambientes lóticos foi investigada em 10 unidades de conservação nos quatro biomas mais representativos da região Sul do Brasil. (Figura 1, Tabela 1). O estudo foi conduzido no período com menor precipitação pluviométrica (entre abril a novembro) de 2005 a 2008. Os pontos de amostragens foram visitados uma vez aplicando-se a técnica de transeção (Necchi Junior et al. 1995). Espécimes foram fixados em solução de formaldeído 4% (Johansson 1982). Amostras representativas foram incorporadas ao Herbário SJRP ou UPCB (Thiers 2012).

As análises microscópicas, medições e fotografias foram executadas com o auxilio de um microscópio trinocular Leica DM 1000 composto por uma câmera de vídeo Leica DFC 280, acoplada a um microcomputador com software Leica IM-50, específico para análise de imagem. Vinte medições aleatórias, para cada população, foram feitas para cada característica morfométrica utilizada na análise taxonômica (Necchi Junior et al. 2001). A identificação específica baseou-se na observação de estruturas sexuais amplamente descritas na literatura especializada (Christensen 1969, Blum 1972, Rieth 1980, Entwisle 1988, Sarma & Rattan 1990). Na ausência de estruturas reprodutivas, não foi possível proceder a identificação específica e, assim, tais populações foram referidas como coletivas (spp). Para cada táxon identificado foram apresentadas as seguintes informações: descrição, ilustrações, distribuição na região Sul e no Brasil, espécimes examinados, características ambientais (média ± desvio-padrão) e considerações taxonômicas quando necessárias.

As seguintes variáveis ambientais foram medidas em cada ponto de amostragem: profundidade, velocidade da correnteza, temperatura da água, turbidez, condutividade específica, pH, oxigênio dissolvido e nutrientes (nitrogênio total e ortofosfato). Exceto pelos nutrientes, todas as variáveis ambientais foram medidas em campo. A temperatura da água, a turbidez, a condutividade específica, o pH e o oxigênio dissolvido foram medidos diretamente com um controlador de qualidade da água Horiba U-10, equipado com uma sonda constituída por múltiplos eletrodos, utilizando-se uma amostra de água coletada no ponto médio do segmento do riacho. A velocidade da correnteza foi medida utilizando-se um fluxômetro mecânico General Oceanics 2030R e a profundidade foi mensurada com uma régua centimétrica. O nível de radiação incidente nos ambientes estudados foi estimado utilizando-se os procedimentos e as classes de sombreamento (aberto, parcialmente sombreado, sombreado e fortemente sombreado) propostas por DeNicola et al. (1992). Por fim, os nutrientes foram quantificados em laboratório, a partir de uma amostra previamente congelada, utilizando-se um espectrofotômetro Spectroquant Nova 60 e reagentes específicos.

Resultados

Aspectos taxonômicos – Chave artificial de identificação das espécies de *Vaucheria* para os ambientes lóticos da região Sul do Brasil:

1. Gametângios não dispostos em gametóforos, anterídeos contíguos a 1-2 oogônios .... *V. sessilis*

1. Gametângios dispostos em gametóforos com oogônios arranjados lateralmente a um anterídeo

2. Gametóforo portando somente um par de oogônios *V. geminata*

2. Gametóforo portando 3 oogônios .... *V. taylorii*

Vaucheria geminata (Vauch.) DC. in Lam. et DC., Fl. fran., ed. 3, 2: 62, 1805.

Basiônimo: *Ectosperma geminata* Vaucher Hist. Conf. d`eau douce: 29, pl. 2, Figura 5, 1803. Figuras 2-3.

Sifões ramificados, monóicos com gametóforos em grupos bissexuais, portando 2 oogônios, raramente 1, dispostos lateralmente a um anterídeo, formando densos tufos verdes sobre o substrato, 39,6-114,8 μm diâm.; pedúnculo do gametóforo raramente mais longo do que os oogônios e curvado para o lado, terminando em um anterídeo; anterídeos circinados, tubulares, (49,4-)54-91,5 μm compr. × 15,0-36,8(–41,8); oogônios reniformes a ovóides, 60,8-97,8 μm compr. × 56,6-85,9 μm diâm. Oósporos preenchendo o oogônio, 44,6-85,5 μm compr. × 40,7-72,7 μm diâm.

Distribuição no Brasil: São Paulo (Branco & Necchi Junior 1996a, b, Necchi Junior et al. 2001).

Distribuição no Sul do Brasil: pontos de amostragem 34 e 51. BRASIL. PARANÁ: Paranaguá, Parque Nacional Saint-Hilaire/ Lange, rio das Pombas, 25° 39’ 18” S and 48° 35’ 42” W, 03-VII-2005,

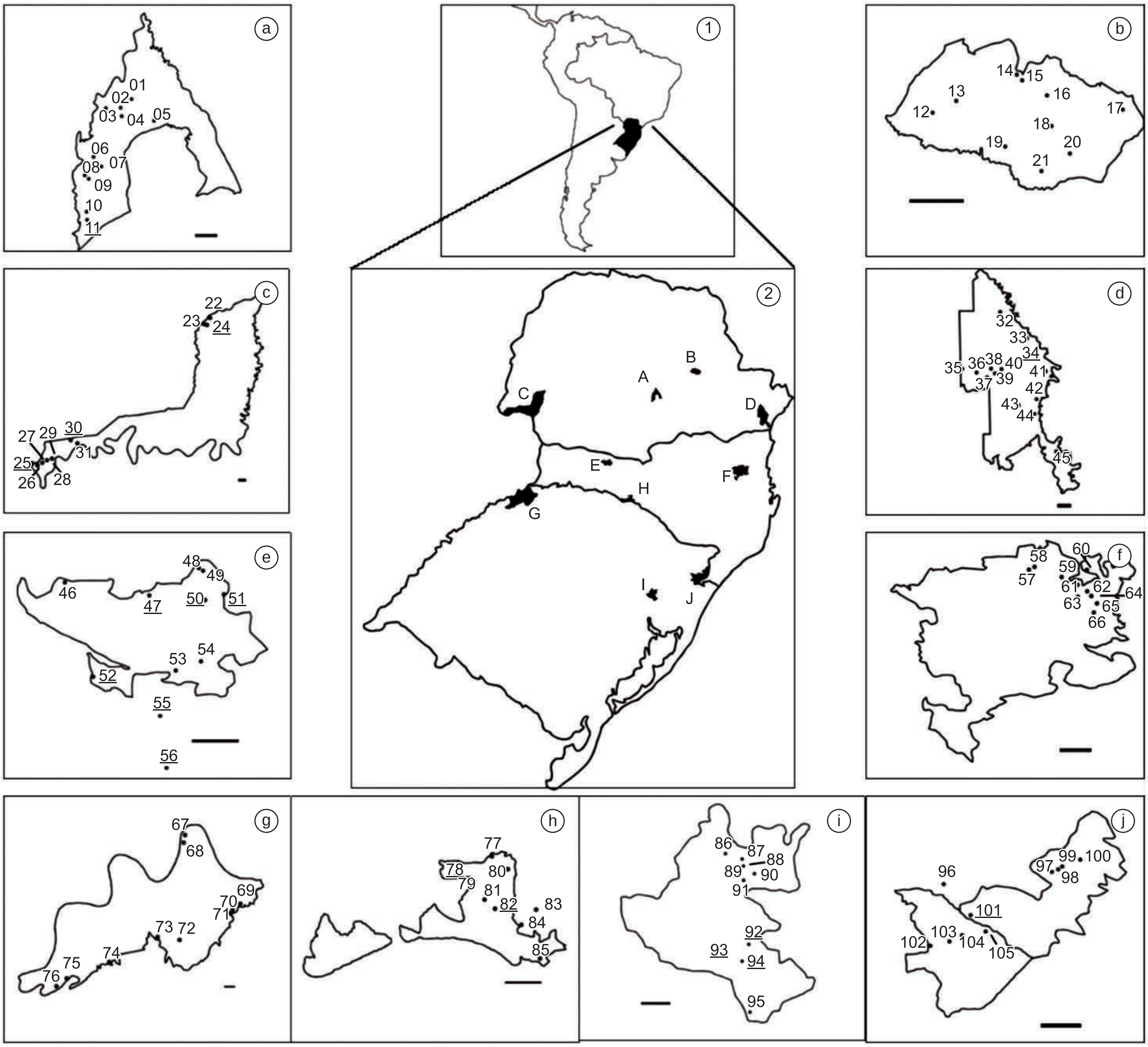

Figura 1. 1.1. Mapa da América do Sul, destacando o Brasil e a região Sul; 1.2 região Sul, destacando os três estados (Paraná, Santa Catarina e Rio Grande do Sul) e a localização das unidades de conservação investigadas; a) Floresta Nacional de Irati; b) Parque Estadual de Vila Velha; c) Parque Nacional do Iguaçú; d) Parque Nacional Saint-Hilaire/Lange; e) Parque Estadual das Araucárias; f) Parque Nacional Serra do Itajaí; g) Parque Florestal Estadual do Turvo; h) Parque Estadual Fritz Plaumann; i) Parque Estadual do Caracol; j) Parque Nacional de Aparados da Serra/ Parque Nacional da Serra Geral. Barras de escalas: 0,5 km – a; 1 km – b, e, g, h e i; 5 km – c, d e j. Pontos com a presença do gênero *Vaucheria* D.C. estão sublinhados.

Figure 1. 1.1. Map of South America, especially Brazil and the Southern region, 1.2 South region, highlighting the three states (Paraná, Santa Catarina and Rio Grande do Sul) and location of conservation areas investigated; a) National Forest of Irati; b) State Park of Vila Velha, c) National Park of Iguaçu, d) National Park of Saint-Hilaire/Lange; e) State Park of Araucárias; f) National Park of Serra do Itajaí, g) Turvo State Forest Park; h) State Park of Fritz Plaumann; i) State Park of Caracol, j) National Park of Aparados da Serra / Nacional Park of Serra Geral. Scale bars: 0.5 km - a; 1 km - b, e, g, h and i, 5 km - c, d and J. Points with the presence of genus Vaucheria D.C. are underlined.

C.C.Z. Branco et al. *s.n.* (UPCB53125); SANTA CATARINA: São Domingos, Parque Estadual das Araucárias, riacho sem denominação, 26° 27’ 21” S and 52° 33’ 41” W, 14-VIII-2007, C.C.Z. Branco et al. *s.n.* (SJRP29766).

Características ambientais (n = 2): temperatura: 19,6 ± 0,2 °C; condutividade: 38 ± 1 μS.cm^{-1}; velocidade da correnteza: 45 ± 23 cm.s^{-1}; turbidez: 8 ± 8 NTU; pH: 6,6 ± 0,1; oxigênio dissolvido: 5,4 ± 0,4 mg.L^{-1}; profundidade: 14 ± 3 cm; P-PO$_4$: 0,07 ± 0,04 mg.L^{-1}; Ntotal: 1,25 ± 0,21 mg.L^{-1}.

Vaucheria sessilis (Vauch.) DC. in Lam. et DC., Fl. fran., ed. 3, 2: 63, 1805.

Basiônimo: *Ectosperma sessilis* Vauch., Hist. Conf. d`eau douce, 31-32, pl. II, Figura 7, 1803.

Sinônimos: *Vaucheria bursata* (OFM.) C.Ag., fide Entwisle, Phycologia 26: 312, 1987. *Conferva bursata* (OFM.) C.Ag., Nova Acta Acad. Sci. Imp. Petropol. 3: 96, pl. 2: Figura 10, 1788. *Vaucheria ovoidea*

Tabela 1. Biomas investigados na região Sul do Brasil com suas respectivas unidades de conservação e número de riachos amostrados.

Table 1. Biomes investigated in southern Brazil with their conservation units and number of streams.

Bioma	Unidade de conservação	Nº de riachos amostrados	Total de riachos por bioma
FE	Parque Nacional do Iguaçu, PR	10	29
	Parque Estadual Fritz Plaumann, SC	9	
	Parque Florestal Estadual do Turvo, RS	10	
FOM	Floresta Nacional de Irati, PR	11	32
	Parque Estadual das Araucárias, SC	11	
	Parque Estadual do Caracol, RS	10	
FOD	Parque Nacional Saint-Hilaire/Lange, PR	14	24
	Parque Nacional da Serra do Itajaí, SC	10	
CAM	Parque Estadual Vila Velha, PR	10	20
	Parque Nacional Aparados da Serra, RS	10	
	Total	105	105

FOM – Floresta Ombrófila Mista, FOD – Floresta Ombrófila Densa, FES – Floresta Estacional Subtropical e CAM – Campos.

FOM - Ombrophilous Mixed Forest, FOD - Ombrophilous Dense Forest, FES - Subtropical Deciduous Forest and CAM - Grasslands.

Hassal, Brit. Freshw. Alg. 1: 57, 1845. *Vaucheria repens* A.H.Hassal, Ann. Mag. Nat. Hist. 11: 430, 1843. Figuras 4-5.

Sifões ramificados, monóicos com, geralmente, um anterídeo e um oogônio pareados; formando densos tufos verdes sobre o substrato, (37-)57-119,7 *µ*m diâm.; anterídeos circinados, tubulares, 48,0-110,0(-121,4) *µ*m compr. × 20,3-30,4 *µ*m diâm., fixos ao filamento por um pequeno pedicelo, perpendicular ao filamento; oogônios sésseis, ovóides, (46,3-)66,2-113,2(-122,7) *µ*m compr. × 59,8-102,4 *µ*m diâm. Oósporos preenchendo o oogônio, (42,6-)52,6-112,6 *µ*m compr. × (37,6-)49,2-91,2 *µ*m diâm.

Distribuição no Brasil: Rio de Janeiro (Zeller 1876); São Paulo Necchi Junior et al. (2001, como *V. bursata*).

Distribuição no Sul do Brasil: pontos de amostragem 50, 51, 78 e 92. BRASIL. RIO GRANDE DO SUL: Canela, Parque Estadual do Caracol, riacho da estrada do teleférico, 29° 18’ 33” S and 50° 50’ 48” W, 02-VI-2008, C.C.Z. Branco et al. *s.n.* (SJRP29726); SANTA CATARINA: Concórdia, Parque Estadual Fritz Plaumann, riacho sem denominação, 27° 16’ 57” S and 52° 07’ 18” W, 20-VIII-2007, C.C.Z. Branco et al. *s.n.* (SJRP29722); *Idem*: São Domingos, Parque Estadual das Araucárias, riacho afluente do rio Jacutinga, 26° 27’ 24” S and 52° 33’ 57” W, 14-VIII-2007, C.C.Z. Branco et al. *s.n.* (SJRP29765); *Idem*: riacho sem denominação, 26° 27’ 21” S and 52° 33’ 41” W, 14-VIII-2007, C.C.Z. Branco et al. *s.n.* (SJRP29766).

Características ambientais (n = 4): temperatura: 16,1 ± 3,7 °C; condutividade: 32 ± 10 µS.cm^{-1}; velocidade da correnteza: 48 ± 33 cm.s^{-1}; turbidez: 9 ± 4 NTU; pH: 6,7 ± 0,2; oxigênio dissolvido: 5,5 ± 0,9 mg.L^{-1}; profundidade: 12 ± 3 cm; P-PO$_4$: 0,11 ± 0,05 mg.L^{-1}; Ntotal: 0,68 ± 0,61 mg.L^{-1}.

Considerações taxonômicas: *Vaucheria sessilis* já foi registrada no Brasil no trabalho de Necchi Junior et al. (2001). Porém, neste trabalho *V. sessilis* foi citada como *V. bursata*, combinação esta utilizada por Entwisle (1987). A dificuldade em separar essas espécies já foi registrada por Rieth (1963) e Christensen (1969). Porém, Rieth (1980) observou que o nome *V. bursata*, apesar de mais antigo, era inválido por ser inicialmente dado a um musgo, considerando, assim, este como sinônimo de *V. sessilis*. Esta mesma interpretação nomenclatural foi utilizada por Johnson & Merrit (2002) na revisão do grupo nas Ilhas Britânicas, sendo então também adotada no presente estudo.

Vaucheria taylorii Blum, Bull. Torrey Bot. Club 98: 191, Figuras 5-12, 1971. Figuras 6-7.

Sifões ramificados, monóicos, gametóforos em grupos bissexuais, portando comumente 3 oogônios e um anterídeo; formando densos tufos verdes sobre o substrato, (42,9-)64,2-87,3(–115,3) *µ*m diâm. anterídeos curvados, tubulares com 21,1-35,3 *µ*m de diâmetro por 58,0-91,9(–115) *µ*m de comprimento, ultrapassando evidentemente os oogônios; oogônios ovóides a oblongo-ovóides, (40,3-)73,7-86,0 *µ*m compr. × (34,2-)61,0-75,7 *µ*m diâm. presos ao gametóforo por pequenos pedúnculos dispostos ao redor do anterídeo. Oósporos preenchendo o oogônio, (43,1-)59,9-75,0 *µ*m compr. × (27,9-)50,8-65,5 *µ*m diâm.

Distribuição no Brasil: primeira ocorrência para território brasileiro.

Distribuição no Sul do Brasil: ponto de amostragem 82. BRASIL. SANTA CATARINA: Concórdia, Parque Estadual Fritz Plaumann, riacho sem denominação, 27° 17’ 28” S and 52° 06’ 37” W, 19-VIII-2007, C.C.Z. Branco et al. *s.n.* (SJRP29716).

Características ambientais (n = 1): temperatura: 16,1 °C; condutividade: 33 µS.cm^{-1}; velocidade da correnteza: 25 cm.s^{-1}; turbidez: 2 NTU; pH: 6,7; oxigênio dissolvido: 5,7 mg.L^{-1}; profundidade: 12 cm; PO$_4$: 0,1 mg.L^{-1}; Ntotal: 0,5 mg.L^{-1}.

Considerações taxonômicas: *Vaucheria taylorii* é descrita pela primeira vez para o território brasileiro. Apesar de a espécie ocorrer comumente em ambientes terrestres, Johnson & Merrit (2002) comentaram que esta espécie pode ocorrer, raramente, em ambientes aquáticos, como registrado no presente estudo. A despeito dos poucos registros em ambientes aquáticos, como os caracteres morfológicos concordam perfeitamente com a descrição desta espécie, a identificação foi mantida como *V. taylorii*.

Vaucheria spp.

Sifões ramificados, formando densos tufos verdes sobre o substrato, 39,6-114,8 *µ*m diâm. Anterídeos e oogônios não observados.

Distribuição no Sul do Brasil: pontos de amostragem 11, 24, 25, 30, 47, 52, 55, 56, 93, 94, 95, 101. BRASIL. RIO GRANDE DO SUL: Canela, Parque Estadual do Caracol, riacho próximo ao castelo sem pregos, 29° 16’ 52” S and 50° 50’ 52” W, 03-VI-2008, C.C.Z. Branco et al. *s.n.* (SJRP29728); *Idem*: rio Caracol, 29° 18’ 41” S and 50° 51’ 23” W, 02-VI-2008, C.C.Z. ranco et al. *s.n.* (SJRP29724); *Idem*: rio Tiririca, 29° 18’ 59” S and 50° 51’ 01” W, 02-VI-2008, C.C.Z. Branco et al. *s.n.* (SJRP29725); *Idem*: Cambará do Sul, Parque Nacional da Serra Geral, riacho afluente do Perdizes, 29° 08’ 23” S and 50° 05’ 21” W, 01-VI-08, C.C.Z. Branco et al. *s.n.*

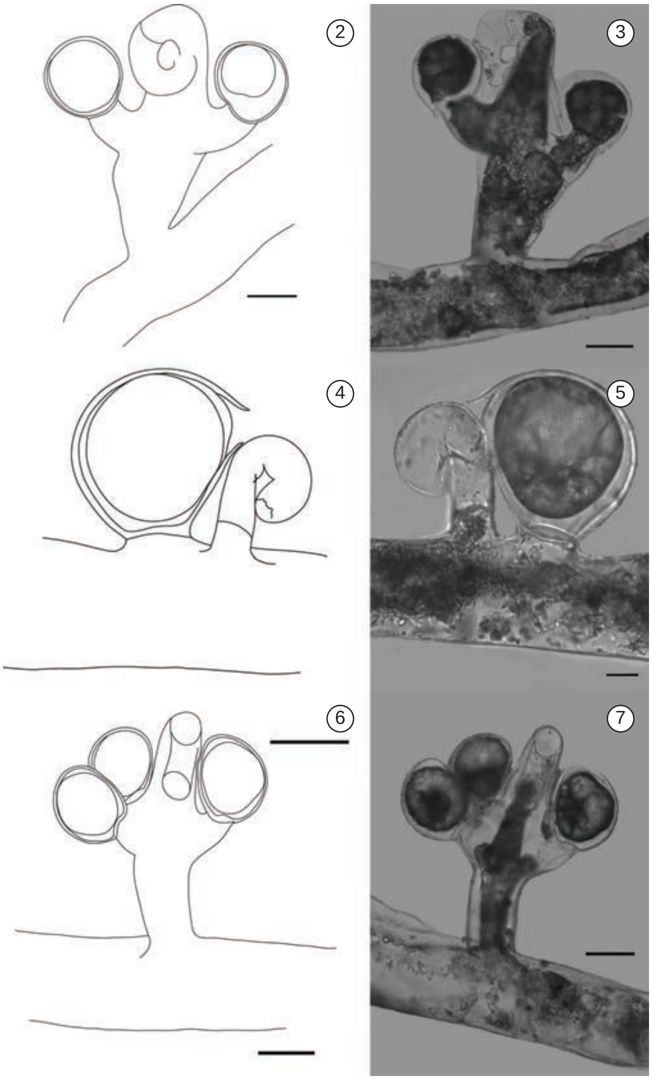

Figura 2-7. Espécies de *Vaucheria* D.C. encontradas em ambientes lóticos no Sul do Brasil, 2-3. *Vaucheria geminata* (Vaucher) DC. in Lam. et DC., 4-5. *V. sessilis* (Vauch.) D.C. in Lam. et D.C., 6-7. *V. taylorii* Blum. (Barras de escala: 20 µm – Figure 5; 50 µm – Figure 2-4; 6-7).

Figure 2-7. Species of *Vaucheria* D.C. found in lotic environments in southern Brazil, 2-3. *Vaucheria geminata* (Vauch.) D.C. in Lam et DC., 4-5. *V. sessilis* (Vauch.) D.C. in Lam et DC., 6-7. *V. taylorii* Blum. (Scale bars: 20 µm - Fig 5; 50 µm - Figure 2-4, 6-7).

(SJRP29789); SANTA CATARINA: São Domingos, Parque Estadual das Araucárias, riacho na divisa, 26° 28’ 20” S and 52° 35’ 26” W, 15-VIII-2007, C.C.Z. Branco et al. *s.n.* (SJRP29769); *Idem*: riacho sem denominação na borda do parque, 26° 28’ 48” S, 52° 34’ 32” W, 15-VIII-2007, C.C.Z. Branco et al. *s.n.* (SJRP29770); *Idem*: riacho sem denominação, 26° 29’ 25” S and 52° 34’ 27” W, 15-VIII-2007, C.C.Z. Branco et al. *s.n.* (SJRP29771); *Idem*: riacho afluente do rio Jacutinga, 26° 27’ 21” S and 52° 34’ 42” W, 15-VIII-2007, C.C.Z. Branco et al. *s.n.* (SJRP29772); PARANÁ: Foz do Iguaçu, Parque Nacional do Iguaçu, rio Apepuzinho, 25° 32’ 01” S and 54° 19’ 36” W, 30-IV-2008, C.C.Z. Branco et al. *s.n.* (SJRP29753); *Idem*: rio São João, 25° 37’ 12” S and 54° 28’ 34” W, 01-V-2008, C.C.Z. Branco et al. *s.n.* (SJRP28759); *Idem*: riacho sem denominação, 25° 09’ 38” S and 53° 49’ 44” W, 02-V-2008, C.C.Z. Branco et al. *s.n.* (SJRP29760); *Idem*: Teixeira Soares, Floresta Nacional de Irati, riacho no talhão 80, 25° 24’ 16” S and 50°35’ 28” W, 19-VII-2005, C.C.Z. Branco et al. *s.n.* (SJRP28239).

Características ambientais (n = 12): temperatura: 14,7 ± 3,6 °C; condutividade: 37 ± 15 µS.cm^{-1}; velocidade da correnteza: 63 ± 25 cm.s^{-1}; turbidez: 18 ± 15 NTU; pH: 6,3 ± 0,4; oxigênio dissolvido: 5,2 ± 0,8 mg.L^{-1}; profundidade: 15 ± 7 cm; P-PO$_4$: 0,10 ± 0,04 mg.L^{-1}; Ntotal: 1,42 ± 1,31 mg.L^{-1}.

Distribuição ambiental – A investigação sobre a distribuição do gênero *Vaucheria* entre os biomas estudados (Tabela 2) revelou ocorrência restrita em apenas aproximadamente 17% dos riachos. As populações ocorreram, em sua maior parte, nos biomas de floresta ombrófila mista (FOM) (61%) e floresta estacional (FES) (31%). Em cada um desses biomas, 42% dos riachos em FOM e 31% dos riachos em FES foram classificados como ambientes parcialmente sombreados, condição em que o gênero foi mais frequente. Biomas tipicamente abertos (Campos, CAM) e sombreados (floresta ombrófila densa, FOD), por sua vez, registraram ocorrência do gênero em apenas um riacho cada.

A maior parte das amostras investigadas (66%) foi representada por populações estéreis. Dentre as populações com espécimes férteis, *Vaucheria sessilis* foi a espécie com distribuição mais ampla, sendo encontrada em quatro pontos de amostragens de dois dos biomas investigados. *V. geminata*, por sua vez, foi encontrada em apenas dois pontos e *V. taylorii* em somente um.

As populações de *Vaucheria* foram, de modo geral, encontradas nas seguintes condições (média ± desvio padrão, n = 18): temperatura 15,6 ± 3,5 °C, condutividade 36 ± 12 μS.cm^{-1}, pH 6,4 ± 0,4, oxigênio dissolvido 5,3 ± 0,7 mg.L^{-1}, turbidez 14 ± 13 NTU, velocidade da correnteza 56 ± 27 cm.s^{-1}, profundidade 14 ± 6 cm, P-PO$_4$ 0,10 ± 0,05 mg.L^{-1} e Ntotal 0,98 ± 1.06 mg.L^{-1}.

O gênero apresentou algumas tendências de ocorrência para alguns parâmetros físicos e/ou químicos (Figura 8). Neste contexto, o grupo registrou maior ocorrência em riachos com valores de pH levemente ácidos a próximo do neutro. Por outro lado, para turbidez a tendência foi contrária à observada para o pH, de modo que o maior número de ocorrências foi registrado em riachos com baixos valores desta variável. Para a velocidade da correnteza, o gênero ocorreu em pontos de amostragem com valores predominantemente baixos. Nenhuma ocorrência foi observada em ambientes classificados como abertos. A maior quantidade de registros de representantes de *Vaucheria* foi anotada em riachos classificados como parcialmente sombreados, diminuindo gradativamente com o aumento do sombreamento.

Discussão

O número de espécies identificadas no presente estudo foi o mesmo que o encontrado para o estado de São Paulo (Necchi Junior et al. 2001), ou seja, apenas três espécies. Entretanto, *V. taylorii* destaca-se como primeiro registro para território brasileiro, sendo um dos raros registros da espécie em ambientes aquáticos (Johnson & Merrit 2002). Assim, destaca-se a grande importância da realização de estudos envolvendo o levantamento taxonômico de macroalgas lóticas, de modo a ampliar o conhecimento sobre diversidade deste grupo de organismos, especificamente do gênero *Vaucheria* de baixa ocorrência. É importante salientar que em ambas as regiões, São Paulo e Sul do Brasil, aproximadamente 60% das amostras foram representadas por populações estéreis, o que sugere que a reprodução sexual possa não ser o principal meio de crescimento populacional neste grupo de algas em ambientes lóticos. Brawley & Johnson (1992), de fato, postularam que a ocorrência de fecundação em ambiente natural é rara, o que é coerente com os resultados do presente

Tabela 2. Lista de ocorrência das espécies por bioma/região do sul brasileiro.

Table 2. List of species occurrence by biome/region of southern Brazil.

Espécies	FOM	FOD	FES	CAM
Vaucheria taylorii Blum 1972	-	-	1	-
Vaucheria geminata (Vaucher) De Candolle in Lamarck et De Candolle 1805	1	1	-	-
Vaucheria sessilis (Vaucher) De Candolle in Lamarck et De Candolle 1805	3	-	1	-
Vaucheria spp. (estéreis)	8	-	3	1
Total	12	1	5	1

C – Campos, FES – Floresta Estacional Subtropical, FOD – Floresta Ombrófila Densa, FOM – Floresta Ombrófila Mista. Os números referem-se ao número de populações (número de pontos de amostragem) registradas em cada bioma.

FOM - Ombrophilous Mixed Forest, FOD - Ombrophilous Dense Forest, FES - Subtropical Deciduous Forest and CAM - Grasslands. The numbers refer to the number of populations (number of sampling points) recorded in each biome.

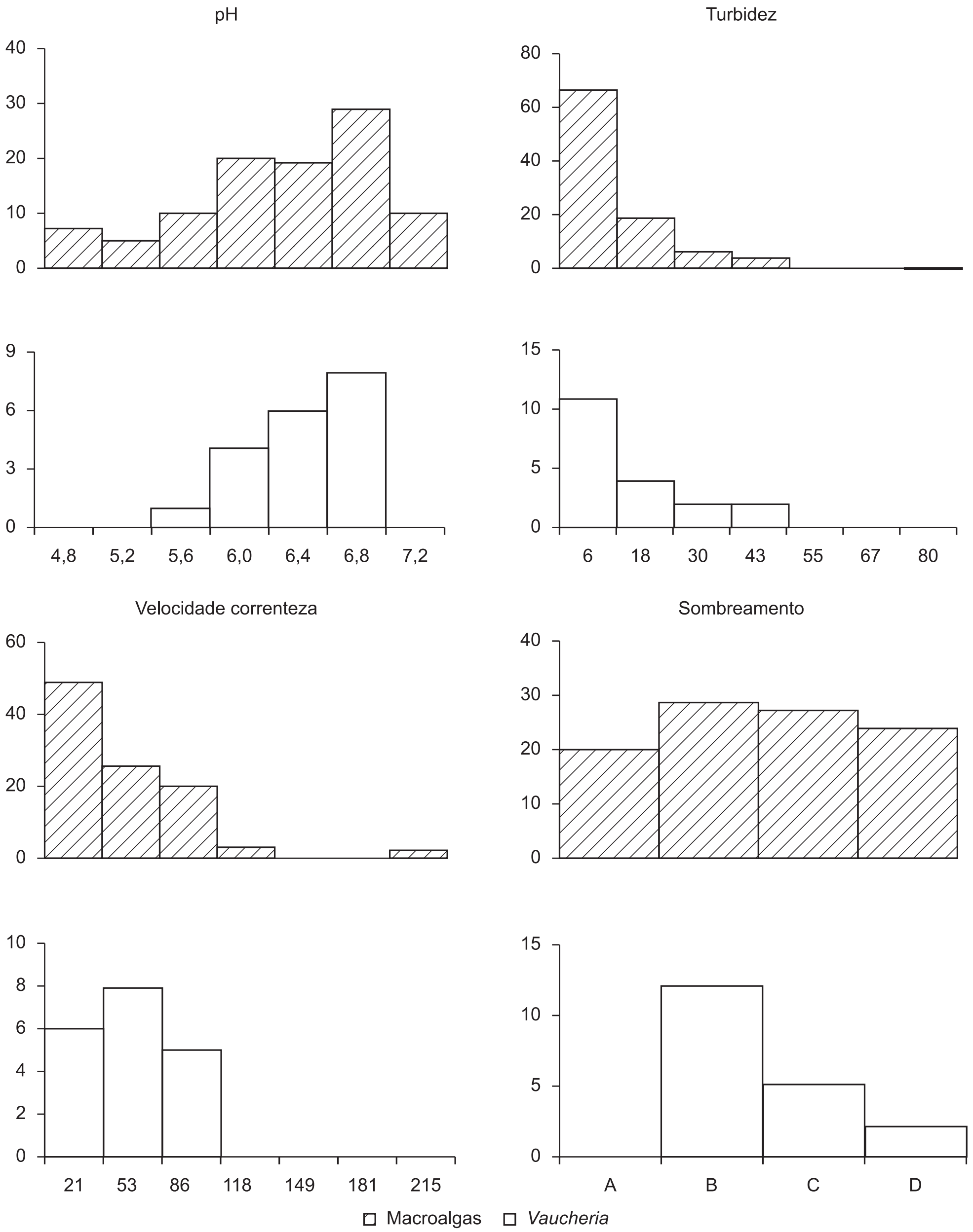

Figura 8. Frequência de distribuição dos riachos amostrados e dos riachos com ocorrência de *Vaucheria* na região Sul do Brasil de acordo com as variáveis ambientais. (sombreamento: a – aberto, b – parcialmente sombreado, c – sombreado e d – fortemente sombreado; Turbidez – NTU; Velocidade da correnteza – cm.s^{-1}). Gráficos pretos – valores referentes a todos os riachos amostrados no Sul do Brasil; Gráficos brancos – valores referentes aos riachos com presença de *Vaucheria* D.C.

Figure 8. Frequency of distribution of the sampled streams and streams where *Vaucheria* D.C. occurred in Southern Brazil, according to environmental variables. (Shading: a - open, b - partially shaded, c - shaded and d - heavily shaded; Turbidity - NTU; Current velocity - cm.s^{-1}). Black Graphics - values for all sampled streams in southern Brazil, white graphics - values for the streams with the presence of *Vaucheria* D.C.

estudo e com registros da literatura (p.ex., Branco & Necchi Junior 1996a, Necchi Junior et al. 2001, Krupek et al. 2008).

A distribuição ambiental das espécies do gênero em relação ao pH revelou maior ocorrência nos riachos com valores de pH próximos do neutro. Assim como os dados de pH, os registros de *Vaucheria* em ambientes lóticos com baixos valores de turbidez e velocidade da correnteza reforçam informações apresentadas em outros estudos prévios (Branco & Necchi Junior 1996a, Necchi Junior et al. 2001, Krupek et al. 2008). Assim, de modo geral, os resultados do presente estudo corroboram dados da literatura e sugerem uma tendência de que espécies de *Vaucheria* ocorrem predominantemente em ambientes lóticos com pH próximo do neutro e baixos valores de velocidade da correnteza e turbidez.

Com relação aos biomas investigados, a maior ocorrência do grupo notificada para os biomas de FOM e FES está, possivelmente, mais relacionada com a condição de sombreamento dos riachos do que com o bioma propriamente dito. O trabalho de Branco & Necchi Junior (1996b), por exemplo, conduzido em uma ampla área de FOD da região oriental do estado de São Paulo, registrou a maioria das populações de *Vaucheria* em riachos classificados como parcialmente sombreados. Necchi Junior et al. (2003, 2008), por outro lado, estudando riachos do bioma de Campos de Altitude da região Sudeste, onde os pontos de amostragem foram predominantemente abertos, não reportaram registros de representantes de *Vaucheria*. Para o presente estudo, a única ocorrência do gênero em riachos do bioma de Campos de Altitude foi em ponto de amostragem com vegetação marginal exuberante e que proporcionava sombreamento. A ocorrência predominante das populações de *Vaucheria* em ambientes com sombreamento moderado, observada no presente estudo e na literatura, esta de acordo com a resposta fotossintética observada por Necchi Junior (2004) quando populações do gênero foram expostas experimentalmente a diferentes níveis de irradiância. Neste trabalho, as populações investigadas foram consideradas intermediárias em termos de adaptação à luz (Necchi Júnior 2004). Assim, a disponibilidade de luz no ambiente parece ser um fator relevante para a ocorrência de representantes de *Vaucheria*, independente do bioma em que se encontram.

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Referências Bibliográficas

ABOAL, M. 1989. Aportacion al conocimiento de lãs algas epicontinentales Del S.E. de España. V-Xantofíceas (Xanthophyceae P. Allorge et Fritsch, 1935). Bol. Soc. Brot. 62:239-248.

ANDERSEN, R.A. & BAILEY, J.C. 2002. Phylogenetic analysis of 32 strains of Vaucheria (Xanthophyceae) using the *rbc*L gene and its two flanking spacer regions. J. Phycol. 38:583-592.

BICUDO, C.E.M. & MENEZES, M. 2006. Gêneros de algas de águas continentais do Brasil chave para identificação e descrição. 2. ed. Rima, São Carlos.

BRANCO, C.C.Z. & NECCHI JUNIOR, O. 1996a. Survey of stream macroalgae of eastern Atlantic Rainforest of São Paulo State, Southeastern Brazil. Algol. Stud. 80:35-57.

BRANCO, C.C.Z. & NECCHI JUNIOR, O. 1996b. Distribution of stream macroalgae of eastern Atlantic Rainforest of São Paulo State, Southeastern Brazil. Hydrobiologia 333:139-150.

BRAWLEY, S.H. & JOHNSON, L.E. 1992. Gametogenesis, Gametes and Zygotes: an Ecological Perspective on Sexual Reproduction in the Algae. Eur. J. Phycol. 27:233-252.

BLUM, J.L. 1971. Notes on American Vaucheriae. Bull. Torrey Bot. Club 98:189-194.

BLUM, J.L. 1972. North American Flora: Vaucheriaceae. The New York Botanical Garden, New York, 51p.

CHRISTENSEN, T. 1956. Studies on the genus *Vaucheria* III. Bot. Not. 109:275-280.

CHRISTENSEN, T. 1969. *Vaucheria* collections from Vaucher`s region. Det Kongelige Danske Videnskabernes Selskab Biologiske Skrifter, v.16, p.25-30.

DENICOLA, D.M., HOGLAND, K.D. & ROEMER, S.C. 1992. Influence of canopy cover on spectral irradiance and periphyton assemblages in a praire stream. J. N. Am. Benthol. Soc. 11:391-404.

ENTWISLE, T.J. 1987. An evaluation of taxonomic characters in the subsection Sessilis, section Corniculatae, of *Vaucheria* (Vaucheriaceae, Chrysophyta). Phycologia 26:297-321.

ENTWISLE, T.J. 1988. A monograph of *Vaucheria* (Vaucheriaceae, Chrysophyta) in south-eastern mainland Australia. Aust. Syst. Bot. 1:1-77.

HOPPAUGH, K. 1930. A taxonomic study of species of the genus Vaucheria collected in California. Am. J. Bot. 17:329-347.

JOHANSSON, C. 1982. Attached algal vegetation in running Waters of Jãmtland, Sweden. Acta Phytogeogr. Suec. 71:1-83.

JOHNSON, L.R. & MERRIT, R. 2002. Phylum Xanthophyta (Yelow Green Algae). In The Freshwater Algal Flora of the British Isles (D.M. John, B.A. Whitton & A.J. Brook, eds.). Cambridge University Press, Cambridge, p.245-270.

KRUPEK, R.A., BRANCO, C.C.Z. & PERES, C.K. 2008. Levantamento florístico das comunidades de macroalgas da bacia do Rio das Pedras, região centro-sul do Estado do Paraná, Sul do Brasil. Hoehnea 35(2):189-208.

LEE, R.E. 2008. Phycology. 4th ed. Cambridge University Press, New York.

MARTIUS, C.F.P. 1833. Algae. In Flora brasiliensis (C.F.P. Martius & F. Escheweiler, eds.). Sumptibus J.G. Cottae, Stuttgartiae, v.1 Algae, Lichens, Hepaticae, p.1-390.

RIETH, A. 1963. Die algen der chinesisch-deustchen biologischen-sammelreise durch Nord-und Nordost China 1956. I. Die Vaucheriaceen. 1 Tril. Limnologica 1(4):287-313.

RIETH, A. 1980. Vaucheriales. In Süsswasserflora Von Mittleeuropa, Xanthophyceae II (H. Ettl, J. Gerloff & H. Heynig, eds.). Gustav Fisher, Stuttgard, p.1-144.

NECCHI JUNIOR, O. 2004. Light-related photosynthetic characteristics of lotic macroalgae. Hydrobiologia 525:139-55.

NECCHI JUNIOR, O., BRANCO, C.C.Z. & BRANCO, L.H.Z. 1995. Distribution of stream macroalgae in the northwest region of São Paulo State, southeastern Brazil. Hydrobiologia 299:219-230.

NECCHI JUNIOR, O., BRANCO, C.C.Z. & BRANCO, L.H.Z. 2000. Distribution of stream macroalgae in São Paulo State, southeastern Brazil. Algol. Stud. 97:43-57.

NECCHI JUNIOR, O., BRANCO, L.H.Z. & BRANCO, C.C.Z. 2003. Ecological distribution of stream macroalgal communities from a drainage basin in the Serra da Canastra National Park, Minas Gerais, southeastern Brazil. Rev. Brasil. Biol. = Braz. J. Biol. 63:635-645.

NECCHI JUNIOR, O., BRANCO, L.H.Z. & SPEZAMIGLIO D.N. 2008. Distribuição ecológica de comunidades de macroalgas de ambientes lóticos do Parque Nacional de Itatiaia (RJ, MG), Brasil. Rev. Bras. Bot. 31:135-145.

NECCHI JUNIOR, O. & PASCOALOTO, D. 1993. Seasonal dynamics of macroalgal communities the Preto River Basin, São Paulo, southeastern Brazil. Arch. Hydrobiol. 129:231-252.

NECCHI JUNIOR, O., PASCOALOTO, D., BRANCO, C.C.Z. & BRANCO, L.H.Z. 1997. Distribution of stream macroalgae in the northwest region of São Paulo State, southeastern Brazil. Algol. Stud. 84:91-112.

NECCHI JUNIOR, O., SPEZAMIGLIO, D.N.; BRANCO, C.C.Z. & BRANCO, L.H.Z. 2001. Estudos taxonômicos e distribuição ecológica do gênero Vaucheria (Xanthophyta, Vaucheriaceae) em ecossistemas lóticos do Estado de São Paulo, Brasil. Hoehnea 28(3):231-242.

PERES, C.K., BRANCO, C.C.Z. & KRUPEK, R.A. 2008. Macroalgas de riachos da Serra da Prata, leste do Paraná, sul do Brasil. Acta Bot. Bras. 22(2):333-344.

SCHAGERL, M. & KERSCHBAUMER, M. 2008. Autoecology and morphology of selected Vaucheria species (Xanthophyceae). Aquat. Ecol. 43(2):295-303.

SARMA, T.A. & RATTAN, R.S. 1990. Genus *Vaucheria* in India. Nova Hedwigia. 51:489-503.

THIERS, B. 2012. Index Herbariorum: A global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium, New York. http://sweetgum.nybg.org/ih/.

VAUCHER, J.P.E. 1803. Histoire des conferves d'eau douce contenant leurs différens modes de reproduction, et la description de leurs principales espèces, suivie de l'histoire des trémelles et des ulves d'eau douce. J. J. Paschoud, Genéve, p.[i]-xv, [1]-285 [2], pls I-XVII plates.

ZELLER, G. 1876. Algae brasilensis circa Rio de Janeiro a Dr. A. Glaziou. In Symbolae ad floram Brasiliae centralis cognoscendam, 22 (E. Warming, ed.). Videnskabelige Meddelelser frra Dansk naturhistrisk Forening I Kjöbenhavn, p.437-438.

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Invasion of the dinoflagellate *Ceratium furcoides* (Levander) Langhans 1925 at tropical reservoir and its relation to environmental variables

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Abstract: Dinoflagellates of the genus *Ceratium* are chiefly marine but there are rare occurrences in freshwater. In this study we analyze the invasion and progressive establishment of *Ceratium furcoides*, an exotic species, in the Furnas Reservoir. Samples were taken at 36 points in the reservoir, during the months of March, June, September and December, 2007. Measurements of some physical and chemical variables were simultaneously performed at each site. The occurrence of *C. furcoides* was registered at 20 sites, with densities varying between 0.57 and 28,564,913.0 ind.m^{-3}. Blooms of this species were recorded in points which were classified as mesotrophic, coinciding with the places receiving high amounts of untreated domestic sewage. *C. furcoides* density was correlated with temperature, nutrients (nitrate and nitrite) and water electric conductivity. The highest density was recorded in June when temperature was low. The presence of *Ceratium furcoides* in the reservoir apparently has not yet affected the reservoir water quality or other plankton communities. However, if it becomes fully established it could perhaps become a problem in the reservoir or even to spread out to other reservoirs in Rio Grande basin.
Keywords: *invasive species, algal blooms, eutrophication, reservoir ecology.*

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Resumo: Dinoflagelados do gênero *Ceratium* são principalmente marinhos, porém existem raras ocorrências em água doce. Neste estudo analisamos a invasão e o estabelecimento progressivo de *Ceratium furcoides*, uma espécie exótica no reservatório da UHE de Furnas. Foram coletadas amostras em 36 locais em todo o reservatório durante os meses de março, junho, setembro e dezembro de 2007. Variáveis físicas e químicas foram aferidas em cada local. *C. furcoides* ocorreu em 20 dos 36 pontos de coleta, em densidades que variaram entre 0.57 e 28.564.913 ind.m^{-3}. A maior densidade da espécie foi registrada na região do rio Marimbondo (G14) classificada como mesotrófica e local onde alto volume de esgoto doméstico sem tratamento é lançado diariamente. A densidade de *C. furcoides* foi correlacionada com os valores de temperatura, nutrientes dissolvidos (nitrato e nitrito) e com a condutividade elétrica. Até o momento do presente estudo, a presença de *Ceratium furcoides* no reservatório aparentemente não afetou as condições ambientais ou outras comunidades, porém, ao se tornar plenamente estabelecida poderá se transformar em um risco ecológico e até mesmo espalhar-se para outras bacias.
Palavras-chave: *espécie invasora, blooms algais, eutrofização, ecologia de reservatórios.*

Introduction

The introduction of exotic species into natural habitats is one of the most serious problems facing communities and endemic species, as it can change irreversibly the ecological functioning of the ecosystems involved (Simberloff 1996). The gravest of these would be the local extinction of native species caused chiefly by strong competition and predation (Baskin 1994). The competitive pressure of introduced species and their consumption of members of native populations can modify the local species composition and the long-term effects depend on the particular response of each community (Delariva & Agostinho 1999).

Freshwater habitats are especially prone to invasion by exotic species, as their dispersion through the natural environment is strongly aided by the flow of water. Aquaculture is nowadays considered one of the main activities by which exotic species have been introduced in many new habitats and countries (Delariva & Agostinho 1999). Moreover, in aquatic environments usually the introduction of species occurs by microscopic organisms, whose invasions are poorly understood, and its impact on the environment is probably underestimated. The invasion and spread of non-native species of many different kinds of organisms is of increasing interest to researchers (Kastovsky et al. 2010).

Species of this genus *Ceratium* have been considered invasive in freshwaters of several countries. According to Mac Donagh et al. (2005), surface blooms created by dinoflagellates of the genus have been seen in tropical reservoirs only recently. For this reason, studies on the temporal and spatial dynamics of the species and how this relates to the conditions in tropical systems are still rare. Blooms of these organisms have been reported in some reservoirs, associated with environmental changes such as decreasing nutrient levels and dissolved oxygen concentration. The changes triggered by *Ceratium* spp. blooms can lead to mass death among fish, as recorded in Thailand and Japan (Taylor et al. 1995), or among invertebrates, as seen in Mexico (Landsberg 2002, Hallengraeff et al. 1995).

Ceratium furcoides was recently recorded for the first time in Brazilian freshwaters at Furnas reservoir in Minas Gerais state by Santos-Wisniewski et al. (2007). After this, a bloom of *Ceratium furcoides* was reported in the eutrophic Billings Reservoir, São Paulo city, by Matsumura-Tundisi et al. (2010) and the authors suggested that this occurrence was related to the intense process of mixing which might have caused a sharp increase in the phosphorus content in the water column and hence favoring the rapid blooming of this algae.

In this study we investigate the hypothesis that the invasion and establishment of *Ceratium furcoides* in the Furnas Reservoir is related to the eutrophication, so that its greatest abundances occur in areas with highest concentrations of nutrients.

The main objective of this study was to determine if *C. furcoides* is already fully established in the reservoir and to analyze if its occurrence is related to other changes in reservoir water quality.

Material and Methods

1. *Study area*

The Furnas reservoir is located in the Rio Grande river basin at the southern part of Minas Gerais State, Brazil. The reservoir extends along parts of the Rio Grande River and several of its tributaries, with a maximum length of 220 km, total perimeter 3,500 km, flooded area 1,440 km^2, total volume 22.95 billion m^3 and a residence time around 160 days. The maximum depth (near the dam) is 90 m and the average depth 13 m (Furnas UHE report 2004). This is the largest reservoir in southeast Brazil and consists of two great arms, River Grande and River Sapucai. The dam lies some kilometers downstream of the confluence of the two arms, between the districts of São José da Barra and São João Batista (Del Aguila 2001).

As the reservoir is constituted by two different drainage basins, it has some quite distinctive features. The River Grande drains soils characteristic of a sand stone plateau of infertile land with extensive cattle-raising. By contrast, the Sapucai River drains the water from soils used for intensive agriculture and pasture, especially intensive cultivation of coffee, potatoes, sugarcane, sweet corn, oranges and soya (Pinto-Coelho & Corgosinho 1998).

Parts of the Furnas reservoir are already undergoing a process of eutrophication, near the districts of Alfenas, Boa Esperança, Carmo do Rio Claro, Fama and Paraguaçu, in which untreated domestic sewage is discharged directly into the water. In the Fama region of the Sapucai compartment, some sites are eutrophic, with excessive growth of cyanobacteria in one of its tributaries, the Machado River (Sá et al. 1996).

2. *Sampling*

Collections were made at three-month intervals, in March, June, September and December, 2007, at 36 sites scattered throughout the Furnas reservoir, including the central body of water and each of the main arms formed in the Grande and Sapucai sub-basins. Up to now this is the first study covering the whole reservoir with such a large number of sampling points. At each site, the plankton was sampled and physical and chemical variables were tested, in both the limnetic and littoral zones (Figure 1).

The temperature (°C) and dissolved oxygen concentration (mg/L) in the water were measured *in situ* up and down the water column, each half meter, by means of a Yellow Springs YSI 30 analog thermistor-oxymeter. The electrical conductivity was measured with a Field conductivity meter (Cole Parmer 19820-10) and the pH with a field pH-meter (Cole Parmer 59002-00). Nutrient concentrations and chlorophyll-*a* concentrations were determined in the surface, middle and bottom layer. The techniques described by Mackereth et al. (1978) (total N, nitrate and nitrite) and Golterman et al. (1978) (total P and ortophosphate) were followed. Reactive silicate was analyzed by the method described in Golterman et al. (1978). The chlorophyll-*a* concentration was estimated by acetone extraction, employing the technique described by Lorenzen (1967). Transparency (m) of the water was determined with a Secchi disk.

Carlson's trophic state index (TSI), modified by Toledo et al. (1983), was calculated from the observed total P, chlorophyll-*a* and Secchi disk results. The trophic state was classified on the following basis: oligotrophic for TSI < 44; mesotrophic for TSI = 44 – 54; eutrophic for TSI > 54.

Vertical hauls in the entire water column using plankton net of 68 μm mesh size were carried out to collect plankton in the entire water column. Samples were fixed in 4% formaldehyde solution and stored in polyethylene flasks. The species were checked for taxonomical identification under high magnification microscope of the Zeiss®.

The *Ceratium furcoides* was identified according to Santos-Wisniewski et al. (2007). It is a member of the family Ceratiaceae and Class Dinophyceae and morphologically close to the species *Ceratium hirundinella* (D.F. Müller) Dujardin 1841 in many characteristics. The main difference between the two species is related to the number of the apical plates. *C. hirundinella* has 4 apical plates reaching the apex while in *C. furcoides* 3 apical plates reaches the apex and the 4th does not reach the apex (Santos-Wisniewski et al. 2007). Additionaly in *C. furcoides* the epivalve is conical whereas in *C. hirundinella* it is elm shaped.

Numerical density of *Ceratium furcoides* organisms were determined by counting 1 mL aliquots of the fixed samples in a Sedgwick-Rafter counting cell under light microscope at x50 magnification.

Environmental variables measured were analyzed by principal component analysis in order to express the importance of each variable. The relationships between *C. furcoides* densities and environmental parameters were analyzed by Canonical Correspondence Analysis, both performed with the also CANOCO statistical package (Ter Braak 1986). The overall variability of variables among the sampling points was evaluated by estimating the coefficient of variation (CV) by the formula: CV = standard deviation/average.

Results

The distribution of *Ceratium furcoides* over the 36 sampling sites in the Furnas reservoir varied appreciably during the study year (Figure 2). In March, June and December, the dinoflagellate was identified at 15 sites and in September, at 16. At two locations, G16 and G17, it was identified in March, but not at any other time. At 3 sites on the Rio Grande (G1, G4 and G10), *C. furcoides* was not recorded in March, but was found from June onwards. At S15, the species was recorded from September, while at S16, it appeared only in December. During the entire study, *C. furcoides* was observed at 20 of the 36 sites, only 3 of these (S15 – 17) being located in the Sapucai River arm, 2 in the central body (G1 and G2) and the rest (G3 – 17) in the Rio Grande arm. Among the sites G1 (at the dam) to G15, there was a noticeable tendency for the density of this species to increase with increasing distance from the dam (Figure 3). Over the whole period, the highest densities of *C. furcoides* were recorded in samples taken at G14, a location known to receive a constant discharge of untreated domestic sewage (Figure 2).

Densities of *C. furcoides* varied greatly among sampling sites and in short periods of time. Although a very low value was recorded in the first sampling (0.57 ind/m^3), it subsequently changed to the maximum of 28,564,913 ind/m^3, in the next monthly sampling (Figure 2).

In addition to the high densities of *C. furcoides* at G14, high values for total nitrogen, total phosphorus and chlorophyll-*a* were also recorded. In general there were no great changes in the values measured in each sampling site. However there is heterogeneity in the values of these variables, which were sampled throughout the water column, indicating that the reservoir is a complex system and dependent on the dam that provides events such as opening and closing of gates, and the existence of different compartments, including lotic, transitional and lentic areas (Table 1 and 2).

Practically all the collecting sites in the Furnas reservoir were oligotrophic, exceptions being S1, G18 and G19, where the water became mesotrophic in December, and G14, which was found to be mesotrophic in June and September and eutrophic in December. In March the whole reservoir was oligotrophic, and the highest density of *C. furcoides* occurred at point G14, but there was a steady rise in the TSI throughout the year, from March to December (Figure 3).

The first two components of the Principal Component Analysis explained 42.0% of the total variability for the environmental variables measured in Furnas Reservoir (Figure 4). It can be observed

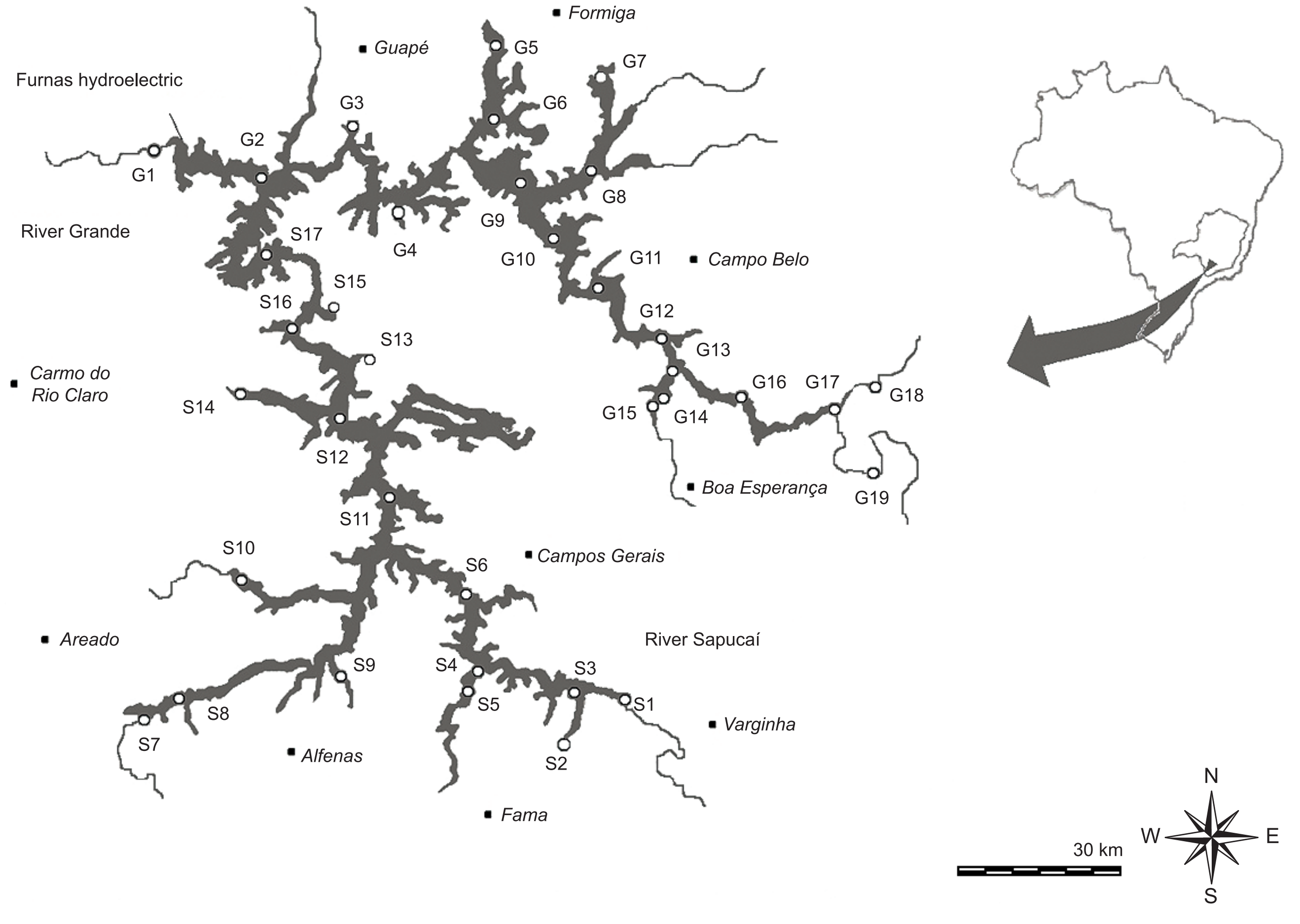

Figure 1. Map of Furnas reservoir showing the location of the 36 sampling sites; Rio Sapucai sub-basin (S1 to S17) on the left, and Rio Grande sub-basin (G1 to G19) on the right.

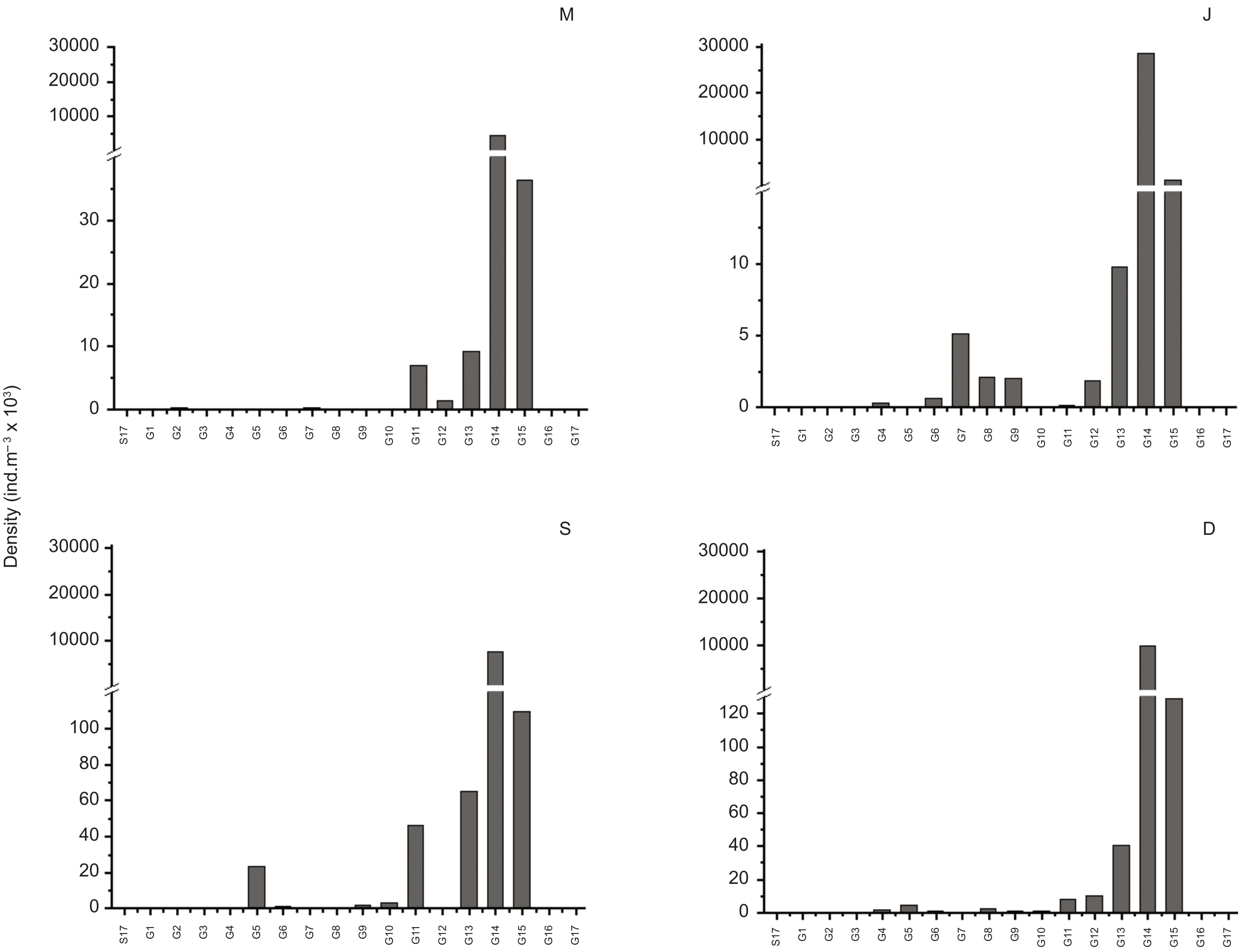

Figure 2. *Ceratium furcoides* mean density (ind/m^3) at each site in the Furnas reservoir, recorded from March to December 2007.

Table 1. Mean values and standard deviations of physical and chemical variables at the main portions of Furnas Reservoir, MG, recorded in March, June, September and December, 2007.

	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (μS/cm)	pH	Chlorophyll-*a* (mg/L)	Tranparency (m)
Lower Portion of River Sapucaí arm	23.5 ± 3.0	6.26 ± 0.7	39.05 ± 4.0	7.55 ± 0.3	2.73 ± 1.5	2.48 ± 1.4
Middle Portion of River Sapucaí arm	23.72 ± 3.0	5.46 ± 1.5	42.50 ± 5.40	7.52 ± 0.6	3.70 ± 1.3	2.28 ± 0,9
Upper Portion of River Sapucaí arm	24.16 ± 24.1	6.40 ± 1.4	35.9 ± 4,8	7.66 ± 0.6	3.25 ± 1.2	2.74 ± 1.3
Lower Portion of River Grande arm	22.97 ± 1.8	5.65 ± 1.1	33.37 ± 3.5	7.40 ± 0.3	0.70 ± 0.4	3.28 ± 1.1
Middle Portion of River Grande arm	24.23 ± 2.0	6.42 ± 1.1	34.96 ± 2.46	7.51 ± 0.34	1.15 ± 0.4	2.73 ± 0.9
Upper Portion of River Grande arm	23.85 ± 3.1	6.61 ± 1.2	42.41 ± 4.30	7.74 ± 0.37	18.21 ± 10.2	1.60 ± 0.6

that the temperature, IET, and the concentrations of total phosphorus, orthophosphate, nitrite, nitrate and dissolved oxygen were the most representative compared to the others as total nitrogen, chlorophyll-*a*, pH and water electrical conductivity. The sampling points located in the Rio Grande (G) portion of the Furnas Reservoir were mainly related to the values of temperature, chlorophyll-*a*, IET, total nitrogen, total phosphorus, nitrite, orthophosphate and water conductivity. On the other hand, the sampling points located in the Rio Sapucaí (S) portion were related to the variables pH, nitrate and dissolved oxygen.

The Canonical Correspondence Analysis (CCA) associating *Ceratium furcoides* densities to the environmental variables had 97.3% of the total variability explained by the first two axes.

Population density values were mainly associated with point G14. The variable water temperature in December was also associated with this point in Rio Grande and to the values of *C. furcatus* density in March. The point G15, where densities of *C. furcoides* were high was also associated with variables indicative of increasing trophic state as the concentrations of nitrite and nitrate and water conductivity in different months along the year of study (Figure 5).

As a whole the highest densities of *C. furcoides* were positively related to water temperature and conductivity and to the concentrations of nitrite and nitrate in the Furnas Reservoir.

Discussion

A wide variation in the abundance of *Ceratium furcoides* across space and time was noted in the samples taken from all parts of the Furnas reservoir, over a period of one year. In spite of the rather favorable growth conditions detected at most of the sites sampled in this study, the great heterogeneity of the chemical and physical variables recorded in the reservoir, could be responsible for the observed variation in the population densities. This was evidenced by wide range variation for each variable (except pH) shown by variation coefficients ranging from 44% to 156%. This heterogeneity of the environmental variables is common in the Furnas reservoir due to its large extension and also by the large inflow of water from many tributaries throughout its area (Table 3).

The recorded density of this reached a peak of 28,564 ind L^{-1} in the Marimbondo River a tributary of the Rio Grande River (site G14). This site is next to a constant discharge of untreated domestic sewage and this is likely to be the main cause of proliferation of this dinoflagellate in the reservoir. At the same site, high concentrations of chlorophyll-*a* were recorded, peaking at 169.2 µg L^{-1} in December. Besides the dinoflagellate bloom itself, these high concentrations of chlorophyll are also due to blooms of other algae, mainly cyanobacteria.

Some authors have recorded *Ceratium* blooms in habitats classed as eutrophic. High densities of *C. hirundinella* were recorded in tropical eutrophic water bodies in Argentina (Claps & Ardohain 2007), Australia (Whittington et al. 2000) and South Africa (Hart 2007). In other studies, however, it has been found that dinoflagellates, including the genus *Ceratium*, tend to become dominant under mesotrophic conditions (Periotto et al. 2007). It follows that *Ceratium furcoides* does proliferate successfully in oligotrophic waters, although it reached the highest densities, under mesotrophic conditions whereas bloom-forming cyanobacteria are more often dominant under eutrophic or hypereutrophic.

Table 2. Mean values and standard deviation of nutrient concentrations for the main areas of Furnas Reservoir, MG, recorded in March, June, September and December, 2007.

	Total N (µg/L)	Nitrite (µg/L)	Nitrate (µg/L)	Total P (µg/L)	Ortofosfate (µg/L)	Silicate (mg/L)
Lower Portion of River Sapucaí arm	597.92 ± 0.1	6.27 ± 1.7	230.20 ± 78.9	45,17 ± 33.6	12.35 ± 7.7	3.50 ± 1.1
Middle Portion of River Sapucaí arm	482.50 ± 0.1	2.90 ± 1.0	61.48 ± 35.6	27.50 ± 21.2	6.66 ± 4.5	4.50 ± 0.8
Upper Portion of River Sapucaí arm	589.33 ± 0.2	2.15 ± 0.9	67.97 ± 28.8	20.12 ± 14.3	6.56 ± 3.6	3.33 ± 0.5
Lower Portion of River Grande arm	491.68 ± 0.2	2.05 ± 1.0	153.60 ± 26.6	21.73 ± 14.0	4.30 ± 1.2	3.43 ± 0.7
Middle Portion of River Grande arm	536.46 ± 0.1	2.10 ± 0.9	99.23 ± 33.7	25.90 ± 24.1	5.68 ± 2.31	3.86 ± 0.7
Upper Portion of River Grande arm	530.36 ± 0.2	2.91 ± 1.2	107.90 ± 58.0	80.07 ± 97.9	10.51 ± 5.53	4.56 ± 1.26

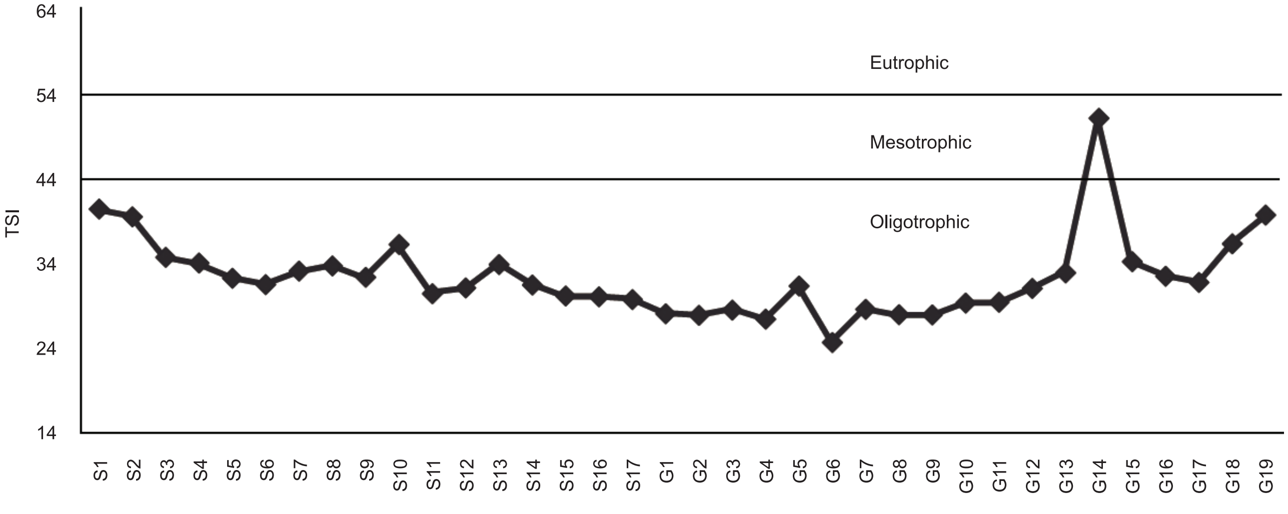

Figure 3. Mean values of trophic state index of Carlson (1971) modified by Toledo et al., (1978) for each sampling site in Furnas reservoir, from March to December 2007.

The highest densities recorded in Furnas reservoir were in June. In this season, large quantities of nutrients could be due to winter water circulation or external forces. The CCA analysis positively associated the densities of C.furcoides with the highest values of the nutrients nitrate and nitrite.

The highest density of *C. furcoides* recorded in the Furnas reservoir was 28,564 ind L^{-1} This value is relatively low, compared to many other reservoirs. For example, in the South African subtropical reservoir at Albert Falls, the density of *Ceratium* species varied from 150 to 1,320,000 ind L^{-1} (Hart 2007). A population of various species of *Ceratium* in an estuary in the Gulf of Nicoya in Costa Rica reached a total density of 4,000,000 ind L^{-1} (Vargas-Montero & Freer 2004), while in the eutrophic lake La Quebrada in Argentina, the single species *C. hirundinella* peaked at 32,500,000 ind L^{-1} (Periotto et al. 2007). It is likely that this difference relates to the fact that the Furnas reservoir is still in oligotrophic and mesotrophic conditions most of the year. However, in the Bilings Reservoir, located in São Paulo state in Brazil, the values (25,000 ind L^{-1}) registered by Matsumura-Tundisi et al. (2010) were close to the values found in this study for the same conditions.

It has been pointed out by Perez-Martınez & Sanchez-Castillo (2001), in a study of Spanish reservoirs that most of the published field studies on the ecology of *C. hirundinella* have been carried out in temperate zones, where the low temperatures and poor

Table 3. Values of coefficient variation (CV) recorded for environmental variables of Furnas Reservoir, MG, in March, June, September and December, 2007. (Temp. – Temperature; Oxy. – Dissolved Oxygen; Cond. – Conductivity; Chlor. – Chlorophyll-*a*; Tranp. – Transparence; Ortop. – Orthophosfate).

(%)	Temp.	Oxy.	Cond.	pH	Chlor.	Transp.	Total N	Nitrite	Nitrate	Total P	Ortop.	Silicate
Maximum	18	44	58	10	92	71	50	77	100	156	97	47
Minimum	1	3	1	1	10	20	1	0	8	23	19	9

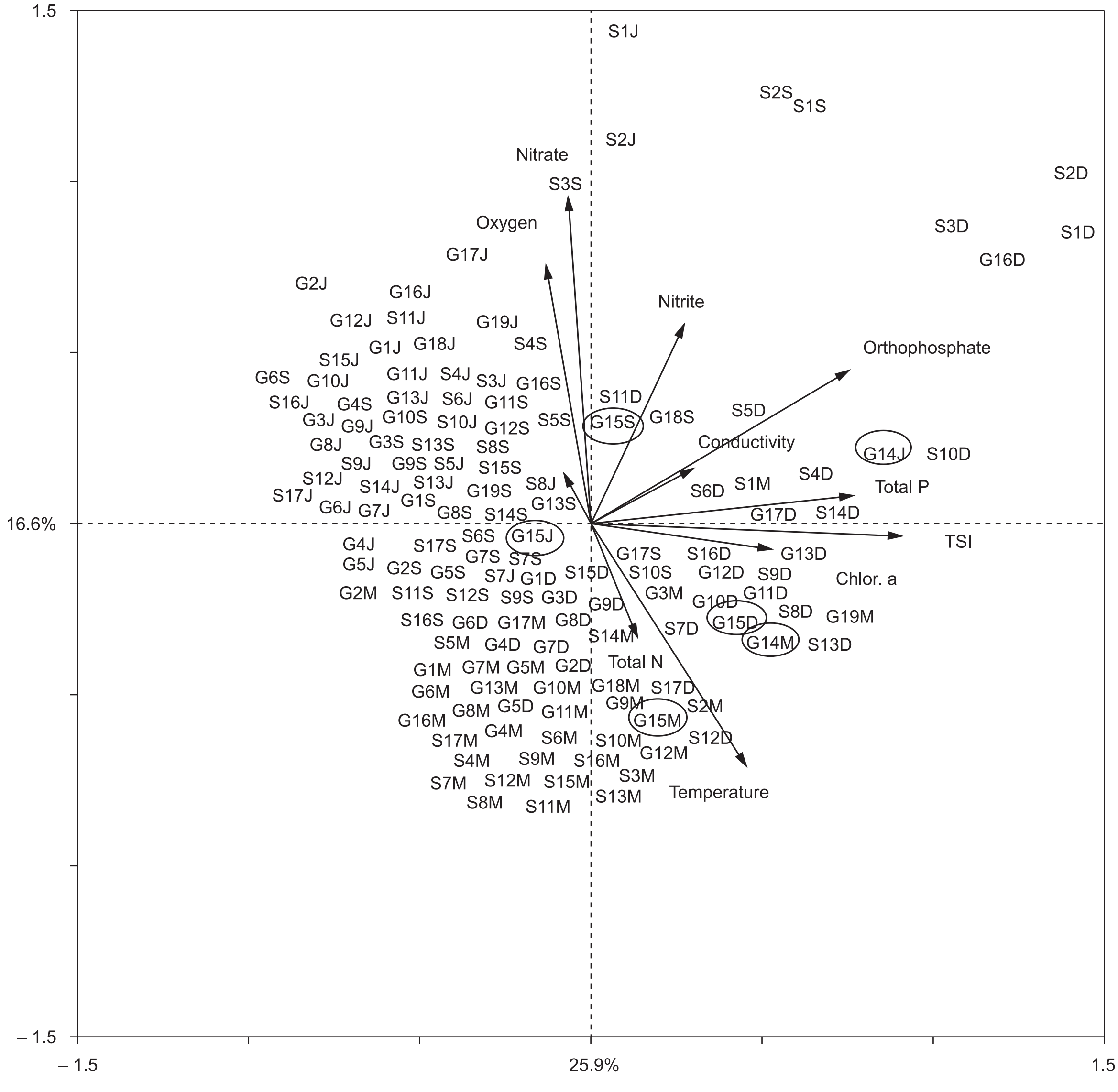

Figure 4. PCA ordination diagram correlating the most significant physical and chemical variables measured in Furnas Reservoir with sampling points and collection months. (M – March; J – June; S – September; D – December).

illumination that prevail in the winter would probably inhibit its permanence. However, in this study, *Ceratium* dinoflagellates should frequently be permanent organisms, recorded in all seasons of the year, owing to the warmer temperatures and especially the highly transparent water observed in the cool, dry months In fact, field studies made in regions where such conditions prevail have shown evidence of the development of these dinoflagellates in all seasons around the year, for example in lake La Quebrada in Argentina (Periotto et al. 2007) and Lake Kinneret in Israel (Pollingher & Hickel 1991). However, despite the occurrence of *C. furcoides* have been ongoing throughout the year, the high densities of *C. furcoides* were related to the low temperatures recorded in winter in the month of June. Therefore, despite being considered a permanent, *C. furcoides* better development occurred in conditions with lower temperatures. The canonical correspondence analysis (CCA) showed a significant relationship between *C. furcoides* densities and the water temperature.

Thus the initial hypothesis of this study that C.furcoides invasion and establishment in Furnas reservoir is related to the increase of nutrients (nitrate and nitrite) in some locations was accepted.

So far the presence of *Ceratium furcoides* in the Furnas reservoir apparently has not yet affected the environmental conditions or other communities, but eventually as it becomes fully established it could turn into a nuisance or spread out to other basins. Watching the effects of *Ceratium furcoides* invasion in Brazilian freshwaters will be of great relevance presently and in the near future.

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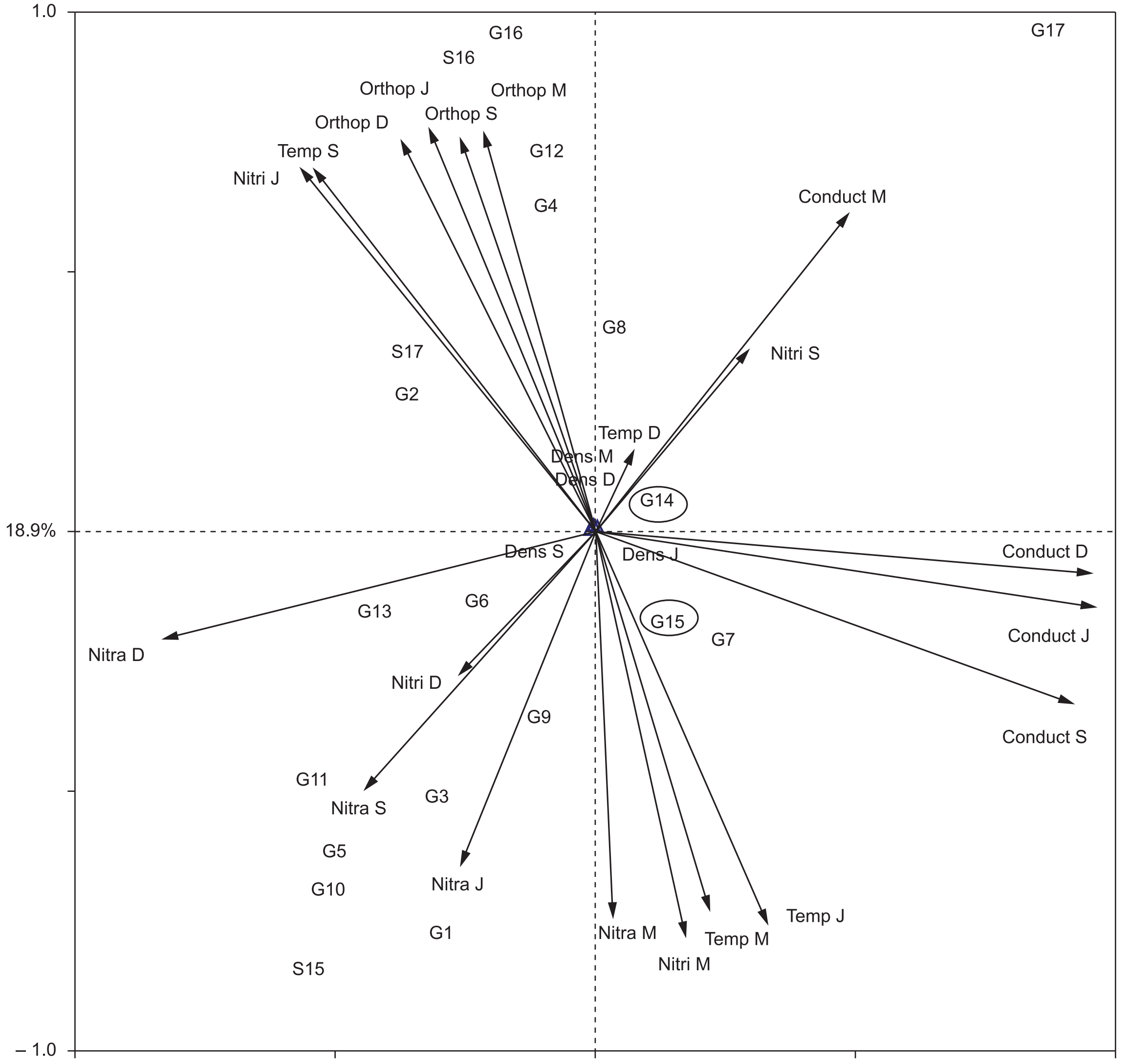

Figure 5. CCA ordination diagram relating the densities (ind.m^{-3}) of *Ceratium furcoides* and environmental variables measured in the Furnas reservoir (M – March; J – June; S – September; D – December; Nitra = Nitrate; Nitri = Nitrite; Temp = Temperature; Conduct = Conductivity; Orthop = Orthophosphate).

References

BASKIN, Y. 1994. Ecosystem function of biodiversity. Rev. BioScience 44(10):657-660. http://dx.doi.org/10.2307/1312507

CLAPS, M. & ARDOHAIN, D. 2007. Zooplankton characterization in a subtropical reservoir (Córdoba, Argentina) during the period 1996-2005. In Plankton Symposium IV. J. Biol. 2:108.

DEL AGUILA, R. 2001. Gradiente trófico no rio Sapucaí (Reservatório de Furnas - MG): Relação com a distribuição do zooplâncton e os usos do solo. Dissertação de mestrado, Universidade Federal de Minas Gerais, Belo Horizonte.

DELARIVA, R.L. & AGOSTINHO, A.A. 1999. Introdução de espécies: uma síntese comentada. Acta Sci. 21 (2): 255-262.

GOLTERMAN, H.L., CLYMO, R.S. & OHNSTAD, M.A.M. 1978. Methods for physical and chemical analysis of freshwater. 2nd ed. Blackwell Scientific Publications, Oxford, 213p.

HALLENGRAEFF, G.M., ANDERSEN, D.M. & CEMBELLA, A.D. 1995. Manual of Harmfull Marine Microalgae. Intergovernmental Oceanographic Commission, UNESCO, 551p.

HART, R.C. 2007. Temporal Dynamics and spatial perspectives of contemporary blooms of the dinoflagellate *Ceratium* in a subtropical South African Reservoir. In Plankton Symposium IV. J. Biol. 2:159.

KASTOVSKY, J., HAUER, T., MARES, J., KRAUTOVA, M., BESTA, T., KOMAREK, J., DESORTOVA, B., HETESA, J., HINDAKOVA, A., HOUK, V., JANECEK, E., KOPP, R., MARVAN, P., PUMANN, P., SKACELOVA, O. & ZAPOMELOVA, E. 2010. A review of the alien and expansive species of freshwater cyanobacteria and algae, a case study from the Czech Republic. Biol. Invasions 12(10):3599-3625. http://dx.doi.org/10.1007/s10530-010-9754-3

LANDSBERG, J.H. 2002. The effects of harmfull algae blooms on aquatic organisms. Rev. Fish. Sci. 10(2):113-390.

LORENZEN, C.J. 1967. Determination of chlorophyl and pheo- pigments: Spectrophotometric equations. Limnol. Oceanogr. 12:343-346. http://dx.doi.org/10.4319/lo.1967.12.2.0343

MAC DONAGH, M.E., CASCO, M.A. & CLAPS, M.C. 2005. Colonization of a neotropical reservoir (Córdoba, Argentina) by *Ceratium hirundinella* (O. F. Miiller). Ann. limnol. - Int. J. Lim. 41(4):291-299.

MACKERETH, J.F.H., HERON, J. & TALLING, J.F. 1978. Water analysis: some revised methods for limnologists. Titus Wilson & Sons Ltda, Kendal. Freshwater Biological Association, n.36, 121p.

MATSUMURA-TUNDISI, T., TUNDISI, J.G., LUZIA, A.P. & DEGANI, R.M. 2010. Occurrence of *Ceratium furcoides* (Levander) Langhans 1925 bloom at the Billings Reservoir, São Paulo State, Brazil. Braz. J. Biol. 70(3):825-829.

PEREZ-MARTINEZ, C. & SANCHEZ-CASTILLO, P. 2001. Temporal occurrence of *Ceratium hirundinella in* Spanish reservoirs. Hidrobiology 452:101-107.

PERIOTTO, M., PRÓSPERI, C., DAGA, C. & RINCÓN, A. 2007. Estudio de *Ceratium hirundinella* en El Embalse La Quebrada, Córdoba, Argentina. In International Congress on Development Environment and Natural Resources: Multi-level and Multi-scale Sustainability. Cochabamba, Bolívia.

PINTO-COELHO, R.M. & CORGOSINHO, P.H.C. 1998. Alterações na estrutura do zooplâncton em resposta a um gradiente de trofia no reservatório de Furnas, Minas Gerais. In Seminário de Ecologia. UFSCar, São Carlos, p.1173-1188.

POLLINGHER, U. & HICKEL, B. 1991. Dinoflagellate associations in a subtropical lake (Lake Kinneret, Israel). Arch. Hydrobiol 120: 267-285.

SÁ, JR., LIMA, M.N., EVANGELISTA, M.A., PERES, S.A. & GOMES, A.P.G. 1996. Programa de monitoramento limnológico. In Caracterização limnológica do reservatório da Usina Hidroelétrica de Furnas (Furnas). Estação de Hidrobiologia e Piscicultura de Furnas.

SANTOS-WISNIEWSKI, M.J., SILVA, L.C., LEONE, I.C., LAUDARES-SILVA, R. & ROCHA, O. 2007. First Record of the occurrence of *Ceratium furcoides* (Levander) Langhans 1925, an invasive species in the hydroelectricity power plant Furnas Reservoir, MG, Brazil. Braz. J. Biol. 67(4):791-793.

SIMBERLOFF, D. 1996. Impacts of introduced species in the United States. Rev. Consequences 2(2):13-24.

TAYLOR, F., FUKUYO, Y. & LARSON, J. 1995. Taxonomy of harmful dinoflagellates. In Manual of harmful marine microalgae (G.M. Hallengraeff, D.M. Andersen & A.D. Cembella, eds.). Intergovernmental Oceanographic Commission, UNESCO, Paris, 551p.

TER BRAAK, C.J.F. 1986. Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. Ecology 67(6):1167-79.

TOLEDO, A.P., TALARICO, M., CHINEZ, S.J. & AGUDO, E.G. 1983. A aplicação de modelos simplificados para avaliação do processo da eutrofização em lagos e reservatórios tropicais. In Congresso Brasileiro de Engenharia Sanitária e Ambiental. Camboriú, p.1-34.

VARGAS-MONTERO, M. & FREER, E. 2004. Presence of the dinoflagellates *Ceratium dens*, *C. fusus* and *C. furca* (Gonyaulacales: Ceratiaceae) in Golfo de Nicoya, Costa Rica. Rev. Biol. Trop. 52(1):115-120.

WHITTINGTON, J., SHERMAN, B., GREEN, D. & OLIVER, R.L. 2000. Growth of *Ceratium hirundinella* in a subtropical Australian reservoir: the role of vertical migration. J. Plankton Res. 22(6):1025-1045.

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Inventory of the Echinodermata collection from the Universidade Federal de Alagoas

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MIRANDA, A.L.S., LIMA, M.L.F., SOVIERZOSKI, H.H. & CORREIA, M.D. **Inventory of the Echinodermata collection from the Universidade Federal de Alagoas**. Biota Neotrop. 12(2): http://www.biotaneotropica.org.br/v12n2/en/abstract?inventory+bn00812022012

Abstract: Collections and inventories provide important and essential information for understanding the composition and distribution of biodiversity. This contribution presents an inventory of the species held in the Echinodermata collection in the Setor de Comunidades Bentônicas (LABMAR/ICBS), Universidade Federal de Alagoas. The collections were made over a period of more than 20 years, at several localities of coastal Alagoas. This collection now includes 16,201 catalogued individual specimens, with 50 species in the five extant classes Crinoidea, Asteroidea, Ophiuroidea, Echinoidea and Holothuroidea, based on 640 records; the class Ophiuroidea is best represented. The results of this inventory contribute significantly to knowledge of marine benthic diversity from the state of Alagoas, and the information presented here expands the data for Echinodermata from the northeastern coast of Brazil.
Keywords: *biodiversity, echinoderm, taxonomy, benthic macroinvertebrate, Brazil.*

MIRANDA, A.L.S., LIMA, M.L.F., SOVIERZOSKI, H.H. & CORREIA, M.D. **Inventário da coleção de Echinodermata da Universidade Federal de Alagoas**. Biota Neotrop. 12(2): http://www.biotaneotropica.org.br/v12n2/pt/abstract?inventory+bn00812022012

Resumo: As coleções e inventários fornecem importantes e essenciais informações para entender a composição e distribuição da biodiversidade. Esta contribuição apresenta um inventário da coleção de Echinodermata pertencente ao Setor de Comunidades Bentônicas (LABMAR/ICBS), da Universidade Federal de Alagoas. As coletas foram realizadas ao longo de mais de vinte anos em diversas localidades da costa de Alagoas. A coleção conta com 16.201 exemplares tombados e 50 espécies distribuídas entre as cinco classes viventes Crinoidea, Asteroidea, Ophiuroidea, Echinoidea e Holothuroidea, com base em 640 registros, sendo a classe Ophiuroidea a melhor representada. O resultado deste inventário vem contribuir significativamente para o conhecimento da diversidade bentônica marinha do Estado de Alagoas ampliando as informações sobre a fauna do filo Echinodermata para a costa nordeste do Brasil.
Palavras-chave: *biodiversidade, equinoderma, taxonomia, macroinvertebrados bentônicos, Brasil.*

Introduction

Zoological catalogues and collections on regional scales are important to understand the composition and distribution of national and global faunas (Mikkelsen & Cracraft 2001). Such data is the principal source of information on biodiversity distribution, providing knowledge of areas yet unexplored, and also reveals local extinctions and reductions in species distributions (Nogueira et al. 2009). Zoological scientific collections are important records of Brazilian biodiversity, because the increasing occupation and intensity of human impacts often result in species extinction (Zaher & Young 2003).

In Brazil, knowledge of zoological collections is still sparse, especially for the North and Northeast regions. For example, information on collections of Echinodermata is mostly limited to the Southeast region, in institutions such as the Museu Nacional of the Universidade Federal do Rio de Janeiro, the Museu de Zoologia of the Universidade de São Paulo and the Museu de Zoologia of the Universidade de Campinas (Amaral & Jablonski 2005, Ventura et al. 2009). In the Brazilian Northeast, other specific collections with Brazilian specimens of Echinodermata have been established more recently in universities in the states of Bahia (Manso et al. 2008), Paraíba (Gondim et al. 2008), Pernambuco (Lima & Fernandes 2009), and Sergipe (Oliveira et al. 2010).

The first reference to the phylum Echinodermata for the Brazilian coast was based on notes published by Verrill (1868), when this group was still called Radiata, based on samples collected in the Abrolhos area off southern Bahia. Later, Rathbun (1879) surveyed the distribution of species of Echinodermata. The species and distribution of Echinodermata according to salinity in Guanabara Bay, state of Rio de Janeiro (RJ) were characterized by Krau (1950). The first catalogue of echinoderms from the Brazilian coast was made available by Brito (1962). Several studies and remarks about the fauna of Echinodermata along the Brazilian coast have been contributed, especially by Tommasi (1985, 1999). The diversity of Echinodermata from the west coast of the Atlantic Ocean was described by Hendler et al. (1995), who provided taxonomic and ecological information, with some citations for the Brazilian coast. Castro et al. (1999) observed the occurrence of Echinodermata at different depths in Ilha Grande Bay (RJ). Netto et al. (2005) published new records from studies on the São Paulo coast. Xavier (2010) reviewed the literature and listed species of Echinodermata from the Santa Catarina coast.

On the Brazilian northeastern coast, Lima-Verde (1969) studied the Echinodermata from shallow waters from the mouth of the Parnaíba River in Piauí state, to the mouth of the São Francisco River in Alagoas state. Albuquerque (1986) investigated the fauna of Ophiuroidea from the northern and northeastern continental shelf. Echinodermata from the coast of Bahia were characterized for several reef and soft bottom substrates (Alves & Cerqueira 2000, Magalhães et al. 2005, Manso et al. 2008). The diversity of echinoderms from the Ceará coast was characterized by Martins & Queiroz (2006**)**. In the intertidal zone of Cabo Branco, Paraíba state, the echinoderm fauna was analyzed according to habitat (Gondim et al. 2008). New records of Ophiuroidea were reported from shallow waters on the coast of Maceió, Alagoas (Lima et al. 2011).

Most of the catalogues of Echinodermata include mainly representatives of class Ophiuroidea, and some of these publications included descriptions of new species and records (Tommasi 1970, 1999, Tommasi & Abreu 1974). Other studies were based on specimens obtained from oceanographic research cruises that dredged along different parts on the Brazilian coast, and included descriptions, notes, ecological and biogeographical aspects of Ophiuroidea (Monteiro 1987, Manso 1989, Absalão & Manso 1990, Manso 1991, Borges et al. 2002, Borges & Amaral 2006, Ventura et al. 2007, Borges et al. 2011).

This contribution presents a catalogue and information on the collection of material of the phylum Echinodermata, held by the Setor de Comunidades Bentônicas (LABMAR/ICBS), Universidade Federal de Alagoas.

Material and Methods

The present inventory is based on specimens from the intertidal zone and shallow waters, including coral reefs, sandstone reefs, beaches, soft bottoms, and the phytal, which is abundant along the coast of Alagoas (Correia & Sovierzoski 2009, Correia 2011).

The specimens were collected from different sites on the coast of Alagoas (8° 55’ S and 36° 10’ W; 10° 30’ S and 36° 23’ W), including the following localities, from north to south: Maragogi - Galés (9° 01’ 07” S and 35° 12’ 13” W); São Miguel dos Milagres - Porto da Rua (9° 15’ 11” S and 35° 20’ 31” W); Passo de Camaragibe – Camaragibe River bar (9° 18’ 47” S and 35° 24’ 54” W); Paripueira – Natural Pool (9° 28’ 25” S and 35° 32’ 40” W); Maceió - Ipioca (9° 29’ 55” S and 35° 33’ 50” W), Ponta do Prego (9° 31’ 48” S and 35° 35’ 30” W), Ponta do Meirim (9° 32’ 37” S and 35° 36’ 52” W), Sereia (9° 34’ 04” S and 35° 38’ 46” W), Riacho Doce (9° 34’ 55” S and 35° 39’ 25” W), Guaxuma (9° 35’ 33” S and 35° 39’ 54” W), Jatiúca (9° 39’ 12” S and 35° 41’ 46” W), Ponta Verde (9° 39’ 57” S and 35° 41’ 32” W), Piscina dos Amores (9° 40’ 39” S and 35° 42’ 10” W), Pajuçara (9° 41’ 06” S and 35° 43’ 22” W), Sobral sewel outfall (9° 40’ 45” S and 35° 45’ 00” W); Marechal Deodoro - channel of the Manguaba lagoon (9° 43’ 13” S and 35° 48’ 23” W), Saco da Pedra (9° 44’ 26” S and 35° 48’ 59” W) and Francês (9° 46’ 03” S and 35° 50’ 13” W); Barra de São Miguel – São Miguel River bar (9° 50’ 10” S and 35° 53’ 05” W); Jequiá da Praia - Lagoa Azeda (9° 58’ 04” S and 35° 58’ 32” W); Coruripe - Pontal do Coruripe (10° 07’ 32” S and 36° 10’ 32” W); and Piaçabuçu - Pontal do Peba (10° 21’ 25” S and 36° 17’ 40” W) (Figure 1).

The samples were transported to the Setor de Comunidades Bentônicas, where they were sorted, anesthetized with 10% $MgCl_2$, and then fixed with 4% formaldehyde for 24 to 48 hours. The specimens were conserved in 70% ethanol and assigned a catalogue number. The material was identified with specialized bibliography to the lowest possible taxonomic category, based on Clark & Downey (1992), Tommasi (1969, 1999), Hendler et al. (1995) and Pawson et al. (2010), and when necessary was sent to a specialist for confirmation of the identification. All remarks on the species of Echinodermata in this collection were entered in a database, available from the Setor de Comunidades Bentônicas, Universidade Federal de Alagoas (UFAL/ECH).

Results

The catalogue lists 16,201 individuals in the five extant classes Crinoidea, Asteroidea, Ophiuroidea, Echinoidea, and Holothuroidea. To date, the collection includes 640 records representing 50 species. The class Ophiuroidea is best represented, followed by the class Holothuroidea. Classes Asteroidea and Echinoidea include fewer families, with different numbers of genera and species. Only one family and a single species of the class Crinoidea are represented.

Most of the Echinodermata species were collected from reef ecosystems. The reefs provide different substrata composed by algae, corals, and sponges, and of these, macroalgae harbored most individuals of Ophiuroidea and Holothuroidea. Specimens of classes Asteroidea, Echinoidea, and Crinoidea were recorded on coral and

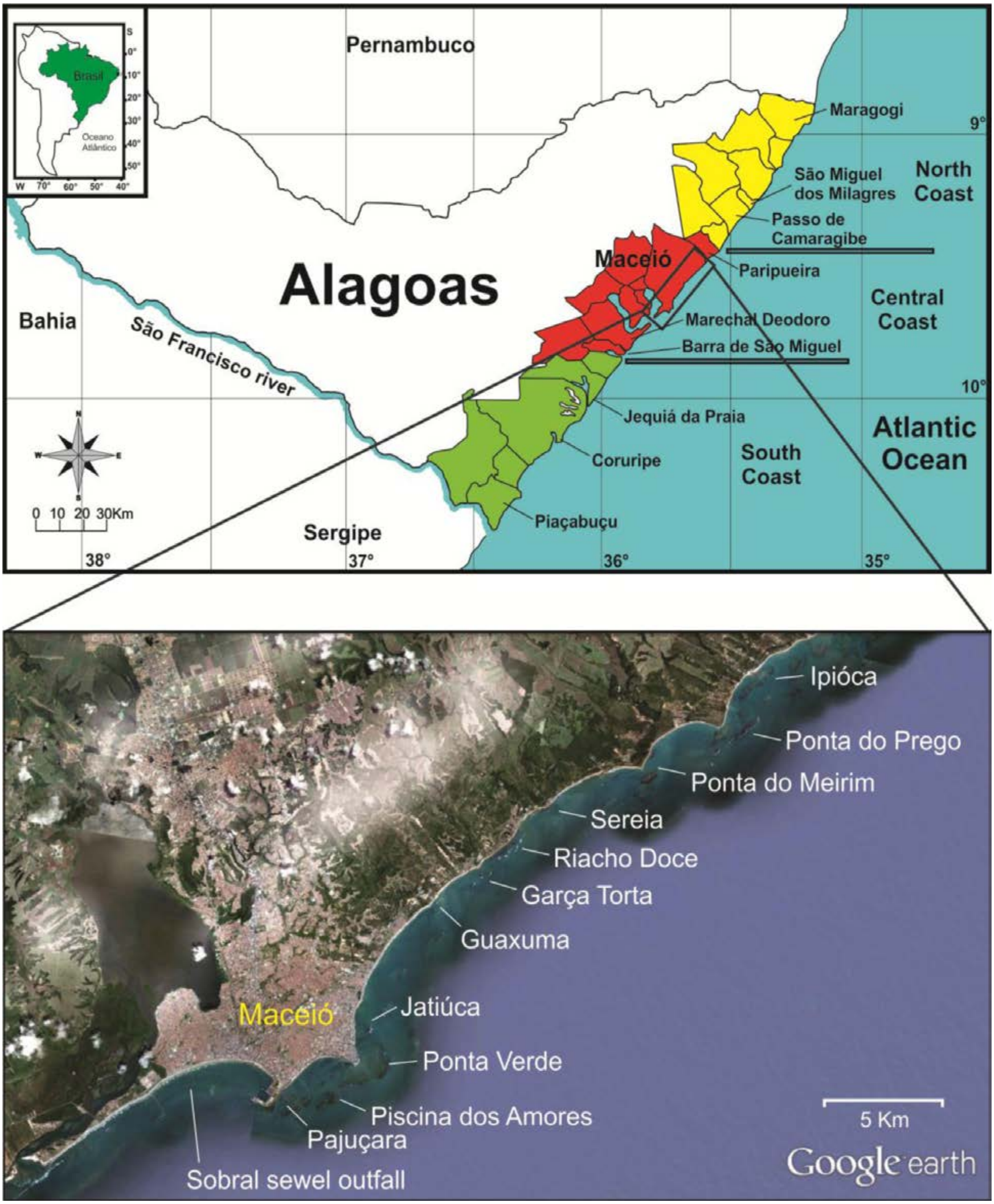

Figure 1. Map showing the sites on the coast of Alagoas state, northeastern Brazil, represented in the Echinodermata collection (UFAL/ECH).

sandstone reefs, and some species of Asteroidea and Echinoidea were also found on soft bottoms.

The class Ophiuroidea is the most abundant taxon recorded for the Alagoas coast, with 14,837 individuals, in seven families and 19 species (Table 1).

Class Ophiuroidea

Order Ophiurida Müller & Troschel, 1840

Family Ophiolepididae Ljungman, 1867

Genus *Ophiolepis* Müller & Troschel, 1840

Ophiolepis impressa Lütken, 1859: one record. Brazil, Alagoas, Paripueira - Natural Pool UFAL/ECH 0620.

Ophiolepis paucispina (Say, 1825): six records. Brazil, Alagoas, Maceió - Ponta do Prego reef UFAL/ECH 0478; Ponta Verde reef UFAL/ECH 0147, 0172, 0249, 0411, 0533.

Table 1. Species of class Ophiuroidea catalogued in the Echinodermata collection of the Setor de Comunidades Bentônicas, Universidade Federal de Alagoas (UFAL/ECH).

Taxa	Nº ind.	Records	Substrate
Family Ophiolepididae			
Ophiolepis impressa	1	1	Coral reef
Ophiolepis paucispina	9	6	Coral reef, algae
Family Ophiodermatidae			
Ophioderma appressa	21	15	Coral reef, sandstone reef, algae
Ophioderma cinerea	10	9	Coral reef, sandstone reef , algae
Family Ophiocomidae			
Ophiocoma echinata	7	4	Coral reef, sandstone reef
Ophiocoma wendti	1	1	Coral reef
Ophiocomella ophiactoides	263	37	Coral reef, algae, coral and hydrocoral
Family Ophionereidae			
Ophionereis reticulata	22	16	Coral reef, sandstone reef
Ophionereis squamulosa	1	1	Coral reef
Family Ophiactidae			
Ophiactis brasiliensis	125	10	Coral reef, sandstone reef, algae, coral
Ophiactis lymani	118	25	Coral reef, sandstone reef, algae, sponge, coral, polychaetes and fouling
Ophiactis quinqueradia	5	4	Sponge
Ophiactis savignyi	7.033	129	Coral reef, sandstone reef, algae, sponge, coral and soft bottom
Family Amphiuridae			
Amphipholis januarii	7	5	Coral reef, soft bottom , algae
Amphipholis squamata	7.084	96	Coral reef, sandstone reef, algae, sponge, coral and fouling
Amphiura kinbergi	1	1	Fouling
Ophiocnida loveni	2	1	Coral reef
Ophiocnida scabriuscula	4	4	Coral reef
Family Ophiotrichidae			
Ophiothrix (*Ophiothrix*) *angulata*	123	60	Coral reef, sandstone reef, algae, sponge, coral and fouling
Total	14.837	425	

Family Ophiodermatidae Ljungman, 1867

Genus *Ophioderma* Müller & Troschel, 1840

Ophioderma appressa (Say, 1825): 15 records. Brazil, Alagoas, Maceió - Ipioca reef UFAL/ECH 0541; Ponta do Prego reef UFAL/ECH 0537, 0549; Ponta do Meirim reef UFAL/ECH 0517, 0526, 0527; Sereia reef UFAL/ECH 0470, 0535; Jatiúca reef UFAL/ECH 0511; Ponta Verde reef UFAL/ECH 0210, 0376, 0412; Pajuçara reef UFAL/ECH 0025. Marechal Deodoro - Saco da Pedra reef UFAL/ECH 0331; Francês reef UFAL/ECH 0387 (Figure 2a).

Ophioderma cinerea Müller & Troschel, 1842: nine records. Brazil, Alagoas, Maceió - Ponta do Prego reef UFAL/ECH 0546; Ponta do Meirim reef UFAL/ECH 0528; Sereia reef UFAL/ECH 0497; Riacho Doce reef UFAL/ECH 0560; Ponta Verde reef UFAL/ECH 0016, 0127, 0133, 0587. Marechal Deodoro - Francês reef UFAL/ECH 0615.

Family Ophiocomidae Ljungman, 1867

Genus *Ophiocoma* L. Agassiz, 1835

Ophiocoma echinata (Lamarck, 1816): four records. Brazil, Alagoas, Maceió - Riacho Doce reef UFAL/ECH 0389; Jatiúca reef UFAL/ECH 0624. Marechal Deodoro - Francês reef UFAL/ECH 0228. São Miguel dos Milagres - Porto da Rua reef UFAL/ECH 0175 (Figure 2b).

Ophiocoma wendti Müller & Troschel, 1842: one record. Brazil, Alagoas, Marechal Deodoro - Francês reef UFAL/ECH 0623.

Genus *Ophiocomella* A.H. Clark, 1939

Ophiocomella ophiactoides (H. L. Clark, 1901): 37 records. Brazil, Alagoas, Maceió - Ponta do Meirim reef UFAL/ECH 0529; Ponta Verde reef UFAL/ECH 0064, 0066, 0067, 0087, 0091, 0110, 0120, 0150, 0160, 0166, 0186, 0197, 0201, 0213, 0225, 0241, 0244, 0248, 0259, 0262, 0265, 0287, 0303, 0329, 0367, 0370, 0374, 0408, 0409, 0442, 0465, 0553, 0593. Maragogi - Galés reef UFAL/ECH 0107, 0109. Marechal Deodoro - Francês reef UFAL/ECH 0614.

Family Ophionereididae Ljungman, 1867

Genus *Ophionereis* Lütken, 1856

Ophionereis reticulata (Say, 1825): 16 records. Brazil, Alagoas, Maceió - Ipioca reef UFAL/ECH 0542; Ponta do Prego reef UFAL/ECH 0547; Ponta do Meirim reef UFAL/ECH 0516; Sereia reef UFAL/ECH 0534, 0563; Riacho Doce reef UFAL/ECH 0390; Jatiúca reef UFAL/ECH 0291, 0636; Ponta Verde reef UFAL/ECH 0142, 0157, 0267; Pajuçara reef UFAL/ECH 0381. Maragogi - Galés reef UFAL/ECH 0105. Marechal Deodoro - Saco da Pedra reef UFAL/ECH 0334, 0480; Francês reef UFAL/ECH 0475 (Figure 2c).

Ophionereis squamulosa Koehler, 1914: 1 record. Brazil, Alagoas, Maceió - Jatiúca reef UFAL/ECH 0625.

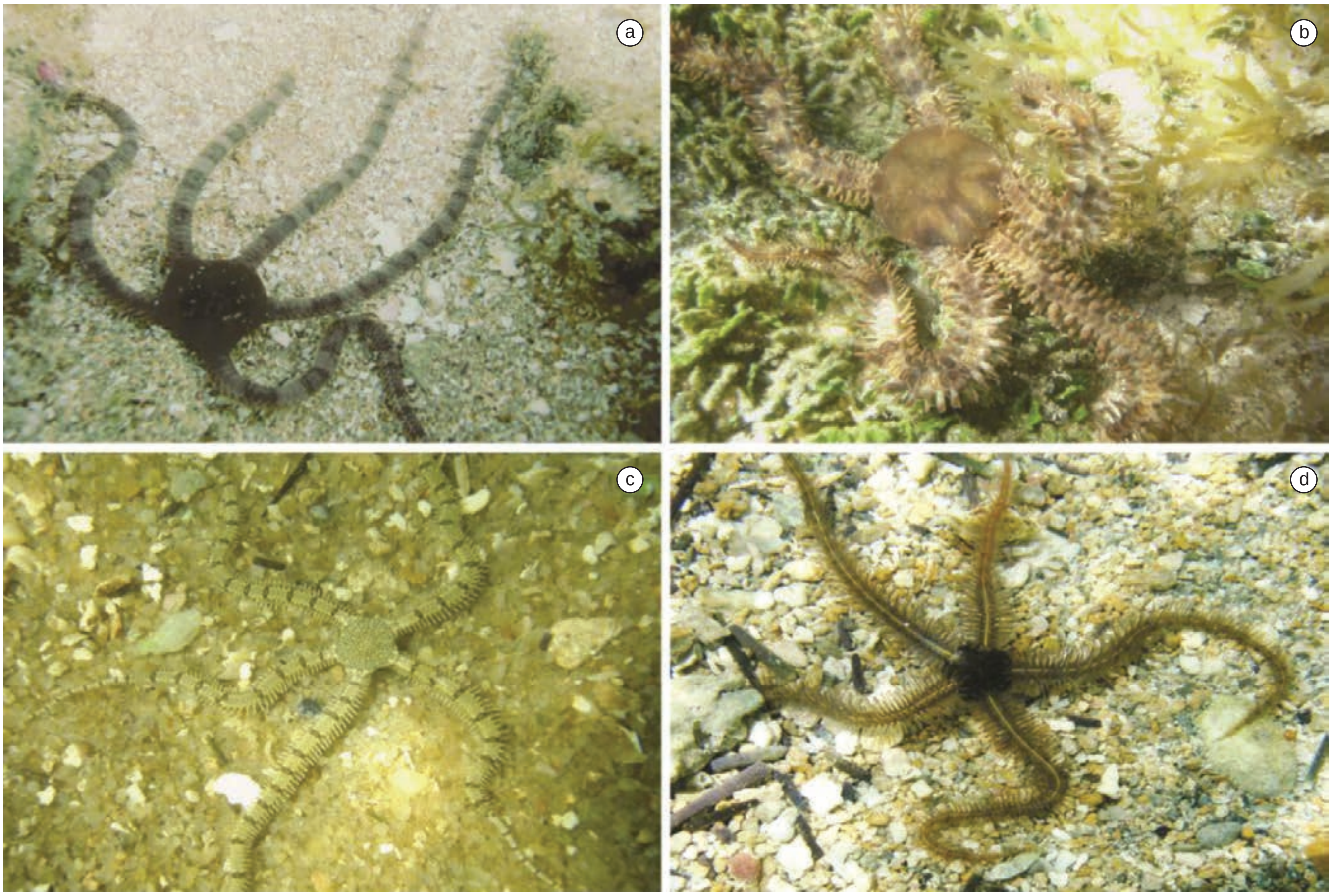

Figure 2. Species of class Ophiuroidea from the Echinodermata collection in the Setor de Comunidades Bentônicas, Universidade Federal de Alagoas (UFAL/ECH): a) *Ophioderma appressa,* b) *Ophiocoma echinata,* c) *Ophionereis reticulata* and d) *Ophiothrix angulata*.

Family Ophiactidae Matsumoto, 1915

Genus *Ophiactis* Lütken, 1856

Ophiactis brasiliensis Manso, 1988: 10 records. Brazil, Alagoas, Maceió - Ponta do Meirim reef UFAL/ECH 0519; Ponta Verde reef UFAL/ECH 0037, 0068; Piscina dos Amores reef UFAL/ECH 0485; Pajuçara reef UFAL/ECH 0380, 0559, 0626. Maragogi - Galés reef UFAL/ECH 0108. Marechal Deodoro - Francês reef UFAL/ECH 0072, 0639.

Ophiactis lymani Ljungman, 1872: 25 records. Brazil, Alagoas, Maceió - Ponta do Meirim reef UFAL/ECH 0518; Ponta Verde reef UFAL/ECH 0089, 0102, 0118, 0164, 0270, 0301, 0325, 0372, 0403, 0404, 0460, 0461, 0552, 0603. Sobral sewel outfall UFAL/ECH 0114, 0585. Jequiá da Praia - Lagoa Azeda reef UFAL/ECH 0231. Maragogi - Galés reef UFAL/ECH 0106. Marechal Deodoro - Francês reef UFAL/ECH 0343, 0638; Saco da Pedra reef UFAL/ECH 0277, 0305, 0337, 0355.

Ophiactis quinqueradia Ljungman, 1872: four records. Brazil, Alagoas, Maceió - Ponta Verde reef UFAL/ECH 0136, 0255. Marechal Deodoro - Saco da Pedra reef UFAL/ECH 0338. Paripueira - Natural Pool UFAL/ECH 0622.

Ophiactis savignyi (Müller & Troschel, 1842): 129 records. Brazil, Alagoas, Maceió - Ponta do Meirim reef UFAL/ECH 0554, 0557, 0564; Sereia reef UFAL/ECH 0489, 0617, 0631; Riacho Doce reef UFAL/ECH 0447; Garça Torta reef UFAL/ECH 0055; Jatiúca reef UFAL/ECH 0309, 0349, 0430, 0443, 0628; Ponta Verde reef UFAL/ECH 0009, 0013, 0036, 0048, 0058, 0060, 0062, 0065, 0070, 0077, 0079, 0081, 0083, 0085, 0088, 0097, 0099, 0101, 0112, 0113, 0117, 0122, 0128, 0134, 0135, 0138, 0143, 0145, 0148, 0158, 0161, 0163, 0180, 0182, 0184, 0193, 0195, 0198, 0205, 0208, 0211, 0220, 0223, 0239, 0242, 0245, 0256, 0257, 0260, 0263, 0269, 0271, 0285, 0298, 0300, 0321, 0322, 0324, 0327, 0365, 0368, 0371, 0398, 0401, 0402, 0436, 0437, 0438, 0457, 0458, 0459, 0543, 0554, 0581, 0592, 0596, 0604, 0606; Piscina dos Amores reef UFAL/ECH 0486; Pajuçara reef UFAL/ECH 0352, 0382, 0627; Sobral sewel outfall UFAL/ECH 0187, 0413, 0424, 0583, 0584, 0599, 0608, 0634. Maragogi - Galés reef UFAL/ECH 0044, 0168. Marechal Deodoro - Saco da Pedra reef UFAL/ECH 0278, 0306, 0308, 0332, 0339, 0354, 0385, 0449, 0450, 0530; Francês reef UFAL/ECH 0023, 0075, 0227, 0272, 0292, 0304, 0342, 0345, 0377, 0616, 0640. Paripueira - Natural pool UFAL/ECH 0358. Passo de Camaragibe - Camaragibe River bar UFAL/ECH 0582. São Miguel dos Milagres - Porto da Rua reef UFAL/ECH 0177.

Family Amphiuridae Ljungman, 1867

Genus *Amphipholis* Ljungman, 1866

Amphipholis januarii Ljungman, 1866: five records. Brazil, Alagoas, Maceió - Jatiúca reef UFAL/ECH 0429; Ponta Verde UFAL/ECH 0200, 0247. Jequiá da Praia - Lagoa Azeda reef UFAL/ECH 0230. Paripueira - Cabeço UFAL/ECH 0618.

Amphipholis squamata (Delle Chiaje, 1828): 96 records. Brazil, Alagoas, Maceió - Ponta do Prego reef UFAL/ECH 0550; Ponta do Meirim reef UFAL/ECH 0520, 0558; Sereia reef UFAL/ECH 0490, 0629; Riacho Doce reef UFAL/ECH 0104; Jatiúca reef UFAL/ECH 0347, 0513; Pajuçara reef UFAL/ECH 0032, 0076; Ponta Verde reef UFAL/ECH 0008, 0014, 0059, 0061, 0063, 0069, 0071, 0078, 0080, 0082, 0084, 0086, 0090, 0098, 0100, 0103, 0115, 0116, 0119, 0144, 0146, 0149, 0159, 0162, 0165, 0173, 0181, 0183, 0185, 0194, 0196, 0199, 0206, 0209, 0212, 0221, 0222, 0224, 0240, 0243, 0246, 0258, 0261, 0264, 0284, 0286, 0297, 0299, 0302, 0323, 0326, 0328, 0366, 0369, 0373, 0405, 0406, 0407, 0439, 0440, 0441, 0462, 0463, 0464, 0501, 0512, 0555, 0556, 0580, 0590, 0595, 0597, 0602, 0605; Sobral sewel outfall UFAL/ECH 0414, 0423, 0427, 0598, 0607, 0635. Maragogi - Galés reef UFAL/ECH 0169. Marechal Deodoro - Saco da Pedra reef UFAL/ECH 0336, 0357; Francês reef UFAL/ECH 0341, 0637. Paripueira - Natural Pool UFAL/ECH 0619.

Genus *Amphiura* Forbes, 1843

Amphiura kinbergi Ljungman, 1872: one record. Brazil, Alagoas, Maceió - Sobral sewel outfall UFAL/ECH 0576.

Genus *Ophiocnida* Lyman, 1865

Ophiocnida loveni (Ljungman, 1867): one record. Brazil, Alagoas, Maceió - Jatiúca reef UFAL/ECH 0275.

Ophiocnida scabriuscula (Lütken, 1859): four records. Brazil, Alagoas, Maceió - Ponta do Meirim reef UFAL/ECH 0514; Jatiúca reef UFAL/ECH 0252; Ponta Verde reef UFAL/ECH 0215, 0266.

Family Ophiotrichidae Ljungman, 1867

Genus *Ophiothrix* Müller & Troschel, 1840

Ophiothrix angulata (Say, 1825): 60 records. Brazil, Alagoas, Maceió - Ponta do Prego reef UFAL/ECH 0538, 0551; Sereia reef UFAL/ECH 0471, 0496, 0532, 0562, 0632; Riacho Doce reef UFAL/ECH 0561; Garça Torta reef UFAL/ECH 0052; Guaxuma reef UFAL/ECH 0499; Jatiúca reef UFAL/ECH 0167, 0251, 0276, 0426; Ponta Verde reef UFAL/ECH 0001, 0002, 0017, 0035, 0188, 0207, 0214, 0226, 0288, 0320, 0330, 0375, 0410, 0466, 0600, 0601; Piscina dos Amores reef UFAL/ECH 0421; Pajuçara reef UFAL/ECH 0420, 0508; Sobral sewel outfall UFAL/ECH 0056, 0425, 0467. Barra de São Miguel - Barra de São Miguel reef UFAL/ECH 0033. Coruripe - Pontal de Coruripe reef UFAL/ECH 0525. Jequiá da Praia - Lagoa Azeda reef UFAL/ECH 0229. Marechal Deodoro - Manguaba lagoon channel UFAL/ECH 0004; Saco da Pedra reef UFAL/ECH 0279, 0307, 0333, 0335, 0353, 0356, 0384, 0388, 0448, 0481; Francês reef UFAL/ECH 0024, 0074, 0268, 0340, 0378, 0386, 0419, 0633. Paripueira - Natural Pool UFAL/ECH 0621. São Miguel dos Milagres - Porto da Rua reef UFAL/ECH 0178 (Figure 2d).

The class Holothuroidea has 1,214 individuals recorded, distributed in eight families and 14 species. *Synaptula hydriformis* is the most abundant species (Table 2).

Class Holothuroidea

Order Dendrochirotida Grube, 1840

Family Psolidae Perrier, 1902

Genus *Lissothuria* Verrill, 1867

Lissothuria braziliensis (Théel, 1886): one record. Brazil, Alagoas, Maceió - Ipioca reef UFAL/ECH 0575.

Family Phyllophoridae Oestergren, 1907

Genus *Phyllophorus* Grube, 1840

Phyllophorus (*Urodemella*) *occidentalis* Ludwig, 1875: six records. Brazil, Alagoas, Maceió - Ponta do Prego reef UFAL/ECH 0539; Riacho Doce reef UFAL/ECH 0394, 0507; Ponta Verde reef UFAL/ECH 0311; Pajuçara reef UFAL/ECH 0020, 0043.

Table 2. Species of class Holothuroidea catalogued in the Echinodermata collection of the Setor de Comunidades Bentônicas, Universidade Federal de Alagoas (UFAL/ECH).

Taxa	Ind.	Records	Substrate
Family Psolidae			
Lissothuria braziliensis	1	1	Coral reef
Family Phyllophoridae			
Phyllophorus (*Urodemella*) *occidentalis*	16	6	Coral reef
Stolus cognatus	6	4	Coral reef
Family Sclerodactylidae			
Pseudothyone belli	1	1	Algae
Family Cucumariidae			
Aslia pygmaea	2	2	Coral reef and algae
Duasmodactyla seguroensis	16	8	Coral reef
Ocnus braziliensis	62	20	Coral reef, sandstone reef
Ocnus suspectus	4	4	Coral reef, sandstone reef
Family Holothuriidae			
Holothuria (*Halodeima*) *grisea*	27	15	Coral reef, sandstone reef
Holothuria (Platyperona) parvula	2	2	Coral reef
Holothuria (*Thymiosycia*) *arenicola*	2	1	Coral reef, sandstone reef
Family Stichopodidae			
Isostichopus badionotus	2	2	Sandstone reef
Family Synaptidae			
Synaptula hydriformis	968	40	Algae
Family Chiridotidae			
Chiridota rotifera	105	35	Coral reef, algae
Total	1.214	141	

Genus *Stolus* Selenka, 1867

Stolus cognatus (Lampert, 1885): four records: Brazil, Alagoas, Maceió - Riacho Doce reef UFAL/ECH 0393, 0612; Jatiúca reef UFAL/ECH 0250, 0274 (Figure 3a).

Family Sclerodactylidae Panning, 1949

Genus *Pseudothyone* Panning, 1949

Pseudothyone belli (Ludwig, 1887): one record: Brazil, Alagoas, Maceió - Ponta do Meirim reef UFAL/ECH 0589.

Family Cucumariidae Ludwig, 1894

Genus *Aslia* Rowe, 1970

Aslia pygmaea (Théel, 1886a):two records. Brazil, Alagoas, Maceió - Sereia reef UFAL/ECH 0609, 0630.

Genus *Duasmodactyla* Ayres, 1854

Duasmodactyla seguroensis (Deichmann, 1930): eight records. Brazil, Alagoas, Maceió - Ponta do Prego reef UFAL/ECH 0446; Riacho Doce reef UFAL/ECH 0392, 0418, 0422, 0613; Jatiúca reef UFAL/ECH 0273; Ponta Verde reef UFAL/ECH 0040, 0232.

Genus *Ocnus* Forbes, 1841

Ocnus braziliensis (Verril, 1868): 20 records. Brazil, Alagoas, Maceió - Sereia reef UFAL/ECH 0494, 0536; Riacho Doce reef UFAL/ECH 0141, 0415, 0504; Garça Torta reef UFAL/ECH 0050; Jatiúca reef UFAL/ECH 0510; Ponta Verde reef UFAL/ECH 0022, 0039, 0053, 0121, 0126, 0395; Pajuçara reef UFAL/ECH 0012, 0029, 0042, 0045, 0046. Marechal Deodoro - Saco da Pedra reef UFAL/ECH 0383. Passo de Camaragibe - Camaragibe river bar UFAL/ECH 0350 (Figure 3b).

Ocnus suspectus (Ludwig, 1874): four records. Brazil, Alagoas, Maceió - Sereia reef UFAL/ECH 0495; Riacho Doce reef UFAL/ECH 0506, 0611; Ponta Verde reef UFAL/ECH 0586.

Order Aspichirotida Grube, 1840

Family Holothuriidae Ludwig, 1894

Genus *Holothuria* Linnaeus, 1767

Holothuria (*Halodeima*) *grisea* Selenka, 1867: 15 records. Brazil, Alagoas, Maceió - Sereia reef UFAL/ECH 0469, 0493; Riacho Doce reef UFAL/ECH 0391, 0505; Garça Torta reef UFAL/ECH 0049; Jatiúca reef UFAL/ECH 0348; Ponta Verde reef UFAL/ECH 0038, 0041, 0140; Pajuçara reef UFAL/ECH 0011, 0018, 0019, 0021, 0359. Marechal Deodoro - Saco da Pedra reef UFAL/ECH 0479 (Figure 3c).

Holothuria (Platyperona) parvula (Selenka, 1867): two records. Brazil, Alagoas, Maceió - Riacho Doce reef UFAL/ECH 0610; Ponta Verde reef UFAL/ECH 0487.

Holothuria (*Thymiosycia*) *arenicola* Semper, 1868; one record. Brazil, Alagoas, Marechal Deodoro - Francês reef UFAL/ECH 0474.

Family Stichopodidae Haeckel, 1896

Genus *Isostichopus* Deichmann, 1958

Isostichopus badionotus (Selenka, 1867): two records. Brazil Alagoas, Marechal Deodoro - Francês reef UFAL/ECH 0344, 0531.

Order Apodida Brandt, 1835

Figure 3. Species of class Holothuroidea from the Echinodermata collection in the Setor de Comunidades Bentônicas, Universidade Federal de Alagoas (UFAL/ECH): a) *Stolus cognatus,* b) *Ocnus braziliensis*, c) *Holothuria grisea* and d) *Synaptula hydriformis*.

Family Synaptidae Burmeister, 1837

Genus *Synaptula* Oersted, 1849

Synaptula hydriformis (Lesueur, 1824): 40 records. Brazil, Alagoas, Maceió - Ponta do Meirim reef UFAL/ECH 0545; Riacho Doce reef UFAL/ECH 0073; Ponta Verde reef UFAL/ECH 0006, 0015, 0057, 0094, 0111, 0132, 0155, 0174, 0179, 0191, 0203, 0204, 0217, 0218, 0236, 0237, 0253, 0254, 0281, 0282, 0294, 0295, 0296, 0317, 0318, 0362, 0363, 0396, 0399, 0416, 0433, 0434, 0455, 0456, 0500, 0588, 0591, 0594 (Figure 3d).

Family Chiridotidae Oestergren, 1898

Genus *Chiridota* Eschscholtz, 1829

Chiridota rotifera (Pourtalès, 1851): 35 records. Brazil, Alagoas, Maceió - Ponta do Prego reef UFAL/ECH 0477; Garça Torta reef UFAL/ECH 0051; Ponta Verde reef UFAL/ECH 0007, 0095, 0154, 0156, 0171, 0176, 0189, 0190, 0192, 0202, 0216, 0219, 0234, 0235, 0238, 0280, 0283, 0293, 0315, 0316, 0319, 0361, 0364, 0397, 0400, 0417, 0431, 0432, 0435, 0454, 0476, 0502, 0503.

The class Echinoidea is represented by 97 individuals, including five families and eight species. The most abundant Echinoidea species are *Echinometra lucunter*, *Eucidaris tribuloides* and *Lytechinus variegatus* (Table 3).

Class Echinoidea

Order Cidaroida Claus, 1880

Family Cidaridae Gray, 1825

Genus *Eucidaris* Pomel, 1883

Eucidaris tribuloides (Lamarck, 1816): five records. Brazil, Alagoas, Maceió - Guaxuma reef UFAL/ECH 0498; Ponta Verde UFAL/ECH 0026. Barra de São Miguel - Barra de São Miguel reef UFAL/ECH 0030. Jequiá da Praia - Lagoa Azeda reef UFAL/ECH 0568, 0570 (Figure 4a).

Ordem Diadematoida Duncan, 1889

Family Diadematidae Gray, 1855

Genus *Diadema* Gray, 1825

Diadema antillarum Philippi, 1845: one record. Brazil, Alagoas, Barra de São Miguel - Barra de São Miguel reef UFAL/ECH 0034 (Figure 4b).

Order Echinoida Claus, 1876

Family Echinometridae Gray, 1825

Genus *Echinometra* Gray, 1825

Echinometra lucunter (Linnaeus, 1758): 10 records. Brazil, Alagoas, Maceió - Sereia reef UFAL/ECH 0491; Ponta Verde reef UFAL/ECH 0123, 0137, 0151, 0170, 0312, 0451; Piscina dos Amores reef UFAL/ECH 0290, 0484. Marechal Deodoro - Saco da Pedra reef UFAL/ECH 0310 (Figure 4c).

Family Toxopneustidae Troschel, 1872

Genus *Lytechinus* A. Agassiz, 1863

Lytechinus variegatus (Lamarck, 1816): 13 records. Brazil, Alagoas, Maceió - Jatiúca reef UFAL/ECH 0129; Ponta Verde reef UFAL/ECH 0027, 0139, 0152, 0153, 0233, 0313, 0314, 0360, 0452; Piscina dos Amores reef UFAL/ECH 0289. Barra de São Miguel - Barra de São Miguel reef UFAL/ECH 0031. Jequiá da Praia - Lagoa Azeda reef UFAL/ECH 0569 (Figure 4d).

Genus *Tripneustes* L. Agassiz, 1841b

Tripneustes ventricosus (Lamarck, 1816): seven records. Brazil, Alagoas, Maceió - Ponta do Prego reef UFAL/ECH 0548; Sereia reef UFAL/ECH 0468, 0488, 0567; Jatiúca reef UFAL/ECH 0346, 0428, 0482 (Figure 4e).

Order Clypeasteroida L. Agassiz, 1835

Family Mellitidae Stefanini, 1912

Genus *Encope* L. Agassiz, 1840

Encope emarginata (Leske, 1778): two records. Brazil, Alagoas, Maceió - Ponta do Prego reef UFAL/ECH 0444. Marechal Deodoro - Francês reef UFAL/ECH 0473 (Figure 4f).

Genus *Leodia* Gray, 1851a

Leodia sexiesperforata (Leske, 1778): one record. Brazil, Alagoas, Marechal Deodoro -Francês reef UFAL/ECH 0565.

Genus *Mellita* L. Agassiz, 1841a

Mellita quinquesperforata (Leske, 1778): two records. Brazil, Alagoas, Maceió - Ponta do Meirim reef UFAL/ECH 0515. Coruripe - Lagoa do Pau UFAL/ECH 0524.

The class Asteroidea is represented by 46 individuals, including five families and eight species. *Luidia senegalensis* and *Linckia guildingi* are the most abundant species (Table 4).

Class Asteroidea

Table 3. Species of class Echinoidea catalogued in the Echinodermata collection of the Setor de Comunidades Bentônicas, Universidade Federal de Alagoas (UFAL/ECH).

Taxa	Ind.	Records	Substrate
Family Cidaridae			
Eucidaris tribuloides	33	5	Coral reef, sandstone reef
Family Diadematidae			
Diadema antillarum	1	1	Coral reef, sandstone reef
Family Echinometridae			
Echinometra lucunter	10	10	Coral reef, sandstone reef
Family Toxopneustidae			
Lytechinus variegatus	36	13	Coral reef, algae, mud
Tripneustes ventricosus	7	7	Coral reef, sandstone reef
Family Mellitidae			
Encope emarginata	6	2	Coral reef, soft bottom
Leodia sexiesperforata	1	1	Coral reef, soft bottom
Mellita quinquesperforata	3	2	Coral reef, soft bottom
Total	97	41	

Figure 4. Species of class Echinoidea from the Echinodermata collection in the Setor de Comunidades Bentônicas, Universidade Federal de Alagoas (UFAL/ECH): a) *Eucidaris tribuloides*, b) *Diademma antillarum*, c) *Echinometra lucunter*, d) *Lytechinus variegatus*, e) *Tripneustes ventricosus* and f) *Encope emarginata*.

Order Paxillosida Perrier, 1884

Family Luidiidae Sladen, 1889

Genus *Luidia* Forbes, 1839

Luidia senegalensis (Lamarck, 1816): three records. Brazil, Alagoas, Jequiá da Praia - Lagoa Azeda reef UFAL/ECH 0572, 0573, 0578.

Luidia alternata (Say, 1825): one record. Brazil, Alagoas, Jequiá da Praia - Lagoa Azeda reef UFAL/ECH 0577.

Family Astropectinidae Gray, 1840

Genus *Astropecten* Gray, 1840

Astropecten brasiliensis Müller & Troschel, 1842: one record. Brazil, Alagoas, Jequiá da Praia - Lagoa Azeda reef UFAL/ECH 0571.

Order Valvatida Perrier, 1884

Family Oreasteridae Fisher, 1911

Genus *Oreaster* Müller & Troschel, 1842

Oreaster reticulatus (Linnaeus, 1758): one record. Brazil, Alagoas, Jequiá da Praia - Lagoa Azeda reef UFAL/ECH 0566.

Family Ophidiasteridae Verril, 1870

Genus *Linckia* Nardo, 1834

Linckia guildingi Gray, 1840: 12 records. Brazil, Alagoas, Maceió - Ponta do Prego reef UFAL/ECH 0445, 0523; Sereia reef UFAL/ECH 0492; Jatiúca reef UFAL/ECH 0130, 0509; Ponta Verde reef UFAL/ECH 0028, 0124, 0131; Piscina dos Amores reef UFAL/ECH 0125, 0522; Pajuçara reef UFAL/ECH 0010; Paripueira - Natural Pool UFAL/ECH 0047 (Figure 5a).

Genus *Narcissia* Gray, 1840

Narcissia trigonaria Sladen, 1889: one record. Brazil, Alagoas, Jequiá da Praia - Lagoa Azeda reef UFAL/ECH 0579.

Order Spinulosida Perrier, 1884

Family Echinasteridae Verril, 1870

Genus *Echinaster* Müller & Troschel, 1840

Echinaster brasiliensis Müller & Troschel, 1842: three records. Brazil Alagoas, Maceió - Ponta Verde reef UFAL/ECH 0093, 0096. Jequiá da Praia - Lagoa Azeda reef UFAL/ECH 0574.

Echinaster echinophorus (Lamarck, 1816): four records. Brazil, Alagoas, Maceió - Jatiúca reef UFAL/ECH 0483; Ponta Verde reef UFAL/ECH 0092, 0453. Piaçabuçu - Pontal do Peba reef UFAL/ECH 0054 (Figure 5b).

The class Crinoidea is represented by only seven individuals in this collection, all *Tropiometra carinata* (Table 5).

Class Crinoidea

Order Isocrinida Sieverts-Doreck, 1952

Table 4. Species of class Asteroidea catalogued in the Echinodermata collection of the Setor de Comunidades Bentônicas, Universidade Federal de Alagoas (UFAL/ECH).

Taxa	Ind.	Records	Substrate
Family Luidiidae			
Luidia senegalensis	16	3	Soft bottom
Luidia alternata	1	1	Soft bottom
Family Astropectinidae			
Astropecten brasiliensis	1	1	Soft bottom
Family Oreasteridae			
Oreaster reticulatus	1	1	Soft bottom
Family Ophidiasteridae			
Linckia guildingi	13	12	Recife de coral, sandstone reef
Narcissia trigonaria	2	1	soft bottom
Family Echinasteridae			
Echinaster brasiliensis	8	3	Coral reef, sandstone reef, soft bottom
Echinaster echinophorus	4	4	Coral reef, sandstone reef
Total	46	26	

Table 5. Species of class Crinoidea catalogued in the Echinodermata collection of the Setor de Comunidades Bentônicas, Universidade Federal de Alagoas (UFAL/ECH).

Taxa	Ind.	Records	Substrate
Family Tropiometridae			
Tropiometra carinata	7	7	Coral reef, sandstone reef
Total	7	7	

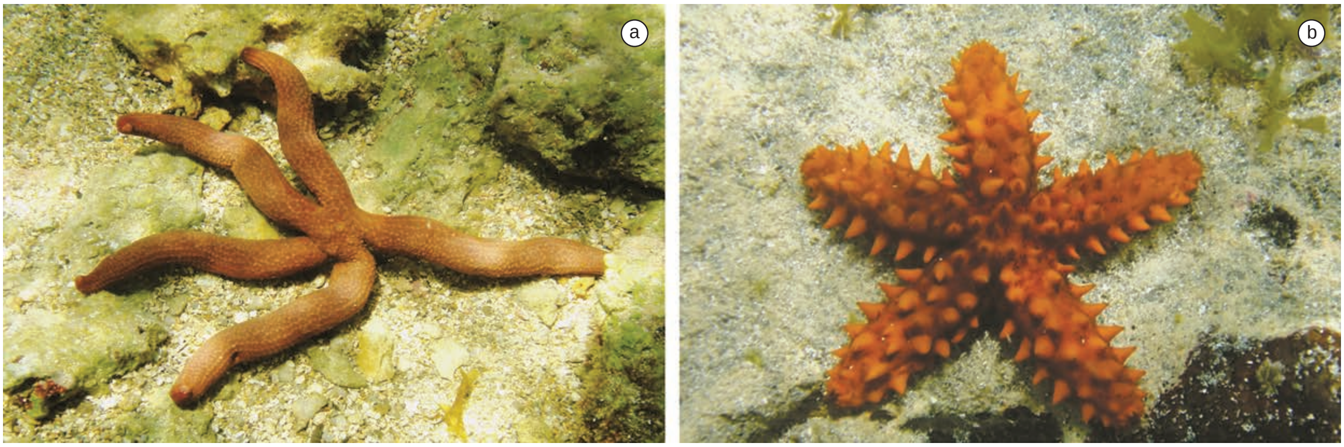

Figure 5. Species of class Asteroidea from the Echinodermata collection in the Setor de Comunidades Bentônicas, Universidade Federal de Alagoas (UFAL/ECH): a) *Linckia guildingi* and b) *Echinaster echinophorus*.

Figure 6. *Tropiometra carinata*, representative of the class Crinoidea in the Echinodermata collection in the Setor de Comunidades Bentônicas, Universidade Federal de Alagoas (UFAL/ECH).

Family Tropiometridae A.H. Clark, 1908

Genus *Tropiometra* A.H. Clark, 1907

Tropiometra carinata (Lamarck, 1816): seven records. Brazil, Alagoas, Maceió - Ponta do Meirim reef UFAL/ECH 0521; Guaxuma reef UFAL/ECH 0540; Pajuçara reef UFAL/ECH 0003, 0005. Marechal Deodoro - Saco da Pedra reef UFAL/ECH 0351; Francês reef UFAL/ECH 0379, 0472 (Figure 6).

Discussion

In this collection, the class Ophiuroidea is the most abundant with 19 taxa, including *Ophiactis savignyi* and *Amphipholis squamata* with the most records. According to Borges et al. (2011), the ophiuroids are the most diverse and frequently abundant group among the echinoderms, living associated with several types of substrata including sand, algae, mud and rubble, or associated with biological substrata such as corals, sponges and polychaete tubes. Numerical and taxa abundance of the class Ophiuroidea was also observed in the echinoderm fauna associated with several types of substrata from the Bahia coast (Magalhães et al. 2005, Borges & Amaral 2006, Manso et al. 2008).

Holothuroidea is the second best-represented class in abundance and taxonomic richness. This group was considered the least studied class in the South Atlantic (Hadel et al. 1999). *Holothuria grisea* is very common, and was reported as the most frequent and numerous holothuroid on the Brazilian coast (Tommasi, 1969, 1999). The most numerous species of this class in the collection is *S. hydriformis*, principally from phytal communities. According to Clark (1908), this species is viviparous and occurs in association with several species of macroalgae.

Several species in the present collection, including the sea cucumber *Isostichopus badionotus*, the sea urchin *Eucidaris tribuloides*, and the sea stars *Echinaster brasiliensis*, *Luidia senegalensis*, *Echinaster echinophorus* and *Narcissia trigonaria*, are considered endangered in some localities on the southeastern Brazilian coast (Hadel et al. 1999, Ventura et al. 2009).

Other catalogues report more specimens and taxa of the classes Echinoidea and Asteroidea than the classes Ophiuroidea and Holothuroidea (Alves & Cerqueira 2000, Lima & Fernandes 2009, Oliveira et al. 2010, Xavier 2010). However, the dominance of these groups is associated with the types of substrates where these species can be found (Gondim et al. 2008). Substrates composed of algae, marine grasses, sponges, and other sessile organisms also contribute to increasing the abundance and richness of the echinoderm fauna (Hendler et al. 1995). The variety of types of substrates where the specimens were collected contributed to increasing the abundance and richness of the species listed in this catalogue, mainly of the classes Ophiuroidea and Holothuroidea.

Conclusion

This inventory of the phylum Echinodermata collection in the Setor de Comunidades Bentônicas, Universidade Federal de Alagoas, illustrates the diversity of this group in the benthic fauna on the coast of Alagoas. The present catalogue contains 50 species, with 640 records and 16,201 individuals, including 19 species of Ophiuroidea, 14 Holothuroidea, 8 Echinoidea, 8 Asteroidea, and one Crinoidea. This collection is an important reference tool for current and future studies of the marine biodiversity of the phylum Echinodermata from the state of Alagoas and the Brazilian northeastern coast.

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References

ABSALÃO, R.S. & MANSO, C.L.C. 1990. Influência da convergencia subtropical na fauna de ofiuróides da costa sul do Brasil. In Simpósio de Ecossistemas da Costa Sul e Sudeste Brasileira. ACIESP, São Paulo, v.1, p.215-223.

ALBUQUERQUE, M.N. 1986. Ophiuroidea Gray, 1840 (Echinodermata) da plataforma continental do Norte e Nordeste do Brasil. Tese de Doutorado, Universidade de São Paulo, São Paulo.

ALVES, O.F.S. & CERQUEIRA, W.R.P. 2000. Echinodermata das praias de Salvador (Bahia, Brasil). Rev. Bras. Zool. 17(2):543-553. http://dx.doi.org/10.1590/S0101-81752000000200024

AMARAL, A.C.Z & JABLONSKI, S. 2005. Conservação da Biodiversidade marinha e costeira do Brasil. Megadiversidade. 1(1):43-51.

BORGES, M., MONTEIRO, A.M.G. & AMARAL, A.C.Z. 2002. Taxonomy of Ophiuroidea (Echinodermata) from the continental shelf and slope of the southern and southeastern Brazilian Coast. Biota Neotrop. 2(2): http://www.biotaneotropica.org.br/v2n2/pt/download?article+BN02302022002+abstract (último acesso em 19/12/2011)

BORGES, M. & AMARAL, A.C.Z. 2006. Filo Echinodermata: Classe Ophiuroidea. In Manual de Identificação dos Invertebrados Marinhos da Região Sudeste-sul do Brasil (A.C.Z. Amaral, A.E. Rizzo & E.P. Arruda, eds.). Editora da Universidade de São Paulo, São Paulo, p.235-272.

BORGES, M., YOKOYAMA, L.Q. & AMARAL, A.C.Z. 2011. Ophiuroidea. In Biodiversidade e ecossistemas bentônicos marinhos do litoral Norte de São Paulo Sudeste do Brasil (A.C.Z. Amaral & S.A.H. Nallin, eds.) http://www.ib.unicamp.br/biblioteca/pubdigitais (último acesso em 14.02.2012)

BRITO, I.M. 1962. Ensaio de catálogo dos equinodermas do Brasil. Avulso - Cent. Estud. Zool. Univ. Bras. 13(1):1-4.

CASTRO, C.B., ECHEVERRÍA, C.A., PIRES, D.O. & FONSECA, C.G. 1999. Distribuição do bentos (Cnidaria e Echinodermata) em costões rochosos da baía da Ilha Grande, Rio de Janeiro, Brasil. In Ecologia dos ambientes costeiros do Estado do Rio de Janeiro (S.H.G. Silva & H.P. Lavrado, eds.). PPGE-UFRJ, Rio de Janeiro, v.7, p.179-193. Série Oecologia Brasiliensis.

CLARK, H.L. 1908. The apodous holothurians; a monograph of the Synaptidae and Molpadiidae, including a report on the representatives of these families in the collections of the United States National Museum. Smithson. Contrib. Knowledge. 35:1-231.

CLARK, A.M. & DOWNEY, M.E. 1992. Starfishes of the Atlantic. Chapman & Hall, London.

CORREIA, M.D. 2011. Scleractinian corals (Cnidaria: Anthozoa) from reef ecosystems on the Alagoas coast, Brazil. J. Mar. Biol. Assoc. U.K. 91(3):659-668. http://dx.doi.org/10.1017/S0025315410000858

CORREIA, M.D. & SOVIERZOSKI, H.H. 2009. Ecossistemas Costeiros de Alagoas - Brasil. Technical Books Editora, Rio de Janeiro.

GONDIM, A.I., LACOUTH, P., ALONSO, C. & MANSO, C.L.C. 2008. Echinodermata da Praia do Cabo Branco, João Pessoa, Paraíba, Brasil. Biota Neotrop. 8(2): http://www.biotaneotropica.org.br/v8n2/pt/abstract?inventory+bn02408022008 (último acesso em 19/12/2011).

HADEL, V.F., MONTEIRO, A.M.G., DITADI, A.S.F., TIAGO, C.G. & TOMMASI, L.R. 1999. Filo Echinodermata. In Biodiversidade do Estado de São Paulo, Brasil – Invertebrados Marinhos (A.E. Migotto & C.G. Tiago, eds.). FAPESP, São Paulo, v.3, p.259-271.

HENDLER, G., MILLER, J.E., PAWSON, D.L. & KIER, P.M. 1995. Echinoderms of Florida and Caribbean: Sea Stars, Sea Urchins and allies. Smithsonian Institution Press, Washington.

KRAU, L. 1950. Observações sobre os Echinodermas da Baía de Guanabara. Mem. Inst. Oswaldo Cruz 48(1):357-362.

LIMA, E.J.B. & FERNANDES, M.L.B. 2009. Diversidade de equinodermos (Echinodermata) no Estado de Pernambuco, Brasil. Rev. Bras. Zoocienc. 11(1):55-63.

LIMA, M.L.F., CORREIA, M.D., SOVIERZOSKI, H.H. & MANSO, C.L.C. 2011 New records of Ophiuroidea (Echinodermata) from shallow waters off Maceió, Alagoas, Brazil. Mar. Biodivers. Rec. 4:1-10.

LIMA-VERDE, J.C. 1969. Primeira contribuição ao inventário dos equinodermas do nordeste brasileiro. Arq. Cienc. Mar. 9(1):9-13.

MAGALHÃES, W.F., MARTINS, L.R. & ALVES, O.F.S. 2005. Inventário dos Echinodermata do Estado da Bahia. Braz. J. Aquat. Sci. Tech. 9(1):59-63.

MANSO, C.L.C. 1989. Os Echinodermata da plataforma continental interna entre Cabo Frio e Saquarema, Rio de Janeiro, Brasil. Rev. Bras. Biol. 49(2):355-359.

MANSO, C.L.C. 1991. Ophiuroidea (Echinodermata) da região Sul-Sudeste do Brasil coletados durante as operações do N/Oc "Almirante Saldanha". Dissertação de Mestrado, Universidade Federal do Paraná, Curitiba.

MANSO, C.L.C., ALVES, O.F.S. & MARTINS, L.R. 2008. Echinodermata da Baía de Todos os Santos e Baía de Aratu (Bahia, Brasil). Biota Neotrop. 8(3): http://www.biotaneotropica.org.br/v8n3/en/abstract?article+bn02208032008 (último acesso em 19/12/2011)

MARTINS, I.X. & QUEIROZ, A.C.M. 2006. Echinodermos do litoral do Estado do Ceará. In Biota marinha da costa oeste do Ceará (H. Matthews-Cascon & T.M.C. Lotufo, eds.). MMA, Brasília, v.24, p.199-220.

MIKKELSEN, P.M. & CRACRAFT, J. 2001. Marine biodiversity and the need for systematic inventories. Bull. Mar. Sci. 69(2):525-534.

MONTEIRO, A.M.C. 1987. Ophiuroidea (Echinodermata) da região de Ubatuba (SP) - Aspectos Morfológicos e Ecológicos. Tese de Doutorado, Universidade de São Paulo, São Paulo.

NETTO, L.F., HADEL, V.F. & TIAGO, C.G. 2005. Echinodermata from São Sebastião Channel (São Paulo, Brazil). Rev. Biol. Trop. 53(3):207-218.

NOGUEIRA, C., VALDUJO, P.H., PAESE, A., RAMOS NETO, M.B. & MACHADO, R.B. 2009. Desafios para identificação de áreas para conservação da biodiversidade. Megadiversidade 5(1-2):43-53.

OLIVEIRA, J.P., OLIVEIRA, J. & MANSO, C.L.C. 2010. Inventário da coleção de equinodermos do LABIMAR, Campus Prof° Alberto Carvalho, Universidade Federal de Sergipe. Scientia Plena 6(12):1-14.

PAWSON, D.L., PAWSON, D.J. & KING, R.A. 2010. A taxonomic guide to the Echinodermata of the South Atlantic Bight, USA: 1. Sea cucumbers (Echinodermata: Holothuroidea). Zootaxa 2449:1-48.

RATHBUN, R. 1879. A List of the Brazilian Echinoderms, with notes on their distribution, etc. Trans. Conn. Acad. Arts Sci. 5(3):139-151.

TOMMASI, L.R. 1969. Lista dos Holothuroidea recentes do Brasil. Contrib. avulsas Inst. Oceanogr., Oceanogr. Biol. 15:1-50.

TOMMASI, L.R. 1970. Os ofiuróides recentes do Brasil e de regiões vizinhas. Contrib. avulsas Inst. Oceanogr., Oceanogr. Biol. 20:1-16.

TOMMASI, L.R. 1985. Equinodermes da região da Ilha Vitória (SP). Bol. Inst. Oceanogr. 13:1-5.

TOMMASI, L.R. 1999. Echinodermata marinhos registrados no litoral brasileiro, recentes e fósseis do Brasil. http://www.bdt.org.br/zoologia/echinodermata/124pp (último acesso em 12/04/2007).

TOMMASI, L.R. & ABREU, J. 1974. Equinodermes do Brasil. IV. Sobre seis espécies novas de Ophiuroidea da região ao largo da Ilha Grande (RJ). Bol. Inst. Oceanogr. 23:17-32.

VENTURA, C.R.R., VERÍSSIMO, I., LIMA, R.N.P., BARCELLOS, C.F. & OIGMAN-PSZCZOL, S.S. 2007. Echinodermata In Biodiversidade Marinha da Baía da Ilha Grande (J.C. Creed, D.O. Pires & M.A.O. Figueiredo, orgs.). MMA, Brasília, p. 271-290.

VENTURA, C.R.R., CERQUEIRA, W.R.P., COSTA-LOTUFO, L.V., FREIRE, C.A.O., HADEL, V.F., MANSO, C.L.C., MONTEIRO, A.M.G., SILVA, J.R.M.C. & TIAGO, C.G. 2009. Echinodermata. In Estado da Arte e Perspectivas para a Zoologia no Brasil (R.M. Rocha & W.A. Boeger, eds). UFPR, Curitiba, v.1, p.183-201.

VERRILL, A.E. 1868. Notes on the Radiata in the Museum of Yale College; 4 - Notice of coral and echinoderms collected by Prof. C. F. Hartt at the Abrolhos Reefs province of Bahia, Brazil. Trans. Conn. Acad. Arts Sci. 1:351-371.

XAVIER, L.A.R. 2010. Inventário dos equinodermos do Estado de Santa Catarina, Brasil. Braz. J. Aquat. Sci. Tech. 14(2):73-78.

ZAHER, H. & YOUNG, P.S. 2003. As coleções zoológicas brasileiras: panorama e desafios. Cienc. Cult. 55(3):24-26.

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Borboletas (Lepidoptera: Hesperioidea e Papilionoidea) de Val de Serra, região central do Rio Grande do Sul, Brasil

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MORAIS, A.B.B., LEMES, R. & RITTER, C.D. **Butterflies (Lepidoptera: Papilionoidea) from Val de Serra, central region of Rio Grande do Sul State, Brazil**. Biota Neotrop. 12(2): http://www.biotaneotropica.org.br/v12n2/en/abstract?inventory+bn01412022012

Abstract: The butterfly fauna of the Atlantic Forest Biome is reasonably well-known up to the southern limit of its distribution. However, there are knowledge gaps nearby the central region of Rio Grande do Sul State, whose forest areas are considered priorities for biological conservation. This study investigated the butterfly assemblage of a riparian fragment in an ecotone area between Mixed Ombrophilous Forest and Seasonal Decidous Forest, in Itaara municipality. From September 2005 to September 2006, after 105 net-hours through active search sampling, 877 butterflies were registered representing 104 species. Three more species were registered posteriorly, increasing total richness to 107. The most abundant species were the Nymphalidae *Hermeuptychia hermes* (Fabricius, 1775), *Yphthimoides celmis* (Godart, [1824]), *Agraulis vanillae maculosa* (Stichel, [1908]), *Tegosa claudina* (Eschscholtz, 1821) and *Vanessa braziliensis* (Moore, 1883). One new record for the State and four new ones for the central region were registered besides the southern endemic Papilionidae *Euryades corethrus* (Boisduval, 1836) and the Lycaenidae *Arcas ducalis* (Westwood, 1852), considered indicator of Atlantic forest preserved areas. Due to the representativeness of the registered fauna, it is suggested the increase of conservation efforts in the area and stimulation of new ecological studies with the local biodiversity.

Keywords: *Arcas ducalis, Atlantic Forest, conservation, Euryades corethrus, species richness.*

MORAIS, A.B.B., LEMES, R. & RITTER, C.D. **Borboletas (Lepidoptera: Hesperioidea e Papilionoidea) de Val de Serra, região central do Rio Grande do Sul, Brasil**. Biota Neotrop. 12(2): http://www.biotaneotropica.org.br/v12n2/pt/abstract?inventory+bn01412022012

Resumo: A fauna de borboletas do Bioma Mata Atlântica encontra-se razoavelmente conhecida até o início do limite sul da distribuição do mesmo. No Rio Grande do Sul, entretanto, ainda existem lacunas próximas à região central do estado, cujas áreas florestais são consideradas prioritárias para conservação biológica. Esse trabalho inventariou a assembléia de borboletas de um fragmento de mata ciliar numa região de ecótono entre Floresta Ombrófila Mista e Floresta Estacional Decidual, no município de Itaara. Durante o período de setembro de 2005 a setembro de 2006, num total de 105 horas-rede com uso do método de procura ativa, foram registradas 877 borboletas representando 104 espécies. Com o acréscimo posterior de mais três espécies, a riqueza total elevou-se para 107. As cinco espécies mais abundantes foram os Nymphalidae *Hermeuptychia hermes* (Fabricius, 1775), *Yphthimoides celmis* (Godart, [1824]), *Agraulis vanillae maculosa* (Stichel, [1908]), *Tegosa claudina* (Eschscholtz, 1821) e *Vanessa braziliensis* (Moore, 1883). Foram registradas uma nova espécie para o estado e quatro para a região central, além do Papilionidae sulino endêmico *Euryades corethrus* (Boisduval, 1836) e o Lycaenidae *Arcas ducalis* (Westwood, 1852), considerado indicador de áreas preservadas de Mata Atlântica. Devido à representatividade da fauna registrada, recomenda-se a necessidade de incrementar os esforços para a conservação da área e estimular novos estudos ecológicos com a biodiversidade local.

Palavras-chave: *Arcas ducalis, Mata Atlântica, conservação, Euryades corethrus, riqueza de espécies.*

Introdução

O Bioma Mata Atlântica, outrora considerado uma das maiores formações florestais pluviais da América do Sul, encontra-se atualmente bastante reduzido (ao redor de 11,7% da formação original) e fragmentado (Ribeiro et al. 2009). A biodiversidade desse bioma, considerado um dos mais importantes “hotspots” tropicais globais (Laurance 2009), é constituída por muitas espécies endêmicas dentre vegetais, invertebrados e vertebrados, grandemente ameaçadas pela destruição e conversão de seus hábitats nativos decorrentes das atividades humanas (Ribeiro et al. 2009). A maioria das áreas de proteção da Mata Atlântica está acima de 1.200 m altitude, porém regiões de altitude intermediária, entre 400 m e 1200 m, representam 74% da área de distribuição desse bioma e, apesar do menor número de espécies endêmicas, são consideradas regiões de transição, abrigando grande ”turnover” de espécies graças a sua heterogeneidade ambiental (Tabarelli et al. 2010). No Rio Grande do Sul encontra-se o limite sul brasileiro da distribuição desse bioma e, apesar das estimativas de que tenha restado apenas 7% da cobertura original de vegetação, existem regiões consideradas de importância biológica para conservação, algumas delas constituídas por remanescentes florestais em recuperação, localizados próximos à região central do estado (Brasil 2007).

Borboletas adultas são insetos alados, diurnos, e com muitas espécies bastante coloridas, formando um grupo carismático para a maioria das pessoas. Além disso, possuem grande associação aos seus hábitats em todos os estágios de vida, constituindo-se em potenciais bioindicadores dos mesmos, especialmente nas regiões tropicais detentoras da maior riqueza de espécies (Beccaloni & Gaston 1995, Brown Junior 1997, Freitas et al. 2003, Bonebrake et al. 2010). Devido a sua sistemática relativamente bem resolvida para a maioria dos grupos (Lamas 2008, Wahlbergh et al. 2009, Heikkilä et al. 2012), podem ser usadas em inventários de curto prazo para monitorar mudanças ambientais e também em estudos de diversidade, conservação e manejo de comunidades e ecossistemas (Freitas et al. 2006, Bonebrake et al. 2010).

Apesar do conhecimento sobre a composição e riqueza de borboletas estar bastante avançado em diferentes biomas brasileiros ainda restam lacunas a serem investigadas, mesmo no Bioma Mata Atlântica, considerado o mais inventariado (Santos et al. 2008). Assim, através de estudos de monitoramento ao longo de grande parte da extensão do bioma por mais de 35 anos, foi possível registrar uma riqueza superior a 2100 espécies, distribuída em seis distintas regiões faunísticas (Brown Junior & Freitas 2000a). Os mesmos autores também identificaram regiões com maior riqueza e grupos taxonômicos considerados indicadores de mudanças ambientais e da paisagem assim como algumas espécies raras e ameaçadas (Brown Junior & Freitas 2000a, b). Mesmo assim, com a intensificação de novos estudos, mais espécies vem sendo descobertas e descritas (Freitas et al. 2011 e outras referências ali citadas).

Estudos ecológicos padronizados recentes com a fauna de borboletas do Rio Grande do Sul mostram uma fauna rica, com número de espécies aproximadamente igual a um terço do total registrado para o Brasil, além da presença de algumas espécies indicadoras (Morais et al. 2007). No Bioma Mata Atlântica em particular, esses estudos ainda estão concentrados principalmente em áreas de conservação localizadas na região nordeste do estado, como nas áreas de abrangência das formações de Floresta Ombrófila Densa (Iserhard & Romanowski 2004, Iserhard et al. 2010) e Floresta Ombrófila Mista (incluindo as formações dos Campos de Cima da Serra) (Teston & Corseuil 1999, 2000a, 2002a, Corseuil et al. 2004, Romanowski et al. 2009, Iserhard et al. 2010, Pedrotti et al. 2011, Ritter et al. 2011). Na formação de Floresta Estacional Decidual, destacam-se os estudos de Giovenardi et al. (2008) e Bonfantti et al. (2010) na região norte do estado e Dessuy & Morais (2007) na região central, já no limite com a área de abrangência do Bioma Pampa.

A escassez de unidades de conservação na região central do estado assim como o grau crescente de degradação e ameaça a biodiversidade de seus hábitats característicos (Cechin et al. 2009, Marchiori 2009) torna urgente a intensificação de estudos com fins de fornecer subsídios para elaboração de estratégias e planos para sua conservação. Algumas das áreas florestais em regeneração da região cobrem encostas de morros ou situam-se às margens de cursos de água e encontram-se atualmente sob uma nova grande ameaça que é a mudança da atual legislação do Código Florestal Brasileiro. Lembrando ainda que os hábitats existentes em áreas de matas ciliares podem abrigar fauna significativa de borboletas ainda não totalmente conhecida (Freitas 2010), com a vantagem adicional de serem passíveis de servir como corredores de biodiversidade (Tabarelli et al. 2010). O presente trabalho faz parte de amplo estudo visando inventariar e descrever padrões de ocorrência e distribuição das comunidades de borboletas do Rio Grande do Sul, através de amostragens ecológicas padronizadas, e tem como objetivo caracterizar a fauna de borboletas da região da Barragem de Val de Serra, município de Itaara, região central do estado.

Material e Métodos

1. *Área de estudo*

O estudo foi realizado num fragmento de mata ciliar do Rio Ibicuí-Mirim, (29° 32’ 15” S and 53° 47’ 30” W), adjacente a Barragem Rodolfo da Costa e Silva, mais conhecida como Barragem de Val de Serra, com altitude média de 420 m, próximo ao topo do Planalto Médio, município de Itaara. O clima é classificado como temperado úmido (Maluf 2000), com temperaturas médias anuais entre 16 °C e 18 °C, com verões quentes (média das máximas 28 °C) e invernos frios (média das mínimas entre 8 °C e 10 °C) (Pereira et al. 1989). As precipitações são regulares o ano todo, sem estação seca definida, com índices pluviométricos anuais variando entre 1500 mm a 1750 mm (Pereira et al. 1989). A fisionomia da vegetação local pode ser caracterizada como um ecótono de Floresta Estacional Decidual com elementos de Floresta Ombrófila Mista (Spathelf et al. 2000, Marchiori 2009). A vegetação ciliar encontra-se em estágio sucessional secundário, sendo mais fechada apenas próxima às margens do rio e estando conectada a vegetação arbustiva com predomínio de vassourinhas (Asteraceae) e presença de algumas mirtáceas como *Acca sellowiana* (Berg) Burret (goiabeira do campo). Para mais detalhes sobre a composição florística consultar Marchiori (2009). A faixa estreita de mata ciliar estende-se pelo curso do rio até a área da Reserva Biológica Estadual do Ibicuí Mirim (área de 598,48 ha), localizada em área de menor elevação, já no município vizinho de Santa Maria.

A propriedade onde se localiza a Barragem é administrada pela Companhia Riograndense de Saneamento (CORSAN) e assim possui acesso restrito, por sediar uma das principais fontes de abastecimento de água potável de Santa Maria. No local, entretanto, existe perturbação antrópica decorrente da presença de criação de gado bovino, proveniente de propriedades vizinhas.

2. *Amostragem*

No período de setembro de 2005 a setembro de 2006, foram realizadas sete amostragens bimestrais, nas quais foi feita procura ativa de borboletas com uso de rede entomológica durante o percurso de trilhas padronizadas. As trilhas foram estabelecidas ao longo da vegetação secundária arbustiva e em trechos de mata mais próximos da margem do rio e da escada da queda de água da barragem. As amostragens foram feitas nos horários de maior atividade das borboletas, conforme o protocolo descrito por Paz et al. (2008) e o esforço amostral médio foi de quatro horas-rede entomológica por quatro amostradores por ocasião. Todas as borboletas avistadas foram identificadas, registradas e/ou coletadas e posteriormente liberadas. Quando não era possível a identificação em campo, elas foram acondicionadas em envelopes entomológicos e levadas ao Laboratório de Interações Inseto-Planta da Universidade Federal de Santa Maria para identificação através de bibliografia especializada (Brown Junior 1992, Tyler et al. 1994, De Vries 1987, 1997, Canals 2000, 2003) e/ou consultas a coleções de referência regionais e especialistas. Os exemplares coletados foram montados e depositados na coleção de referência do referido laboratório. A nomenclatura seguiu Lamas (2004) e Mielke (2005).

3. *Análise dos dados*

Foram analisados os valores totais de abundância (N) e riqueza (S) de espécies de borboletas. Também foi construida uma curva de suficiência amostral e calculados os estimadores analíticos de riqueza Michaelis-Menten (MM), Bootstrap, ACE, ICE, Chao 1, Chao 2, Jackknife 1 (Jack 1) e Jackknife 2 (Jack 2) com uso do programa EstimateS 8.0 (Colwell 2007). Posteriormente, tomaram-se como base apenas os valores máximos e mínimos de riqueza estimados obtidos.

Para confirmação de novos registros para a região central e estado foram consultados os trabalhos de Biezanko (1958, 1959a, b, 1960a, b, c, d, e, 1963), Biezanko & Mielke (1973), Link et al. (1977, 1980), Biezanko et al. (1978), Mielke (1980a, b), Teston & Corseuil (1998, 2000a, b, 2001, 2002a, b, 2008a, b, c), Schwartz & Di Mare (2001), Kruger & Silva (2003), Corseuil et al. (2004), Iserhard & Romanowski (2004), Quadros et al. (2004), Marchiori & Romanowski (2006a, b), Teston et al. (2006), Dessuy & Morais (2007), Giovenardi et al. (2008), Paz et al. (2008), Sackis & Morais (2008), Bonfantti et al. (2009), Iserhard et al. (2010), Pedrotti et al. (2011), Ritter et al. (2011), e Rosa et al. (2011).

Resultados e Discussão

Em 105 horas de amostragem, foram registrados 877 indivíduos, pertencentes a 104 espécies (Tabela 1). De acordo com a curva de acúmulo de espécies (Figura 1), com intervalo de confiança de 95%, a assíntota ainda não foi atingida, indicando que um maior esforço de amostragem aumentaria a estimativa da riqueza local de borboletas. De acordo com os estimadores de riqueza calculados, os valores de Chao2 (148,12 ± 17,37) e Jack 2 (165,95 ± 4,19) expressariam melhor a riqueza esperada do local. Posteriormente ao período amostral do presente estudo, foram registradas mais três espécies de borboletas no local (Tabela 1), elevando a riqueza observada para 107, o que representa quase metade da riqueza registrada até o momento para o município vizinho de Santa Maria (Cechin et al. 2009).

Em relação à abundância total de indivíduos, Nymphalidae foi a família mais representativa, (73,7% do total registrado), seguida de Hesperiidae (13,7%), Pieridae (5,9%), Papilionidae (3,5%), Lycaenidae (3,2%) e Riodinidae (1,1%). Em relação à riqueza total de espécies, Nymphalidae também ficou em primeiro lugar em representatividade (49% do total registrado) e Hesperiidae veio a seguir (20,6%), seguida de Lycaenidae (8,8%), Pieridae (7,8%) e Papilionidae e Riodinidae (ambas com 6,9% cada). De modo geral, essa representatividade se assemelha àquela registrada para o estado do Rio Grande do Sul como um todo (Morais et al. 2007), com exceção da menor representatividade de Hesperiidae em relação à riqueza. Essas borboletas são conhecidas pela dificuldade de amostragem, devido a sua raridade e comportamento de vôo rápido e vigoroso, e sua presença pode indicar abundância e regularidade de recursos florais (Brown Junior & Freitas 1999, 2000a).

Nymphalidae é a família mais diversa e com maior número de espécies dentre as borboletas (Lamas 2008), e dentro desse táxon, mais de 75% da abundância total registrada em Val de Serra foram indivíduos das subfamílias Satyrinae, Nymphalinae e Heliconinae. Os Satyrinae constituem o subgrupo mais rico dentro da família, seus adultos possuem dieta frugívora e na maioria usam monocotiledôneas, abundantes em parte da área de estudo, como planta hospedeira (Beccaloni et al. 2008, Marín et al. 2011). Os Heliconiinae são nectarívoros e associados a plantas hospedeiras da família Passifloraceae e os Nymphalinae possuem hábitos variados e podem estar associados a ambientes perturbados (De Vries 1987, Brown Junior & Freitas 1999).

As cinco espécies de borboletas mais abundantes em Val de Serra foram os Nymphalidae Satyrinae *Hermeuptychia hermes* (Fabricius, 1775) (n = 95) e *Yphthimoides celmis* (Godart, [1824]) (n = 79),o Heliconiinae *Agraulis vanillae maculosa* (Stichel, [1908]) (n = 44), e os Nymphalinae *Tegosa claudina* (Eschscholtz, 1821) (n = 42) e *Vanessa braziliensis* (Moore, 1883) (n = 36). Três dessas espécies, *H. hermes*, *Y. celmis e V. braziliensis*, também foram encontradas com relativa abundância em estudos anteriores realizados em fragmentos de Floresta Estacional Decidual no centro (Dessuy & Morais 2007), norte (Giovenardi et al. 2008) e em outras regiões do estado do Rio Grande do Sul (Morais et al. 2007). A sistemática dos Satyrinae ainda não está completamente elucidada (Marín et al. 2011) e, de acordo com estudo de revisão recente com as espécies do gênero *Hermeuptychia*, mais de uma espécie desse grupo poderiam ser encontradas em simpatria no Rio Grande do Sul (N. S. Pereira, dados não publicados). *T. claudina* é uma espécie abundante no estado (Morais et al. 2007), e seus indivíduos são encontrados em ambientes florestais e abertos perturbados tanto na Floresta Estacional Decidual da região norte do estado (Giovenardi et al. 2008, Bonfantti et al. 2009) como na Floresta Ombrófila Mista (Grazia et al. 2008, Romanowski et al. 2009, Iserhard et al. 2010, Ritter et al. 2011). *V. braziliensis* também é considerada espécie comum em ambientes antropizados (Sackis & Morais 2008) e também ambientes secundários da Floresta Ombrófila Mista, sendo típica de locais abertos em alto de morros (Grazia et al. 2008, Romanowski et al. 2009).

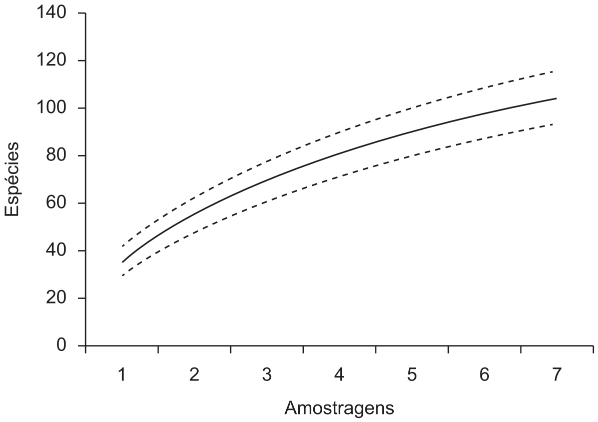

Figura 1. Número cumulativo de espécies de borboletas registradas em sete ocasiões amostrais, com intervalos de confiança de 95%, em Val de Serra, município de Itaara, Rio Grande do Sul, de setembro de 2005 a setembro de 2006.

Figure 1. Cumulative number of butterfly species registered on seven sampling occasions, with 95% confidence intervals, in Val de Serra, Itaara municipality, Rio Grande do Sul State, from September 2005 to September 2006.

Tabela 1. Borboletas (Lepidoptera: Hesperioidea e Papilionoidea) registradas em Val de Serra, município de Itaara, Rio Grande do Sul, Brasil.

Table 1. Butterflies (Lepidoptera: Hesperioidea and Papilionoidea) registered in Val de Serra, Itaara municipality, Rio Grande do Sul State, Brazil.

Família/Subfamília	Espécie	N
HESPERIIDAE (S = 21)		
Pyrginae (S = 12)	*Achlyodes mithridates thraso* (Hübner, 1807)	11
	Codatractus aminias (Hewitson, 1867)	2
	Gorgythion sp.	3
	Heliopetes arsalte arsalte (Linnaeus, 1758)	18
	Heliopetes omrina (Butler, 1870)	3
	Pellicia sp.*	1
	Pyrgus orcus (Stoll, 1780)	31
	Urbanus doryssus albicuspis (Herrich-Schäffer, 1869)	3
	Urbanus proteus proteus (Linnaeus, 1758)	2
	Urbanus teleus (Hübner,1821)	13
	Urbanus sp.*	1
	Xenophanes tryxus (Stoll, 1780)	2
Hesperiinae (S = 9)	*Callimormus rivera* (Plötz, 1882)	3
	Conga chydaea (Butler, 1877)*	1
	Conga iheringii (Mabille, 1891)	7
	Panoquina ocola (W.H. Edwards, 1863)*	1
	Polites vibex catilina (Plötz, 1886)	8
	Psoralis stacara (Schaus, 1902)	2
	Vehilius clavicula (Plötz, 1884)	3
	Vehilius inca (Scudder, 1872)*	1
	Wallengrenia premnas (Wallengren, 1860)	4
PAPILIONIDAE (S = 7)		
Papilioninae (S = 7)	*Battus polydamas polydamas* (Linnaeus, 1758)	5
	Euryades corethrus (Boisduval, 1836)	2
	Heraclides anchisiades capys (Hübner, [1809])	2
	Heraclides astyalus astyalus (Godart, 1819)	4
	Heraclides hectorides (Esper, 1794)	13
	Heraclides thoas brasiliensis (Rothschild & Jordan, 1906)	3
	Pterourus scamander grayi (Boisduval, 1836)	2
PIERIDAE (S = 9)		
Dismorphiinae (S = 2)	*Enantia lina psamathe* (Fabricius, 1793)	2
	Pseudopieris nehemia (Boisduval, 1836)*	1
Coliadinae (S = 5)	*Eurema albula* (Cramer, 1775)	X
	Eurema deva deva (Doubleday, 1847)	19
	Eurema elathea flavescens (Chavannes, 1850)	6
	Phoebis neocypris neocypris (Hübner, [1823])	20
	Phoebis philea philea (Linnaeus, 1763)	2
Pierinae (S = 2)	*Hesperocharis erota* (Lucas, 1852)*	1
	Teochila maenacte itatiayae (Foetterle, 1902)*	1
LYCAENIDAE (S = 9)		
Theclinae (S = 8)	*Arawacus binangula* (Schaus, 1902)*	1
	*Arawacus meliboeus (*Fabricius, 1793)	4
	Arcas ducalis (Westwood, 1852)*	1
	Calycopis caulonia (Hewitson, 1877)	5
	Laothus phydela (Hewitson, 1867)*	1
	Rekoa malina (Hewitson, 1867)*	1
	Rekoa meton (Cramer, 1779)	2
	Theritas triquetra (Hewitson, 1865)	2

(N = Abundância; S = Riqueza; * = espécies “singleton”; X = espécies encontradas fora do período amostral). (N = Abundance; S = Richness; * = singleton species; X = species sampled outside sampling period).

Tabela 1. Continuação...

Table 1. Continued...

Família/Subfamília	Espécie	N
Polyommatinae (S = 1)	*Leptotes cassius* (Cramer, 1775)*	1
RIODINIDAE (S = 7)		
Euselasiinae (S = 1)	*Euselasia eucerus* (Hewitson, 1872)	3
Riodininae (S = 6)	*Calephelis aymaran* McAlpine,1971*	1
	Chorinea licursis (Fabricius, 1775)*	1
	Emesis fatimella Westwood, 1851*	1
	Emesis mandana (Cramer, 1780)*	1
	Mesosemia odice (Godart, [1824])*	1
	Riodina lycisca (Hewitson, [1853])	2
NYMPHALIDAE (S = 54)		
Ithomiinae (S = 6)	*Dircenna dero celtina* Burmeister, 1878	2
	Episcada hymenaea hymenaea (Prittwitz, 1865)	2
	Epityches eupompe (Geyer, 1832)*	1
	Methona themisto (Hübner, 1818)	7
	Pseudoscada erruca (Hewitson, 1855)*	1
	Pteronymia carlia Schaus, 1902*	1
Satyrinae (S = 9)	*Blepolenis batea batea* (Hübner, [1821])	3
	Eteona tisiphone (Boisduval, 1836)*	1
	Forsterinaria necys (Godart, [1824])*	1
	Hermeuptychia hermes (Fabricius, 1775)	95
	Morpho aega aega (Hübner,[1822])	2
	*Morpho epistrophus catenaria (*Perry, 1811)	5
	Paryphthimoides phronius (Godart, [1824])	3
	Praepedaliodes phanias (Hewitson, 1862)	3
	Yphthimoides celmis (Godart, [1824])	79
Charaxinae (S = 1)	*Zaretis strigosus* (Gmelin 1790)*	1
Biblidinae (S = 7)	*Biblis hyperia nectanabis* (Fruhstorfer, 1909)	12
	Callicore pygas thamyras (Ménétriés, 1857)	6
	Diaethria candrena candrena (Godart, [1824])	9
	Dynamine agacles agacles (Dalman, 1823)*	1
	Dynamine myrrhina (Doubleday, 1849)	16
	Eunica eburnea Fruhstorfer, 1907	17
	Hamadryas epinome (C.Felder & R.Felder, 1867)	7
Apaturinae (S = 1)	*Doxocopa laurentia laurentia* (Godart, [1824])	23
Nymphalinae (S = 13)	*Anartia amathea roeselia* (Eschscholtz, 1821)	8
	Chlosyne lacinia saundersi (Doubleday, [1847])	X
	Eresia lansdorfi (Godart, 1819)*	1
	Hypanartia bella (Fabricius, 1793)*	1
	Hypanartia lethe (Fabricius, 1793)	4
	Junonia evarete (Cramer, 1779)	27
	Ortilia dicoma (Hewitson, 1864)*	1
	Ortilia ithra (W.F. Kirby, 1900)	8
	Ortilia orthia (Hewitson, 1864)	2
	Siproeta epaphus trayja Hübner, [1823]	9
	Siproeta stelenes meridionalis (Fruhstorfer, 1909)	X
	Tegosa claudina (Eschscholtz, 1821)	42
	Tegosa orobia orobia (Hewitson, 1864)	34
	Vanessa braziliensis (Moore, 1883)	36
	Vanessa myrinna (Doubleday, 1849)*	1

(N = Abundância; S = Riqueza; * = espécies "singleton"; X = espécies encontradas fora do período amostral). (N = Abundance; S = Richness; * = singleton species; X = species sampled outside sampling period).

Tabela 1. Continuação...

Table 1. Continued...

Família/Subfamília	**Espécie**	**N**
Limenitidinae (S = 3)	*Adelpha mythra* (Godart, [1824])	9
	Adelpha syma (Godart, [1824])	30
	Adelpha thessalia indefecta Fruhstorfer, 1913*	1
Heliconiinae (S = 12)	*Actinote carycina* Jordan, 1913	6
	Actinote discrepans d' Almeida, 1958*	1
	Actinote mamita mamita (Burmeister, 1861)*	1
	Actinote melanisans Oberthür, 1917	2
	Actinote pyrrha (Fabricius, 1775)	2
	Agraulis vanillae maculosa (Stichel, [1908])	44
	Dione juno juno (Cramer, 1779)	10
	Dryadula phaetusa (Linnaeus, 1758)	2
	Dryas iulia alcionea (Cramer, 1779)	31
	Euptoieta hortensia (Blanchard, 1852)	12
	Heliconius erato phyllis (Fabricius, 1775)	18
	Heliconius ethilla narcaea Godart, 1819	5
Abundância total		**877**

(N = Abundância; S = Riqueza; * = espécies "singleton"; X = espécies encontradas fora do período amostral). (N = Abundance; S = Richness; * = singleton species; X = species sampled outside sampling period).

T. orobia orobia (Hewitson, 1864) foi a sexta espécie mais abundante na área de estudo (n = 34) e merece destaque por representar um registro recente para Floresta Ombrófila Mista do Rio Grande do Sul (Iserhard et al. 2010). Essa espécie já foi registrada há mais tempo para a região do planalto centro-sul do estado do Paraná, cujas fisionomias vegetais incluem Floresta Ombrófila Mista, Campos Naturais e Floresta Estacional Semidecidual (Dolibaina et al. 2011). Apesar de não ter sido identificada a planta hospedeira dessa espécie de *Tegosa* na área de estudo, pertencente à família Acanthaceae, havia uma grande abundância de plantas herbáceas da família Verbenaceae (gênero *Glandularia*) utilizadas para oviposição por *T. claudina* (Beccaloni et al. 2008).

Algumas outras espécies de Nymphalidae consideradas comuns e características da Floresta Ombrófila Mista do Rio Grande do Sul, (Grazia et al. 2008, Romanowski et al. 2009), foram registradas em Val de Serra, como *Adelpha syma* (Godart, [1824]) e *Doxocopa laurentia laurentia* (Godart, [1824]), mais abundantes, e *Morpho epistrophus catenaria* (Perry, 1811), associada a Mata Atlântica, e com apenas cinco indivíduos registrados no mês de janeiro. Todas elas também foram observadas na Floresta Estacional Decidual do centro e norte do estado (Link et al. 1980, Dessuy & Morais 2007, Giovenardi et al. 2008, Bonfantti et al. 2009).

A espécie mais abundante de Hesperiidae encontrada, *Pyrgus orcus* (Stoll, 1780), é considerada comum em ambientes campestres conservados no Rio Grande do Sul (Morais et al. 2007), embora também esteja presente em ambientes perturbados (Sackis & Morais 2008). Também pertencentes à mesma família, *Polites vibex catilina* (Plötz, 1884) e *Vehilius inca* (Scudder, 1872) foram menos abundantes em Val de Serra, mas são mencionados como espécies típicas de vegetação de campos naturais no estado do Paraná (Dolibaina et al. 2011).

Os Pieridae mais abundantes em Val de Serra foram *Phoebis neocypris neocypris* (Hübner, [1823]) e *Eurema deva deva* (Doubleday, 1847). Os indivíduos da primeira espécie também são mais comuns no Rio Grande do Sul (Morais et al. 2007) e em ambos os tipos de Floresta, Estacional Decidual e Ombrófila Mista, quando comparado com a segunda espécie, bem menos representada na Floresta Ombrófila Mista (Link et al. 1977, Dessuy & Morais 2007, Giovenardi et al. 2008, Grazia et al. 2008, Romanowski et al. 2009, Iserhard et al. 2010).

A espécie mais abundante de Papilionidae amostrada foi *Heraclides hectorides* (Esper, 1794), considerada comum no município de Santa Maria e associada a maior cobertura vegetal (Schwartz & Di Mare 2001). Indivíduos machos dessa espécie também foram encontrados nas margens do rio na área da Reserva Biológica Estadual do Ibicuí Mirim, contígua à área de estudo, (A.B.B. Morais, dados não publicados), confirmando sua preferência por ambientes com areia úmida (Brown Junior 1992).

De acordo com a bibliografia consultada, uma espécie de Lycaenidae constitui-se em novo registro para o estado do Rio Grande do Sul: *Rekoa meton* (Cramer, 1779) (Val de Serra, 16.III.2006, Robbins *det.*;, Ritter *leg.*). Essa borboleta consta da lista de espécies da Mata Atlântica de Santa Teresa, Espírito Santo (Brown Junior & Freitas 2000a) e está referida como de ocorrência incomum na Serra do Japi, estado de São Paulo (Brown Junior 1992). Outras quatro espécies, todas registradas uma única vez ("singletons"), constituem-se em primeiros registros para a região central do Rio Grande do Sul, o Nymphalidae *Dynamine agacles agacles* (Dalman, 1823), o Hesperiidae *Conga chydaea* (Butler, 1877), o Riodinidae *Emesis mandana* (Cramer, 1780), e o Pieridae *Hesperocharis herota* (Lucas, 1852). Enquanto a primeira espécie já possui registros para a região norte do Estado, nas Florestas Ombrófila Densa (Iserhard & Romanowski 2004) e Ombrófila Mista (Ritter et al. 2011), as outras duas foram encontradas no sul do estado, em Pelotas (Biezanko 1963, Krüger & Silva 2003). E *H. erota* constitui-se em uma espécie típica de ambientes de altitude na borda da Floresta Ombrófila Mista e Campos de Cima da Serra (Grazia et al. 2008, Romanowski et al. 2009).

Dois indivíduos do papilionídeo Troidini *Euryades corethrus* (Boisduval, 1836) foram amostrados na área de vegetação arbustiva de Val de Serra. Apesar de endêmica dos campos naturais da região sul do Brasil (Tyler et al. 1994, Dolibaina et al. 2011) e ocorrer com relativa abundância em áreas campestres de Santa Maria (A.B.B Morais, dados não publicados), a biologia populacional dessa espécie ainda é pouco conhecida. No estado do Paraná, ela faz parte da lista vermelha de espécies ameaçadas e recentemente foi proposta uma alteração de seu critério de ameaça da categoria em perigo (EN) para espécie criticamente em perigo (CR), devido à ameaça de perda de seu habitat natural, além da ausência de unidades de conservação representativas desse tipo de vegetação (Dolibaina et al. 2010). Esse mesmo tipo de ameaça também está presente no Rio Grande do Sul, como a conversão de áreas para pastoreio intensivo, degradação de hábitat, introdução de espécies exóticas e carência de áreas de conservação representativas dos campos sulinos (Overbeck et al., 2007).

Merece destaque o registro em Val de Serra da espécie "singleton" *Arcas ducalis* (Westwood, 1852), Lycaenidae considerado indicador de ambientes bem preservados de Mata Atlântica (Brown Junior & Freitas 2000a). Na região sul, representantes dessa espécie têm sido registrados no estado do Paraná (Dolibaina et al. 2010, 2011). Porém no Rio Grande do Sul só havia poucos registros anteriores, no sul do estado (Krüger & Silva 2003) e região nordeste, em área de abrangência de Floresta Ombrófila Densa, acima de 400 m de altitude (Iserhard & Romanowski 2004, Morais et al. 2007).

Assim, mesmo decorrente de inventário feito com relativamente pequeno esforço amostral, foi registrada uma assembléia de borboletas com riqueza e composição representativas em Val de Serra. A heterogeneidade ambiental e a abundância de recursos hídricos constituem-se em condições importantes para preservação dessa fauna no local. Apesar de localizada no limite sul da distribuição do Bioma Mata Atlântica, foram amostradas na área de estudo espécies características das duas formações florestais, Floresta Estacional Decidual e Floresta Ombrófila Mista, além de algumas associadas a campos. Lembrando que esse fragmento pode funcionar como corredor de biodiversidade por conectar-se com área florestal contígua da Reserva Biológica Estadual do Ibicuí Mirim, recomenda-se a necessidade de incrementar os esforços para a conservação da área e estimular novos estudos ecológicos com a biodiversidade local.

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Referências Bibliográficas

BECCALONI, G.W. & GASTON, K.J. 1995. Predicting species richness of Neotropical forest butterflies: Ithomiinae (Lepidoptera: Nymphalidae) as indicators. Biol. Conserv. 71:77-86.

BECCALONI, G.W., VILORIA, A.L., HALL, S.K. & ROBINSON, G.S. 2008. Catalogue of the hostplants of the neotropical butterflies. S.E.A. RIBES, CYTED, The Natural History Museum & IVIC, Monografias Tercer Milenio, Zaragoza, v.8, 536p.

BIEZANKO, C.M. 1958. Ib. Pieridae da Zona Sueste do Rio Grande do Sul. Arq. Entomol., Ser. A:1-15.

BIEZANKO, C.M. 1959a. Ia. Papilionidae da Zona Sueste do Rio Grande do Sul. Arq. Entomol., Ser. A:1-17.

BIEZANKO, C.M. 1959b. Ia. Papilionidae da Zona Missioneira. Arq. Entomol., Ser. B:1-12.

BIEZANKO, C.M. 1960a. Ib. Pieridae da Zona Missioneira do Rio Grande do Sul. Arq. Entomol., Ser. B:1-12.

BIEZANKO, C.M. 1960b. III. Danaidae et Ithomidae da Zona Sueste do Rio Grande do Sul. Arq. Entomol., Ser. A:1-6.

BIEZANKO, C.M. 1960c. III. Danaidae et Ithomidae da Zona Missioneira do Rio Grande do Sul. Arq. Entomol., Ser. B:1-6.

BIEZANKO, C.M. 1960d. IV. Satyridae, Morphidae et Brassolidae da Zona Sueste do Rio Grande do Sul. Arq. Entomol., Ser. A:1-13.

BIEZANKO, C.M. 1960e. IV. Satyridae, Morphidae et Brassolidae da Zona Missioneira do Rio Grande do Sul. Arq. Entomol., Ser. B:1-10.

BIEZANKO, C.M. 1963. VI. Hesperiidae da Zona Sueste do Rio Grande do Sul. Arq. Entomol., Ser. A:1-25.

BIEZANKO, C.M. & MIELKE, O.H.H. 1973. Contribuição ao estudo faunístico dos Hesperiidae americanos. IV Espécies do Rio Grande do Sul, Brasil, com notas taxonômicas e descrições de espécies novas (Lepidoptera). Acta Biol. Parana 2(1-4):51-102.

BIEZANKO, C.M., MIELKE, O.H.H. & WEDDERHOFF, A. 1978. Contribuição ao estudo faunístico dos Riodinidae do Rio Grande do Sul, Brasil (Lepidoptera). Acta Biol. Parana 7(1-4):7-22.

BONEBRAKE, T.C., PONISIO, L.C., BOGGS, C.L. & EHRLICH, P.R. 2010. More than just indicators: a review of tropical butterfly ecology and conservation. Biol. Conserv. 143:1831-1841.

BONFANTTI, D., Di MARE, R.A. & GIOVENARDI, R. 2009. Butterflies (Lepidoptera: Papilionoidea and Hesperioidea) from two forest fragments in northen Rio Grande do Sul, Brazil. Check List. 5(4):819-829.

BRASIL. Ministério do Meio Ambiente - MMA. 2007. Portaria MMA nº 9, de 23 de janeiro de 2007. Áreas prioritárias para conservação, uso sustentável e repartição de benefícios da biodiversidade brasileira; atualização. 2. ed. Ministério do Meio Ambiente, Secretaria de Biodiversidade e Florestas, Brasília. (Série Biodiversidade, n.31).

BROWN JUNIOR, K.S. 1992. Borboletas da Serra do Japi: diversidade, habitats, recursos alimentares e variação temporal. In História natural da Serra do Japi: ecologia e preservação de uma área florestal no sudeste do Brasil (L.P.C. Morellato, org.). Editora da UNICAMP, Campinas, p.142-186.

BROWN JUNIOR, K.S. 1997. Diversity, disturbance, and sustainable use of Neotropical forests: insects as indicators for conservation monitoring. J. Ins. Cons. 1:25-42. http://dx.doi.org/10.1023/A:1018422807610

BROWN JUNIOR, K.S. & FREITAS, A.V.L. 1999. Lepidoptera. In Biodiversidade do Estado de São Paulo, Brasil. Invertebrados terrestres (C.R.F. Brandão & E.M. Cancello, eds.). FAPESP, São Paulo, p.227-243.

BROWN JUNIOR, K.S. & FREITAS, A.V.L. 2000a. Atlantic Forest butterflies: indicators for landscape conservation. Biotropica 32(4b):934-956. http://dx.doi.org/10.1111/j.1744-7429.2000.tb00631.x

BROWN JUNIOR, K.S. & FREITAS, A.V.L. 2000b. Diversidade de Lepidoptera em Santa Teresa, Espírito Santo. Bol. Mus. Biol. Mello Leitao 11-12:71-118.

CANALS, G.R. 2000. Butterflies of Buenos Aires. L.O.L.A., Buenos Aires, 347p.

CANALS, G.R. 2003. Mariposas de Misiones. L.O.L.A., Buenos Aires, 492p.

CECHIN, S.Z., MORAIS, A.B.B., CÁCERES, N.C., SANTOS, S., KOTZIAN, C.B., BEHR, E.R., ARRUDA, J.S., & DELLA FLORA, F. 2009 A fauna de Santa Maria. Cienc. Ambient. 38(1):113-144.

COLWELL, R.K. 2007. Estimates 8.0: statistical estimation of species richness and shared species from samples. University of Connecticut, Connecticut. http://viceroy.eeb.ucon.edu/estimates.

CORSEUIL, E., QUADROS, F.C., TESTON, J.A. & MOSER, A. 2004. Borboletas (Lepidoptera, Papilionoidea e Hesperioidea) coletadas no Centro de Pesquisas e Conservação da Natureza Pró-Mata. 4. Lycaenidae. Divul. Mus. Ciênc.Tecnol. PUCRS 9:65-70.

DESSUY, M.B. & MORAIS, A.B.B. 2007. Diversidade de borboletas (Lepidoptera: Papilionoidea e Hesperioidea) em fragmentos de Floresta Estacional Decidual em Santa Maria, Rio Grande do Sul, Brasil. Rev. Bras. Zool. 24(1):108-120.

DE VRIES, P.J. 1987. The butterflies of Costa Rica and their natural history: Papilionidae, Pieridae, Nymphalidae. Princeton University Press, Princeton, 327p.

DE VRIES, P.J. 1997. The butterflies of Costa Rica and their natural history: Riodinidae. Princeton University Press, Princeton, 288 p.

DOLIBAINA, D.R., CARNEIRO, E., DIAS, F.M.S., MIELKE, O.H.H. & CASAGRANDE, M.M. 2010. Registros inéditos de borboletas (Papilionoidea e Hesperioidea) ameaçadas de extinção para o Estado do Paraná, Brasil: novos subsídios para reavaliação dos critérios de ameaça. Biota Neotrop. 10(3): http://www.biotaneotropica.org.br/v10n3/en/abstract?article+bn01210032010. http://dx.doi.org/10.1590/S1676-06032010000300007

DOLIBAINA, D.R., MIELKE, O.H.H. & CASAGRANDE, M.M. 2011. Borboletas (Papilionoidea e Hesperioidea) de Guarapuava e arredores, Paraná, Brasil: um inventário com base em 63 anos de registros. Biota Neotrop.11(1): http://www.biotaneotropica.org.br/v11n1/en/abstract?inventory+bn00211012011. http://dx.doi.org/10.1590/S1676-06032011000100031

FREITAS, A.V.L. 2010. Impactos potenciais das mudanças propostas no Código Florestal Brasileiro sobre as borboletas. Biota Neotrop. 10(4): http://www.biotaneotropica.org.br /v10n3/en/ abstract?article +bn008100422010.

FREITAS, A.V.L., FRANCINI, R.B. & BROWN JUNIOR, K.S. 2003. Insetos como indicadores ambientais. In Métodos de estudos em biologia da conservação e manejo da vida silvestre (L. Cullen Junior, C. Valladares-Pádua & R. Rudran, orgs.). Editora da UFPR, Curitiba, p.125-151.

FREITAS, A.V.L., LEAL, I.R., PRADO, M.H. & IANNUZZI, L. 2006. Insetos como indicadores de conservação de paisagem. In Biologia da conservação: essências (C.F.D. Rocha, H.G. Bergallo, M. Van Sluys & M.A.S. Alves, eds.). Rima, São Carlos, p.357-384.

FREITAS, A.V.L., MIELKE, O.H.H., MOSER, A., SILVA-BRANDÃO, K.L. & ISERHARD, C.A. 2011. A new genus and species of Euptychiina (Lepidoptera: Nymphalidae: Satyrinae) from southern Brazil. Neotrop. Entomol. 40(2):231-237.

GIOVENARDI, R., DI MARE, R.A., SPONCHIADO, J., ROANI, S.H., JACOMASSA, F.A.F., JUNG, A.B. & PORN, M.A. 2008. Diversidade de Lepidoptera (Papilionoidea e Hesperioidea) em dois fragmentos de floresta no município de Frederico Westphalen, Rio Grande do Sul, Brasil. Rev. Bras. Ent. 52(4):599-605.

HEIKKILÄ, M., KAILA, L., MUTANEN, M., PENA, C. & WAHLBERG, N. 2012. Cretaceous origin and repeated tertiary diversification of the redefined butterflies. Proc. R. Soc. B 279:1093-1099.

GRAZIA, J., ROMANOWSKI, H.P., ARAÚJO, B., SCHWERTNER, C.F., ISERHARD, C.A., MOURA, L.A. & FERRO, V.G. 2008. Artrópodos Terrestres. In Biodiversidade dos Campos de Cima da Serra (G. Bond-Buckup, org.). Libretos, Porto Alegre, p.76-97.

ISERHARD, C.A. & ROMANOWSKI, H.P. 2004. Lista de espécies de borboletas (Lepidoptera: Papilionoidea & Hesperioidea) da região do vale do Rio Maquine, Rio Grande do Sul, Brasil. Rev. Bras. Zool. 21(3):649-662.

ISERHARD, C.A., QUADROS, M.T., ROMANOWSKI, H.P. & MENDONÇA JUNIOR, M.S. 2010. Borboletas (Lepidoptera: Papilionoidea e Hesperioidea) ocorrentes em diferentes ambientes na Floresta Ombrófila Mista e nos Campos de Cima da Serra do Rio Grande do Sul, Brasil. Biota Neotrop. 10(1): http://www.biotaneotropica.org.br/v10n1/pt/abstract?inventory+bn029100012010. http://dx.doi.org/10.1590/S1676-06032010000100026

KRÜGER, C.P. & SILVA, E.J.E. 2003. Papilionoidea (Lepidoptera) de Pelotas e seus arredores, Rio Grande do Sul, Brasil. Entomol. Vectores 10(1): 31-45.

LAMAS, G. 2004. Checklist: Part 4A. Hesperioidea-Papilionoidea. In Atlas of Neotropical Lepidoptera. (J.B. Heppner, ed.). Association for Tropical Lepidoptera/Scientific Publishers, Gainesville, p.1-439.

LAMAS, G. 2008. La sistemática sobre mariposas (Lepidoptera: Hesperioidea y Papilionoidea) en el mundo: estado actual y perspectivas futuras. In Contribuciones taxonómicas en órdenes de insectos hiperdiversos (J.L. Bousquets & A. Lanteri, eds.). Las Prensas de Ciencias, UNAM, México D.E., p. 57-70.

LAURANCE, W.F. 2009. Conserving the hottest of the hotspots. Biol. Conserv. 142:1137. http://dx.doi.org/10.1016/j.biocon.2008.10.011

LINK, D.; BIEZANKO, C.M.; TARRAGÓ, M.F. & CARVALHO, S. 1977. Lepidoptera de Santa Maria e arredores. I: Papilionidae e Pieridae. Rev. Cent. Cienc. Rurais 7(4):381-389.

LINK, D.; BIEZANKO, C.M.; TARRAGÓ, M.F. & CARVALHO, S. 1980. Lepidoptera de Santa Maria e arredores. II: Morphidae e Brassolidae. Rev. Cent. Cienc. Rurais 10(2):191-195.

MALUF, J.R.T. 2000. Nova classificação climática do estado do Rio Grande do Sul. Rev. Bras. Agromet. 8(1):141-150.

MARCHIORI, J.N.C. 2009. A vegetação em Santa Maria. Cienc. Ambient. 8(1):93-112.

MARCHIORI, M.O. & ROMANOWSKI, H.P. 2006a. Species composition and diel variation of a butterfly taxocene (Lepidoptera, Papilionoidea and Hesperioidea) in a restinga forest at Itapuã State Park, Rio Grande do Sul, Brazil. Rev. Bras. Zool. 23(2):443-454. http://dx.doi.org/10.1590/S0101-81752006000200019

MARCHIORI, M.O. & ROMANOWSKI, H.P. 2006b. Borboletas (Lepidoptera, Papilionoidea e Hesperioidea) do Parque Estadual do Espinilho e entorno, Rio Grande do Sul, Brasil. Rev. Bras. Zool. 23(4):1029-1037. http://dx.doi.org/10.1590/S0101-81752006000400007

MARÍN, M.A., PEÑA, C., FREITAS, A.V.L., WAHLBERG, N. & URRIBE, S.I. 2011. From the phylogeny of the Satyrinae butterflies to the systematics of Euptychiina (Lepidoptera: Nymphalidae): history, progress and prospects. Neotrop. Entomol. 40(1):1-13.

MIELKE, O.H.H. 1980a. Contribuição ao estudo faunístico dos Hesperiidae americanos. V Nota suplementar – As espécies de Pyrrhopyginae e Pyrginae do Rio Grande do Sul, Brasil (Lepidoptera). Acta Biol. Parana 8-9:7-17.

MIELKE, O.H.H. 1980b. Contribuição ao estudo faunístico dos Hesperiidae americanos. VI Nota suplementar – As espécies de Hesperiinae do Rio Grande do Sul, Brasil (Lepidoptera). Acta Biol. Parana 8-9:127-172.

MIELKE, O.H.H. 2005. Catalogue of the American Hesperioidea: Hesperiidae (Lepidoptera). Sociedade Brasileira de Zoologia, Curitiba, 1536p.

MORAIS, A.B.B., ROMANOWSKI, H.P., ISERHARD, C.A., MARCHIORI, M.O.O. & SEGUI, R. 2007. Mariposas del sur de Sudamérica (Lepidoptera: Hesperioidea y Papilionoidea). Cienc. Ambient. 35(2):29-46.

OVERBECK, G.E., MÜLLER, S.C., FIDELIS, A., PFADENHAUER, J., PILLAR, V.D., BLANCO, C.C., BOLDRINI, I.I., BOTH, R., FORNECK, E.D. 2007. Brazil's neglected biome: the South Brazilian *Campos*. Perspect. Plant Ecol. Evol.Syst. 9(2):101-116.

PAZ, A.L.G., ROMANOWSKI, H.P. & MORAIS, A.B.B. 2008. Nymphalidae, Papilionidae e Pieridae (Lepidoptera: Papilionoidea) da Serra do Sudeste do Rio Grande do Sul, Brasil. Biota Neotrop. 8(1): http://www.biotaneotropica.org.br/v8n1/pt/abstract?inventory+bn01608012008. http://dx.doi.org/10.1590/S1676-06032008000100017

PEDROTTI, V.S., BARROS, M.P., ROMANOWSKI, H.P. & ISERHARD, C.A. 2011. Borboletas frugívoras (Lepidoptera: Nymphalidae) ocorrentes em um fragmento de Floresta Ombrófila Mista no Rio Grande do Sul, Brasil. Biota Neotrop. 11(1): http://www.biotaneotropica.org.br/ v11n1/en/abstract?article +bn03011012011.

PEREIRA, P.R.B., GARCIA NETTO, L.R., BORIN, C.J.A. & SARTORI, M.G.B. 1989. Contribuição à geografia física do município de Santa Maria; unidades de paisagem. Geogr. Ens. Pesqui. 3:37-68.

QUADROS, F.C., DORNELES, A.L. & CORSEUIL, E. 2004. Ninfalídeos (Lepidoptera, Nymphalidae) ocorrentes no norte da Planície Costeira do Rio Grande do Sul. Biociências 12(2):147-164.

RIBEIRO, M.C., METZGER, J.P., MARTENSEN, A.C., PONZONI, F.J. & HIROTA, M.M. 2009. The Brazilian Atlantic Forest: how much is left, and how is the remaining forest distributed? implications for conservation. Biol. Conserv. 142:1141-1153.

RITTER, C.D., LEMES, R., MORAIS, A.B.B. & DAMBROS, C.S. 2011. Borboletas (Lepidoptera: Hesperioidea e Papilionoidea) de fragmentos de Floresta Ombrófila Mista, Rio Grande do Sul, Brasil. Biota Neotrop. 11(1): http://www.biotaneotropica.org.br/v11n1/pt/abstract?inventory+bn00511012011. http://dx.doi.org/10.1590/S1676-06032011000100033

ROMANOWSKI, H.P., ISERHARD C.A. & HARTZ, S. M. 2009. Borboletas da floresta com araucária. In Floresta com araucária: ecologia, conservação e desenvolvimento sustentável (C.R. Fonseca, A.F. Souza, A.M. Leal-Zanchet, T.L. Dutra, A. Backes & G. Ganade, orgs.). Holos, Ribeirão Preto, p.229-240.

ROSA, P.L.P., CHIVA, E.Q. & ISERHARD, C.A. 2011. Borboletas (Lepidoptera: Papilionoidea e Hesperioidea) do sudoeste do pampa brasileiro, Uruguaiana, Rio Grande do Sul, Brasil. Biota Neotrop.11(1): http://www.biotaneotropica.org.br/v11n1/en/abstract?inventory+bn00411012011. http://dx.doi.org/10.1590/S1676-06032011000100032

SACKIS, G.D. & MORAIS, A.B.B. 2008. Borboletas (Lepidoptera: Hesperioidea e Papilionoidea) do campus da Universidade Federal de Santa Maria, Santa Maria, Rio Grande do Sul. Biota Neotrop. 8(1): http://www.biotaneotropica.org.br/v8n1/pt/abstract?inventory+bn0190801. http://dx.doi.org/10.1590/S1676-06032008000100018

SANTOS, E.C., MIELKE, O.H.H. & CASAGRANDE, M.M. 2008. Inventários de borboletas no Brasil: estado da arte e modelo de áreas prioritárias para pesquisa com vistas à conservação. Nat. Conserv. 6(2):68-90.

SCHWARTZ, G. & DI MARE, R. A. 2001. Diversidade de quinze espécies de borboletas (Lepidoptera, Papilionidae) em sete comunidades de Santa Maria, RS. Ciênc. Rural 31(1):49-55. http://dx.doi.org/10.1590/S0103-84782001000100008

SPATHELF, P., FLEIG, F.D., VACCARO, S. & ESBER, L.M. 2000. Análise dendroecológica de *Ocotea pulchella* Ness et Mart. Ex Nees (canela lageana) na Serra Geral de Santa Maria, RS, Brasil. Ciênc. Florestal 10(1):95-108.

TABARELLI, M., AGUIAR, A.V., RIBEIRO, M.C., METZGER, J.P. & PERES, C.A. 2010. Prospects for biodiversity conservation in the Atlantic Forest: lessons from aging human-modified lanscapes. Biol. Conserv. 143:2328-2340.

TESTON, J.A. & CORSEUIL, E. 1998. Lista documentada dos Papilionídeos (Lepidoptera, Papilionidae) do Rio Grande do Sul, Brasil. Biociências 6(2):81-94.

TESTON, J.A. & CORSEUIL, E. 1999. Borboletas (Lepidoptera, Rhopalocera) ocorrentes no Centro de Pesquisas e Conservação da Natureza Pró-Mata. 1: Papilionidae. Divul. Mus. Ciênc.Tecnol. PUCRS 4:1-125.

TESTON, J.A. & CORSEUIL, E. 2000a. Borboletas (Lepidoptera, Rhopalocera) ocorrentes no Centro de Pesquisas e Conservação da Natureza Pró-Mata. 2: Pieridae. Divul. Mus. Ciênc.Tecnol. PUCRS 5:1-155.

TESTON, J.A. & CORSEUIL, E. 2000b. Lista documentada dos Pierídeos (Lepidoptera, Pieridae) do Rio Grande do Sul, Brasil. Biociências 8(2):115-132.

TESTON, J.A. & CORSEUIL, E. 2001. Ninfalídeos (Lepidoptera, Nymphalidae) ocorrentes no Rio Grande do Sul, Brasil. Parte I. Danainae e Ithomiinae. Biociências 9(1):51-61.

TESTON, J.A. & CORSEUIL, E. 2002a. Borboletas (Lepidoptera, Rhopalocera) ocorrentes no Centro de Pesquisas e Conservação da Natureza Pró-Mata. 3. Nymphalidae. Divul. Mus. Ciênc.Tecnol. PUCRS. 7:1-208.

TESTON, J.A. & CORSEUIL, E. 2002b. Ninfalídeos (Lepidoptera, Nymphalidae) ocorrentes no Rio Grande do Sul, Brasil. Parte II. Brassolinae e Morphinae. Biociências 10(1):75-84.

TESTON, J.A. & CORSEUIL, E. 2008a. Ninfalídeos (Lepidotera, Nymphalidae) ocorrentes no Rio Grande do Sul, Brasil. Parte IV. Apaturinae e Charaxinae. Biociências 16(1):28-32.

TESTON, J.A. & CORSEUIL, E. 2008b. Ninfalídeos (Lepidoptera, Nymphalidae) ocorrentes no Rio Grande do Sul, Brasil. Parte V. Biblidinae e Limenitidinae. Biociências 16(1):33-41.

TESTON, J.A. & CORSEUIL, E. 2008c. Ninfalídeos (Lepidoptera, Nymphalidae) ocorrentes no Rio Grande do Sul, Brasil. Parte VI. Nymphalinae e Satyrinae. Biociências 16(1):42-51.

TESTON, J.A., TOLEDO, K.G. & CORSEUIL, E. 2006. Ninfalídeos (Lepidoptera, Nymphalidae) ocorrentes no Rio Grande do Sul, Brasil. Parte III. Heliconiinae e Libytheinae. Biociências 4(2):208-213.

TYLER, H.A., BROWN JUNIOR, K. S. & WILSON, K.H. 1994. Swallowtail butterflies of the Americas: a study in biological dynamics, ecological diversity, biosystematics, and conservation. Scientific Publishers, Gainesville, 376p.

WAHLBERG, N., LENEVEU, J., KODANDARAMAIAH, U., PEÑA, C., NYLIN, S., FREITAS, A.V.L. & BROWER, A.V.Z. 2009. Nymphalid butterflies diversity following near demise at the Cretaceous/Tertiary boundary. Proc. R. Soc. B. 276:4295-4302.

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Nest stolen: the first observation of nest predation by an invasive exotic marmoset (*Callithrix penicillata*) in an agricultural mosaic

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Abstract: Invasive exotic species can negatively impact local biodiversity. We present here a report of a nest predation of an endemic bird species, variable oriole (*Icterus pyrrhopterus*) by the introduced black-tufted marmoset (*Callithrix penicillata*) in an agricultural landscape highly disturbed by human activities. Two nestlings were predated, by adults of the introduced marmoset during two alternate days. Antipredator behavior and vocal mimicry were observed in variable oriole, while copulation was observed in black-tufted marmoset during the predation. The use of mobbing against predators by *I. pyrrhopterus* was observed and it is described here by the first time. The potential impact of the introduced marmosets to local biodiversity is discussed.
Keywords: *invasive alien species, birds, mobbing behaviour, nest predation, nest defense.*

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Resumo: Espécies exóticas invasoras podem impactar negativamente a biodiversidade de um local. Nós descrevemos aqui um relato de predação a um ninho de uma espécie de ave endêmica, inhapim (*Icterus pyrrhopterus*) pelo sagüi-de-tufo-preto (*Callithrix penicillata*), espécie exótica invasora, em uma paisagem agrícola altamente impactada pelas atividades humanas. Dois ninhegos foram predados por adultos de sagüi em dois dias alternados. Durante a predação foram observados comportamento anti-predatório e imitações vocais pelo inhapim, e atividade de cópula do sagüis-de-tufo-preto. Descrevemos também o primeiro relato do uso de *mobbing* por *I. pyrrhopterus* contra predadores. O impacto potencial dos sagüis introduzidos na biodiversidade local é discutido.
Palavras-chave: *espécies invasoras, aves, interação interespecífica, mobbing, predação de ninhos, defesa de ninho.*

Introduction

Biological invasions by exotic species are considered one of the greatest threats to biodiversity driving losses in the biological diversity of native species and populations (Lodge 1993, Vitousek et al. 1997a, b, McGeoch et al. 2010). The enormous impact of non-native species is often irreversible, especially when invaders are biotic disturbance agents, altering the ecosystem structure and function (Vitousek 1990, Mack & D'Antonio 1998). The clear effects on ecosystem-level properties are related to differences in resource acquisition and/or use efficiency, the alteration of trophic structure of the area invaded, or the alteration of disturbance frequency and/or intensity (Vitousek 1990, Crooks & Soulé 1999).

Abundant mesopredators can negatively affect avian community by nest predation (Rogers & Caro 1998, Crooks & Soulé 1999, Galetti et al. 2009). Nest predation is considered the main cause of nest failure in tropical birds (Skutch 1985, Wilcove 1985, Roper & Goldstein 1997), being more frequent in fragmented and urban areas (Wilcove 1985, Robinson et al. 1995). Nest predation may increase with fragmentation (Robinson et al. 1995) and human density (Jokimaki & Huhta 2000, Thorington & Bowman 2003).

The presence of introduced marmosets in southeastern Brazil has been reported as a potential threat to local biodiversity. Marmosets could compete with other primate species and birds for resources (Negrão & Valladares-Pádua 2006, Ruiz-Miranda et al. 2006, Lyra-Neves et al. 2007), depredate birds and eggs (Lyra-Neves et al. 2007, Begotti & Landesmann 2008, Galetti et al. 2009), hybridize with conspecifics (Alonso et al. 1987, Passamani et al. 1997, Nunes 2006, Ruiz-Miranda et al. 2006, Begotti & Landesmann 2008), and be vehicles for the introduction of new pathogens (Sales et al. 2010).

In this context, we described here the first well documented nest predation event by an introduced and opportunistic species, the black-tufted marmoset (*Callithrix penicillata* E. Geoffroy 1812), on a native bird species, the variable oriole (*Icterus pyrrhopterus* Vieillot 1819) having a highly disturbed agricultural mosaic as a background. The marmoset inhabits mature gallery forests of the Brazilian Central Plateau, with a distribution ranging from the states of Maranhão and southwest Piauí to the north of São Paulo, including most of Bahia, Minas Gerais and Goiás (Vivo 1991, Rylands et al. 1993), but nowadays, the species is widely distributed in the whole southeastern Brazil. The species are able to live in the most unfavorable and anthropogenic environments possibly due to their general habitat requirements, large food niche breadth, and high capacity to adapt to disturbed areas. Their diet includes insects, spiders, small vertebrates, bird's eggs, fruits, seeds and tree exudates (Nowak & Paradiso 1983, Miranda & Faria 2001, Vilela & Faria 2002, Mamede & Alho 2008). The distribution of food resources can influence their home range size (Castro 2003), reaching up 18.5 ha (Miranda & Faria 2001). The threat of niche overlapping and competition for resources between *C. penicilatta* and *Callithrix aurita* (E. Geoffroy 1812) (endemic species from semideciduous forest) and *Leontopithecus rosalia* (Linnaeus 1766) (the reintroduced endangered golden lion tamarin) have been reported (Stevenson & Rylands 1988, Ruiz-Miranda et al. 2006). The abundance of introduced marmosets in southeastern Brazil and its great potential for adaptation and colonization of new habitats have triggered a number of questions about its impact on local biodiversity.

Material and Methods

We observed a predation event that occurred in a tropical garden close to a university building in the "Luiz de Queiroz" campus (Piracicaba, São Paulo, Southeastern Brazil) (Figure 1). The area is characterized as an agricultural mosaic formed by urban areas, pasture, experimental plantations of annual and perennial crops, reforestation's areas and forest remnants (Sparovek 1993). The entire predation event lasted three consecutive days (April 2011), but the attacks were observed only in the first and in the third day. The event was observed with binoculars, documented by photos and video, and then transcribed in detail.

Results and Discussion

Two nestlings (around 5-8 days old) were depredated, one per each day, by adults of introduced marmoset during two alternate days. The day before the first attack, a nest of *I. pyrrhopterus* with three nestlings was found on a palm leaf which broke away from the canopy (15 m) and fell down over the bushes (2.5 m). Adults of *I. pyrrhopterus* stayed with the nestlings, feeding them and actively defending the territory even after nest had fallen. The day after the fall, we observed the first predation on the nest by an adult of *C. penicillata* (about 4 pm), while four other individuals (two adults and two infants) were also present. An adult marmoset ate the nestling without sharing it with the rest of the group. Although this group is often seen foraging together every day in the afternoon on the same site, this was the first time that predation of nestlings was observed and reported on campus. Two days later, we observed a new attack to the same nest by the same group (Figure 2). An adult female approached, grabbed the second nestling, while others remained a few meters away. After the capture, the predator moved away from the nest with the prey in its hands and ate it almost completely (head, wings and breast) (Figure 3) sharing only a small part with a male which compete for food with her. While the female was still eating, we observed the male searching for a new prey in the nest that was empty. After finishing, the male approached and copulated with the female. The copulation lasted just a few seconds. At the end, the marmosets moved away. As the nest was empty after the second predation observed we assumed the third nestling was depredated one day before.

The antipredator behavior of *I. pyrrhopterus* was documented only on the last predation. During the whole predation event (approaching, capture and feeding) the parents remained very close to the nest vocalizing intensively while the marmosets were in the site. We observed alarm calls and vocal mimicry from both *I. pyrrhopterus*. Species such as campo flicker (*Colaptes campestris* Vieillot 1818), roadside hawk (*Rupornis magnirostris* Gmelin 1788), sapphire-spangled emerald (*Amazilia lactea* Lesson 1832), boat-billed flycatcher (*Megarynchus pitangua* Linnaeus 1766), great kiskadee (*Pitangus sulphuratus* Linnaeus 1766) and smooth-billed ani (*Crotophaga ani* Linnaeus 1758) were imitated by parents. All mimics lasted less than one second, and were mixed with sharp notes that are common on the *I. pyrrhopterus***.** They also produced a sequence of calls of two flock species of Psitacidae, yellow-chevroned parakeet (*Brotogeris chiriri* Vieillot 1818) and blue-winged parrotlet (*Forpus xanthopterygius* Spix 1824). These calls indeed attracted species that were mimicked, like sapphire-spangled emerald (*Amazilia lactea*), but also non-mimicked such as bananaquit (*Coeraba flaveola* Linnaeus 1758) and pale-breasted thrush (*Turdus leucomelas* Vieillot 1818).

This mimicry behavior has been previously described for *I. cayannensis* in Argentina by Fraga (1987). Although, vocal mimicry was not observe during a nest predation event, Fraga (1987) inferred that the behavior might reduce predation risk (Morton 1976, Morse 1977). Our observation is consistent with this supposition and we believe that *I. pyrrhopterus* mimics started mobbing (Altmann 1956, Wilson 1975, Krams et al. 2009) the predator. Vocal mimics were only performed while the marmosets remained near the nest and when the depredation began. In all other situations only the species-specific alarm calls were performed. Aggressive flights at marmosets, but without physical contact, followed by vocal bass notes, were also observed. Defense of the nest from predator is also reported in other species (Knight & Temple 1986, Breitwisch 1988, Arnold 2000, Hogstad 2004, Lyra-Neves et al. 2007).

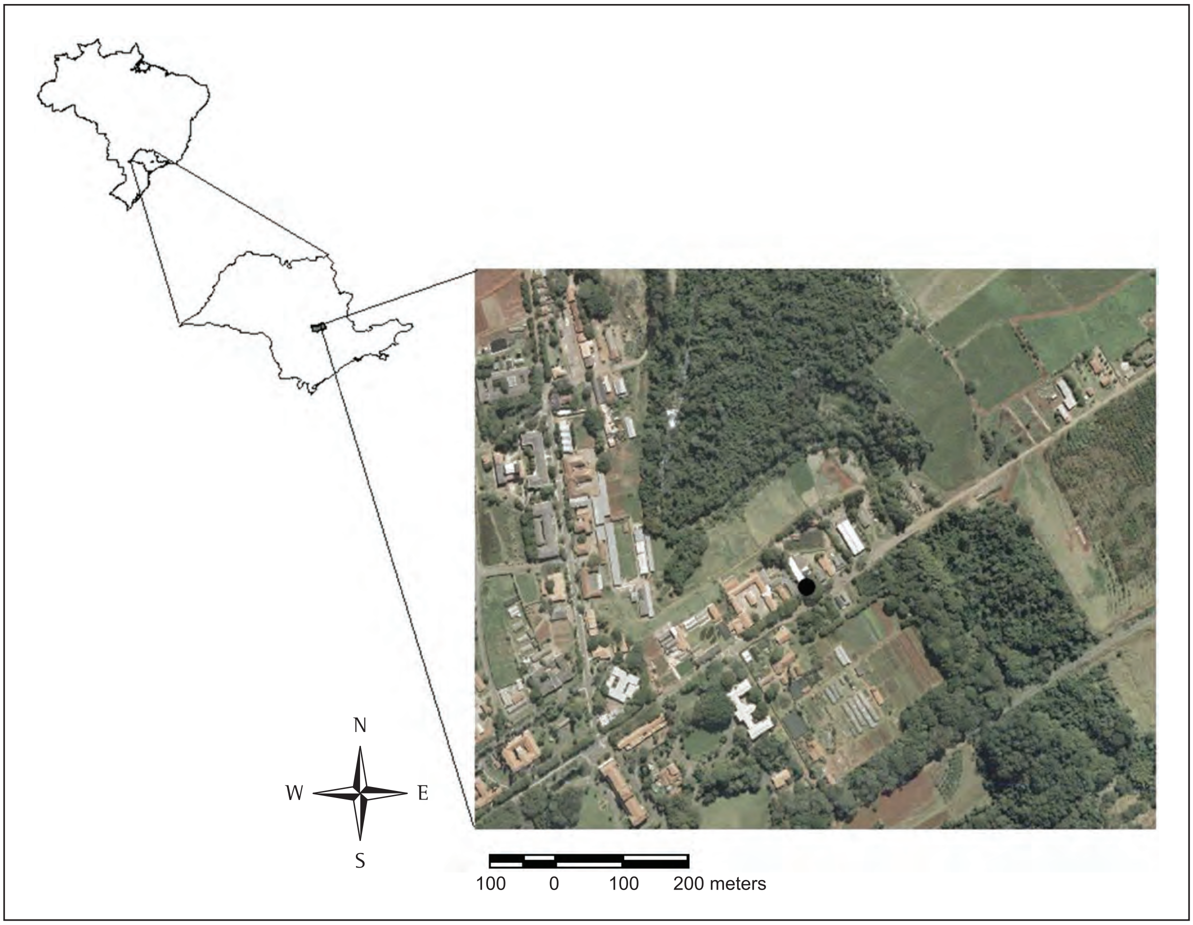

Figure 1. Predation site in Piracicaba, São Paulo state, Brazil.

Figura 1. Local da predação em Piracicaba, Estado de São Paulo, Brasil.

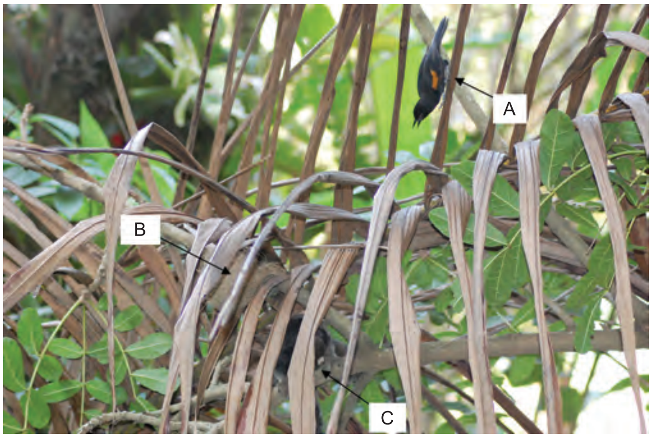

Figure 2. The parental of variable oriole (*Icterus pyrrhopterus*) (a) close to the nest (b) before attack predation by the black-tufted marmoset (*Callithrix penicillata*) (c).

Figura 2. Parental de inhapim (*Icterus pyrrhopterus*) (a) próximo do ninho (b) antes da predação feita pelo sagüi-de-tufo-preto (*Callithrix penicillata*) (c).

Figure 3. The black-tufted marmoset (*Callithrix penicillata*) predating a nestling of variable oriole (*Icterus pyrrhopterus*).

Figura 3. Sagüi-de-tufo-preto (*Callithrix penicillata*) predando um ninhego de inhapim (*Icterus pyrrhopterus*).

Despite being a single-event, this predation report may illustrate the possible impact of this invasive species on native bird species. Investigation about its real impact as the possible impact mitigation actions should be proposed and implemented. Our observation of nest predation suggests that exotic marmosets have the potencial to act as predators of native birds and, thus, may harm local avian populations.

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References

ALONSO, C., FARIA, D.S., LANGGUTH, A. & SANTEE, D.F. 1987. Variação da pelagem na área de intergradação entre *Callithrix jacchus* e *Callithrix penicillata*. Braz. J. Biol. 47:465-470.

ALTMANN, S.A. 1956. Avian mobbing behavior and predator recognition. Condor 58(4):241-253. http://dx.doi.org/10.2307/1364703

ARNOLD, K.E. 2000. Group mobbing behaviour and nest defence in a cooperatively breeding Australian bird. Ethol. 106(5):385-393.

BEGOTTI, R.A. & LANDESMANN, L.F. 2008. Predação de ninhos por um grupo híbrido de sagüis (*Callithrix jacchus/penicillata*) introduzidos em área urbana: implicações para a estrutura da comunidade. Neotrop. Primates 15(1):28-29.

BREITWISCH, R. 1988. Sex-differences in defense of eggs and nestling by northern mockingbirds, *Mimus polyglottos*. Anim. Behav. 36:62-72. http://dx.doi.org/10.1016/S0003-3472(88)80250-1

CASTRO, C.S.S. 2003. Tamanho da área de vida e padrão de uso do espaço em grupos de sagüis, *Callithrix jacchus* (Linnaeus) (Primates, Callitrichidae). Rev. Bras. Zool. 20(1):91-96.

CROOKS, K. & SOULÉ, M.E. 1999. Mesopredator release and avifaunal extinctions in a fragmented system. Nature 400:563-566.

FRAGA, R.M. 1987. Vocal mimicry in the Epaulet Oriole. Condor 89(1):133-137. http://dx.doi.org/10.2307/1368767

GALETTI, M., BOVENDORP, R.S., FADINI, R.F., GUSSONI, C.O.A., RODRIGUES, M., ALVAREZ, A.D., GUIMARÃES JUNIOR, P.R. & ALVES, K. 2009. Hyper abundant mesopredators and bird extinction in an Atlantic forest island. Zoologia 26(2):288-298.

HOGSTAD, O. 2004. Nest defence strategies in the Fieldfare *Turdus pilaris*: the responses on an avian and a mammalian predator. Ardea 92(1):79-84.

JOKIMAKI, J. & HUHTA, E. 2000. Artificial nest predation and abundance of birds along an urban gradient. Condor 102(4):838-847. http://dx.doi.org/10.1650/0010-5422(2000)102[0838:ANPAAO]2.0.CO;2

KNIGHT, R.L. & TEMPLE, S.A. 1986. Nest defence in the American goldfinch. Anim. Behav. 34(3): 887-897.

KRAMS, I., BERZINS, A. & KRAMA, T. 2009. Group effect in nest defence behaviour of breeding pied flycatchers, *Ficedula hypoleuca*. Anim. Behav. 77:513-517.

LODGE, D.M. 1993. Biological invasions: lessons for ecology. Trends Ecol. Evol. 8(4):133-136.

LYRA-NEVES, R.M., OLIVEIRA, M.A.B., TELINO-JUNIOR, W.R. & SANTOS, E.M. 2007. Comportamentos interespecíficos entre *Callithrix jacchus* (Linnaeus) (Primates, Callitrichidae) e algumas aves de Mata Atlântica, Pernambuco, Brasil. Rev. Bras. Zool. 24(3):709-716.

MACK, M.C. & D'ANTONIO, C.M. 1998. Impacts of biological invasions on disturbance regimes. Trends Ecol. Evol. 13(5):195-198.

MAMEDE, S.B. & ALHO, C.J.R. 2008. Impressions of the cerrado & pantanal a guide for the observation of the non – flying mammals. 2nd ed. UFMS, Campo Grande.

McGEOCH, M.A., BUTCHART, S.H.M., SPEAR, D., MARAIS, E., KLEYNHANS, E.J., SYMES, A., CHANSON, J. & HOFFMANN, M. 2010. Global indicators of biological invasion: species numbers, biodiversity impact and policy responses. Divers. Distrib. 16(1):95-108.

MIRANDA, G.H.B. & FARIA, D.S. 2001. Ecological aspects of black-pincelled marmoset (*Callithrix penicillata)* in the cerradão and dense cerrado of the Brazilian Central Plateau. Braz. J. Biol. 61(3):397-404.

MORSE, D.H. 1977. Feeding behavior and predator avoidance in heterospecific groups. BioScience 27(5):332-339. http://dx.doi.org/10.2307/1297632

MORTON, E.S. 1976. Vocal mimicry in the Thick-Billed Euphonia. Wilson Bull. 88(3):485-487.

NEGRÃO, M.F.F. & VALLADARES-PÁDUA, C. 2006. Registros de mamíferos de maior porte na Reserva Florestal do Morro Grande, São Paulo. Biota Neotrop. 6(2): http://www.biotaneotropica.org.br/v6n2/pt/abstract?article+bn00806022006 (último acesso em 13/10/2011). http://dx.doi.org/10.1590/S1676-06032006000200006

NOWAK, R.M. & PARADISO, J.L. 1983. Walker's mammals of the world. 4th ed. John Hopkins University Press, Baltimore.

NUNES, A.M. 2006. Ecologia cognitiva e forrageio social em híbridos de *Callithrix penicillata x Callithrix jacchus* (Primates: Cebidae: Callitrichinae) introduzidos na ilha de Santa Catarina. Dissertação de mestrado, Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre.

PASSAMANI, M., AGUIAR, L.M.S., MACHADO, R.B. & FIGUEIREDO, E. 1997. Hybridization between *Callithrix geoffroyi* and *C. penicillata* in Southeastern Minas Gerais, Brasil. Neotrop. Primates 5(1):9-10.

ROBINSON, S.K., THOMPSON III, F.R., DONOVAN, T.M., WHITEHEAD, D.R. & FAABORG, J. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science 267:1987-1990.

ROGERS, C.M. & CARO, M.J. 1998. Song sparrows, top carnivores and nest predation: a test of the mesopredator release hypothesis. Oecologia 116(1-2):227-233. http://dx.doi.org/10.1007/s004420050583

ROPER, J.J. & GOLDSTEIN, R.R. 1997. A test of the Skutch Hypothesis: does activity at nests increase nest predation risk? J. Avian. Biol. 28(2):111-116.

RUIZ-MIRANDA, C.R., AFFONSO, A.G., MORAIS, M.M., VERONA, C.E., MARTINS, A. & BECK, B. 2006. Behavioral and ecological interactions between reintroduced golden lion tamarins (*Leontopithecus rosalia* Linnaeus, 1766) and introduced marmosets (*Callithrix* spp Linnaeus, 1758) in Brazil's Atlantic Coast Forest fragments. Braz. Arch. Biol. Technol. 49(1):99-109.

RYLANDS, A.B., COIMBRA-FILHO, A.F. & MITTER-MIEIER, R.A. 1993. Systematics, geographic distribution, and some notes on the conservation status of the Callitrichidae. In Marmosets and tamarins: systematics, behaviour, and ecology (A.B. Rylands, ed.). Oxford University Press, Oxford, p.11-77.

SALES, I.S., RUIZ-MIRANDA, C.R. & SANTOS, C.P. 2010. Helminths found in marmosets (*Callithrix penicillata* and *Callithrix jacchus*) introduced to the region of occurrence of golden lion tamarins (*Leontopithecus rosalia*) in Brazil. Vet. Parasitol. 171(1-2):123-129.

SKUTCH, A.F. 1985. Clutch size, nesting success, and predation on nests of neotropical birds, reviewed. Ornithol. Monogr. 36:575-594.

SPAROVEK, G. 1993. Avaliação das terras do campus "Luiz de Queiroz": aspectos físicos, capacidade de uso, uso da terra, adequação de uso e aptidão. ESALQ, Departamento de Solos, Piracicaba.

STEVENSON, M.F. & RYLANDS, A.B. 1988. The marmosets, genus *Callithrix*. In Ecology and Behavior of Neotropical Primates (R.A. Mittermeier, A.B. Rylands, A.F. Coimbra-Filho & G.A.B. Fonseca, eds.). World Wildlife Fund, Washington, v.2.

THORINGTON, K.K. & BOWMAN, R. 2003. Predation rate on artificial nests increases with human housing density in suburban habitats. Ecography 26(3):188-196.

VILELA, L.S. & FARIA, D.S. 2002. Dieta do *Callithrix penicillata* (Primates, Callitrichidae) em áreas do cerrado no Distrito Federal, Brasil. Neotrop. Primates 10(1):17-20.

VITOUSEK, P.M. 1990. Biological invasions and ecosystem processes: towards an integration of population biology and ecosystem studies. Oikos 57(1):7-13. http://dx.doi.org/10.2307/3565731

VITOUSEK, P.M., D'ANTONIO, C.M., LOOPE, L.L., REJMANEK, M. & WESTBROOKS, R.1997a. Introduced species: a significant component of human caused global change. New Zeal. J Ecol. 21(1):1-16.

VITOUSEK, P.M., MOONEY, H.A., LUBCHENCO, J. & MELILLO, J.M. 1997b. Human domination of Earth's ecosystems. Science 277:494-499. http://dx.doi.org/10.1126/science.277.5325.494

VIVO, M.1991. Taxonomia de *Callithrix* Erxleben, 1777 (Callitrichidae, Primates). Fundação Biodiversitas, Belo Horizonte.

WILCOVE, D.S.1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology 66(4):1211-1214. http://dx.doi.org/10.2307/1939174

WILSON, E.O. 1975. Sociobiology: the new synthesis. Belknap Press of Harvard University Press, Cambridge.

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Editorial

RESILIENT PEOPLE RESILIENT PLANET: A Future Worth Choosing

In 2030, a child born in 2012 — the year our report is published — will turn 18. Will we have done enough in the intervening years to give her the sustainable, fair and resilient future that all of our children deserve? This report is an effort to give her an answer.

1. Today our planet and our world are experiencing the best of times, and the worst of times. The world is experiencing unprecedented prosperity, while the planet is under unprecedented stress.
2. Every day, millions of choices are made by individuals, businesses and governments. Our common future lies in all those choices. Because of the array of overlapping challenges the world faces, it is more urgent than ever that we take action to embrace the principles of the sustainable development agenda. It is time that genuine global action is taken to enable people, markets and governments to make sustainable choices.
3. The need to integrate the economic, social and environmental dimensions of development so as to achieve sustainability was clearly defined a quarter of a century ago. It is time to make it happen.
4. The challenges we face are great, but so too are the new possibilities that appear when we look at old problems with new and fresh eyes. These possibilities include technologies capable of pulling us back from the planetary brink; new markets, new growth and new jobs emanating from game-changing products and services; and new approaches to public and private finance that can truly lift people out of the poverty trap.
5. The long-term vision of the High-level Panel on Global Sustainability is to eradicate poverty, reduce inequality and make growth inclusive, and production and consumption more sustainable, while combating climate change and respecting a range of other planetary boundaries. This reaffirms the landmark 1987 report by the World Commission on Environment and Development, "Our Common Future" (United Nations document A/42/427, annex), known to all as the Brundtland report.
6. But what, then, is to be done if we are to make a real difference for the world's people and the planet? We must grasp the dimensions of the challenge. We must recognize that the drivers of that challenge include unsustainable lifestyles, production and consumption patterns and the impact of population growth. As the global population grows from 7 billion to almost 9 billion by 2040, and the number of middle-class consumers increases by 3 billion over the next 20 years, the demand for resources will rise exponentially. By 2030, the world will need at least 50 per cent more food, 45 per cent more energy and 30 per cent more water — all at a time when environmental boundaries are throwing up new limits to supply. This is true not least for climate change, which affects all aspects of human and planetary health.
7. The current global development model is unsustainable. We can no longer assume that our collective actions will not trigger tipping points as environmental thresholds are breached, risking irreversible damage to both ecosystems and human communities.
8. A quarter of a century ago, the Brundtland report introduced the concept of sustainable development to the international community as a new paradigm for economic growth, social equality and environmental sustainability. The report argued that sustainable development could be achieved by an integrated policy framework embracing all three of those pillars. The Brundtland report was right then, and it remains right today. The problem is that, 25 years later, sustainable development remains a generally agreed concept, rather than a day-to-day, on-the-ground, practical reality. The Panel has asked itself why this is the case, and what can now be done to change that.
9. The Panel has concluded that there are two possible answers. They are both correct, and they are interrelated. Sustainable development has undoubtedly suffered from a failure of political will. It is difficult to argue against the principle of sustainable development, but there are few incentives to put it into practice when our policies, politics and institutions disproportionately reward the short term. In other words, the policy dividend is long-term, often intergenerational, but the political challenge is often immediate.
10. There is another answer to this question of why sustainable development has not been put into practice. It is an answer that we argue with real passion: the concept of sustainable development has not yet been incorporated into the mainstream national and international economic policy debate. Most economic decision makers still regard sustainable development as extraneous to their core responsibilities for macroeconomic management and other branches of economic policy. Yet integrating environmental and social issues into economic decisions is vital to success.
11. For too long, economists, social activists and environmental scientists have simply talked past each other — almost speaking different languages, or at least different dialects. The time has come to unify the disciplines, to develop a common language for sustainable development that transcends the warring camps; in other words, to bring the sustainable development paradigm into mainstream economics. That way, politicians and policymakers will find it much harder to ignore.
12. That is why the Panel argues that the international community needs what some have called "a new political economy" for sustainable development. This means, for example: radically improving the interface between environmental science and policy; recognizing that in certain environmental domains, such as climate change, there is "market failure", which requires both regulation and what the economists would recognize as the pricing of "environmental externalities", while making explicit the economic, social and environmental costs of action and inaction; recognizing the importance of innovation, new technologies, international cooperation and investments responding to these problems and generating further prosperity; recognizing that an approach should be agreed to quantify the economic cost of sustained social exclusion — for example, the cost of excluding women from the workforce; recognizing that private markets alone may be incapable of generating at the scale necessary to bring about a proper response to the food security crisis; and requiring international agencies, national Governments and private corporations to report on their annual sustainable development performance against agreed

sustainability measures. We must also recognize that this is a core challenge for politics itself. Unless the political process is equally capable of embracing the sustainable development paradigm, there can be no progress.

13. The scale of investment, innovation, technological development and employment creation required for sustainable development and poverty eradication is beyond the range of the public sector. The Panel therefore argues for using the power of the economy to forge inclusive and sustainable growth and create value beyond narrow concepts of wealth. Markets and entrepreneurship will be a prime driver of decision-making and economic change. And the Panel lays down a challenge for our Governments and international institutions: to work better together in solving common problems and advancing shared interests. Quantum change is possible when willing actors join hands in forward-looking coalitions and take the lead in contributing to sustainable development.
14. The Panel argues that by embracing a new approach to the political economy of sustainable development, we will bring the sustainable development paradigm from the margins to the mainstream of the global economic debate. Thus, both the cost of action and the cost of inaction will become transparent. Only then will the political process be able to summon both the arguments and the political will necessary to act for a sustainable future.
15. The Panel calls for this new approach to the political economy of sustainable development so as to address the sustainable development challenge in a fresh and operational way. That sustainable development is right is self-evident. Our challenge is to demonstrate that it is also rational — and that the cost of inaction far outweighs the cost of action.
16. The Panel's report makes a range of concrete recommendations to take forward our vision for a sustainable planet, a just society and a growing economy:
    a. It is critical that we embrace a new nexus between food, water and energy rather than treating them in different "silos". All three need to be fully integrated, not treated separately if we are to deal with the global food security crisis. It is time to embrace a second green revolution — an "ever-green revolution" — that doubles yields but builds on sustainability principles;
    b. It is time for bold global efforts, including launching a major global scientific initiative, to strengthen the interface between science and policy. We must define, through science, what scientists refer to as "planetary boundaries", "environmental thresholds" and "tipping points". Priority should be given to challenges now facing the marine environment and the "blue economy";
    c Most goods and services sold today fail to bear the full environmental and social cost of production and consumption. Based on the science, we need to reach consensus, over time, on methodologies to price them properly. Costing environmental externalities could open new opportunities for green growth and green jobs;
    d. Addressing social exclusion and widening social inequity, too, requires measuring them, costing them and taking responsibility for them. The next step is exploring how we can deal with these critical issues to bring about better outcomes for all;
    e. Equity needs to be at the forefront. Developing countries need time, as well as financial and technological support, to transition to sustainable development. We must empower all of society — especially women, young people, the unemployed and the most vulnerable and weakest sections of society.
    f. Any serious shift towards sustainable development requires gender equality. Half of humankind's collective intelligence and capacity is a resource we must nurture and develop, for the sake of multiple generations to come.
    g. Many argue that if it cannot be measured, it cannot be managed. The international community should measure development beyond gross domestic product (GDP) and develop a new sustainable development index or set of indicators;
    h. Financing sustainable development requires vast new sources of capital from both private and public sources. It requires both mobilizing more public funds and using global and national capital to leverage global private capital through the development of incentives.
    i. Governments at all levels must move from a silo mentality to integrated thinking and policymaking. They must bring sustainable development to the forefront of their agendas and budgets and look at innovative models of international cooperation. Cities and local communities have a major role to play in advancing a real sustainable development agenda on the ground;
    j. International institutions have a critical role. International governance for sustainable development must be strengthened by using existing institutions more dynamically and by considering the creation of a global sustainable development council and the adoption of sustainable development goals;
    k. Governments and international organizations should increase the resources allocated to adaptation and disaster risk reduction and integrate resilience planning into their development budgets and strategies;
    l. Governments, markets and people need to look beyond short-term transactional agendas and short-term political cycles. Incentives that currently favour short-termism in decision-making should be changed. Sustainable choices often have higher up-front costs than business as usual. They need to become more easily available, affordable and attractive to both poor consumers and low-income countries.
18. This Panel believes it is within the wit and will of our common humanity to choose for the future. This Panel therefore is on the side of hope. All great achievements in human history began as a vision before becoming a reality. The vision for global sustainability, producing both a resilient people and a resilient planet, is no different.

Extracted from the Report of the UN Secretary General High Level Panel on Global Sustainability
http://www.un.org/wcm/content/site/climatechange/pages/gsp

Concordance between macroinvertebrate communities and the typological classification of white and clear-water streams in Western Brazilian Amazonia

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Abstract: In this study we have attempted to answer whether there is correspondence between aquatic macroinvertebrate communities and the typological classification of white and clean-water streams in western Amazonia lowlands. We worked within two distinct hydrographic basins: Moa River catchment (clear-water streams) and Azul River catchment (white-water streams) in Serra do Divisor National Park, Acre State, Brazil, sampling 10 streams in each basin. A total of 2,952 individuals were collected, distributed among 134 taxa. Our results show that macroinvertebrate communities, at genus as well as family level, are in concordance to a priori classifications that distinguish between white and clear water streams. The main implication of our results for biomonitoring is that biotic variation between white and clear streams can be partitioned regionally, which would improve the bioassessment accuracy of the Amazonian streams.
Keywords: *aquatic insects, biodiversity, neotropical region, biomonitoring, Brazil.*

ROQUE, F.O., LIMA, D.V.M., SIQUEIRA, T., VIEIRA, L.J.S., STEFANES, M. & TRIVINHO-STRIXINO, S. **Concordância entre comunidade de macroinvertebrados e classificação tipológica de igarapés em águas brancas e claras no oeste Amazônico, Brasil**. Biota Neotrop. 12(2): http://www.biotaneotropica.org.br/v12n2/pt/abstract?article+bn01512022012

Resumo: Neste trabalho, nós investigamos se há correspondência entre comunidade de macroinvertebrados e classificação de igarapés em águas claras e brancas no oeste da Amazônia. Nós trabalhos em duas bacias hidrográficas, Rio Moa (águas claras) e Rio Azul (águas brancas) no Parque Nacional da Serra do Divisor, Acre, Brasil, amostrando 10 igarapés em cada bacia. Coletamos 2952 indivíduos, distribuídos em 134 taxa. Nossos resultados mostram que a comunidade de macroinvertebrados, identificada com baixa e alta resolução taxonômica, responde claramente a classificação tipológica de igarapés em águas claras e brancas. A principal implicação dos nossos resultados no âmbito de biomonitoramento é que a partição da variação biótica entre igarapés de águas claras e brancas pode melhorar a racionalidade e implantação de sistemas de avaliação ambiental na Amazônia.
Palavras-chaves: *insetos aquáticos, biodiversidade, região neotropical, biomonitoramento, Brasil.*

Introduction

Studies on the correspondence between communities and aquatic system classifications have a long history in ecology and limnology, going back to the pioneer studies of Thienemam in the beginning of the 1900s. Recently, there has been renewed interest in typologies and classifications of aquatic ecosystems due to their implication for biomonitoring and conservation (Heino et al. 2003, Padial et al. 2012). Many classification schemes have been used to test for concordance between landscape patterns and structural and functional aspects of biological communities (e.g. Hawkins & Norris 2000).

In the Neotropical region, particularly in Amazonia, it has been accepted that differences in river discharges, channel morphologies, flood cycles and water chemistry have reflected in the evolution and ecology of aquatic communities (Sioli 1984, Junk & Soares 2001). Amazonian rivers and streams are classified in terms of their size, channel morphology (anastomosing, braided and meandering) and 'color' (white water, black water and clear water) (Sioli 1950, Junk & Furch 1985). While white-water rivers have muddy color due to their high sediment content, black-water rivers have dark transparent water because of the large amount of dissolved humic substances carried from the forest, and clear-water rivers drain areas where there is little erosion.

Despite the broad acceptance of this classification based on water-color, and their hypothetical importance for evolution and ecology of Amazonian diversity, few data on macroinvertebrate distribution in black and clear-water streams in Amazonia exist. Moreover, most of the available information is from the central part of the region (Fittkau 1971, Walker 1995, Couceiro et al. 2007, Nessimian et al. 2008) and to our knowledgement there is no previous study on white-water streams.

Western Amazonian forests have been postulated to possess one of the most diverse and endemic faunal and floral biota on Amazonia (Gentry 1988, Wilson & Sandoval 1996, S.O.S. Amazônia 1998). The western part of the Amazon basin is a region characterized by abundant dynamic headwaters of the Amazonas River, being influenced by tectonic activities of the Andean foothills and foreland (Räsänen et al. 1987). Streams of this region provide a good system for exploring and testing possible association between different types of streams and biological communities. Besides the fact that the area encompasses high biological diversity and variable geomorphologies along its basins (S.O.S. Amazônia 1998), it is possible to find the three types of water (white, clear and black).

In this study we attempt to answer whether there is correspondence between macroinvertebrate communities and the typological classification of white and clear-water streams in western Amazonian lowlands, particularly in the northern area of the Serra do Divisor National Park (SDNP), one of the most pristine and understudied areas of the western Brazilian Amazonia. Considering that water-color types could serve as good 'surrogates' of more complex variables in nature (e.g. vegetation patterns, water chemistry, nutrient content, potential productivity and biological interactions), we predict significant differences in terms of composition and abundance in macroinvertebrate communities between stream types. In addition, regarding the increasing demand for methods of rapid stream bioassessment in tropical region, including taxonomic resolution simplification, we assess how concordant is the pattern of macroinvertebrate variation between stream types based on genus/morphospecies and family level identification. We also discuss the implications of our findings for future biomonitoring programs in the region.

Materials and Methods

1. *Study area*

The north area of the Serra do Divisor National Park (SDNP) is located in the Acre State, the most western Brazilian Amazonia extremity (Figure 1 7° 09' 55" S and 73° 43' 55" W). The altitude in the region varies from 200 m to 650 m and the annual rainfall is around 2,200 mm (S.O.S. Amazônia 1998). The mean annual temperature is 26 °C along the rainy season, possibly reaching 4 °C in the drier months. The SDNP includes a diversity of geological formations within its limits as a result of the complex evolutionary history associated with the geological processes that occurred in the Amazonian region. The study area consists of a series of elevations and valleys, and it is covered by primary and secondary Open Tropical Forest.

We worked within two distinct hydrographic basins of the SDNP (Figure 1): River Moa catchment (clear-water streams) and River Azul catchment (white-water streams). We used a comprehensive classification of white and clear stream waters based on a visual evaluation of the color of the water. We sampled 10 streams in each basin, varying from first to second orders. These streams were fairly typical of forested headwater streams in Amazonian dry land with water depths less than 50 cm, canopy covered ~70% of the channel, absence of macrophytes and high dissolved oxygen levels. Streams were slightly acidic for clear water (pH 5.12 to 6.46) and white water (pH 5.85 to 6.92). Water temperature ranged from 23.8-24.8 °C in clear water and from 23.2-24.5 °C in white water. The substrates of the clear-water streams were characterized by a predominance of rocks and sand whereas white-water streams had an abundance of organic matter and mud. Electric conductivity ranged from 1 to 10 mS/cm^{-1} (in clear waters), and from 10 to 80 mS/cm^{-1} (in white waters).

2. *Sampling design*

We adopted a stratified sampling design to investigate macroinvertebrate distribution in pools and riffle habitats, with three samples in each one. We collected macroinvertebrates on a single occasion with a Surber sampler to a depth of ~5 cm within the substrate of each stream. Afterwards all subsamples were pooled for statistical analyses.

Specimens were identified to the lowest practical level possible, due to limited knowledge of Neotropical fauna. Specimens were preserved in alcohol 70% and were deposited in the collection of the Universidade Federal do Acre.

3. *Statistical analysis*

We checked the magnitude of the difference among the two water types in relation to taxa abundance using a t-test. We used Non-metric Multidimensional Scaling (NMDS) to generate a two-dimensional ordination as a visual summary of the associations between streams. The taxa abundance matrix was logged [logbase (x + 1)] to calculate an association matrix (Bray-Curtis dissimilarity). A stress level, or measure of the goodness of fit, was calculated for each ordination. Lower stress values are desirable, as indicated by values of 0.2 or less (Clarke & Warwick 2005). The result matrix of Bray-Curtis was submitted to a one-factor ANOSIM (Analysis of Similarity).

We evaluated the relative contributions of different taxa to dissimilarities using a Similarity Percentage Analysis (SIMPER) routine (Clarke 1993). We calculated the degree of concordance between different taxonomic resolutions using the second-stage NMDS procedure (Somerfield & Clarke 1995). This analysis generate a 'second stage' similarity matrix based on the Spearman rank

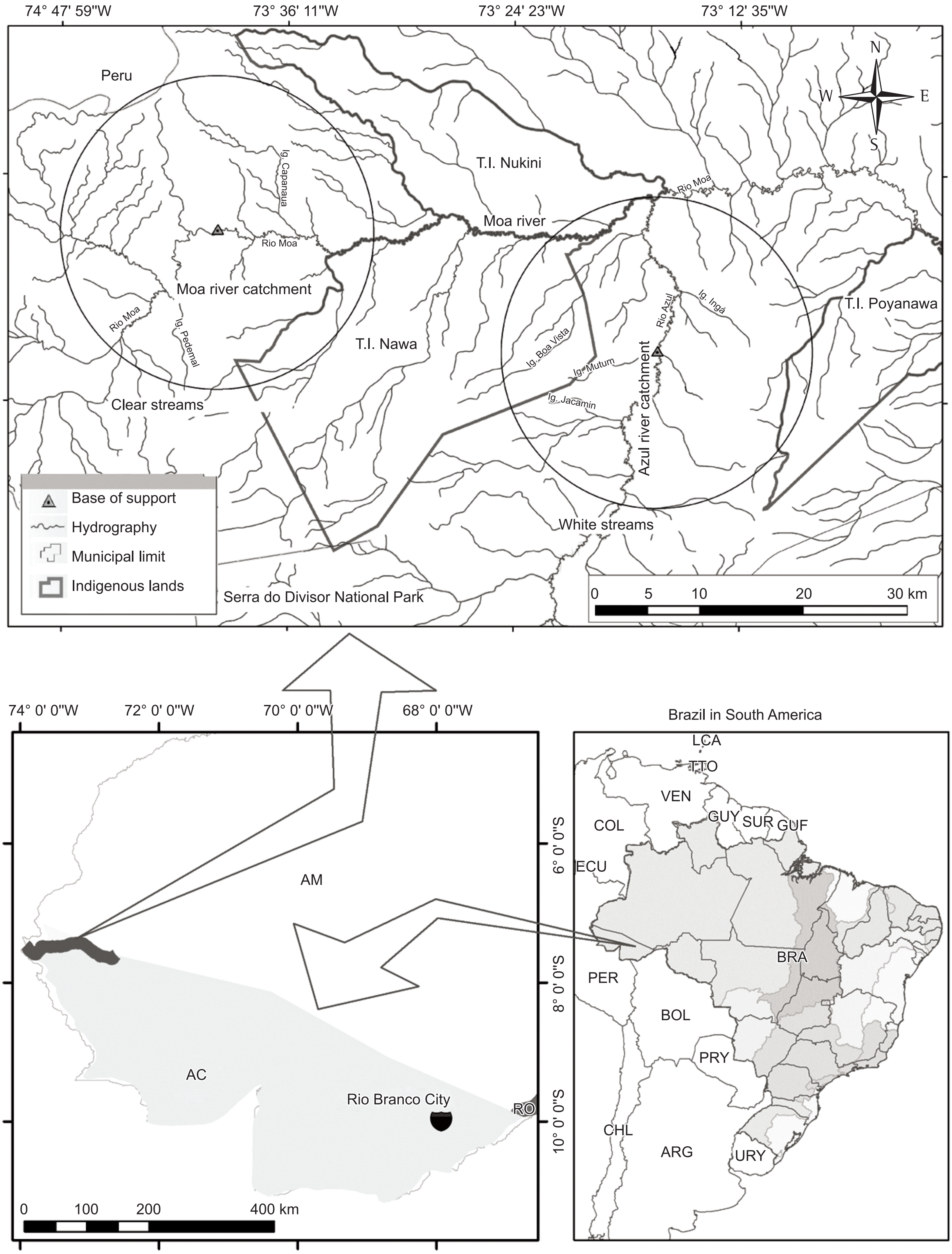

Figure 1. The sampling areas in Parque Nacional da Serra do Divisor, Acre, Brazil: Moa river catchment characterized by clear waters (left circle) and Azul river catchment characterized by white waters (right circle).

correlation (q) between the similarity matrices resulting from the data sets; when q = 0, there is no concordance between matrices and when q = 1, the different data sets are identical. The significance of q was determined using a permutation test (Clarke & Gorley 2001).

Results

We collected a total of 2,952 individuals, distributed in 134 taxa, which belong to 65 families and 13 orders. We found that the total number of individuals was significantly higher (t = –4.10; $p < 0.001$) in clear-water streams (1,972) than in white-water streams (980).

The abundance of Decapoda (t = 3.99; $p < 0.001$), Ephemeroptera (t = 2.64; $p = 0.016$) and Hemiptera (t = 2.83; $p = 0.01$), was significantly higher in white waters than in clear waters. In clear-water streams Diptera (t = –5.55; $p < 0.001$), Plecoptera (t = –1.80; $p = 0.08$) and Trichoptera (t = –9.85; $p < 0.001$) were significantly more abundant. In the case of Hirudinea (t = 1.03; $p = 0.31$), Megaloptera (t = –0.70; $p = 0.48$), and Odonata (t = 0.11; $p = 0.90$), no significant differences between stream types were found.

1. *Comparing taxonomic patterns in white water and clear water streams at family level*

The NMDS ordination indicated a clear separation in the community organization between clear waters and white waters when using family level identification (Stress = 0.202; Figure 2). We found that macroinvertebrate community structure was significantly different between stream types (ANOSIN; $R = 0.9993$; $p < 0.001$) and that Leptophlebiidae (20.21%), Trichodactylidae (13.96%), Corixidae (13.56%), and Gomphidae (12.41%) were the most important groups characterizing white-water streams, whereas clear waters were characterized by Hydropsychidae (10.30%), Gomphidae (7.89%), Tanypodinae (7.70%), and Chironominae (7.48%) (SIMPER analysis). Hydropsychidae (5.48%), Odontoceridae (4.43%), Elmidae (4.36%), Ptilodactilidae (4.36%), Corixidae (3.76%), Tanypodinae (3.52%), Orthocladiinae (3.39%), and Trichodactylidae (3.35%), were important in determining differences between the water types.

2. *Comparing taxonomic patterns in white-water and clear-water streams at genus level*

Of the 134 genera identified in the two water types, 44 exclusively occurred in clear waters and 24 in the white ones. Among the genera we found in white waters, Tipulidae 1 occurred in all streams whereas Trichodactylidae 1 and *Miroculis* (Leptophlebiidae) were present in all samples of the clear-water streams.

We also found a clear separation of the macroinvertebrate communities between clear and white waters based on genus level identification (NMDS analysis; Stress = 0.144; Figure 3). Community organization was also significantly different between water types (ANOSIM; $R = 0.9995$; $p < 0.001$).

Assemblages in white-water streams were typified by *Miroculis* (18.59%), Trichodactylidae 1 (13.96%), Corixidae 1 (13.58%), *Brasilocaenis* (6.71%), and *Farrodes* (4.39%), whereas *Smicridea* (9.46%), *Miroculis* (5.88%), *Marilia* (5.08%), Ptilodactilidae 1 (4.89%), *Anacroneuria* (4.59%), *Progomphus* (4.56%), and *Neoelmis* (4.56%) were the most important in typifying clear-water streams.

Seventy-one genera accounted for 90% of the dissimilarities between groups. *Smicridea* (3.64%), Trichodactilidae 1 (3.35%), *Marilia* (2.98%), Ptilodactilidae 1 (2.95%), *Neoelmis* (2.86%), Corixidae 1 (2.59%), *Anacroneuria* (2.24%), and *Brasilocaenis* (2.16%) were the most important taxa (Appendix 1).

The second-stage NMDS analysis showed that the arrangement of the rank order of similarities in the matrix derived from the family and genus level was correlated (q = 0.80). This means that there is little difference between analyses based on genus and family level.

Discussion

1. *Macroinvertebrate commnunity patterns*

Black, white and clear water Amazonian streams are expected to have different biotic communities (Fittkau 1971), but these patterns have been documented quantitatively only recently. Most studies have documented patterns of macroinvertebrate communities between black and white streams which correspond to the Solimões and Negro River catchments. Walker (1995) compared macroinvertebrate communities from both water types (black and white) and showed that the taxonomic composition seems to be similar, but taxa richness and abundance seems to be greater in black-water streams. Here we show that there is a correspondence between previously established classifications (clear and white-water streams) and macroinvertebrate communities, at both genus and family resolutions.

The most abundant and frequent taxa collected in this study were Decapoda, Ephemeroptera, Odonata and Chironomidae. These groups have also been showed to be the most frequent taxa in Central Amazonian black water streams (Walker 1995) and in less impacted streams around Manaus (Couceiro et al. 2007).

The significant differences we found between clear and white water streams, based on many typifying taxa, suggest that the biological processes that act to influence taxa establishment and their persistence is manifested most strongly at this regional spatial scale with different groups behaving in a dominant way depending

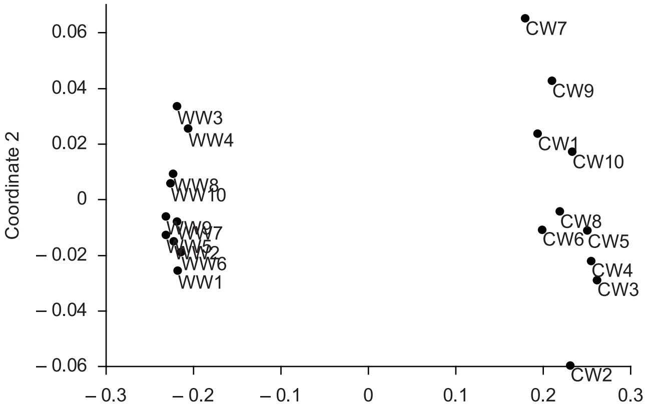

Figure 2. NMDS ordination (Bray-Curtis) of macroinvertebrate structure communities at family level in streams in Serra do Divisor National Park, Acre, Brazil. Stress = 0.2021 (cw = clear water; ww = white water).

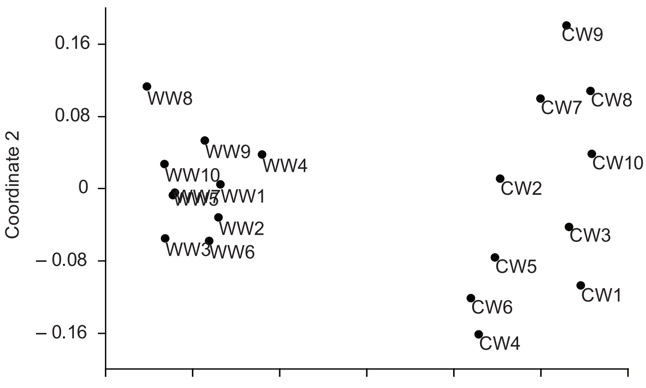

Figure 3. NMDS ordination (Bray-Curtis) of macroinvertebrate structure communities at genus level in streams in Serra do Divisor National Park, Acre, Brazil. Stress = 0.1441 (cw = clear water; ww = white water).

on the stream type. It is particularly important to the understanding of Amazonian biogeographical patterns that we can distinguish between historical and contemporaneous processes affecting stream biodiversity (Tuomisto & Ruokolainen 1997). As no physical barrier seems to separate our sampling areas of white and clear waters, at least for adults of aquatic insects, we believe that the patterns evidenced in our analysis are most related to local contemporaneous ecological filters acting regionally in the same species pool.

There are few similar studies that can be quantitatively compared to our results. Grossly comparing our findings with those from streams of central Amazonia, macroinvertebrate richness at genus level found in the present study is similar to the 152 taxa found in 68 streams studied by Couceiro et al. (2007) and the 151 taxa in 20 streams reported by Nessimian et al. (2008). Unfortunately, few data are available from low-order streams of other Neotropical forested biomes for macroinvertebrate communities at the regional scale, so direct comparisons are difficult because the methods and taxonomic resolution differed considerably. Studies on macroinvertebrate diversity in Atlantic forest streams of South-eastern Brazil found taxa richness ranging from 117-162 (Melo & Froehlich 2001, Baptista et al. 2001) which provides evidence to support the proposition of Vinson & Hawkins (2003) that streams within similar biomes have similar numbers of aquatic insects regardless of the biogeographical area. However, taking a more detailed taxonomic resolution, it is clear that species richness is underestimated due to low taxonomic resolution. For example, Roque et al. (2007) assessed chironomid species richness only from 15 low-order streams in the Atlantic rainforest and distinguished a total of 191 morphospecies, and estimated a species richness ranging from 200 (credibility interval, 195-207) to 267 (248-288).

There are some non-exclusive reasons to explain why macroinvertebrate communities correspond to water types. First, our findings agree with previous studies that found associations between the distribution patterns of aquatic insects and the geographical features through which streams flow, especially where marked differences in topography or water chemistry (e.g. conductivity and pH) are found (Hawkins & Norris 2000, Roque et al. 2010, Siqueira et al. 2012). Second, Amazonian stream classification based on color may reflect fundamental discontinuities of nature (e.g. vegetation patterns, substrate composition, water chemistry, nutrient content, potential productivity and biological interactions), which could serve as a good 'surrogate' for relevant indicators of benthic organism diversity. Third, biological interactions can play an important role in shaping the distributional patterns of aquatic insects in Amazonian streams. In nutrient-poor waters, fungi play the most important role at the beginning of decomposition process of litter, while in white waters bacteria dominate. As white and clear water streams are characterized by differences in the amount of macroconsumers and habitat quality, there is likely to be a trade-off between strategies to avoid predation and strategies to live in waters with high amounts of sediment, which may influence macroinvertebrate distributions in clear and white water streams. Fourth, the importance of considering ecological variation related to geographical location has been stressed in recent years (Legendre 1993, Roque et al. 2010). The spatial structure of ecological communities can be molded by abiotic and biotic process (e.g. population growth, geographic organization, differential fertility or mortality, social organization, competition). In our study, the spatial location of streams sampled may account for a significant portion of the variation in macroinvertebrate distributional data. Such patterns detected at genus level are most likely to be related to the non-random distribution of the streams sampled (e.g. the clear streams were close to each other, the same for clear waters). The spatial distribution of the streams may also underlie relevant biological factors not measured here (e.g. biological interactions). Considering the fact that water-type distributions are not randomly distributed across the Amazonian landscape, we emphasize the need to consider geographical location when interpreting biodiversity distributions at the regional scale (Heino et al. 2003, Roque et al. 2010).

2. *Biomonitoring implication*

Freshwater monitoring strategies rely on stream classifications based on environmental and biotic groups and this approach is the cornerstone of most biomonitoring programs. Classification is therefore a critical component in many bioassessment programs designed to assess the health of streams, small rivers, lakes, and some estuaries (Bailey et al. 1998). Inferences are typically derived from a classification of sites that relates variation in biological proprieties of interest to class memberships. It is imperative that the most robust classification systems possibly are developed and implemented. Our analyses show that macroinvertebrate communities, at genus as well as family level, are concordant to a priori classifications that distinguish between white and clear water streams. The main implication of our results for biomonitoring is that biotic variation between white and clear streams can be partitioned regionally, which would improve the bioassessment accuracy of the Amazonian streams.

The taxonomic resolution used in our analysis has practical consequences for water biomonitoring. In our study, family and genus levels yielded the same pattern differentiating white and clear Amazonian streams. These results agree with previous studies suggesting that family-level information is enough for grossly detecting ecological patterns (Marchant et al. 1995, Melo 2005, Feio et al. 2006). However we are only beginning to document macroinvertebrates in white and clear streams in Amazonia. Information from other parts of Amazonia is essential for understanding macroinvertebrate distributional patterns and for testing the generality of the results detected here.

From an applied perspective, knowledge about macroinvertebrate occurrences in preserved and impacted Amazonian streams is fundamental for future biomonitoring programs. For instance, white water streams contained predominantly Chironomidae, which are often associated with impacted areas and/or areas with low water flow, whereas clear water streams were characterized by great numbers of EPT and by the presence of sensitive taxa (e.g. Polythoridae), groups associated with areas of low anthropic influence and higher water flow. This means that one type of stream can not be used as reference for the other. For example, if one use clear water stream biological information for setting expectations about the ecological condition of white water streams, we can run the risk of interpreting white water streams as 'naturally impacted'. Therefore, future biomonitoring programs in Amazonian streams should be based on regional information about its biodiversity; in contrast, we could misinterpret ecological conditions of Amazonian streams.

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References

BAPTISTA, D.F., DORVILLÉ, L.F.M., BUSS, D.F. & NESSIMIAN, J.L. 2001. Spatial and temporal organization of aquatic insect assemblages in the longitudinal gradient of a tropical river. Braz. J. Biol. 61:295-304.

BAILEY, R.C., KENNEDY, M.G., DERVISH, M.Z. & TAYLOR, A.R.M. 1998. Biological assessment of freshwater ecosystems using a reference condition approach: comparing predicted and actual benthic invertebrate communities in Yukon streams. Freshwater Biol. 39:765-774.

CLARKE, K.R. 1993. Non-parametric multivariate analyses of changes in community structure. Aust. J. Ecol. 18:117-143. http://dx.doi.org/10.1111/j.1442-9993.1993.tb00438.x

CLARKE, K.R. & GORLEY, R.N. 2001. Software PRIMER. Primer–E Ltd., Plymouth, v.5.

CLARKE, K.R. & WARWICK, R.M. 2005. Change in marine communities - an approach to statistical analysis and interpretation. 2. ed. Plymouth, Primer–E Ltd.

COUCEIRO, S.R.M., HAMADA, N., LUZ, S.L.B., FORSBERG, B.R. & PIMENTEL, T.P. 2007. Deforestation and sewage effects on aquatic macroinvertebrates in urban streams in Manaus, Amazonas, Brazil. Hydrobiologia 575:271-284.

FEIO, M.J., REYNOLDSON, T.B. & GRAÇA, M.A.S. 2006. The influence of taxonomic level on the performance of a predictive model for water quality assessment. Can. J. Fish Aqua. Sci. 63:367-376.

FITTKAU, E.J. 1971. Distribution and ecology of Amazonian chironomids (Diptera). Can. Entomol. 103:407-413. http://dx.doi.org/10.4039/Ent103407-3

GENTRY, A.H. 1988. Changes in plant community diversity and floristic composition on environmental and geographical gradients. Ann. Missouri Bot. Gard. 75:1-34. http://dx.doi.org/10.2307/2399464

HAWKINS, C.P & NORRIS, R.H. 2000. Landscape classifications: aquatic biota and bioassessments. J. N. Am. Benthol. Soc. 19(3). http://dx.doi.org/10.2307/1468113

HEINO, J., MUOTKA, T., MYKRÄ, H., PAAVOLA, R., HÄMÄLÄINEN, H. & KOSKENNIEMI, E. 2003. Defining macroinvertebrate assemblage type of headwater streams: implications for bioassessment and conservation. Ecol. Appl. 13:842-852.

JUNK, W.J. & FURCH, K. 1985. Key Environments Amazonia. In The physical and chemical properties of the Amazonian waters and their relationships with the biota (GT Prance & TE Lovejoy, eds.). Pergamon Press, Oxford, p.3-17.

JUNK, W.J. & SOARES, M.G.M. 2001. Freshwater fish habitats in Amazonian: state of knowledge, management, and protection. AEHM 4:437-451.

LEGENDRE, P. 1993. Spatial autocorrelation: trouble or new paradigm? Ecology 74:1659-1673. http://dx.doi.org/10.2307/1939924

MARCHANT, R., BARMUTA, L.A. & CHESSMAN, B.C. 1995. Influence of sample quantification and taxonomic resolution on the ordination of macroinvertebrate communities from running waters in Victoria, Australia. Mar. Fresh Res. 46:501-506.

MELO, A.S. & FROEHLICH, C.G. 2001. Macroinvertebrates in neotropical streams: richness patterns along a catchments and assemblage structure between 2 seasons. J. N. Am. Benthol. Soc. 20:1-16.

MELO, A.S. 2005. Effects of taxonomic and numeric resolution on the ability to detect ecological patterns at a local scale using stream macroinvertebrates. Arch. Hydrobiol. 164:309-323. http://dx.doi.org/10.1127/0003-9136/2005/0164-0309

NESSIMIAN, J.L., VENTICINQUE, E.M., ZUANON, J., DE MARCO JUNIOR, P., GORDO, M., FIDELIS, L., BATISTA, J.D. & JUEN, L. 2008. Land use, habitat integrity and aquatic insect ssemblages in Central Aamazonian streams. Hydrobiologia 614:117-131.

PADIAL, A.A., SIQUEIRA, T., HEINO, J., VIEIRA, L.C.G., BONECKER, C.C., LANSAC-TÔHA, F.A., RODRIGUES, L.C., TAKEDA, A.M., TRAIN, S., VELHO, L.F.M. & BINI, L.M. 2012. Relationships between multiple biological groups and classification schemes in a Neotropical floodplain. Ecol. Indic. 13:55-65. http://dx.doi.org/10.1016/j.ecolind.2011.05.007

RÄSÄNEN, M., SALO, J.S. & KALLIOLA, R.J. 1987. Long-term fluvial perturbance in the western Amazon basin: regulation by long-term sub-Andean tectonics. Science. 238:1398-1401.

ROQUE, F.O., SIQUEIRA, T., BINI, L.M., RIBEIRO, M.C., TAMBOSI, L.R., CIOCHETI, G. & TRIVINHO-STRIXINO, S. 2010. Untangling associations between chironomid taxa in Neotropical streams using local and landscape filters. Freshwater Biol. 55:847-865. http://dx.doi.org/10.1111/j.1365-2427.2009.02314.x

ROQUE, F.O., TRIVINHO-STRIXINO, S., MILAN, L.A. & LEITE, J.G. 2007. Chironomid species richness in low order streams in Brazilian Atlantic Forest: a first approximation through Bayesian approach. J. N. Am. Benthol. Soc. 26:221-231.

SIQUEIRA, T., BINI, L.M., ROQUE, F.O., COUCEIRO, S.R.M., TRIVINHO-STRIXINO, S. & COTTENIE, K. 2012. Common and rare species respond to similar niche processes in macroinvertebrate metacommunities. Ecography 35:183-192. http://dx.doi.org/10.1111/j.1600-0587.2011.06875.x

SIOLI, H. 1950. Das Wasser im Amazonasgebiet. Forsch. Fortschr. 26:274-280.

SIOLI, H. 1984. Amazon: limnology and landscape ecology of a mighty tropical river and its basin. In The Amazon and its main afluents: Hydrology, morphology of the river courses and river types (H. Sioli, ed.). Dordrecht, W. Junk Publishers, p.127-165.

SOMERFIELD, P.J. & CLARKE, K.R. 1995. Taxonomic levels, in marine community studies, revisited. Mar. Ecol. Prog. Ser. 127:113-119.

S.O.S. AMAZÔNIA. 1998. Plano de Manejo do Parque Nacional da Serra do Divisor - PNSD. SOS Amazônia, IBAMA.

TUOMISTO, H. & RUOKOLAINEN, K. 1997. The role of ecological knowledge in explaining biogeography and biodiversity in Amazonia. Biodiv. Conserv. 6:347-357.

VINSON, M.R. & HAWKINS, C.P. 2003. Broad-scale geographical patterns in local stream insect genera richness. Ecography 26:751-767.

WALKER, I. 1995. Limnology in Brazil. In Amazonian streams and small rivers (J.G. Tundise, C.E. Bicudo & T. Matsumura-Tundisi, eds.). ABC/SBL, Rio de Janeiro, p.75-92.

WILSON, D.E. & SANDOVAL, A. 1996. Manu-the Biodiversity of Southeastern Peru. Smithsonian Institution and Editorial Horizonte, Lima.

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Appendix

Appendix 1. Summary of SIMPER analysis identifying the contribution of individual taxa to total dissimilarity between water types in Amazonian streams, Acre, Brazil.

Taxa	Genus	White water %	Clear water %	White vs Clear water %
Plecoptera				
Perlidae		3.75	5.16	3.21
	Anacroneuria Klapálek	2.17	4.59	2.24
	Macrogynoplax Lenderlein	-	1.09	1.16
Trichoptera				
Calamoceratidae		-	2.55	2.75
	Phylloicus Müller	-	2.55	1.83
Glossosomatidae		-	-	-
	Glossomatidae 1	-	-	-
Helicopsychidae		-	3.40	2.44
	Helicopsyche Siebold	-	3.57	1.66
Hydropsychidae		-	10.30	5.48
	Leptonema Guérin	-	1.08	1.39
	Smicridea McLachlan	-	9.46	3.64
	Synoestropsis Ulmer	-	-	0.54
	Macronema Pictet	-	-	-
	Macrostemum Kolenati	-	1.76	1.28
Leptoceridae		-	2.81	2.77
	Nectopsyche Müller	-	-	0.63
	Triplectides Kolenati	-	-	-
	Oecetis McLachlan	-	2.27	1.47
Odontoceridae		-	4.95	4.43
	Marilia Müller	-	5.08	2.98
Philopotamidae		-	-	1.24
	Wormaldia McLachlan	-	-	0.64
	Chimarra Stephens	-	-	0.45
Polycentropodidae		-	-	1.33
	Polycentropodidae 1	-	-	0.44
	Polypectropus Ulmer	-	-	-
	Cyrnellus Banks	-	-	-
Seracostomatidae		-	-	-
	Seracostomatidae 1	-	-	-
Xiphocentronidae		-	-	1.40
	Xiphocentron Brauer	-	-	0.99
Coleoptera				
Eylaidae		-	-	-
	Eylaidae 1	-	-	-
Crysomelidae		-	-	-
	Crysomelidae 1	-	-	-
Curculionidae		-	-	-
	Curculionidae 1	-	-	-
Dytiscidae		-	-	-
	Dytiscidae 1		-	-
Elmidae		-	4.72	4.36
	Neoelmis Musgrave	-	4.56	2.86
	Heterelmis Sharp	-	-	-
Scirtidae		-		0.95
	Prionocyphon Redtenbacher	-	-	-
	Scirtidae 1	-	-	-
	Cyphon Paykull	-	-	0.65

Appendix 1. Continued...

Taxa	Genus	White water %	Clear water %	White vs Clear water %
Haliplidae		1.84	-	1.03
	Haliplidae 1	1.97	-	-
Hydrophilidae		-	-	-
	Tropisternus Solier	-	-	0.35
Noteridae		1.67	-	-
	Noteridae 1	1.72	0.90	-
Ptilodactylidae		-	4.72	4.36
	Ptilodactylidae 1	-	4.89	2.95
Diptera				
Ceratopogonidae		-	3.80	2.75
	Ceratopogonidae 1	-	4.01	1.89
Tanypodinae		2.47	7.70	3.52
	Ablabesmyia Johannsen	-	3.72	1.87
	Aff. *Denopelopia* Roback & Rutter	-	-	-
	Larsia Fittkau	-	-	0.38
	Pentaneura Philippi	-	-	0.54
	Zavrelimyia Fittkau	-	-	0.38
	Coelotanypus Kieffer	-	-	0.54
	*Djalmabatista*Fittkau	-	-	0.37
	Procladius Skuse	-	-	0.36
Orthocladiinae		4.90	7.72	3.39
	Corynoneura Winnertz	-	-	-
	Thienemanniella Kieffer	-	-	0.53
	Parametriocnemus Goetghebuer	-	0.80	1.07
	Cricotopus v. d. Wulp	-	-	0.40
Chironominae		6.03	7.48	3.05
	Beardius Reiss & Sublette	-	-	0.78
	Chironomus Meigen	-	-	0.39
	Endotribelos Grodhaus	1.76	2.34	1.43
	Fissimentum Cranston & Nolte	-	-	-
	Goeldichironomus Fittkau	-	-	0.81
	Pelomus Reiss	-	-	-
	Lauterborniella Thienemann & Bause	-	-	-
	Oukuriella Epler	-	-	-
	Nilothauma Kieffer	-	-	-
	Paratendipes Kieffer	-	-	0.41
	Polypedilum Kieffer	1.67	2.66	1.33
	Harnischia complex	-	-	-
	Stenochironomus Kieffer	0.94	0.86	1.14
	Caladomyia Säwedall	-	-	1.03
	Tanytarsini sp1	-	1.14	1.12
	Rheotanytarsus Thienemann & Bause	2.58	2.36	1.63
	Tanytarsini	-	1.93	1.37
	Tanytarsus v. d. Wulp	-	2.34	1.48
Diptera Family 1		-	-	-
	Diptera 1	-	-	-
Diptera Family 2		-	-	-
	Diptera 1	-	-	-
Culicidae		-	-	1.99
	Culicidae 1	-	1.86	1.42
Dixidae		-	-	-
	Dixidae 1	-	-	-

Appendix 1. Continued...

Taxa	Genus	White water %	Clear water %	White vs Clear water %
Dolichopodidae		-	-	-
	Dolichopodidae 1	-	-	-
Ephydridae		-	-	0.70
	Ephydridae 1	-	-	-
Muscidae		-	-	-
	Muscidae 1	-	-	-
Sciomyzidae		-	-	0.82
	Sciomyzidae 1	-		0.58
Simuliidae		-	1.87	2.72
	Simulium Latreille	-	2.06	1.92
Syrphidae		-	-	-
	Syrphidae 1	-	-	-
Tabanidae		-	-	-
	Tabanidae 1	-	-	-
Tipulidae		-	4.16	2.32
	Tipulidae 1	-	-	1.58
Ephemeroptera				
Baetidae		-	-	1.41
	Americanbaetis Kluge	1.12	-	0.88
	Zelusia Lugo-Ortz & McCafferty	-	-	-
Caenidae		6.27	-	3.12
	Brasilocaenis Puthz	6.71	-	2.16
Coloburiscidae		-	-	-
	Coloburiscidae 1	-	-	0.45
Leptohyphidae		-	-	-
	Traverhyphes Molineri	-	-	0.40
	Tricorythodes Ulmer	-	-	0.56
Leptophlebiidae		20.21	6.71	2.88
	Farrodes Peters	4.39	-	1.95
	Fittkaulus Hubbard	-	-	0.66
	Microphlebia Savage & Peters	-	-	-
	Miroculis Edmundis	18.59	5.88	1.86
	Perissophlebiodes Savage	-	-	0.53
	Hagenulopsis Ulmer	-	-	0.76
	Terdipes Demoulin	-	-	-
	Thraulodes Ulmer	-	-	0.93
	Ulmeritoides Traver	1.69	-	0.98
Polymitarcyidae		-	-	-
	Polymitarcyidae 1	-	-	-
Hemiptera				
Belostomatidae		2.06	-	1.58
	Belostomatidae 1	2.18	-	1.10
Corixidae		12.96	1.98	3.76
	Corixidae 1	13.58	2.09	2.59
Gerridae		-	-	-
	Gerridae 1	-	-	-
Nepidae		-	-	-
	Nepidae 1	-	-	-
Notonectidae		-	-	1.32
	Notonectidae 1	-	-	0.91
Veliidae		-	-	-
	Veliidae 1	-	-	-
Megaloptera				

Appendix 1. Continued...

Taxa	Genus	White water %	Clear water %	White vs Clear water %
Corydalidae		-	-	-
	Corydalus Latreille	-	-	-
	Corydalidae 1	-	-	-
Odonata				
Aeshnidae		-	-	-
	Gynacantha Rambur	-	-	0.53
Coenagrionidae		-	-	1.01
	Argia Rambur	-	-	-
	Cyanallagma Kennedy	-	-	-
	Oxyagrion Selys	-	-	-
Dicteriadidae		-	-	-
	Heliocharis Selys	-	-	-
Cordulidae		-	-	-
	Cordulidae 1	-	-	0.42
Gomphidae		12.41	7.89	1.41
	Agriogomphus Selys	5.76	0.96	1.67
	Aphylla Selys	-	-	0.41
	Desmogomphus Selys	-	-	-
	Gomphoides Selys	-	-	0.90
	Neogomphus Selys	-	-	-
	Peruviogomphus Klots	-	-	-
	Phyllocycla Calvert	-	-	-
	Progomphus Selys	4.20	4.56	1.63
Polythoridae		-	2.77	2.19
	Chalcopteryx Selys	-	2.90	1.50
Perilestidae		3.08	-	2.00
	Perilestes Selys	3.27	-	1.38
Protoneuridae		-	-	-
	Epipleoneura William	-	-	-
	Neoneura Selys	-	-	-
	Protoneura Selys	-	-	-
Megapodagrionidae		-	-	0.92
	Heteragrion Selys	-	-	0.53
	Oxystigma Selys	-	-	-
Libellulidae		-	-	2.00
	Brechmorhoga Kirby	-	-	0.92
	Libellulidae 1	-	-	-
	Gynothemis Calvert	-	-	-
	Macrothemis Hagen	-	-	-
	Orthemis Hagen	-	-	-
	Perithemis Hagen	-	-	0.39
Decapoda		13.16	-	-
	Trichodactylidae 1	13.96	-	3.35
Palaemonidae		-	-	1.97
	Macrobranchium Bate	-	1.66	1.38
Nematoda		-	-	-
	Nematoda 1	-	-	-
Annelida				
Hirudinea		-	-	1.14
	Hirudinea 1	1.24	-	0.78
Oligochaeta		-	-	-
Gastropoda		-	-	1.33
	Pomacea (Perry)	0.95	-	-

A survey of mid and large bodied mammals in Núcleo Caraguatatuba, Serra do Mar State Park, Brazil

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NORRIS, D., RAMÍREZ, J.M., ZACCHI, C. & GALETTI, M. **A survey of mid and large bodied mammals in Núcleo Caraguatatuba, Serra do Mar State Park, Brazil**. Biota Neotrop. 12(2): http://www.biotaneotropica.org.br/v12n2/en/abstract?inventory+bn00312022012

Abstract: We applied complementary survey techniques to obtain a baseline species list of mid and large bodied mammals in Núcleo Caraguatatuba, Serra do Mar State park, Brazil. Between May and September 2011 we surveyed the community of mid and large bodied mammals using diurnal line transect census (212.4 km), camera-traps (223.2 camera-trap days) and track-stations (478 track-station days). A total of 18 species were recorded from 14 families in eight orders. We recorded the presence of seven species considered threatened in the State of São Paulo, including Primates (*Brachyteles arachnoides*), Artiodactyla (*Mazama* cf. *americana* and *Tayassu pecari*), Carnivora (*Leopardus pardalis*, *Leopardus tigrinus* and *Puma concolor*) and Perissodactyla (*Tapirus terrestris*). Based on extrapolated (First order jackknife) species richness estimates we predict that there are between 19 and 32 species of mid and large bodied mammals in the Núcleo. Our revised Mammal Priority Index ranked Núcleo Caraguatatuba as being of medium overall importance for the conservation of mid and large bodied mammals in the Atlantic Forest. Combined with the number and diversity of species recorded, our results demonstrate that this Núcleo is an important area for mammal conservation.
Keywords: *Atlantic forest, inventory, mammals, protected area.*

NORRIS, D., RAMÍREZ, J.M., ZACCHI, C. & GALETTI, M. **Mastofauna de médio e grande porte na Núcleo Caraguatatuba, Parque Estadual Serra do Mar, SP, Brasil**. Biota Neotrop. 12(2): http://www.biotaneotropica.org.br/v12n2/pt/abstract?inventory+bn00312022012

Resumo: Nós aplicamos técnicas de amostragem complementares para obter uma lista de espécies de mamíferos de médio e grande porte no Núcleo Caraguatatuba, Parque Estadual da Serra do Mar, Brasil. As amostragens de campo realizaram-se nos meses de Maio e Setembro de 2011. Utilizou-se, censo ao longo de transectos (212,4 km), armadilhas fotográficas (223,2 armadilhas-dias) e armadilhas de pegadas (478 armadilhas-dias). Foram obtidos registros de 18 espécies, pertencentes a 14 famílias e oito ordens. Nós registramos a presença de sete espécies consideradas ameaçadas no Estado de São Paulo, incluindo primatas (*Brachyteles arachnoides*), Artiodactyla (*Mazama americana* e *Tayassu pecari*), Carnivora (*Leopardus pardalis*, *Leopardus tigrinus* e *Puma concolor*) e Perissodactyla (*Tapirus terrestris*). Com base em numa extrapolação da riqueza de espécies ("First order jackknife") nós prevemos que existem entre 19 e 32 espécies de mamíferos de médio e grande porte no Núcleo. Nosso "Mammal Priority Index" classificou o Núcleo Caraguatatuba como uma área de importância "média" para a conservação de mamíferos de médio e grande porte na Mata Atlântica. Combinado com o número e a diversidade de espécies registradas, nossos resultados demonstram que este Núcleo é uma área importante para a conservação de mamíferos no Estado.
Palavras-chave: *mata Atlântica, inventário, mamíferos, unidade de conservação.*

Introduction

The Atlantic Forest is the most intensively studied biome for Brazilian mammals (Brito et al. 2009). The sampling intensity and availability of both published and un-published studies has enabled the establishment of priority areas for the conservation of mammals across the Atlantic Forest biome (Galetti et al. 2009, Albuquerque et al. 2011). Yet these studies also highlight that there remain significant gaps not only in our understanding but also in the published data describing Atlantic Forest mammals (Brito et al. 2009, Galetti et al. 2009, Albuquerque et al. 2011). With greater attention required for the development and dissemination of studies focusing on obtaining solutions to the management problems facing wild mammal species (Brito et al. 2009).

Conservation initiatives in Brazil, particularly the Atlantic Forest, are cited as examples of the successful integration of legal protection, protected area management, and science-based conservation planning (Russo 2009, Brancalion et al. 2010, Tabarelli et al. 2010). However, despite such positive examples, the situation for the fauna and flora of the Brazilian Atlantic Forest remains precarious (Marsden et al. 2005, Tabarelli et al. 2005, Fonseca et al. 2009, Galetti et al. 2009, Teixeira et al. 2009, Tabarelli et al. 2010). Protected areas are recognized as a key part of conservation initiatives (Naughton-Treves et al. 2005, Rands et al. 2010, Stockstad 2010) with >13% of Brazilian terrestrial biomes receiving legal protection at federal or state levels (Rylands & Brandon 2005). There are >700 areas of Atlantic Forest with at least some level of legal protection (Galindo-Leal & Câmara 2003, Tabarelli et al. 2010). However, the management of protected areas for mid and large bodied mammals in the Atlantic Forest is challenging as the majority of these areas (~75%) are small i.e. <100 km^2 (Ribeiro et al. 2009) and may not retain suitable environmental conditions for endangered species (Norris et al. 2011a, Norris et al. 2011b) and threats from anthropogenic perturbations such as urbanization, illegal hunting and palm heart harvesting are ubiquitous (Galetti & Fernandez 1998, Tabarelli et al. 2005, Galetti et al. 2009, Teixeira et al. 2009, Tabarelli et al. 2010).

The Serra do Mar biogeographical sub-region is the largest area of Atlantic Forest in Brazil. More than 50% of forest cover in the sub-region is found in forest fragments >50,000 ha and it also includes the largest remnant - a continuous forest area of 1,109,546 ha that is located along the coast of São Paulo State (Ribeiro et al. 2009). The Serra do Mar State Park is embedded within this continuous area, protecting 315,390 ha of Atlantic Forest that includes a variety of habitat types from lowland (sea-level) coastal restinga to highland (>200 masl) dense mountainous ombrofilous forest (Instituto Florestal 2008, p. 11-15). The size of the protected area generates unique management challenges and to meet these challenges it was necessary to divide the area into eight administrative units or "Núcleos" (Instituto Florestal 2008, p. 13-15). Although this area is continuous, the Serra do Mar continues to suffer from intensive hunting and palm heart harvesting. The numerous highways that cross the park, and the presence of major gas and oil pipelines facilitates entry of hunters to "remote" park areas (Aguiar et al. 2003, Instituto Florestal 2008, p. 129). Additionally, park borders are densely populated and illegal hunting, palm heart and bromeliad harvesting is common place (Instituto Florestal 2008, p. 119-143).

Although challenging from a management perspective, the size and diversity of protected habitats means that we expect to find high levels of biodiversity within the Serra do Mar State park (Aguiar et al. 2003). Indeed, within such a well connected and biodiverse expanse of forest (Aguiar et al. 2003) it is not unreasonable to predict the occurrence of a significant proportion of the 45 species (De Vivo et al. 2011) of mid and large bodied terrestrial mammals recorded in São Paulo State within this park. However, even the most basic management information (i.e. which mammal species are present) is not available for the majority of the Serra do Mar Núcleos, with 6 of the 8 classified as having zero or low levels of knowledge regarding the mammalian fauna (Instituto Florestal 2008, p. 180).

Recent diurnal line transect surveys recorded a maximum of 8 mid to large bodied mammal species within 4 of the Serra do Mar Núcleos (Picinguaba, Caraguatatuba, Cunha and Santa Virginia (Galetti et al. 2009). Although standardized line transect surveys provide a powerful dataset for analysis of species abundances they are unlikely to approximate a truly representative sample of the mid and large bodied mammal fauna. This group includes rare, cryptic and illusive species that to achieve management objectives including knowledge of which species are present are best surveyed with a combination of techniques (Michalski & Peres 2007, Espartosa et al. 2011, Munari et al. 2011). The objective of the present study was to use complementary survey techniques to obtain a baseline species list and estimate the species richness of mid and large bodied mammals in Núcleo Caraguatatuba as the first step to increasing our knowledge of the regional mammalian fauna and to support the management activities within this protected area.

Material and Methods

1. *Study area*

Mammal surveys took place in Núcleo Caraguatatuba of the Serra do Mar State park (Figure 1). Núcleo Caraguatatuba protects 49,953 ha (Instituto Florestal 2008) of the pre-Cambrian Serra do Mar mountain chain (Mantovani 1993). Of the eight administrative "Núcleos" of the Serra do Mar, 5 including Caraguatatuba are coastal, with Núcleo Caraguatatuba being located in the center of the "litoral" tourist region of the state, receiving approximately 5000 visitors annually. The Núcleo is bisected by the Tamoios road, a state highway that leads to the town of Caraguatatuba (45° 25' 57" W and 23° 35' 52" S). The western portion of the Núcleo is also traversed by one of the main pipelines of the Brazilian petroleum company "Petrobras". The poorly monitored access provided by the Tamoios highway and the pipeline are the two principal vectors of anthropogenic pressure (i.e. illegal hunting and palm-heart harvesting) in the Núcleo (Instituto Florestal 2008, p. 119-143).

The regional climate is subtropical, with a mean annual temperature of 23.2 (daily means ranging from 4.6 to 36.1, data from 2010 downloaded from the Brazilian weather center http://www.cptec.inpe.br/, station ID: 83671, Lat: –21.98, Long: –47.35 m a.s.l. = 598) and annual rainfall from 1400 to 4000 mm (Mantovani 1993). Soils are predominantly nutrient-impoverished yellow-red latosol, podzols and lithosols (Brasil 1983). Forests range from coastal (≈20 m) to elevations >900 m, generating stark floristic gradients, from shrubs to well-developed montane forests (Veloso et al. 1991).

2. *Mammal surveys*

Between May and September 2011 we used complementary techniques (line transect census, track surveys and camera-traps) to sample the mid and large bodied mammal community across Núcleo Caraguatatuba (Figure 1). Surveys were conducted by two observers with a minimum of 5 years experience in monitoring neotropical mammals. Nomenclature follows that presented in De Vivo et al. (2011) except for *Alouatta guariba* which follows Groves (2005).

During 34 days we conducted a total of 212.4 km of diurnal line transect census along 13 (total km = 71.9) preexisting (established for >10 years) trails (trail length: mean, range = 4.9, 0.7-15.7 km).

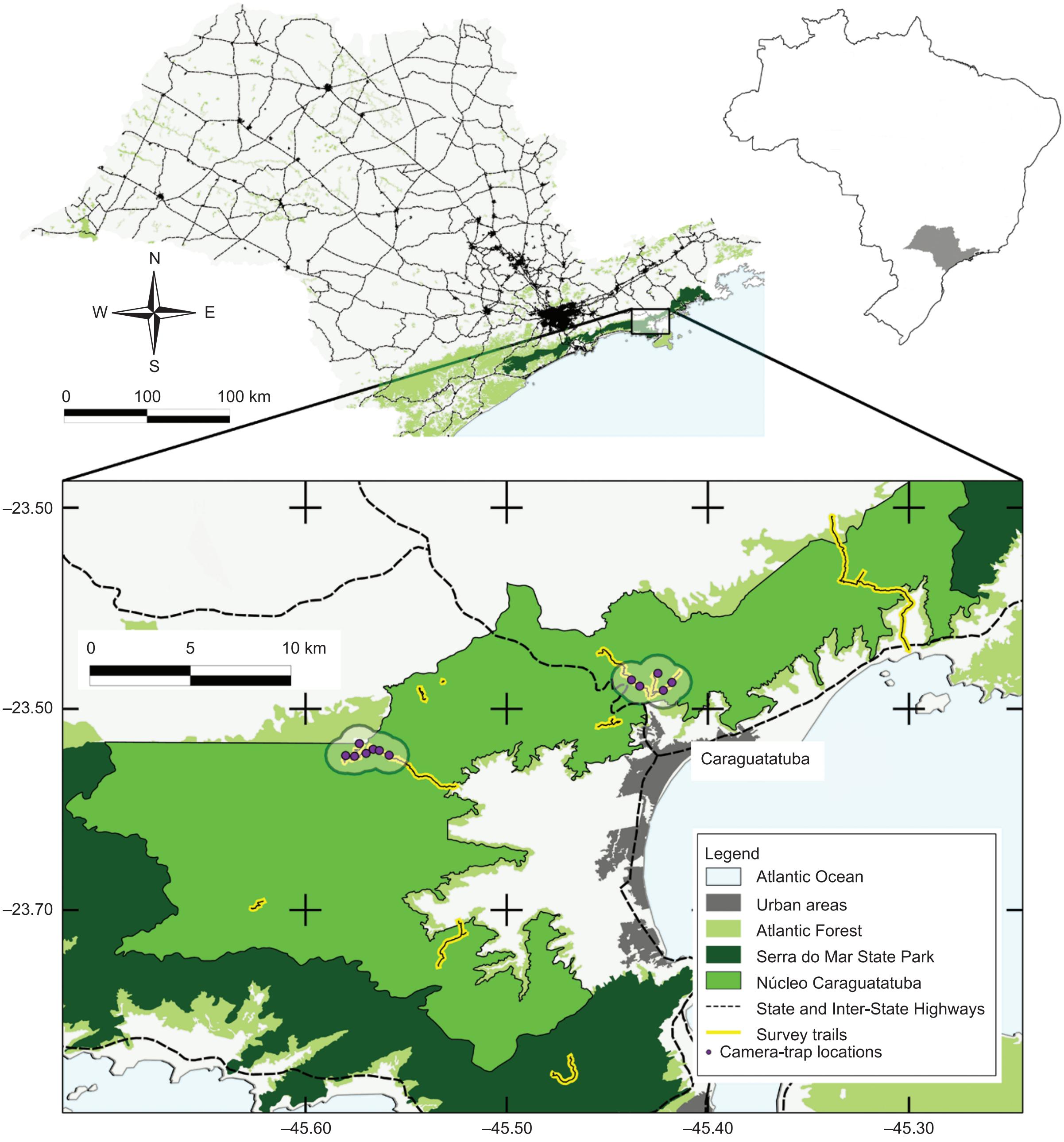

Figure 1. Study area showing locations of survey trails and camera-traps used to survey mid and large bodied mammals in Núcleo Caraguatatuba, Serra do Mar State Park, São Paulo, Brazil.

To provide a representative sample, trails were distributed throughout the Núcleo (Figure 1) and encompassed a variety of secondary and primary forest habitats. From the total of 71.9 trail km, the majority (51.9 km) were in forest dominated by early or advanced secondary successional stages, followed by primary (7.9 km) and eucalyptus and pine plantations (6.8 km).

Standard line transect protocols (Peres 1999, Buckland et al. 2010) were adapted to fit our main objective of sampling mid and large bodied mammals across the widest possible variety of habitats within the park. Census was not conducted during heavy rainfall but did occur during light showers i.e. when observers could walk comfortably without wearing protective clothing. Census was carried out during the morning (5:40 AM - 1:13 PM) and or afternoon (12:47 PM - 5:35 PM), with times varying due to logistical constraints and weather conditions. Although there was a slight overlap between the timing of morning and afternoon census, on any one day there was a minimum of 2 hours between the end of morning and start of afternoon census when we used the same trail and a minimum of 1 hour between morning and afternoon census when different trails were used. We do not consider this extension of the timing of our morning census to have biased our surveys. The standardization of census times has been determined from studies in tropical conditions where the heat during midday hours (between 12:00 AM and 2:00 PM) limits mammal activity (Peres 1999). Diurnal temperatures within our sub-tropical study area are not comparable to those in these tropical areas. At the latitude of Núcleo Caraguatatuba mammals are often seen during these "midday" hours, appearing to avoid activity during the often cold (<14 °C) early mornings. For example we did not detect any mammals before 9 AM. To enable us to survey the maximum range of habitats possible we did not follow the recommended line transect survey speed of ≈1.25 km per hour (Peres 1999, Buckland et al. 2010). Although we did pause regularly at 100 to 300 m intervals to listen for detection cues, our mean per trail census speed was above the recommended value (survey speed: mean, range = 2.4, 1.1-3.4 km per hour). Although it is possible that this increased census speed resulted in missed detections, we found no significant relationship between the number of detections recorded per km and the survey speed (Spearmans correlation, rho = –0.223, p = 0.221). We are therefore confident that our modifications of the standard census protocols did not introduce any systematic bias and that our line transect survey results are directly comparable with previous studies.

During our line transect surveys we also recorded tracks that were visible along the trails. These "ad hoc" detection events were supplemented by a total of 25 un-baited track-stations placed along two of our census trails (Figure 1). Track-stations were prepared by removing leaf litter, rocks and surface roots from a 75 × 75 cm quadrant followed by loosening, separating and smoothing the soil surface with a machete so that it would be possible to discern track impressions of mid to large bodied mammals >2 kg (tested by the gentle application of finger tips to the prepared surface). Track-stations were checked at 3-6 day intervals. Days with heavy rain were excluded from our effort, resulting in an overall effort of 478 track-station days. Observers (each with >5 years experience of surveying mid and large bodied mammals in Neotropical forests) recorded the species identity of tracks with reference to field guides (Becker & Dalponte 1991, Emmons & Feer 1997). In cases where species identity was uncertain we took photos that were sent to specialists for confirmation. Any tracks that could not be reliably identified were not included in our analysis.

From June to July 2011 we installed 12 digital camera-traps (6 Reconyx, RECONYX, Inc. Wisconsin, USA - http://www.reconyx.com/ and 6 Ecotone, ECOTONE, São Paulo, Brazil http://www.ecotonebrasil.com). Cameras were installed in two areas (Figure 1) separated by a 12.9 km straight line distance – one close to the park base (5 cameras – 103.7 camera-trap days) and one in an area that receives no visitors and has been relatively undisturbed for at least 30 years (7 cameras – 119.5 camera-trap days), providing a total effort of 223.2 camera-trap days. Cameras were operational continuously over the 24 hours diel cycle and placed at random locations between 5 and 15 m to the side of existing trails within each area, with a minimum straight line nearest neighbor distance of 530 m. However, due to the steep topography including near vertical ravines, the minimum distance between cameras for any terrestrial mammal is effectively >1400 m. We attached cameras to trees at a height of ≈ 40 cm above the ground. The area in front of cameras was cleared of green foliage and herbs to prevent sunlight reflections damaging image quality. Due to licensing restrictions cameras remained un-baited, but were checked at 2 – 9 day intervals to ensure continuous operation and for routine maintenance e.g. to change batteries.

3. Data analysis

To understand the relationship between species richness and our survey effort we used the "specaccum" function of the "vegan" package (Oksanen et al. 2011) in the R software (R Development Core Team 2011) to estimate the individual based rarefaction curve of mean species richness per sample day. For this analysis we summed all individuals recorded for each species using any technique by the survey date, generating a matrix of 18 species by 22 survey days (we excluded days with no mammal species records). To predict the total number of species present in the Núcleo that it would be possible to detect using the combination of survey techniques we used the "First order jackknife" estimator to extrapolate the species richness from the frequencies of species encountered per day (function "specpool", package "vegan"). Although a number of extrapolation estimators are available we chose this one to enable comparison with previous studies (Espartosa et al. 2011).

To provide a measure of the conservation importance of Núcleo Caraguatatuba we calculated the Mammalian Priority Conservation Index (Galetti et al. 2009). This index provides a comparitive measure of the importance of the site by incorporating native species richness, species threat status (based on the threat status in the State of São Paulo (Magalhães-Bressan et al. 2009), species uniqueness and body size as well as the site forest area (see Galetti et al. 2009 for full details of index calculation and interpretation). To enable comparison with previous studies (Galetti et al. 2009) we only used data from the line transect censuses to derive the index.

Results

We obtained records of 18 mid to large bodied mammal species from 14 families in 8 orders, of which seven species are considered threatened ("Vulnerable" or "Endangered") in the State of São Paulo and five (27.8%) are considered threatened internationally (Table 1). Camera-traps recorded the most species (12), followed by tracks (10), other indirect detections (7) and finally direct visual detections from diurnal line transect census (6). *Tapirus terrestris* was the only species recorded with all four classes of detection technique, whereas six species (*Didelphis aurita* - photos, *Tayassu pecari* - tracks, *Leopardus tigrinus* - photos, *Lontra longicaudis* - tracks, *Bradypus variegatus* - carcass and *Brachyteles arachnoides*- visual) were only recorded by a single class (Table 1).

The estimated curve of species richness per survey day did not reach an asymptote, with species continuing to accumulate at a rate of 0.4 species per day after 22 survey days (Figure 2). Based on the First order jackknife our extrapolated species richness was 26 species (estimate ± 95% CI = 25.63 ± 6.07).

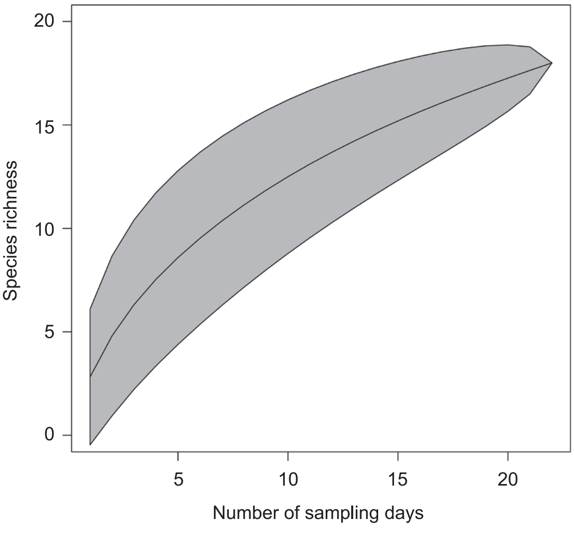

Figure 2. Mean accumulation curve and 95% confidence interval (shaded area) of the expected number of mid to large bodied mammal species in Núcleo Caraguatatuba, Serra do Mar State Park, São Paulo, Brazil.

Table 1. List of mammal species from Núcleo Caraguatatuba, Serra do Mar State Park, São Paulo, Brazil.

Order	Family	Species	Detection type[a]				Threat	Abundance[d]	
			Photo	Track	Visual	Other	S[b]/Int[c]	LT	CT
Artiodactyla									
	Cervidae	*Mazama* cf. *americana* (Erxleben, 1777)		X	X		VU/DD	0.040	
	Tayassuidae	*Pecari tajacu* (Linnaeus, 1758)	X	X		X	NT/LC		0.081
		Tayassu pecari (Link, 1795)		X			EN/NT		
Carnivora									
	Felidae	*Leopardus pardalis* (Linnaeus, 1758)	X	X			VU/LC		0.161
		Leopardus tigrinus (Schreber, 1775)	X				VU/VU		0.081
		Puma concolor (Linnaeus, 1771)	X	X			VU/LC		0.081
	Mustelidae	*Lontra longicaudis* (Olfers, 1818)		X			NT/DD		
Cingulata									
	Dasypodidae	*Dasypus novemcinctus* (Linnaeus, 1758)	X	X		X	LC/LC		0.242
Didelphimorphia									
	Didelphidae	*Didelphis aurita* (Wied-Neuwied, 1826)	X				LC/LC		0.242
Perissodactyla									
	Tapiridae	*Tapirus terrestris* (Linnaeus, 1758)	X	X	X	X	VU/VU	0.040	0.524
Pilosa									
	Bradypodidae	*Bradypus variegates* (Schinz, 1825)				X	LC/LC		
Primates									
	Atelidae	*Alouatta guariba* (Humboldt, 1812)			X	X	NT/LC	0.202	
		Brachyteles arachnoides (É. Geoffroy, 1806)			X		EN/EN	0.040	
	Cebidae	*Cebus nigritus* (Goldfuss, 1809)	X		X	X	NT/NT	1.089	0.040
Rodentia									
	Caviidae	*Hydrochoerus hydrochaeris* (Linnaeus, 1766)	X			X	LC/LC		0.081
	Cuniculidae	*Cuniculus paca* (Linnaeus, 1766*)*	X	X			NT/LC		0.040
	Dasyproctidae	*Dasyprocta* cf. *azarae* (Lichtenstein, 1823)	X	X			LC/DD		0.040
	Sciuridae	*Guerlinguetus ingrami* (Thomas, 1901)	X		X		LC/NE	0.040	0.040

[a]How species were detected. Photo = camera-trap, Track = tracks observed along trails or on prepared track-stations, Visual = diurnal line transect census, and Other = carcass, feces, or vocalizations; [b]Threat status in the State of São Paulo (Magalhães-Bressan et al. 2009, p. 599). From least to most threatened: LC = least concern, NT = near threatened, VU = vulnerable, EN = endangered; [c]International threat status following (International… 2011). NE = not evaluated, DD = data deficient, then from least to most threatened: LC = least concern, NT = near threatened, VU = vulnerable, EN = endangered; [d]Species relative abundance.LT = detections per 10 km of line transect census and CT = independent photos per 10 camera-trap nights.

Relative abundances from line transect census ranged from 0.040 (*Brachyteles arachnoides*, *Mazama* cf. *americana*, *Tapirus terrestris*, and *Guerlinguetus ingrami*) to 1.089 (*Cebus nigritus*) detections per 10 km. The relative abundances obtained from diurnal census enabled us to calculate a revised Mammalian Priority Index of 15.29, which following the thresholds established by Galetti et al. (2009) classifies the Núcleo as an area of medium overall importance for large-bodied mammals in the Atlantic Forest.

Although rarely detected during diurnal censuses *Tapirus terrestris* was the most commonly recorded species with camera-traps (0.524 independent photos per 10 camera-trap nights), followed by *Dasypus novemcinctus* and *Didelphis aurita* (0.242 independent photos per 10 camera-trap nights). The most infrequently photographed species were *Cebus nigritus*, *Cuniculus paca*, *Dasyprocta* cf. *azarae*, and *Guerlinguetus ingrami* (0.040 independent photos per 10 camera-trap nights).

Discussion

Although Atlantic Forest mammals are relatively well studied there is little comparative data available from studies of mid and large bodied mammals in continuous forest areas. In a recent compilation (Galetti et al. 2009) found that from a total of 31 mid and large bodied mammal species a maximum of only 13 (41.9%) species were recorded using diurnal line transect census in 34 mainland Atlantic Forest sites. Other studies that employ a range of techniques generally record a greater number of species on a per site basis. For example, using line transect census (241 km) in secondary forest areas of the Morro Grande Forest Reserve - a 10,870 ha protected area close to the city of São Paulo Negrão & Valladares-Pádua (2006) recorded five species of mid to large bodied mammals but when these results were combined with sand track-stations (600 track-station days) a total of 18 species were recorded in the same area (Negrão & Valladares-Pádua 2006). Other studies from the Brazilian Atlantic Forest report similar patterns with more species recorded when different techniques were applied simultaneously: a total of 16 species were recorded in a 221 ha area of semi-deciduous Atlantic Forest using visual searches and camera-traps (Abreu Junior & Köhler 2009), 23 species in a 230 ha semi-deciduous forest area using line transect census (271 km), camera-traps (336.5 camera-trap days) and track-stations (1258 track-station nights) (Gaspar 2005), 29 species in a 17 491 ha protected area using visual searches (128 km), camera-traps (1842 camera-trap nights) and nocturnal surveys along park roads (Kasper et al. 2007). However none of these studies present species richness curves/

estimates that would facilitate a between site comparison of the mid to large bodied mammal communities.

Previous studies have demonstrated the importance of protected areas for the regional conservation of Atlantic Forest mammals (De Araujo et al. 2008, Galetti et al. 2009, Paviolo et al. 2009, Norris et al. 2011a, Norris et al. 2011b). Although it is not possible to make direct comparisons with other Atlantic Forest studies our predicted species richness shows the importance of Núcleo Caraguatatuba for the conservation of regional masto-fauna. Of the 18 species recorded seven (39%) are threatened in the State of São Paulo and five (27.8%) are threatened internationally (Table 1, Magalhães-Bressan et al. 2009, International… 2011). It is worth noting that of the 18 species recorded, populations of only one (*D. novemcinctus*) are increasing (Abba & Superina 2009). From a survey of 24 secondary forest sites (some connected to the western part of the Serra do Mar forest massive) using baited camera-traps (minimum effort of 2160 camera-trap days) and baited sand track-stations (minimum effort of 1224 track-station days) Espartosa et al. (2011) recorded a total of 14 native species of mid to large bodied mammals, with species richness estimates predicting a maximum of 15 native species present in the 10 000 ha study region. We managed to record a similar number of species to Espartosa et al. (2011) using a fraction of their survey effort and time, which emphasizes the richness and diversity of the mid and large bodied mammal community in Núcleo Caraguatatuba compared with unprotected and fragmented Atlantic Forest remnants. Another important difference is that the mammal community within the Núcleo appears to be relatively intact including large bodied species such as *T. terrestris* and *T. pecari*, whereas the species recorded by Espartosa et al. (2011) represented a relatively simplified assemblage of smaller bodied generalists.

As our species richness estimate showed that we missed between 2 and 14 species we also expect further studies to add to the list of threatened species within the Núcleo. For example populations of the threatened buffy-tufted-ear marmoset (*Callithrix aurita*) have been recorded in the neighboring Núcleo Santa Virginia (Norris et al. 2011b) and it seems likely that there may be as yet undetected populations within Núcleo Caraguatatuba. We would also expect to find carnivores such as jaguar (*Panthera onca*) and the crab-eating fox (*Cerdocyon thous*) plus at least one additional cervid species - the small brocket deer (*Mazama bororo*). Indeed, cervids highlight a remaining problem in neotropical mammalogy - uncertainty in species identification and classification (Brito et al. 2009). We identified the cervid species (*M.* cf. *americana*) based on characteristic size and coloration, however similarities with *M. bororo* mean that genetic studies are necessary to confirm the species presence. The same is true for the rodent *D. azarae*, which may be confused with *D. leporina*. Although the characteristic “red-rump” of *D. leporina* was not apparent in the photo taken, further genetic studies are required to confirm the species identity within the Núcleo. Although predicting which species are likely to be detected is inherently speculative, these issues highlight that even though the Atlantic Forest is the most intensively studied biome for mammals in Brazil (Brito et al. 2009), the knowledge necessary for effective conservation and management of Atlantic Forest mammals is far from complete.

Our revised Mammal Priority Index ranked Núcleo Caraguatatuba as being of medium overall importance for the conservation of mid and large bodied mammals in the Atlantic Forest. Combined with the number and diversity of species recorded we believe this group of mammals must be considered a management priority within this protected area. Our species list provides a baseline upon which management activities can be measured and evaluated. However, future studies focusing on species ecology, habitat preferences and population densities are required to inform management activities. For example further studies are required to enable the definition of zones within the protected area as defined by Brazilian Law (Law: 9.985/2000 (SNUC)). Zonation will enable the myriad objectives of a protected area to be met efficiently and in harmony with the regional and national socio-economic context (Wells & Brandon 1993, Halpin 1997). Although species richness and diversity is a criteria for establishing the conservation value of zones within the park (Instituto Florestal 2008, p. 257), there is as yet no data to define a spatially explicit map of species distributions for any floral or faunal group within Núcleo Caraguatatuba. We hope the list of mammals presented here encourages future studies to fill such gaps.

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References

ABBA, A.M. & SUPERINA, M. 2009. Dasypus novemcinctus. In: IUCN Red List of Threatened Species (International Union for Conservation of Nature - IUCN). version 2011.1. http//www.iucnredlist.org (último acesso em 10/09/2011).

ABREU JUNIOR, E.F. & KÖHLER, A. 2009. Mastofauna de médio e grande porte na RPPN da UNISC, RS, Brasil. Biota Neotrop. 9(4): http://www.biotaneotropica.org.br/v9n4/en/abstract?inventory+bn02109042009 (último acesso em 05/08/2011).

AGUIAR, A.P., CHIARELLO, A.G., MENDES, S.L. & DE MATOS, E.N. 2003. The Central and Serra do Mar Corridors in the Brazilian Atlantic Forest. In The Atlantic Forest of South America: biodiversity status, threats, and outlook (C. Galindo-Leal & I. Câmara, eds.). Island Press, Washington, p.118-132.

ALBUQUERQUE, F., TEIXEIRA ASSUNCAO-ALBUQUERQUE, M.J., GALVEZ-BRAVO, L., CAYUELA, L., RUEDA, M. & REY BENAYAS, J.M. 2011. Identification of Critical Areas for Mammal Conservation in the Brazilian Atlantic Forest Biosphere Reserve. Nat. Conserv. 9:73-78.

BECKER, M. & J.C. DALPONTE. 1991. Rastros de mamiferos silvestres Brazileiros: um guia de campo. Universidade de Brasilia, Brasília, 180p.

BRANCALION, P.H.S., RODRIGUES, R.R., GANDOLFI, S., KAGEYAMA, P.Y., NAVE, A.G., GANDARA, F.B., BARBOSA, L.M. & TABARELLI, M. 2010. Legal instruments can enhance high-diversity tropical forest restoration. Rev. Arvore 34:455-470.

BRASIL. Ministério das Minas e Energia. Secretária Geral. 1983. Projeto RADAMBRASIL: levantamento de recursos naturais. IBGE, Rio de Janeiro.

BRITO, D., OLIVEIRA, L.C., OPREA, M. & MELLO, M.A.R. 2009. An overview of Brazilian mammalogy: trends, biases and future directions. Zoologia 26:67-73.

BUCKLAND, S.T., PLUMPTRE, A.J., THOMAS, L. & REXSTAD, E.A. 2010. Design and analysis of line transect surveys for primates. Int. J. Primatol. 31:833-847.

DE ARAUJO, R.M., DE SOUZA, M.B. & RUIZ-MIRANDA, C.R. 2008. Density and population size of game mammals in two Conservation Units of the State of Rio de Janeiro, Brazil. Iheringia Ser. Zool. 98:391-396.

DE VIVO, M., CARMIGNOTTO, A.P., GREGORIN, R., HINGST-ZAHER, E., IACK-XIMENES, G.E., MIRETZKI, M., PERCEQUILLO, A.R., ROLLO, M.M., ROSSI, R.V. & TADDEI, V.A. 2011. Checklist of mammals from São Paulo State, Brazil. Biota Neotrop. 11(1a): http://www.biotaneotropica.org.br/v11n1a/en/abstract?inventory+bn0071101a2011 (último acesso em 02/08/2011).

EMMONS, L.H. & FEER, F. 1997. Neotropical rainforest mammals: a field guide. 2nd ed. University of Chicargo press, London, 281p.

ESPARTOSA, K., PINOTTI, B. & PARDINI, R. 2011. Performance of camera trapping and track counts for surveying large mammals in rainforest remnants. Biodivers. Conserv. 20:2815-2829.

FONSECA, C.R., GANADE, G., BALDISSERA, R., BECKER, C.G., BOELTER, C.R., BRESCOVIT, A.D., CAMPOS, L.M., FLECK, T., FONSECA, V.S., HARTZ, S.M., JONER, F., KAEFFER, M.I., LEAL-ZANCHET, A.M., MARCELLI, M.P., MESQUITA, A.S., MONDIN, C.A., PAZ, C.P., PETRY, M.V., PIOVENSAN, F.N., PUTZKE, J., STRANZ, A., VERGARA, M. & VIEIRA, E.M. 2009. Towards an ecologically-sustainable forestry in the Atlantic Forest. Biol. Conserv. 142:1209-1219.

GALETTI, M. & FERNANDEZ, J.C. 1998. Palm heart harvesting in the Brazilian Atlantic Forest: changes in industry structure and the illegal trade. J. Appl. Ecol. 35:294-301.

GALETTI, M., GIACOMINI, H.C., BUENO, R.S., BERNARDO, C.S.S., MARQUES, R.M., BOVENDORP, R.S., STEFFLER, C.E., RUBIM, P., GOBBO, S.K., DONATTI, C.I., BEGOTTI, R.A., MEIRELLES, F., NOBRE, R., CHIARELLO, A.G. & PERES, C.A. 2009. Priority areas for the conservation of Atlantic Forest large mammals. Biol. Conserv. 142:1229-1241.

GALINDO-LEAL, C. & CÂMARA, I.G. 2003. The Atlantic Forest of South America: Biodiversity status, threats, and outlook. Island Press, Washington.

GASPAR, D.A. 2005. Comunidade de mamíferos não voadores em um fragmento de floresta Atlântica semidecídua no município de Campinas, SP. Tese de Doutorado, Universidade Estadual de Campinas, Campinas.

GROVES, C.P. 2005. Order Primates. In Mammal Species of the World (D.E. Wilson & D.M. Reeder eds.). The Johns Hopkins University Press, Baltimore, Maryland, p.111-184.

HALPIN, P.N. 1997. Global climate change and natural-area protection: Management responses and research directions. Ecol. Appl. 7:828-843.

INSTITUTO FLORESTAL. 2008. Parque Estadual da Serra do Mar Plano de Manejo. Instituto Florestal do Estado de São Paulo, São Paulo.

INTERNATIONAL UNION FOR CONSERVATION OF NATURE - IUCN. 2011. IUCN Red List of Threatened Species. version 2011.1. http//www.iucnredlist.org (último acesso em 10/09/2011).

KASPER, C.B., MAZIM, F.D., SOARES, J.B.G., DE OLIVEIRA, T.G. & FABIÁN, M.E. 2007. Composição e abundância relativa dos mamíferos de médio e grande porte no Parque Estadual do Turvo, Rio Grande do Sul, Brasil. Rev. Bras. Zool. 24:1087-1100.

MAGALHÃES-BRESSAN, P., MARTINS-KIERULFF, M.C. & MIDORI SUGIEDA, A. 2009. Fauna Ameaçada de Extinção no Estado de São Paulo: Vertebrados Fundação Parque Zoológico de São Paulo. Secretaria do Meio Ambiente, São Paulo.

MANTOVANI, W. 1993. Estrutura e dinâmica da floresta Atlântica na Juréia, Iguape-SP. Tese de Livre Docência, Universidade de São Paulo, São Paulo.

MARSDEN, S., WHIFFIN, M., GALETTI, M. & FIELDING, A. 2005. How Well Will Brazil's System of Atlantic Forest Reserves Maintain Viable Bird Populations? Biodivers. Conserv. 14:2835-2853.

MICHALSKI, F. & PERES, C.A. 2007. Disturbance-mediated mammal persistence and abundance-area relationships in Amazonian forest fragments. Conserv. Biol. 21:1626-1640.

MUNARI, D.P., KELLER, C. & VENTICINQUE, E.M. 2011. An evaluation of field techniques for monitoring terrestrial mammal populations in Amazonia. Mamm. Biol. 76:401-408.

NAUGHTON-TREVES, L., HOLLAND, M.B. & BRANDON, K. 2005. The role of protected areas in conserving biodiversity and sustaining local livelihoods. Annu. Rev. Env. Resour. 30:219-252.

NEGRÃO, M.F.F. & VALLADARES-PÁDUA, C. 2006. Records of mammals of larger size in the Morro Grande Forest Reserve, São Paulo. Biota Neotrop. 6(2): http://www.biotaneotropica.org.br/v6n2/pt/abstract?article+bn00506022006 (último acesso em 03/08/2011).

NORRIS, D., ROCHA-MENDES, F., FROSINI DE BARROS FERRAZ, S., VILLANI, J.P. & GALETTI, M. 2011a. How to not inflate population estimates? Spatial density distribution of white-lipped peccaries in a continuous Atlantic Forest. Anim. Conserv. 14(5):492-501.

NORRIS, D., ROCHA-MENDES, F., MARQUES, R., DE ALMEIDA NOBRE, R. & GALETTI, M. 2011b. Density and Spatial Distribution of Buffy-tufted-ear Marmosets (Callithrix aurita) in a Continuous Atlantic Forest. Int. J. Primatol. 32:811-829.

OKSANEN, J., GUILLAUME BLANCHET, F., KINDT, R., LEGENDRE, P., O'HARA, R.B., SIMPSON, G.L., SOLYMOS, P., STEVENS, M.H.H. & WAGNER, H. 2011. Vegan: Community Ecology Package. version 1.17-10. http://CRAN.R-project.org/package=vegan (último acesso em 02/08/2011).

PAVIOLO, A., DI BLANCO, Y.E., DE ANGELO, C.D. & DI BITETTI, M.S. 2009. Protection affects the abundance and activity patterns of pumas in the Atlantic Forest. J. Mammal. 90:926-934.

PERES, C.A. 1999. General guidelines for standardizing line-transect surveys of tropical forest primates. Neotrop. Primates 7:11-16.

R DEVELOPMENT CORE TEAM. 2011. R version 2.13.0: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/ (último acesso em 13/01/2011).

RANDS, M.R.W., ADAMS, W.M., BENNUN, L., BUTCHART, S.H.M., CLEMENTS, A., COOMES, D., ENTWISTLE, A., HODGE, I., KAPOS, V., SCHARLEMANN, J.P.W., SUTHERLAND, W.J. & VIRA, B. 2010. Biodiversity Conservation: Challenges Beyond 2010. Science 329:1298-1303.

RIBEIRO, M.C., METZGER, J.P., MARTENSEN, A.C., PONZONI, F. & HIROTA, M.M. 2009. Brazilian Atlantic Forest: how much is left and how is the remaining forest distributed? Implications for conservation. Biol. Conserv. 142:1141-1153.

RUSSO, G. 2009. Biodiversity's bright spot. Nature 462:266-269.

RYLANDS, A.B. & BRANDON, K. 2005. Brazilian Protected Areas. Conserv. Biol. 19:612-618.

STOCKSTAD, E. 2010. Despite progress, biodiversity declines. Science 329:1272-1273.

TABARELLI, M., AGUIAR, A.V., RIBEIRO, M.C., METZGER, J.P. & PERES, C.A. 2010. Prospects for biodiversity conservation in the Atlantic Forest: Lessons from aging human-modified landscapes. Biol. Conserv. 143:2328-2340.

TABARELLI, M., PINTO, L.P., SILVA, J.M.C., HIROTA, M. & BEDÊ, L. 2005. Challenges and Opportunities for Biodiversity Conservation in the Brazilian Atlantic Forest. Conserv. Biol. 19:695-700.

TEIXEIRA, A.M.G., SOARES-FILHO, B.S., FREITAS, S.R. & METZGER, J.P. 2009. Modeling landscape dynamics in an Atlantic Rainforest region: Implications for conservation. Forest Ecol. Manag. 257:1219-1230.

VELOSO, H.P., RANGEL-FILHO, A.L.R. &. LIMA, J.C.A. 1991. Classificação da vegetação brasileira adaptada a um sistema universal. IBGE, Rio de Janeiro.

WELLS, M.P. & BRANDON, K.E. 1993. The principles and practice of buffer zones and social and local participation in biodiversity conservation. Ambio 22:157-162.

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