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O **Boletim da Sociedade Brasileira de Mastozoologia** (ISSN 1808-0413) é uma publicação quadrimestral da **Sociedade Brasileira de Mastozoologia (SBMz),** distribuído gratuitamente aos associados. Indivíduos e instituições que desejem informações sobre a inscrição na **SMBz** e recebimento do Boletim devem entrar em contato com sbmz.diretoria@gmail.com.

O desenho gráfico foi realizado por Airton de Almeida Cruz e a capa por Ana Lazar.

Mais informações disponíveis em: www.sbmz.org.

Capa: Capivara (*Hydrochoerus hydrochaeris*). Fêmea com filhotes. Base de Estudos do Pantanal, Passo do Lontra, MS. Agosto de 2019.

Sobre a SBMz

A **Sociedade Brasileira de Mastozoologia (SBMz)** é uma sociedade científica, sem fins lucrativos, criada em 1985, com a missão de congregar, organizar e amparar profissionais, cientistas e cidadãos que atuam ou estão preocupados com as temáticas ligadas à pesquisa e conservação de mamíferos.

A **SBMz** tem como objetivo incentivar o estudo e pesquisa dos mamíferos, além de difundir e incentivar a divulgação do conhecimento científico desenvolvido no Brasil sobre os mamíferos. A **SBMz** também atua frente a órgãos governamentais, Conselhos Regionais e Federal de Biologia, e instituições privadas, representando e defendendo os interesses dos sócios, e atendendo a consultas em questões ligadas a mamíferos. Nossa Sociedade oferece e incentiva cursos de Mastozoologia em níveis de graduação e pós-graduação, além de conceder bolsas de auxílio financeiro para simpósios e congressos nacionais e internacionais. Além disso, ajudamos a estabelecer e zelar por padrões éticos e científicos próprios da Mastozoologia brasileira.

A **SBMz** foi fundada durante o "XII Congresso Brasileiro de Zoologia", realizado em Campinas, em fevereiro de 1985. Desde então, a **SBMz** cresceu em número de sócios, e agora conta com congressos próprios bienais realizados nas diversas regiões do país, além do apoio e promoção de eventos regionais. Nossa sociedade conta com uma publicação própria intitulada **Boletim da Sociedade Brasileira de Mastozoologia,** com 3 números anuais, classificada como B3 pela CAPES na área de Biodiversidade. Além disso, nossa sociedade atualmente mantém conta com parceria com a SAREM (Sociedade Argentina para o Estudio de los Mamíferos, fornecendo aos sócios a revista Mastozoologia Neotropical. A **SBMz** financia a publicação de livros acerca de mamíferos brasileiros para ser distribuído gratuitamente aos sócios.

Fazemos parte da Rede Latino-Americana de Mastozoologia (RELAM), o que abre portas para cooperação com pesquisadores de 12 países latino-americanos que fazem parte da rede. Integramos o Fórum da International Federation of Mammalogists (IFM), e também temos cooperação com a Sociedade Brasileira de Zoologia e Sociedade Brasileira para o Estudo de Quirópteros, facilitando a participação em congressos destas sociedades e promovendo o intercambio de informação entre seus associados.

Fruto da criação e organização proporcionadas pela **SBMz** ao longo desses anos, atualmente o Brasil apresenta uma comunidade científica mastozoológica madura e conectada, que congrega profissionais trabalhando em organizações e instituições públicas e privadas por todo país.

Boletim da Sociedade Brasileira de Mastozoologia
Uma publicação da SBMz

INSTRUÇÕES GERAIS PARA AUTORES

O **Boletim da Sociedade Brasileira de Mastozoologia** é um periódico publicado pela **SBMz** para os sócios quites, com propósito de funcionar como um meio de comunicação para a comunidade de mastozoólogos. O **Boletim da SBMz** publica artigos, notas e ensaios originais, revisados por pares, sobre temas relacionados à biologia de mamíferos.

Os manuscritos devem ser enviados por e-mail para bolsbmz@gmail.com, aos cuidados de Erika Hingst-Zaher e Lena Geise. A mensagem de e-mail enviada deverá conter uma declaração de que se trata de trabalho inédito, não submetido a outro periódico. Deverá especificar ainda se a contribuição se trata de uma nota, ensaio, artigo ou resumo. Os autores deverão indicar até cinco sugestões de revisores, com seus nomes e endereço eletrônico.

Os manuscritos enviados serão considerados para publicação, sob a forma de notas, artigos ou ensaios, seguindo o pressuposto de que os autores estão de acordo com os princípios éticos do **Boletim da SBMz** (ver os princípios no site da **SBMz**). O primeiro autor (ou o autor para correspondência) deverá, ao submeter o manuscrito, enviar o e-mail com cópia para todos os demais autores. Desta forma, será oficializada a concordância de todos os autores quanto à submissão/publicação do manuscrito no **Boletim da SBMz.** Neste mesmo e-mail deverá vir explicitado que o manuscrito é original, não tendo sido publicado e/ou submetido a outro periódico. No caso de resumos, é suficiente o envio do arquivo anexado à mensagem, já que este tipo de contribuição não passa pelo processo de revisão.

Os critérios para publicação dos artigos, notas e ensaios são a qualidade e relevância do trabalho, clareza do texto, qualidade das figuras e formato de acordo com as regras de publicação. Os manuscritos que não estiverem de acordo com as regras aqui definidas, ou ainda se nenhum dos autores estiver com o pagamento da **SBMz** em dia, serão devolvidos sem passar pelo processo de revisão.

As submissões são direcionadas pelas Editoras aos Editores de Área, que os enviarão para pelo menos dois pares para revisão. Os Editores de Área retornam as revisões e recomendações para os Editores para a decisão final. Toda a comunicação será registrada por meio eletrônico entre os Editores e o autor correspondente.

Os trabalhos devem seguir o **Código Internacional de Nomenclatura Zoológica,** e espécimes relevantes mencionados devem ser propriamente depositados em uma coleção científica reconhecida. Amostras relacionadas aos exemplares-testemunho (tecidos, ecto e endoparasitas, células em suspensão, etc.) devem ser relacionadas a seus respectivos exemplares. Os números de acesso às sequências depositadas no **Genbank** ou **EMBL** são obrigatórios para publicação. Localidades citadas e exemplares estudados devem vir listadas de forma completa, no texto ou em anexo, dependendo do número de registros. É fundamental a inclusão, no texto, do número da Licença de Coleta e a concordância do Comitê de Ética da Instituição onde foram desenvolvidos os trabalhos, quando aplicável. Todos os textos, antes do envio aos editores de área ou revisores serão analisados quanto a sua originalidade, com o uso de programas para verificação de plágio.

Números Especiais: Também poderão ser publicadas monografias e estudos de revisão de até 350 (trezentas e cinquenta) páginas, individualmente. Como apenas um número limitado poderá ser publicado, autores devem entrar em contato com os Editores previamente à submissão. Números Especiais seguem as mesmas regras de submissão e revisão dos artigos, notas e ensaios. Considerando as despesas de impressão e envio, autores serão solicitados a contribuir com R$ 40,00 (quarenta reais) por página publicada.

Mulheres na ciência e na mastozoologia brasileira: conquistando o espaço merecido

Nas últimas décadas, as mulheres vivenciaram avanços e conquistas decorrentes de suas lutas por ampliação de direitos. Porém, a desigualdade de gênero ainda persiste nos dias atuais. De acordo com dados do Índice de Desigualdade de Gênero divulgado pela Organização das Nações Unidas, as mulheres permanecem prejudicadas em âmbito mundial no que se refere ao acesso à educação, atuação no mercado de trabalho, acesso à saúde reprodutiva e representatividade em instituições governamentais (UNDP, 2019). No Brasil, as mulheres recebem, em média, 79,5% do valor salarial atribuído aos homens no mercado de trabalho (IBGE – PNAD Contínua, 2019), e o alto índice de disparidade entre mulheres e homens, reportado frequentemente nos últimos anos, representa um dos principais obstáculos ao desenvolvimento humano a curto, médio e longo prazos.

A ciência, por sua vez, não está isenta de tais desigualdades. Embora a proporção de mulheres na ciência tenha aumentado no último século, apenas 28% dos pesquisadores do mundo são mulheres (UNESCO, 2015). Estudos empíricos sobre desigualdade de gênero têm demostrado que as mulheres encontram-se sub-representadas em conselhos editoriais (Cho *et al.,* 2014), autorias acadêmicas (Astegiano *et al.,* 2019; Holman *et al.,* 2018), revisões paritárias (Helmer *et al.,* 2017), palestras em conferências acadêmicas (Débarre *et al.,* 2018, Ford *et al.,* 2018, veja Rossoni *et al.,* 2019 neste número especial), financiamentos e auxílios científicos (van der Lee & Ellemers, 2015). Com relação a este último tópico, no Brasil, apenas 38% das Bolsas de Produtividade em Pesquisa concedidas pelo CNPq foram atribuídas às mulheres no ano de 2019. Em nosso país, à medida que se progride nas carreiras científicas e ensino superior, verificamos uma diminuição ou mesmo ausência de mulheres ocupando os níveis mais altos da academia (Agrello & Garg, 2009; Brito *et al.,* 2015; Valentova *et al.,* 2017). O termo "efeito tesoura" ("leaky pipeline"), tem sido empregado mundialmente como referência metafórica à descontinuidade da progressão profissional de mulheres, especialmente nas carreiras aplicadas à ciência, tecnologia, engenharia e matemática. A perda de profissionais qualificados nas diversas áreas de estudo tem consequências diretas para o progresso científico a longo prazo.

Estudos recentes têm refletido a importância de se promover redes sociais colaborativas entre mulheres na ciência visando superar a sub-representação na área, e promover o desenvolvimento profissional e pessoal (Bernal *et al.,* 2019, Yang *et al.,* 2019). Grupos colaborativos, bem como a discussão aberta entre pares e a sociedade, são fundamentais para identificar os desafios e elaborar ações diretas para combater as desigualdades de gênero na ciência.

Durante o IX Congresso Brasileiro de Mastozoologia – CBMz, sediado em Pirenópolis – GO no ano de 2017, foi apresentada a primeira comunicação oral abordando a temática de participação de mulheres palestrantes em diferentes categorias de apresentações orais ao longo das edições do CBMz. As análises iniciais provenientes desta contribuição revelaram uma marcante sub-representação das mulheres entre as diferentes categorias de apresentações orais no CBMz, e abriram espaço para discussões de propostas e medidas urgentes que promovessem a igualdade de gênero nas reuniões científicas futuras, tendo apoio tanto da Sociedade Brasileira de Mastozoologia – SBMz quanto de colegas da profissão. Os resultados completos deste estudo estão publicados em forma de artigo no presente número. Tais debates sobre gênero e ciência tiveram repercussão direta na organização do X CBMz (o qual será realizado em setembro de 2019 em Águas de Lindóia), não só no que se refere à proporção de conferencistas convidadas e já confirmadas, como também nas próprias regras de submissão de mesas-redondas e simpósios que exigiram um número mínimo de mulheres pesquisadoras participantes. Além disso, no mês de abril de 2018, o periódico científico publicado pela SBMZ (Boletim da SBMz) abriu uma chamada para o Número Especial intitulado "Mulheres na Mastozoologia Brasileira". Essa ideia se originou no IX CBMz e a fundamentação inicial da proposta foi discutida em uma reunião na última tarde do congresso, contando com a participação das editoras Erika Hingst-Zaher e Lena Geise, as editoras convidadas Bárbara Costa, Daniela M. Rossoni, Maria João Ramos Pereira e Rebeca Barreto, as editoras de área Alexandra Bezerra, Ana Lazar, Francisca Almeida e Valéria Tavares e as colaboradoras Gisele Lessa e Ludmilla Aguiar.

Esse número especial tem como objetivo destacar os trabalhos de alta qualidade e as contribuições fundamentais realizadas por mulheres em todas as áreas da Mastozoologia Brasileira, bem como propor uma discussão sobre igualdade de gênero na ciência. Nele, apresentamos trabalhos inéditos, incluindo ensaios em que, além do conteúdo científico, as autoras compartilham histórias pessoais ou de outras pesquisadoras, bem como os desafios que marcaram suas carreiras e pesquisas. Um dos ensaios deste número apresenta um histórico das contribuições significativas feitas por mulheres à SBMz e para o estudo de mamíferos no Brasil desde o início do século XX até o ano 2000. Além de destacar o lapso temporal entre o surgimento dos primeiros pesquisadores no Brasil e o efetivo reconhecimento das mulheres na Mastozoologia Brasileira, o ensaio presta uma homenagem a estas mulheres notáveis por seus feitos (veja Bezerra & Lazar 2019 neste número especial).

Neste número especial, artigos, notas e ensaios têm como primeira e última autoras mulheres, sendo ao menos uma, sócia da SBMz. No caso dos resumos, foram apenas considerados trabalhos de mulheres orientadas por mulheres. As revisoras dos trabalhos, com apenas duas exceções, foram mulheres. Gostaríamos de agradecer a a todas as pessoas que revisaram de forma anônima por suas contribuições fundamentais aos manuscritos e pela dedicação em manter

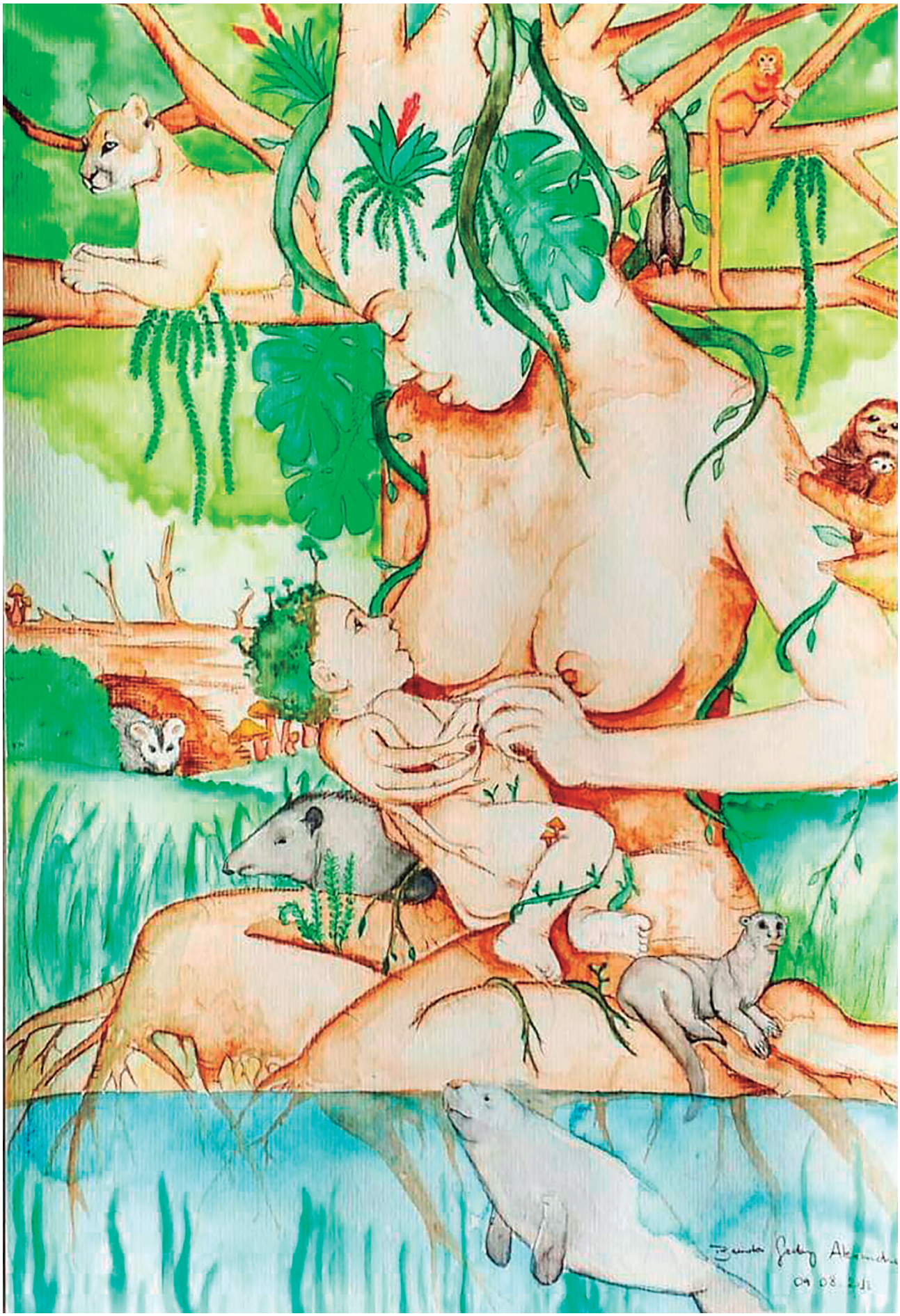

Figura 1: Ilustração de Brenda de Godoy Alexandre.

o elevado nível de qualidade que pretendíamos atingir com este número especial. Agradecemos ainda à Lena Geise e Erika Hingst-Zaher o nosso convite para compor o quadro de editoras convidadas desta edição especial, bem como ao trabalho e dedicação demandados. Nossos sinceros agradecimentos à Brenda de Godoy Alexandre por sua contribuição com a belíssima ilustração que compõe este Número Especial (Figura 1).

Acreditamos que dar visibilidade às Mulheres na Mastozoologia, destacando seus feitos e contribuições na área, é fundamental para incentivar e inspirar as atuais e futuras gerações de mulheres cientistas. Esperamos, com este número especial, contribuir para esse objetivo. Nós dedicamos este Número Especial do Boletim às mulheres que de várias maneiras contribuíram e contribuem para o desenvolvimento da Mastozoologia brasileira, incluindo pesquisas de campo, docência, trabalhos em museus, laboratórios, empresas e trabalhos sociais. Nosso mais sincero respeito, orgulho e total apoio às mulheres que lutam a cada dia por igualdade em suas diversas áreas de atuação.

As editoras deste número especial agradecem a Alexandra Maria Ramos Bezerra, Ana Lazar, Francisca Cunha Almeida e Valéria da Cunha Tavares pelo auxilio como editoras de área; agradecem ainda a Gisele Mendes Lessa del Giúdice e a Ludmilla Moura de Souza Aguiar pela colaboracão.

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NOTÍCIA

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No período de 26 a 28 de junho de 2019, no Centro Nacional de Pesquisa e Conservação de Mamíferos Carnívoros – CENAP/ICMBio em Atibaia, SP, reuniram-se os especialistas em pequenos mamíferos e líderes de grupo taxonômico do ICMBio Cibele R. Bonvicino (INCA, Fiocruz), Paulo Sérgio D'Andrea (Fiocruz), Alexandre R. Percequillo (ESALQ-USP), Lena Geise (UERJ) e Júlio F. Vilela (CAFS-UFPI), além de uma equipe de profissionais de diferentes centros do ICMBio como Elizabeth Santos de Araújo (COPAN), Estevão Carino Fernandes de Souza (CBC), Lívia de Andrade Rodrigues, Raquel Costa da Silva, Mariella Butti de Freitas Guilherme, Marina Peres Portugal e Rogério Cunha de Paula (todos do CENAP). O intuito desta reunião foi definir os recortes para os Planos de Ação Nacionais de Pequenos Mamíferos – Rodentia, Didelphimorphia e Lagomorpha, as possíveis datas para a realização das oficinas dos PANs e também das oficinas de avaliação do estado de conservação das espécies destas ordens.

Os limites de recorte dos Planos de Ação Nacionais (PAN) foram definidos com base na distribuição geográfica das espécies de pequenos mamíferos não voadores ameaçadas de extinção, considerando também as fitofisionomias associadas. O primeiro recorte, 'Áreas Abertas', compreende áreas que em sua maior parte estão associadas à diagonal seca, Pantanal, agregando também os campos do sul do Brasil. O outro recorte, 'Áreas Florestadas' tem sua maior contribuição atribuída aos limites da Floresta Atlântica no extremo leste do país, incluindo os campos de altitude e uma pequena porção da Floresta Amazônica, em uma área do estado de Rondônia. Definidos os recortes, foram revistas as listas de espécies classificadas como "Menos Preocupante" (LC – *Least Concern*) segundo a IUCN, definidas nas oficinas do 1º ciclo de avaliação, realizadas em 2012 (Didelphimorphia) e 2013 (Rodentia e Lagomorpha). Esta revisão foi baseada no mapa de distribuição de cada espécie gerado na referida oficina e na existência de informações novas que alterem essa condição. Foram consideradas possíveis alterações na área geográfica ocupada pelo táxon atualmente com base na literatura atualizada. Com isso foi indicado se o táxon deveria ou não ser mantido como LC para confirmação em plenária durante a próxima oficina de avaliação.

As oficinas de Elaboração tiveram as seguintes datas definidas: para o PAN Pequenos Mamíferos de Áreas Abertas, 29 de outubro a 01 de novembro de 2019, e para o PAN Pequenos Mamíferos de Áreas Florestadas, 03 a 07 de dezembro de 2019. O convite dos participantes das diferentes oficinas será feito individualmente pelo ICMBio em data ainda a ser definida. Para o convite dos especialistas será considerado a experiência nos táxons ameaçados e a área geográfica de atuação. Possíveis sobreposições na atuação serão avaliadas caso a caso, tendo em vista que uma oficina de Elaboração de PAN não é exclusiva para pesquisadores e envolve a participação de diferentes atores das esferas pública, privada e de terceiro setor. Assim, profissionais atuantes em secretarias estaduais de meio ambiente, agências reguladoras, ONGs, e também aqueles inseridos de áreas técnicas vistas como potenciais ameaças ao meio-ambiente como empresas do agronegócio também serão chamados para contribuir na construção de um plano viável e de sucesso, onde o objetivo primeiro será reduzir impactos e ameaças e consequentemente retirar as espécies da lista vermelha.

Quanto às oficinas de avaliação, foram lançadas duas possibilidades de datas para a avaliação do estado de conservação das espécies de Didelphimorphia, 02 a 04 ou 16 a 18 de outubro de 2019. Já a oficina para a avaliação das espécies de Rodentia deverá ocorrer entre 13 e 17 de abril de 2020. As oficinas de avaliação por sua vez são restritas à especialistas dos táxons, contudo haverá a possibilidade de contribuição de todos para informações acerca da biologia e distribuição de todos os pequenos mamíferos a serem avaliados. Esse período aberto a contribuições será definido pelo ICMBio e deverá ocorrer através do acesso à plataforma SALVE de forma *on-line.*

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ARTIGOS

Influência do pulso sazonal de inundação na densidade de registros de lontras (*Lontra longicaudis*) e ariranhas (*Pteronura brasiliensis*) no médio rio Teles Pires, sul da Amazônia

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Resumo: Os sistemas de rios e lagos da Amazônia são fortemente influenciados pelo pulso sazonal de inundação, que se caracteriza pela alteração no nível da água ao longo de um ciclo anual de cheia e seca. Espécies que dependem tanto do ambiente terrestre, quanto do ambiente aquático para realizar suas atividades, como os mamíferos semiaquáticos, podem ser influenciadas pela dinâmica sazonal em ambos os tipos de ecossistema. Nesse sentido, o objetivo do trabalho foi avaliar se existe diferença na densidade de registros de lontras e ariranhas com as fases do pulso sazonal de vazante, seca, enchente e cheia na região do médio rio Teles Pires, nos estados do Mato Grosso e Pará. Para as lontras, não houve diferença na densidade de registros entre os períodos de vazante, seca, enchente e cheia e o nível da água não influenciou na taxa de registros (p = 0,289). Para ariranhas, em contrapartida, maiores densidades foram registradas nos períodos de águas baixas, sendo encontradas diferenças principalmente entre a estação de seca e cheia (p = 0,001). Quando o nível do rio decresceu, houve o aumento na densidade de registros para a espécie, fator que pode estar relacionado com a maior disponibilidade de barrancos, pedrais, troncos e bancos de areia, que os indivíduos utilizam para realizar suas atividades.

Palavras-Chave: Cheia; Mamíferos Semiaquáticos; Sazonalidade; Seca.

Abstract: Influence of the seasonal pulse on the density of records of Neotropical (Lontra *longicaudis*) and giant otters (*Pteronura brasiliensis*) in the middle Teles Pires river, southern Amazonia. Amazonian river and lake systems are strongly influenced by the seasonal flood pulse, which is characterized by changes in water level over an annual cycle of flood and drought. Species that depend on both the terrestrial and the aquatic environments to perform their activities, such as semi-aquatic mammals, may be affected by seasonal dynamics in both types of ecosystem. In this sense, the aims of this work were to evaluate if there is a difference in the density of records of neotropical and giant otters related the seasonal phases of the hydrological pulse: low water, rising, hight water and falling, in the region of the middle Teles Pires river, Mato Grosso and Pará States, Brazil. For Neotropical otters, there was no difference in density among the phases, and the water level did not influence in the records (p = 0.289). For giant otters, higher densities were recorded in the low water periods, being found differences mainly between the dry and full season (p = 0.001). When the river level decreased, there was an increase in the density of records for the species, a factor that may be related to the greater availability of ravines, rocks, trunks and sandbars, which individuals use for their daily requirements.

Key-Words: Dry; Flooded; Seasonality; Semi-Aquatic Mammals.

INTRODUÇÃO

Uma das características dos sistemas de rios e lagos da Amazônia é a forte influência do pulso sazonal de inundação sobre a biodiversidade (Bodmer *et al.,* 2017; Santos *et al.,* 2007). Esse pulso está relacionado principalmente com variações na precipitação ao longo do ano e a consequente alteração no nível da água dos rios que, no período das cheias, transborda o canal principal e invade os ambientes terrestres contribuindo para a ciclagem de nutrientes e para a alteração na riqueza, composição e distribuição das espécies aquáticas e terrestres (Beja *et al.,* 2010; Faustino & da Silva, 2006; Haugaasen & Peres, 2005; Junk *et al.,* 1989; Oliveira *et al.,* 2015).

Mamíferos compõem um grupo altamente diversificado, possuindo representantes que estão adaptados aos mais variados tipos de ambientes (Redford & Eisenberg, 1992). As lontras (*Lontra longicaudis*) e as

ariranhas (*Pteronura brasiliensis*), particularmente, são classificadas como semiaquáticas por dependerem tanto da água quanto da terra para exercerem suas atividades (Kruuk, 2006; Redford *et al.,* 1992). Características como a presença de áreas ripárias para a construção de tocas e de ambientes aquáticos com disponibilidade de recursos alimentares são os principais fatores para a seleção de habitat, fazendo com que sejam espécies altamente influenciadas pela dinâmica desses dois tipos de ecossistemas (Duplaix *et al.,* 2015; Lariviére, 1999; Lima *et al.,* 2012; Noonan *et al.,* 2017; Soldateli & Blacher, 1996).

Nos períodos de cheia, espécies aquáticas e semiaquáticas como peixes-boi, botos, lontras e ariranhas tendem a seguir a migração dos peixes para os igarapés, aumentando sua área de vida em vários quilômetros em rios da Amazônia (Arraut *et al.,* 2017; Duplaix, 1980; Faustino & da Silva, 2006; Martim & da Silva, 2004). Consequentemente, pode haver uma redução na taxa de encontros e no número de registros nesse período (Cabral *et al.,* 2010; Duplaix, 1980; Faustino & da Silva, 2006; Rosas *et al.,* 2007). Na seca, em contrapartida, há um incremento na taxa de registros obtidos, particularmente os indiretos como tocas, fezes, latrinas, acampamentos, pegadas e marcações de garras (Oliveira *et al.,* 2015). Assim, em períodos de águas mais altas o estudo dessas espécies, incluindo mustelídeos semiaquáticos, é dificultado pela redução na taxa de registros devido a expansão da área de vida, quando os indivíduos incorporam locais sazonalmente inundados e de difícil acesso (Georgiadis *et al.,* 2015).

O rio Teles Pires é um dos principais afluentes do Tapajós e um dos mais importantes rios da bacia Amazônica. Esse rio nasce no município de Serra Azul, na Chapada dos Guimarães e estende-se por 1.457 km, cruzando quase todo o estado do Mato Grosso e chegando na sua porção ao norte, no estado do Pará (ANA, 2018; Veiga *et al.,* 2013). Como acontece em outros corpos aquáticos da Amazônia, ele também é fortemente influenciado pela sazonalidade (Umetso *et al.,* 2007; Veiga *et al.,* 2013). Considerando que os estudos com mustelídeos semiaquáticos na região do médio rio Teles Pires ainda são preliminares, o objetivo do trabalho é apresentar os dados de densidade dos registros de lontras e ariranhas ao longo das estações de vazante, seca, enchente e cheia, testando a hipótese de que há diferenças na densidade de vestígios dessas espécies entre essas fases, com maiores valores nos períodos de águas baixas, quando há uma maior disponibilidade de áreas de terra expostas para suas atividades.

MATERIAL E MÉTODOS

A área de estudo abrange a região do médio Rio Teles Pires e seus afluentes (09°23’13”S e 56°46’33”W, Datum WGS84), incluindo os rios Paranaíta e Santa Helena, além de pequenos canais, totalizando uma área de cerca de 80 km entre os pontos mais extremos (Figura 1). O estudo faz parte do Programa de Monitoramento de Mamíferos Semiaquáticos da Hidrelétrica de Teles Pires, localizada no extremo norte do Mato Grosso, na divisa com o Estado do Pará, a 60 km do município de Alta Floresta. Lontras e ariranhas foram estudadas na região de junho de 2012 a julho de 2016 (Calaça *et al.,* 2015; Calaça & Melo, 2017), totalizando 11 campanhas de pré-enchimento e quatro de pós-enchimento e um esforço de 8.901,98 km de rios percorridos.

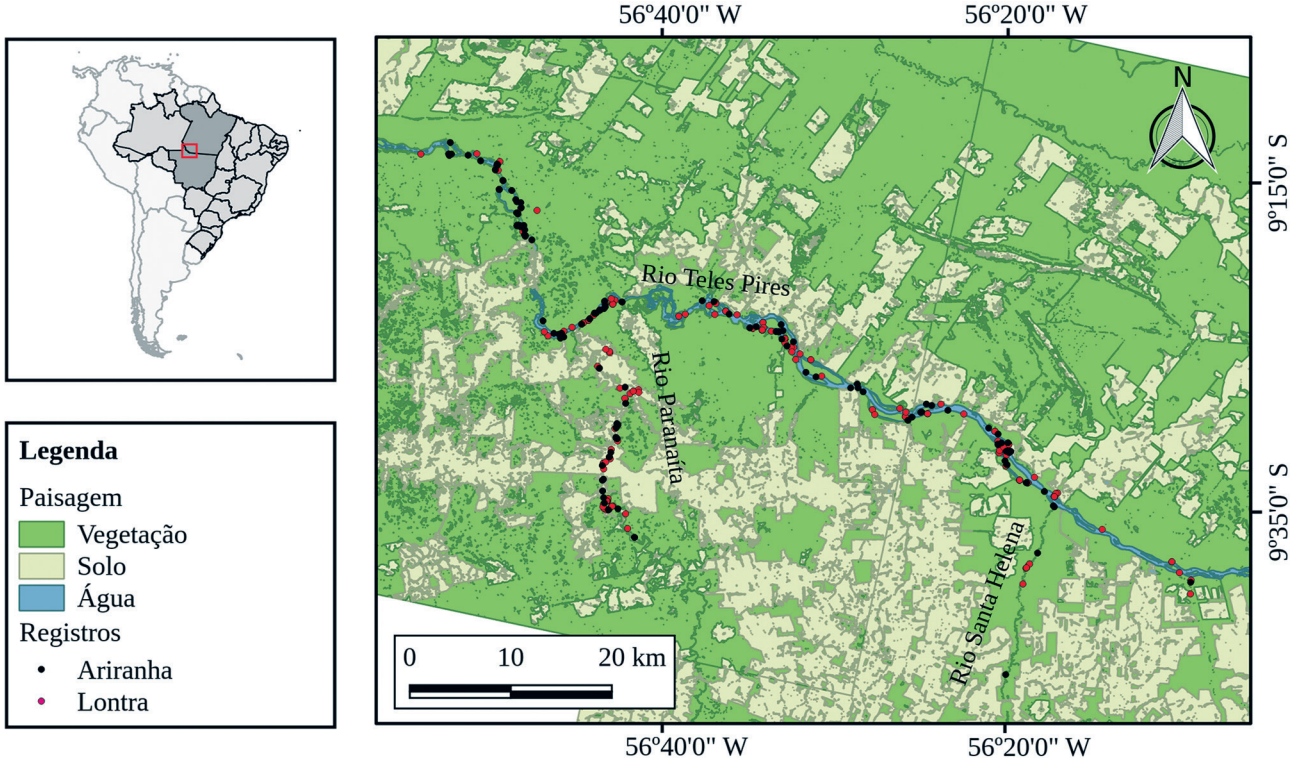

Figura 1: Área de estudo localizada na região do médio rio Teles Pires, Estados de Mato Grosso e Pará. Círculos pretos e vermelhos indicam os trechos com registros de ariranha e lontra, respectivamente.

Para a amostragem da distribuição de lontras e ariranhas, foi utilizada uma embarcação de 6 metros com motor de 25 HP, em uma velocidade de aproximadamente 10 km/h. Ambas as margens dos rios foram costeadas e inspecionadas com o auxílio de um binóculo, na busca por qualquer tipo de indícios das espécies. Além da visualização, vestígios como odores, pegadas, fezes, tocas, acampamentos, locais de descanso e marcação de garras também foram analisados (seguindo Groenendijk *et al.,* 2005, com modificações). Quando qualquer tipo de indício foi localizado, os pontos foram georreferenciados e as características de cada registro examinadas e anotadas em ficha de campo.

Em um ciclo anual é possível identificar quatro fases ou períodos sazonais nos sistemas de rios e lagos no Teles Pires, cujo nível da água pode variar de quatro a 13 metros. De acordo com os dados fluviométricos obtidos junto à base de dados da ANA – a Agência Nacional de Águas na estação Montante Dois do rio Teles Pires (http://www.snirh.gov.br) – na enchente, de meados de outubro a dezembro, há o início da ascensão no nível da água, que chega ao seu valor máximo no período da cheia, de janeiro a março, sendo enchente e cheia períodos sazonais considerados de água alta. No período da vazante, de abril a junho, o nível da água começa a diminuir até que na seca, de julho a setembro, é comum registrar vários trechos extremamente rasos, quando o nível da água atinge o seu nível mínimo, sendo as fases de vazante e seca consideradas de água baixa (Figura 2).

A densidade de registros foi analisada considerando o número de registros diretos e indiretos obtidos para cada uma das espécies e o esforço amostral, calculado através do número de quilômetros percorridos em cada trecho durante cada campanha sazonal. Para testar a hipótese de que há diferenças na densidade de registros entre as fases sazonais do pulso de inundação, foram consideradas 11 campanhas de pré-enchimento e uma de pós-enchimento. Apesar de na campanha de pós-enchimento, correspondente ao período sazonal da cheia, as áreas já estarem sob influência da alteração do ambiente pela usina hidrelétrica, não foram encontradas diferenças significativas na densidade de registros de mamíferos semiaquáticos com as campanhas de cheia anteriores ao impacto (t = 1,793; p = 0,110). Desse modo, a campanha foi incorporada para deixar os dados balanceados e mais robustos para os testes estatísticos, permitindo a análise de três campanhas para cada período sazonal. O teste de ANOVA foi usado para testar a hipótese de que há diferenças na densidade de registros entre as fases sazonais e testes não paramétricos de Kruskal-Walis foram utilizados quando não houve homogeneidade de variâncias. Adicionalmente, os dados foram relacionados com o nível da água do rio através de uma regressão linear simples para avaliar a influência do pulso sazonal na densidade de registros encontrados. Todas as análises foram feitas no software Statistica 7.0 (StatSoft, 2004).

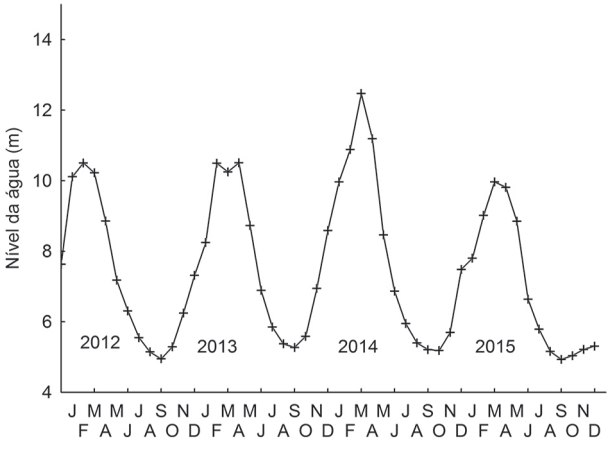

Figura 2: Variação anual no nível da água do médio rio Teles Pires, Mato Grosso e Pará, entre os anos de 2012 e 2015.

RESULTADOS

Entre os anos de 2012 e 2015, foram obtidos 410 registros de mamíferos semiaquáticos, dos quais 146 pertencentes às lontras e 264 às ariranhas. A distribuição dos registros de lontra foi homogênea ao longo dos períodos sazonais, diferente das ariranhas que apresentaram oscilações e picos de maior densidade em fases sazonais de águas baixas (Figura 3).

Não foram encontradas diferenças significativas na densidade de registros de lontras entre os períodos sazonais (F = 1,295; g.l = 3, p = 0,289; Figura 4A), mas para ariranhas os períodos de águas baixas concentraram uma maior quantidade de registros, com diferenças particularmente observadas entre a seca e cheia, corroborando a hipótese levantada (KW = 16,149; g.l = 3, p = 0,001; Figura 4B).

Quando os dados de densidade de registros foram relacionados com o nível da água, não houve diferenças significativas para lontras (R^2 = 0,062; p = 0,101), mas para ariranhas houve uma relação significativa, com maiores valores de registros nos períodos de seca (R^2 = 0,155; p = 0,008).

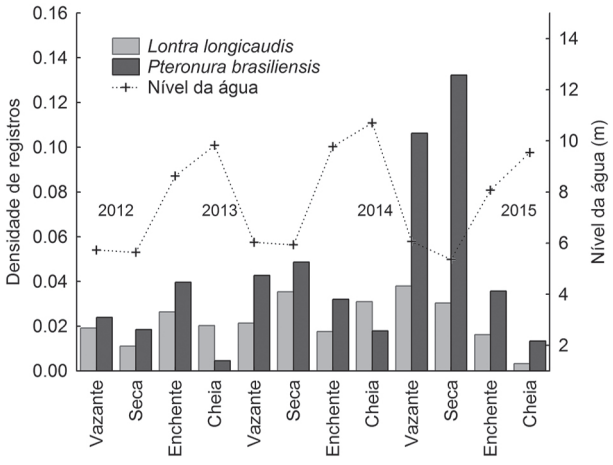

Figura 3: Variação na densidade média de registros (número de registros/km percorrido) de lontra (*Lontra longicaudis*) e ariranha (*Pteronura brasiliensis*) com o nível da água do rio ao longo das campanhas sazonais monitoradas entre os anos de 2012 e 2015 no médio rio Teles Pires, Estados de Mato Grosso e Pará.

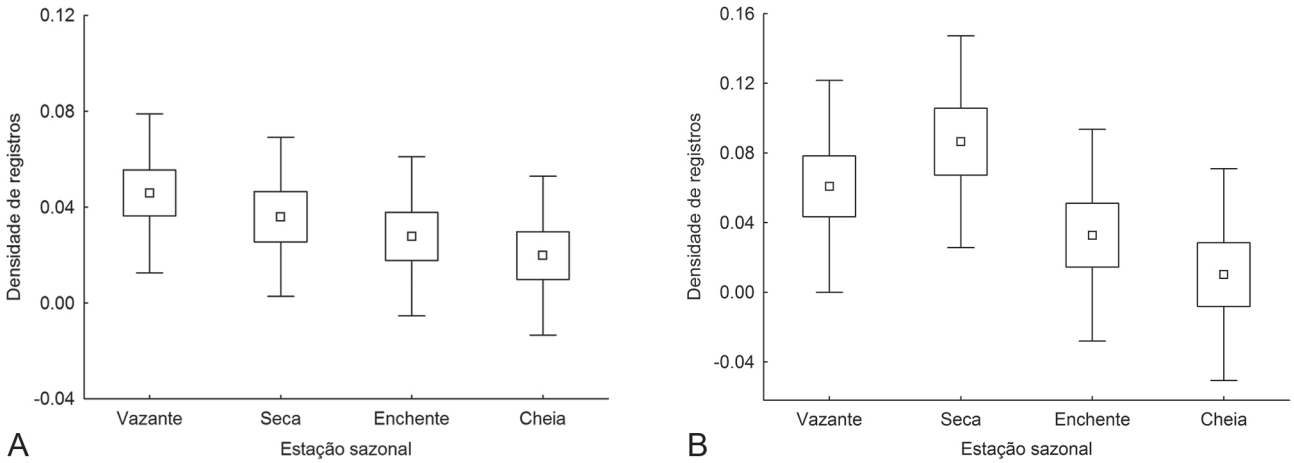

Figura 4: Densidade de registros de lontras (A) e ariranhas (B) (número de registro por km) por fase sazonal do pulso de inundação no rio Teles Pires, Estados de Mato Grosso e Pará.

DISCUSSÃO

A sazonalidade exerce forte influência na ecologia de mamíferos semiaquáticos, particularmente na dinâmica espacial (Duplaix, 1980). No caso especial das ariranhas, Utreras *et al.* (2005) encontraram áreas de vida dos grupos variando de 0,45 km² a 2,79 km² durante a seca e de 1,98 km² a 19,55 km² durante o período da cheia para lagos no Equador, uma variação de quatro a 13 vezes maior no período de cheia, quando comparada com a seca. Do mesmo modo, no Pantanal, áreas de vida dos grupos de ariranhas apresentaram tamanhos de quatro a 59 vezes maior no período de cheia (Leutchtenberger *et al.,* 2013). Nessa época do ano, os indivíduos tendem a abandonar ou expandir seus territórios temporariamente e incorporar várias áreas sazonalmente inundadas, incluindo lagos e lagoas marginais, dentro de sua área vida, comportamento que tem sido observado para diferentes ecorregiões dentro da distribuição da espécie, incluindo a Amazônia (Duplaix, 1980; Cabral *et al.,* 2010; Evangelista & Rosas, 2011), o ecótono Amazônia/Cerrado (Giorgiadis *et al.,* 2015) e o Pantanal (Leutchtenberger *et al.,* 2013).

Para as lontras neotropicais, consideradas uma das espécies de lontras mais pobremente estudadas, não existem muitas informações sobre aspectos da área de vida e a influência sazonal, possivelmente devido ao pequeno número de visualizações e a ausência de marcas individuais (Rheingantz *et al.,* 2017). Ao nosso conhecimento, apenas dois trabalhos publicados realizaram a captura de indivíduos de lontra no Brasil para a implantação de rádios transmissores visando avaliar a área de vida (Marmontel *et al.,* 2011; Nakano-Oliveira *et al.,* 2004), como tem sido feito para ariranhas e outras espécies de lontras (Kruuk, 2006; Leutchtenberger *et al.,* 2013; Leutchtenberger *et al.,* 2015; Quaglietta *et al.,* 2012; Reid *et al.,* 1994; Silveira *et al.,* 2011), mas ambos apresentaram problemas técnicos (Marmontel *et al.,* 2011; Nakano-Oliveira *et al.,* 2004).

Desse modo, grande parte das informações disponíveis na literatura sobre o uso do hábitat e a distribuição espacial de lontras neotropicais é baseada em dados de registros indiretos tais como vestígios (Coletti *et al.,* 2013; Parera, 1996; Quadros, 2012; Rheingantz *et al.,* 2017; Waldemarin & Colares, 2000). Na área de estudo, as variações nas densidades de registros para as lontras ao longo das fases do pulso sazonal foram mais sutis do que para as ariranhas, não havendo diferenças significativas entre os períodos. Foi observada certa fidelidade às áreas com maior intensidade de uso – as chamadas *"áreas núcleos"* – e, mesmo nos períodos de cheia, as lontras permaneceram próximas a elas. Devido aos hábitos crípticos e solitários da espécie, a maioria dos registros obtidos são vestígios como fezes, que são utilizadas para comunicação social (Lariviére, 1999) e, assim, geralmente depositadas em lugares altos e visíveis (Lariviére, 1999; Kruuk, 2006; Santos & Reis, 2012). A variação no nível da água não influenciou na densidade desses registros porque mesmo nos períodos de água alta, estruturas da paisagem como troncos íngremes, pontas de pedrais e barrancos altos foram utilizados pela espécie, que possui o hábito de escalar bem desenvolvido (Silva & Quintela, 2010).

Para as ariranhas, em contrapartida, os indivíduos foram mais propensos a se dispersar para os pequenos rios já durante a fase de enchente, reduzindo a probabilidade de registros nesse período. Nos pequenos canais e outros tributários em que foi possível adentrar com o barco durante os períodos de água alta, foram registrados alguns indivíduos a mais de oito quilômetros de distância do rio principal. Nesse período também foram registrados alguns encontros fortuitos em lagoas dentro da mata a mais três quilômetros de distância do rio Teles Pires. Assim, na cheia a densidade de registros de ariranhas no rio Teles Pires caiu drasticamente em todos os anos monitorados. Apesar da relação entre o nível da água e a densidade de registros ter sido significativa para a espécie, o modelo linear explicou apenas 15% da variação dos dados, o que se deve provavelmente ao fato de que, mesmo na cheia, os grupos de ariranhas ainda utilizem o leito dos rios principais (Leutchtenberger *et al.,* 2013; Leutchtenberger *et al.,* 2015).

A maior densidade de registros na seca e vazante era prevista porque nesses períodos de água baixa há

um aumento das chances de se registrar as espécies no canal principal, onde existe uma maior concentração de recursos, principalmente de peixes, como observado em outros estudos (Cabral *et al.,* 2010; Duplaix, 1980; Silveira *et al.,* 2011; Utreras *et al.,* 2005). Estruturas da paisagem como troncos, bancos de areias, pedrais e barrancos também ficam mais expostos durante esses períodos, sendo mais fácil obter registros indiretos como fezes e pegadas. No período de cheia, os animais tendem a expandir suas áreas de vida (Evangelista & Rosas, 2011; Leuchtenberger *et al.,* 2013; Leuchtenberger *et al.,* 2015; Utreras *et al.,* 2005) e se deslocar para igarapés e pequenos rios seguindo a migração dos peixes (Cabral *et al.,* 2010; Duplaix, 1980). Ademais, a ascensão da água encobre tocas e os locais utilizados para paragens e descanso (Duplaix, 1980; Evangelista & Rosas, 2011; Rosas, 2004; Rosas *et al.,* 2007), dificultando a obtenção de registros, considerando que ariranhas são menos propensas a escalar as áreas íngremes disponíveis em maior quantidade na cheia, como fazem as lontras (Duplaix *et al.,* 2015). Leuchtenberger *et al.* (2013), entretanto, conseguiram registrar a presença de latrinas depositadas sobre arbustos no período dos picos mais elevados de cheia no Pantanal. Provavelmente, esses locais foram mais fáceis de serem encontrados porque os animais estavam marcados com transmissores.

Avaliar a variação na densidade e distribuição de registros ao longo das fases do pulso sazonal é importante para conhecer aspectos da dinâmica espacial das espécies semiaquáticas e pode fornecer subsídios para predizer como as espécies responderão às alterações físicas no seu ambiente, incluindo a construção de usinas hidrelétricas, que tendem a alterar o ambiente de lótico para lêntico e homogeneizar a influência do pulso sazonal e a disponibilidade de recursos (Calaça *et al.,* 2015; Calaça & Melo, 2017; Palmeirim *et al.,* 2014; Rosas *et al.,* 2007). Os dados de densidade variando com os períodos, foram importantes para a escolha das campanhas sazonais mais significativas para uma amostragem eficiente no período de pós-enchimento do reservatório da UHE Teles Pires, quando o monitoramento passou a ser semestral. Assim, os resultados desse estudo podem servir como base para direcionar futuras pesquisas realizadas em hidrelétricas na Amazônia e ressalta a importância de incluir a fase de pré-enchimento do reservatório dentro dos programas de monitoramento, principalmente devido ao fato de que a maioria dos trabalhos avaliando a influência de hidrelétricas na biodiversidade só ocorre durante ou após o impacto, gerando resultados difíceis de serem comparáveis (Calaça *et al.,* 2015; Calaça & Melo, 2017; Rosas *et al.,* 2007).

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Geographical variation and sexual dimorphism in cranial size and shape of *Kannabateomys amblyonyx* (Rodentia: Echimyidae)

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Abstract: The echimyid rodent *Kannabateomys amblyonyx,* also known as the bamboo rat, is restricted to the Atlantic rainforest of Brazil, Uruguay, Paraguay and Argentina. This species feeds exclusively on bamboo stems and leaves, making it a highly specialist species. Due to the lack of studies about this group, partly because of the poor sample sizes available in museums and collections, morphological diversity aspects and intraspecific variation are poorly understood. Our study is a first evaluation of the sexual and geographic variation in the cranial structure of *K. amblyonyx.* To assess this, we used linear (Euclidean distances) and geometric morphometrics (size and shape) approaches. We investigated intraspecific differences using an analysis of variance (ANOVA), and principal component analyses (PCA). We did not find evidence of sexual dimorphism in the skull of *K. amblyonyx,* using both linear distances and landmark analyses. On the other hand, we found a geographical differentiation between populations, with both morphometric methods used. Most differences were observed in populations from the extremes of its distribution, as São Paulo and Espírito Santo states. Our study is the first attempt to elucidate important information about morphological diversity of *K. amblyonyx.*

Key-Words: Bamboo rat; Cranial variation; Echimyidae; Linear and geometric morphometrics.

Resumo: Variação geográfica e dimorfismo sexual no tamanho e forma do crânio de Kannabateomys amblyonyx (Rodentia: Echimyidae). O roedor equimídeo *Kannabateomys amblyonyx,* também conhecido como rato-do-bambu, distribui-se ao longo do bioma Mata Atlântica presente no Brasil, Uruguai, Paraguai e Argentina. Esta espécie se alimenta exclusivamente de folhas e brotos de bambu, sendo assim altamente especialista. Devido à ausência de estudos envolvendo este grupo, parcialmente associada à pequena disponibilidade de amostras em museus e coleções, aspectos de sua diversidade morfológica e variações intraespecíficas permanecem pouco compreendidas. Nesta perspectiva, nosso estudo compreende uma primeira avaliação da variação sexual e geográfica na estrutura craniana de *K. amblyonyx.* Para acessar tais questões, nós utilizamos morfometria linear (distâncias euclidianas) e geométrica (forma e tamanho). Nós investigamos diferenças intraespecíficas utilizando análises de variância (ANOVA) e análise de componentes principais (PCA). Não encontramos evidência de dimorfismo sexual no crânio de *K. amblyonyx,* utilizando ambas as análises das distâncias e marcadores geométricos. Por outro lado, nós encontramos uma diferenciação geográfica entre populações em ambos os métodos morfométricos utilizados. A maioria das diferenças foi observada em populações provenientes de distribuições extremas, como São Paulo e Espírito Santo. Nosso estudo é a uma primeira tentativa de preencher uma lacuna importante no conhecimento da diversidade morfológica de *K. amblyonyx.*

Palavras-Chave: Echimyidae; Morfometria linear e geométrica; Rato-do-bambu; Variação craniana.

INTRODUCTION

The bamboo rat, *Kannabateomys* Jentink, 1891, is a monotypic genus represented by the species *K. amblyonyx* (Wagner, 1845), which is restricted to the Atlantic rainforest of Brazil, Uruguay, Paraguay and Argentina (Patton *et al.,* 2015). This species is a habitat specialist that only occurs in bamboo vegetation and feed exclusively on bamboo stems and leaves (Olmos *et al.,* 1993; Silva *et al.,* 2008). Due to its highly specialized habitat, there is very little literature about its natural history or evolutionary history. Most of the information available

in the literature addresses aspects regarding its conservation status (Silva *et al.,* 2012) and its reproductive strategy (Silva *et al.,* 2008; Siman *et al.,* 2017). Moreover, Fabre *et al.* (2017) were proposed a hypothesis of the evolutionary trajectory and phylogenetic relationships between *K. amblyonyx* and its closest relative species in a study where they investigated the phylogenetic relationships of the Echimyidae family, the taxonomic family to which *K. amblyonyx* belongs. Although the studies mentioned above provide some insights about the phylogenetic position of *K. amblyonyx* within the Echymidae family, as well as some aspects about its ecology, we know little about its morphological variation and the possible evolutionary mechanisms that might have shaped the phenotype of this highly specialized species. Therefore, our study is a first attempt to fill such gap by describing the geographical and sexual variation in the skull morphology of this species.

There are a few studies that have investigated the morphometric variation in Echimyidae, including specimens from *Kannabateomys,* focusing on the tooth (Candela & Rasia, 2012) and the skull morphology (Perez *et al.,* 2009). Those studies gave us a better understanding on the ecological and evolutionary factors leading to the morphological diversification of this group. Furthermore, analyses of skull morphometric using size and shape variables have already been used to investigate sexual and geographic variation in echimid rodents (Monteiro *et al.,* 1999).

The skull is responsible for performing numerous tasks in mammals, and is directly involved in several ecological aspects such as feeding, acquiring and manipulating food, protecting sensorial organs and the brain (Fish, 2017). Due to its multitude of important tasks the skull represents an important structure when trying to elucidate evolutionary aspects within and among populations. Size changes associated with allometric processes are one of the key factors driving cranial diversification in mammalian clades (Cardini & Polly, 2013). In addition, environmental and lifestyle differences, such as diet and locomotion, can also be important drivers of skull morphological variation (Nogueira *et al.,* 2009; Tavares *et al.,* 2010).

In particular, a common phenomenon in mammals is sexual dimorphism, where females are morphologically different from males. These differences can be manifested as difference in size (Lindenfors *et al.,* 2007) or in specific traits (Camargo & Oliveira, 2012; Sebastião & Marroig, 2013). One of the mechanisms behind sexual dimorphism is sexual selection. According to sexual selection theory, the differences between the sexes are a consequence of intrasexual competition for mating opportunities or epigamic selection, in which mating choice is initially influenced by characteristics in the opposite sex that increase the fitness of its offspring (Jones & Ratterman, 2009). Another mechanism that can generate sexual dimorphism is distinct growth trajectories. Irrespective of the mechanism generating this pattern, in echimyid rodents, sexual dimorphism is usually small or absent (Bezerra & Oliveira, 2010; Monteiro *et al.,* 1999).

Local ecological aspects (*e.g.,* competition, climate and resource availability) and phylogenetic history may have an important influence on species distribution and influence geographical variation, as well as in promoting different selective pressures leading to morphological variation within a species (Cardini *et al.,* 2010). In some cases, morphological differences observed along the geographical distribution of a species become the starting point to investigate the presence of a new species (Moratelli *et al.,* 2011) or delimit subspecies (Soisook *et al.,* 2013). In echimyids, the genus *Thrichomys* has been the subject of several studies involving morphometric analyses that aimed to assess the degree and patterns of geographic variation (Duarte *et al.,* 2000; Monteiro *et al.,* 1999; Monteiro *et al.,* 2003; Reis *et al.,* 2002). These analyses were performed based on populations from Central and Northeastern Brazil. In general, the results showed shape differences in regions associated with mastication and correlated with a general latitudinal environmental gradient (Monteiro *et al.,* 2003), as well as the segregation of single populations from all others (Duarte *et al.,* 2000). Perez *et al.* (2009) showed, in species group in Echimyidae, a strong concordance between shape variation of four cranial units (vault, base, oragnathofacial complex and mandible) and their ecological niches.

Knowledge of variations within a species is crucial to investigate functional, evolutionary, ecological and conservation hypotheses in different groups (Des Roches *et al.,* 2018). The main goal of the present contribution is to evaluate the geographic and sexual variation in the skull of *K. amblyonyx,* analyzing those ecological aspects potentially relevant to morphological changes.

MATERIALS AND METHODS

We analyzed 59 skulls of *Kannabateomys amblyonyx* deposited at the following institutions: Instituto Nacional da Mata Atlântica (INMA, Santa Teresa – ES), Museu Nacional (MN, Rio de Janeiro – RJ), Museu de Zoologia da Universidade de São Paulo (MZUSP, São Paulo – SP) and Museu de Zoologia João Moojen (MZUFV, Viçosa – MG). All skulls were assigned to age classes following Silva (2014) and only adult specimens were used to avoid possible ontogenic influences in morphological variation. In an attempt to cover the total geographical distribution of the species, we analyzed skulls from four different Brazilian States in the Southeastern region that contain the Atlantic Forest biome. Our samples came from the States of São Paulo (SP, n = 17), Rio de Janeiro (n = RJ, 5), Espírito Santo (ES, n = 7) and Minas Gerais (MG, n = 20) and included 19 male and 26 female specimens. The list of sampled specimens divided by state and sex is presented in Table S1.

Three-dimensional coordinates were recorded for 32 landmarks in each skull, using a 3D digitizer (MX-Microscribe®) (Figure 1 and Table 1). Whenever one side of the skull was damaged, the measurement and/or landmark information of the other side was used. Each specimen was digitized twice, and repeatability was

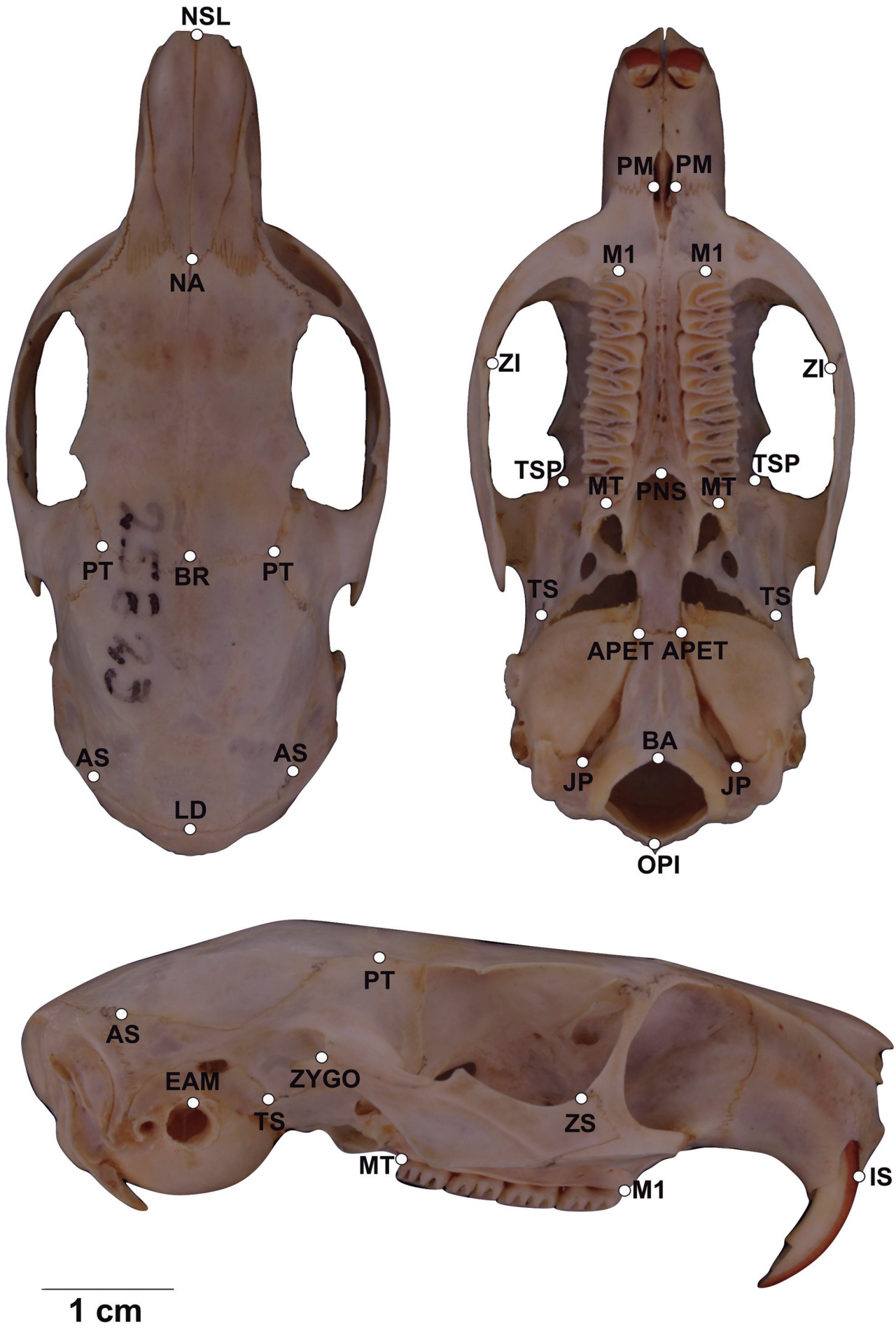

Figure 1: Representation of the three views from *K. amblyonyx* skull (dorsal, ventral and lateral) and their respective geometric landmarks.

Table 1: Description of landmarks used in the *K. amblyonyx* skull according to Figure 1. The sagittal and bilateral positions represent measurements located in left and right size of the skull, respectively.

Landmark	Position	Description
IS	SAGITAL	Intradentale superior
NSL	SAGITAL	"Nasale" – Anterior extremity of nasal bone
NA	SAGITAL	"Nasion" – Posterior extremity of nasal bone
BR	SAGITAL	"Bregma" – Suture between frontal and parietal
ZS	BILATERAL	Zygomaxillare superior
PT	BILATERAL	"Pterion" – Suture between frontal and parietal
TSP	BILATERAL	Temporo-pheno-parietal suture
PM	BILATERAL	Pre-maxillare-maxillare suture at the alveolus
ZI	BILATERAL	Zygomaxillare inferior
MT	BILATERAL	Maxillary tuberosity
PNS	SAGITAL	Posterior nasal spine
ZYGO	BILATERAL	Suture between zygomatic and temporal
TS	BILATERAL	Temporo-sphenoidal junction at petrous
EAM	BILATERAL	Anterior external auditory meatus
JP	BILATERAL	Jugular process
APET	BILATERAL	Anterior petrous temporal
BA	SAGITAL	"Basion" – Ventral point of foramen magnum
OPI	SAGITAL	"Opistion" – Dorsal point of foramen magnum
LD	SAGITAL	Lambda
AS	BILATERAL	"Asterion" – Suture between parietal and occipital

estimated to assess measurement reliability according to Lessels & Boag (1987). All specimens showed high values of repeatability for all measurements (see Table S2). Therefore, all subsequent analyses were carried out using the average replicated measurements and were performed in the R statistical environment (R development Core Team, 2015).

We used a combination of geometric and linear morphometrics to analyze geographic variation and sexual dimorphism in skulls of *K. amblyonyx.* Using geometric morphometrics, we analyzed isometric size changes using centroid size, which is a shape independent variable (Bookstein, 1991) and the skull shape, defined as "all the geometric information that remains when location, scale and rotational effects are filtered out from an object" (Kendall, 1977; Zelditch *et al.,* 2004). The geometric morphometric framework represents a powerful tool to assess shape variation between groups, as it removes effects of scaling (isometric size) from the analyses. The shape variables were obtained by scaling, aligning and transforming the landmark coordinates for each specimen through General Procrustes Alignment (GPA) using the R packages "AMP", "OSymm", "unifyVD" (Haber *et al.,* 2015) and "Geomorph" (Adams & Otarola-Castillo, 2013). In addition, we also analyzed skull morphology using linear morphometric. From the landmarks, we estimated a set of 35 Euclidean distances (Table 2). Those distances were chosen because they represent important functional aspects of the mammalian skull (Cheverud, 1982; Marroig & Cheverud 2001).

We checked for normality using *"stem and leaf"* display to evaluate the distribution of values in a graphical data (Tukey, 1977). To evaluate sex and geographic variation, we performed a Principal Component Analysis (PCA) to detect potential cranial variations between

Table 2: Euclidean distances estimated from 32 markers obtained from skull and their respective functional/development groups. Distances were chosen to represent evolutionary important traits that could have impacted the biological phenomenon that we were interested in (sexual dimorphism and geographical variation).

Distances	Functional Subregion	Region
IS-PM	Oral	Face
IS-NSL	Nasal	Face
IS-PNS	Oral/Nasal	Face
PM-ZS	Oral	Face
PM-ZI	Oral	Face
PM-MT	Oral	Face
NSL-NA	Nasal	Face
NSL-ZS	Nasal	Face
NSL-ZI	Oral/Nasal	Face
NA-BR	Cranial Vault	Neurocranium
NA-PNS	Nasal	Face
BR-PT	Cranial Vault	Neurocranium
BR-APET	Cranial Vault	Neurocranium
PT-APET	Cranial Vault	Neurocranium
PT-BA	Cranial Vault	Neurocranium
PT-EAM	Cranial Vault	Neurocranium
PT-ZYGO	Zygomatic	Face
PT-TSP	Cranial Vault/Zygomatic	Neurocranium/Face
ZS-ZI	Oral/Zygomatic	Face
ZI-MT	Oral	Face
ZI-ZYGO	Zygomatic	Face
ZI-TSP	Zygomatic	Face
MT-PNS	Oral	Face
PNS-APET	Skull Base	Neurocranium
APET-BA	Skull Base	Neurocranium
APET-TS	Skull Base	Neurocranium
BA-EAM	Skull Base	Neurocranium
EAM-ZYGO	Zygomatic	Face
ZYGO-TSP	Zygomatic	Face
LD-AS	Cranial Vault	Neurocranium
BR-LD	Cranial Vault	Neurocranium
OPI-LD	Cranial Vault	Neurocranium
PT-AS	Cranial Vault	Neurocranium
JP-AS	Skull Base	Neurocranium
BA-OPI	Skull Base	Neurocranium

individuals of *K. amblyonyx* related to skull linear distances, centroid size and geometric morphometric shape. To test if these differences were statistically significant, we performed an analysis of variance (ANOVA, p-value of 0.05) for centroid size and mean shape. For multiple tests (35 linear distances), we correct the level of significance using a Bonferroni correction (*i.e.,* p-value of 0.05/35 = 0.001). Visual information related to changes in cranial shape regarding the first and second principal component axes of variation was analyzed through deformation grids (*Thin-plate spline, TPS*).

RESULTS

Tests for sexual dimorphism on linear distances were not significant, indicating the absence of absolute dimorphism. On the other hand, in the geographical variation analyses, only one linear measurement was

Table 3: Linear and geometric morphometric ANOVA results for geographic differentiation analyses representing the variance (*F*), values of probability (*p-value*) and descriptive statistics, with maximum and minimum values, means and standard deviations (SD) for localities.

Variables	F	*p-value*	São Paulo		Rio de Janeiro		Espírito Santo		Minas Gerais	
			Min/Max	Mean/SD	Min/Max	Mean/SD	Min/Max	Mean/SD	Min/Max	Mean/SD
PTAPET	7.85	0.000	18.06/20.81	19.26/0.82	17.98/19.24	18.80/0.51	16.52/18.53	17.78/0.72	17.71/19.75	18.57/0.60
Shape	2.50	0.009	—	—	—	—	—	—	—	—

significant (PT-APET). Individuals from RJ and SP showed higher mean values for this measurement than those from other localities (Table 3).

The Euclidean measurements were compared using a Principal Component Analysis (PCA) and the projection of each individual in the first and second principal component space (Figure 2). The first principal component axis summarizes 36% of the total variation and the second principal component axis 13% of the variation. In the principal component analysis, the individuals of both sexes overlap along the first and second principal components, demonstrating that the major axes of variation do not separate sexes. On the other hand, the different sampling localities showed a pronounced segregation in the principal component space, mostly between SP and ES, while the other localities (MG and RJ) presented an intermediary, partially overlapping, position (Figure 2).

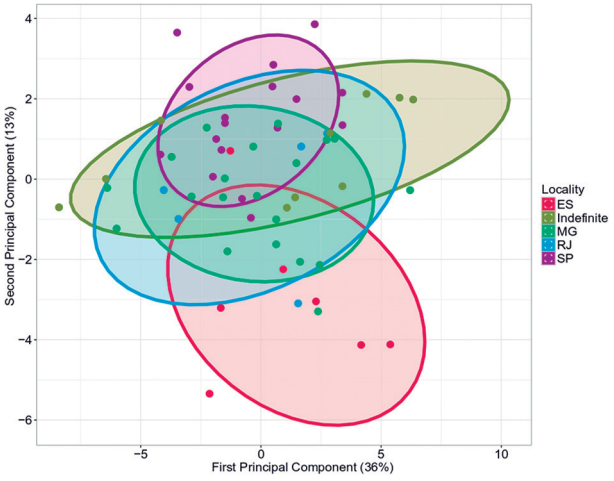

Figure 2: Scores of each specimen in the first and second principal component space based on the values of 35 linear distances, showing differentiation among localities. Males and females remain overlapping in subspace.

There were no statistically significant differences in centroid sizes between sexes (p = 0.561, Figure 3). There were no statistically significant differences in centroid sizes between localities as well (p = 0.4, Figure 4). The Procrustes ANOVA showed no statistical differences between sexes (p = 0.217). In contrast, the Procrustes ANOVA demonstrated significantly shape differences among localities (Table 3). In the Principal component multivariate shape space, the first principal component axis summarized 14% of the variation and the second principal component represented 13% of the variation. Males and females presented a large overlap in projection of the first two principal components, whereas the localities presented a similar segregation pattern as the linear distances results (Figure 5).

For a better visualization of shape change we performed a deformation grid analysis (Figure 5). The first principal shape component represents an axis of strong deformation in the cranial vault and skull base region towards the positive (PC1max) and negative (PC1min) axis of PC1. Specimens with higher loading values in PC1 space (PC1max) presented an extension of those regions, while PC1min values are associated with retraction of those regions. Individuals from ES (PC1max) and SP (PC1min) are positioned at such extremes. The second principal component axis also represents deformations related to the cranial vault and skull base, as well as with the addition of the nasal region. In general, there was a narrowing of the skull as a whole toward the PC2max. The individuals from ES, MG (PC2max) and SP (PC2min) are positioned near the positive and negative axis of the second principal component.

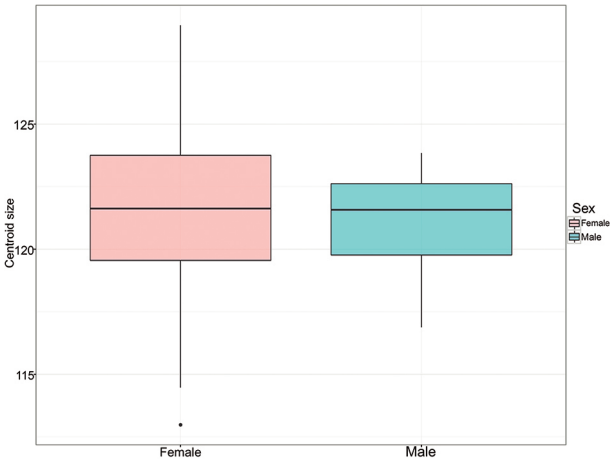

Figure 3: Boxplot indicating the compared values of centroid size obtained for males and females.

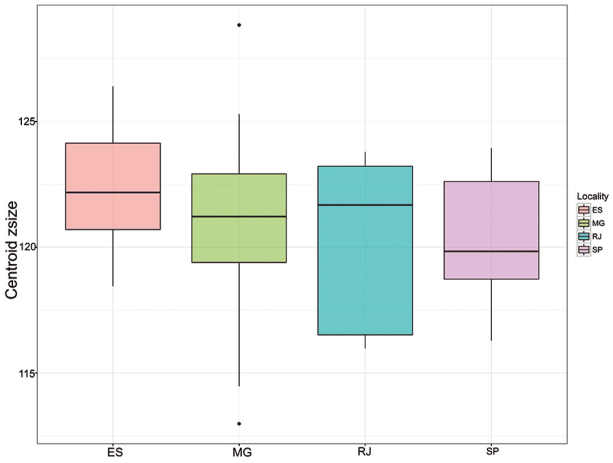

Figure 4: Boxplot indicating the compared values of centroid size obtained for geographic localities.

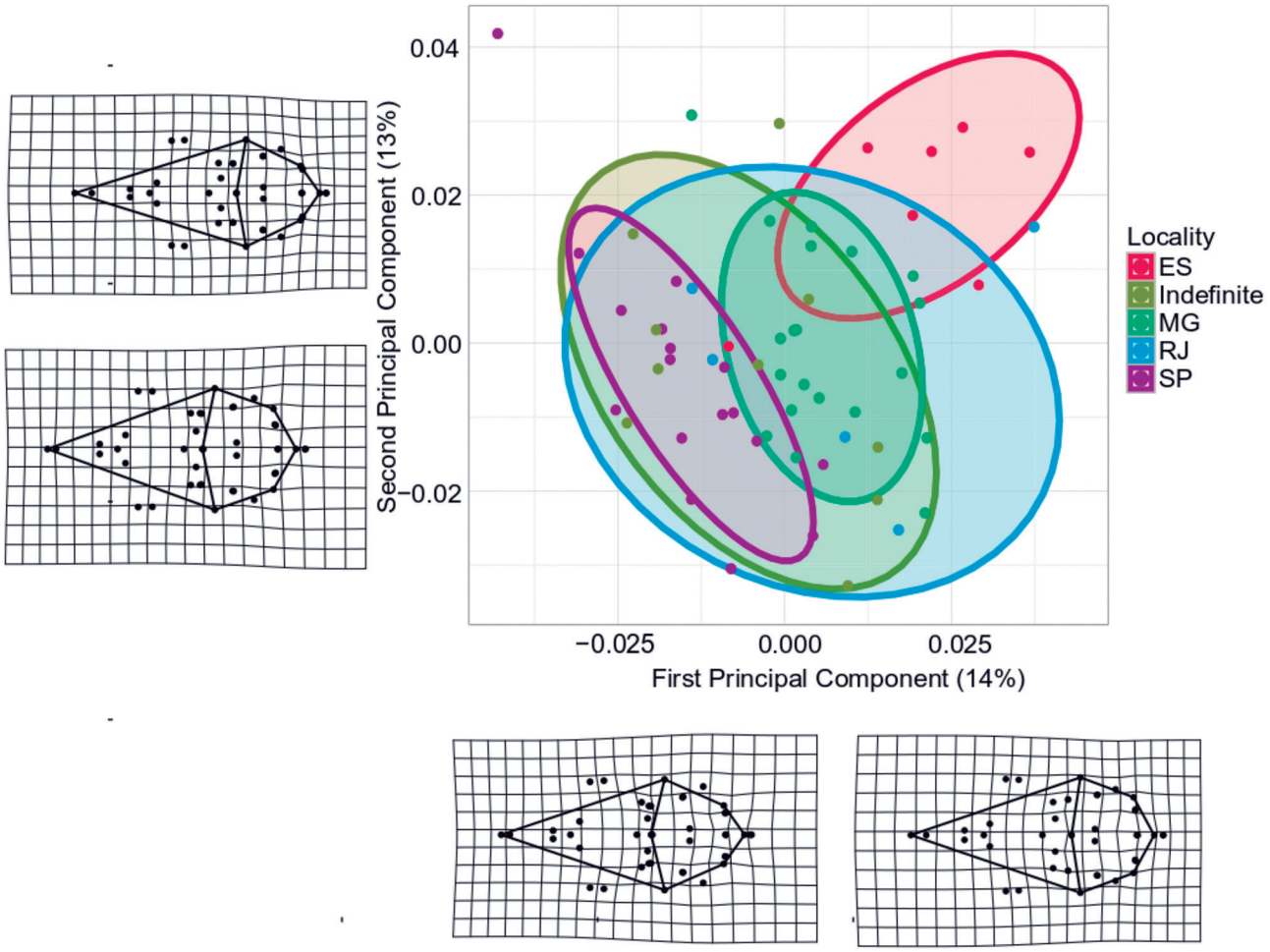

Figure 5: Scores of each specimen in the first and second principal component space based on the shape coordinates, showing differentiation among localities. Males and females remain overlapping in subspace. Deformation grids representing skull shape differences for *K. amblyonyx* observed in first and second principal component towards the positive and negative axis for dorsal view of the cranium. Variations related to cranial vault region can be observed.

DISCUSSION

Our study investigated morphological variation in the highly specialist species *Kannabateomys amblyonyx.* We found that most intraspecific morphological variation was due to geographical differentiation. We found no evidence of sexual dimorphism in this species, in any data analyzed, linear measurements, centroid size or shape variables, indicating the absence of this phenomenon in *K. amblyonyx.* Sexual monomorphism was also described by Silva *et al.* (2008) in body mass of specimens from Southern Brazil.

On the other hand, sexual dimorphism has already been reported for other echimyids taxa. For example, the genus *Proechimys* presents size sexual dimorphism, with males larger than females (Corti *et al.,* 2001). In contrast, *Thrichomys apereoides* are not dimorphic in shape or size of skull (Monteiro *et al.,* 1999). In mammals, the presence of sexual dimorphism is most often attributed to a polygamous mating system, where individuals (usually males) compete for sexual partners (Andersson, 1994; Lu *et al.,* 2014). Alternatively, intersexual morphological differences, such a habitat use, may be associated with environmental factors. In this sense, with each sex using different resources, we would expect different selective pressures acting upon each sex leading to a pattern of sexual dimorphism (Butler *et al.,* 2007). Despite the scarcity of ecological data, Olmos *et al.* (1993) described social and habit characteristics of *K. amblyonyx,* such as feeding and calling behavior, showing no clear sexual segregation, which might help explain the lack of sexual dimorphism pattern found.

The absence of sexual dimorphism can be explained by several factors related to specific aspects of *K. amblyonyx*'s natural history and ecology (Silva *et al.,* 2008). This species is monogamous with biparental care (Silva *et al.,* 2008). Moreover, food resource distribution is homogenous across space, since this species is extremely dependent on bamboo shoots as a food resource (Oliveira & Bonvicino, 2006; Silva & Vieira, 2006; Silva *et al.,* 2008; Silva *et al.,* 2012). In addition, another factor that may explain this result is the low occurrence of sexual dimorphism generally found in small mammals (Lu *et al.,* 2014), and particularly in histricognats rodents (Bezerra & Oliveira, 2010, Lessa & Pessôa, 2005; Pessôa & Reis, 1991; Pessôa & Reis, 1992; Pessôa & Strauss, 1999).

On the other hand, we did find geographical differentiation in the cranial structures of *K. amblyonyx.*

These differences were detected using linear measurements (PT-APET) and geometric morphometric, with the exception of centroid size, where no statistical differences between localities were found. The shape deformation grids showed that the axes with greatest variation were related to the cranial vault, skull base and nasal region. These regions exert several different functional demands on the skull, with the cranial vault responsible for protecting the superior and lateral portions of the brain, whereas the skull base is associated with protecting the cerebral connection with the face/body and also provides a platform under which the rest of skull develops (Lee *et al.,* 2017). Finally, the nasal region is associated with respiratory and olfactory systems and with water balance regulation in mammals (Schimidt-Nielsen *et al.,* 1970).

Therefore, the regions where most morphological changes were observed are associated with lifestyle tasks, such as protection and feeding. The feeding habits of *K. amblyonyx* only include bamboo shoots and leaves. However, studies involving anatomical variations among Atlantic Forest bamboo are scarce, and therefore we cannot say that the feeding does not vary, as regards the hardness and thickness of seeds and leaves. The existence of geographic variation could be a result of ecological aspects, involving biotic (interspecific competition) and physical aspects (climatic conditions) (Bornholdt *et al.,* 2008). The Atlantic forest region is characterized by its highly heterogeneous environmental conditions with large altitudinal range, complex topography and strong seasonality (Morellato & Haddad, 2000). Additionally, despite the lack of information, behavioral data described by Olmos *et al.* (1993) for *K. amblyonyx* reported the existence of vocalization between individuals for territorial and defensive functions. Following this reasoning, it is known that the vocal tract is formed by anatomical structures of the upper respiratory pathway (*e.g.,* throat, laryngeal, oral and nasal cavity) and communicational differences can promote vocal tract specializations (Frey & Gebler, 2009). Variation in the form of the bulla is also associated with acoustic signals, and can promote different configurations in the skull base region (Perez *et al.,* 2009). Intraspecific variation of these behavioral characteristics was already reported for Neotropical singing mice *Scotinomys teguina,* however, cranial variations were not investigated (Campbell *et al.,* 2010). In this way, potential vocalization differences among populations of *K. amblyonyx* could be influencing the geographic variation in cranial structure, although further studies are needed to test this hypothesis.

Moreover, the differences observed in the functional regions of the skull (cranial vault, skull base and nasal region) might be related to the isolation-by-distance model (Wright, 1943). This model proposes that an increase in the geographic distance results in a decrease in the total gene flow among populations, favoring the genetic, and consequently the morphological, and divergence between populations. For echimyids, isolation-by-distance has already been proposed as the mechanism explaining skull variation in *Thrichomys apereoides* (Reis *et al.,* 2002). In our study, the principal component analyses indicate differences between populations from Espírito Santo and São Paulo, which constitute the most extreme locations analyzed. Therefore, the geographic isolation is also a viable mechanism to explain the morphological differentiation observed in our analyses. Unfortunately, due to the small number of localities sampled in our study, we are unable to test this hypothesis.

Future studies are needed to elucidate the specific mechanisms proposed here that are responsible for the morphological differentiation observed in *K. amblyonyx.* The present study represents a descriptive first attempt to characterize intraspecific morphological variation in the skull of *K. amblyonyx.* However, it is important to note that our samples were limited due to the rarity of specimens in museum collections. Therefore, even though our study represents a first step in characterizing morphological variation in *K. amblyonyx,* more studies (including field sampling efforts) are necessary to corroborate our findings. Even with the scarcity of data, the geometric morphometric approaches used were able to detect geographic variation, filling gaps in the morphological evolutionary history of this species. Moreover, we present evidence for the lack of sexual dimorphism in this species, in both shape and size variation. In the future, we intend to investigate aspects of morphological integration and their evolutionary consequences, comparing the very specialized lifestyle of *K. amblyonyx* to other echimyids rodents.

The supplementary information is available in: https://sbmz.org/publicacoes. Legends: **Table S1.** List of measured specimens and their respective scientific collections. Sex information is indicated as F (female) and M (male); **Table S2.** Representation of the values obtained in the repeatability analysis of the measurements for *K. amblyonyx* species; **Table S3.** Pairwise ANOVA comparing the linear measurement difference between pairs of populations. This table only shows the statistically different populations after Bonferroni correction ($p < 0.001$).

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ARTIGOS

Additional data for the virtual bank of cytogenetics of Brazilian mammals: karyotypes of medium and large mammals

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Abstract: Cytogenetic studies are important for species characterization and differentiation; furthermore, due to the highly variable and complex characteristics, karyotypes can assist in research that seeks to detect changes in genome organization, reveal phylogenetic history, and distinguish cryptic species. From the articles published in the literature, the karyotype information of terrestrial mammals of medium and large sizes was collected, with the intention of gathering them in a virtual database. For the searches, tools such as PubMed (National Center for Biotechnology Information) and Google Scholar were used; the words "karyotype", "diploid number" and "2n" were combined with the names of each species from the following orders of terrestrial mammals of Brazil: Cetartiodactyla, Carnivora, Cingulata, Lagomorpha, Perissodactyla, Pilosa and Primates. Here, we present information for 115 species with data referring to diploid number, the number of autosomes, the morphology of the sex chromosomes and, if present, karyotypic variation. From this information, Portable Document Format extension (.pdf) files were made for each species, which contained, as well as the aforementioned karyotype information, the name, author and year of publication of each species, diagrams from the original karyotypes and a link to download the original article. All documents and information are available at http://citogenetica.ufes.br, which already includes the cytogenetic data of Brazilian small mammals in its database.

Key-Words: Chromosome morphology; Database; Diploid number; Karyotype variation.

Resumo: Dados adicionais para o banco virtual de citogenética de mamíferos brasileiros: cariótipos de mamíferos de médio e grande portes. Estudos citogenéticos são importantes para a caracterização e diferenciação de espécies; além disso, devido às características altamente variáveis e complexas, os cariótipos podem auxiliar em pesquisas que buscam detectar mudanças na organização do genoma, revelar história filogenética e distinguir espécies crípticas. A partir dos artigos publicados na literatura, coletou-se a informação cariotípica de mamíferos terrestres de médio e grande porte, com o intuito de reuni-los em um banco de dados virtual. Para as buscas, foram utilizadas ferramentas como PubMed (Centro Nacional de Informações em Biotecnologia) e Google Scholar; palavras-chaves como "cariótipo", "número diplóide" e "2n" foram combinadas com os nomes de cada espécie das seguintes ordens de mamíferos terrestres do Brasil: Cetartiodactyla, Carnivora, Cingulata, Lagomorpha, Perissodactyla, Pilosa e Primatas. Aqui, apresentamos informações para 115 espécies com dados referentes ao número diplóide, o número de braços autossômicos, a forma dos cromossomos sexuais e, se presente, a variação cariotípica. A partir dessas informações, foram confeccionados arquivos de extensão *Portable Document Format* (.pdf) para cada espécie, os quais continham, além do cariótipo, o nome, autor e ano de publicação de cada espécie, figuras vetorizadas dos cariótipos originais e um link para baixar o artigo original. Todos os documentos e informações estão disponíveis em http://citogenetica.ufes.br, que já inclui os dados citogenéticos de pequenos mamíferos brasileiros em sua base de dados.

Palavras-Chave: Banco de dados; Morfologia dos cromossomos; Número diploide; Variação cariotípica.

INTRODUCTION

The Mammalia class is divided into 12 orders, of which seven are accounted for in Brazilian terrestrial mammals of medium and large sizes: Cetartiodactyla, with two families, six genera and 10 species; Carnivora, with seven families, 23 genera and 33 species; Cingulata, with one family, five genera and 11 species; Lagomorpha, with one family, one genus and one species; Perissodactyla, with one family, one genus and one species; Pilosa, with four families, five genera and eight species; and Primates, with five families, 19 genera and 118 species (Paglia *et al.,* 2012). Most of these orders differ in relation to the number of species found in each of the

Brazilian biomes (Paglia *et al.,* 2012); they are species that play an important role in the dynamics of ecosystems, such as top predators of the food chain (Sazima *et al.,* 1982) and seed dispersers (Jordano *et al.,* 2006).

It is well known that cytogenetic data are important tools for taxonomic and systematic studies, therefore aiding in the diagnosis of morphologically similar species, since karyotypes may be species-specific (Azevedo *et al.,* 2012; Bonvicino & Weksler, 1998; Wurster & Benirschke 1968). Additionally, they contribute to the elucidation of evolutionary and phylogenetic ambiguities (Robinson & Yang, 2012), increasing knowledge of species relationships (Romanenko *et al.,* 2007; Voss & Jansa, 2009) and revealing changes in genome organization at intra- and interspecific levels (Marshall *et al.,* 2008; Sagrillo *et al.,* 2005).

Given the importance of cytogenetic studies and the high diversity of Brazilian mammals, the gathering of karyotype information into one virtual guide, to be frequently updated, will contribute as a consistent tool to assist researchers who could be interested in systematic studies of the evolution and taxonomy of this group. Thus, this study intended to gather the cytogenetic data available in the literature for terrestrial mammals of Brazil, in order to complement an existing virtual library (http://citogenetica.ufes.br), where karyotype data for about 180 species of small non-flying mammals in Brazil (Paresque *et al.,* 2018) are already available.

MATERIALS AND METHODS

To gather the karyotypes for each species, a survey of the scientific papers available in the literature was carried out. To do so, the search tools PubMed of the National Center for Biotechnology Information (NCBI) and Google Scholar were employed, using the keywords "karyotype", "diploid number" and "2n", combined with the names of the mammalian species of interest.

Once the cytogenetic data were obtained, a general spreadsheet was created in Excel® containing information such as: scientific and popular name of each species, 2n (diploid number), FN (fundamental number), sex chromosome morphology and references. From this information, files with a Portable Document File (.pdf) extension were made, which were then made available for consultation in the UFES website (http://citogenetica.ufes.br). On this site, the data were organized according to the current taxonomic classification for the group. Each of these files contain the name, author and year of publication of each species, their karyotypic data, vectorized images of the original karyotypes, references and a download link to the original paper (Figure 1).

RESULTS

The cytogenetic data of 115 species of terrestrial mammals in Brazil were collected, corresponding to the 63.2% of all species (Table 1). Among the orders that present the known karyotypes of all the species are: Cetartiodactyla, Lagomorpha, Perissodactyla and Pilosa. Despite being the most diverse orders, Carnivora and Primates have scarce data, with only 39.4% and 61.8% of species, respectively, having known acknowledged karyotype information.

In Cetartiodactyla, the diploid number varied from 2n = 26 and FN = 46 in *Tayassu pecari* to 2n = 70 and FN = 70 in *Mazama gouazoubira. Mazama americana* was the species that presented the highest intraspecific karyotypic variation, ranging from 2n = 42 to 2n = 53, due to the occurrence of chromosomal rearrangements occurring in common ancestors (Almeida *et al.,* 2001). The high diversity of chromosome sets and variations in sex chromosomes, without a predominant morphology or size for X and Y, contributes to the identification of the species of this group, allowing for species-specific karyotypes.

For the order Carnivora, the karyotypes of 13 species were compiled. The diploid number ranged from 2n = 38 in species of the families Felidae, Mustelidae and Procyonidae up to 2n = 76 in *Atelocynus microtis* and *Chrysocyon brachyurus* (Family Canidae); the variation in autosome number ranged from FN = 68 for members of the families Mustelidae and Procyonidae to FN = 106 in *Cerdocyon thous.* It is worth mentioning that, in this case, the level of variation does not necessarily represent a high diversity of 2n, because the diploid number within each family repeats, leading to low interspecific variation. Thus, the differentiation of the chromosomal complements is subject to the combination of the form and size of the autosomal and sex pairs of each species.

In Cingulata, information was recorded for nine species (81.8% of the total species present in Brazil), which showed a diploid number variation from 2n = 38 in *Tolypeutes matacusa* to 2n = 64 in *Dasypus* species. The autosomal number ranged from FN = 68 in *Dasypus septemcinctus* to FN = 98 in *Euphractus sexcinctus.* With regard to the morphology of sex chromosomes, the majority of the members of this group presented a submetacentric X and small acrocentric Y.

The Pilosa order presented a variation from 2n = 49 in *Choloepus hoffmanni* to 2n = 65 in *Choloepus didactylus,* whereas the variation in the autosomal number ranged from FN = 56 in *Bradypus tridactylus* to FN = 108 in members of the Myrmecophagidae family. As for the sex chromosomes, the meta/submetacentric form predominated for the X, with the acrocentric form of the Y in Myrmecophagidae and metacentric form in Bradypodidae.

Finally, for Primates, information was collected for 73 species, with distinct patterns of karyotype variations observed depending on the family. The Aotidae family presented a diploid number ranging from 2n = 46 in *Aotus vociferans* to 2n = 54 in *Aotus nancymaae* and *A. trivirgatus,* with an X chromosome that showed a large submetacentric form for most species, and a Y that was variable. In Atelidae, variation ranged from 2n = 32 in *Ateles paniscus* to 2n = 62 in members of the genera *Brachyteles* and *Lagothrix;* the X chromosome was

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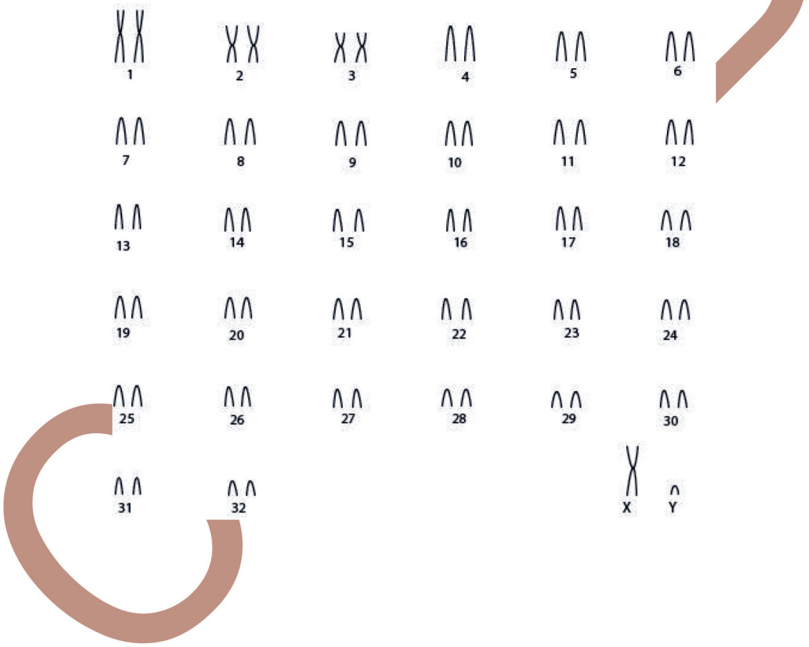
Blastocerus dichotomus (Illiger, 1815)

Cariótipo de Duarte & Giannoni (1995)

2n	NF	Cromossomo X	Cromossomo Y	Localidade
66	74	Metacêntrico grande	Submetacêntrico pequeno	São Paulo (Brasil)

Coloração Comum



Referência

Barbanti Duarte, J. M.; Giannoni, M. L.. Cytogenetic analysis of the Marsh Deer, Blastocerus dichotomus (Mammalia, Cervidae). Revista Brasileira de Genetica, v. 18, n. 2, p. 245-248, 1995.

Link

http://hdl.handle.net/11449/64568

Figure 1: Model of the file prepared for each mammalian species of medium and large sizes whose karyotype is known in the literature. The files have a .pdf extension (Portable Document Format) and are available for consultation in the database at http://citogenetica.ufes.br. Each file presents: name, author and year of publication of each species, diploid number, autosomal number, form and size of the sex chromosomes, vectorized images of the original karyotypes, bibliographical reference and the hyperlink to consult the original article on the corresponding cytogenetic data.

Table 1: Compilation of cytogenetic data of medium and large Brazilian mammals, with the respective popular name in Brazil, diploid number (2n), fundamental number (FN), morphology of the X and Y chromosomes and references. ND = not described.

Order	Species	Popular name in Brazil	2n	FN	X	Y	References
Cetartiodactyla	*Blastocerus dichotomus*	Cervo do Pantanal	66	74	Large metacentric	Small submetacentric	Duarte & Giannoni, 1995
Cetartiodactyla	*Mazama americana*	Veado mateiro	42 to 53	48 to 56	Submetacentric	Metacentric	Cursino *et al.,* 2014
Cetartiodactyla	*Mazama bororo*	Veado bororó de São Paulo	32 to 34	46	Medium submetacentric	Small acrocentric	Duarte & Jorge, 2003
Cetartiodactyla	*Mazama gouazoubira*	Veado catingueiro	70	70	Large Acrocentric	Small acrocentric	Neitzel, 1979
Cetartiodactyla	*Mazama nana*	Veado bororó do sul	36 to 40	56 to 60	Medium metacentric	Small metacentric	Abril & Duarte, 2008
Cetartiodactyla	*Mazama nemorivaga*	Veado da Amazônia	68-69	70	Medium submetacentric	Small metacentric	Fiorillo *et al.,* 2013
Cetartiodactyla	*Odocoileus virginianus*	Veado da cara branca	70	74	Large submetacentric	Small metacentric	Wurster & Benirschke, 1967
Cetartiodactyla	*Ozotoceros bezoarticus*	Veado campeiro	68	74	Large metacentric	Small metacentric	Duarte & Giannoni, 1995
Cetartiodactyla	*Pecari tajacu*	Cateto or caititu	30	46	Medium Acrocentric	Small acrocentric	Lima *et al.,* 2004
Cetartiodactyla	*Tayassu pecari*	Queixada or porco do mato	26	46	Medium Acrocentric	Small acrocentric	Andrea *et al.,* 2001; Adega *et al.,* 2007
Carnivora	*Atelocynus microtis*	Cachorro do mato de orelha curta	74 and 76	76	Submetacentric	Submetacentric	Wurster & Benirschke, 1968
Carnivora	*Cerdocyon thous*	Cachorro do mato	74	106	Large submetacentric	Small acrocentric	Hatanaka *et al.,* 1998
Carnivora	*Chrysocyon brachyurus*	Lobo guará	76	78	Large submetacentric	Medium acrocentric	Pieńkowska-Schelling *et al.,* 2008
Carnivora	*Eira barbara*	Irara	38	68	Medium submetacentric	ND	Wurster & Benirschke, 1968
Carnivora	*Galictis cuja*	Furão	38	68	Metacentric	Small acrocentric	Barbosa, 2013
Carnivora	*Leopardus geoffroyi*	Gato do mato grande	38	72	Medium metacentric	Small submetacentric	Wurster & Benirschke, 1968
Carnivora	*Lycalopex gymnocercus*	Raposa do campo	74	76	Submetacentric	Acrocentric	Brum-Zorrilla & Langguth, 1980
Carnivora	*Lycalopex vetulus*	Raposinha	74	76	Metacentric	Metacentric	Wurster & Benirschke, 1968
Carnivora	*Nasua nasua*	Quati	38	68	Medium submetacentric	Small acrocentric	Wurster & Benirschke, 1968
Carnivora	*Panthera onca*	Onça pintada	38	72	Medium submetacentric	Small submetacentric	Ledesma *et al.,* 2004
Carnivora	*Pteronura brasiliensis*	Ariranha	38	64	Submetacentric	Submetacentric	Franco-de-Sá *et al.,* 2007
Carnivora	*Puma yagouaroundi*	Gato mourisco	38	76	Medium submetacentric	ND	Wurster & Benirschke, 1968
Carnivora	*Speothos venaticus*	Cachorro vinagre	74	ND	Large submetacentric	Small acrocentric	Carvalho *et al.,* 2010
Cingulata	*Cabassous tatouay*	Tatu de rabo mole grande	50	68	Small metacentric	Acrocentric	Barroso & Seuánez, 1991
Cingulata	*Cabassous unicinctus*	Tatu de rabo mole	46	ND	Medium submetacentric	Small acrocentric	Jacintho *et al.,* 2009
Cingulata	*Dasypus hybridus*	Tatu mulita	64	76 and 81	Large submetacentric	Small crocentric	Lizarralde *et al.,* 2005; Saez *et al.,* 1964
Cingulata	*Dasypus kappleri*	Tatu de quinze quilos	64	ND	ND	ND	Redi *et al.,* 2005
Cingulata	*Dasypus novemcinctus*	Tatu galinha	64-65	78	Large metacentric	Small acrocentric	Beath *et al.,* 1962; Bernirschke *et al.,* 1969
Cingulata	*Dasypus septemcinctus*	Tatuí	64	76	Submetacentric	Acrocentric	Barroso & Seuánez, 1991
Cingulata	*Euphractus sexcinctus*	Tatu peba	58	98	Submetacentric or Acrocentric	Acrocentric	Jorge *et al.,* 1978; Barroso & Seuánez, 1991
Cingulata	*Priodontes maximus*	Tatu canastra	50	76	Submetacentric	Metacentric	Bernirschke & Wurster, 1969
Cingulata	*Tolypeutes matacus*	Tatu bola	38	ND	Metacentric	Acrocentric	Jorge *et al.,* 1978
Lagomorpha	*Sylvilagus brasiliensis*	Tapeti	40	68	Large submetacentric	Small submetacentric	Langguth & Sousa, 2008
Perissodactyla	*Tapirus terrestris*	Anta	80	80	Large submetacentric	Small acrocentric	Houck *et al.,* 2000
Pilosa	*Bradypus torquatus*	Preguiça de coleira	50	64	Submetacentric	Metacentric	Azevedo *et al.,* 2012
Pilosa	*Bradypus tridactylus*	Preguiça de três dedos	52	56	Metacentric	Metacentric	Dobigny *et al.,* 2005
Pilosa	*Bradypus variegatus*	Bicho preguiça	54	ND	ND	ND	Azevedo *et al.,* 2012
Pilosa	*Choloepus didactylus*	Preguiça real	65	ND	ND	ND	Dobigny *et al.,* 2005

Order	Species	Popular name in Brazil	2n	FN	X	Y	References
Pilosa	*Choloepus hoffmanni*	Preguiça real	49	61	Metacentric	ND	Corin-Frederic, 1969
Pilosa	*Cyclopes didactylus*	Tamanduá	64	100	Submetacentric	ND	Jorge *et al.,* 1985; Jorge, 2000
Pilosa	*Myrmecophaga tridactyla*	Tamanduá bandeira	60	108	Large metacentric	Small acrocentric	Pereira Júnior *et al.,* 2004
Pilosa	*Tamandua tetradactyla*	Tamanduá mirim	54	108	Large metacentric	Small acrocentric	Dobigny *et al.,* 2005
Primate	*Alouatta belzebul*	Guariba-de-mãos-ruivas	49-50	70	Submetacentric	ND	Armada *et al.,* 1987; Lima & Seuánez, 1989
Primate	*Alouatta caraya*	Bugio	52	70	Submetacentric	Acrocentric	Egozcue & De Egozcue, 1966
Primate	*Alouatta guariba*	Bugio ruivo	45-46, 49-50, 52	64, 66, 72	Submetacentric	Small acrocentric	Oliveira *et al.,* 1998; Oliveira *et al.,* 2000
Primate	*Alouatta macconnelli*	Bugio	47 to 49	ND	ND	ND	Lima & Seuánez, 1991
Primate	*Alouatta nigerrima*	Bugio	50	66	Submetacentric	ND	Armada *et al.,* 1987
Primate	*Alouatta seniculus*	Bugio	43 to 45	50, 52, 54	Small acrocentric	Small submetacentric	Yunis *et al.,* 1976
Primate	*Alouatta ululata*	Guariba de mãos ruivas	49	70	Submetacentric	ND	Viana *et al.,* 2015
Primate	*Aotus azarae*	Macaco da noite	49-50	69-70	Metacentric	ND	Mudry de Pargament *et al.,* 1984
Primate	*Aotus infulatus*	Macaco da noite	49-50	ND	ND	ND	Pieczarka & Nagamachi, 1988
Primate	*Aotus nancymaae*	Macaco da noite	54	72	Large submetacentric	Small acrocentric	Pieczarka *et al.,* 1992
Primate	*Aotus nigriceps*	Macaco da noite	51-52	65-66	Submetacentric	Submetacentric	Ma *et al.,* 1980
Primate	*Aotus trivirgatus*	Macaco da noite	50 and 54	72 and 74	Submetacentric	Small metacentric	Egozcue *et al.,* 1969; Menezes *et al.,* 2010
Primate	*Aotus vociferans*	Macaco da noite	46 to 48	70	Large submetacentric	Small acrocentric	Pieczarka *et al.,* 1992; Ma *et al.,* 1976; Descailleaux *et al.,* 1990
Primate	*Ateles belzebuth*	Macaco aranha	34	62	Medium submetacentric	Acrocentric	Medeiros *et al.,* 1997
Primate	*Ateles chamek*	Macaco aranha da cara preta	34	62	Medium submetacentric	Small acrocentric	Medeiros *et al.,* 1997
Primate	*Ateles marginatus*	Macaco aranha	34	62	Medium submetacentric	Subtelocentric	Medeiros *et al.,* 1997
Primate	*Ateles paniscus*	Macaco aranha	32	58	Metacentric	Acrocentric	Pieczarka *et al.,* 1989
Primate	*Brachyteles arachnoides*	Muriqui do sul	62	78	Submetacentric	ND	Koiffman & Saldanha, 1978
Primate	*Cacajao calvus*	Uacari-branco	46	ND	Submetacentric	Acrocentric	Bernirschke *et al.,* 1976
Primate	*Cacajao melanocephalus*	Uacari-branco	45	65	Submetacentric	Acrocentric	Koiffmann & Saldanha, 1981
Primate	*Callicebus coimbrai*	Guigó	44	ND	ND	ND	Rodrigues *et al.,* 2004
Primate	*Callicebus cupreus*	Zogue-zogue	46	66	Submetacentric	Small acrocentric	Dumas *et al.,* 2005
Primate	*Callicebus donacophilus*	Zogue-zogue	50	70	Submetacentric	Submetacentric	Minezawa & Borda, 1984; de Boer, 1974; Barros *et al.,* 2003
Primate	*Callicebus hoffmannsi*	Zogue-zogue	50	68	Submetacentric	Acrocentric	Rodrigues *et al.,* 2001
Primate	*Callicebus lugens*	Zogue-zogue	16	22	ND	ND	Bonvicino *et al.,* 2000, Stanyon *et al.,* 2003
Primate	*Callicebus moloch*	Arabasu	46, 48 e 50	64, 66 e 72	Submetacentric	Small acrocentric	Dumas *et al.,* 2005
Primate	*Callicebus pallescens*	Guigó	50	66	Submetacentric	Metacentric	Dumas *et al.,* 2005
Primate	*Callicebus personatus*	Guigó	44	62	Submetacentric	ND	Rodrigues *et al.,* 2004
Primate	*Callicebus personatus nigrifrons*	Guigó	42	68	Submetacentric	Metacentric	Nagamachi *et al.,* 2003
Primate	*Callicebus torquatus*	Zogue-zogue	20 and 22	26 and 28	Submetacentric	ND	Egozcue *et al.,* 1969; Benirschke & Bogart, 1976; Barros *et al.,* 2000
Primate	*Callimico goeldii*	Sagui de Goeldi	47-48	ND	Submetacentric	Small acrocentric	Dutrillaux *et al.,* 1988
Primate	*Callithrix aurita*	Sagui da serra escuro	46	74	Submetacentric	Acrocentric	Nagamachi *et al.,* 1997
Primate	*Callithrix flaviceps*	Sagui da serra	46	ND	ND	ND	Armada *et al.,* 1982
Primate	*Callithrix geoffroyi*	Sagui de cara branca	46	74	Medium submetacentric	Metacentric	Nagamachi *et al.,* 1997

Order	Species	Popular name in Brazil	2n	FN	X	Y	References
Primate	*Callithrix jacchus*	Sagui de tufos branco	46	74	Medium submetacentric	Acrocentric	Mudry *et al.,* 1990; Sherlock, 1996
Primate	*Callithrix kuhlii*	Sagui	46	74	Medium submetacentric	Metacentric	Nagamachi *et al.,* 1997
Primate	*Callithrix penicillata*	Sagui	46	74	Medium submetacentric	Metacentric or submetacentric	Nagamachi *et al.,* 1997
Primate	*Cebuella pygmaea*	Sagui-leãozinho	44	74	Submetacentric	Small acrocentric	Nagamachi *et al.,* 1992
Primate	*Cebus albifrons*	Caiarara	52 and 54	68	Submetacentric	Small acrocentric	Amaral *et al.,* 2008; Egozcue e Egozcue, 1967
Primate	*Cebus olivaceus*	Caiarara	52	70	Medium submetacentric	Small acrocentric	Amaral *et al.,* 2008
Primate	*Chiropotes israelita*	Cuxiú	54	74	Submetacentric	ND	Stanoyn *et al.,* 2004
Primate	*Chiropotes satanas chiropotes*	Cuxiú	54	74	Submetacentric	Acrocentric	Seuánez *et al.,* 1992
Primate	*Chiropotes satanas utahicki*	Cuxiú	54	74	Submetacentric	Acrocentric	Seuánez *et al.,* 1992
Primate	*Lagothrix lagothricha*	Macaco barrigudo	62	88	Medium submetacentric	Small acrocentric	Stanyon *et al.,* 2001; Clemente *et al.,* 1987
Primate	*Lagothrix lagothricha cana*	Macaco barrigudo	62	90	Medium submetacentric	Small acrocentric	Garcia *et al.,* 1980
Primate	*Lagothrix lagothricha poeppigii*	Macaco barrigudo prateado	62	90	ND	ND	Garcia *et al.,* 1980
Primate	*Leontopithecus caissara*	Mico-leão-de-cara-preta	46	74	Submetacentric	Acrocentric	Sbalqueiro *et al.,* 1992
Primate	*Leontopithecus chrysomelas*	Mico-leão-de-cara-dourada	46	74	Submetacentric	Subtelocentric	Nagamachi *et al.,* 1997
Primate	*Leontopithecus chrysopygus*	Mico-leão-preto	46	76	Submetacentric	Subtelocentric	Seuánez *et al.,* 1988
Primate	*Leontopithecus rosalia*	Mico-leão-dourado	46	74	Submetacentric	Subtelocentric	Nagamachi *et al.,* 1997
Primate	*Mico argentatus*	Sagui-branco	44	74	Submetacentric	Small metacentric	Egozcue *et al.,* 1968
Primate	*Mico chrysoleucos*	Sauim	44	74	Submetacentric	Small metacentric	Nagamachi *et al.,* 1996
Primate	*Mico emiliae*	Sauim	44	74	Submetacentric	Small metacentric	Barros *et al.,* 1990
Primate	*Mico humeralifer*	Sagui	44	74	Submetacentric	Small metacentric	Nagamachi *et al.,* 1996
Primate	*Mico mauesi*	Sagui-de-Maués	44	74	Large submetacentric	Small acrocentric	Nagamachi *et al.,* 1994
Primate	*Pithecia irrorata*	Parauacú	48	64	Medium submetacentric	ND	Finotelo *et al.,* 2010
Primate	*Pithecia pithecia*	Parauacú	48	64	Metacentric	Small acrocentric	Henderson *et al.,* 1977
Primate	*Saguinus bicolor*	Sauim-de-coleira	46	74	Submetacentric	Metacentric or acrocentric	Dantas & Barros, 1997
Primate	*Saguinus fuscicollis*	Sauim-de-cara-suja	46	74	Submetacentric	Small metacentric	Egozcue *et al.,* 1969
Primate	*Saguinus imperator*	Sauim-imperador	46	74	Submetacentric	Acrocentric	Dantas & Barros, 1997
Primate	*Saguinus labiatus*	Sauim-de-bigode	46	74	Submetacentric	Acrocentric	Marczynska *et al.,* 1983
Primate	*Saguinus martinsi*	Sauim	46	74	ND	ND	Dantas & Barros, 1997
Primate	*Saguinus midas*	Sagui-de-mão-dourada	46	74	Submetacentric	Acrocentric	Nagamachi & Pieczarka, 1988
Primate	*Saguinus mystax*	Sagui-de-boca-branca	46	74	Submetacentric	Metacentric	Dantas & Barros, 1997
Primate	*Saguinus niger*	Sagui-una	46	74	Submetacentric	ND	Nagamachi & Pieczarka, 1988
Primate	*Saguinus nigricollis*	Sagui, sauim	46	74	Submetacentric	Metacentric	Benirschke *et al.,* 1962
Primate	*Saguinus weddelli*	Sauim	46	74	Submetacentric	Acrocentric	Dantas & Barros, 1997
Primate	*Saimiri boliviensis*	Macaco-de-cheiro	44	72	Medium ubmetacentric	Small acrocentric	García *et al.,* 1995
Primate	*Saimiri macrodon*	Macaco-de-cheiro	44	74	Submetacentric	Acrocentric	Bender & Mettler, 1958
Primate	*Saimiri sciureus*	Macaco-de-cheiro	44	74	Submetacentric	Acrocentric	Mudry *et al.,* 1990
Primate	*Saimiri ustus*	Macaco-de-cheiro	44	74	ND	ND	Romagno, 2001
Primate	*Saimiri vanzolinii*	Macaco-de-cheiro	44	72	ND	ND	Yassuda & Chu, 1985
Primate	*Sapajus apella*	Macaco-prego	54	72	Submetacentric	Submetacentric	Freitas & Seuánez, 1981

predominantly submetacentric, but variable in size, and the Y was as variable in form as in size. The Callitrichidae family presented low interspecific variation, from 2n = 44 in species of *Cebuella* and *Mico* to 2n = 48 in *Callimico goeldii;* for this group, an FN = 74 predominated, with the exception of *Leontopithecus chrysopygusm,* which presented an FN = 76. The same constancy was observed in the submetacentric form of the X chromosome, with having only the Y chromosome showed any variation. In Cebidae, the diploid number ranges from 2n = 44 in members of the genus *Saimiri* to 2n = 54 in *Sapajus paella;* the submetacentric forms for the X and acrocentric for the Y prevailed in the sex chromosomes. Representatives of Pitheciidae presented the greatest variation, ranging from 2n = 16 and FN = 22 in *Callicebus lugens* to 2n = 54 and FN = 74 in members of the genus *Chiropotes;* the X chromosome was shown to be submetacentric, except for in *Pithecia pithecia,* while different forms and sizes of the Y chromosome were observed. In general, there is a consensus among the authors about the importance of cytogenetic data as a tool that is capable of assisting in the diagnosis of primate species.

From this information, .pdf files were made for all species, which contained images of the karyotypes recorded in the literature (Figure 1); these files are available and can be consulted at http://citogenetica.ufes.br.

DISCUSSION

The database of Cytogenetics of Brazilian Mammals (CIMAB) and its electronic address are available for consultation. This compilation is the result of a constant effort and is an important step in facilitating access to the cytogenetic characteristics of mammalian species occurring in Brazil. Some taxonomic groups, such as Carnivora and Primates, still lack karyotype data for a number of species; these orders were the ones with the lowest number of species with known cytogenetic data, indicating that new efforts should be made, focusing on these groups. The combined analysis of diploid numbers, autosomal numbers, as well as size and shape of the sex chromosomes at different taxonomic levels revealed that cytogenetics can be considered an important tool for the recognition and diagnosis of species, since, for the most part, this combination leads to karyotypes that are considered species-specific. The work of implanting the site and the insertion of new data should not stop here; the team from the Research Center on Evolution and Anatomy is constantly gathering efforts to keep the information updated with the publication of new articles. In addition, all researchers and authors of articles on mammalian cytogenetics are invited to contribute with new information. In the future, we intend to add information to other groups of mammals that have not yet been contemplated, along with data on interdisciplinary techniques involving chromosomes; our intention is to build a solid database and reference for the study of mammalian cytogenetics.

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ARTIGOS

Same but different: slight sexual dimorphism and allometric relationships in the external morphology of the common bottlenose dolphins *Tursiops truncatus* from north-central coast of Cuba

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Abstract: Morphometric and allometric studies are the primordial approaches for the comprehension of the ontogenetic modifications throughout the life history of a species. Sexual dimorphism and allometric growth in 194 dolphins *Tursiops truncatus* from the central coast of the Sabana-Camagüey Archipelago, in Cuba, were analyzed through the evaluation of 13 external morphological measurements. Absolute and relative body measurements were compared between sexes and age categories. T-test, principal component analysis (PCA), multivariate analysis of variance (MANOVA) and multivariate analysis of covariance (MANCOVA) were performed to investigate sexual dimorphism in body size and proportions in this population of *T. truncatus.* Growth patterns for males and females were described through the analysis of allometry. As a result, slightly overall sexual dimorphism in size was detected. Males were always larger than females, with a significant difference between sexes in four measurements (total body length, height of dorsal fin, posterior length of the flipper, and total flukes span). This dimorphism seems to be manifested to a lesser degree when compared to other geographical regions. The allometric trends seem to be more related to differences between age-category than between-sex differences. However, growth differences between males and females were also detected, mainly related to dimensions of the fins.

Key-Words: Caribbean Sea; Cetaceans; External morphometrics; Ontogeny.

Resumo: Iguais, mas diferentes: sutil dimorfismo sexual e relações alométricas na morfologia externa dos golfinhos-nariz-de-garrafa *Tursiops truncatus* da costa centro-norte de Cuba. Estudos morfométricos e alométricos são abordagens primordiais para a compreensão das modificações ontogenéticas ao longo da história de vida de uma espécie. O dimorfismo sexual e o crescimento alométrico de 194 golfinhos *Tursiops truncatus* da costa central do Arquipélago de *Sabana-Camagüey* em Cuba, foram analisados em 13 medidas morfológicas externas. As medidas corporais absolutas e relativas foram comparadas entre sexos e categorias etárias. O dimorfismo sexual foi avaliado no tamanho e nas proporções corporais pelo teste *t* para a comparação entre as médias, pela análise de componentes principais (PCA) e pela análise multivariada da variância (MANOVA) e análise multivariada de covariância (MANCOVA). Os padrões de crescimento para machos e fêmeas foram descritos através da análise da alometria. Como resultado, um sutil dimorfismo sexual foi detectado. Os machos foram maiores que as fêmeas em todas as variáveis, com uma diferença significativa entre os sexos em quatro medidas (comprimento total do corpo, altura da nadadeira dorsal, comprimento posterior da nadadeira peitoral e a largura total da cauda). Este dimorfismo parece manifestar-se em menor grau quando comparado a outras regiões geográficas. As tendências alométricas desta população parecem estar mais relacionadas às diferenças entre as categorias de idade do que entre os sexos. Contudo, diferenças de crescimento entre machos e fêmeas também foram detectadas, principalmente relacionadas à dimensão das nadadeiras.

Palavras-Chave: Cetáceos; Mar do Caribe; Morfometria externa; Ontogenia.

INTRODUCTION

Sexual dimorphism for some mammal species is commonly expressed as subtle variations of body shape or size, with no obvious secondary sexual characters appearing (Ralls, 1977). Specifically in cetaceans, the degree of sexual dimorphism is usually small to moderate, and increases with larger body sizes, following the

general mammalian pattern (Ralls, 1977). In general, the toothed whale males are larger than females, being *Physeter macrocephalus* and *Orcinus orca* the most obvious examples in terms of size differences. However, in some species, females are slightly larger than males (*e.g., Pontoporia blainvillei, Platanista gangetica,* and *Phocoena phocoena*), and few monomorphic species have been also described (*e.g., Stenella clymene, Stenella frontalis,* and *Sotalia guianensis*) (Ralls & Mesnick, 2009).

Various mechanisms of sexual selection, such as mate choice competition, contest competition, and sperm competition, have probably influenced the dissimilarities in the degree of sexual dimorphism between cetacean species (Perrin & Mesnick, 2003; Ralls & Mesnick, 2009). In addition, morphological studies on this group have revealed that some dimorphic traits may reflect ecological differences between the sexes (differences in vocalization, foraging behavior, and locomotion – Conry *et al.,* 2016, Del Castillo *et al.,* 2014), while others may be related to aspects as parental investment (*e.g.,* neonate size or number of calves – Ralls & Mesnick, 2009; Ralls, 1977). Furthermore, some morphological differences between sexes (like differences in skull shape), can be more related to geographical variation than to mating strategies (Francesco & Loy, 2016; Mead & Potter, 1995; Perrin *et al.,* 2011; Van Waerebeek, 1993). In this scenario, even when sexual dimorphism had been documented in external traits, only few studies so far have explored the quantitative variation in body size and shape in live dolphins into the wild (Hersh *et al.,* 1990; McFee *et al.,* 2012; Read *et al.,* 1993; Tolley *et al.,* 1995). This lack of information reinforces the need of studies that allow understanding intraspecific morphological variations, sexual dimorphism and geographical variation in this group, as basic evidence for populations' characterization and delimitation. Understand the ontogeny is also important, because the external part of the individual is in direct contact with the environment. In this context, it is more possible that the external surface changes than the inner bone (Schlichting & Pigliucci, 1998).

The common bottlenose dolphin *Tursiops truncatus* (Montagu 1821) (Cetartiodactyla: Delphinidae) is one of the most studied cetaceans. This species has a cosmopolitan distribution, including tropical and temperate areas of all oceans, demonstrating a great phenotypic plasticity associated with the diversity of ecosystems where it inhabits (*e.g.,* shallow and warm bays of tropical waters, pelagic and oceanic waters, cold waters of fjords) (Charlton-Robb *et al.,* 2011; Costa *et al.,* 2015; Curry & Smith, 1997; Fruet *et al.,* 2017; Wang *et al.,* 2000). The sexual dimorphism in common bottlenose dolphins is mainly related to size and usually described as males being larger than females (Fernandez & Hohn, 1998; Francesco & Loy, 2016; Mattson *et al.,* 2006; McFee *et al.,* 2010; McFee *et al.,* 2012; Perrin *et al.,* 2011; Read *et al.,* 1993; Tolley *et al.,* 1995). However, this pattern is not always related to differences between sexes, in fact, is due to the existence of several morphotypes that differ in body size and proportions (Cockcroft & Ross, 1990; Van Waerebeek *et al.,* 1993). For example, the maximum length in adults may range from 200 cm to 400 cm according to the location (*e.g.,* maximum length: 381 cm – East North Atlantic (Perrin, 1984); 234 cm – West North Atlantic (Perrin & Really, 1984); 257 cm – Australian coast (Cockcroft & Ross, 1990); 200 cm – Mississippi coast (Mattson *et al.,* 2006). In addition, a geographical variation of sexual dimorphism, mainly related to skull shape, was described for different localities (Francesco & Loy, 2016; Perrin *et al.,* 2011). Differences between sexes are also observed in the postnatal growth, a phase that embraces a second stage of acceleration in growth that overlaps with sexual maturity, which is more pronounced in males as suggested by several authors (Kerem *et al.,* 2013; Mattson *et al.,* 2006; McFee *et al.,* 2010).

In the Atlantic Ocean, studies on ontogeny and/or sexual dimorphism on the external morphology of common bottlenose dolphins are limited to three principal regions: the north coast of Gulf of Mexico (*e.g.,* Fernandez & Hohn, 1998; Hersh *et al.,* 1990; McFee, 2012; McFee *et al.,* 2010; Neuenhoff *et al.,* 2011; Perrin *et al.,* 2011; Read *et al.,* 1993; Turner *et al.,* 2006), the north-western coast of USA (*e.g.,* Hersh & Duffield, 1990; Mallette *et al.,* 2016; Mead & Potter, 1990; Tolley *et al.,* 1995), and in the South American coast (*e.g.,* Barreto, 2016; Miranda, 2016; Siciliano *et al.,* 2007). In contrast, in the Caribbean islands, coastal populations of *T. truncatus* are still poorly understood, with almost no information on comparative morphology and/or geographical variation. This lack of knowledge is possibly due to the challenging logistics to obtain the data from live capture or stranded specimens. In both cases, a large sample size is necessary, and in the case of carcasses analysis, they must be in the lowest possible degree of decomposition. In general, sexual dimorphism, ontogenetic development, and geographical variation were mainly analyzed based on skulls and/or skeletons of specimens from scientific collections or museums, which can only provide partial or exclusively internal anatomy information (*e.g.,* Barreto, 2016; Kurihara & Oda, 2009; Parés-Casanova & Fabre, 2013; Perrin *et al.,* 2011; Turner & Worthy, 2003; Wickert *et al.,* 2016).

In Cuba, *T. truncatus* is the most frequent sighted cetacean species, with some populations known as residents for specific regions (López *et al.,* 2013; Pérez-Cao *et al.,* 2009; Whitt *et al.,* 2011). Since 1983, several studies were conducted in order to understand the ecology, health and genetics of these local populations (*e.g.,* Álvarez-Alemán *et al.,* 2009; Cruz *et al.,* 2014; López *et al.,* 2013; Pérez-Cao, 1996). In addition, two preliminary studies addressed geographical variation in the external morphology of *T. truncatus:* Blanco & Olachea (1996) and Blanco & Olachea (2000) found morphological variation in body size among populations from three coastal localities of the Cuban Archipelago (*Varadero* Peninsula and Central coast of *Sabana-Camagüey* Archipelago in the north coast and in *Guacanayabo* Gulf in south coast of the country). These authors also reported the existence of sexual dimorphism in the species, but only related to flippers and body's anterior part. However, the inclusion of young and adults specimens in the analysis

may have led to ambiguous conclusions, since sexual dimorphism may be confused with ontogenetic variation in size and shape (Tolley *et al.,* 1995).

The external appearance of individuals is the most evident reflection of the species adaptive potential, due to the direct contact of the body with the local environment and their changes. Ontogeny and allometry studies are fundamental approaches for understanding this kind of individuals' phenotypic expression (Schlichting & Pigliucci, 1998). Morphometric studies allow investigating morphological diversity within a species and anatomical variation between the different growth stages, while allometric studies describe the relationship between body size and shape (Stewar & German, 1999). This information is fundamental for the comprehension of the ontogenetic modifications that appear throughout the life history of individuals, like those linked to sexual maturity, sexual differentiation or development stages (Mallette *et al.,* 2016; Sebens, 1987).

In this context, we examined the sexual dimorphism and allometric trends in external body measurements during postnatal growth in *T. truncatus* from the central coast of the *Sabana-Camagüey* Archipelago, Cuba. This study brings new information about sexual dimorphism and ontogeny of common bottlenose dolphins in Caribbean waters, and it is important because the understanding of these local specificities in the external morphology of common bottlenose dolphins allow us to know how morphology traits can change in response to local environmental characteristics.

MATERIALS AND METHODS

The *Sabana-Camagüey* Archipelago (SCA) is on the north-central coast of Cuba, with an area of 3,414 km² (Figure 1). This archipelago comprises a line of approximately 2,500 small islands and cays, distributed mainly along the edge of the platform of the island of Cuba. This archipelago is considered the largest system of islands of the Greater Caribbean (Alcolado *et al.,* 1999). The arrangement of these islands allows the formation of an internal semi-enclosed area, segmented in seven principal shallow bays.

The Cuban common bottlenose dolphins were live-captured inside of *San Juan de los Remedios* Bay and *Buenavista* Bay, in the central area of the *Sabana-Camagüey* Archipelago, between the coordinates of 22°56'N, 80°00'W and 22°23'N, 78°46'W (Datum: SIRGAS 2000).

We analyzed 194 live specimens of *T. truncatus* (97 males and 97 females). All specimens were captured

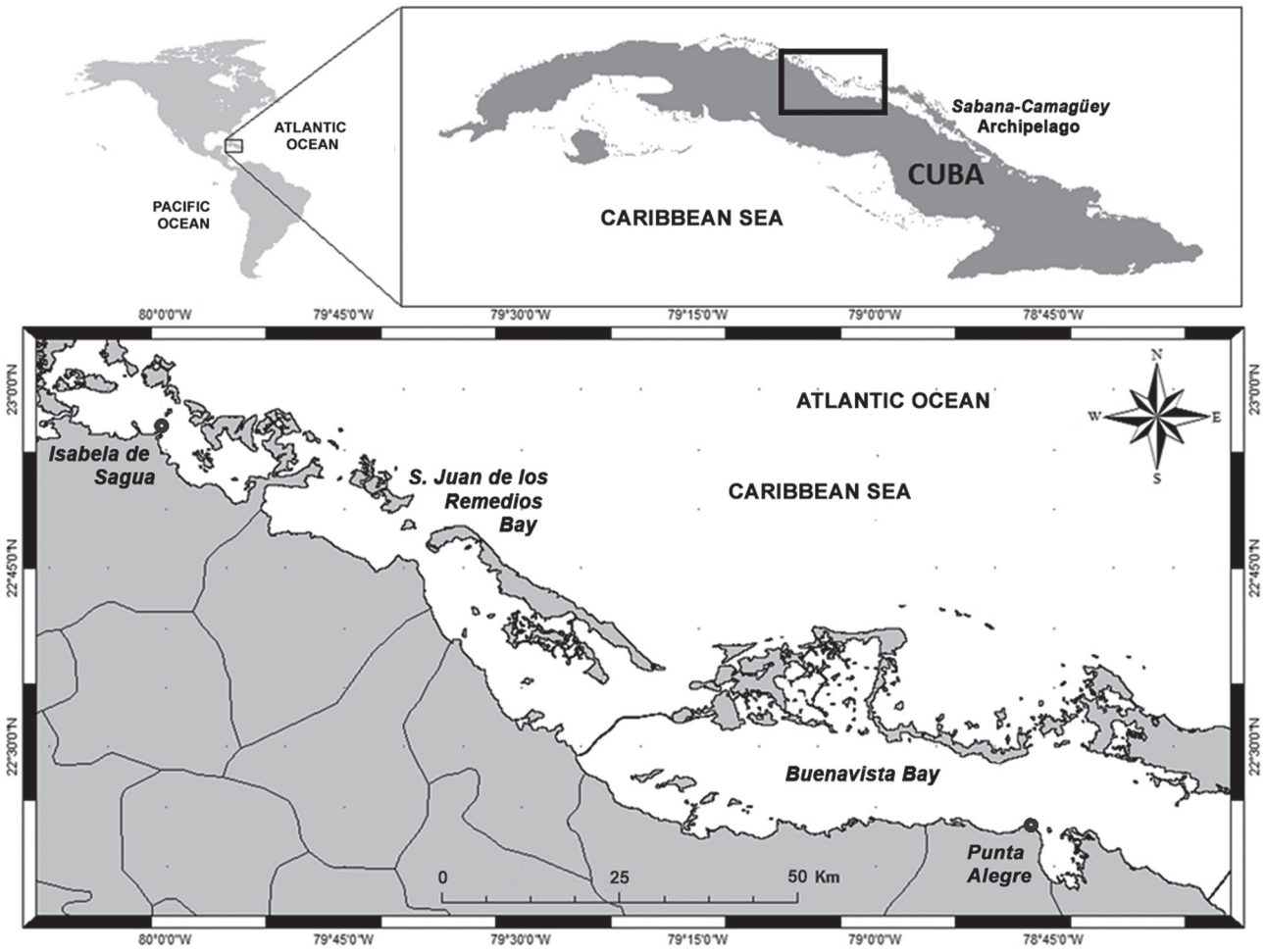

Figure 1: Study area: central coast of *Sabana-Camagüey* Archipelago in Cuba is in the square. The localities of *Isabela de Sagua* and *Punta Alegre* indicates the limits of the sampling area.

between 2000 and 2016, always in the same season (rainy season – from May to October) in order to avoid measurement oscillations in girth and the body mass, which vary seasonally in response to changes in water temperature (Read *et al.,* 1993; Tolley *et al.,* 1995). All specimens had the sex, date and the locality of capture registered. Females visually considered as pregnant in advanced stage or with very young calf were not captured, in order to avoid manipulation stress. However, few females were identified as pregnant after the manipulation. In this case, their measurements were included in the analyses, excepting the maximum girth.

This study was part of the research project on the health and biology of common bottlenose dolphins along the north-central coast of Cuba. The captures were conducted in safety conditions to the dolphins and researchers, following the procedures of NOAA's protocol NOS-NCCOS-49 for the manipulation of dolphins in the natural environment (Fair *et al.,* 2006), and under the license number No. 19/2015 from the Environmental Inspection and Control Center of Cuba (CICA).

We analyzed 13 body measurements, according to Norris (1961) and Blanco & Olachea (2000) (Figure 2). For the description of abbreviations used for each measurement see Table 1. Previous to the measurements, the dolphins were encircled with a net in water < 2 m deep, captured and moved to a boat. The specimens were placed on mattress, and their clinical and biological data were collected during a maximum of 45 minutes of procedure, as described in Cruz *et al.* (2014). The body measurements were taken by trained researchers, using a commercial measuring tape (with 0.5 cm of precision), and always on the right side of the animal.

Table 1: External measurements taken from common bottlenose dolphin *Tursiops truncatus* in this study.

Measurement Abbreviation	Description
ALF	Flipper length, from the anterior insertion to the tip.
BDF	Basal length of dorsal fin, measured from the anterior to the posterior insertion.
BH-DF	Distance from the blowhole to the anterior insertion of dorsal fin.
E-DF	Distance from the center of the eye to the anterior insertion of the dorsal.
HDF	Measure in a straight line, from de fin tip to the base.
LRF	Distance from the tip of the right fluke, to the base of tail peduncle.
MG	Measured at the anterior base of dorsal fin.
PL	From posterior base of dorsal fin to tail notch.
PLF	Flipper length, from the posterior insertion to the tip.
R-E	Distance from the tip of the upper jaw to the center of the eye.
R-FA	Distance from the tip of the upper jaw to the anterior insertion of the flipper.
TBL	Distance from the tip of the upper jaw to the deepest part of the notch between flukes.
TFS	Distance between the tips of the flukes.

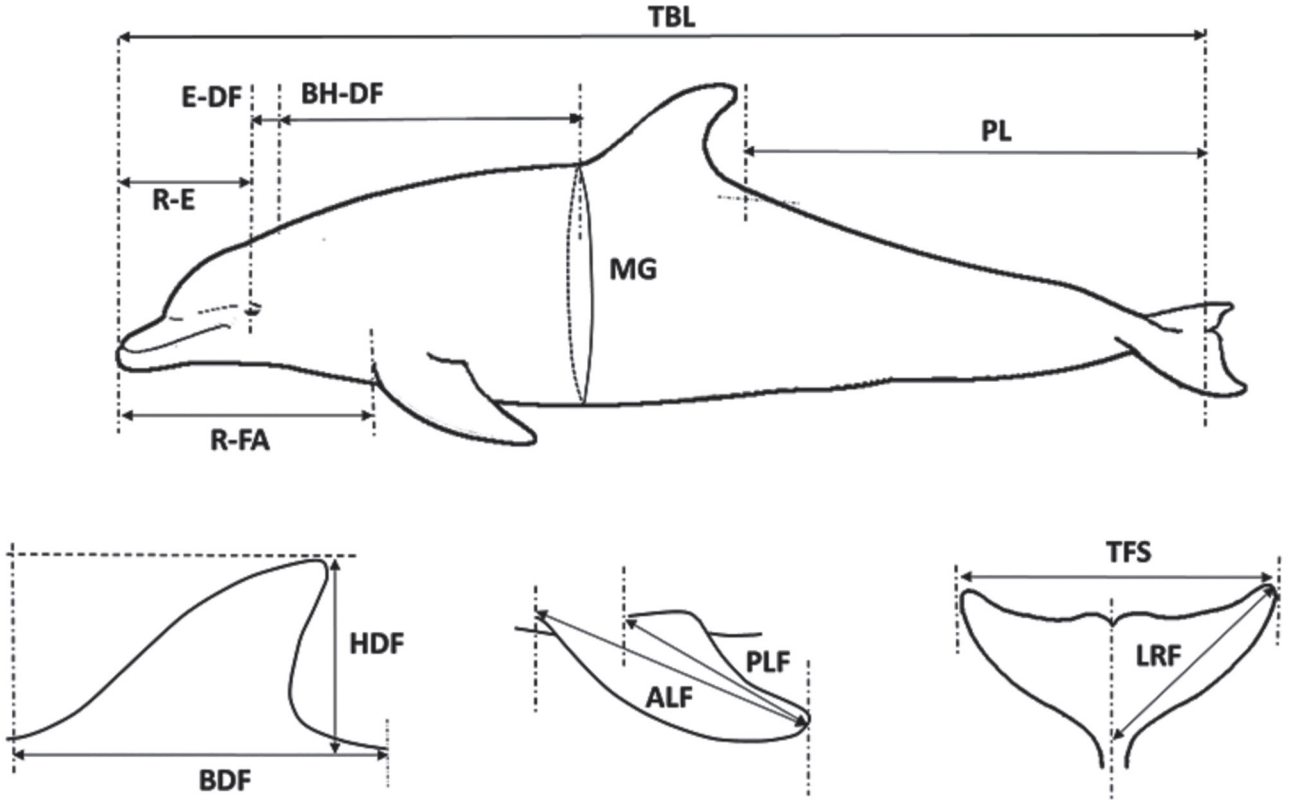

Figure 2: Thirteen body measurements analyzed from common bottlenose dolphin, *Tursiops truncatus,* from the central coast of *Sabana-Camagüey* Archipelago, Cuba. ALF: anterior length of flipper, BDF: basal length of dorsal fin, BH-DF: distance from blowhole to anterior base of dorsal fin, E-DF: distance from eye to anterior base of dorsal fin, HDF: height of dorsal fin, LRF: Diagonal length of right fluke, from the tip to the base of tail peduncle, MG: Maximum girth, PL: caudal peduncle length, from posterior base of dorsal fin to tail notch, PLF: posterior length of flipper, R-E: distance from tip of rostrum to center of eye, R-FA: distance from tip of rostrum to anterior insertion of flipper, TBL: Total body length, from tip of rostrum to tail notch, and TFS: total flukes span.

The relative age category (adult and young) was assigned for the specimens based on the asymptotic value of total body length (TBL ∞), previously established for males and females of this specific population using the Gompertz equation as a model of growth (Ruenes, 2018). The asymptotic length is defined as the mean length that individuals from a specific population would attain if they would continue to grow indefinitely in time (Stamps *et al.,* 1998), and it reflects the adult size at age. Therefore, considering male's TBL ∞ = 247.4 and female's TBL ∞ = 237.6 as values of minimal body size of physical maturity for this population, 175 individuals (89 males and 86 females) of the total dolphins captured were classifieds as young (= physically immature), and 19 (eight males and 11 females) were classifieds as adult (= physically mature).

The differences between sexes were analyzed using univariate and multivariate approaches. A descriptive analysis (mean, maximum and minimum length as well as standard deviations) was conducted to all measurements and for adult and young males and females of *T. truncatus.* Sexual dimorphism in size was initially evaluated base on the traditional (linear) morphometric analysis (Marcus, 1990). For this analysis, only physically mature specimens (classified as adult individuals, 11 females and eight males) were used. All measurements from both sexes were tested for normality and homogeneity of variance (Levene's test). An alpha of 0.01 was considered as a significant value for univariate and multivariate tests.

Since the results of some measurements were not normally distributed, all dataset was transformed to logarithm before the analysis. In order to verify the existence of significant differences between sexes, the t-test was employed. Moreover, a multivariate analysis of variance (MANOVA) using the logarithms of all measurements was applied to investigate overall absolute dimorphism. It is important to highlight that not all measurements were available for all specimens, and multivariate analysis is sensitive to missing data. In this context, the missing values were estimated by sex through the multiple imputation (MI) method, using the TBL as an explanatory variable in the regression models, and the remaining measurements as auxiliary variables (following Murphy & Rogan, 2006; Torre *et al.,* 2014).

Sexual dimorphism was also analyzed taking into account in the relative size of each measurement in relation to the geometric mean (GM). The GM is a variable derived from the Nth root of the product of N measurements, and it can be used as a proxy of size (Tarnawski *et al.,* 2014; 2015). These ratios make possible the analysis of body proportions because ratios reflect geometric differences in shape. The statistic accuracy of the use of these ratios has been widely probed (Baur & Leuenberg, 2011; Coleman, 2008; Tarnawski *et al.,* 2015). A multivariate analysis of covariance (MANCOVA) was also conducted, in order to investigate general sexual dimorphism only in body proportions. Relative or proportional dimorphism of each measurement was tested with an analysis of covariance (ANCOVA). In both statistical analyses, the GM was used as the covariate variable.

Posteriorly, in order to explore multivariate differences in the proportions between sexes (Neff & Marcus, 1980), a principal component analysis (PCA) was performed.

For the analysis of the patterns of allometric growth and their subsequent comparisons between the sexes, the same 13 body measurements for all 194 specimens (98 females and 96 males) were used. For *T. truncatus,* a secondary spurt of growth has been identified around the age of sexual maturity for both sexes (Matson *et al.,* 2006; McPhee *et al.,* 2010; Read *et al.,* 1993). However, this process seems to be more evident in males (Read *et al.,* 1993). For that reason, the sample was divided into four subsets and classified as: young females, young males, adult females, and adult males.

In the allometric analysis, the GM was used as independent variable and proxy of body size (Klingenberg, 2016; Tarnawski *et al.,* 2014). The allometric equation used was: $\text{Log}(y) = \log(b_o) + b_1 \log(x) + \log(e)$, where y represents the analyzed measurement (dependent variable), x represents the GM (explanatory variable), $a = \log(b_o)$ is the y-intercept or elevation, b_1 is the slope or growth coefficient and e is the error term (Alexander, 1985). The GM was not included in the table of results related to this analysis, because it was used as independent variable in the allometric equation.

The criterion of allometric level was defined as follows: negative allometry: when the value of the growth coefficient was significantly < 1.0; positive allometry: when the value of the growth coefficient was significantly > 1.0; and isometry: when there was no significant difference between the value of the growth coefficient and it is 1.0. The standardized major axis (SMA) regression was used to determinate the line of best fit of the data (Warton *et al.,* 2006). In order to test the existence of significant differences between 1.0 and the values obtained for the growth coefficient, the F-test was applied with 0.01 as a significant level. The existence of common slope (coefficient of allometry) among the trajectories of young females, young males, adult females, and adult males was tested through a likelihood ratio test for common SMA slope and compared it to a chi-square distribution. When a common slope was shared, a y-intercept (b_o) was compared using the Wald statistic for inference (Warton *et al.,* 2006). When the slope and the y-intercept were the same for the four subsets, the existent of shift along the axis was tested through the Wald statistic, as described in Warton *et al.* (2006). All statistical analyses were performed using SPSS 24.0.0 (SPSS for Windows, Chicago, IL) and SMART (Standardised Major Axis Tests & Routines) version 2.0 (Falster *et al.,* 2006).

RESULTS

The total body length (TBL) ranged from 172 cm to 251 cm in the *Sabana-Camagüey* population of *T. truncatus,* with a mean of 220.2 cm and a standard deviation of 17.93 cm. The mean values for males and females were 219.8 ± 19.8 cm SD and 220.5 ± 15.9 cm SD,

Table 2: Descriptive statistics of 13 body measurements (cm) and the geometric mean (GM) for females and males of common bottlenose dolphin *Tursiops truncatus* from the central coast of the *Sabana-Camagüey* Archipelago, Cuba. In dark the GM and the measurements statically different between sexes for $p < 0.01$ in the *t-test* result.

Category	Var.	Females					Males					*t*	*p* (0,01)
		N	Mean	Min	Max	SD	N	Mean	Min	Max	SD		
Young	**GM**	**86**	**52.69**	**45**	**66**	**4.28**	**89**	**53.59**	**43**	**63**	**4.72**		
	ALF	77	37.67	33	43	2.29	84	37.88	31	44	3.33		
	BDF	81	30.13	24	40	3.62	85	32.35	22	43	4.90		
	BH-DF	82	67.18	56	77	5.41	88	67.01	54	82	6.55		
	E-DF	84	68.50	56	79	5.45	85	68.01	55	82	6.56		
	HDF	81	19.77	16	24	1.89	87	21.33	13	29	3.04		
	LRF	78	35.58	25	44	4.47	84	36.29	23	44	5.00		
	MG	83	113.24	93	136	9.97	89	115.43	90	137	10.7		
	PL	83	92.79	74	113	8.09	89	94.06	68	118	11.45		
	PLF	79	28.18	19	34	3.32	82	28.84	20	34	3.14		
	R-E	78	30.98	27	35	1.90	87	31.19	25	36	2.14		
	R-FA	82	49.40	40	60	4.12	82	50.81	41	61	3.68		
	TBL	85	217.80	180	237	14.47	88	217.19	172	245	18.5		
	TFS	84	54.09	43	64	4.60	85	57.08	41	69	6.54		
Adult	**GM**	**11**	**57.08**	**54**	**60**	**1.87**	**8**	**59.61**	**57**	**63**	**2.26**	**2.661**	**0.016**
	ALF	11	40.18	37	44	2.18	8	42.00	40	44	1.19	2.133	0.048
	BDF	11	33.00	31	35	1.48	8	34.12	32	36	1.64	1.549	0.140
	BH-DF	11	75.27	73	79	1.95	8	76.62	74	80	1.84	1.531	0.144
	E-DF	11	75.90	73	80	2.50	8	78.80	76	83	2.12	2.656	0.017
	HDF	**11**	**21.54**	**20**	**25**	**1.50**	**8**	**26.62**	**23**	**32**	**3.50**	**4.546**	**0.000**
	LRF	11	37.63	34	40	1.74	8	38.64	37	42	1.55	0.834	0.416
	MG	11	129.00	120	137	5.77	8	130.87	126	135	3.39	0.844	0.410
	PL	11	110.09	104	115	3.30	8	112.25	109	115	2.49	1.554	0.139
	PLF	**11**	**31.81**	**30**	**34**	**1.47**	**8**	**34.25**	**33**	**36**	**1.16**	**3.835**	**0.001**
	R-E	11	31.54	29	35	1.86	8	30.75	25	35	3.57	-0.658	0.476
	R-FA	11	54.54	49	60	2.97	8	57.12	50	64	5.02	1.249	0.196
	TBL	**11**	**243.36**	**238**	**249**	**3.52**	**8**	**249.00**	**247**	**251**	**1.60**	**4.661**	**0.001**
	TFS	**11**	**58.81**	**56**	**65**	**2.52**	**8**	**62.12**	**60**	**66**	**2.35**	**2.940**	**0.009**

respectively. In addition, most of the specimens sampled had TBL between 220 cm and 229 cm (Figure 3). The TBL range of distributions was similar for females and males. However, males have a greater range of TBL varying from 172 cm to 251 cm, while females vary from 180 cm to 249 cm (see Table 1 and Figure 3).

The multivariate analysis did not reveal significant differences between males and females in the overall variance of size and shape (MANOVA: λ de Wilks, F = 7.3947; *d.f.* = 13; *p* = 0,019). However, results of *t*-test indicated differences between sexes in four of the 13 body measurements (Table 2): flipper posterior length (PLF), the height of dorsal fin (HDF), total body length (TBL), and total flukes span (TFS), with males been larger than females. The nine remaining measurements did not show significant differences between adult males and females.

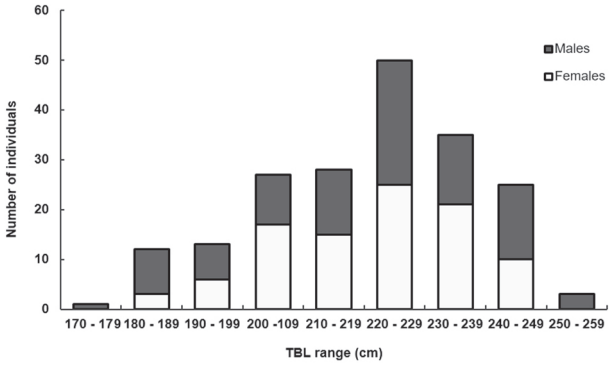

Figure 3: Distribution of TBS intervals obtained for 194 common bottlenose dolphins *Tursiops truncatus,* from the central area of the *Sabana-Camagüey* Archipelago, Cuba.

Otherwise, overall sexual dimorphism in body proportions was present in common bottlenose dolphins (MANCOVA: Wilks' Lambda = 455.67, d.f. = 12, p = 8.8488E-7). The result of ANCOVA, using GM as covariable, showed that only two relative measurements were dimorphic, the proportions related to the height of dorsal fin (HDF/GM: F = 26.737, p = 0,0001) and the diagonal length of right fluke (LRF/GM =, F = 3838.024, p = 1.736E-20). For both measurements, males (HDF/GM: Mean = 0.445 ± 0.042, LRF/GM: Mean = 0.575 ± 0.014) have bigger proportions than females (HDF/GM: Mean = 0.377 ± 0.018, LRF/GM: Mean = 0.557 ± 0.014).

In the PCA analysis, the first three principal axes explained 73.41% of the total variability observed, with 47.82% for PC1, 16.65% for PC2, and 9.58% for PC3 (Figure 4). The measurements with higher loadings on PC1 were total body length (TBL) and the other variables related to the body length (HB-DF, E-DF, and PL). The positive loadings for these eigenvectors suggested

that they were all highly correlated with size. For PC2, the measurements ALF, PLF, LRF, BDF, and HDF, related to pectoral, caudal and dorsal fins had the highest loadings. Most of the variation in PC3 was represented for only one measurement, the distance from the tip of the rostrum to the center of the eye (R-E).

Scores of the specimens in the first two components (Figure 4) partially separate two groups based on sex, but with a certain level of overlap between them. Males and females were separated in part from each other, mainly along the first component axis (Figure 4), suggesting that sexual dimorphism is more related to size than shape, with males being slightly larger than females (Table 2).

Regression analysis showed high values of correlation in all dependent variables for young males and females, and adult females of *T. truncatus,* with the exception of the HDF in young females ($R^2 = 0.28$). Adults males of the species showed low values of correlation in four of the 13 measurements, the distances from the blowhole to the dorsal fin (BH-DF: $R^2 = 0.28$), distance from the eye to the dorsal fin (E-DF: $R^2 = 0.40$), rostrum-eye distance (R-E: $R^2 = 0.37$), and flipper anterior length (R-AF: $R^2 = 0.32$) (Table 3).

In the analysis of the ontogenetic trajectories in both sexes, considering the young and adult categories, five variables did not change their allometric trends with the reach of the adult size (ALF, BH-DF, E-DF, HDF, and MG). In females, other four variables did not change their trends between age category (PL, R-E, R-FA, and TFS). For males, all variables changed their allometric trends when the adult stage was reached (Table 3).

In the young category, eight of 13 measurements presented isometric growth for females: total body length (TBL), total flukes span (TFS), distance from the blowhole to the dorsal fin (BH-DF), distance from the eye to the dorsal fin (E-DF), peduncle length (PL), distance from the tip of the rostrum to the eye (R-E), distance from rostrum to pectoral fin (R-PF), and the maximum girth (MG). The remaining measurements, all related to fins, showed positive allometry. The young males showed isometric growth pattern in the total body length (TBL), the distance from the blowhole to the dorsal fin (BH-DF), distance from the eye to the dorsal fin (E-DF), the maximum girth (MG), and unlike females, in the flipper anterior length (ALF). The positive allometry in young males was present in the measurements related to the dorsal fin (BDF and HDF), flukes (TFS and LFR), flipper posterior length (PLF) and peduncle length (PL). The males of this category also showed negative allometry in the distance from the tip of the rostrum to the eye (R-E), and distance from the tip of the rostrum to the anterior insertion of dorsal fin (R-FA).

In adult individuals of both sexes, 13 of 15 measurements showed the same isometry trend, being only the total body length (TBL) with negative allometry, and the height of dorsal fin (HDF) with positive allometry. The distance from the tip of the rostrum to the eye (R-E) and the distance from the tip of the rostrum to the anterior insertion of dorsal fin (R-FA) had positive allometry in adult males, but it was an isometric measurement in adult females.

As a part of SMA analysis, the comparison of growth trends between sexes (Table 4) indicated that eight of 15 variables had a common slope for the four subsets growth trajectories (young females, young males, adult females, and adult males). In addition, adult females and young individuals shared more similarities than adult males with females and young males. For instance, adult females showed a common slope with young individuals in 11 for 15 variables. Alternatively, adult males showed a higher slope for the height of dorsal fin (HDF) and the distance of the tip of the rostrum to the anterior insertion of dorsal fin (R-FA) (Table 4). Young dolphins showed a higher slope for the total body length (TBL) and peduncle length (PL) in comparison to adults. No changes were

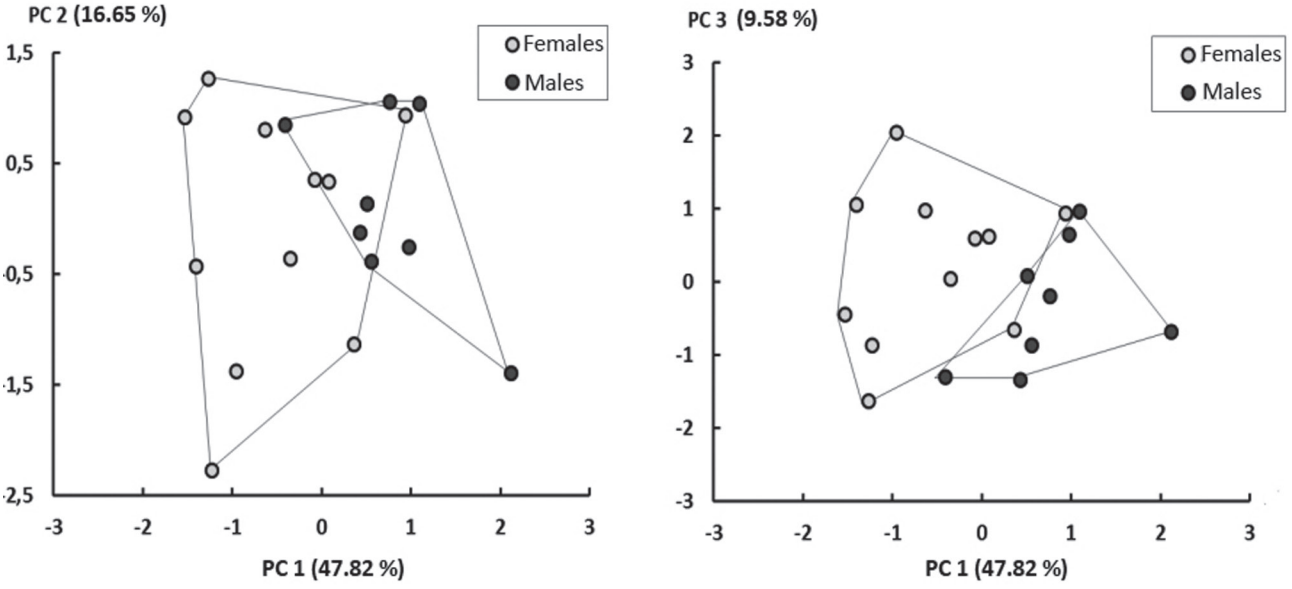

Figure 4: Scores of the specimens of common bottlenose dolphin *Tursiops truncatus* in the first three axes of the principal component analysis (PCA) from the central coast of *Sabana-Camagüey* Archipelago, Cuba. Females: withe circle. Males: dark circle.

Table 3: Allometric growth patterns of external morphological measurements for females and males of common bottlenose dolphin *Tursiops truncatus* from the central region of the *Sabana-Camagüey* Archipelago, Cuba. F_y: young females; M_y: young males; F_a: adult females; M_a: adult males; N: sample number; R^2: regression coefficient; b_o: intercept, b_1: growth coefficient (slope); CI: Confidence intervals; Trend: allometric growth type (< 1: negative allometry, > 1: positive allometry, = 1: isometry); *p:* provability value for significant differences between b_1 and 1.

Variable	Group	N	R^2	b_o	LowCI	UppCI	b_1	LowCI	UppCI	F	*p* (0.01)	Trend
ALF	F_y	77	0.522	0.173	-0.124	0.468	0.8161	0.661	1.006	6.576	0.012	= 1
	M_y	84	0.673	-0.12	-0.403	0.163	0.9832	0.833	1.161	0.072	0.789	= 1
	F_a	11	0.552	-1.319	-3.438	0.800	1.6641	0.849	3.262	5.679	0.041	= 1
	M_a	8	0.322	0.286	-1.38	1.952	0.7532	0.265	2.142	0.731	0.426	= 1
BDF	F_y	81	0.411	-1.156	-1.756	-0.555	1.532	1.222	1.92	25.890	0.000	+
	M_y	85	0.375	-1.586	-2.293	-0.879	1.788	1.425	2.244	50.129	0.000	+
	F_a	11	0.611	-0.894	-2.524	0.737	1.373	0.729	2.585	2.403	0.156	= 1
	M_a	8	0.758	-0.74	-2.431	0.952	1.28	0.643	2.549	1.544	0.260	= 1
BH-DF	F_y	82	0.575	0.078	-0.258	0.414	1.016	0.839	1.22	0.045	0.832	= 1
	M_y	88	0.645	-0.072	-0.393	0.249	1.097	0.927	1.298	2.091	0.152	= 1
	F_a	11	0.426	0.491	-0.647	1.628	0.789	0.373	1.669	0.896	0.369	= 1
	M_a	8	0.282	0.758	-0.687	2.202	0.635	0.218	1.846	1.852	0.222	= 1
E-DF	F_y	84	0.541	0.083	-0.263	0.428	1.018	0.837	1.238	0.056	0.814	= 1
	M_y	85	0.702	-0.029	-0.323	0.265	1.076	0.92	1.26	1.506	0.223	= 1
	F_a	11	0.707	0.111	-0.913	1.153	1.002	0.574	1.75	0.000	0.991	= 1
	M_a	8	0.398	0.647	-0.82	2.115	0.704	0.259	1.912	1.281	0.301	= 1
HDF	F_y	81	0.275	-0.922	-1.483	-0.363	1.288	1.003	1.654	7.112	0.009	+
	M_y	87	0.488	-1.479	-2.052	-0.905	1.623	1.325	1.988	42.100	0.000	+
	F_a	11	0.611	-2.312	-4.774	0.15	2.075	1.102	3.906	14.684	0.004	+
	M_a	8	0.887	-4.626	-7.698	-1.553	3.407	2.091	5.552	129.07	0.000	+
LRF	F_y	78	0.463	-1.557	-2.246	-0.867	1.807	1.45	2.252	55.583	0.000	+
	M_y	84	0.595	-1.184	-1.692	-0.677	1.586	1.319	1.907	46.268	0.000	+
	F_a	11	0.643	-1.63	-3.707	0.447	1.827	0.993	3.359	10.309	0.011	= 1
	M_a	8	0.521	-0.256	-2.186	1.674	1.038	0.416	2.59	0.018	0.899	= 1
MG	F_y	83	0.542	0.123	-0.258	0.507	1.119	0.919	1.363	2.255	0.137	= 1
	M_y	89	0.72	0.243	-0.028	0.515	1.052	0.907	1.221	0.799	0.374	= 1
	F_a	11	0.647	-0.307	-1.863	1.249	1.376	0.751	2.522	2.688	0.136	= 1
	M_a	8	0.785	0.898	0.043	1.754	0.686	0.357	1.32	4.143	0.088	= 1
PL	F_y	83	0.482	-0.007	-0.423	0.41	1.147	0.929	1.414	2.943	0.090	= 1
	M_y	89	0.608	-0.403	-0.822	0.017	1.374	1.152	1.638	23.164	0.000	+
	F_a	11	0.573	0.425	-0.718	1.569	0.92	0.476	1.778	0.146	0.711	= 1
	M_a	8	0.857	1.008	0.412	1.603	0.587	0.341	1.012	13.109	0.011	= 1
PLF	F_y	79	0.39	-1.454	-2.136	-0.772	1.6892	1.338	2.132	38.003	0.000	+
	M_y	82	0.626	-0.711	-1.103	-0.32	1.2579	1.051	1.505	11.463	0.001	+
	F_a	11	0.736	-0.972	-2.349	0.405	1.4088	0.828	2.396	4.164	0.072	= 1
	M_a	8	0.615	-0.061	-1.56	1.437	0.899	0.389	2.078	0.177	0.688	= 1
R-E	F_y	78	0.293	0.018	-0.357	0.393	0.856	0.666	1.104	2.558	0.114	= 1
	M_y	87	0.41	0.139	-0.158	0.436	0.784	0.631	0.975	8.666	0.004	–
	F_a	11	0.374	-1.666	-4.377	1.045	1.801	0.829	3.916	5.590	0.042	= 1
	M_a	8	0.367	-4.105	-10.84	2.627	3.149	1.137	8.721	19.003	0.005	+
R-FA	F_y	82	0.413	-0.112	-0.52	0.295	1.0496	0.839	1.313	0.320	0.573	= 1
	M_y	82	0.683	0.311	0.079	0.542	0.8076	0.685	0.953	11.697	0.001	–
	F_a	11	0.369	-1.209	-3.74	1.325	1.6766	0.769	3.654	4.163	0.072	= 1
	M_a	8	0.742	-2.395	-5.586	0.798	2.3378	1.151	4.748	21.190	0.004	+
TBL	F_y	85	0.671	0.881	0.639	1.122	0.847	0.718	0.999	7.049	0.010	= 1
	M_y	88	0.849	0.648	0.462	0.835	0.976	0.875	1.09	0.324	0.571	= 1
	F_a	11	0.681	1.609	1.134	2.085	0.442	0.248	0.79	23.296	0.001	–
	M_a	8	0.961	2.094	2.046	2.146	0.17	0.141	0.197	1264.8	0.001	–
TFS	F_y	84	0.501	-0.114	-0.494	0.265	1.073	0.874	1.316	0.807	0.372	= 1
	M_y	85	0.749	-0.524	-0.855	-0.194	1.32	1.143	1.526	26.223	0.000	+
	F_a	11	0.341	-0.478	-2.452	1.498	1.279	0.579	2.828	0.846	0.382	= 1
	M_a	8	0.605	0.030	-1.646	1.706	0.993	0.426	2.315	0.001	0.980	= 1

observed between sexes in the slope of young specimens, but changes in the intercepts were founded in this category for the total flukes span (TFS), and distance from the blowhole to the anterior insertion of the dorsal fin (BH-DF). In adult dolphins, females and males showed the same common intercept in all measurements. In addition, a significant difference in the shift along common slope was detected for eight measurements, when the

Table 4: Test of a common slope, common intercept, and shift for both sex and age categories of common bottlenose dolphin *Tursiops truncatus,* from the central area of the *Sabana-Camagüey* Archipelago, Cuba. F_y: young females; M_y: young males; F_a: adult females; M_a: adult males; Y: young; A: adults.

	Common Slope				Common intercept (b_o)			Shift		
	b_1	*Lr*	*p*	Trend	W	*p*	intercept	W	*p*	shift
ALF	0,932	8,964	0,023	$F_y = {}_yM_y = F_a = M_a$	2,554	0,466	$F_y = M_y = F_a = M_a$	91,581	0,000	$F_y = M_y$; $F_a = M_a$; Y < A
BDF	1,593	3,439	0,311	$F_y = M_y = F_a = M_a$	29,466	0,000	$F_y = M_y$;$F_a = M_a$; $F_a = F_y$; $M_y > M_a$	64,376	0,000	$F_y < M_y$; $F_a = M_a$; Y < A
BH-DF	1,038	3,613	0,312	$F_v = M_v = F_a = M_a$	23,513	0,000	$F_v = M_v = M_a$; $F_a = M_a$; Y < F_a	137,427	0,000	$F_v = M_v$; $F_a = M_a$; Y < A
E-DF	1,040	1,746	0,62	$F_v = M_v = F_a = M_a$	28,333	0,000	$F_v > M_v$; $F_a = M_a$; Y < F_a; M_a = Y	126,586	0,000	$F_v = M_v$; Y < F_a < M_a
HDF	1,579	17,075	0,003	$F_y = M_y$; $F_a = M_a$; Fa = Y; Y < M_a						
LRF	1,658	3,854	0,278	$F_v = M_v = F_a = M_a$	37,478	0,000	$F_v = M_v$; $F_a = M_a$; Y > A	55,732	0,000	$F_v = M_v$; $F_a = M_a$; Y < A
MG	1,070	5,628	0,124	$F_v = M_v = F_a = M_a$	20,651	0,000	$F_v = M_v$; $F_a = M_a$; Y < A	115,369	0,000	$F_v = M_v$; $F_v = M_a$; Y < A
PL	1,218	14,516	0,004	$F_y = M_y$; $F_a = M_a$; F_a = Y, M_a < Y						
PLF	1,378	9,111	0,025	$F_v = M_v = F_a = M_a$	1,144	0,767	$F_v = M_v = F_a = M_a$	118,657	0,000	$F_v = M_v$; Y < F_a < M_a
R-E	0,869	16,761	0,003	$F_y = M_y$; $F_a = M_a$; $F_a = F_y$; Y < A						
R-FA	0,927	20,106	0,001	$F_y = M_y$; $F_a = M_a$; F_a = Y; Y < M_a						
TBL	0,899	40,576	0,001	$F_y = M_y$; $F_a > M_a$; A < Y						
TFS	1,225	5,302	0,151	$F_v = M_v = F_a = M_a$	26,246	0,000	$F_v < M_v$;$F_a = M_a$; $F_v = F_a$; $M_a <$ Y	81,952	0,000	$F_v = M_v$; $F_a < M_a$; Y < A

adult males presented the highest value in total flukes span (TFS), distance from the eye to the dorsal fin (E-DF) and flipper posterior length (PLF) (Table 4).

DISCUSSION

The present study revealed a slight sexual dimorphism in overall body size of common bottlenose dolphins *Tursiops truncatus* from the central coast of the *Sabana-Camagüey* Archipelago, in the north of Cuba. Moreover, according to the maximum values of total body length obtained in this study (TBL for females = 249 cm; TBL for males = 251 cm), the population of common bottlenose dolphins from central coast of the *Sabana-Camagüey* Archipelago seems to have smaller body length than those inhabiting other regions of the Caribbean and Gulf of Mexico.

For example, one of the nearest populations to *Sabana-Camagüey* Archipelago is the common bottlenose dolphin population from the East coast of the Gulf of Mexico, in Sarasota Bay, Florida. This is also one of the most studied population of the species in the world. For this population, Tolley *et al.* (1995) reported maximum TBL of 265 cm and 283 cm for females and males, respectively. Other studies in Florida, Texas and Mississippi coast had described maximum body sizes for females similar to our results (245 cm – Fernandez & Hohn, 1998; 250 cm – Read *et al.,* 1993; 250 cm – Stolen *et al.,* 2002), but males were always larger than in the Cuban population (264 cm – Fernandez & Hohn, 1998; 260 cm – McFee *et al.,* 2012; 270 cm – Read *et al.,* 1993). This evidence supports a possible smaller body size in Cuban insular population of common bottlenose dolphins, maybe related to their residence in shallower coastal and/or semi-enclosed waters with higher sea temperature (Perrin, 1984), and probably influencing the slight difference in body length observed between males and females.

Otherwise, the expression of slight sexual dimorphism in total body size of marine mammals is also consistent with the general pattern of male competence for access to dispersed females, rather than to a system in which large males are able to monopolize and mate with aggregated females (Trivers, 1985). For *T. truncatus,* although the variety of reproductive behaviors and matting strategies displayed throughout the species distribution, the male alliances and coalitions are the most observed conducts (Connor *et al.,* 1996; 2001; Scott *et al.,* 1990). These males travel through their home range searching for females in estrous stage for mating. Once the females are separated from their original group, brief associations between females and one or more males, called "consortships", are formed. This strategy allows males to associate with different females in search of mating opportunities. However, some physical aggressive encounters could occur with other male coalitions in order to restrict females from choosing other males (Connor *et al.,* 1996; 2000). In this context, a mating strategy, where male-male alliance and male-female multiple associations are predominant, but with the existence of agonistic behaviors, could develop other morphological structures in males, instead of changes in total body size as a main sexual character.

In our study, the absolute measurements and the body proportions only revealed signals of sexual dimorphism in four body structures, which were mainly related to the fins, flukes, and total body size. Therefore, the general pattern for cetaceans was confirmed (Ralls & Mesnick, 2009), with sexual dimorphism more related to size than shape, and with males being slightly larger than females. Correspondingly, the PCA confirmed this partial differentiation between sexes. The analysis of body proportion, using a geometric mean as a proxy of body size,

also suggested that the main differences between sexes were in the dimension of dorsal fin and fluke, with males having major ratios. As confirmed in our results, dorsal fins in males are commonly larger than in female dolphins. For instance, Tolley *et al.* (1995) observed apparent sexual dimorphism in dorsal fin size of *T. truncatus* from Florida (US), with males having larger dorsal fins (height and length) when compared with the females of the same species. Similar results were found in males of *T. truncatus* from Doubtful Sound, New Zealand (Rowel *et al.,* 2008; Rowel & Dawson, 2009). The level of significance of these differences in dorsal fin size and shape are unknown, but they may serve as thermoregulatory function and/or as a visual signal (Ralls & Mesnick, 2009).

Similarly, differences between the sexes can also occur in the flukes, which may be longer and wider in males, or differently shaped (Ralls & Mesnick, 2009; Tolley *et al.,* 1995). Structures as flukes and flippers are used for propulsion, maneuvering, as well as in defensive and offensive encounters with other dolphins (*e.g.,* agonistic and antagonistic relationships, capture and herding of females). These interactions are more frequent in male-male competition as a part of the *T. truncatus* reproductive strategies (Connor *et al.,* 2000; Tolley *et al.,* 1995). Moreover, bigger fins and bigger flukes have been associated to the general form of the species from inshore and shallow warm waters, where the size of these structures can bring an advantageous performance during swimming, for the persecution of pray, as part of reproduction behavior, and for heat dissipation (Hersh & Duffield, 1990; Perrin, 1984; Ross, 1984; Tolley *et al.,* 1995).

Murphy and Rogan (2006) suggested that the degree of sexual dimorphism in aquatic mammals is related to many particular characteristics such as sexual reproduction ratio, social structure, mating system, behavior, habitat characteristics, diet, distribution, and abundance of food resources. For common bottlenose dolphin population of *Sabana-Camagüey* Archipelago, we suggested the existence of slightly sexual dimorphism, related in part to the small body size developed in this population as an adaptation to tropical shallow waters. However, further analyses are necessary to understand how the local reproductive strategy is influencing this tendency of slight sexual dimorphism in this population.

Our study also showed that in common bottlenose dolphins from *Sabana-Camagüey* Archipelago, the allometric trend is more related to differences between age-category than between sexes. For instance, males and females from the same age-category share a common slope and the same intercepts in almost all measurements. However, adult males show a strong shift in the flipper posterior length (PLF), eye-dorsal fin distances (E-DF) and total flukes span (TFS), with the highest values for all these variables. These variations in the growth trajectories of adult males could be related to variations in the growth rate, and indicate slightly different development between sexes. This result supports the finding of sexual dimorphism for some morphological measurements in the previous analysis of body measurements and body proportions, and corroborates the hypothesis that males have slightly larger fins than females.

Differences in ontogenetic allometry between the sexes do not always result in sexually dimorphic body components in adults (McLellan *et al.,* 2002), but may indicate a different investment in the development of specific body components according to the stages of growth during the life of the dolphins (Murphy & Rogan, 2006). This phenomenon was previously described for other cetaceans such as *Delphinus delphis* (Murphy & Rogan, 2006), *Phocoena phocoena* (Read & Tolley, 1997), *Phocoenoides dalli* (Amano & Miyasaki, 1993) and *Stenella* spp. (Perrin, 1975).

Despite the large number of studies about morphological characteristics of local populations of common bottlenose dolphins (Hale *et al.,* 2000; Hersh *et al.,* 1990; Kemper, 2004; Montie *et al.,* 2008; Perrin *et al.,* 2011; Tolley *et al.,* 1995; Turner & Worthy 2003; Walker, 1981), allometry trends in ontogeny and its differences related to sexual dimorphism have not been fully examined. Allometry trends in growth and development of common bottlenose dolphins have been explored before, for example, to understand the variation in the weight of organs through ontogenetic development (Turner *et al.,* 2006). Allometry was also used to determinate differences in skull shape due to size in an ontogenetic series, to assign the main factors influencing skull shape differences due to size, and to describe the growth patterns of body components (Mallette *et al.,* 2016). In this context, our result on the existence of an allometric trend more related to differences between age-category than between sexes in the *Sabana-Camagüey* dolphins incorporates an additional approach to understand variations in the external morphology of *T. truncatus* during the growth.

For the dolphins of the central coast of the *Sabana-Camagüey* Archipelago, five measurements had positive allometry in young animals, which were exclusively related to fin, flukes and flipper growth, indicating an early development of these structures. The accelerate growth of an appendix may allow greater agility and independence in the aquatic environment, supporting the survival of young individuals. This growth rate also allows relatively higher sizes of the appendix and could be related to the thermoregulation function, since it would allow a larger area for heat dispersion. This fact will be important in resident populations of shallow waters of tropical coast, such as *T. truncatus* from *Sabana-Camagüey* Archipelago, where the average sea surface temperature reaches 30°C most of the year (Fernández-Vila & Chirino, 1993). Otherwise, the positive allometry of the caudal peduncle observed in young males may indicate a higher rate of development of the axial and locomotor musculatures in *T. truncatus* males. According to Hurov *et al.* (1988), and Stewart & German (1999), the positive allometric growth of these specific muscles in mammals is probably related to the increase in locomotor capacity and the maintenance (at least in part) of muscle strength with increase in body size. Since males have relatively higher body length and width fluke when

adults, probably this early development of the peduncle influences the attaining of that final body size. Besides, it is described that *T. truncatus* males normally spend a greater investment of energy in social interactions during the early years of life, until reaching sexual maturity (Cockcroft & Ross, 1990; Read *et al.,* 1993; Wells & Scott, 2002). Consequently, the early development of the caudal peduncle would be advantageous for better performance in these interactions. In adults, the negative allometry or isometry observed in all measurements related to body size (TBL, BH-DF, E-DF, R-AF and PL) reinforced the observed reduction of the growth rate in old animals in this species, after reaching the physical maturity (McFee *et al.,* 2012; Read *et al.,* 1993).

Finally, we can say that the Caribbean way of growth in common bottlenose dolphins is similar to other geographical region but different in some aspects. The allometric pattern in growth between males and females suggested the existence of a slight sexual dimorphism in common bottlenose dolphins from *Sabana-Camagüey* Archipelago, Cuba. Moreover, this dimorphism seems to be in a lesser degree when compared to other geographical regions, with males being slightly larger than females, mainly in the fins. Further studies on external morphology of the species from other Caribbean populations are recommended, in order to demonstrate whether these variations are maintained in resident tropical populations of common bottlenose dolphins.

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Effects of damming on a small mammal assemblage in Central Brazilian Cerrado

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Abstract: Cerrado is a South American hotspot and studies that investigate the impacts of natural habitat loss in its fauna represent important contributions for the biome conservation. In this study I present data on the impacts of habitat loss – due to flooding by a hydropower reservoir – in a non-volant small mammal assemblage located in the right margin of the dammed Tocantins River, northern Goiás state, central Brazil. Twenty species were recorded over a 2-ha grid with a total effort of 28,599 live and pitfall trap-nights distributed over a mosaic of habitats. As predicted, small mammals presented high habitat selectivity and a decrease in numbers – of species, individuals and density – as the water reached the study area. This decline was observed for both forest and open-area dwellers advising the impacts of flooding affected the overall assemblage. Indeed, the high recapture rates before flooding suggest that most individuals were residents, and the abrupt decline in numbers after flooding could be an evidence of increased mortality. The high diversity found in the study area as well as the presence of rare species and Cerrado endemics highlight the need to look for alternative energy sources in order to preserve this biodiversity.

Key-Words: Didelphimorphia; Flooding; Impacts; Neotropical Savanna; Rodentia.

Resumo: Efeitos do represamento em uma comunidade de pequenos mamíferos no Cerrado do Brasil Central. O Cerrado é um dos biomas mais diversos e ameaçados da América do Sul, e estudos que investigam os impactos da perda de habitats naturais sobre esta diversidade, representam importantes contribuições para sua conservação. Neste estudo, eu apresento dados a respeito do impacto da perda de habitats – ocasionado pelo alagamento decorrente da implantação de uma usina hidrelétrica – sobre uma comunidade de pequenos mamíferos não voadores, situada às margens do reservatório, no rio Tocantins, norte de Goiás, Brasil Central. Foram registradas 20 espécies em uma área de 2 hectares, aplicando-se um esforço total de 28.599 armadilhas-noite (incluindo armadilhas de contenção e de interceptação e queda) distribuídas ao longo de um mosaico de habitats. Como esperado, os pequenos mamíferos apresentaram elevada seletividade de habitats e um decréscimo no número de espécies, de indivíduos e na densidade, assim que a água alcançou a área de estudo. Este declínio foi observado tanto para as espécies florestais quanto para as habitantes das formações abertas, evidenciando o impacto do alagamento em toda comunidade. Além disso, a elevada taxa de recaptura no período anterior ao alagamento indica que a maioria dos indivíduos era residente. O declínio nas variáveis após o alagamento, portanto, pode ser resultado do aumento da taxa de mortalidade nesta comunidade. A elevada diversidade amostrada, representada tanto por espécies raras quanto endêmicas do Cerrado, denota a urgência em estabelecermos fontes alternativas de produção de energia com o intuito de preservarmos esta biodiversidade.

Palavras-Chave: Alagamento; Didelphimorphia; Impactos; Savana Neotropical; Rodentia.

INTRODUCTION

Since great part of the planet have been modified by humans, we are faced with the urgent need to understand how species of animals and plants behave in relation to these habitat changes in order to mitigate the impacts and conserve the remaining biodiversity (Fearnside, 2008; Lees *et al.,* 2016; Myers *et al.,* 2000). In this sense, small mammals are considered as good bioindicators since they can be monitored by the use of live traps, present high number of individuals, high habitat selectivity and fidelity to microhabitat conditions, showing rapid changes in species richness, composition and abundance associated with environmental instabilities (Metzger *et al.,* 2009; Palmeirim *et al.,* 2018a; Prevedello *et al.,* 2012). Responses of this group of mammals have been studied in relation to the effects of habitat loss and fragmentation along distinct biomes in Brazil, as detailed bellow, increasing our knowledge on this respect. For instance, we already know that habitat generalist species increase in number while habitat specialists are more prone to local extinctions upon disturbance (Bonecker *et al.,* 2009;

Lambert *et al.,* 2006; Pardini *et al.,* 2009; Pinotti *et al.,* 2015); the importance of native vegetation fragment size, in which larger fragments support richer communities than small ones (Cáceres *et al.,* 2010; Pardini *et al.,* 2005; 2010); the connectivity between these natural patches, in the sense that closer ones allow the species to disperse among them (Brito & Grelle, 2004; Pires *et al.,* 2002); as well as the type of matrix where the natural patches are imbedded, with anthropogenic habitats represented by agriculture, pastures and monocultures, such as *Pinus* and *Eucalyptus* plantations, showing distinct permeability for small mammal assemblages (Gheler-Costa *et al.,* 2012; Martin *et al.,* 2012; Umetsu & Pardini, 2007). In the Cerrado, studies investigating the impacts of habitat loss and fragmentation upon small mammal communities have shown similar results (Bonvicino *et al.,* 2002; Cáceres *et al.,* 2010). However, since the Cerrado is characterized by a mosaic of open and forest formations, and small mammals present high habitat selectivity (Alho, 1981; Carmignotto *et al.,* 2012; Mares *et al.,* 1986; Santos-Filho *et al.,* 2012), the impacts on their communities should be directly related with the type of most affected habitats (Passamani & Cerboncini, 2013).

In the case of hydroelectric dams, environmental impacts are mainly represented by habitat loss and fragmentation due to flooding (Fearnside *et al.,* 2016; Finer *et al.,* 2012). Soon after the closure of the main river channel, lowland areas are flooded until the reservoir is full; in a second moment, highland areas form islands of varying sizes, the so called land-bridge islands, and the lake comprises the new matrix where these islands are imbedded together with the mainland areas in the reservoir margins (Irving *et al.,* 2018; Jones *et al.,* 2016; Palmeirim *et al.,* 2018b). Regarding vertebrates, the few studies in hydroelectric reservoirs have shown the increase in populations of alien species and the decline of rare and habitat specialists after the flooding (Andriolo *et al.,* 2013; Cosson *et al.,* 1999; Liao *et al.,* 1988; Terborgh *et al.,* 1997). The size of the land-bridge islands, as well as their degree of isolation, and the number and size of distinct habitat patches available – in these islands and in the mainland located in the reservoir margins – can affect the colonization rates, population size, and local species diversity (August, 1983; MacArthur & Wilson 1967). For instance, most of land-bridge islands, as well as areas surrounding the reservoir, present an impoverished fauna (Brandão & Araújo, 2008; Fowler, 1992; Irving *et al.,* 2018). For Cerrado small mammals that show great habitat selectivity (Alho *et al.,* 1986; Carmignotto *et al.,* 2014; Mares *et al.,* 1989), and due to the fact that gallery forests are the most affect habitat by the flood (Silva Jr., 1995), one could expect a decline in overall species richness, abundance and density, with the loss of most forest dwellers (Passamani & Cerboncini, 2013).

During the end of the 80s, some of the largest hydropower plants were already functioning in Brazil, such as the Balbina, Samuel and Tucuruí dams in the Amazon biome; the Itaipu in the Atlantic forest; and the Itaparica in the Caatinga (Fearnside, 2015; Ziober & Zanirato, 2014). Although the criticisms regarding these large hydroelectric projects mainly due to the huge areas of permanent habitat lost (Cochrane *et al.,* 2017; Faria & Jaramillo, 2017; Sperling, 2012), and the lack of studies dealing with their impacts on the local biodiversity (Agostinho *et al.,* 2016; Alho, 2011; Lees *et al.,* 2016), they continue to be planned and constructed (Prado *et al.,* 2016). The Serra da Mesa dam, located in the Cerrado biome, is currently the largest reservoir in water volume of Brazil, with 54.4 billion m³ and a flooded area of 1,784 km² (FURNAS, 2013). So, in order to increase our knowledge in relation to the impacts of flooding on local biodiversity, I have conducted a 12 month survey of a

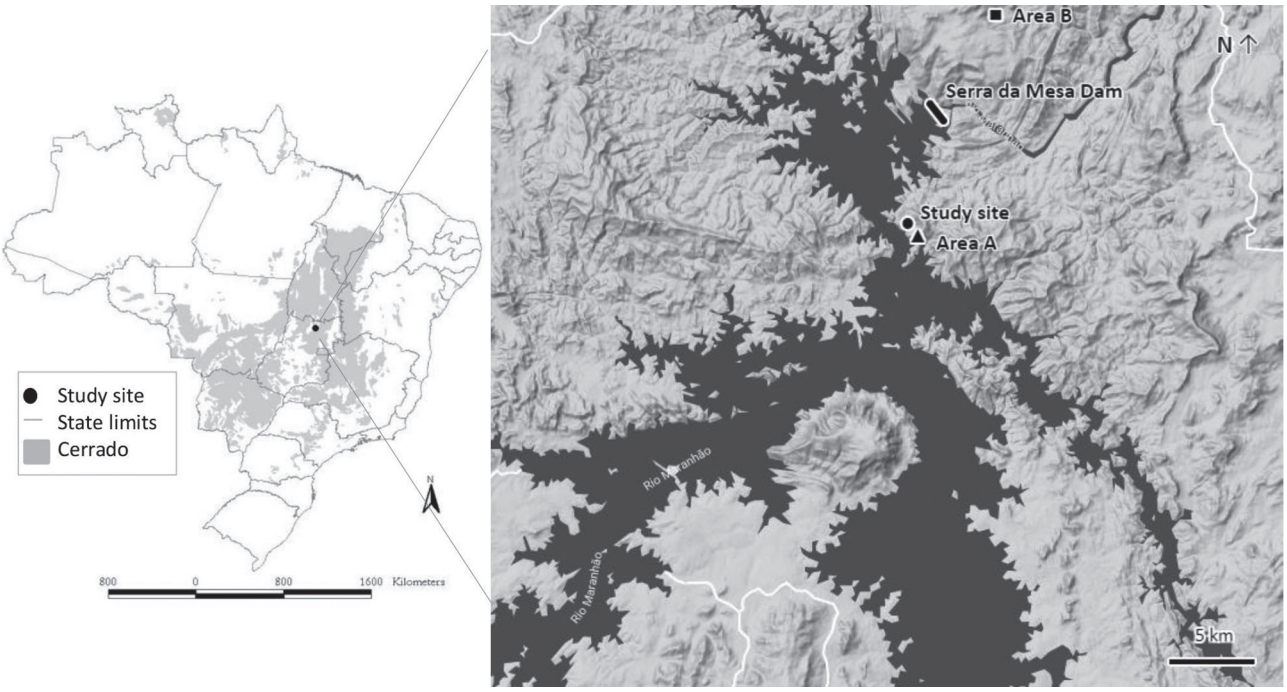

Figure 1: Study site at the Serra da Mesa dam, state of Goiás, central Brazil. Area A = replica area. Area B = control area.

small mammal assemblage located in the margin of this mega dam reservoir. Based on previous studies (Cosson *et al.,* 1999; Lynam, 1997; Palmeirim *et al.,* 2018b; Passamani & Cerboncini, 2013), I expect an overall decrease in number of species and individuals in the study area by habitat loss due to flooding; and since the areas most affected are those represented by gallery forests and wet grasslands (Brandão & Araújo, 2008), I also expect these habitat dwellers to be the most affected ones.

MATERIALS AND METHODS

The Serra da Mesa dam is situated in the upper Tocantins River basin, northern Goiás state, Brazil, at 485 meters above sea level, in the municipality of Minaçu, and its area extends to other four nearby municipalities: Colinas do Sul, Campinorte, Niquelândia, and Uruaçu (Figure 1). The study site was located 6 km away from the dam and 600 meters distant from the right margin of Tocantins River (13°53'29"S and 48°19'24"W; datum SAD-69) (Figure 1). The lake began to form soon after the closure of the main river channel, in October 1996, and it took 32 months to be completely full, with a maximum depth of 140 meters (Silva Jr., 1995). After this period, almost 280 land-bridge islands – ranging in area from 0.5 to 1,000 ha – were formed by the isolation of hill tops (Brandão & Araújo, 2008). The water reached the study site, located in the reservoir margin, by the seventh month of survey (May, 1997). In the last month surveyed (November, 1997) the original grid was 27% flooded (Figure 2a).

The climate is warm and wet, and highly seasonal, with a wet and dry season well defined as can be seen by the Walter's climate diagram of this area (Figure 3). The vegetation is represented by a mosaic of forested and

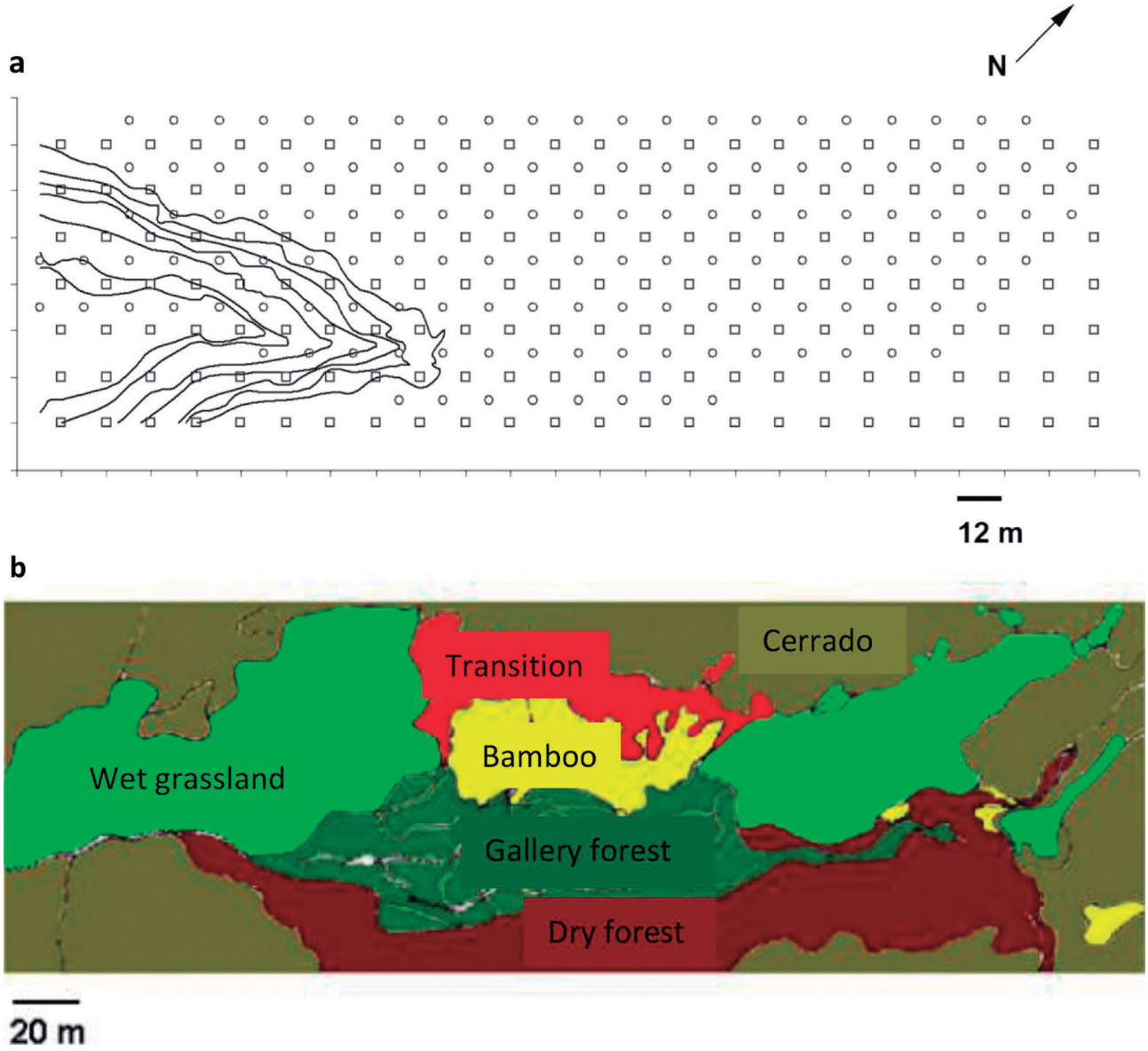

Figure 2: a = The different curves represent the flooded areas when the water reached the study site grid during the distinct months of surveys: 12th May, 21st May, 21st June, 1st August, 8th September, 15th October and 26th November of 1997, respectively. The live (squares) and pitfall (circles) traps in the study area grid of 19,872 m² (276 × 72 meters). b = The distinct habitats surveyed at the study site: in brown the arboreal dense savannas and grasslands of different shrub densities (cerrado), in light green the wet grasslands, in dark green the gallery forest, in dark red the dry forest, in yellow a forested formation with the presence of bamboos, and in light red a transitional region between the dry forest and the cerrado.

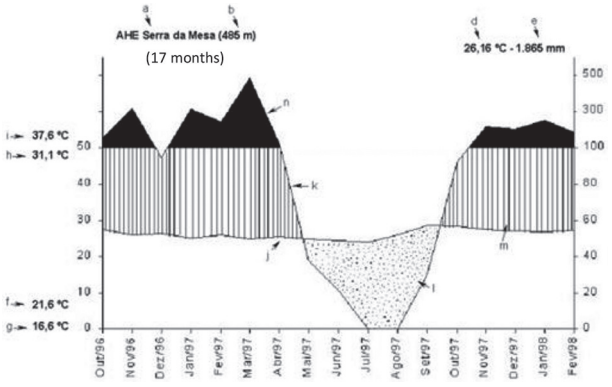

Figure 3: Walter's climate diagram of the study site (Serra da Mesa, Goiás, Brazil) during the period of study (from October 1996 to February 1998). In the horizontal axis the months, in the vertical axis the mean monthly temperature (Celsius degrees), to the right: monthly precipitation (mm). a = meteorological site, b = altitude, c = observation period, d = mean annual temperature, e = year precipitation (from December 1996 to December 1997), f = minimum mean diary temperature from the coldest month, g = minimum absolute temperature, h = maximum mean diary temperature of the hottest month, i = maximum absolute temperature, j = mean monthly temperature curve, k = mean monthly precipitation curve, l = relative dry period (dotted), m = relative wet period (hatched), n = precipitation higher than 100 mm (hyper humid season in black).

open areas, comprising six distinct habitats: 1 = arboreal dense savannas (*cerrado sensu stricto*) and grasslands of different shrub densities (*campo cerrado* and *campo sujo*) summed here as cerrado (*cerrado sensu lato*) in Figure 2b; 2 = wet grasslands (*campo úmido*); 3 = gallery forest; 4 = dry forest; 5 = a transitional area between the open and forested formations; and 6 = a forested formation dominated by bamboos (Figure 2b).

Small non-volant mammals were live and pitfall trapped in an area of 19,872 m² (a 276 × 72 meters rectangular grid – Figure 2a) comprising a total effort of 28,599 trap-nights distributed over a mosaic of habitats (Figure 2b). The 168 live traps were spaced from each other by 12 meters and were represented by Young traps (30 cm × 15 cm × 15 cm) baited with a mixture of peanut butter, sardine, corn meal and Scott's emulsion fixed on a slice of manioc, totaling 15,847 trap-nights. The pitfall series were composed by 134 buckets of 37 liters spaced 12 meters from each other and 6 meters from the live traps, totaling 12,752 pitfall-nights. Small mammals were surveyed during 12 months (from October 1996 to November 1997), once a month, during eight consecutive days, and traps were checked twice a day (in the morning and afternoon). When the water reached the study site (May, 1997), the live and pitfall traps were translocated to the opposite side of the flood, maintaining the 2 ha grid area. However, the habitat patches changed in area, with the wet grasslands, gallery and dry forests been the most affected ones, with the cerrado increasing in area (Table 1). In addition, three parallel live and pitfall trap lines – comprising 1,153 trap-nights – were placed 200 meters away from the grid, and 400 meters distant from Tocantins River, during the months of December 1996, January and February 1997, in order to observe animal movements away from the flooding. In December 1997, two new areas were surveyed: one

Table 1: Percentage of area of each habitat type in the study site, located at Serra da Mesa dam, northern Goiás state, Brazil. Before flooding (from October 1996 to April 1997), and after flooding (from May to November 1997).

Habitats	Before flooding	After flooding
Cerrado	29.1	44.0
Wet grassland	29.5	18.9
Gallery forest	14.2	11.6
Dry forest	14.6	13.0
Bamboo	7.0	7.0
Transition	5.6	5.6
Total	100%	100%

replica area – A (nearby the study site, 366 live trap-nights) and one control area – B (downstream the Tocantins River, 425 live trap-nights) in order to compare with the study site grid results (Figure 1). These new areas presented similar habitat mosaics, including both forested and open formations.

Specimens were individually marked with numbered ear tags (Michel ear tags – Le Boulengé-Nguyen & Le Boulengé, 1986) and toe clipping (Loreto *et al.,* 2013). The specimens captured, marked and released were identified at species level and classified in relation to sex, age, and reproductive conditions and had their standard measures extracted (head and body, tail length, and mass). In order to check the taxonomic identity of the specimens surveyed, vouchers were collected under the permit of IBAMA (Instituto Brasileiro do Meio Ambiente e Recursos Naturais). These were morphologically examined, identified at species level, and deposited in the mammal collection of the Museu Nacional, Rio de Janeiro (MN). The nomenclature and classification of the species surveyed follow Voss & Jansa (2009) and Voss *et al.* (2018) for the marsupials; and Patton *et al.* (2015) and Suárez-Villota *et al.* (2018) for the rodents.

The number of individuals from each species surveyed was estimated by the Minimum Number Known to be Alive (MNKA), which considers the presence in the population of all individuals once captured, even though not all of them may be captured in between surveyed periods (Krebs, 1966). Although this methodology is dependent on trappability success, which varies among species and along the time (Fernandez, 1995), it is indicated for qualitative comparisons among studies with small sample sizes, such as this one and others conducted in the Cerrado (*e.g.,* Mares & Ernest, 1995). Density was estimated by MNKA per unit of area, based on the area of the grid surveyed (2 hectares).

Habitat selectivity (hereafter, HS) of the most abundant species (with at least N = 5 see Table 2; and 10 captures) was estimated by the ratio (HS = cf/af) between the capture frequency in each habitat (cf = number of capture per habitat in relation to the total number of captures) and the frequency of live and pitfall traps available in each habitat (af = number of traps in each habitat in relation to the total number of traps). When HS > 1, the species presents a positive selection in relation to the habitat analyzed; HS = 1, a neutral selection; and HS < 1, a negative selection. Also, the observed and

Table 2: Species, number of individuals and relative abundance (in number of individuals – in mass) of small mammals recorded at Serra da Mesa, GO, Brazil. Habitat group (Forest × Open-area dwellers) was estimated based on Chi quadrat test (χ^2; degrees of freedom = 5) and habitat selectivity index (HS) for species with at least 10 captures in the study site.

ORDER Family	Species	N	Relative abundance (%)	Habitat group (χ^2) P < 0.001
DIDELPHIMORPHIA	*Didelphis albiventris*	02	0.8 – 4.3	—
Didelphidae	*Gracilinanus agilis*	27	10.8 – 2.1	Forest (33.8)
	Marmosa demerarae	01	0.4 – 0.4	—
	Marmosa murina	03	1.2 – 0.5	—
	Monodelphis domestica	24	9.6 – 4.6	Open (36.2)
	Monodelphis kunsi	02	0.8 – 0.1	—
	Philander canus	04	1.6 – 2.7	—
	Thylamys karimii	04	1.6 – 0.5	—
Total	**08**	**67**	**26.8 – 15.2**	
RODENTIA	*Calomys tener*	06	2.4 – 1.2	—
Cricetidae	*Cerradomys scotti*	05	2.0 – 1.5	Open (30.2)
	Hylaeamys megacephalus	32	12.8 – 8.3	Forest (177.3)
	Necromys lasiurus	31	12.4 – 8.3	Open (169.4)
	Nectomys rattus	05	2.0 – 6.8	Forest (55.0)
	Oecomys gr. *catherinae**	08	3.2 – 1.9	Forest (47.6)
	Oligoryzomys spp.**	34	13.6 – 4.1	—
	Rhipidomys macrurus	07	2.8 – 3.1	Forest (44.0)
Total	**09**	**128**	**51.2 – 35.2**	
Echimyidae	*Carterodon sulcidens*	02	0.8 – 1.5	—
	Proechimys roberti	17	6.8 – 14.2	Forest (63.0)
	Thrichomys sp.***	36	14.4 – 33.9	Open (203.0)
Total	**03**	**55**	**22.0 – 49.6**	
TOTAL	20	250	100 – 100	

* Specimens from central Brazil were identified as a putative new species under the *Oecomys catherinae* complex: *Oecomys catherinae* central clade by Suárez-Villota *et al.* (2018). Here we treat this taxon as *Oecomys* gr. *catherinae.*

** Two species of the genus *Oligoryzomys* were recorded in the study area: *O. mattogrossae* and *O. moojeni* (see Weksler & Bonvicino, 2015). Since the individuals marked and released were not distinguished between these two species, they were summed in the table.

*** Specimens from the study area presented a karyotype of 2n = 30, NF = 56 being treated as an undescribed species of the genus *Thrichomys,* cited here as *Thrichomys* sp. following Pessôa *et al.* (2015).

expected capture numbers – considering a homogeneous distribution in the study grid – were compared via Chi-Quadrat-Test (χ^2) considering the six habitat types – degrees of freedom = 5 (Ludwig & Reynolds, 1988).

The temporal differences between richness, abundance and density were statistically compared via the non-parametric test of Kruskal-Wallis (K-W). In order to increase the sample size, the 12 capture sessions were summed and analyzed per trimester (Zar, 1996). Since the Cerrado presents a high seasonality, these data were also analyzed in relation to each season: the rainy (October to April) and dry season (May to September) via the non-parametric test of Mann-Whitney (*U*). Similarly, the two capture sessions from distinct years – October/November 1996 and October/November 1997 – were also compared via Mann-Whitney (*U*) (Zar, 1996). Since the abundance varied very much among the trimesters, seasons and capture sessions analyzed, I also checked the differences in relation to species richness through rarefaction curves considering the minimum number of individuals surveyed within these samples (Ludwig & Reynolds, 1988).

RESULTS

Twenty small mammal species were recorded and, as predicted, they presented a non-homogeneous distribution and high habitat selectivity (Table 2). For species that presented at least N = 5 and 10 captures, I found four open-area specialists: *Cerradomys scotti* (HS = 2.7 for cerrado; χ^2 = 30.2; p < 0.001), *Monodelphis domestica* (HS = 2.7 for cerrado; χ^2 = 36.2; p < 0.001), *Necromys lasiurus* (HS = 2.6 for wet grassland; χ^2 = 169.4; p < 0.001) and *Thrichomys* sp. (HS = 2.6 for cerrado; χ^2 = 203.0; p < 0.001); and six forest dwellers: *Gracilinanus agilis* (HS = 2.9 for dry forest; HS = 2.1 for bamboo; χ^2 = 33.8; p < 0.001), *Hylaeamys megacephalus* (HS = 2.8 for gallery forest; HS = 2.5 for dry forest; HS = 1.6 for bamboo; χ^2 = 177.3; p < 0.001), *Nectomys rattus* (HS = 5.0 for gallery forest; χ^2 = 55.0; p < 0.001), *Oecomys* gr. *catherinae* (HS = 6.0 for bamboo; HS = 2.6 for gallery forest; χ^2 = 47.6; p < 0.001), *Proechimys roberti* (HS = 2.4 for gallery forest; HS = 2.3 for bamboo; HS = 1.9 for dry forest; χ^2 = 63.0; p < 0.001) and *Rhipidomys macrurus* (HS = 4.0 for gallery forest; HS = 2.3 for dry forest; χ^2 = 44.0; p < 0.001).

A continuous decrease in numbers – of species and individuals – as the water reached the study area (Figure 4) was observed. The rarefaction curves have shown decreasing values of richness from the first to the fourth trimesters considering the minimum number of individuals surveyed within the analyzed period (n = 13 in the fourth trimester – Figure 5a). These data were attested by the analyses of variance among the trimesters, which have shown significant differences in species richness

(K-W; P < 0.05; median = 14; 9; 6; and 3 from first to fourth trimester, respectively) and number of individuals (K-W; P < 0.05; median = 58; 38; 15 and 5) during the study period. The analyses between the two seasons have also shown decreasing values by the rarefaction curves (n = 40 in the dry season – Figure 5b), which were statistically distinct, with the rainy season presenting higher values (richness median = 12.5; abundance median = 42.5) than the dry season (richness median = 5.0; abundance median = 11.0; *U* – P < 0.05). The analyses between the two capture sessions in consecutive years showed significant differences as well: October/November 1996, before flooding (median = 13 species; 46 individuals) and October/November 1997, after flooding (median = 2.5 species; 8 individuals); attested by the rarefaction curves (n = 8 in Oct/Nov/97 – Figure 5c). These data point to a significant change in community structure and composition after the flooding.

Although the most affected habitats by the flooding were the wet grasslands and gallery forest (Figure 2; Table 1), the decline in numbers was not exclusive of wet grasslands or forest dwellers, with open-area inhabitants (cerrado in Figure 2b) showing the same pattern of diversity loss (Figure 6). The analysis of variance among the trimesters was significant for five species density (K-W; P < 0.05), with the exception of *G. agilis* (K-W; P = 0.2). Although *G. agilis* have shown an increase in density in the final months of the dry season, it also declined in the end of the study period (Figure 6).

The species surveyed showed high recapture rates before the flooding, with the most recaptured species being: *N. lasiurus,* with a mean individual recapture rate of 9.6 during the overall study period; *Thrichomys* sp. of 5.9; *H. megacephalus* of 5.0; and *P. roberti* of 4.7. I also observed a low recapture rate in the study grid of specimens marked in the extra transect lines located 400 meters away from the Tocantins River and 200 meters from the study grid (Table 3).

Since the dry season was concomitant with the period of flooding in the study site, and in order to segregate the effects of seasonality and that of flooding, I also compared the results obtained in a replica (area A) and a control area (area B) surveyed during December 1997, with the study site grid results. The control area (B) showed comparatively higher numbers of species and individuals (Figure 7).

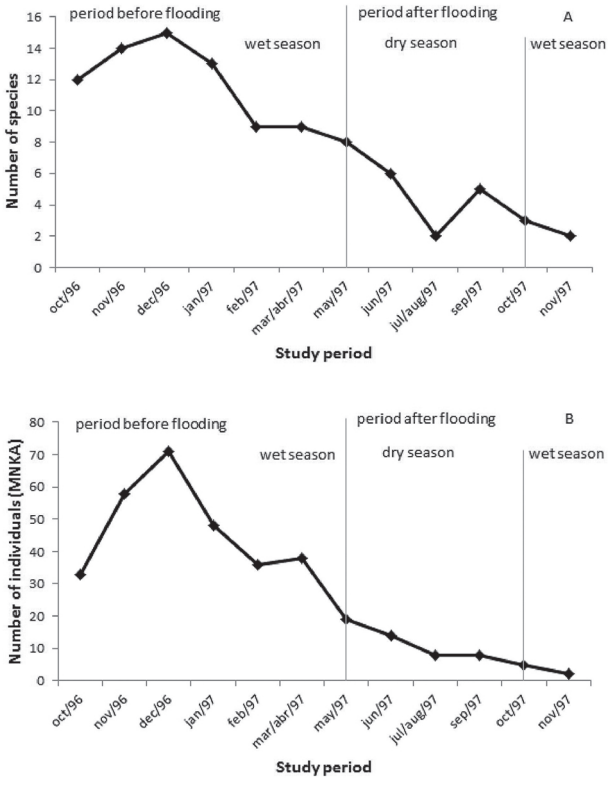

Figure 4: Species richness (A) and abundance (B) of the small mammal assemblage studied from October 1996 to November 1997 at Serra da Mesa, GO, Brazil.

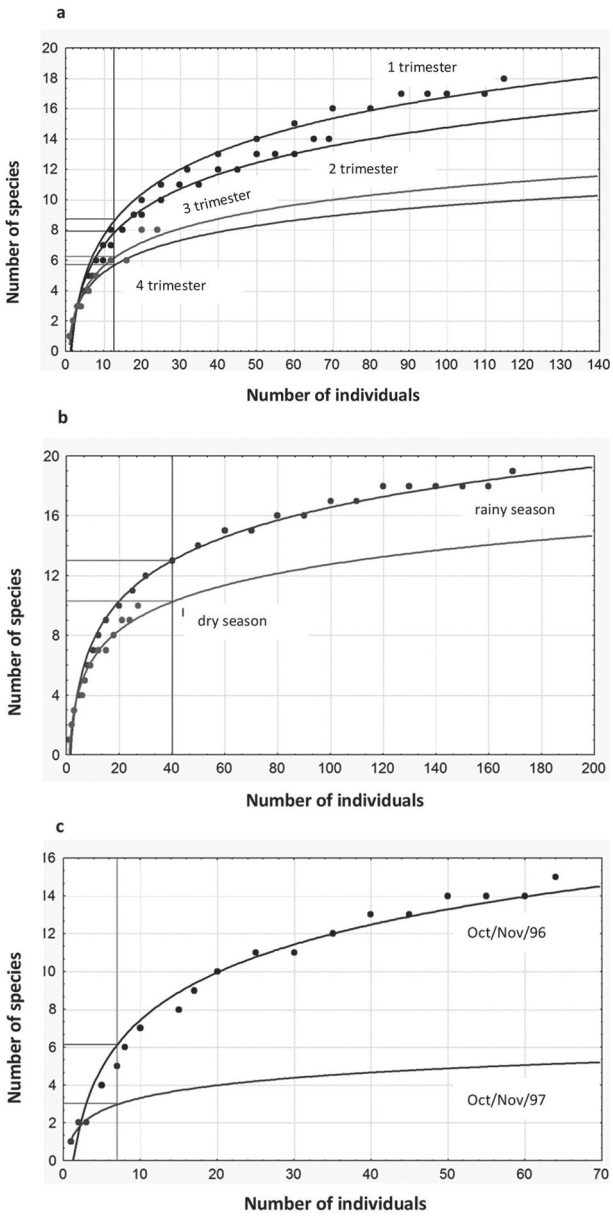

Figure 5: Expected number of species based on rarefaction curves considering the minimum sample size (number of individuals) in each period analyzed at Serra da Mesa, GO, Brazil: a = among the four trimesters (October to December 1996; January to April 1997; May to August 1997 and September to November 1997); b = between the two seasons (rainy: October to April 1997 and dry: May to September 1997); c = between the two capture sessions in consecutive years (October/November 1996 and October/November 1997).

DISCUSSION

Results have shown a non-homogeneous distribution for the most abundant species in the study area. Indeed, the habitat selectivity index indicated a positive selection to certain habitat types, defining two species groups: the open habitat specialists (*C. scotti, M. domestica, N. lasiurus* and *Thrichomys* sp.) and the forest dwellers (*G. agilis, H. megacephalus, N. rattus, O.* gr. *catherinae, P. roberti, R. macrurus*). These data are in accordance with previous studies about Cerrado small mammals that are characterized by the high habitat

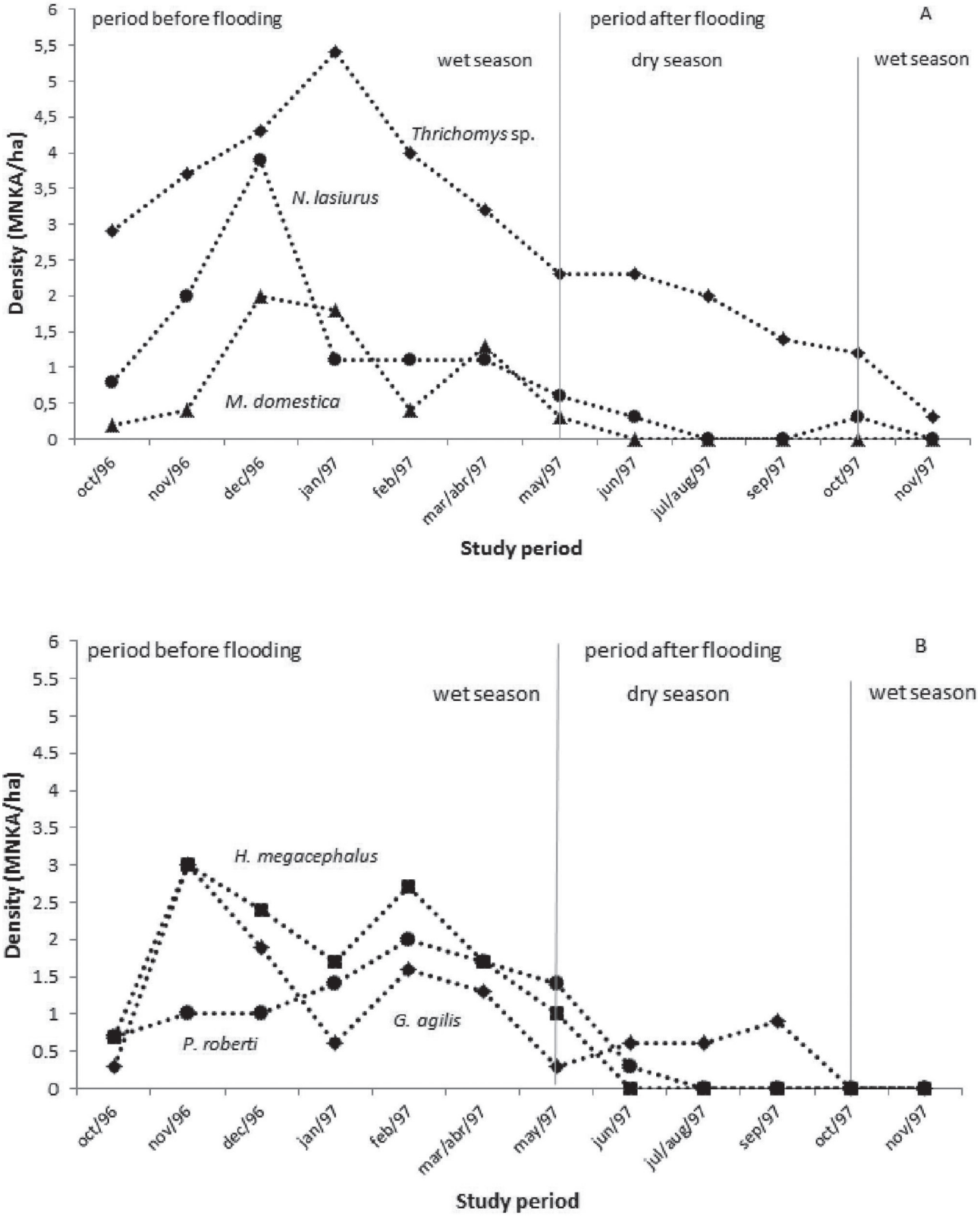

Figure 6: Density of the small mammal species (relative abundance superior to 5%) surveyed from October 1996 to November 1997 at Serra da Mesa, GO, Brazil. A = open-area inhabitants and B = forest dwellers.

Table 3: Marked individuals in an area 200 meters away from the study site and near the Tocantins River during the months of December 1996, January and February 1997, showing the recapture rates of these specimens in the study site, at Serra da Mesa, GO, Brazil.

Species	Number of individuals captured in the three extra transect lines	Number of individuals recaptured in the study grid
Gracilinanus agilis	2	0
Monodelphis domestica	3	1
Hylaeamys megacephalus	9	3
Necromys lasiurus	3	0
Nectomys rattus	1	0
Oligoryzomys spp.	6	0
Proechimys roberti	4	1
Total	28 (100%)	05 (18%)

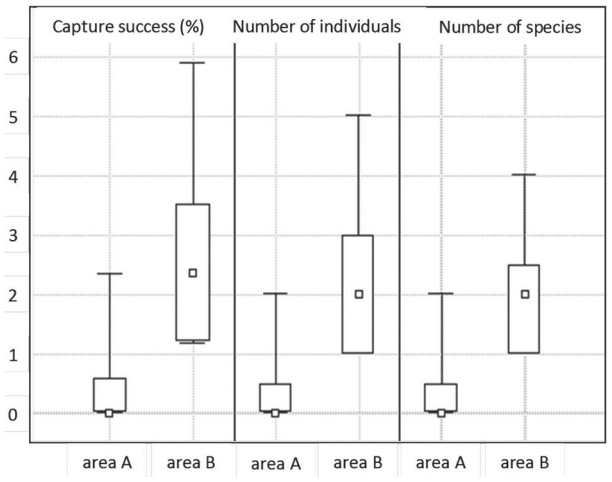

Figure 7: Capture success, number of individuals and species captured during December 1997 in the replica (area A – nearby the study site) and control (area B – downstream the Tocantins River) areas surveyed at Serra da Mesa, GO, Brazil. Minimum and Maximum data and median are shown in the box plots.

selectivity (Bonvicino *et al.,* 2012; Carmignotto *et al.,* 2014; Marinho-Filho *et al.,* 2002). Additionally, the preferred habitat type of the species surveyed at Serra da Mesa agrees with studies conducted in distinct localities of the biome, reinforcing the association of each species to a forest or open-area habitat group in the Cerrado (Carmignotto & Aires, 2011; Gomes *et al.,* 2015; Santos-Filho *et al.,* 2012).

Since the impacts of habitat loss due to flooding in hydroelectric reservoirs are directly related with the size of natural habitat patches available (Alho, 2011; Andriolo *et al.,* 2013; Gomes *et al.,* 2015), and given that wet grasslands and gallery forests were the most affected habitats in the study site, we would expect a decrease in abundance of species restricted to those habitats. In fact, the densities of the most abundant forest and wet grassland dwellers have declined during the study period. However, the same pattern was observed for the cerrado inhabitants, suggesting that additional factors, besides the size of habitat patches, have influenced the decrease in numbers of the overall assemblage at the study site. The high recapture rates in the study site compared with the low rates of specimens recaptured from the extra transect lines, indicate that most individuals were residents and few made movements away from the flood. These data suggest that dispersion was not responsible for the decrease in numbers at the study period. Indeed, the few studies dealing with the impacts of damming in Cerrado small mammals have shown a decrease in species richness and abundance after the flooding for the overall community, with no evidence of increased density due to the fleeing of individuals from nearby flooded areas (Gomes *et al.,* 2015; Passamani & Cerboncini, 2013).

The area reduction and isolation by the flood have also been erected as important factors affecting the diversity in these new environments (Cosson *et al.,* 1999; Palmeirim *et al.,* 2018a; Terborgh *et al.,* 1997). In the present study, although the grid area did not change during the study, a decrease in total area was observed due to the flooding of adjacent lowlands. This area reduction may have increased the mortality rate of small mammals, especially through predation. In fact, Passamani & Cerboncini (2013) observed an increased predation rate after the damming, measured as the number of attacks from potential small mammal predators to the live traps, pointing predation as the most important factor affecting this group of mammals in areas affected by the flooding. Although predator attacks were not analyzed in the present study, I also observed an increased number of attacks by snakes and ants to the live traps and by medium size mammals to the pitfall traps after the flooding, suggesting that predation has played an important role in reducing species richness and abundance in the study site.

Seasonality may also have affected the variables analyzed, since there is two well defined seasons in the Cerrado (Sarmiento, 1983). It is known that small mammal abundances fluctuate in relation to the rainy and dry seasons (Becker *et al.,* 2007; Ribeiro & Marinho-Filho, 2005; Vieira *et al.,* 2010), so we would expect similar results in the present study. Some species may increase in numbers in the rainy season (Carmignotto *et al.,* 2014; Mares & Ernest, 1995) while others present higher numbers in the dry season (Gomes *et al.,* 2015; Lessa & Paula, 2014; Magnusson *et al.,* 1995). Although the marked seasonality observed in the study site, the abundances of all species have decreased during the study period. Since these numbers did not recover in the beginning of the next rainy season, these data highlight the impacts of flooding and not seasonality in the decline of species abundance in the study site. Additionally, a downstream area surveyed at the rainy season (area B), not affected by the flooding, showed higher number of species and individuals when compared to an area adjacent to the study site (area A), suggesting that in areas located at the reservoir margin, both directly and indirectly affected by the flooding, there was a substantial decrease in species richness and abundance, evidencing a greater magnitude of the impacts of flooding in the small mammals studied.

Although the construction of hydropower plants is widespread and continues to increase in Brazil (Couto &

Olden, 2018; Prado *et al.,* 2016), most studies evaluating the impacts of damming have demonstrated the negative effects for vertebrates (Brandão & Araújo, 2008; Gomes *et al.,* 2015; Passamani &Cerboncini, 2013). In the Serra da Mesa region, Brandão & Araújo (2008) have also shown a decrease of 30% in anurans species richness after the flooding in the land-bridge islands surveyed. In this case, the most affected species were those gallery forest dependent or semi-dependents, since in the hill tops of land-bridge islands the most representative habitat formations is now the cerrado *sensu stricto.* These data highlight the importance to preserve the habitat mosaic once present in the region in order to preserve local species richness.

Recently, studies evaluating the impacts of flooding in land-bridge islands and in areas surrounding the reservoirs – monitored many years after flooding – have also demonstrated the perpetuation of negative effects of damming, particularly related to the impoverishment of vertebrate communities (Irving *et al.,* 2018; Palmeirim *et al.,* 2018a, b). These studies have shown the strong relationship between local species richness, land-bridge island area and isolation, as well as habitat patches availability in islands and on surrounding mainland (Benchimol & Peres, 2015a, b; Irving *et al.,* 2018; Palmeirim *et al.,* 2018a, b). Moreover, the potential of species to persist in the new areas is related with the capacity to use the habitats now available, being habitat specialists more prone to local extinctions (Andriolo *et al.,* 2013; Irving *et al.,* 2018; Palmeirim *et al.,* 2018a, b). Not only terrestrial vertebrates, but also the semiaquatic mammals have decreased in numbers due to the loss of good quality habitats, represented by food and shelter availability (Palmeirim *et al.,* 2014). Thus, the decrease in non-volant mammal species richness and abundance due to habitat loss observed in the present study may also persist in this region for many years after the flooding.

In order to minimize such negative effects of damming, the majority of studies recommend the creation of reserves that effectively conserve the local biodiversity, and, if the hydropower plants may be unavoidable, large land-bridge and connected islands with native and diverse vegetation cover must be prioritized in order to maintain the local species richness (*e.g.,* Benchimol & Peres, 2015a, b; Brandão & Araújo, 2008; Palmeirim *et al.,* 2018a). Based on the results from the present study, I also suggest the preservation of areas not directly affected by the flooding, as those located downstream from the dam (area B), in order to preserve the biodiversity found in this region of Cerrado.

The small mammal species richness found in the study area (20 species) can be considered significantly high, since the mean number of local species richness found in the overall Cerrado varied from one to 26 species, with a mean of 5.82 ± 3.55 (review dataset in Mendonça *et al.,* 2018). Considering only studies in Protected Areas that have applied significant capture effort (more than 5,000 live-trap-nights) and have used complementary methods of survey (live and pitfall traps), species richness varied from 19 to 24 species (Pereira & Geise, 2009; Carmignotto & Aires, 2011; Carmignotto *et al.,* 2014; Gomes *et al.,* 2015). In fact, previous studies developed in Serra da Mesa before the dam closure have found three additional species: *Dactylomys dactylinus* (Bezerra *et al.,* 2007); *Rhipidomys mastacalis* (Andrades-Miranda *et al.,* 2002 and Tribe, 2015); and *Oecomys cleberi* (Andrades-Miranda *et al.,* 2001 and Suárez-Villota *et al.,* 2018) evidencing the high species richness of this region. Besides the high richness, its species composition highlights the priority for conservation, since it presents Cerrado endemics such as *C. sulcidens, C. scotti, O. cleberi* and *R. macrurus* (Carmignotto *et al.,* 2012); Cerrado geographically restricted species, such as *Oligoryzomys moojeni* (Weksler & Bonvicino, 2015); as well as new and undescribed species, such as *Oecomys catherinae* central clade (Suárez-Villota *et al.,* 2018) and *Thrichomys* sp. (Pessôa *et al.,* 2015).

So, considering the negative effects of flooding in the small mammal assemblage surveyed, evidencing the strong decrease in species richness, abundance and density and leading to the local extinction of these populations in the study area, attesting the results obtained in previous studies (Gomes *et al.,* 2015; Passamani & Cerboncini, 2013; Palmeirim *et al.,* 2018b), it's time to rethink about the expansion of the hydroelectric source of energy. Since not only the mega dams but also the small hydropower plants have shown substantial environments impacts (Couto & Olden, 2018), we urge to investigate alternative energy sources to preserve our biodiversity (Faria & Jaramilllo, 2017; Fearnside *et al.,* 2016).

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ARTIGOS

Topics in Oryzomyini rodents (Cricetidae, Sigmodontinae): natural history, diversity and the contribution of Brazilian researchers

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Abstract: Brazilian Mammalogy started standing out in the international scientific scene a couple decades ago, therefore, there is a substantial portion of mammal diversity that still needs to be studied. Rodentia is the most specious order among living mammals, and the New World subfamily Sigmodontinae is the most diverse in the Neotropics, inhabiting a wide variety of habitats and exhibiting diverse habits. The pioneer studies on New World mammals take place during the European and North American expeditions (XVI and XIX centuries). After 1980's, autochthonous groups of Brazilian mammalogist started to rise. From then on, local researchers have contributed substantially to increase the knowledge in this diverse group. Herein, we summarize the available information on the most diverse group of the subfamily Sigmodontinae, the tribe Oryzomyini, in two different perspectives: (i) compiling natural history data for currently recognized species; and (ii) analyzing the contribution of Brazilian researchers on the study of Oryzomyini rodents. Data were gathered from literature and the graphs were built in R. Natural history data show that rodents are mostly nocturnal, cursorial and plant eaters; mainly inhabiting forests up to 4,000 m and present low threat of extinction. Brazilian researchers contributed to more than a half of species descriptions after 1959, and most of these studies were conducted in the state of Rio de Janeiro. The most published topic is related to evolutionary biology, with women participation in most of them. The number of publications is still growing up, with a considerable increase after the 2000's.

Key-Words: Brazilian Mammalogy; Mammals; Research Activity; South America.

Resumo. Tópicos em Oryzomyini (Cricetidae, Sigmodontinae): história natural, diversidade e contribuição dos pesquisadores brasileiros. A Mastozoologia no Brasil vem se destacando no cenário científico internacional, contudo, ainda existe uma porção substancial da diversidade de mamíferos a ser estudada. Os roedores compreendem a ordem mais rica dentre os mamíferos, e a subfamília Sigmodontinae é a mais diversa da região Neotropical, sendo essa diversidade refletida na grande variedade de hábitos apresentados e habitats ocupados. Os primeiros estudos com mamíferos do Novo Mundo começaram durante as expedições europeias e norte-americanas (séculos XVI e XIX). Após a década de 1980, grupos brasileiros de mastozoólogos começaram a estudá-los. A partir de então, a pesquisa em mamíferos no Brasil vem contribuindo substancialmente para aumentar o conhecimento deste grupo. Assim, exploramos as informações disponíveis sobre a tribo Oryzomyini em duas perspectivas diferentes: (i) reunindo dados de história natural disponíveis para as espécies atualmente reconhecidas; e (ii) o progresso dos estudos com esses roedores no Brasil. Os dados foram compilados da literatura e os gráficos foram construídos no software R. Os dados de história natural mostram que esses roedores são majoritariamente noturnos, cursoriais e se alimentam de vegetais, habitando principalmente florestas até 4.000 metros de altitude, e apresentam baixo risco de extinção. O Brasil contribuiu com mais da metade das descrições de espécies após 1959, e a maior parte desses estudos foram conduzidos no estado do Rio de Janeiro. O tópico mais publicado foi sobre biologia evolutiva, com grande participação feminina nas produções científicas. O número de publicações está crescendo, com um aumento considerável depois do ano 2000.

Palavras-Chave: América do Sul; Atividades de Pesquisa; Mamíferos; Mastozoologia Brasileira.

INTRODUCTION

Mammalogy in Brazil is currently standing out in the international scientific scene, partly because of its important contribution to the discovery and description of the Neotropical biodiversity, but also by the growth of the most applied sciences that depend on up to date taxonomic knowledge, such as systematics, biogeography, basic and applied ecology, and conservation. Although this growth has increased substantially over the past two decades, there is still a considerable portion of mammal diversity to be studied and described (May, 2010; Mora *et al.,* 2011; Percequillo, 2017).

Rodents represent about 42% of all living mammals (Burgin *et al.,* 2018; Wilson *et al.,* 2017) and the New World family Cricetidae is by far the most diversified group of rodents in this region (Pardiñas *et al.,* 2017; Wilson & Reeder, 2005). Among Cricetidae, the subfamily Sigmodontinae is the most specious lineage, with species occurring predominantly and throughout the Neotropical region. Sigmodontine rodents inhabit a variety of environments and exhibit distinct ecological and life history traits (D'Elía & Pardiñas, 2015; Pardiñas *et al.,* 2017). In the past 20 years, phylogenetic analyzes formalized sigmodontines grouped in different tribes (*e.g.,* Braun, 1993; D'Elía *et al.,* 2003, 2005, 2006; Pacheco, 2003; Pardiñas *et al.,* 2015; Percequillo *et al.,* 2011; Salazar-Bravo *et al.,* 2016; Smith & Patton, 1993, 1999; Steppan, 1995; Voss & Carleton, 1993; Weksler, 2003, 2006), increasing the activity on the tribe delimitation depending on the method applied (see D'Elía & Pardiñas, 2015 for a review). Currently there are 11 recognized tribes within Sigmodontinae, named, Abrotrichini, Akodontini, Andinomyini, Euneomyini, Ichthyomyini, Oryzomyini, Phyllotini, Reithrodontini, Sigmodontini, Thomasomyini, and Wiedomyini (*sensu* Salazar-Bravo *et al.,* 2016). The tribe Oryzomyini is the most diverse and widely distributed group of Sigmodontinae (Weksler, 2015). These rodents occur from the southern U.S.A. to Tierra del Fuego, and they are predominantly cursorial (although some species present arboreal or semiaquatic habits), omnivorous and nocturnal (Pardiñas *et al.,* 2017; Weksler, 2015; Weksler & Percequillo, 2011). Taxonomic studies on Oryzomyini stand out between the second half of the XX century and the beginning of the XXI (Weksler, 2015). Brazil, with its vast territory including different landscapes and biomes, hosts a large portion of the oryzomyine diversity (almost 50% of the diversity of both species and genera; Patton *et al.,* 2015). However, very few publications describing new taxa have resulted from Brazilian researches (Pardiñas *et al.,* 2017).

In 1959, Nikolaj Vorontzov officially named the tribe Oryzomyini, but an "oryzomyine" lineage was previously identified by Hershkovitz (1944) as a "natural assemblage" of related cricetines that share some cranial and molar characters. Almost 80% of the Oryzomyini species were described before 1959 and all of them by foreign naturalists and researchers, as a result of field expeditions occurred between the XVI and XIX centuries, when Brazil was a colony of Portugal and at the beginning of the Republican period in Brazilian (Ávila-Pires & Oliveira, 2014; Percequillo, 2017). As a consequence of the European naturalistic expeditions to Brazil, large series of specimens and type-specimens of several nominal taxa are housed in European collections. Among the institutions that received the greatest number of specimens from Brazil during this period are the Muséum National d'Histoire Naturelle, in Paris, the Natural History Museum, in London, and the Museum für Naturkunde, in Berlin (Ávila-Pires & Oliveira, 2014). Important names in mammalogy, such as I. von Olfers, A.G. Desmarest, A. Brants, J.F. Brandt, P.W. Lund, J.A. Wagner and M.R.O. Thomas, stand out as the greatest descriptors of the new rodent species collected during this period (Bezerra, 2015; Percequillo, 2017).

In the second half of the XIX century North American museums began to organize scientific expeditions to Brazil, and from this period onwards the knowledge about oryzomyine diversity began to grow up considerably, especially with studies of Joel Asaph Allen (Percequillo, 2017). The American Museum of Natural History (AMNH, New York) organized one of most famous North American expedition to Brazil, in 1913, with President Theodore Roosevelt composing the team. The main goal of this expedition was to map the "Rio da Dúvida", later renamed "Rio Roosevelt", however they also performed biodiversity surveys along the river, and all mammals collected were sent to the AMNH (Ávila-Pires & Oliveira, 2014; Bezerra, 2016). Only after 1980, Brazilian mammalogists began to take part in the large foreign scientific expeditions in Brazil and also to claim to keep part of the series of specimens collected in local institutions (Ávila-Pires & Oliveira, 2014).

Between late 1950's and early 1960's, zoology was recognized and established as a career in Brazil, however, the professional qualification in mammalogy was almost inexistent until the 1980's, which was directly related to the negligence with the few Brazilian scientific collections at the time, such as *Museu de Zoologia da Universidade de São Paulo* (MZUSP), *Museu Nacional da Universidade Federal do Rio de Janeiro* (MN/UFRJ), and *Museu Paraense Emílio Goeldi* (MPEG) (Ávila-Pires & Oliveira, 2014; Cerqueira, 2008). From late 1980's and early 1990's, there was a considerable increase in the number of professionals capable of conducting independent mammalogy researches in Brazil (Cerqueira, 2008). According to Cerqueira (2008), this fact is a result of the long-term public investment policies for training of scientists, and the creation of the Brazilian Society of Mammalogy. From the 1990's to the present, the number of researchers studying mammals continued to increase considerably (Cerqueira, 2008). For example, Oliveira *et al.* (2008) compiled the studies available in the Annals of the first three editions of the Brazilian Congress of Mammalogy and noted an increase in publications in each edition, with 268 papers presented at the first meeting (2001), 413 in the second (2003) and 473 in the third (2005). Another interesting information presented by Oliveira *et al.* (2008) is that the Southeast region was responsible for about 48% of the studies presented in all meetings, and the majority of researches were related to

Ecology and Diversity Survey. The taxonomic history of the tribe Oryzomyini directly reflects this low activity of Brazilian mammalogists prior to 1990. The first description of an oryzomyine species by a Brazilian researcher occurred in 1981, when Martha Locks named a new species of *Oecomys, O. cleberi,* based on morphological and morphometric data. After that, only in 1995, J.L. Patton and M.N.F da Silva described again a new species of oryzomyine. Along with taxonomic and systematic studies, other approaches (*e.g.,* anatomic, physiologic, ecologic, and biogeographic) involving the tribe Oryzomyini also showed a significant increase after 1990.

In this context, we intend to explore the available knowledge regarding the tribe Oryzomyini in two distinct perspectives: (i) to characterize the general patterns of natural history for the currently recognized species; and (ii) to present an outlook of the progress in the studies of oryzomyine rodents in Brazil during the last decades. Furthermore, we present some perspectives to the advance on the knowledge of this group.

MATERIALS AND METHODS

We compiled all information on ecology and natural history of 141 Oryzomyini species available in Pardiñas *et al.* (2017) and Patton *et al.* (2015). Both publications present exhaustive reviews, made by specialists, of data published in scientific articles and gray literature (*e.g.,* thesis and dissertations). Based on the information presented in Pardiñas *et al.* (2017), we organized information on natural history for each species in five categories (modified from Wilson *et al.,* 2017): habit, habitat, elevation, diet, and activity pattern. To complement our dataset, we also compiled the IUCN status (IUCN, 2019) of each species.

We standardized classes on each of the five natural history categories based on the descriptions found in Pardiñas *et al.* (2017) and Patton *et al.* (2015) (see below). A table containing the data surveyed for each species is available as supplementary material.

Habit: Arboreal, scansorial, semiaquatic, semiarboreal, and cursorial;

Habitat: Anthropic areas, crops, forest (including the phytophysiognomic types such as montane forest, tropical forest, deciduous forest, semideciduous seasonal forest), gallery forest, and open areas (including wet and dry open areas such as grasses, marshes, savannas, deserts). Forest and open areas were considered as unique categories including their distinct subcategories because there was no standardization in the nomenclature used by the authors in Pardiñas *et al.* (2017) and Patton *et al.* (2015) to define the phytophysiognomy occupied by the species. Since gallery forest is a forest environment that occurs in open areas, we considered it separately;

Diet: Carrion, crops, flowers, fruits, fungi, invertebrates, nectar, omnivore, plants, pollen, seeds, and vertebrates. We understand that there is some overlap among categories of herbivore, such as crops, flowers, fruits, nectar, plants, pollen and seeds, however this is how the information is presented in the two sources used here. Therefore, to avoid loss of more detailed information, instead of putting all the herbivore categories under "plants", we decided to keep the categories as found in the textbooks, only including stalk and leaves under "plants";

Activity pattern: Diurnal and nocturnal;

IUCN Status: Critically endangered, data deficient, endangered, least concern, near threatened, vulnerable, and no information available;

Elevation: there is no information available about altitudinal range or altitudinal records for all oryzomyine species. Therefore, only in this category, we compiled information on genera level instead of species level.

The percentage or the number of species and/or genera sharing each one of these classes by category was presented as pie or bar charts built in the software R (R Core Team 2014).

Additionally, we draw a parallel between the increasing of scientific knowledge gathered for the tribe Oryzomyini and the development of mammalogy as a study field in Brazil to understand the role played by Brazilian researchers, especially women researchers. We considered descriptions of species and studies placed on different categories (see bellow) focusing specifically in the tribe Oryzomyini. We also compiled data regarding the main institutions responsible for Oryzomyini studies, women representativeness in the production of this knowledge, the period of greater data generation, and the most studied research area.

We applied two approaches to collect the data used in these analyses. At first, we compiled information of names and institutions of the authors, and year of publication of the original descriptions of the 141 valid species of Oryzomyini, considering the institution of correspondence of each author at time of publication. These data are presented in bar and pie charts showing the descriptions of new species by institution, the differences in percentage of the amount of species described by foreign and Brazilians researchers, as well as between Brazilians men and women.

Second, we used two peer-reviewed literature databases, Scopus® (Elsevier, 2019) and Web of Science™ (Clarivate Analytics, 2018), to retrieve scientific papers regarding oryzomyine rodent different study fields. Our goal here was to find comprehensive studies on specific subjects (*e.g.,* taxonomy, ecology, physiology) rather than simple reports on fauna surveys. We used the expression "Oryzomyini OR oryzomyine" to search in the title of the article, abstract and/or keywords, with the 1959-present temporal cut, due to the formalization of the name Oryzomyini. In addition, aiming to increase our bibliographic coverage, we search for publications including any oryzomyine genera name in the title.

The main guide for choosing the field study categories was the Web of Science™ research areas. However, these categories are sometimes very ambiguous, sorting articles with different subjects in the same category, or sometimes classifying an article in more than one category. To simplify the organization of articles into unique groups we reclassified them in the follow categories: Anatomy, including papers with anatomical description; Behavior, observations on behavior; Biodiversity Conservation, papers with biodiversity surveys; Biogeography, papers with biogeographical analysis; Biology, for the first records of some taxa; Ecology, for papers on life history and spatial patterns; Evolutionary Biology, for papers that include any phylogenetic analysis or evolutionary approach; Genetics, for papers that describe chromosomal or molecular characters; Molecular Biology, papers describing biochemical issues of the DNA; Physiology, papers with experiments in physiology; and Zoology, papers with deep morphological and/or morphometric considerations. Following this proposal, each paper fit in only one category.

To explore these data, we first created a map with the geographic distribution of the number of papers published per institution, as well as the number of researchers per institution. Subsequently, we produce a pie chart with the differences between the amount of papers published by men and women; and finally, we exhibit a temporal view of Brazilian publications, and the most applied fields of studies in oryzomyine rodents.

RESULTS

Regarding the natural history data, our results on period of activity pointed out that oryzomyine rodents are mostly nocturnal, with very few exceptions, such as *Melanomys chrysomelas* and *Zygodontomys brevicauda* – which are active during both diurnal and nocturnal periods (Figure 1a).

We gathered diet information for 56 out of the 141 species of Oryzomyini (see supplementary material for species details). The most consumed food resources (Figure 1b) are plants (35 of the 129 records), invertebrates (25) and fruits (24; Figure 1b). Other parts of plants, such as seeds and flowers, also comprehend an important portion of the diet.

Regarding the habitat where these rodents occur, we present information for all species. It is important to highlight that species do not necessarily use only one type of habitat, which is why the number of records exceed the number of species. Forest is by far the most important phytophysiognomy for this group, as 98 species occur in forest habitats, which can range from humid tropical lowland evergreen forests to montane and cloud forests (Figure 1c). Open areas, such as swamps, savannas, shrubs, also harbor a great species diversity, accounting for 61 species out of 141. We recorded 25 species in gallery forest. Oryzomyine rodents are also good opportunists, which can be found in both agricultural (20 species) and anthropogenic (five species) areas.

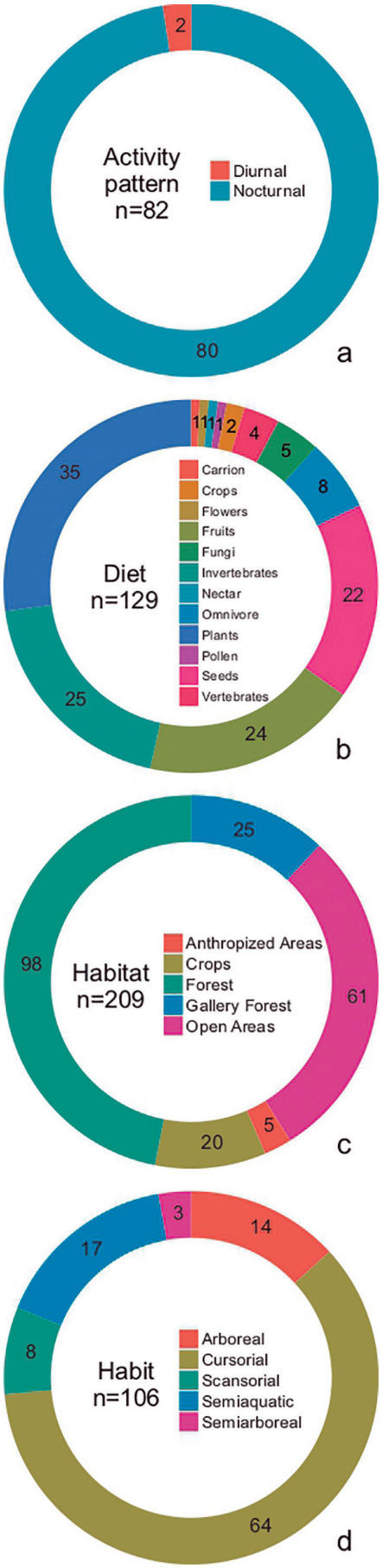

Figure 1: Characterization of the ecology and natural history traits in the rodents of tribe Oryzomyini. The figure shows the number of records (n) of the categories of four ecological traits: (a) activity pattern, (b) diet, (c) habitat, and (d) habit.

The most frequent habit is the cursorial, present in 64 out of 96 species recorded, representing 64 out of 106 habit records (Figure 1d, see supplementary material for habit type in each species). Of the 96 species, *Oecomys bicolor, O. roberti, O. rutilus,* and *O. superans,* are arboreal and cursorial, and *Hylaeamys megacephalus, Cerradomys subflavus,* and *Aegialomys ica* are cursorial and scansorial. The ability to swim is found in 17 species of the genera *Holochilus, Lundomys, Nectomys, Amphinectomys, Oryzomys,* and *Sigmodontomys.*

In addition to the large latitudinal and longitudinal distribution, the tribe Oryzomyini also has a large altitudinal range. There are species occupying different elevational strata, ranging from see level up to more than 4,000 m above sea level (Figure 2), as the case of *Oecomys superans,* which reach an elevation of up to 400 m, while *Microryzomys altissimus* is present at elevations ranging from 2,500 to 4,300 m (Pardiñas *et al.,* 2017; Patton *et al.,* 2015; Prado & Percequillo, 2013). The greatest intrageneric altitudinal range is found in *Oligoryzomys,* with species ranging from sea level up to 4,000 m (*e.g., O. andinus;* Pardiñas *et al.,* 2017). It is also important to note that, with few exceptions, most genera occur below 2,000 m, characterizing the tribe as a predominantly lowland group.

In terms of conservation status, information is lacking in the IUCN red list for a large amount of species. Thirty-five species (about 25% of the total oryzomyine species) are not classified by the IUCN, and 14 species are treated as Data Deficient (10%; Figure 3). Among the species with available information, most are listed as Least Concern (52% of the total oryzomyine species), 6% are listed as Vulnerable or Endangered. Only one species is listed as Critically Endangered, *Melanomys zunigae,* and two species as Near Threatened, *Hylaeamys oniscus* and *H. laticeps* (Figure 3).

Data on the progress of oryzomyine studies in Brazil shows that only 22% of the Oryzomyini species were described after its formal designation in 1959. From that, we verified that almost 50% of the species descriptions (14 out of 32 descriptions) involved Brazilian citizens (irrespective to the nationality of the affiliations at the time of the description; see Supplementary material). However, the number of authors, as well as the institutions where these authors belong are very few. Only 12 Brazilian researchers from nine Brazilian Institutions were

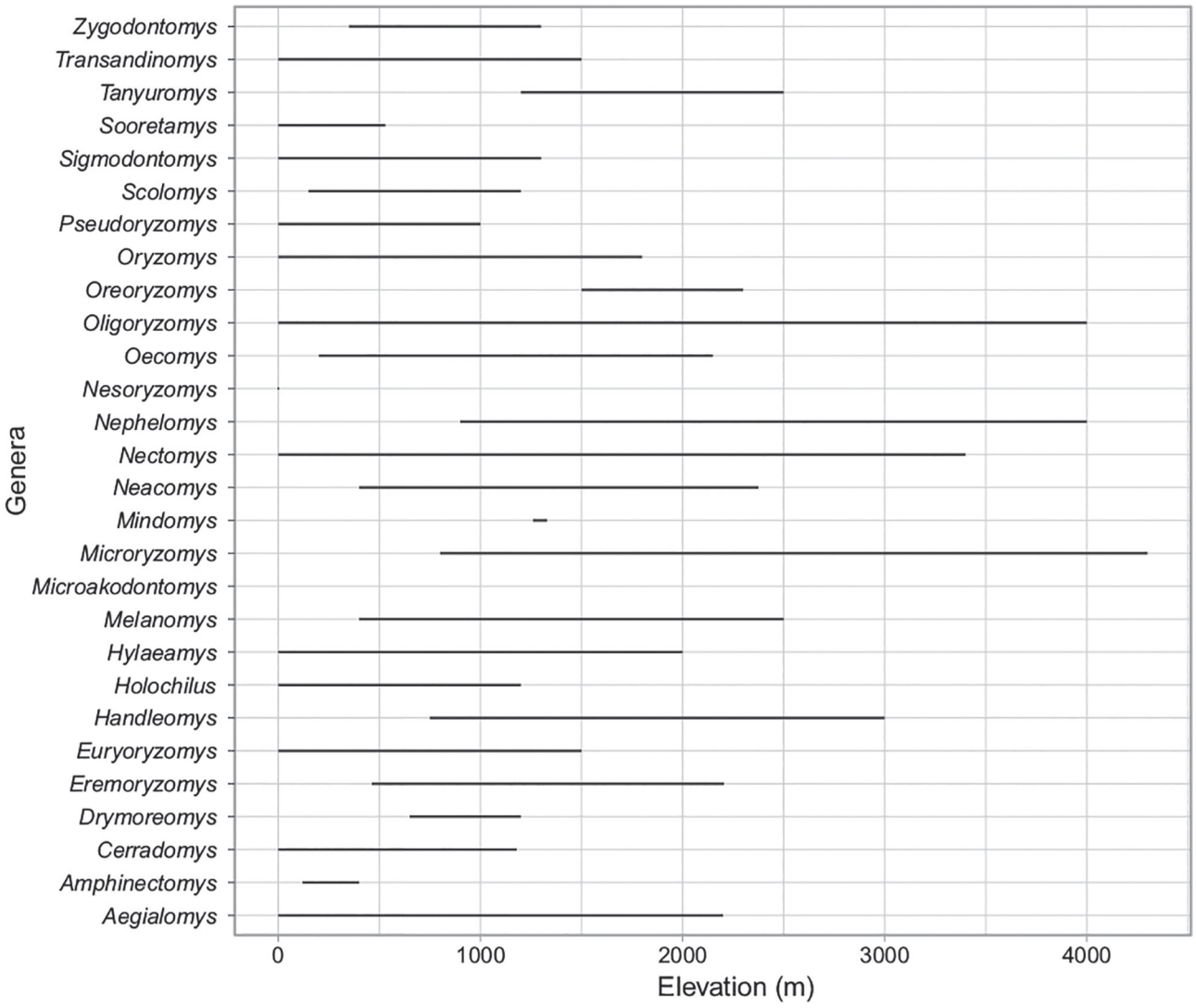

Figure 2: Altitudinal range distribution of the genera of the tribe Oryzomyini, in meters (m). Note that the Range includes all elevational records available for each genus.

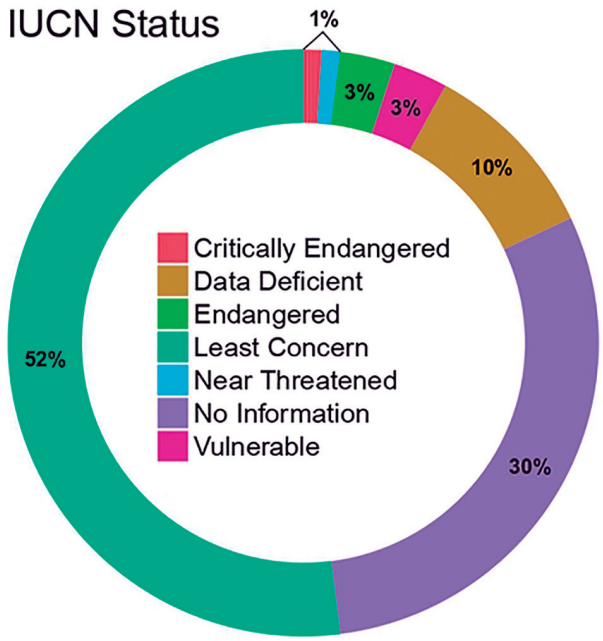

Figure 3: Conservation Status of the species of the tribe Oryzomyini defined by the IUCN red list showing the percentage of species that was classified in one of the IUCN categories: Critically Endangered, Data Deficient, Endangered, Least Concern, Near Threatened, Vulnerable. The species not evaluated for IUCN red list are showed in the category of "No Information".

responsible for the description of the 14 new species and 10 new genera in the last three decades (Figure 4). The institutions from where the descriptions came out are: *Instituto Nacional de Câncer* (INCA), *Instituto Oswaldo Cruz* (FIOCRUZ), *Museu Nacional/Universidade Federal do Rio de Janeiro* (MN/UFRJ), *Universidade Federal do Rio de Janeiro* (UFRJ), *Instituto Nacional de Pesquisas da Amazônia* (INPA), *Museu de Zoologia da Universidade de São Paulo* (MZUSP), *Universidade Federal do Espírito Santo* (UFES), *Universidade Federal da Paraíba* (UFPB), and *Universidade de São Paulo* (USP). Note that we considered MZUSP and MN/UFRJ as institutions apart from USP and UFRJ, respectively, since they represent different nucleus of research (Figure 4). Among the Brazilian researchers, half of them are females and seven works on institutions located in the Rio de Janeiro State (INCA, FIOCRUZ, MN/UFRJ, and UFRJ).

The researcher that most contributed to increase the knowledge about Oryzomyini species diversity is Cibele R. Bonvicino from the *Instituto Nacional de Câncer* (Figure 4). C.R. Bonvicino was involved in the description of nine species (Bonvicino, 2003; Bonvicino, Casado & Weksler, 2014; Bonvicino & Weksler, 1998; Langguth & Bonvicino, 2002; Percequillo, Hingst-Zaher & Bonvicino, 2008; Weksler & Bonvicino, 2005). Other researchers

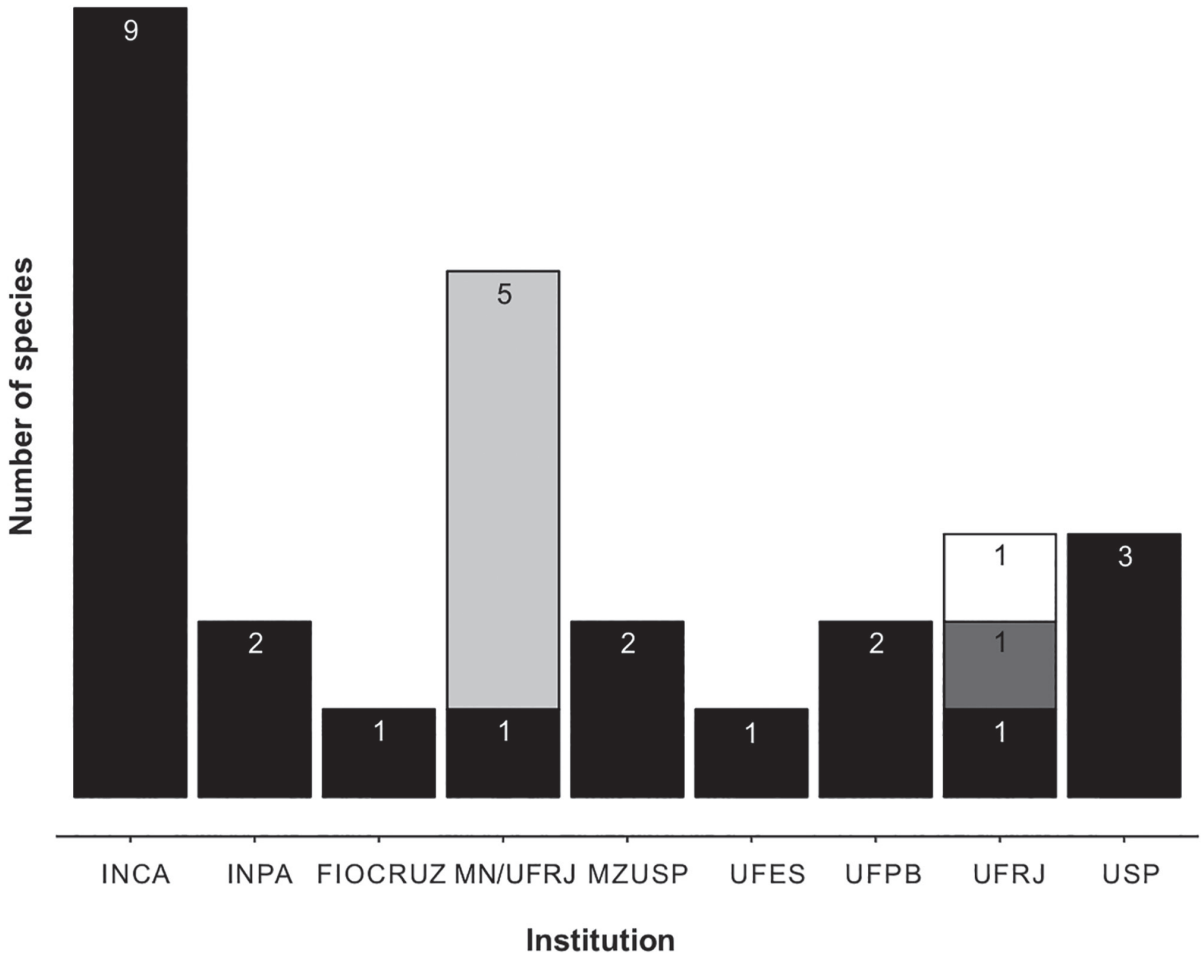

Figure 4: Number of species of the tribe Oryzomyini described by Brazilian Institutions and researchers. Size and number inside the bar represent the number of species described by authors from that institution, and the number of different colors per bar represent the number of distinct authors per institution and how much species they described. Researcher by institutions: INCA = C.R. Bonvicino; INPA = M.N.F da Silva; FIOCRUZ = F. Casado; MN/UFRJ = M. Locks (1) and M. Weksler (5); MZUSP = E. Hingst-Zaher; UFES = L.P. Costa; UFPB = A. Langguth; UFRJ = W.C. Tavares, L.M Pessôa, and P.R. Gonçalves.

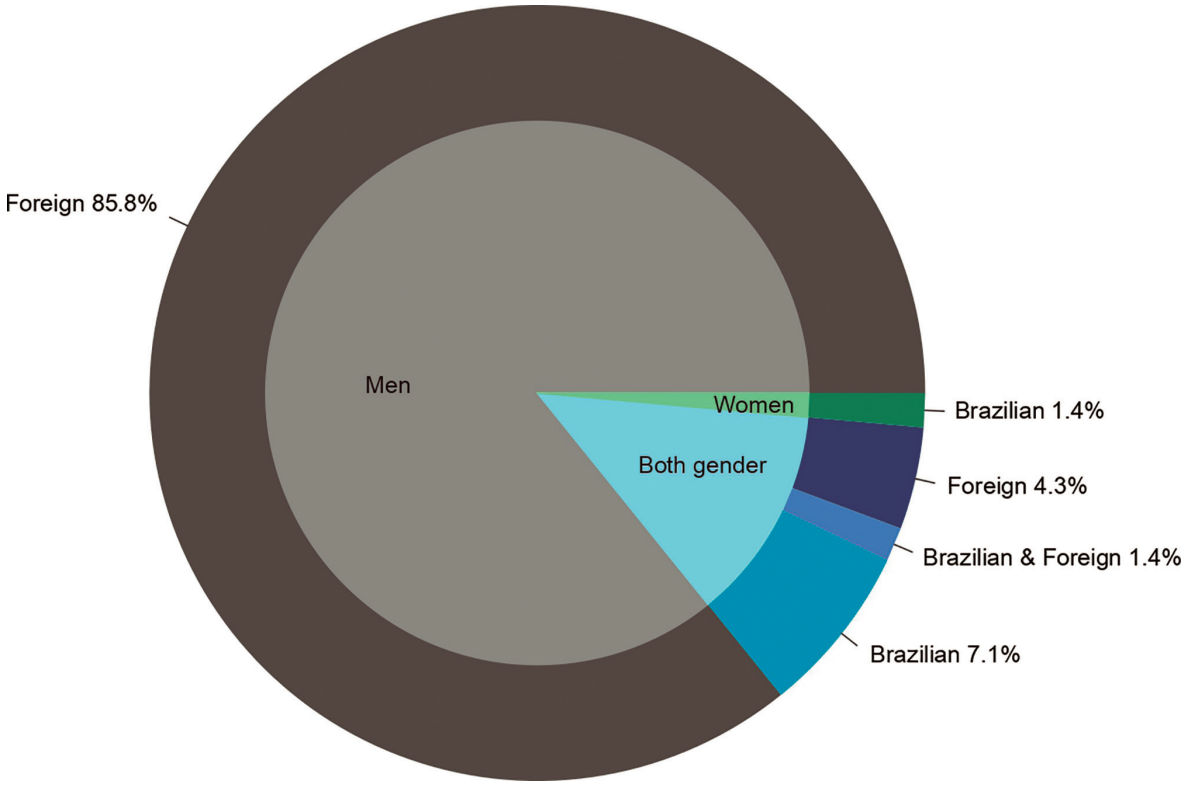

Figure 5: Percentage of species description that currently belong to the tribe Oryzomyini separated in the more external ring by nationality (Brazilian vs Foreign), and in the more internal ring by gender (women, men and both genders).

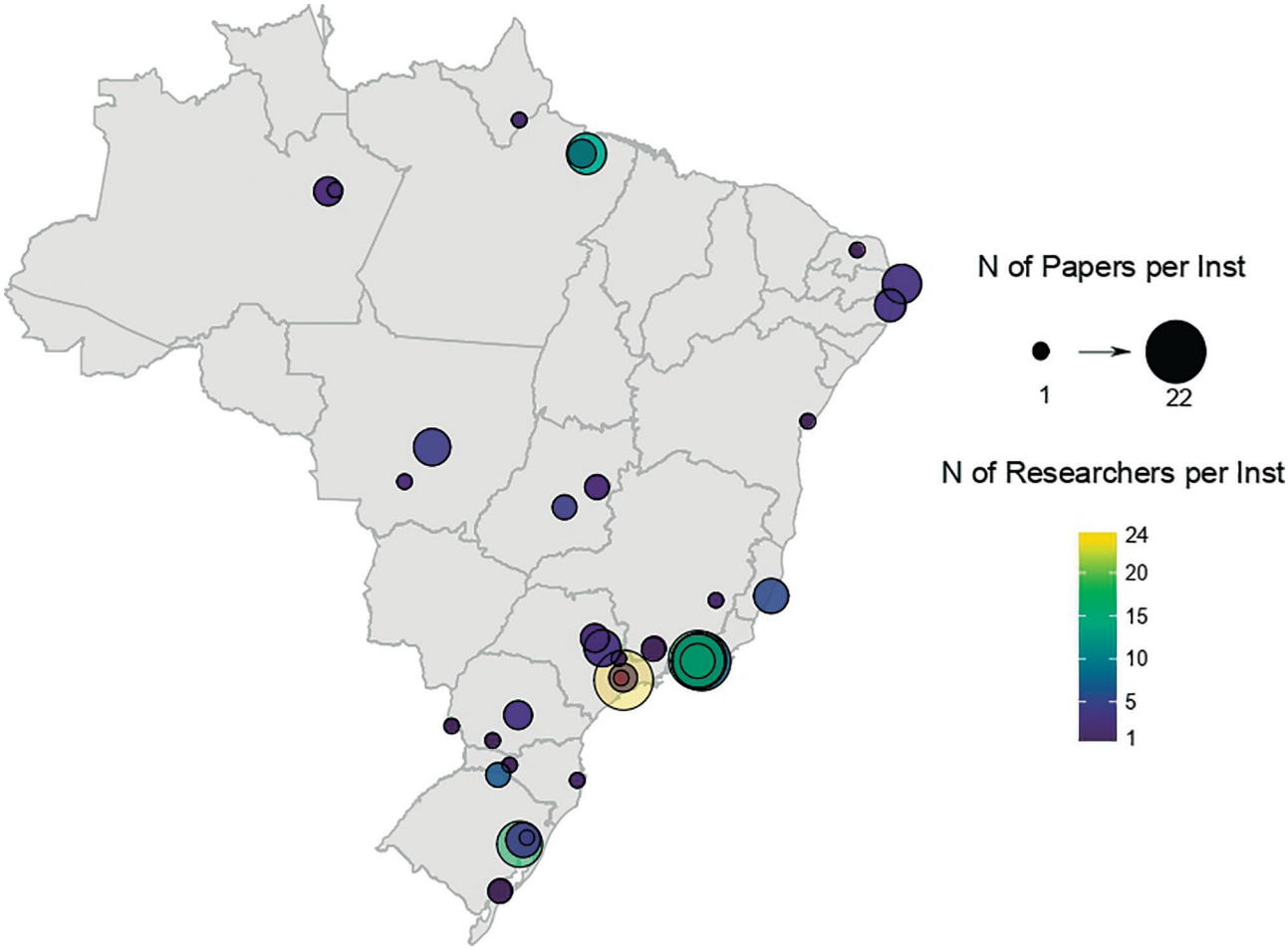

Figure 6: Map of Brazil showing the geographic distribution of the number of authors and papers published per institution in all fields of oryzomyine rodent studies. The difference in the size of the circles represents the increase in the number of published articles, *e.g.,* the larger the circle, the greater the number of published studies, ranging from 1-22; and the range of colors shows the number of researchers per Institution (ranging from 1-24).

with great contribution in the recognition of new taxa are Marcelo Weksler, co-authoring the description of three species while associated to a Brazilian institution (MN/UFRJ), and Alexandre R. Percequillo (USP), with also three species descriptions (Figure 4).

The recent species and genera descriptions involving Brazilian authors are result of 12 publications, of which only three involved also foreign researchers: the description of *Neacomys musseri* and *N. minutus* (Patton *et al.,* 2000), the description of the genera *Aegialomys, Cerradomys, Eremoryzomys, Euryoryzomys, Hylaeamys, Mindomys, Nephelomys, Oreoryzomys, Sooretamys,* and *Transandinomys* (Weksler *et al.,* 2006), and the description of the genus *Tanyuromys* (Pine *et al.,* 2012).

Nevertheless, a very different panorama is observed considering all the 141 oryzomyine valid species (109 described before 1959, and 32 after this year; Figure 5). In this case, 86% of the species were described by foreign researchers, and most of those by male researchers. When we look at the 9% of the diversity that involved Brazilian researchers, there is a balance between the number of men (six) and women (six) authoring the descriptions (Figure 5).

Considering the research categories, Scopus® and Web of Science™ databases retrieved 95 papers from 1980 to 2018 with oryzomyine rodents as the main subject of study and with Brazilian collaborators. Both databases do not archive papers published before 1980. In general, the Brazilian research on Oryzomyini is developed mainly in the states of Rio de Janeiro, São Paulo, Pará and Rio Grande do Sul, whereas there is no record of papers from Roraima, Acre, Rondônia, Mato Grosso do Sul, Tocantins, Maranhão, Piauí, Paraíba, Alagoas, and Sergipe states (Figure 6). In addition, the state of São Paulo has the largest group working with Oryzomyini,

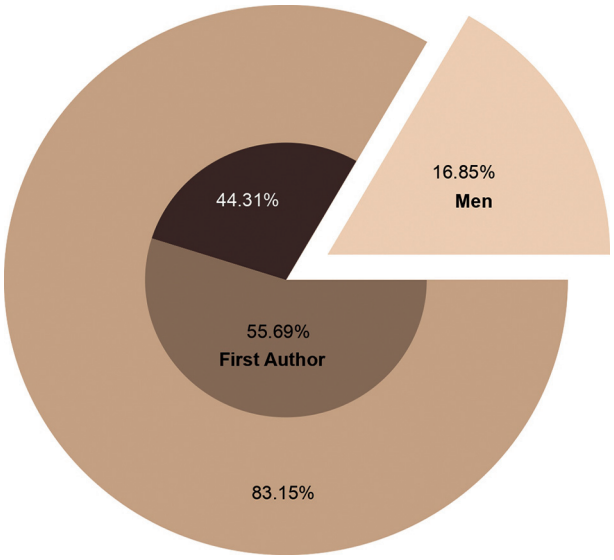

Figure 7: Pie chart showing the percentage of papers published that included woman or not in all fields of oryzomine rodent studies. The more external ring shows the percentage of articles published only by men (16.85%) and the percentage of published articles including women (83.15%). The internal ring highlights the percentage of papers with women as first author (55.69%).

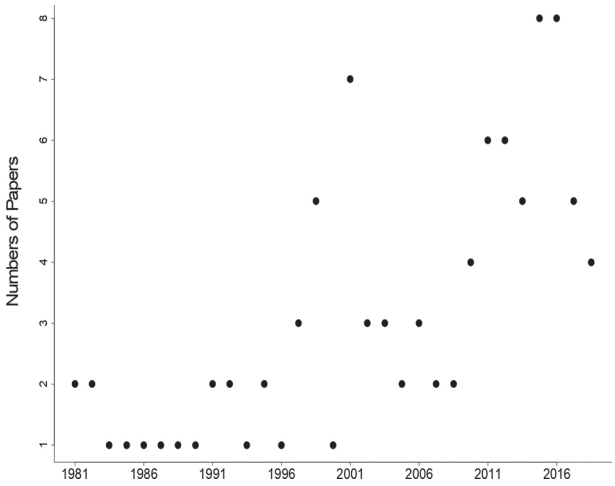

Figure 8: Scatterplot showing the temporal variation in the number of papers published in all fields of oryzomyine rodent studies, per year, from 1981 to 2018.

followed by the states of Rio de Janeiro, Rio Grande do Sul, and Pará.

This scientific production has about 83% of women participation, and more than half of these (55.7%) have a woman as first author (Figure 7). On a temporal scale, after the 2000's the number of papers published per year increased considerable – 81% of the studies were published after 2000. During this period, we noticed two peaks with great publication activity: one between 2001 and 2003, with 13 papers published, and another after 2011 until nowadays, with 46 papers published (Figure 8). The 1980's and 1990's were the less productive decades.

The predominant study subject with oryzomyine rodents is Evolutionary Biology, followed by Genetics, Zoology, and Ecology (Figure 9). Of the selected categories, the fields Anatomy, Behavior, Biodiversity Conservation, Molecular Biology and Physiology were the least studied.

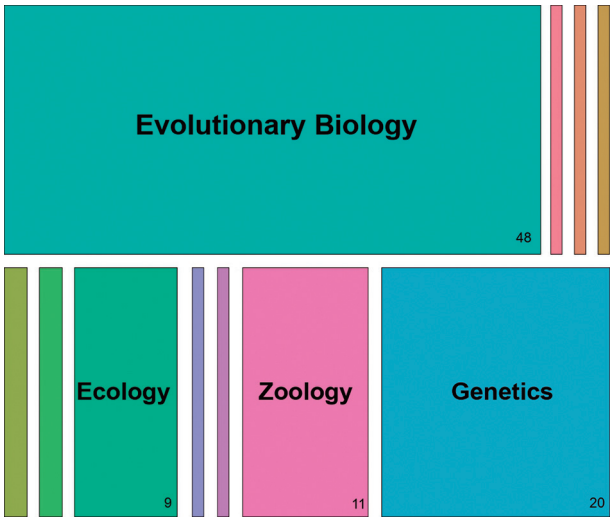

Figure 9: Mosaic plot showing the fields of studies with papers published about oryzomyine rodent. The size of the rectangle is associated with the number of papers classified in this field study category. In the bottom right are the numbers of observation for each category. The narrow bars represent areas of study with two or one observations.

DISCUSSION

The contribution of Brazilian researchers describing new species of Oryzomyini changed during the period from late 1950's and early 1960's. The establishment of the Brazilian federal and state financial agencies (*e.g.,* National Council for Scientific and Technological Development – CNPq, Coordination for the Improvement of Higher Education Personnel – CAPES, States Research Foundations – FAPs) hold up research groups in universities and institutes and helped them to emerge and consolidate as science promoters. As a consequence, in the 80's the Brazilian Society of Mammalogy was created (Cerqueira, 2008). Some research groups became strong and exponents in mammalian taxonomy, including taxonomy of sigmodontine rodents, and the number of studies on Oryzomyini has increased substantially among Brazilian researchers since then (Figure 8).

The understanding of ecology and behavior of rodent species is of great importance since they are probably the most successful mammalian radiation, occupying almost every niche (Patton *et al.,* 2015). In this sense, our study brings a different overview on the description of several traits in natural history and ecology. The novelty of our approach is not in the information itself (which had already been raised and published in the aforementioned studies), but in the way these data are organized here, graphically, visually and quantitatively.

The natural history patterns recovered for oryzomyine species here are similar from those found in Paglia *et al.* (2012), who analyzed only Brazilian species. Oryzomyine rodents are mostly nocturnal and cursorial, and their diet is specially focused in fruits and plants, with few exceptions. However, complementing the data presented in Paglia *et al.* (2012) and others studies (*e.g.,* Pardiñas *et al.,* 2017), we brought these information in diagrams separated by traits and not by species, what gives an idea of the frequency of some trait among Oryzomyini species.

The predominance of inhabiting forested habitats by oryzomyine rodents is related with the evolutionary history of the tribe in South America (Machado *et al.,* 2014; Prado & Percequillo, 2013). Hershkovitz (1962, 1966, 1972) was the first one to examine patterns of differentiation of sigmodontines comparing dwellers of open and forest vegetation. According to Hershkovitz (op. cit), the tribe Oryzomyini was the basal lineage of Sigmodontinae and, in its initial periods of diversification, contained only forest-dwelling, being the base of an evolutionary transition to non-forest habitats. Therefore, the transition to a more open environment occurred different times during the evolution of this group, but the forest was always the major habitat for most of the species (Hershkovitz, 1962, 1966, 1972).

Additionally, very interesting results emerged from our literature survey. One is the concentration of the majority of studies in a few research centers. Brazil has 296 public universities (INEP, 2016), but only six universities and other three institutions have publications regarding the tribe Oryzomyini. The Southeast region of Brazil is the most representative in number of species descriptions and also general studies with Oryzomyini. This fact is directly associated with the presence of the largest museums of natural history (MZUSP and MN/UFRJ), as well as a reflection of the financial investment coming from science-supporting agencies in this region. For example, CNPq invested (CNPq, 2015), in 2015, R$ 1,039,774,000 in fellowships and research fomentation in the Southeast region (43% of the total investment by CNPq), while the North region – location of the *Museu Paraense Emílio Goeldi* (MPEG), the third largest natural history collection in the country (Bezerra, 2013; De Vivo *et al.,* 2014) – received only R$ 73,422,000 (3% of the total).

Another interesting point is the high concentration of studies in Evolutionary Biology, revealing that Brazilian research is still mainly focused on describing process and patterns of diversity. This is an expected pattern for a large, tropical and diverse country, like Brazil. While most other countries (especially those located in temperate zones) are more focused on explaining evolutionary processes that generate diversity, most of our studies are a step before: identifying, understanding, and describing our biodiversity (Percequillo, 2017).

Even with the intense effort in the last decades describing and generating knowledge on oryzomyine species, we still have a lot to do. This is highlighted by the IUCN Red List, where 25% of all oryzomyine have not yet been evaluated, and 10% does not have enough data to be evaluated, and are classified as data deficient (DD, Figure 8).

Our survey also demonstrated that women have the same contribution as men in the Brazilian mammalogy. This result agrees with data provided by CNPq (2015), where women were awarded with 61% of the fellowships provided by the agency in the Biological area in 2015. Data presented here, as well as provided by CNPq, agree that, both in mammalogy and general biological sciences, women have a similar-to-large representation than men. However, even with the largest number of fellowships granted to women, the percentage of Productivity Research Fellowship (*Bolsa de Produtividade*), also provided by CNPq, is still a little higher for men (64%).

Finally, thirty-two years ago, De Vivo (1986) gave us some suggestions to make Latin-American mammalogy more expressive, such as, expanding contacts with foreign researchers but protecting the national productivity, improving collections, increasing geographic representativeness and data sharing, and publishing studies in Brazilian journals, especially those edited by museums.

Brazil made great effort to improve the scientific interchange between local research groups and international groups, through the creation of the program called "Science without borders" – a program created to promote science, technology and innovation in Brazil through international exchange – which was very succeed on its goals (Ramos, 2018). The outcomes of this effort will be soon noticed in the advance of Brazilian science. There are also major advances in data sharing; Brazilian collections are currently indexed in different international databases, such as SpeciesLink (http://splink.cria.org.br) and GBIF (http://www.gbif.org), which

increases the access to such information by foreign researchers (Bezerra, 2013).

However, regarding the publication in Brazilian journals, unfortunately the periodicals of local museums (*e.g., Papéis Avulsos de Zoologia, Arquivos de Zoologia, Boletim do Museu de Biologia Mello Leitão, Boletim do Museu Paraense Emílio Goeldi,* and *Boletim do Museu Nacional*) are not indexed in any important database, such as Scopus®, Web of Science™, and Scientific Eletronic Library Online (SciELO – http://www.scielo.org). The only exceptions are the *Papéis Avulsos de Zoologia* and the *Boletim do Museu Paraense Emílio Goeldi* that are indexed in SciELO. Therefore, most of museum journals present a low impact factor (IF) if any. For example, the Qualis evaluation (*i.e.,* a classification recorded by CAPES and performed by specialized consultant committees, each one focusing on a specific area of knowledge and following different criteria) for these journals varies from B2, in the *Papéis Avulsos de Zoologia,* and B5, in the *Boletim do Museu Paraense Emílio Goeldi,* and C in the others.

As the IF is accepted as a reasonable measurement of the quality of a journal (Meneghini *et al.,* 2008) and researchers frequently seek to publish in prestigious journals (since it influences their career advancement and success in obtaining funding), most of the time, our museum journals are not considered for publication by researchers. Although much effort is being made to improve the quality of the Brazilian journals, as well as the relevance and accuracy of papers, and international visibility (for example the creation of the SciELO programme, in 1997, supported nowadays by São Paulo Research Foundation – FAPESP, Latin American and Caribbean Center of Health Sciences Information – BIREME, and CNPq), they still do not fully solve the problem and we still need to direct efforts to improve the impact of these journals (Meneghini & Packer, 2007).

In summary, although much progress has been made in recent years, Brazilian mammalogy should be more strengthened. Brito *et al.* (2009) argue that one of the most important issues is to understand why most of the researches that are published as poster/oral presentations at congresses do not become a formal publication in scientific journals. In addition, encouraging integration among researchers from different regions could improve the role of Brazilian mammalogy in producing scientific knowledge (Brito *et al.,* 2009). This could be done through the support of our society, the reduction of bureaucratic aspects at the governmental level, but also within institutions, which delay and impedes the progress of research. Increasing financial investment for basic science is also crucial to the development of our field. Support and investment in Natural History Museums, which hold systematic, research, reference, didactics and exhibition collections, and play a central role in the study of animal diversity, as they contain an immeasurable information on biodiversity, as well as historical-scientific documentation, institutional scientific journals, and public exhibitions (Bezerra, 2013; De Vivo *et al.,* 2014).

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We also leave here our deep concern about how our government and society do not decode the role of the public university and do not understand its importance in transforming the community. In addition, we emphasize the importance of strengthening public institutions in both basic and applied science and reiterate the need for us researchers to learn more and more to translate our research into a language that is fully accessible to our community. We are very thankful to Edson Fiedler de Abreu Jr. for careful reading and commenting on early version of the manuscript. We also acknowledge two reviewers and Barbara Maria de Andrade Costa for comments. This study was financed by CAPES (JRP 88887.185904/2018-00 and 88887.336032/2019-00, EAC 88887.311700/2018-00), CNPq (EAC 154219/2018-5), FAPES (JRP 125/2018, EAC 77806336/17).

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ARTIGOS

To stripe or not to stripe? Natural selection and disruptive coloration in two sympatric species of Neotropical marsupials from the genus *Monodelphis* (Mammalia, Didelphidae)

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Abstract: Disruptive coloration, such as striped pelage, is a form of camouflage that breaks out the animal outline and makes it hard to be visually detected in the background. As consequence, it diminishes the chances of being caught by predators and confers adaptive advantage to its possessor, thus being referred as a classic example of natural selection. *Monodelphis microdelphys americana* and *Monodelphis microdelphys iheringi* are small Neotropical marsupials that present similar disruptive pelage pattern with dorsal longitudinal black stripes, which are lost only in adult males of *M. m. americana* when these two species are in sympatry. Here, we investigated the effectiveness of stripes for camouflage in these species following two approaches: (i) visual search test by human volunteers using an Android application; and (ii) natural predation on artificial models made with plasticine. Results showed that presence of stripes decreased detectability of the target when tested by humans and by predators in natural habitat. The predation test also showed that the stripes are more advantageous when combined with a reduced body size. Thus the loss of stripes as a means of camouflage in an adult male of *M. m. americana* (the larger species) should not have a great impact as it would probably have in smaller individuals, such as youngsters and females of both species, or even adult males of *M. m. iheringi* (the smallest species).

Key-Words: Camouflage; Crypsis; Predation; Plasticine model; Visual search.

Resumo: Ter ou não ter listras? Seleção natural e coloração disruptiva em duas espécies simpátricas de marsupiais Neotropicais do gênero *Monodelphis* (Didelphidae, Mammalia). Coloração disruptiva, como presença de listras na pelagem, é uma forma de camuflagem que quebra o contorno da silhueta de um animal, dificultando a sua detecção no ambiente de fundo. Como consequência, diminui as chances de o mesmo ser localizado e atacado por predadores, conferindo vantagem adaptativa ao indivíduo que a possui, sendo, portanto, um exemplo clássico de seleção natural. *Monodelphis microdelphys americana* e *Monodelphis microdelphys iheringi* são pequenos marsupiais Neotropicais que apresentam padrões similares de pelagem disruptiva com listras escuras longitudinais, que são perdidas apenas nos machos adultos de *M. m. americana* quando essas duas espécies estão em simpatria. Neste trabalho, investigamos a efetividade das listras para a camuflagem nestas duas espécies, com duas abordagens: (i) teste de busca visual com humanos voluntários usando um aplicativo para Android; e (ii) predação natural em modelos artificias feitos com plasticina. Os resultados mostraram que a presença de listras diminui a detectabilidade do alvo por humanos e por predadores em ambiente natural. O teste de predação também mostrou que listras são mais vantajosas quando combinadas com tamanho corporal reduzido. Logo, a perda de listras para fins de camuflagem em machos adultos de *M. m. americana* (a espécies maior) não deve ter um impacto tão grande como teria em indivíduos menores, assim como em jovens e fêmeas de ambas as espécies, e até machos adultos de *M. m. iheringi* (a menor espécie).

Palavras-Chave: Busca visual; Camuflagem; Cripsia; Modelo de plasticina; Predação.

INTRODUCTION

Camouflage refers to the ability of to become (almost) undetected in a given background (Stevens & Merilaita, 2009). Several camouflage strategies can be found in nature, including disruptive camouflage, distractive markings, background matching, and countershading, which have been associated with predator evasion (Stevens & Merilaita 2009; 2011). Specifically, disruptive coloration, which is defined as contrasting colors or irregular markings in coloration pattern that creates the appearance of false edges and boundaries, helps disrupting the animal's silhouette as well as parts of its body, hence impairing the chances of being caught by predators (Cott, 1940; Merilaita, 1998; Stevens & Merilaita, 2009; Thayes, 1896).

Disruptive coloration along with background matching have been referred as examples of natural selection outcomes by conferring adaptive advantage (Schaefer & Stobbe, 2006). Several studies show the importance of these patterns in the survival of individuals in different animal groups, including fishes (Chiao *et al.,* 2007; Sazima *et al.,* 2006; Stummer *et al.,* 2004), birds (Sazima, 2010; Speed *et al.,* 2004), amphibians (Lima, 2013; Toledo *et al.,* 2011; Toledo & Haddad, 2009), reptiles (Stuart-Fox *et al.,* 2004) and primates (Kamilar, 2009). Among mammals is common to find cryptic color patterns, including stripes, spots or other types of pelage markings, which have been associated with predator evasion, social communication or camouflage (Cott, 1940; Endler, 1990; Fenton, 1992; Rowland, 1979). Longitudinal stripes are not rare in mammals, albeit animals as different as zebras and bats may present them (Fenton, 1992; Godfrey *et al.,* 1987; Ortolani, 1999). But when it comes to small mammal studies on camouflage are still scarce. Very few observations are made on camouflage and coloration in small mammals (rodents and marsupials) and, when existent, consist on punctual observations, and not case studies that deal more comprehensively with its mechanisms and functions (Stevens & Merilaita, 2011). One exception is the study on the small rodent *Peromyscus,* which has two very distinct color patterns: beach mice with a light dorsal fur, similar to the sand color; and continent mice with a dark dorsal fur, similar to the country fields color where they can be found (Vignieri *et al.,* 2010). As they occur in very dissimilar habitats, experimental studies are possible (Barret *et al.,* 2019; Pelletier *et al.,* 2019). Previous authors have shown, using artificial models, animal survival increases with higher similarity between dorsal fur color and substrate where animals are found (Vignieri *et al.,* 2010).

Another good example of pelage color variation in small mammals is the marsupial *Monodelphis,* the most diverse genera in Didelphidae with 24 species widespread in the Neotropics (Pavan, 2019; Pavan *et al.,* 2017; Pavan & Voss, 2016). Amongst this genus, species from subgenus *Microdelphys* (*M. m. americana, M. m. gardneri, M. m. iheringi* and *M. m. scalops*) stand out for its dorsal black stripes pelage pattern. Species from this group inhabit forested areas in Peruvian Andes (*M. m. gardneri*) and at Brazil in at least three different biomes: Atlantic Forest (*M. m. americana, M. m. iheringi* and *M. m. scalops*); Amazon region on easternmost of Pará State; and within the geographical limits of the Cerrado and Caatinga, apparently exclusively associated with gallery forests and humid-forest patches (*M. m. americana*). Striped *Monodelphis* are terrestrial with diurnal activity and have small body size. Its brown dorsal coloration is similar to the background where it can be found, mostly due to being an animal with semi-fossorial life, which forages under and through the leaf litter in the humid ground of the forest (Emmons & Feer, 1997; Paglia *et al.,* 2012). Ventral coloration varies from beige to orange, both lighter than the dorsal color. The black dorsal striped pattern in this group might be an indication of disruptive camouflage, making it indistinguishable in tropical forests humid and shady ground.

Albeit belonging to the same subgenus and having similar habits, *M. m. americana* and *M. m. iheringi* have differential stripe patterns (intra and interspecific) and body sizes. *Monodelphis m. americana* is larger and its stripe pattern is variable and linked to sexual dimorphism and ontogeny (Duda & Costa, 2015). Adult males of *M. m. americana* display erythrism, its striped tend to gradually disappear and its fur acquires a reddish color (Duda & Costa, 2015). On the other hand, this variation was not found in *M. m. iheringi,* in which stripes remain through life in both sexes (Duda & Costa, 2015). Apparently, stripe pattern changes on *M. m. americana* only occurs when it is in sympatry with *M. m. iheringi* – as reported by Duda and Costa (2015) at Reserva Biológica de Duas Bocas, Espírito Santo, Brazil. Thus, stripe loss on *M. m. americana* may indicate that sexual selection outweighs natural selection, making males lose their stripes and become more conspicuous than their striped kin (Duda & Costa, 2015). Although striking, the occurrence of stripes and its role in camouflage and communication in Neotropical small mammals are still poorly understood. Pavan *et al.* (2014) suggest that pelage color pattern in *Monodelphis* and habitat are supposedly linked, but there is still lack of empirical tests to investigate this association and the role of dorsal striped pelage in *Monodelphis* species.

Here, we investigated the effectiveness of stripes in pelage of *M. m. americana* and *M. m. iheringi* for camouflage. We used empirical tests to assess the ability of the stripes in diminishing the animal's detectability and its effectiveness in evading from predators in natural habitat. For that, we compared predation rates on artificial models with and without stripes and with different body sizes. Additionally, we assessed the influence of ecologic and environmental factors on predation rates, through analysis of activity periods and seasonality.

METHODS

Experiment 1. Visual search test using Android application: In order to test the visual perception of

Monodelphis stripes camouflage by human volunteers, we developed an Android application (app) that showed a picture of a plasticine model, very similar to individuals of *M. m. americana* and *M. m. iheringi,* in a natural background, and prompted the participating volunteer to visually find the model and click on it. Models with and without stripes of the same size were photographed on top of natural leaf litter background, in several quadrants of the frame, keeping the same distance between the camera and the object, in a period of 30 minutes of a sunny day as to avoid the influence of light intensity in the experiment. A total of 20 pictures were included in the app, half displaying striped models and the other half models without striped. Before the test, we showed volunteers images of both artificial models (striped and non-striped) to provide a search image. During the test, five pictures of each model were randomly showed, and volunteers were asked to try to find the target in the image. Whenever the volunteer tapped the screen (Figure 1), regardless of hitting the right target or not, it was taken to the next picture. For each volunteer, the time of response (*i.e.,* the time needed to tap the screen) and the place where the screen was tapped was recorded. Results were saved for subsequent analysis. This experiment was conducted in a Tablet Motorola Zoom Media Edition, with an 8.2" screen. A total of 80 non-specialist volunteers were asked to perform this experiment without knowing the hypothesis being tested. Records were then organized into four-time scenarios: (i) captures with the maximum time of five seconds, (ii) captures with the maximum time of 10 seconds, (iii) captures with the maximum time of 15 seconds and, (iv) captures with no time limit.

Experiment 2. Predation on artificial model test: The study was conducted at Reserva Biológica de Duas Bocas, a protected area located in the southeast region of Espírito Santo, between latitudes 20°14'04" and 20°18'30"S, and longitudes 40°28'01" and 40°32'07"W (Datum WGS84). It has an area of 2,910 ha and the elevation ranges from 300 to 738 m. The climate is tropical humid, with mostly primary forest (Tonini *et al.,* 2010). This area was chosen because it is the natural habitat of two species of the striped *Monodelphis: M. m. americana* and *M. m. iheringi.* They co-occur in this area and both were captured in a previous study (Tonini *et al.,* 2010). We used four of the six transects used by Tonini *et al.* (2010).

Artificial models of *Monodelphis* were handmade using nontoxic plasticine (Acrilex® odorless play dough) in order to represent striped and uniform forms, in two different sizes: a smaller model with body measurements similar to male adult individuals of *M. m. iheringi* and young individuals of *M. m. americana* (~ 9 cm); and a larger model with body measurements similar to male adult individuals of *M. m. americana* (~ 11.5 cm) (Figure 2). Plasticine is commonly used for this type of test because it is a soft modeling material able to preserve predation and attack marks, allowing to link the attacks to great groups (birds, mammals, snakes) (Bateman *et al.,* 2017; Brodie, 1993; Niskanen & Mappes, 2005).

The artificial models were deposited in four previously delimited transects, with a test station implemented at every 10 m with an equal ratio of individuals with and without stripes of both sizes, deposited directly over the leaf litter. We implemented 44 stations, with four models each, displayed radially at a distance of 3 m

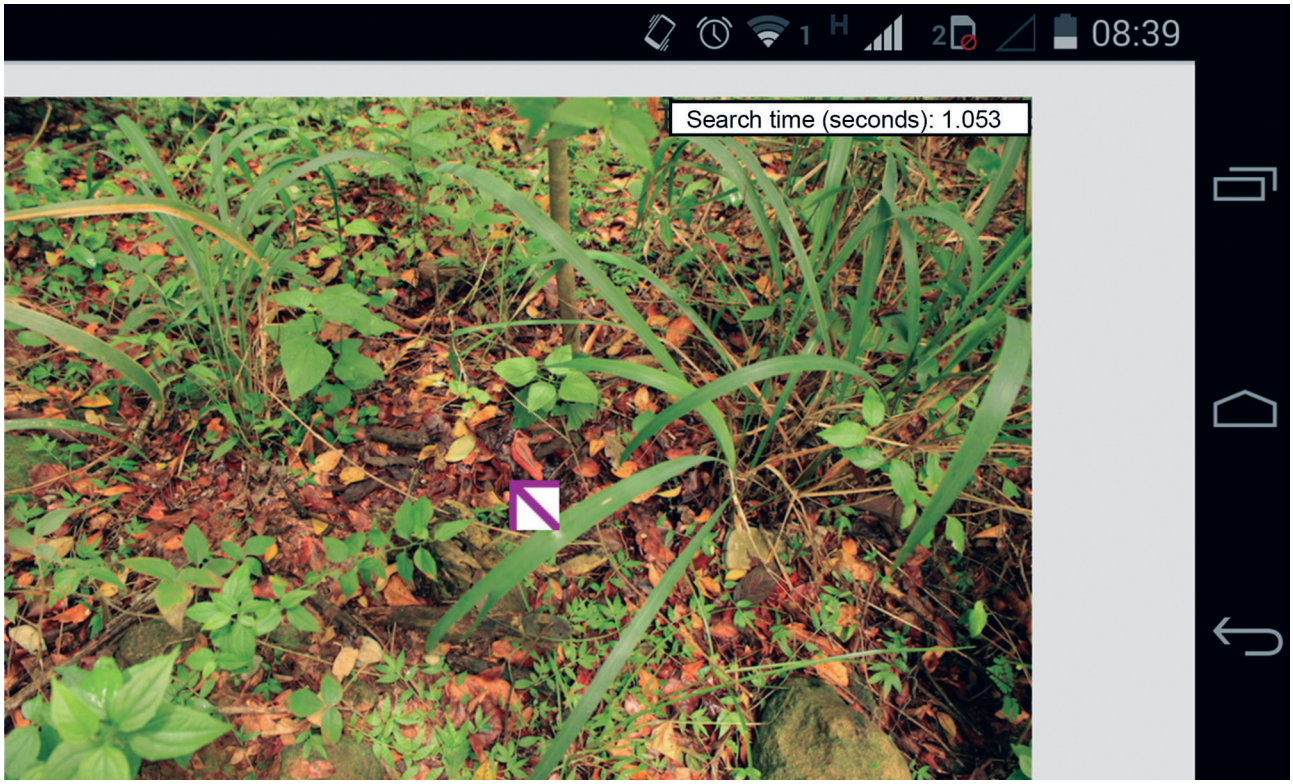

Figure 1: Screen shot of the application showing where the volunteer tapped (pink arrow) and how long it took to locate the model (search time in seconds).

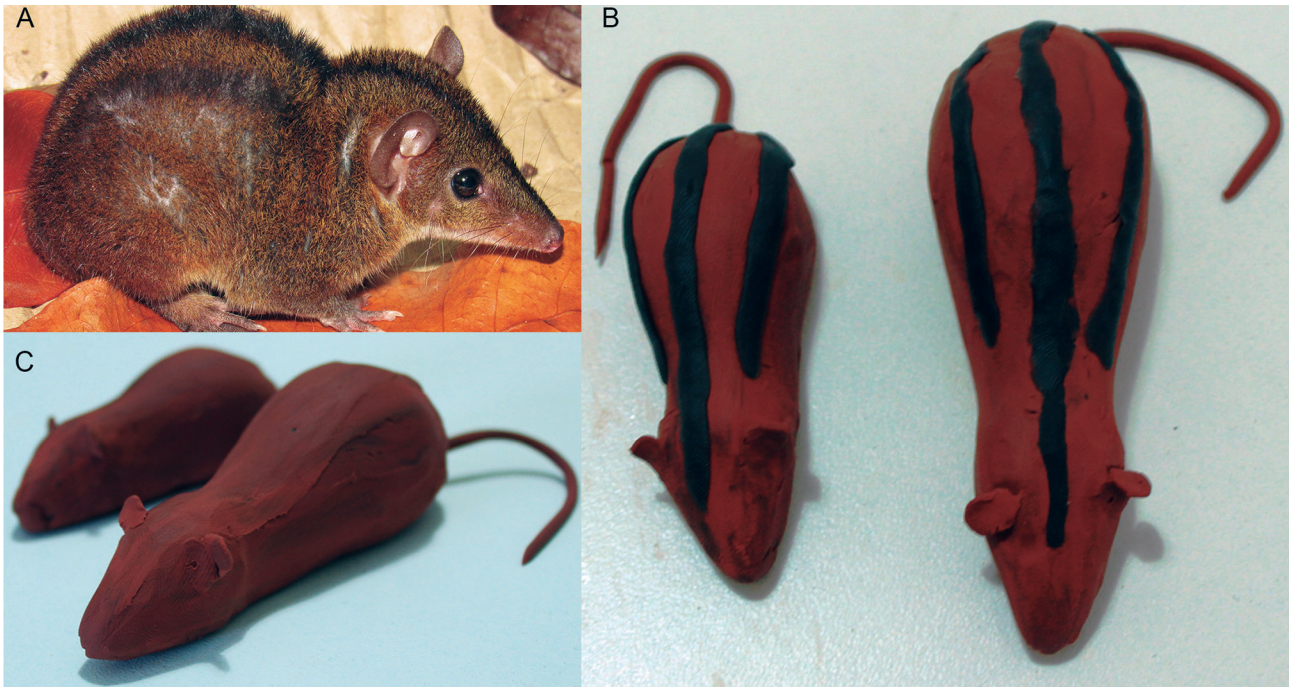

Figure 2: (A) Live animal used as a model to make the artificial prey; (B) dorsal view of plasticine models with stripes. (C) Lateral view of plasticine models without stripes.

from the central spot. During a period of 10 consecutive days, models were checked for predation marks during the early morning and late afternoon, to discriminate nocturnal and diurnal predatory activity, respectively. Damaged models and models that were not found were replaced by intact models of the same color and size. We conducted four test campaigns between January and September of 2013.

We also conducted an extra campaign in September of 2013, in which we left artificial models free of human interference for 14 days, in order to verify if the researchers presence along the transects was intervening with the predation rate. The results of this extra campaign were not computed for the statistical analysis, considering that the methodology was different from the other campaigns.

Multiple attack marks were considered as a single attack, due to the possibility of belonging to a single individual. Models that were not found were classified as ambiguous data because they could be result of the inability of the researchers to locate them. Only unambiguous marks were considered a predatory attack. Marks made by insects such as ants were not considered a predatory attack and, therefore, were not included in the analysis.

Data analysis: For the data analysis of the app experiment, we used the Wilcoxon's test to assess the significance of the hit rate and capture time, following the methodology used by Fraser *et al.* (2007).

For the data analysis of the artificial model experiment, we followed the methodology used by Brodie e Janzen (1995), Kutcha (2005), Noonan e Comeault (2009) and Vignieri *et al.* (2010). The ratio of preyed striped and uniform models was calculated as a percentage (the number of attacked striped or uniform models compared to the total attacked models) and the significance measured using G test with an expected ratio of 1:1.

Selection force was estimated through the Selection Index (SI; Dice, 1949) that quantifies relative survival of two phenotypes, initially in equal abundance. This analysis was performed considering: all phenotypes together, large models only, small models only, and also taking into account humid season (January/May) and dry season (July/September).

RESULTS

Experiment 1. Visual search test: The app test was conducted with 80 volunteers, yielding 800 photo-tests, half of those displaying striped models and half models without stripes. The error rate is inversely proportional to the response time, with an increased error up to 39.5% and 24% for detecting striped and uniform models during a period of five seconds (Table 1). Photos with striped models always yielded to higher error rate (Table 1).

The longest time it took to detect a model without stripes was 61 seconds, while the longest time to detect a striped model was 127.35 seconds (Figure 3). Wilcoxon test show that average time to detect a target is statistically different ($p > 0.0001$) in every scenario, and volunteers took more time to detect striped models than uniform models. Average time to detect models without stripes remains approximately the same in all four-time scenarios, while average time to detect striped models increased when volunteers were given more time (Figure 3).

Experiment 2. Predation test: After an effort of 6160 models-night, we recorded only 43 attacks, which

Table 1: Number of hits and errors in locating the models, striped and uniform, by the volunteers using the Android app, considering four different time limit scenarios, with each respective percentage regarding total hits.

		Errors	%	Hits	%
No time limit	Uniform	9	2.25	391	97.75
	Striped	20	5	380	95
Under 15s	Uniform	33	8.25	367	91.75
	Striped	52	13	348	87
Under 10s	Uniform	55	13.75	345	86.25
	Striped	75	18.75	325	81.25
Under 5s	Uniform	96	24	304	76
	Striped	158	39.5	242	60.5

represent 0.70% of the total effort of models disposed in the environment. Of these 43 attacks, 13 were in large striped models, 17 were in large uniform models, 3 were in small striped models, and 10 were in small uniform models. Based on attacking marks on the models we were able to identify some predators such as birds and rodents (Figures 4 and 5).

The survival rate was smaller in uniform models, which accounted for 61% of the attacks, showing a significantly higher predation rate (G = 8.42; p = 0.003). Considering the body size within the same group (with and without stripes), larger models were always more attacked: 63% of the uniform models were large and 37% small; whereas of the striped models, 81.25% were large and only 18.75% were small (Figure 5). The selection index (SI) did not show a big disadvantage for uniform models when we consider all sizes (SI = 0.22, x^2/df = 2.96), but if we analyze only the small models, that index showed a great selective disadvantage for not having stripes (SI = 0.6363, x^2/df = 4.4857). When we analyze only large models, selection index was also not significant (SI = 0.1333, x^2/df = 0.5370) for the absence of

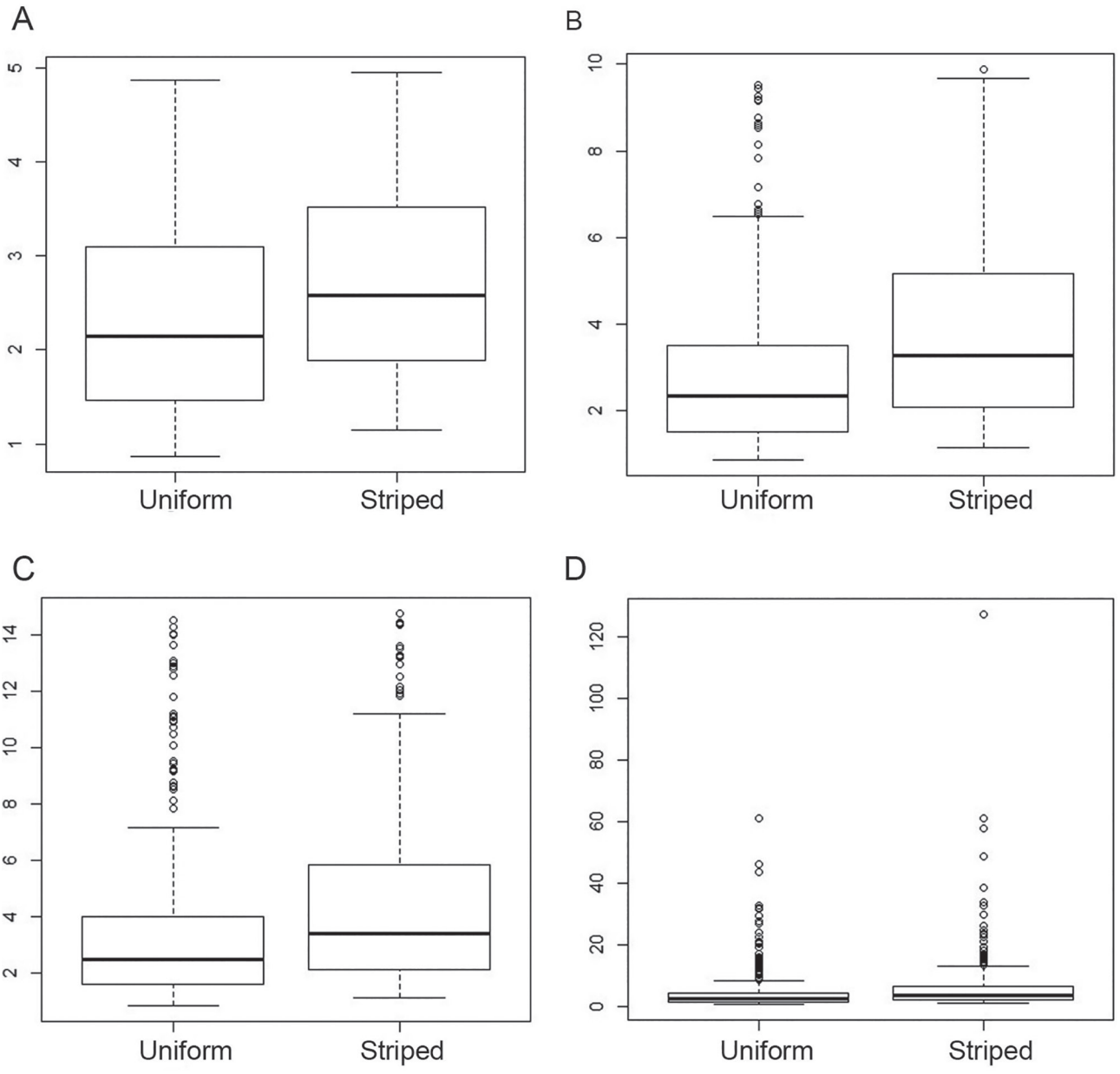

Figure 3: Box plots displaying detection time of uniform models and striped models in four different time scenarios. (A) Detections under 5 seconds; (B) under 10 seconds; (C) under 15 seconds; (D) no time limit.

Table 2: Selection Index (SI) and chi-squared by size, for presence or absence of stripes.

	Large	Small
SI for presence of stripes	SI = -0.1333	SI = -0.6363
	x^2/df = 0.5370	x^2/df = 4.4857
SI for absence of stripes	SI = 0.1333	SI = 0.6363
	x^2/df = 0.5370	x^2/df = 4.4857

stripes (Table 2). When we look only at the size variable, the larger body was shown to be significantly disadvantageous (SI = 0.4634, x^2/df = 8.86), and most of the attacked models were in this category (73.17%) (Table 3, Figure 4).

Results from campaigns during humid (January and May) and dry (July and September) seasons were different. In the humid season, there was a significantly higher predation rate of non-striped models over the striped ones (16 and 6 respectively), whereas during dry season this difference was not observed (Table 4). Regarding body size, larger models were always more attacked, regardless of the season. In humid season, attacks in large models exceeded in twice the numbers of attacks in small ones, whilst in the dry season that number is even larger, with the large models being attacked four times more frequently than the small ones. Even though those numbers are high, the selection index was only significant for the dry season. As for the differential predation, regarding nocturnal and diurnal periods, there was no significant difference, as the morning rounds resulted in a total of 24 attacks (58% of the total attacks), whilst the afternoon rounds reached a similar value (42%), albeit slightly smaller in total numbers (17).

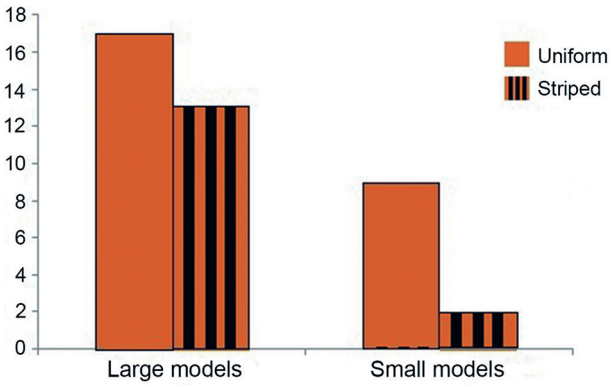

Figure 4: Number of attacked models sorted by size and presence of stripes. Results for large models are on the left and for the small models are on the right.

Table 3: Total number of models displayed (Nmodels), number of attacked models in each campaign, sorted by size (large and small) and disregarding stripes, as well as its selection index (SI) and chi-squared. Significant values are marked with *.

Campaign	Nmodels	Large	Small	SI against being large	x^2/df
January	1408	5	6	-0.0909	0.091
May	1584	10	1	0.8181	*7.41
July	1584	12	0	1	*12.08
September	1584	3	4	-0.1428	0.14
Total	6160	30	11	0.4634	*8.84

Table 4: Total number of displayed models (Nmodels) sorted by season (humid season corresponds to campaigns in January and May; dry season corresponds to July and September), number of models attacked sorted by presence or absence of stripes (above lines) and sorted by body size (below lines), SI against absence of stripes and against larger body size, with respective chi-squares. Significant values are marked with *.

Season	Nmodels	Attacked models		SI against absence of stripes	x^2/df
		Uniform	Striped		
Humid	2992	16	6	0.4545	4.57*
Dry	3168	10	9	0.0526	0.053
		Large	Small	SI against large body size	
Humid	2992	15	7	0.3636	2.929
Dry	3168	15	4	0.5789	6.413*

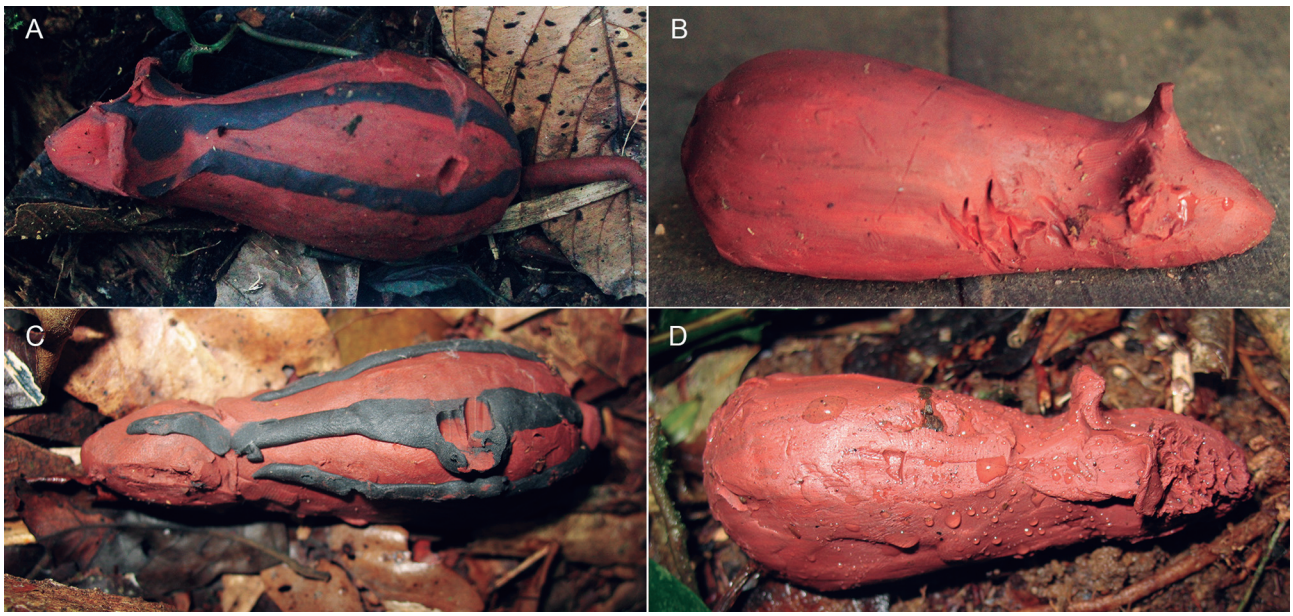

Figure 5: Examples of attacked models both on striped (left) and uniformly colored (right) models. (A and B) Attack markings identified as bird markings; (C) Attack markings identified as rodent markings; (D) Unidentified attack markings.

DISCUSSION

Stripes as a disruptive pattern: The results of our research showed that the presence of disruptive markings decreased detectability of the target when tested by human volunteers. The error rate to identify striped models was higher in all-time scenarios analyzed, particularly when the cutting point was five seconds. Similarly, the target detection time by volunteers was significantly different in all scenarios, taking longer to detect striped models. It is also important to highlight that the average time to detect models without stripes remained about the same in all time scenarios, while time to detect striped models increased according to the time limit.

Our results go against the results found by Stevens *et al.* (2011), who registered more frequent capture of striped objects instead of objects that showed a color similar to its background. However, Stevens *et al.* (2011) used two-dimensional and geometrical objects, and the models used here were three-dimensional and were placed in a natural background, which may have influenced the difference in the results. Indeed our results support the idea that the presence of dark stripes would create false edges and consequently impair the detection of an object (Cuthill *et al.,* 2006; Stevens, 2007). However, as possible predators have different visible spectrum, including UV vision (Caro, 2005; Fraser *et al.,* 2007), further ecological and behavioral aspects need to be access in order to better understand if *Monodelphis* striped pattern is an efficient camouflage for a broad range of predators.

Differential evasion of predators: Our study showed that further from just making detection more difficult, the presence of stripes give an adaptive advantage to individuals in evading predation. We showed that models with stripes were less attacked than its uniform counterpart. As pointed out by Helversen *et al.* (2013), from an evolutionary point of view, a slight increase in survival rate can result in a great selective pressure, referring to Haldane's mathematical theory of natural selection (Haldane, 1927).

Although the presence of stripes helps to evade predation, it is noteworthy that body size has a great importance on the individual's survival given that 70% of attacked models were in large models. If we take in consideration only large models, the difference in the attack rate of striped and uniform models was smaller and not significant than the one found in small models, leading us to believe that body size plays an important role in how easily the animal can be spotted in the environment. In fact, the adaptive advantage of stripes was higher if we considered only small models (SI of 0.53). These results suggest that stripe lost would have a more negative impact in smaller individuals rather than in larger ones. Thus the loss of stripes as a means of camouflage in an adult male of *M. m. americana* (the larger species) should not have a great impact as it would probably have in smaller individuals, such as youngsters and females of both species, or even adult males of *M. m. iheringi* (the smallest species).

In several species, such as tapirs (*Tapirus terrestris*) and several deer species (*e.g., Odocoileus virginianus, Dama dama, Cervus elaphus*), stripes are only found in youngsters. This is also true for young individuals of *M. m. americana,* in which males and females have stripes in early life, but adults males tend to lose them as they grow sexually mature. Interesting this occurs when *M. m. americana* and *M. m. iheringi* occur in sympatry, suggesting that stripes play a considerable role in intraspecific recognition (Duda & Costa, 2015). The loss of stripes observed in adult males of *M. m. americana,* when in sympatry with *M. m. iheringi* might be explained by sexual selection, making it easier for females to recognize male partners of the same species (Duda & Costa, 2015). This color variation can possibly be due to a balance in differences of predation risks, sexual selection and the recognition of potential partners (Deutsch, 1997; Endler, 1978), in which the females, responsible for maintaining the offspring (Pough *et al.,* 2008; Reynolds *et al.,* 2002), keep their stripes. However, this hypothesis would need specific testing to associate the presence and absence of stripes and intra/interspecific recognition between these species of *Monodelphis.*

Additionally, we found differences in attack rates between seasons. During the humid season, uniform models were significantly more predated than striped models. During the humid season, the forest ground becomes darker due to higher humidity, which probably makes striped models even more hidden in the background. In contrast, during the dry season, the ground becomes clearer, making both models stand out in the background, as showed by the similar attack rates between striped and uniform models. Larger models were significantly more predated in the dry season regardless of the presence or absence of stripes. This result corroborates the hypothesis that the loss of stripes in adult males of *M. m. americana* would not have a large impact on their survival rate.

Finally, our results did not allow us to distinguish predatory activity throughout different periods of the day. We found no significant difference between the number of attacks during the night and morning periods. Although, the presence of stripes in small mammals has been associated with species with peaks of activity during the day, such as squirrels of the genus *Tamias* (Wilson & Ruff, 1999), our results are in agreement with reports on the natural history of the genus *Monodelphis.* Even though more often described as diurnal (Davis, 1947; Nitikman & Mares, 1987), some species of the genus, such as *M. m. scalops* (Massoia *et al.,* 2000) and *M. m. americana* (Goeldi, 1894), also present nocturnal activity, and can, therefore, be preyed on both shifts without distinction.

Here we show evidence of the role of disruptive camouflage in decreasing the detectability of prey. We also show the efficacy in using human volunteers as model predators for testing camouflage hypotheses using a controlled foraging environment. Field tests support the influence of stripes on the predation rate of the models by real predators (not necessarily specific predators of *Monodelphis*), especially on small size models.

Large models are more easily detected, regardless of the presence or absence of the stripes, while in small models stripes have a great impact on avoiding detection of the models. The results with plasticine models in the field, especially for small models, were similar to tests with human volunteers. This is relevant because the results with human volunteers are undoubtedly a result of failure to detect, whereas detectability in the field is inferred as the cause of the difference in predation rates. This does not detract from the importance of further fieldwork in order to provide ecological validation, showing how real predators would behave in an environment with varying lighting and substrate conditions. In addition, experimental studies with controlled ecological context can contribute to the understanding of evolutionary forces under disruptive coloration patterns in two sympatric species of *Monodelphis.* Furthermore, our results suggest that if the loss of stripes in adult males of *M. m. americana* confers advantage from a sexual selection perspective by allowing them to be differentiate from sympatric *M. m. iheringi,* it seems to not confer disadvantage from the natural selection perspective, given that predation rate were not affect by loss of stripes in adults models.

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Addressing gender disparity in speaking opportunities at the Brazilian Congress of Mammalogy

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Abstract: We investigated the proportion of female speakers in four different categories of presentation at the Brazilian Congress of Mammalogy (CBMz), and the associated representativeness by Brazilian regions. We found a significant disparity in the proportion of female speakers across presentation categories and geographic regions throughout the nine CBMz editions. Remarkably, as visibility increases along with the categories of presentation, the proportion of female speakers disproportionately decreases, indicating that women are underrepresented in the most prestigious categories. Our results highlight the importance of such quantitative estimates of gender disparities in scientific Brazilian conferences and the urgent need to provide equal opportunities in speaking roles. We discuss potential factors leading to the observed gender bias and recommend practical actions for conference organizers and attendees to promote gender equitability in future scientific meetings.

Key-Words: Academic conferences; Conference presentations; Equal opportunity; Scientific visibility; Women in science.

Resumo: Desigualdade de gênero em apresentações orais no Congresso Brasileiro de Mastozoologia. Investigamos a proporção de mulheres palestrantes em quatro diferentes categorias de apresentação oral no Congresso Brasileiro de Mastozoologia (CBMz), e sua representatividade por regiões brasileiras. Encontramos disparidade significativa na proporção de mulheres palestrantes em todas as categorias de apresentação e nas regiões geográficas ao longo das nove edições do CBMz. A proporção de mulheres palestrantes diminui consideravelmente a medida que a visibilidade aumenta ao longo das categorias de apresentação, indicando que as mulheres estão sub-representadas nas categorias de maior prestígio. Nossos resultados destacam a importância de estimativas quantitativas sobre disparidades de gênero em conferências científicas brasileiras e a necessidadae de oferecermos oportunidades iguais em papéis de fala. Discutimos os fatores potenciais que levaram ao viés de gênero observado e recomendamos ações práticas para os organizadores e participantes do evento promoverem igualdade de gênero em futuras reuniões científicas.

Palavras-Chave: Conferências acadêmicas; Apresentações em conferências; Oportunidades iguais; Visibilidade científica; Mulheres na ciência.

INTRODUCTION

Despite the increasing number of women in scientific fields over the last decades (Ceci *et al.,* 2014), empirical studies on gender inequality have shown that female scientists are still underrepresented as academic authors, editorial board members, reviewers, prestigious award winners, and conference speakers (Bornmann & Daniel, 2005; Casadevall & Handelsman, 2014; Davenport & Snyder, 1995; Débarre *et al.,* 2018; Ferber & Brün, 2011; Ford *et al.,* 2018; Isbell *et al.,* 2012; Jones *et al.,* 2014; Kretschmer *et al.,* 2012; Schroeder *et al.,* 2013; Smith & Kaufman, 1996; Wellenreuther & Otto, 2016; Wennerås & Wold, 1997). The visibility of women in science and academia is paramount, as it might encourage other women to feel included and represented in those domains and can further help determine whether they are interested in pursuing scientific and academic careers. Scientific visibility results partly from attending and presenting research at organized conferences and meetings (Carter *et al.,* 2018; Casadevall & Handelsman, 2014; Débarre *et al.,* 2018; Ford *et al.,* 2018; Holman *et al.,* 2018; Jones *et al.,* 2014; Martin, 2015; Schroeder *et al.,* 2013; Wellenreuther & Otto, 2016). In any stage of the scientific career, attending and presenting research at scientific meetings are ways to exchange

ideas, expand professional networks, spread scientific results among colleagues and seek collaborators. In particular, giving talks and presenting research as an invited speaker during conferences is important for academic advancement, especially for improving communication skills, finding academic/job positions, receiving grants, prizes, and recognition within the scientific community (Casadevall & Handelsman, 2014; Débarre *et al.,* 2018; Ford *et al.,* 2018; Jones *et al.,* 2014; Schroeder *et al.,* 2013).

Previous studies have shown that women are significantly underrepresented among invited speakers at scientific conferences (Débarre *et al.,* 2018; Ford *et al.,* 2018; Isbell *et al.,* 2012; Kalejta & Palmenberg, 2017; Schroeder *et al.,* 2013), and such inequality has been reported in all areas of science, technology, engineering, and mathematics (STEM). Moreover, different studies have suggested that the proportion of female speakers depends on the gender of the conference organizers, resulting in fewer women invited as speakers when conveners are all male (Casadevall & Handelsman, 2014; Débarre *et al.,* 2018; Gurevitch, 1988; Isbell *et al.,* 2012; Kalejta & Palmenberg, 2017; Klein *et al.,* 2017; Sardelis & Drew, 2016). The present state of quantitative knowledge on gender disparities in Brazilian scientific conferences is incipient, as are discussions, debates, and proposals regarding the reduction of such inequalities. There is, thus, strong demand for quantitative estimates of the female speaker representation at scientific conferences in Brazil, to get a consistent picture of the current situation. In this contribution, we focus on mammalogy as a case study, since the authors' own research is grounded on evolutionary, ecological and systematic approaches using this group as a model.

The Brazilian Society of Mammalogy (SBMz) was established in 1985 (Cerqueira, 2005), and for over thirty years it has played a key role in encouraging and disseminating the study of mammals in Brazil. In 2001, the SBMz organized the First Brazilian Congress of Mammalogy (CBMz), hosted in Porto Alegre, Rio Grande do Sul state. Since then, this event has taken place usually every two years in different Brazilian states covering all areas of mammalogy and assembling an expressive number of researchers from different regions. An analysis of abstracts published in the proceedings of the CBMzs over these years offers a good sample of the proportion of female speakers in the different presentation categories at the Brazilian Congress of Mammalogy, as well as their representativeness in different Brazilian regions. Additionally, such a database provides estimates of women's visibility in Brazilian Mammalogy.

In this study, we set out to answer the following questions: (1) are there differences in the proportion of female and male speakers within and across different oral presentation categories representing a gradual increase of visibility? (2) If so, is the level of gender disparity similar across Brazilian regions or are there regions where this inequality is more pronounced? (3) How did the proportion of female speakers vary over time across presentation categories?

MATERIALS AND METHODS

We surveyed the proceedings for all CBMz editions representing nine years: 2001, 2003, 2005, 2008, 2010, 2012, 2014, 2015 and 2017. The gender of each participant was inferred from the first name registered in the proceedings. Whenever gender characterization directly from names was ambiguous, we performed a Google search for images using the participant's full name. If images of only one gender were found, then that gender was assigned to the participant. In those cases where only the surname was available, a search for the author's citation surname associated with the keyword "mastozoology" and the year of the conference attendance was conducted in order to confirm the participation in that edition. The participant was excluded from the analysis whenever the citation name and/or image searching were inconclusive or dubious. It should be mentioned that the gender classification used here is binary (female/woman; male/man) and therefore does not encompass the whole spectrum of human gender identity (see Dess *et al.,* 2018).

We grouped the types of presentation into four categories characterizing a gradual increase of visibility, as follows: (1) oral presentation, (2) roundtable or symposium, (3) plenary talk and (4) special talk. These categories were established according to the exposure time of the speaker and the competition for audience. For example, a typical oral presentation has a total duration of 15 minutes (12 minutes are used for the presentation itself and three minutes for questions, discussions, and transitions). This category is usually a voluntary contribution from the author, is subject to the acceptance of a scientific committee and tends to occur concomitantly with presentations in other panels; so, the conference attendees must choose between different presentations given simultaneously. This category represents the lowest visibility among all types in our study. We combined symposia and roundtables into one single category because they present similar structures and especially because data for both were not systematically available in the proceedings for all editions allowing a coherent comparative analysis over time. This category is composed by a given number of specialists focused on discussing a certain topic in their area of interest. Usually, roundtables include the speakers and a coordinator, who is responsible for mediating the discussion. Plenary talks include different invited speakers every day and are scheduled at a time when everyone can attend. Finally, special talks represent the highest category in terms of visibility, spanning 60 minutes of exposure with no competition for the audience during the lecture. For this category, conference organizers invite different speakers to open and close the conference.

To evaluate gender disparity in the proportion of speakers among Brazilian regions we registered the author's affiliation and used the official division of the Brazilian territory into five regions (North, Northeast, Central-West, Southeast, and South).

We combined the data from all editions in order to analyze the attendance of women on CBMz editions

quantitatively. Analyses of differences in the percentage of women within each edition were not performed due to insufficient sample sizes available. Thus, the data was assembled by calculating the overall ratio of female speakers to all participants as follows: women participation = women/(men + women).

First, we tested whether the proportion of women was different across types of presentation (oral presentation, roundtable or symposium, plenary talk, and special talk) using a Fisher's exact tests (function fisher.test in the "stats" package for R; R Core Team (2019)). The null hypothesis for this test is that there is no association between the categories of presentation and the percentage of female speakers. If the null hypothesis was rejected, we performed Fisher tests for pairwise comparisons between categories of presentation in order to investigate which categories had statistically significant differences in the proportion of female speakers. For that purpose, we used the function pairwise.fisher.test from the R package "reporttools v1.1.2", applying Bonferroni correction for multiple comparisons. The same statistical approach was used to investigate gender disparities in the proportions of speakers across Brazilian regions.

Besides investigating the difference in the percentage of female speakers across categories of presentation, we also sought to evaluate whether the percentage of women in each category was in agreement with the overall percentage of women attending or who had subscribed to the conference. A complete list of participants was available only for five editions, covering the years of 2010, 2012, 2014, 2015 and 2017; for those, the percentage of woman subscribed as participants was always higher than 50%. In order to adopt a more conservative approach as we did not have data available to all conference editions, we compared the percentage of women in each category of presentation with 50%, as this is the most parsimonious gender ratio expected for a given population (50:50 sex ratio). Accordingly, we used Fisher's exact tests to compare the percentage of women in each category of presentation with the expected probability of 50%.

Finally, we evaluated the attendance of women to CBMz over time, from 2001 to 2017, by plotting the percentage of female speakers as a function of presentation categories. We did the same considering the percentage of female speakers as a function of Brazilian states from 2001 to 2017. As the roundtable category is composed of different speakers and a coordinator, we explored the proportions of roundtables composed of (1) exclusively men, (2) exclusively women and (3) both men and women (mixed) over time. Additionally, we investigated whether the proportion of women assigned as coordinators or speakers in this category was lower or higher than 50%. The data regarding this specific information (proportion of women assigned as coordinators or speakers) was not available for 2012 and 2014 editions, so these were excluded from the analyses. All analyses were performed in R version 3.6.1 (R development Core Team, 2019).

RESULTS

Pooling all participant data across the nine CBMz editions, we obtained an estimated percentage of 45% women attendees. For those years where a complete list of participants was available, the percentage of women attending the event was always higher than 50%, as follows: 2010: 54.6%, 2012: 61.4%, 2014: 60.3%, 2015: 58.5%, 2017: 57.6%.

Using Fisher's exact tests, we rejected the null hypothesis of independence between all categories of presentation and the percentage of female speakers (simulation method; p-value < 0.001). The results from pairwise Fisher tests indicated that the percentage of female speakers in oral presentations differed significantly from all other categories analyzed (Table 1; critical p-value after Bonferroni correction = 0.0083). Moreover, this test suggested that the percentage of female speakers in roundtables differed significantly from that found in the plenary talks (Table 1; critical p-value after Bonferroni correction = 0.0083). We observed that the percentage of female speakers for each category considering all editions supports these results, pointing out that the percentage of female speakers in oral presentations and roundtables is higher when compared to other categories with greater visibility (oral presentation: 54.31%, roundtable: 26.56%, plenary talk: 8.33% and special talk: 5.26%).

Table 1: Pairwise Fisher tests between the percentage of female speakers and different categories of presentation, with the respective p-values (above diagonal) and Fisher test results (below diagonal). Statistically significant results after Bonferroni correction are indicated by **.

Pairwise Fisher	Oral Presentation	Roundtable	Plenary Talk	Special Talk
Oral Presentation	—	< 0.001	< 0.001	< 0.001
Roundtable	3.28**	—	0.001	0.055
Plenary Talk	13.05**	3.97**	—	1
Special Talk	21.36**	6.49	0.61	—

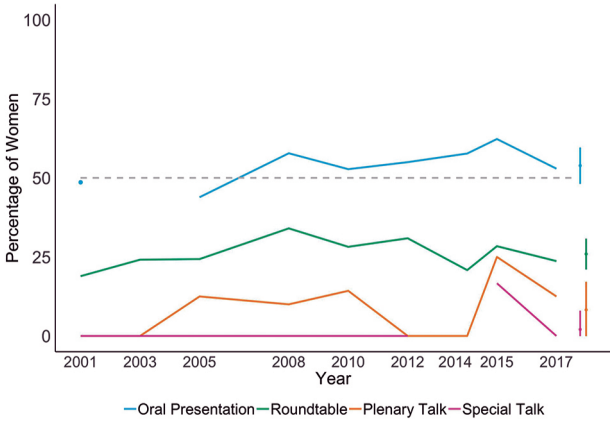

Figure 1: Percentage of female speakers from 2001 to 2017, considering categories of presentation differing in terms of visibility from low to high, as follow: (1) oral presentation, (2) roundtable, (3) plenary talk and (4) special talk. Side bars indicate mean and standard deviation for each category across years. Dashed line indicates the expected percentage according to the overall population.

Table 2: Fisher's exact test comparing observed percentage of male/female speakers in each category of presentation with a 50:50 gender ratio. Statistically significant results after Bonferroni correction are indicated by **.

Fisher's exact tests	Percentage of Woman	Odds Ratio	P-value
Oral Presentation	54.31**	0.841	0.027
Roundtable	26.55**	2.765	< 0.001
Plenary Talk	8.33**	10.99	< 0.001
Special Talk	5.26**	17.987	< 0.001

The greater percentage of women as speakers in oral presentations and roundtables compared to the categories with greater visibility was consistent over time (2001 to 2017; Figure 1). In addition, the percentage of women attending oral presentations remained relatively stable over time, oscillating between 50 and 60%. Remarkably, as visibility increases among categories of presentation, the proportion of female speakers disproportionately decreases, indicating women's underrepresentation in the most prestigious categories (Figure 1). Despite a punctual increase in 2015, the proportion of female speakers in the plenary talks never reached higher than 25% of the presenters. This is much lower than the expected 50% of the sampled population, or 60% if we consider women's attendance in oral presentations in the same year. Our results revealed that the only time a woman gave a special talk was in 2015 (Figure 1). In this event, five guests were invited to compose a roundtable for a closing lecture in CBMz; from the five members invited, only one was a woman.

The results from Fisher tests comparing the proportion of women with the expected 50:50 gender ratio indicated that the percentage of female speakers differed from 50% in all presentation categories (Table 2; critical p-value after Bonferroni correction = 0.005). Again, the proportion of women in oral presentations was higher than the percentage in other categories. In fact, this is the only category that exceeded 50% of female speakers in all CBMz editions (Table 2).

From 2001 to 2017, the majority of roundtables presented mixed composition (consisting of both women and men as speakers), but over these years there was not a single roundtable composed exclusively of female speakers (Figure 2). The percentage of women in mixed roundtables increased from zero in 2001 to 25% in 2008, dropped between 2010 to 2015 and increased to 28% in 2017 (Figure 3). Moreover, the percentage of women assigned as coordinators or speakers in roundtables was also always lower than 50% (Figure 4).

Considering all editions of CBMz and all categories of presentation, the percentage of female speakers from different Brazilian regions was: North: 53.03%, South: 49.43%, Southeast: 46.85%, Northeast: 44.8% and Central-West: 33.78%. Using Fisher's exact tests, we rejected the null hypothesis of independence between Brazilian regions and the proportion of female speakers in the CBMz (simulation method; p-value = 0.019). Additionally, the results from pairwise Fisher tests indicated that the percentage of women speakers from the Central-West differed significantly from the percentage from the South and Southeast regions (Table 3; critical p-value after Bonferroni correction = 0.005). From 2001 to 2017, the North region presented the highest proportion of female speakers, on average higher than 50%, while the percentage of female speakers from Central-West region was always lower than 50% (Figure 5).

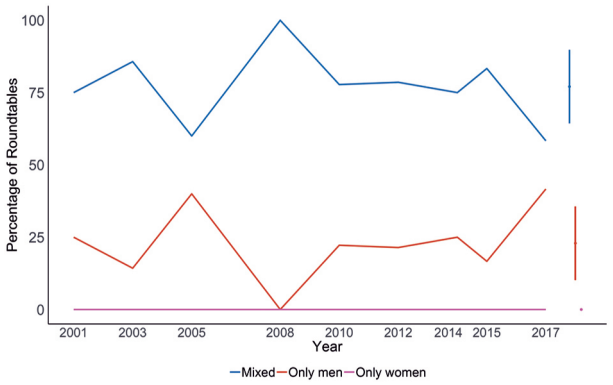

Figure 2: Percentage of roundtables composed of: (1) exclusively men (only men), (2) exclusively women (only women) and (3) both men and women (mixed), from 2001 to 2017. Side bars indicate mean and standard deviation for each category across years.

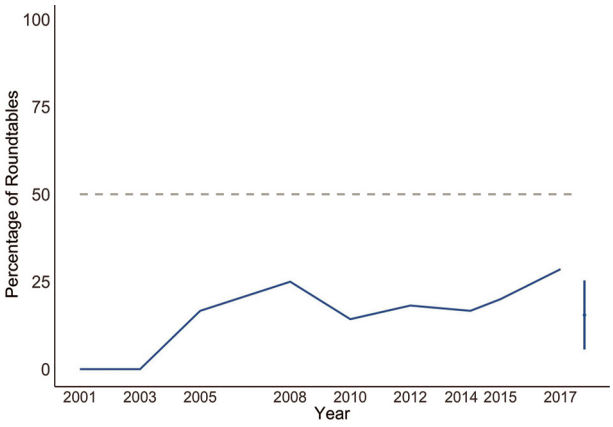

Figure 3: Percentage of women at the mixed roundtables from 2001 to 2017. Side bar indicates mean and standard deviation for the category across years. Dashed line indicates the expected percentage according to the overall population.

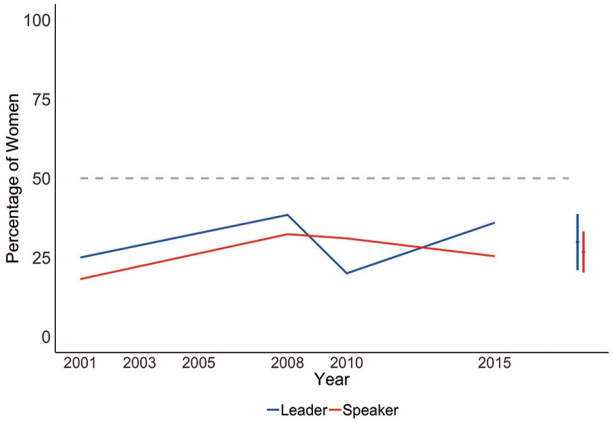

Figure 4: Percentage of women assigned as coordinators (Leader) and speakers in roundtables. Data regarding this specific information was not available for 2012 and 2014 editions. Side bar indicates mean and standard deviation for ech category across years. Dashed lines indicates the expected percentage according to the overall population.

Table 3: Pairwise Fisher tests between the percentage of female speakers and the region of Brazil (according to the their affiliations), with the respective p-values (above diagonal) and Fisher test results (below diagonal). Statistically significant results after Bonferroni correction are indicated by **.

Pairwise Fisher	South	Southeast	North	Northeast	Central-West
South	—	0.47	0.68	0.44	0.003
Southeast	0.9	—	0.36	0.69	0.004
North	1.15	1.28	—	0.29	0.01
Northeast	0.83	0.92	0.72	—	0.081
Central-West	0.52**	0.57**	0.45	0.63	—

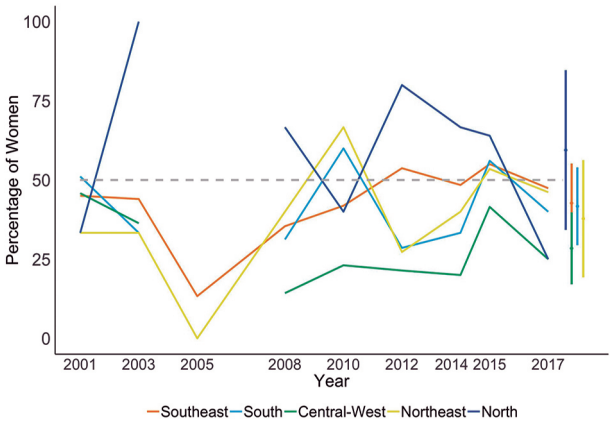

Figure 5: Percentage of female speakers from 2001 to 2017, considering their affiliation divided by Brazilian regions. Side bar indicates mean and standard deviation for each category across years. Dashed line indicates the expected percentage according to the overall population.

DISCUSSION

Here we provide the first comprehensive analysis of the proportion of female speakers in different categories of presentation at the Brazilian Congress of Mammalogy (CBMz) and their participation by Brazilian geographic regions. Our results suggested two fundamental trends. First, there is a significant difference in the percentage of female speakers at different presentation categories in CBMz editions. Remarkably, the proportion of female speakers decreases in categories with increased visibility, revealing an underrepresentation of women in the most prestigious categories of presentation. Second, there is also a gender disparity in the proportions of female speakers between Brazilian regions.

Several studies have been discussing the importance of achieving career visibility through conference attendance, oral presentations and participation in plenary talks (Carter *et al.,* 2018; Casadevall & Handelsman, 2014; Débarre *et al.,* 2018; Ford *et al.,* 2018; Holman *et al.,* 2018; Jones *et al.,* 2014; Martin, 2015; Schroeder *et al.,* 2013; Wellenreuther & Otto, 2016). For instance, it has been suggested that invitations to speak at national meetings might influence careers success and academic job opportunities (Casadevall & Handelsman, 2014; Gurevitch, 1988; Jones *et al.,* 2014). Studies on gender inequality have been frequently surveyed and published specially for meetings sponsored by North American and European Scientific Societies (Casadevall & Handelsman, 2014; Débarre *et al.,* 2018; Ford *et al.,* 2018; Gurevitch, 1988; Isbell *et al.,* 2012; Schroeder *et al.,* 2013; Smith & Kaufman, 1996). However, knowledge about gender disparities in Brazilian scientific meetings is incipient, as are discussions, debates and practical proposals regarding this important theme (but see Pardini *et al.,* 2016). Despite the existence of female experts in the field, different studies have shown that women receive fewer opportunities to speak at scientific events than men overall (Débarre *et al.,* 2018; Ford *et al.,* 2018; Isbell *et al.,* 2012; Kalejta & Palmenberg, 2017; Schroeder *et al.,* 2013).

By surveying the abstracts published in the proceedings of CBMz events we found that, except for oral presentations, the percentage of women has always been lower than expected based on the 50% or more of women subscribed to these events. Since the oral presentation category depends both on participants' requests during abstract submissions and scientific commitees' approval, we suggest two complementary explanations for the results we found. Firstly, a significant proportion of women have submitted their work to compete for a chance to present an oral presentation, indicating their interest in disseminating the results of their studies, as well as seeking for visibility for their careers in mastozoology. Additionally, women have received significantly fewer invitations as speakers in the remaining categories of presentation throughout all nine CBMz editions.

An important follow-up to our work would be to examine whether there is an association between gender composition of the team of conveners and the proportions of male and female invited speakers at CBMz editions. Previous studies demonstrated a positive association between the proportion of invited female speakers and the presence of women as organizers (see Casadevall & Handelsman, 2014; Débarre *et al.,* 2018; Gurevitch, 1988; Isbell *et al.,* 2012; Kalejta & Palmenberg, 2017; Klein *et al.,* 2017; Sardelis & Drew, 2016). Based on a comprehensive dataset including two large meetings sponsored by the American Society of Microbiology, Casadevall & Handelsman (2014) discussed how the gender of conveners at scientific meetings affects the gender distribution of invited speakers. These authors argue that having at least one woman as a convener greatly increased the proportion of women among invited speakers at scientific meetings (Casadevall & Handelsman, 2014). Débarre *et al.* (2018) quantified the proportion of women announced as invited speakers in Evolutionary Biology conferences, congress symposia, and specialized courses. Across all types of events, the authors found a significant positive effect of the proportion of women among organizers on the proportion of women among the invited speakers (Débarre *et al.,* 2018).

Since the attributes that characterize scientists invited to speak at conferences are also questionable, it is important to consider different metrics in the analyses, such as sex ratio based on faculty position or career stage (see Schroeder *et al.,* 2013). We were unable to access those metrics to quantify potential causal factors that might affect, and limit, the proportion of women

Table 4: List of suggested actions for organizing the CBMZ in ways equitable for women mastozoologists. Some suggestions will ensure quantitative analysis and data comparability among editions.

Actions at the beginning of the organization
1. Plan the CBMz with equitable gender representation in mind.
2. Invite women to participate in the organization team and to act as conveners (at least 50:50 gender ratio). The committee must have women satisfactorily represented*.
3. Communicate with other conveners and conference organizers the expectation to achieve the goal of having gender parity at CBMz.
4. Invite women to speak at different categories of presentations.
5. Promote students and early career women speakers**.
6. Think on logistical and supportive structures that can make the conference welcoming to women in science with children's (childcare, nursing places).
7. Whenever possible offers travel and/or registration grants for women in science with children.
8. Think on strategies to increase diversity. Gender equity is just a starting point!
9. Never ever think you are making a favor considering gender equality and equal opportunities. Both are basic human rights and must be treated as natural.
10. Think on organizing a roundtable or a talk about diversity and gender equality aiming to openly discuss these topics with all member at CBMz.
11. Include a code of conduct or anti-harassment code in the CBMz materials.
Actions for men proposing symposium and/or roundtables
1. Look hard to your collaborative scientific network. Ask yourself if most of your collaborators are male***. Do not hesitate to break your circle.
2. You must certainly have female colleagues whose work is good, interesting and admirable. Invite women to your proposal.
Actions during registration
1. Collect demographic data such as gender, ethnicity, date of birth, highest degree obtained including the year, current professional position and affiliated institution.
2. The members should be asked to self-report gender (female, male, other gender categories, prefer not to answer).
3. Collect information on the total number of participants, the number of females and males registered for each edition.
4. Collect information on the number and gender of all invited speakers.
5. Collect information on the number and gender of researchers who declined an invitation.
6. Collect information on the number and gender of conveners who invited speakers.
7. Collect information on the number and gender of participants and the categories of presentation they attended (*e.g.,* poster, oral, symposium, roundtable, plenary talk, and special talk).
Actions during the conference
1. Promote discussions on gender equality and diversity priorities among female participants (these might improve networking opportunities and visibility).
2. Ask female colleagues about their experiences as scientists in the academy and as a woman in society.
3. Collect information on the number and gender of award winners.
Actions after the conference
1. Discuss with all conveners and conference organizers if you have achieved the goal of having gender equality and diversity at CBMz.
2. Discuss possible issues that already persist and seek solutions to solve it for the next editions.

* Please, see our discussion about female organizers and female speakers at conferences.
** Please, see our discussion regarding this important topic.
*** Please, see our discussion on the existence of exclusive male collaborative networks in science (Massen *et al.,* 2017). See also Cooper *et al.* (2018) arguing that men in STEM areas tend to underestimate the abilities of female colleagues and overestimate their own intelligence.

among the different categories of presentation at CBMz. Since each edition of the event was planned and organized differently, we were unable to access gender and academic position of all conveners, for example, and investigate whether these variables influenced the gender distribution of invited speakers across the gradient of visibility. However, whatever the mechanisms driving our findings, our results explicitly raise a crucial point: women are underrepresented in the most prestigious categories of presentation in the CBMz, and we are all responsible for changing this scenario. In order to mitigate the current situation, we provide a list of suggestions and practical actions to increase gender equitability in CBMz from now on (see Table 4).

We have faced a great challenge organizing and surveying the data for the present study from abstracts published in the proceedings of the CBMz editions. There were cases where only the author's surname was available, hindering identification of the participant's gender. Some proceedings did not provide information on poster presentations, making it impossible for us to retrieve data regarding this important category. To facilitate short and long-term analyses from now on, we recommend the future conveners and conference organizers of the Brazilian Society of Mammalogy (SBMz) to standardize the data collection process during conference registration (see Table 4). It is particularly important to collect demographic data such as gender, ethnicity, date of birth, highest degree obtained (including the year when it was obtained), current professional position or career stage, and affiliated institution. For example, the members should be asked to voluntarily self-report gender (female, male, other gender categories or prefer not to answer) and ethnicity during registration. Other key parameters to perform quantitative analyses are the total number of participants, the number of females and males registered for each edition; in particular, the number and gender of all invited speakers and of those

that declined an invitation are important information for future analyses. Additionally, it is essential to establish a friendly way of gathering and importing the abstracts, categories of presentation (*e.g.,* poster, oral presentation, symposium, roundtable, plenary talk, and special talk) and membership data so that all information, including all the demographic data described above, be made available for future analyses (see Table 4). As such a database would provide a rich resource to investigate diversity and equity in CBMz meetings, the standardization of data achievement during registration is critical to ensure data comparability among editions.

Our results on roundtables suggest that despite presenting a mixed composition, none of them was composed exclusively of women over the years, and the percentage of women assigned as coordinators or speakers was significantly lower than expected. Roundtables are composed by a number of specialists focused on discussing a certain topic and, usually, in this modality, a coordinator suggests a topic in the area of interest and invite other members to participate. Our results find support in two recent publications (see Massen *et al.,* 2017; Cooper *et al.,* 2018). Massen *et al.* (2017) testing human's prosocial behavior (*i.e.,* willingness to share) in academia; one of the most competitive fields of the modern society. The authors reported most prominent male to male prosociality, suggesting that men tend to value more each other as researchers and collaborators in academia (Massen *et al.,* 2017). The authors also suggest the existence of exclusive male collaborative networks in science (Massen *et al.,* 2017). Cooper *et al.* (2018) found that men in STEM areas tend to underestimate the abilities of female colleagues and conversely, overestimate their own intelligence and credentials. The authors state that even when the evidence demonstrates the opposite, women tend to doubt more of their abilities in STEM areas (Cooper *et al.,* 2018). These studies not only support the results found throughout CBMz editions, but might also be considered, among other implicit and explicit biases (see Carli *et al.,* 2016; Ceci *et al.,* 2014; Dean *et al.,* 2012; Ford *et al.,* 2018; Moss-Racusin *et al.,* 2012), as an important factor behind the leaky pipeline for women in STEM.

We were unable to gather data on female scientists that declined invitations to attend roundtables, plenary talks and special talks at CBMZ editions, and this would have been an important variable to interpret our results more accurately. Schroeder *et al.* (2013) discussed different reasons that lead women scientists declining invitations more often, such as childcare and career duties. Supportive structures, including arrangements for childcare and nursing facilities for mother attending conferences is a way to provide equitable logistics for researchers with children. Some conferences indeed offer travel and/or registration grants for women in science with children. Additionally, encouraging and organizing discussions on gender equality and diversity priorities, as well as networking opportunities during the conference, is a great opportunity to start conversations about these themes among participants. We also believe that another fundamental avenue for future research would be to examine other underrepresented categories in the CBMz in order to reach and embrace more diversity in our field. Finally, it is important to consider that many female participants at the CBMz are students in early career stages. Previous studies demonstrated that inviting students as speakers at early career stages may help improve the overall parity in presentation opportunities (Ford *et al.,* 2018; Kalejta & Palmenberg, 2017).

Overall, our results provide the first comprehensive overview of women's representation in the CBMz, and they explicitly show a trend of underrepresentation of female speakers in more prestigious categories of presentations (especially among those that require invitation), helping us recognize this problem and better consider effective actions to mitigate it. Our motivation for the present contribution was to document gender disparities in the Brazilian Congress of Mammalogy and discuss the potential underlying mechanisms that may cause the scientific community to unfairly neglect to care about the space provided for female speakers in conferences. We draw attention for a behavior that might lead us to miss out a significant proportion of high-quality studies in the field and slow down scientific progress in the long term. We advocate that women receive equal opportunities, recognition, and visibility compared to men, and we suggest practical actions for the conference organizers and attendees to promote gender equitability in future scientific meetings.

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New records of carnivore mammals at the Araucárias National Park and surrounding areas in Southern Brazil

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Abstract: The Araucárias National Park (ANP) is one of the largest remaining areas of the Araucaria Forest, a threatened ecosystem in Brazil. The ANP protects biodiversity, including threatened species of carnivore mammals. In addition to the fauna listed in the ANP Management Plan, we recorded five carnivore species: *Galictis cuja* and *Conepatus chinga* (new records); *Leopardus wiedii, Herpailurus yagouaroundi* and *Eira barbara* (interviews confirmation). *Conepatus chinga* is usually associated with open environments but occurred in dense forested areas. The results highlight the importance of ANP and its surrounding areas for protection of vulnerable species and the need of long-term research.

Key-Words: Araucaria Forest; Atlantic Forest; Carnivora; Conservation unit.

Resumo: Novos registros de mamíferos carnívoros no Parque Nacional das Araucárias e entorno no Sul do Brasil. O Parque Nacional das Araucárias (PNA) é um dos maiores remanescentes de Floresta com Araucária, um dos ecossistemas mais ameaçados do Brasil. O PNA protege a biodiversidade, como espécies ameaçadas de mamíferos carnívoros. Complementando a lista de fauna do Plano de Manejo do PNA, registramos cinco espécies de carnívoros: *Galictis cuja* e *Conepatus chinga* (novos registros); *Leopardus wiedii, Herpailurus yagouaroundi* e *Eira barbara* (confirmação de antigas entrevistas). *Conepatus chinga,* geralmente associado a ambientes abertos, ocorreu em áreas densamente florestadas. Os resultados destacam a importância do PNA e seu entorno para espécies vulneráveis e a necessidade de pesquisas de longo prazo.

Palavras-Chave: Carnivora; Floresta Atlântica; Floresta com Araucária; Unidade de conservação.

Protected Areas (PAs) play an important role in safeguarding biodiversity, genetic resources, and ecological processes (Simões, 2008). In the Brazilian National System of PAs (SNUC; Brasil, 2000), National Parks are responsible for the preservation of natural ecosystems of high ecological relevance. Thus, PAs are essential for species conservation in high biodiverse but fragmented ecosystems, like those of the Atlantic Forest biome (Myers *et al.,* 2000). According to the SNUC (Brasil, 2000), every PA, including its buffer zone and surrounding areas, must have a Management Plan to delineate its use. The PA's fauna must be inventoried, added to their Management Plan, and updated during its revision (Galante *et al.,* 2002). Brazil is one of the most megadiverse countries in the world (Mittermeier *et al.,* 1997). Its territory includes two biomes considered *hotspots* for biodiversity and priorities for conservation: the Cerrado and the Atlantic Forest (Myers *et al.,* 2000). One of the most threatened ecosystems of the Atlantic Forest is the Araucaria Forest, with less than 13% of its original cover remaining and more than one third of its territory in the Santa Catarina State (Ribeiro *et al.,* 2009). The Araucárias National Park (ANP) was created in 2005 (MMA/ICMBio/APREMAVI, 2010) and comprises one of the last and largest remaining Araucaria Forest in Santa Catarina State (Tiepo, 2010). Its Management Plan describes the occurrence of 26 species of medium and large sized mammals (Gruener, 2010), including seven endangered species (Brasil/MMA, 2014). Of those 26 species, 11 are carnivores (Gruener, 2010), including four endangered species (Brasil/MMA, 2014). The number of carnivores recorded in the ANP is representative considering the 16 species of this order documented for Santa Catarina State according to Cherem *et al.* (2004; not including *Galictis vittata* mentioned by these authors due to its new distribution data) and ICMBio (2013).

Species of the Carnivora order include important top predators (Estes *et al.,* 2011). Usually, carnivores present diverse ecological requirements and have large home ranges and territories (Emmons & Feer, 1997; Eisenberg & Redford, 1999; Nowak, 2005). Most carnivores are target species of conservation strategies, but information gaps about their microscale occurrence is an obstacle to understand their distribution and to develop regional conservation programs (see ICMBio, 2013). The confirmation of a species occurrence in a PA is important

not only for its conservation, but also to demonstrate to governmental agencies, wildlife managers and deliberative councils that the PA is ensuring the representativeness of local species (Brasil, 2000). Information about microscale occurrences improves knowledge about endangered or poorly studied species. These occurrences also contribute data on the biology and habitat use of these species within and around PAs. The objectives of this study were (i) to report new records of carnivore mammals occurring in the ANP and its surrounding areas and (ii) to confirm previous records registered during interviews of local residents included in the ANP's Management Plan.

The Araucárias National Park (26°45'53"S, 51°58'03"W; Datum WGS84) is mainly composed of coniferous forest, characteristic of the Araucaria Forest (Atlantic Forest biome; MMA/ICMBio/APREMAVI, 2010). The ANP is located in the western part of the Santa Catarina State, within the municipalities of Ponte Serrada and Passos Maia, surrounded by 13 rural districts (Figure 1). It has 12,841 ha of secondary forest patches in different stages of regeneration; this area includes patches of pristine and exploited primary forest, standing forest with native (yerba mate *Ilex paraguariensis*) and exotic species vegetation (*Pinus* spp. and *Eucalyptus* spp.), and areas of agriculture and pasture. There are detrimental activities in the ANP region including poaching, animal traffic, unsustainable collection of araucaria seeds, agriculture expansion, presence of domestic and exotic animals, road kill, and infrastructure for electricity networks and hydroelectric power (MMA/ICMBio/APREMAVI, 2010).

From 2008 to 2016, three research projects were carried out to survey the fauna within the ANP, its 500 m buffer zone, and surrounding areas (up to 10 km away from the ANP's limits) (SISBIO/ICMBio licenses 15513-2, 40214-1, 25133 and 41776). These projects contributed data via sampling efforts and provided new records of carnivore mammals neither documented in the ANP's management plan nor confirmed by reliable methods (*i.e.,* only recorded through interviews with local residents; see Gruener, 2010). Interviews may be considered an unreliable method due to a major susceptibility of errors in the identification of species by non-specialists, inaccuracy of time (disregarding possible local extinction) and/or imprecision of space (wide geographical range). Mammals of ANP and surrounding areas were surveyed from 2008 to 2014 by researchers via camera traps and direct and indirect (*e.g.,* tracks) observations. In addition, since 2012, ANP has been consistently monitored by its management team and other wildlife researchers. Their reliable records (*e.g.,* pictures and direct observation) were considered in the present study. Twenty analog and 20 digital camera traps operated at least 3 km distance apart in crossing paths of medium and large bodied mammals within different habitats, functioning 24 hours/day with three minutes intervals between shots. The camera traps totalized an effort of

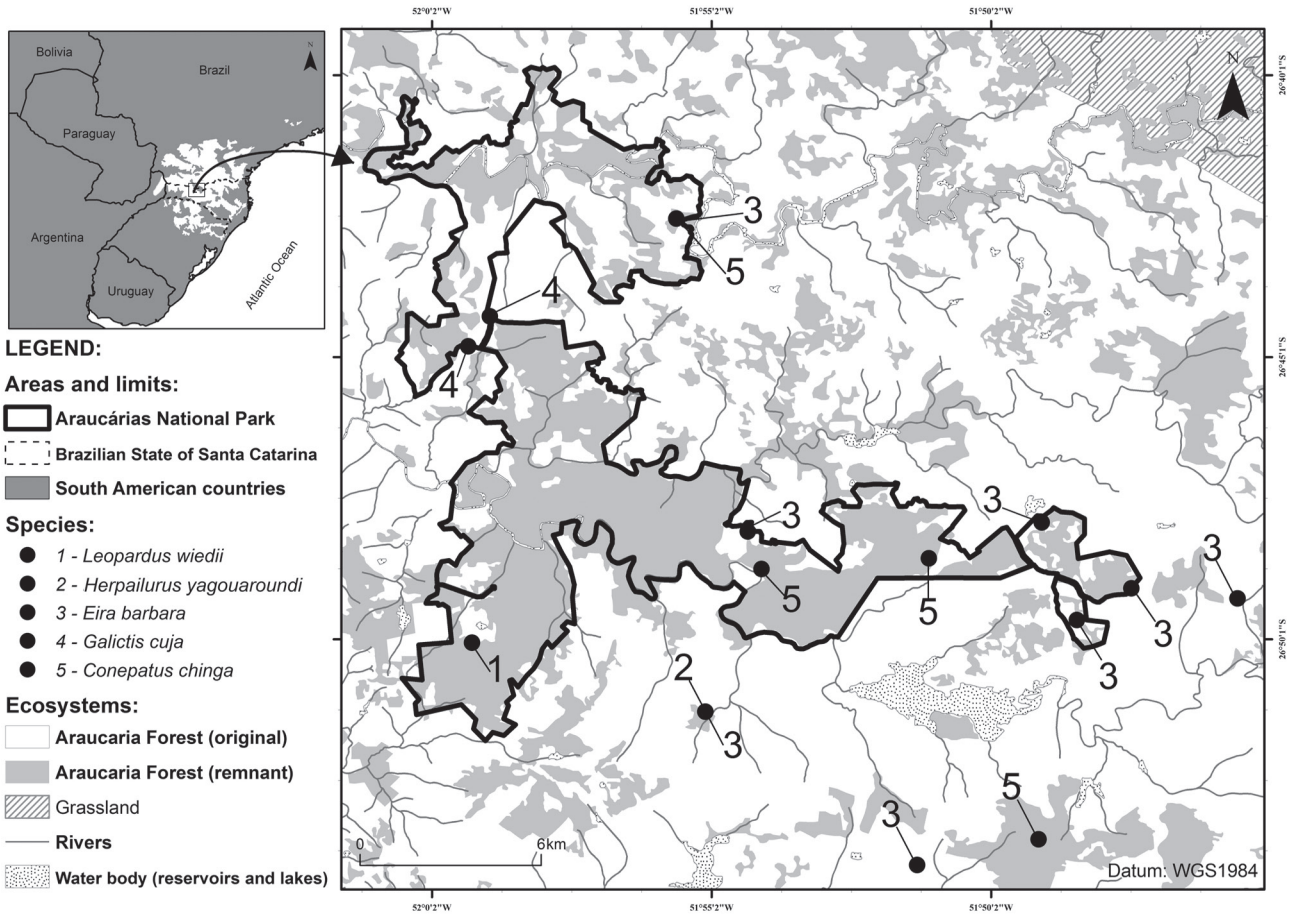

Figure 1: New records of carnivore mammals from 2008 to 2016 in the Araucárias National Park and surroundings. Datum WGS84.

Table 1: New records and confirmation of the presence of carnivorous mammals between 2008 and 2016 in the Araucárias National Park (ANP), southern Brazil. Local: ANP = Araucárias National Park, SU = surrounding. Habitat: AF = Araucaria Forest in middle to advanced stage of regeneration, AFF = Araucaria Forest in medium to advanced stage of regeneration with field area, P = small glade with regeneration pasture. Method: CT = camera trap, T = track, DO = direct observation, I = interview, ND = not detected.

Family and Species	Coordinates	Local	Habitat	Method (this study)	Method (management plan*)
Felidae					
Leopardus wiedii	26°50'04.7"S, 51°59'18.9"W	ANP	AF	CT	I
Herpailurus yagouaroundi	26°51'18.2"S, 51°55'8.5"W	SU	AF	CT	I
Mustelidae					
Eira barbara	26°49'40.5"S, 51°48'30.0"W	ANP	AFF	CT	I
	26°47'56.8"S, 51°49'07.7"W	ANP	AFF	CT	I
	26°42'33.6"S, 51°55'39.7"W	ANP	AF	CT	I
	26°49'06.8"S, 51°47'31.5"W	ANP	AFF	CT	I
	26°48'06.4"S, 51°54'23.1"W	ANP	AF	CT	I
	26°48'34.9"S, 51°51'08.8"W	ANP	AFF	CT	I
	26°51'18.2"S, 51°55'08.5"W	SU	AF	CT	I
	26°49'17.5"S, 51°45'37.5"W	SU	AF	CT	I
	26°49'17.5"S, 51°45'37.5"W	SU	AF	CT	I
	26°51'18.2"S, 51°55'08.5"W	SU	AF	CT	I
	26°49'17.5"S, 51°45'37.5"W	SU	AF	CT	I
	26°54'01.2"S, 51°51'21.3"W	SU	AF	CT	I
Galictis cuja	26°44'17.6"S, 51°58'59.9"W	ANP	P	DO	ND
	26°44'49.5"S, 51°59'22.9"W	ANP	P	DO	ND
Mephitidae					
Conepatus chinga	26°48'46.4"S, 51°54'08.4"W	ANP	AF	T	ND
	26°42'33.6"S, 51°55'39.7"W	ANP	AF	CT	ND
	26°53'33.8"S, 51°49'10.9"W	SU	AF	T	ND

* MMA/ICMBio/APREMAVI 2010.

2,871 camera trap-nights: 25-45 days in the summer and winter seasons of each year from 2008 to 2011 and 26 days in summer 2013 and winter 2014. To increase the reliability of the identifications, experts also evaluated photos and video recorded in the present study.

A total of 19 records of five carnivore species were made (Table 1). Some species were either previously recorded only during interviews of local residents, such as *Leopardus wiedii* (Schinz, 1821) (margay; n = 1), *Herpailurus yagouaroundi* (É Geoffroy Saint-Hilaire, 1803) (jaguarundi; n = 1) and *Eira barbara* (Linnaeus, 1758) (tayra; n = 12), or they were new records, such as *Galictis cuja* (Molina, 1782) (lesser grison; n = 2) and *Conepatus chinga* (Molina, 1782) (hog-nosed skunk; n = 3). Records were made within ANP (n = 10) and its 5 km surrounding areas (n = 9) through camera traps (n = 15), animal tracks (n = 2), and direct observations (n = 2; Table 1). Most records occurred within well-conserved Araucaria Forest (AF; n = 13; *L. wiedii, H. yagouaroundi, E. barbara* and *C. chinga*), while others were within areas of Araucaria Forest in medium to advanced stages of regeneration merged with field areas (AFF; n = 4; only *E. barbara*) and open areas, *i.e.,* old pasture (P; n = 2; only *G. cuja;* Table 1).

Our results increased the species list of Carnivore mammals protected by the ANP by 18%, including the confirmation of two nationally threatened species: *Leopardus wiedii* and *Herpailurus yagouaroundi* (both Vulnerable; Brasil/MMA, 2014). Previously, the ANP Management Plan (Gruener, 2010) listed more carnivore species (n = 11) than a carnivore mammal survey conducted in several locations within the Chapecó river basin, which is in the ANP surrounding areas (n = 9; Mazzolli, 2007). This present study offers unprecedented records of carnivore species and confirms records for the ANP and its surrounding areas, which is important for Santa Catarina State and its PAs system.

Leopardus wiedii is a felid vulnerable to extinction in Brazil (Brasil/MMA, 2014). It inhabits most of the Brazilian territory and is predominantly associated with forested environments (Oliveira, 2008; Tortato *et al.,* 2013). In the ANP, it had only been recorded through interviews as presented in the Management Plan (Gruener, 2010). In the present study, it was registered within a substantial Araucaria Forest area. A literature review shows records of *Leopardus wiedii* in a PA in western Santa Catarina State (see Hendges *et al.,* 2015) and in six PAs in the coastal region (Cherem *et al.,* 2011; FATMA/APREMAVI, 2016; Goulart *et al.,* 2009; Gruener, 2009; Tortato, 2009; Tortato *et al.,* 2013; Tortato *et al.,* 2014; Table 2). *Herpailurus yagouaroundi* (see recent revised taxonomy in Kitchener *et al.,* 2017) is another felid vulnerable to extinction in Brazil (Brasil/MMA, 2014) and it is associated with forest and open environments (see studies in Almeida *et al.,* 2013 and Oliveira, 1998). In Santa Catarina State, this species was recorded in eight PAs (Cherem *et al.,* 2011; FATMA/APREMAVI, 2016; FATMA/CAIPORA, 2007; Gruener, 2009; Hendges *et al.,* 2015; Santos *et al.,* 2004; Tortato, 2009; Tortato *et al.,* 2014; Wallauer *et al.,* 2000) and in the same municipality where a protected area occurs (Cherem, 2005; Table 2). *Herpailurus yagouaroundi* was included in the ANP Management Plan due to reports during interviews (Gruener, 2010), and it was confirmed in the present study in an area close

Table 2: Occurrence of carnivores in the Araucárias National Park (ANP) and surroundings, and in other protected areas or its municipality of Santa Catarina State, southeastern Brazil. The species are represented by *L. w. = Leopardus wiedii, H. y. = Herpailurus yagouaroundi, E. b. = Eira barbara, G. c. = Galictis cuja, C. c. = Conepatus chinga.*

Species/Protected Areas or its municipality	*L. w.*	*H. y.*	*E. b.*	*G. c.*	*C. c.*
Serra do Itajaí National Park (Gruener, 2009)	X	X	X	X	
São Joaquim National Park municipality (Cherem *et al.,* 2004)					X
Aparados da Serra National Park (Santos *et al.,* 2004)		X	X		X
Três Barras National Forest municipality (Cherem & Peres, 1996)				X	
Três Barras National Forest (Wallauer *et al.,* 2000)		X	X		
Araucárias State Park (FATMA/APREMAVI, 2016; FATMA/CAIPORA, 2007)	X	X	X	X*	X**
Serra do Tabuleiro State Park (Cherem *et al.,* 2011; Goulart *et al.,* 2009)	X	X	X	X	X
Fritz Plaumann State Park (Hendges *et al.,* 2015)	X	X	X		
Rio Canoas State Park municipality (Cherem, 2005)		X	X	X*	X
State Biological Reserve of Aguaí (Tortato, 2009)	X	X	X	X	X
State Biological Reserve of Sassafrás (Tortato & Althoff, 2007; Tortato *et al.,* 2014)	X	X	X	X	
Ecological Reserve of Caraguatá (Goulart *et al.,* 2009; Tortato *et al.,* 2013)	X				

* Original record for *Galictis* sp.
** Only recorded in the protected areas' municipality.

to this previous report, but within the 5 km buffer zone of the ANP. The individual had a gray/dark phenotype coloration, common in southern Brazil and in moist/dense forests (Silva *et al.,* 2016). *Eira barbara* is a mustelid widely distributed (Rodrigues *et al.,* 2013) and currently not threatened in Brazil (see Brasil/MMA, 2014). In Santa Catarina State, this species is present in eight PAs (Cherem *et al.,* 2011; FATMA/Caipora, 2007; Goulart *et al.,* 2009; Gruener, 2009; Hendges *et al.,* 2015; Santos *et al.,* 2004; Tortato & Althoff, 2007; Tortato, 2009; Tortato *et al.,* 2014; Wallauer *et al.,* 2000) and in the same municipality where a protected area occurs (Cherem, 2005; Table 2). Although this species had been previously recorded through interviews in one region of the ANP, the present study lists 12 records in other parts of this PA and its surrounding areas. *Eira barbara* is highly associated with areas of dense vegetation (Eisenberg & Redford, 1999; Emmons & Feer, 1997), and its occurrence in the buffer zone of ANP may be explained by its tolerance to disturbed habitats (Indrusiak & Eizirik, 2003; Presley, 2000). *Galictis cuja* is a mustelid that it is not threatened in Brazil (see Brasil/MMA, 2014). Its distribution runs northeast, central-west, southeast and south of Brazil (Kasper *et al.,* 2013b) within the interior and edges of both pristine or less disturbed forests (see Kasper *et al.,* 2013b) and open habitats (fields and savannas; Rodrigues *et al.,* 2002). It is considered one of the least studied Neotropical carnivores (Morato *et al.,* 2004; Oliveira, 2006, 2009) due to its unusual behavior leading to rare sightings and its population fluctuations (Kasper *et al.,* 2013b). This species is rarely detected during wildlife surveys (Kasper *et al.,* 2013b), which may result in regional sub samples. Moreover, such distribution records can also be influenced by temporary disappearance of the species or inefficiency in detection methods (Kasper *et al.,* 2013b). In Santa Catarina State, *G. cuja* is recorded in four PAs (Cherem *et al.,* 2011; Gruener, 2009; Tortato, 2009; Tortato *et al.,* 2014). Due to the records of *Galictis* sp., it is possibly registered in another PA (FATMA/Caipora, 2007) and in two municipalities where protected areas occur (Cherem, 2005; Cherem & Peres 1996; Table 2). Despite the fact that the ANP is located in the *G. cuja* distribution area (see Kasper *et al.,* 2013b), this species was not listed in the ANP Management Plan (Gruener, 2010). Current sighting records occurred in areas distant from the sampling points of ANP Management Plan. *Galictis cuja* and *G. vittata* (greater grison) are similar species, and recently, scientists have been researching their possible distribution overlap (Bornholdt *et al.,* 2013; Poo-Muñoz *et al.,* 2014). *Galictis vittata'*s distribution in Brazil is known to be mainly restricted to the northern region (Oliveira, 2009). However, a recent study indicated its occurrence in the southern region of Paraguay, in coexistence with *G. cuja* (Bornholdt *et al.,* 2013) and next to the ANP latitude, showing the proximity of *G. vittata* to southern Brazil. Nevertheless, the records made in the ANP refer to *G. cuja* as confirmed by a specialist in both species. *Conepatus chinga* is a mephitid not threatened in Brazil (Brasil/MMA, 2014) and occurs in open vegetation environments within southern regions, such as the Pampa biome and Campos Gerais of Atlantic Forest biome (Kasper *et al.,* 2013a). In Santa Catarina State, *C. chinga* was recorded in three PAs (Cherem *et al.,* 2011; FATMA/Caipora, 2007; Santos *et al.,* 2004; Tortato, 2009) and in three municipalities where protected areas occur (Cherem, 2005; Cherem & Peres 1996; Cherem *et al.,* 2004; Table 2). The present study provides the first three records of the species at the ANP and its surrounding areas. Although previous records of *C. chinga* in Santa Catarina State were done mainly in the central region (Cherem, 2005; Cherem *et al.,* 2004, 2007; Kasper *et al.,* 2012), the species has already been reported in the western part of the State (Bazilio *et al.,* 2015; FATMA/Caipora, 2007). However, Passos Maia and Ponte Serrada municipalities, where the ANP is located, were not considered part of geographic distribution of *C. chinga,* according to previous species review (Kasper *et al.,* 2013a). Despite the fact that the ANP is surrounded by a matrix of forested patches and open areas (original or due to deforestation; see Tiepo, 2010), the three sightings occurred in forested areas, where the species is not expected (Kasper *et al.,* 2013a). Records

like these are considered occasional occurrence or expansion of the species' distribution due forest fragmentation (Kasper *et al.,* 2013a). Other records for this species in forest areas include the Atlantic Forest in Paraná State (Cáceres, 2004) and Serra da Bodoquena (Atlantic Forest and Cerrado biomes) in Mato Grosso do Sul State (Cáceres *et al.,* 2007; recorded from interview). For the present study, the records of *C. chinga* may represent an expansion of the Campos Gerais population, located few kilometers north (12 to 22 km; see Figure 1).

Thus, the records obtained in this study include two carnivore mammal species detected for first time (*G. cuja* and *C. chinga*) at ANP and that should be protected in its surrounding areas. We also confirmed the presence of three carnivore mammals in the ANP and its surrounding areas, previously registered only through interviews in the ANP Management Plan, two of which are vulnerable to extinction: *L. wiedii* (within the ANP area) and *H. yagouaroundi* (in ANP's surroundings). With the exception of *C. chinga* records, all specimens were recorded in habitats consistent with those described in the literature (see studies in Cheida *et al.,* 2011). The records of *C. chinga* in forest areas, draws the attention for more investigation into biological aspects or other causes related to this scenario. This study also draws attention to the importance of a PA's surrounding areas to Vulnerable and/or lesser-known species. Finally, this study demonstrates the importance of long-term research on mammals in the Araucaria Forest region in order to better understand the local community of carnivore species, their territorial needs, and possible anthropogenic threats.

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NOTAS

Registro de interação antagonista entre *Leopardus pardalis* e *Cerdocyon thous* no limite sul da Mata Atlântica

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Resumo: Neste trabalho é apresentado o registro de uma interação antagonista resultado de possível predação intraguilda ou eliminação de competidor em Carnivora, no qual um indivíduo de *Leopardus pardalis* carrega um indivíduo de *Cerdocyon thous.* O registro foi obtido através de armadilhagem fotográfica no Centro de Pesquisas e Conservação da Natureza – Pró-Mata/PUCRS localizado no município de São Francisco de Paula, Rio Grande do Sul, Brasil. O registro é inédito e relevante para que se obtenha uma perspectiva mais completa das interações ecológicas entre as duas espécies.

Palavras-Chave: Canidae; Felidae; Jaguatirica; Graxaim-do-mato; Rio Grande do Sul.

Abstract: Record of antagonistic interaction between *Leopardus pardalis* and *Cerdocyon thous* at the southern limit of the Atlantic Forest. In this study we present a record of an antagonistic interaction potentially resulting from intraguild predation or elimination of competitor within the Carnivora, in which an individual of *Leopardus pardalis* carries an individual of *Cerdocyon thous.* This record was obtained through camera trapping at the Pró-Mata Center for Research and Nature Conservation/PUCRS located in São Francisco de Paula, Rio Grande do Sul, Brazil. The record is unprecedented and relevant to allow a more comprehensive understanding of the ecological interactions between these two species.

Key-Words: Canidae; Felidae; Ocelot; Crab-eating fox; Rio Grande do Sul.

A família Felidae é composta por espécies de mamíferos que são carnívoros obrigatórios (Sunquist & Sunquist, 2002). A dieta destes animais pode variar de acordo com a disponibilidade temporal e espacial de presas, com sua preferência por determinadas espécies e pela presença de competidores intraguilda (Macdonald & Loveridge, 2010). A jaguatirica, *Leopardus pardalis* (Carnivora, Felidae), é um felídeo de médio porte, medindo entre 70 e 100 cm de comprimento e pesando de 11 a 16 kg (Murray & Gardner, 1997). A espécie possui uma ampla distribuição geográfica na região Neotropical, ocorrendo desde o sul dos Estados Unidos até o norte da Argentina (Sunquist & Sunquist, 2014). No Brasil, ocorre ao longo de todo o território nacional com exceção da porção sul do Rio Grande do Sul (Oliveira *et al.,* 2010; Trigo *et al.,* 2013). Apresenta grande plasticidade na dieta ao longo da sua distribuição, comportando-se como oportunista (Moreno & Giacalone, 2006). A sua dieta parece ser principalmente constituída por pequenos roedores (< 1 kg) (Emmons, 1987; Sunquist & Sunquist, 2002), incluindo também animais de médio e grande porte (1-25 kg), como tatus, cutias, pacas, capivaras, preguiças, macacos e até mesmo veados (Aliaga-Rossel *et al.,* 2006; Bianchi & Mendes, 2007; Delibes *et al.,* 2011; Moreno & Giacalone, 2006; Tirelli, 2010).

Esse comportamento oportunista pode afetar negativamente felídeos neotropicais de menor dimensão, visto que pode ocorrer sobreposição de dieta, gerando competição interespecífica ou até mesmo morte interespecífica (Donadio & Buskirk, 2006; Oliveira *et al.,* 2010). No entanto, pouco se sabe sobre a influência de *L. pardalis* sobre outras espécies de mesopredadores que fazem parte da mesma guilda trófica, como o graxaim-do-mato (*Cerdocyon thous,* Carnivora, Canidae) (Oliveira *et al.,* 2010; Oliveira & Pereira, 2014). Este canídeo pode chegar a 1 cm de comprimento, com peso médio variando entre 5 e 9 kg e apresentando dieta onívora (Berta, 1982; Kasper *et al.,* 2014). Sua distribuição é restrita à América do Sul, (Berta, 1982), onde ocorre em simpatria com *L. pardalis.* Aqui apresentamos um evento, não descrito na literatura, envolvendo essas duas espécies. Em dois vídeos registrados simultaneamente, (Vídeo S1

e Vídeo S2), provindos de duas armadilhas fotográficas instaladas de forma pareada, registramos um indivíduo macho de *L. pardalis* carregando em sua boca um indivíduo já sem vida de *C. thous* (Figura 1). Os vídeos, de 10 segundos cada, foram obtidos no Centro de Pesquisas e Conservação da Natureza Pró-Mata (CPCN Pró-Mata) da PUCRS, localizado no município de São Francisco de Paula, Rio Grande do Sul (Figura 2). O município de São Francisco de Paula situa-se na região da Serra Geral, e é caracterizado por um clima subtropical com temperatura média anual de 16°C e um alto grau de umidade (IBGE, 1986). O CPCN Pró-Mata abriga um remanescente do bioma Mata Atlântica em regeneração natural (Marques *et al.,* 2011).

O registro ocorreu no dia 22 de janeiro às 00h02min, na área próxima do limite do CPCN Pró-Mata com uma propriedade privada (29°29'29.6"S, 50°13'53.9"O) (Figura 2). O Datum utilizado foi o *World Geodetic System* 1984 (WSG84).

Pelas imagens obtidas simultaneamente nas duas armadilhas fotográficas (Figura 1) é possível observar na armadilha fotográfica 1 o indivíduo de *L. pardalis* carregando uma presa identificada como *C. thous* (Figura 1a); embora o evento tenha também sido registrado na armadilha fotográfica 2, o ângulo não permite uma nítida identificação da presa, mas demonstra a dificuldade do felídeo em carregar uma presa de tamanho corporal semelhante ao seu (Figura 1b). A morte de *C. thous* pode ter sido causada por *L. pardalis,* resultando de predação intraguilda (PI) ou de eliminação de competidor, designada por morte interespecífica (MI) (Oliveira & Pereira, 2014). A predação intraguilda (PI) ocorre quando há predação entre competidores da mesma guilda trófica; tais eventos podem beneficiar duplamente o predador, ao eliminar um competidor e ao mesmo tempo podendo alimentar-se dele. Já a morte interespecífica (MI) caracteriza-se pela morte de um indivíduo de outra espécie por um indivíduo de espécie competidora, sem que o último se alimente do primeiro. Tal interação não traz aparente vantagem imediata por ganho energético, porém elimina potenciais competidores. Ambos os tipos de interação parecem ser importantes na estruturação das assembleias de carnívoros (Oliveira & Pereira, 2014; Polis *et al.,* 1989).

No presente estudo, no caso de não haver consumo da presa, se configuraria um caso de morte interespecífica,

Figura 1: Imagens obtidas pelas armadilhas fotográficas pareadas registrando a interação antagonista entre um indivíduo de *Cerdocyon thous* (graxaim-do-mato) e um indivíduo de *Leopardus pardalis.* (a) Armadilha fotográfica 1 registrando *Leopardus pardalis* de perfil, sendo possível identificar o indivíduo de *Cerdocyon thous* em sua boca; (b) Armadilha fotográfica 2 mostrando o indivíduo de *Leopardus pardalis* de costas carregando o indivíduo de *Cerdocyon thous.*

NOTAS

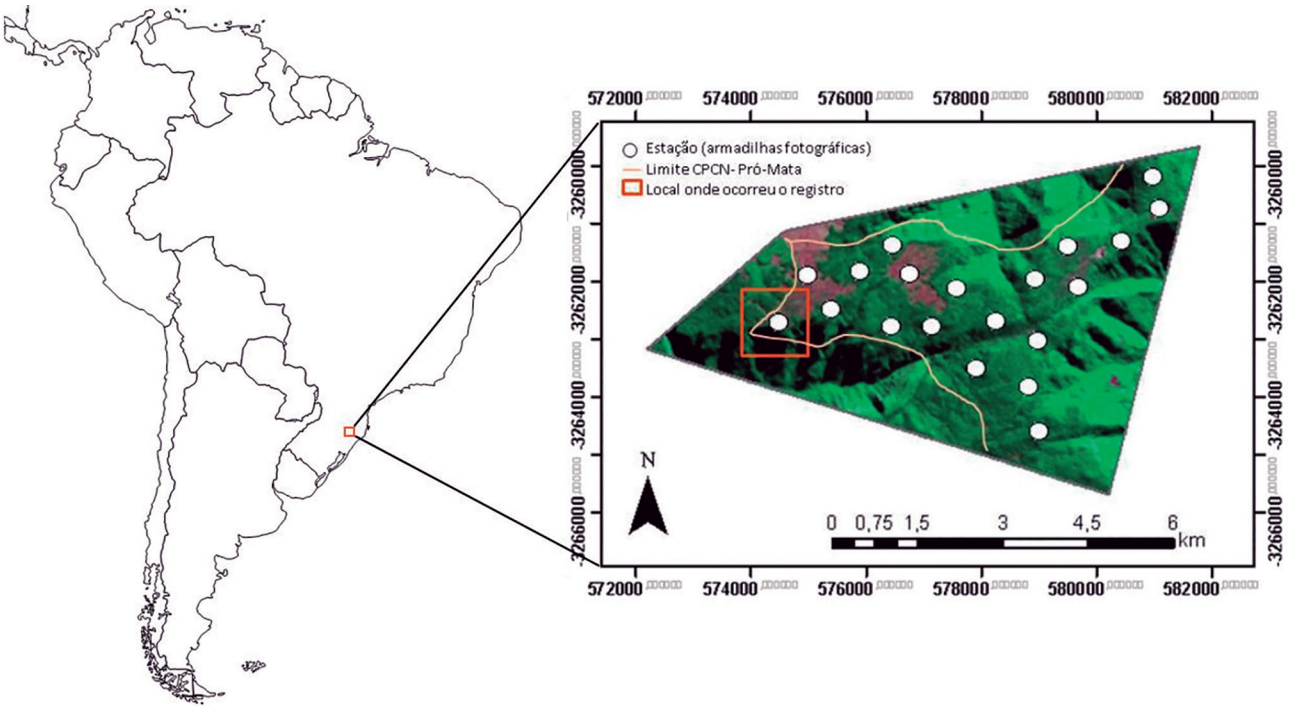

Figura 2: Localização da área de estudo, no Centro de Pesquisas e Conservação da Natureza Pró-Mata (CPCN-Pró-Mata), município de São Francisco de Paula, Rio Grande do Sul, Brasil. Em destaque, o local onde estava instalada a estação (com duas armadilhas fotográficas pareadas) que registrou a interação antagonista. Coordenadas geográficas da estação: 29°29'29.6"S, 50°13'53.9"O (Datum usado: WSG84).

onde o predador teria um ganho por eliminação de eventuais competidores (Oliveira & Pereira, 2014). Porém, apesar de não ter sido registrada a ingestão propriamente dita, este evento poderia tratar-se de um caso de predação intraguilda, visto que *L. pardalis* tende a carregar suas presas para alimentar-se em locais distintos de onde ocorreu a predação (Aliaga-Rossel *et al.,* 2006; Delibes *et al.,* 2011). Ainda em relação a padrões de dieta, existe pelo menos um registro de *L. pardalis* alimentando-se de um *C. thous* atropelado (Crawshaw, 1995).

Em grande parte dos casos, quer de morte interespecífica, quer de predação intraguilda, o predador é um carnívoro obrigatório, enquanto que a presa tende a possuir hábitos mais onívoros, como é o caso dos felídeos sobre outros grupos de carnívoros (Oliveira & Pereira, 2014). A massa corporal também pode ser um fator importante para a ocorrência destas interações. Com efeito, Donadio & Buskirk (2006) analisaram dados globais de mortes interespecíficas em Carnivora tendo detectado que, embora exista frequentemente sobreposição de nicho entre as espécies interatuantes, as mortes acontecem em maior frequência quando os predadores apresentam massa corporal duas a cinco vezes maior que a das presas. Oliveira & Pereira (2014) estimaram também possíveis interações de morte interespecífica e predação intraguilda em Carnivora sul-americanos baseados em sua massa corporal e áreas de sobreposição entre espécies, indicando *C. thous* como possível presa de *L. pardalis.* De todos os casos de morte em que *L. pardalis* é o predador, 77.8% indicam que tal predação está associada a exclusão competitiva, sugerindo ainda que *L. pardalis* tem forte efeito sobre a estruturação da comunidade de carnívoros (Oliveira & Pereira, 2014). Desta forma, informações adicionais sobre os padrões de ocorrência, densidade e dieta de *L. pardalis* em diferentes regiões poderão auxiliar no entendimento das interações entre as espécies que constituem as assembleias de carnívoros neotropicais.

Informações suplementares encontram-se em http://sbmz.org/publicacoes. VS1: Vídeo da interação antagonista obtido pela armadilha fotográfica 1; VS2: Vídeo da interação antagonista obtido pela armadilha fotográfica 2.

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Informações suplementares disponíveis on-line para este arquivo em http://sbmz.org/publicacoes.

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NOTAS

New records of occurrence of maned three-toed sloth *Bradypus torquatus* Illiger, 1811 (Pilosa, Bradypodidae) in the geological complex of Morro do Moreno, Vila Velha, Espírito Santo, Brazil

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Abstract: The maned three-toed sloth, *Bradypus torquatus,* is considered a vulnerable specie, endemic to the Atlantic Forest. We recorded the occurrence of *B. torquatus* in three new locations, all of them in the geological complex of the Morro do Moreno, Vila Velha, Espírito Santo. These new records increase the species distribution, although the fragments are pretty small and show a high disturbance level. The occurrence of sloths in small fragments under strong anthropic influence raises new efforts to understand the maintenance capacity in urban environments and furthermore, can subsidize studies about the species management and conservation.

Key-Words: *Bradypus torquatus;* Coast; Morro do Moreno; New occurrence.

Resumo: Novos registros de ocorrência de preguiça-de-coleira *Bradypus torquatus* Illiger, 1811 (Pilosa, Bradypodidae) no complexo geológico de Morro do Moreno, Vila Velha, Espírito Santo, Brasil. A Preguiça-de-coleira, *Bradypus torquatus,* é considerada uma espécie vulnerável, endêmica da Floresta Atlântica. Registramos a ocorrência de *B. torquatus* em três novas localidades, todas no complexo geológico do Morro do Moreno. Os novos registros ampliam a área de ocorrência da espécie, apesar dos fragmentos serem pequenos e a mata relativamente descaracterizada. A presença dos animais suscita novos esforços no sentido de compreender a capacidade de manutenção de preguiças em ambientes urbanos e, além disso, subsidiar estudos para o manejo e conservação dessa espécie.

Palavras-Chave: *Bradypus torquatus;* Litoral; Morro do Moreno; Nova ocorrência.

INTRODUCTION

Bradypus torquatus Illiger, 1811 is the most threatened species of sloth in the South American continent (Aguiar & Fonseca, 2008). In the Brazilian territory is classified as vulnerable (IUCN, 2016). Its area of occurrence covers a narrow region between the states of Espírito Santo (Chiarello, 1998), Pernambuco and Bahia (Abba & Superina, 2009). However, more recent studies mention its new occurrence in other states, such as Sergipe (Chagas *et al.,* 2009), Rio de Janeiro (Boffy *et al.,* 2010) and based on ecology analysis supposed a more extended geographical range in northeast of Espírito Santo and north of Rio de Janeiro (Moreira *et al.,* 2014). It is still in the Brazilian Atlantic Forest biome.

In the Espírito Santo State, Lara-Ruiz *et al.* (2008) carried out studies focused on the species in four locations: Santa Maria de Jequitibá, Santa Teresa and Itarana in the country of the State, whose region is formed by forested mountains between 600 m and 1000 m above the sea level and over near the coast in the region of Aracruz, in private forest reserves.

The Southeastern region of Vitória's Bay is characterized by the Morro do Moreno geological complex: Morro do Moreno, Morro do Convento de Nossa Senhora da Penha and Morro da Ucharia. They are a geomorphological set of magmatic rocks (Rangel Filho, 2007), covered by fragments of the Atlantic Forest, forming an urban ecological corridor across the Vila Velha city, along with the Jaburuna mountain complex (Envirionlink, 2014).

The Morro do Moreno is a rocky massif measuring 190 m of height and 730.854,17 m² of area (Envirionlink, 2014). It is considered, according to the Brazilian environmental law, as an APP – Permanent Protection Area, that includes the top of hills or mountains with a minimum height of 100 meters and a half average greater than 25°C of slope and it is also a remainder of the Atlantic Forest.

Despite the importance of its preservation area, this location is undergoing debates to establish it as a Conservation Unit (Sathler & Rosa, 2015). At the center of the conflict there are about 508 inhabitants domiciled in 274 households (IBGE, 2010). In addition, the location is considered a natural touristic attraction receiving several visitors on weekends, which are not under any

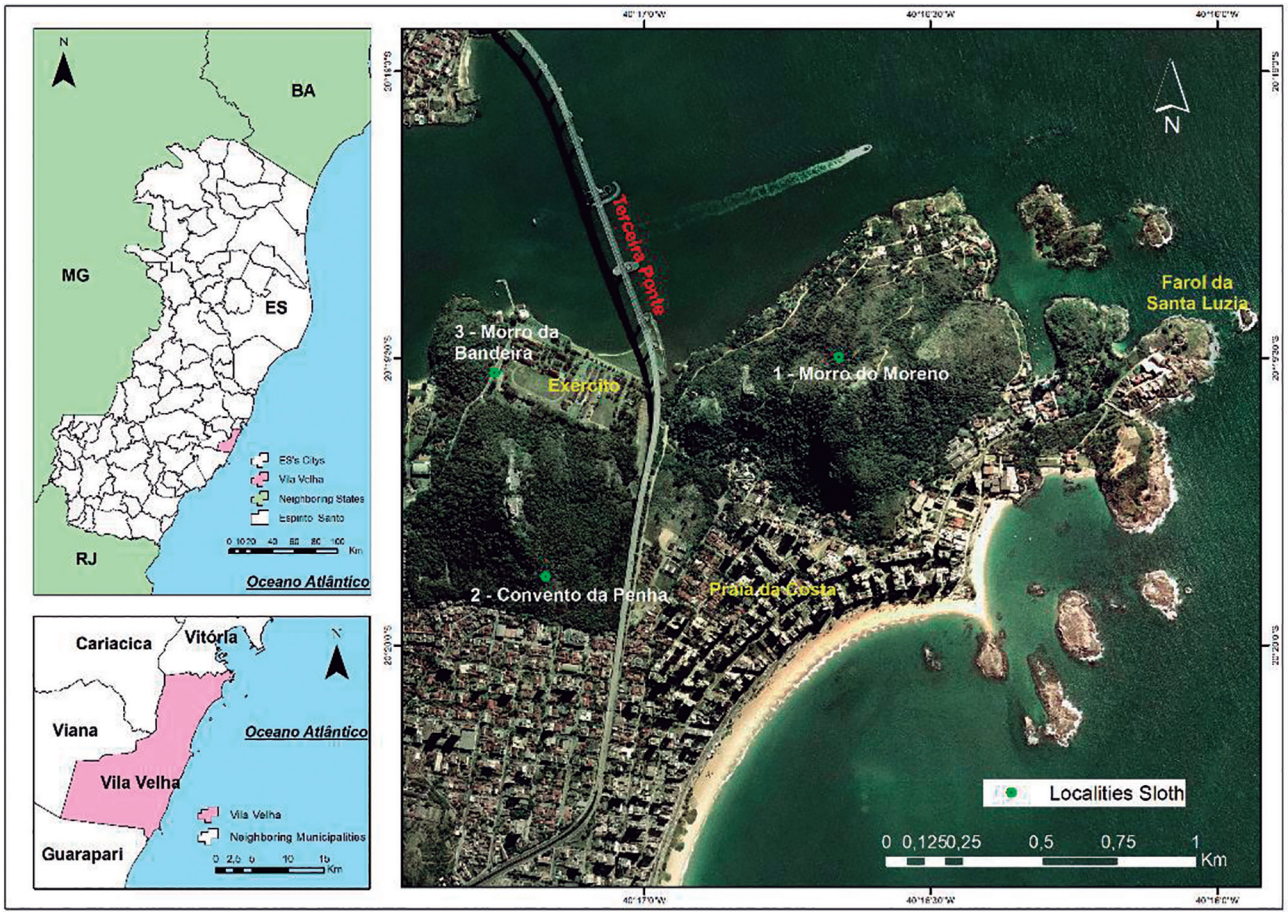

Figure 1: Map of the Morro do Moreno geological complex in Vila Velha – ES. The green dots indicate the three areas where the specimens of maned three toed sloth were found.

type of control or receiving any kind of guidance for the safety of the forest and wild animals.

The Morro do Convento de Nossa Senhora da Penha hosts the second most visited religious patrimony in Brazil, with 154 meters of height (Prefeitura de Vila Velha, 2017). It is covered by a fragment of vegetation in early regeneration stage. Little is known about its ecological state due the scarcity of studies.

The Morro da Ucharia is an area that has belonged to the Brazilian Army since 1908, it is also known as the 38th Batalhão de Infantaria of Vila Velha (Exército Brasileiro, 2018). There is no information available regarding the local environment features, since it is a restricted area used for military training.

We report the occurrence of maned three-toed sloth in these three sites located in Vila Velha city – ES, all of them composed by fragments of coastal Atlantic Forest with a high anthropogenic disturbance degree (Figure 1).

The first record of the species occurred at Morro do Moreno on June 14th, 2014. At 20°19'05.9"S and 40°16'52.3"W Datum WGS 84. The sloth was an adult female which was spotted at 09:15 am during an environmental maintenance event carried out by the Jacarenema Environmental Research Institute. The animal was sighted at one and a half meters from the observer. The second registration occurred on February 15th, 2015 at the top of the massive at 10:22 am. The animal, an adult male was upright, probably coming down to the ground to defecate (Figure 2A). At Morro do Convento de Nossa Senhora da Penha, we got a record of a female carrying her baby during the religious traditional celebration, in the morning at 09:30 am, on April 2nd, 2016, at 20°19'23.1"S and 40°17'10.2"W Datum WGS 84.

In the Morro da Ucharia, the registration was carried out on May 26th, 2016 at 11:00 am at 20°19'02.6"S and 40°17'15.6"W Datum WGS 84. The sloth was an adult male walking down on the ground, crossing over the road from the battalion facilities towards the Morro do Convento de Nossa Senhora da Penha (Figure 2B). The previous records of the species in Espírito Santo occurred mainly in mountainous regions, where the vegetation reaches relevant conservation levels and is found in the National, State or private parks. Lara-Ruiz *et al.* (2008) found noteworthy a high degree of forest connectivity among the Santa Teresa, Santa Maria de Jequitibá and Itarana fragments, and the lowest among the mountainous region and the Aracruz city.

We understand that the bay of Vitória and the catchment area of the Santa Maria da Vitória river constitute a natural barrier between the country populations and those of the coast. These geographic factors contribute to a knowledge gap regarding the origin of *B. torquatus* populations found in the metropolitan region of Vitória city.

The few studies carried out on the Morro do Moreno complex were limited to geological mapping (Rangel Filho, 2007) e and the conflicts of the territory

Figure 2: (A) A male adult of *Bradypus torquatus* coming down to the ground by the vines at Morro do Moreno and (B) another male adult crossing over the road at Morro da Ucharia. Fotos de Instituto Jacarenema.

occupation (Côgo, 2015). The unique mention of the existence of maned three-toed sloths was provided by local people but they did not provide more details about the occurrence sites or even taxonomic data confirming the species. The scarcity of research in the region of the Morro do Moreno geological complex can be explained by the low allocation of public resources, high declivity and areas with landslides that are in risk of collapse (Origge *et al.,* 2016), which make a large part of the ecosystems in the area remain unknown, even though they are of great ecological, tourist and landscape relevance.

These new records, for Espírito Santo coast, not only confirm the occurrence of the species in these localities, but also suggest that additional research should be done to evaluate the size and conservation status of the maned sloth population.

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Everything for the Muriquis: reflections from a long-term field study on a critically endangered primate

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Abstract: Long-term field studies on wild primates can provide unique insights into the behavioral flexibility that permits long-lived, socially complex animals to adapt to changing ecological and demographic conditions. Long-term studies are also important for the development of informed conservation and management plans for critically endangered species, and for providing training opportunities for future scientists and conservationists. In this essay I reflect on my personal experiences with the northern muriqui (*Brachyteles hypoxanthus*), from the time of my first visit to Brazil in June 1982 to June 2018. I review the many discoveries we have made about the muriquis, the scientific and conservation contexts in which the Muriqui Project of Caratinga has been able to grow, and the human dimensions that have made this international collaboration possible.

Key-Words: Muriqui; Long-term study; Conservation; Behavioral flexibility; International collaboration.

Resumo: Tudo pelos Muriquis: reflexões sobre um estudo de campo de longo-prazo sobre um primata criticamente ameaçado. Estudos ecológicos de longa duração sobre primatas selvagens podem possibilitar a aquisição de conhecimentos sobre a flexibilidade comportamental que permite que animais socialmente complexos e longevos se adaptem a condições ecológicas e demográficas em mudança. Tais estudos são também importantes para o desenvolvimento de planos efetivos de conservação e manejo para espécies criticamente ameaçadas, assim como para fornecer oportunidades de treinamento para futuros cientistas e conservacionistas. Neste ensaio, reflito sobre minhas experiências pessoais com o muriqui-do-norte (*Brachyteles hypoxanthus*), desde o momento da minha primeira visita ao Brasil em junho de 1982 até junho de 2018. Aqui reviso as muitas descobertas que fizemos sobre os muriquis, sobre os contextos científico e conservacionista que possibilitaram o desenvolvimento do Projeto Muriqui de Caratinga, e sobre as dimensões humanas que possibilitaram esta colaboração internacional.

Palavras-Chave: Colaboração internacional; Conservação; Estudo de longa duração; Flexibilidade comportamental; Muriqui.

INTRODUCTION

During my first visit to Brazil, in June 1982, I fell irreversibly in love with the northern muriqui (*Brachyteles hypoxanthus*). I was a 23-year old American graduate student from Harvard University, in search of a subject to investigate for my doctoral dissertation. I had learned about this rare, elusive monkey from a documentary film, "The Cry of the Muriqui," that was produced by Russell (Russ) Mittermeier when he worked at the World Wildlife Fund, and narrated by my PhD advisor, Irven DeVore. The muriqui was the largest nonhuman primate in the Americas and considered to be one of the most endangered primates in the world, but almost nothing about its behavioral ecology was yet known.

This lack of information made the muriqui an ideal study species for someone with my interest in understanding primate social behavior from a comparative perspective, because in those days most of what was known came from only a few species such as baboons and chimpanzees with ecological or phylogenetic affinities to humans. My plan was to use the social and ecological theories developed from studies of those familiar Old World primates to generate predictions about how this New World primate, the muriqui, should behave. Then all that I would need to evaluate my predictions was a group of muriquis that I could recognize individually and observe systematically as they went about their daily routines.

Mittermeier thought that my best prospect would be the small muriqui population inhabiting the small, privately owned forest at Fazenda Montes Claros, in Caratinga, Minas Gerais, where most of the muriqui footage in his film had been shot. So, he introduced me to some of the Brazilians leading conservation efforts in the Atlantic Forest, all of whom had been inspired by Alvaro Aguirre's (1971) pioneering report on the alarming decline in muriquis throughout their range. These included Dr. Célio Valle (Professor of Zoology at UFMG, who also became my Brazilian sponsor during the early years of my research), Dr. Adelmar Coimbra-Filho (Director of the Rio de Janeiro Primate Center), and Almirante Ibsen de

Gusmão Câmara (President of FBCN). Russ also introduced me to the owner of Fazenda Montes Claros, Senhor Feliciano Miguel Abdala, who by protecting his forest and prohibiting hunting had single-handedly preserved one of the last remaining strongholds for this species.

No one knew at the time that nearly two decades later, in 2001, Sr. Feliciano's family would transform their forest into a private, federally protected reserve, named the RPPN Feliciano Miguel Abdala in his honor. However, everyone agreed that maintaining a continuous research presence in Sr. Feliciano's forest would add an important component to the other local conservation initiatives underway. Although it seems completely obvious today, this way of thinking about science as a tool for conservation was new to me then, and it fundamentally shifted my perspective from what had been an academic, theoretical interest in muriquis to a much more compelling one encompassing the application of basic research findings to inform conservation and management decisions.

I discovered early in my career that scientific curiosity, fueled by the even greater cause of conservation urgency, is a powerful aphrodisiac with addictive properties. Combine this underlying motivating force with the enormous aesthetic appeal of the muriquis, whose expressive faces, graceful movements, and uniquely gentle manners set them apart from other primates, and it is not surprising that I was so easily and enduringly seduced.

It also helped that I felt so welcomed by most of the Brazilians I met. Thanks to the remarkable friendship and collaboration of a growing network of students and colleagues with shared concern for the muriquis, and with the support of many funding organizations, the Muriqui Project of Caratinga has grown from my dissertation field research to become one of the longest running field studies of any primate in the world.

In this essay I describe how the project developed and review some of the major scientific discoveries that have emerged during our studies of wild northern muriquis over the past 35 years, beginning in June 1983 when I returned to Fazenda Montes Claros to conduct the 14-month field study described in my doctoral dissertation. I also integrate the significance and application of these discoveries for the conservation and management of muriquis. It is clear that conservation priorities have not only intersected with, but also driven the direction of the research and thus underlie or are responsible for many of our key discoveries. Because most of the scientific and conservation parts of the project have been published elsewhere, I provide citations to the literature where the data and analyses can be found but otherwise focus on the narrative. This narrative also includes the names of many key colleagues and collaborators, without whom none of our research or conservation advances with the Caratinga muriquis could have been made.

In the final section, I briefly draw on personal experiences and perceptions to consider some of the ways in which the socio-political climate for primate field research and conservation in Brazil has changed my perspective as an American woman with a background in Biological Anthropology, the subfield of Anthropology in which the majority of North American field primatologists are based, in contrast to that of Zoology, Psychology, or Bioscience in Brazil. These different disciplinary contexts arise based on where primates are situated along the animal-human continuum in different academic traditions. The U.S. tradition has been to emphasize the phylogenetic status of primates as the closest living relatives to humans and therefore field primatology is closely linked with evolutionary anthropology, in contrast to the traditions of most primate habitat countries (Strier, 2000, 2017a). Yet regardless of how primates in general are viewed, there is no doubt that the muriqui is a most remarkable mammal, endemic to Brazil.

Research and Conservation Milestones

The long-term field study can be partitioned into four phases, each of which is associated with particular scientific initiatives and conservation milestones (Figure 1). Initially, both the research and conservation were narrowly focused on one study group and the forest at Fazenda Montes Claros. Today, our research includes all four muriqui groups that comprise this isolated population, and we are addressing questions that require the unique longitudinal data we now have. Similarly, our conservation efforts have expanded beyond this single muriqui population to include collaborating on comparative field studies and on projects aimed at habitat expansion and forest connectivity. We are also involved with the Brazilian government's integrated National Action Plan for the Conservation of Muriquis (Jerusalinsky *et al.,* 2011).

Phase I: Behavioral Ecology

I returned to Harvard in August 1982 to write grant proposals for support of a 14-month field study, and by June 1983 I was back in the forest with funding from U.S. sources, Célio Valle as my Brazilian sponsor, and permission from the Brazilian government. Sr. Feliciano had donated a small house at the edge of the forest along a dirt road in the central valley, known as the Matão valley, for the use of researchers, and by the time I arrived other students-all Brazilians-were already there. One of them, Rosa Lemos de Sá[1], had come to help me to set up some vegetation plots so that I could compare the seasonal patterns of availability in fruits, leaves, and flowers to the foods that the muriquis chose to eat. Another, Gustavo Alberto Fonseca[2], was collecting comparative data on muriquis at

1 Rosa helped me for about 5-6 weeks and later conducted her Masters' dissertation research on another population of muriquis at Fazenda Esmeralda, in Rio Casca, MG, and we collaborated on a comparative study of the forest structure of our respective study sites (Lemos de Sá and Strier, 1992). She also led the first capture-release study of wild muriquis to obtain morphological and genetic data (Lemos de Sá *et al.,* 1990). As of this writing, Rosa is the CEO of Funbio.

2 After defending his PhD dissertation on the small mammal community from University of Florida-Gainesville, Gustavo became a Professor in the Zoology Department at UFMG and Director of Conservation International – Brazil. Gustavo served as my Brazilian

Fazenda Montes Claros and Fazenda Esmeralda, also in Minas Gerais, for his Masters' dissertation. Gustavo and I watched the muriquis together for a few weeks before he moved on to his second field site, and he served as my Brazilian counterpart with CNPq for many years.

A third student, Sérgio Lucena Mendes, had just begun a field study on the sympatric brown howler monkeys for his Masters' dissertation from the Universidade de Brasilia. Sérgio[3] was the only other student who spent the whole year at the forest, and once I could converse in Portuguese he became a close friend and has remained so ever since. We have also been close collaborators, and Sérgio has been my Brazilian counterpart and the co-director of the Muriqui Project of Caratinga for about two decades (Strier & Mendes, 2012).

It was great to have other people around, but it was also really difficult to be living in such close quarters without being able to join in the conversations. Although I had studied some Portuguese, communicating with any fluency was one of the greatest challenges I faced during those initial weeks. My way of coping was to minimize human contact by spending as much daylight time as I could in the forest, where it was my observational skills instead of my linguistic ability that mattered (Strier, 2014).

Even with such intensive effort, it took a few months to gain the muriquis' trust and to be able to follow them when they moved away from the dirt roads that were used by the local farmers and their families. Deeper into the forest, the muriquis were much more cautious. Gradually, as I learned their travel routes and how to behave in their presence, the muriquis became habituated to me. By August, Célio had found me a student from UFMG to help as my field assistant. We worked it out so that Eduardo Veado[4] would stay with the muriquis one week every month while I was recording phenological data in the vegetation plots.

The muriquis spent about 50% of their daylight time resting (Strier, 1987a), often in close proximity to one another. These quiet times were especially important because they provided opportunities for me compare the physical attributes of each muriqui to the others, a process that led me to be able to recognize all 23 members of my study group by the differences in their pelage and natural facial and genital markings (Strier, 2007).

That first year of continuous, extended observations was full of new discoveries about muriquis that led to new ways of thinking about the behavioral ecology of other primates (Strier, 1994, 2017b). One of the key insights was that although muriquis spent more than half of their feeding time consuming leaves, they still went out of their way, often traveling long distances, to find large patches of preferred fruits and flowers, where they would camp-out for days (Strier, 1987b). This feeding pattern made it difficult to fit them into the prevailing dietary categories, which were based on the highest percentages of different food types in primate diets. By these traditional criteria, the muriquis would be classified as folivores, even though everything else about their behavior and ranging patterns made more sense in terms of their preference for fruits, with leaves serving more of a "critical function" to supplement their diets when preferred fruits were scarce. Over time, this alternative perspective, with its implications for interpreting broader patterns of primate behavioral variation and flexibility, has been supported by comparative data from other muriqui populations living in different habitats, but back then it was at odds with ideas about species-typical diets and the implications of these diets for social behavior (Strier, 1992, 2016).

A second major and much more publicized discovery was even more surprising because the muriquis showed no evidence of the hierarchical societies known to characterize all other primate species known at the time. Instead, muriqui society was unexpectedly peaceful, with nonaggressive, egalitarian social relationships among and between males and females (Strier, 1990; Strier *et al.,* 2002a). There was no evidence of the agonistic-based interactions that in other primates determine who has alpha status and gains priority of access to limited resources such as food and mates. The muriqui's extreme social tolerance was especially striking during their mating bouts, which occur in full view of other group members and unlike most other primates, often involve multiple males waiting in turn to mate with the same female, without any overt signs of aggression or hostility toward one another or toward a female if she opts to move away (Possamai *et al.,* 2007; Strier, 1994, 1997).

As word of the muriqui's promiscuous, laid-back lifestyle got out through presentations, publications, and the popular press, the muriquis were rapidly nicknamed "hippie" primates. This reputation also provided an endearing distinction that gave us a new platform for raising interest and awareness about their critically endangered status.

The high tolerance among males and the assertiveness of females made more sense once the muriqui's pattern of male philopatry and female dispersal began to emerge. In most semi-terrestrial Old World monkeys that live in similarly sized multi-male, multi-female groups, females remain in their natal groups in extended matrilines for life, whereas males disperse. In muriquis, by contrast, males spend their entire lives living with their fathers, brothers, and uncles, as well as their mothers, whereas females typically leave their families behind to join new groups where they remain to reproduce.

My original study group, the Matão group, was one of the two muriqui groups in the forest, so when

counterpart for the Muriqui Project of Caratinga until his move to the U.S. As of this writing, he is Director of Programs at the Global Environment Facility in Washington, DC.

3 After defending his Masters dissertation on brown howler monkeys, Sérgio completed his PhD on the biogeography and taxonomy of callitrichids from the Universidade de Campinas, and was Director of the Museum Augusto Ruschi before becoming a Professor in Biological Sciences at UFES. He is currently the Director of the Instituto Nacional da Mata Atlantica, and a recipient of the 2018 award, Faz Diferenca, in Health, Science, and Society from O Globo, and the Muriqui Prize from Conselho Nacional da Reserva da Biosfera da Mata Atlantica.

4 Eduardo worked as my field assistant during my dissertation research, and then served as the Director of the Estação Biológica de Caratinga, where the Muriqui Project of Caratinga was based, until the RPPN Feliciano Miguel Abdala was created. Eduardo's many contributions on behalf of muriquis have been described in Strier and Pinto (2005).

an unfamiliar, nulliparous female suddenly appeared, she could only have come from the other group, named after the Jaó valley it occupied to the north. I had the chance to document this female's successful immigration (named Cher) and that of a second female (named Blacky) from Jaó a few months later that year, but there

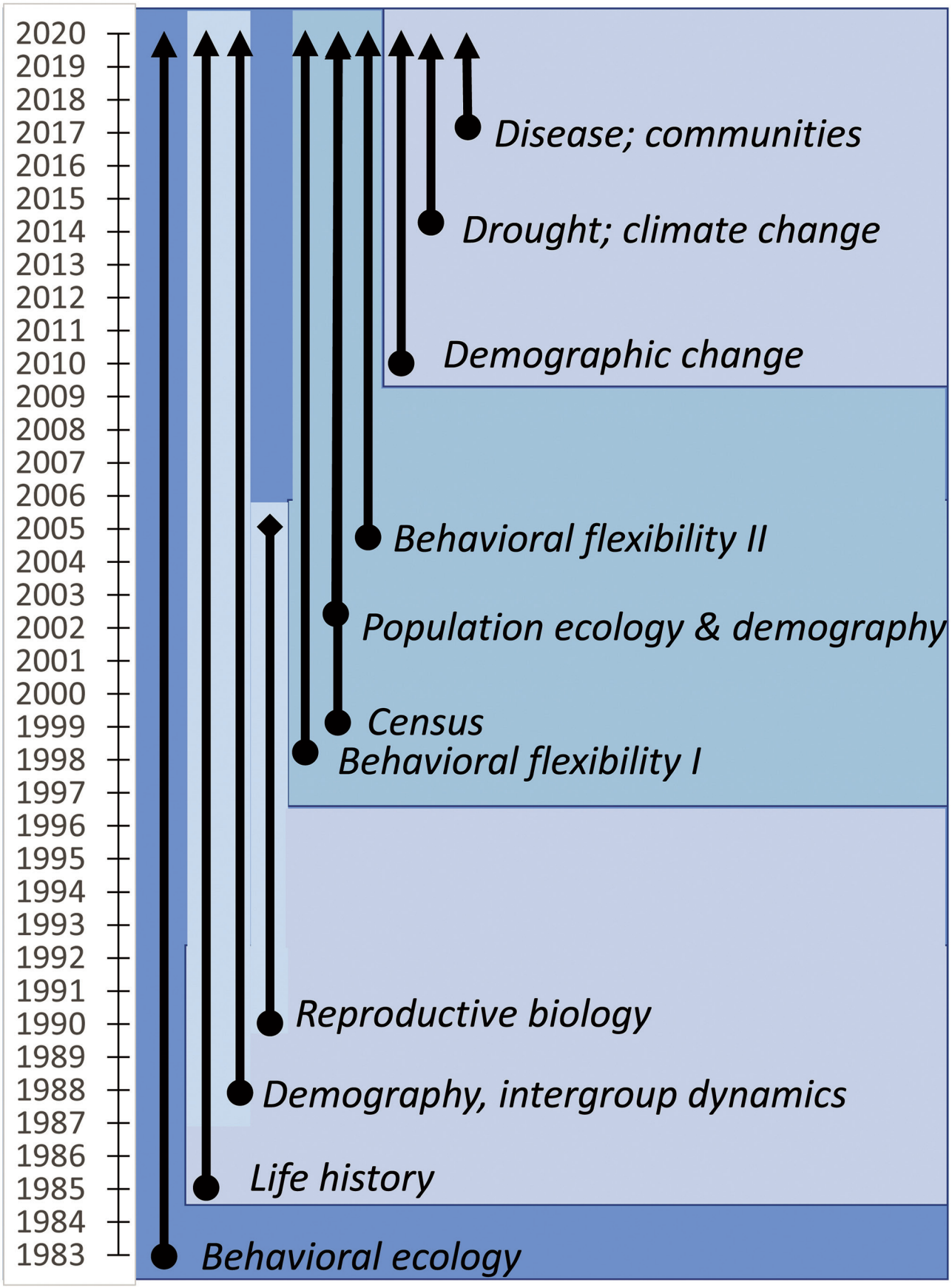

Figure 1: Timeline of research initiatives for the Muriqui Project of Caratinga, 1983-present. Arrows indicate the duration of the research interest; color groupings show the successive phases of the project, corresponding to those described in the text.

were no changes in male group membership. Nonetheless, it took many years to confirm that male muriquis were patrilocal and lived in extended patrilines, whereas females routinely disperse at about six years of age, prior to the onset of puberty and sexual activity (Printes & Strier, 1999; Strier & Ziegler, 2000; Strier *et al.,* 2015).

Decoding the muriqui's dispersal patterns was fortuitous and fantastically important. In addition to providing insights into the genetic relationships underlying muriqui social relationships, the discovery of female-biased dispersal also had important implications for management programs that involve translocations to increase the genetic variation in small, isolated populations (Chaves *et al.,* 2011; Mendes *et al.,* 2005).

Phase II: Life History, Demography, and Reproductive Biology

A second phase of research was initiated between 1985 and 1990, when the potential for developing a long-term study that transcended my dissertation became clear (Figure 1). The first step was to make sure that we could distinguish the same individual muriquis over the duration of their lives. I did not want to capture or mark the muriquis in any way, so the only solution was to train other people how to recognize individuals by the same physical characteristics I associated with each of the names I had assigned. This would permit us to determine which females were reproducing and at what intervals, and to document other important life history events, such as the ages at which females of known age disperse, and the ages at which natal males of known age become sexually active. It would also permit us to determine the ages at death. Most primates have slow life histories relative to other mammals of similar body mass, but my 14-month study was too short to determine just how slow the life histories of muriquis would be.

I took a break from working on my dissertation to return to the forest for a brief visit in September 1985. I had heard that some of the females in my study group were carrying new infants, and I wanted to know which of them had given birth. Coincidentally, soon after I reached the forest, Célio was visited by Francisco (Dida) Mendes, a Masters' student from USP who was interested in muriqui social behavior. Célio sent Dida to meet with me at the forest, and there we agreed that I would return after my defense, in June 1986, to teach him how to recognize the individuals in the same group I had studied. Dida was the first of the more than 60 Brazilian students who have participated on the project to date[5].

Dida encouraged one of his friends, José (Zé) Rímoli, to follow in his footsteps, and during the roughly three years that Zé and his wife, Adriana, spent on the project, the behavior of the muriquis had begun to change. We knew that the Matão group was increasing in size, and it was beginning to become less cohesive. At the same time, a subset of females and males from the Jaó group began to make increasingly frequent incursions into the Matão group's home range, often (but not always) accompanied by aggressive intergroup encounters, and often remaining instead of retreating north to the Jaó side of the forest (Strier *et al.,* 1993).

It took many years and a second fission of the Jaó group in 2002 before we could fully appreciate the significance of these intergroup dynamics (Strier *et al.,* 2006; Tokuda *et al.,* 2012, 2014) or how much the increase from two to four groups would contribute to facilitating female dispersal and minimizing close inbreeding (Strier, 1997; Strier *et al.,* 2011, 2015).

In 1988, the XII Congress of the International Primatological Society (IPS) was held in Brasilia, thanks to Milton Thiago de Mello, another pioneer in Brazilian primatology and conservation who served as Secretary for the Americas to the IPS for more than a decade. The Congress attracted many foreign primatologists, and more than a dozen of them came to visit the muriquis along the way. One of them was Charles (Chuck) Snowdon, an expert on primate communication from the University of Wisconsin-Madison who met Dida and agreed to help him with his dissertation research on muriqui vocalizations. Another visitor was Toni Ziegler, a post doc working in Chuck's lab on reproduction in callitrichids. During Toni's visit we talked about how little was known about the muriqui's reproductive biology, and the idea for a collaborative, non-invasive study using steroids extracted from muriqui feces was born (Strier & Ziegler, 2019).

By September 1990, I knew that muriqui interbirth intervals were about three years, and so I focused my collections on females muriquis who had given birth two years earlier and were expected to resume mating soon. Toni was able to extract and measure fecal estradiol and progesterone, and we had a glimpse of a wild muriqui's ovarian cycle (Strier & Ziegler, 1994). The whole idea of getting hormonal information without handling the animals is still magical for me. Over the next decade or so, Toni validated the assays with simultaneous urine and fecal samples with help from Alcides Pissinati at the Rio de Janeiro Primate Center (Ziegler *et al.,* 1997) and we went on to document an average gestation length of 216 days and cycle intervals of 21 days (Strier & Ziegler, 1997), the onset of puberty and timing of first reproduction in immigrant females (Strier & Ziegler, 2000), and divergent patterns of seasonal cortisol and testosterone (or androgen) levels in males and in females (Strier & Ziegler, 2005; Strier *et al.,* 1999b, 2003). Years later, other collaborators would extract and amplify fecal DNA for critically needed genetic analyses (Chaves *et al.,* 2011; Fagundes *et al.,* 2008).

I had planned to maintain comparative studies, one in Caratinga and others in larger, less disturbed forests. With Sérgio and Gustavo's help, we arranged for UFMG students, including Luiz Paulo de Pinto, to study muriquis in the large forest at the Reserva Biológica de Agusto Ruschi, in Santa Teresa, ES. That study was conducted in 1989 (Pinto *et al.,* 1993), and today the muriqui

5 For a list of all the students who have participated on the Murqiui Project of Caratinga, please see: http://strierlab.anthropology.wisc.edu/muriqui-project-of-caratinga-acknowledgements.

population is being monitored as part of Sérgio's research in the region. A few years earlier, with help from Russ, I was able to support some students to work with the southern muriquis at Carlos Botelho State Park, SP. One of them, Mauricio Talebi, took over the project and has sustained it as the only comparative long-term study of southern muriquis to date (Talebi & Soares, 2005).

Phase III: Behavioral Flexibility and Population Demography

By 1998, the Matão group had more than doubled from its original size and its 60 or so members exploited a correspondingly larger home range. This made sense because of the greater food supply area a larger group would need. However, there was no difference in average daily distances traveled, suggesting that the muriqui's switch to a fluid, fission-fusion pattern of association was a way to minimize per capita energetic costs (Dias & Strier, 2003). We hypothesized that this behavioral flexibility was an adaptive response to the demographic changes in the group.

There were also signs of population-level demographic changes. Until this time, the number of Matão female emigrants and Jaó female immigrants was closely matched, but by the late 1990s, there were more females leaving the Matão group than joining it (Strier, 2005). This raised the potential of there being a source-sink dynamic between the two groups and stimulated us to organize the first census of the entire primate community in August 1999 (Strier *et al.,* 1999a). Sérgio was the Director of the Museu Melo Leitão in Santa Teresa, ES, which was hosting the Congresso da Sociedade Brasileira de Primatologia. Many former students who had participated on the Muriqui Project were attending the Congress, so we invited about a dozen of them to take an extra week to help with the census.

Among the most important findings to emerge from the census was that the Jaó group was as large as the Matão group, and that several of the natal females from Matão that had emigrated to Jaó could still be identified by the former students. It seemed important to try to find a way to study this other half of the muriqui population, and to recover as much of the life histories of females of known ages as we could. For this reason, I did not think twice when I was given the opportunity to select a Brazilian primate ecologist, Jean Phillipe Boubli, for a five-year Millennium Post-Doctoral Fellowship sponsored by the San Diego Zoo.

Jean's post doc project was to help open up the Jaó group for our long-term demographic monitoring (Strier & Boubli, 2006;Strier *et al.,* 2002b, 2006) and to pursue ecological studies aimed at characterizing the forest and its potential to support the growing muriqui population (Boubli *et al.,* 2011). Two experienced students from the Matão study helped with the habituation and identification of the Jaó group members, and they not only recognized some of the Matão females that had previously migrated but also detected the presence of two subgroups in Jaó (named Jaó and Nadir, after one of the leading females from Matão), which split during the following years (Tokuda *et al.,* 2012). By then we also knew that the Jaó animals we had been seeing more frequently on the Matão side of the forest since the late 1980s had become a well-established group, named M2, and another former Matão student, Carla de Borba Possamai, took responsibility for habituating and identifying these muriquis. Carla conducted her Masters' research on the Matão group beginning in 2001 (Possamai *et al.,* 2005, 2007) and her doctoral research on the Jaó, Nadir, and M2 groups, and she is still working with us and helping to coordinate the Muriqui Project in 2018.

Since 2003 we have been monitoring the entire muriqui population in the forest, tracking female movements and comparing behavioral and demographic changes across the four groups. There is extensive home range overlap among groups, and intergroup encounters are more frequent. GPS data obtained while accompanying the muriquis reveal that they are using almost the entire forest and give the impression that the habitat may be approaching saturation as the population continues to grow.

One potential indication of the muriqui's response to habitat saturation may be reflected in their increasingly terrestrial behavior. Members of the Matão group have used the ground to cross open areas since the outset (Dib *et al.,* 1996; Valle *et al.,* 1984), and occasionally to drink from streams or feed on fallen fruit. Members of the Jaó and Nadir groups were also observed in these terrestrial activities. However, by 2005, the Matão muriquis had expanded both the frequency and the range of their terrestrial activities to include socializing and resting (Mourthé *et al.,* 2007).

Fernanda Pedreira Tabacow was the first "graduate" of the Muriqui Project of Caratinga to establish a comparative monitoring study on another isolated muriqui population inhabiting the RPPN Mata do Sossego in 2010. More recently, former Matão student Mariane Kaizer, along with former Jaó student Daniel Ferraz and their other colleagues established another comparative monitoring study in the large Parque Nacional de Caparaó, which straddles the border of the states of Minas Gerais and Espírito Santo.

The urgent need for comparative studies such as these became increasingly apparent with the taxonomic revision of the muriqui (Groves, 2001). It had been treated as a monotypic species, *Brachyteles arachnoides* until the millennium, when both the southern muriqui (*B. arachnoides*) and the northern muriqui (*B. hypoxanthus*) were recognized (Vieira, 1944). This reclassification was initially confusing because although I was still studying the same individuals in the Caratinga population as I had in 1983, they were suddenly given a new Latin name. But it also made great sense from a conservation perspective because, in addition to morphological and genetic differences (Chaves *et al.,* 2018; Lemos de Sá & Glander, 1993; Lemos de Sá *et al.,* 1990), the greatest threats facing many of the southern populations in RJ and SP were from hunting, whereas those facing most

northern populations in MG and ES were from habitat loss and fragmentation (Strier & Fonseca, 1996/1997). Behavioral differences were also beginning to emerge from comparisons between northern and southern populations, although how much these differences can be attributed to ecological and demographic differences between populations versus taxonomy is still unclear (Carvalho Jr., *et al.,* 2004; Martins, 2005; Moraes *et al.,* 1998; Talebi & Soares, 2005; Talebi *et al.,* 2009).

Indeed, at the time of our Muriqui Population and Habitat Viability Workshop, held in Belo Horizonte in 1998, the muriqui was still considered to be a monotypic species (Rylands *et al.,* 1998). However, both species were recognized by 2003, when IBAMA established the international Committee for the conservation and management of the muriqui (Oliveira *et al.,* 2005). New information generated from three muriqui projects in Minas Gerais and Espírito Santo, supported simultaneously by the Projeto de Conservação e Utilização Sustentável de Diversidade Biológica Brasileira (PROBIO) of the Ministry of the Environment (MMA), combined with accumulating insights from Caratinga, led to an action plan for the northern muriqui alone (Mendes *et al.,* 2005).

In 2005, the name of the muriqui committee was changed to the Committee for the Conservation and Management of the Atlantic Forest Atelids to include the brown howler monkey, *Alouatta guariba* (Oliveira *et al.,* 2005). Following the publication of the Plano de Ação Nacional para Conservação dos Muriquis, or PAN Muriqui (Jerusalinsky *et al.,* 2011), ICMBio/MMA established the Grupo de Assessoramento Técnico, or GAT-PAN, to accompany its implementation (DOU Edição № 119, seção 2, quarta-feira, 25 de junho de 2014, PORTARIA № 265).

Many of our findings about the northern muriqui were incorporated in one form or another into the 2011 PAN Muriqui. Recognition of the scientific value of our long-term behavioral, ecological, and demographic data, together with the size and protected status of the Caratinga population, continue to make the Caratinga muriqui population one of the top conservation priorities for this species (Strier *et al.,* 2017).

Phase IV: Demography, Drought and Disease

Between 1983 and 2010, our muriqui study population had more than quintupled in size, growing from about 50 individuals to 288 individuals and representing nearly one-third of the entire species. Most of the early population growth could be attributed to extremely low mortality across all age-sex classes, and a strongly female-biased birth sex ratio. By 2000, however, the population's birth sex ratio shifted to male-biased and mortality across all age-sex classes had increased. This rise in mortality was to be expected from the muriquis' increased exposure to terrestrial predators coincidental with their increased use of the ground. However, the muriquis also exhibited an unexpected increase in fertility, which we hypothesized might be related to the additional foods they could access as they expanded their vertical niche to include the ground (Strier & Ives, 2012). The energetics of maternal care might also be lower on the ground than in the trees (Guedes *et al.,* 2008).

Regardless of the mechanism, the muriqui population was continuing to grow. However, 2014 and 2015 were two of the driest consecutive years in our rainfall records, and in late 2016 the most severe outbreak of yellow fever in history struck the region. Coincidental with these catastrophes, the muriqui population in the Reserve has suffered a significant decline for the first time since the Muriqui Project began (Strier *et al.,* in preparation).

We do not know what has been responsible for the muriquis' high mortality. It could have been a delayed response to poor nutrition during the drought years, together with the yellow fever, or something else as yet unknown, or a combination of different factors. There were no clear behavioral clues of impending fatalities, and there was nothing remarkable about the few skeletal remains we have recovered.

We know that the muriquis were affected by the drought. Their water sources in the forest were drying up and my students sent me photos of them seeking moisture by reaching deep into mud. I also noticed that there were not as many young leaves as usual, so the muriquis may have had difficulty obtaining sufficient protein in addition to water. Comparative analyses of long-term life history data suggest that muriqui fertility may be sensitive to warming temperatures (Campos *et al.,* 2017), and nutritional stress may have made them more susceptible to infection or disease.

The yellow fever outbreak was even more alarming because of the rapidity and the magnitude of its effects. Within a few months it had killed hundreds of people and thousands of monkeys of many different species (including, we suspect, some muriquis), but no one knows what made this outbreak so lethal, or why it spread so quickly, or what its long-term consequences will be.

The other three primate species that are sympatric with the muriquis have also exhibited tremendous changes in their population sizes over the past few years (Possamai *et al.,* 2019). Brown howler monkeys (*Alouatta guariba*), in particular, are known to be especially susceptible to yellow fever (Bicca-Marques & Freitas, 2010; Holzmann *et al.,* 2010), and we have estimated an 80-90% decline in the howler monkey population in the Reserve, at least some of which may be attributed to yellow fever.

Understanding how the interacting effects of climate and disease affect the survival of muriquis and other sympatric primates has become an urgent research and conservation priority for the Muriqui Project. It has stimulated an expanding monitoring initiative of the entire primate community in the Reserve, currently being led by Carla. It has also reinforced the importance of maintaining the long-term muriqui study, which is providing the individual-based life history and demographic data needed to interpret the potential impact of new causes of mortality on their population recovery.

The warming temperatures, drought, and high virulence in this latest yellow fever outbreak are harbingers

of the climate change and increasing disease risks to come. Both climate change and disease will also affect human health and survival in the region, and whatever we can learn about the responses of other primates to these risk factors may provide unique insights that can be helpful to our own species as well.

Socio-political Contexts

On other occasions I have described some of the human dimensions of my research experiences in Brazil, focusing mainly on my interactions with the local people and with Brazilian students, colleagues, and friends (Strier, 2000, 2007, 2010, 2014). Here, I consider some of the socio-political contexts that have most directly impacted the long-term study to date.

The Local Community and the Reserve

The world seemed much bigger in the early 1980s than it has since the expansion of internet and other accessible modes of global communication systems. Before these, conducting any kind of field research in any foreign country could mean being cut-off from family and friends for months at a time, and this was certainly how it was for me. During my fieldwork at Fazenda Montes Claros in 1983-1984, the closest telephone was located in the city of Ipanema, some 28 km along a dirt road that became impassable to cars and buses after heavy rains. Calling the U.S. was prohibitively expensive, and there was no way for anyone from home to call me. Contact was nearly exclusively via the mail, which was delivered by the milkman on his morning circuit between Ipanema and the Fazenda. It could take up to three weeks for a letter to arrive in either direction.

The lack of close social contact with people from home gave the friendly social gestures of the local people and my fellow students great value. I do not think either my students or I would fare as well under these conditions as we did in the past, when the expectations for constant contact with our social and professional networks were so different. I think as a result of the social networks we now carry with us, we may be less motivated to make the efforts to establish new social bonds.

Sr. Feliciano and the local farming community had already hosted another foreigner, Japanese primatologist Akisato Nishimura, who had spent a few months at Fazenda Montes Claros studying the muriquis in 1977. His adventures were still a part of the local folklore when I came to live there in 1983. I am not sure how much my being an American mattered compared to the foreignness of my chosen profession to spend my days in the forest for more than a year. I don't know if being a young, single female made me more of a local curiosity than I would have been as an older woman or a man, but I definitely felt a certain protectiveness toward me as a result of being young and female that contributed to my sense of security.

The social dynamics understandably changed as all of us aged. For many years of the project I was able to spend nearly three consecutive months at the forest, but my stays at the forest have been reduced to short visits two or three time each year as my responsibilities in the U.S. have grown.

Sr. Feliciano's death also brought changes to the Fazenda and to the Muriqui Project. His family established an NGO, the Sociedade para a Preservação do Muriqui (SPM), to administer the RPPN they had created in his honor. Its president is Ramiro Abdalla Passos, one of Sr. Feliciano's grandsons who is an airplane pilot by profession but who has been instrumental in advancing the research and conservation missions of the RPPN. Ramiro hired a biologist, Marcello Nery, to develop the RPPN's management plan and to coordinate it various activities. It would not have been possible for me to sustain the Muriqui Project after Sr. Feliciano's death without Ramiro's commitment and support and Marcello's logistical help.

Academic and Conservation Communities

Although the conservation leaders I met through Russ in the early 1980s were all senior men, this was no different from my experience in academia in the U.S. There were always other female students and researchers around when I visited Célio at his lab at UFMG and among the groups of students that he and other UFMG professors brought on fieldtrips to the forest. Within the narrow academic and conservation community I encountered as a student in Brazil, coming from the U.S. and being American-trained felt more exceptional than being a woman.

For example, I had access to research funds in the U.S. that were much harder to obtain in Brazil. With these, I could afford a decent pair of lightweight waterproof binoculars, a good camera (along with the film and high development costs needed then), and as many rolls of flagging tape to mark trails and muriqui feeding trees as needed. Some of these items were either impossible to find or else prohibitively expensive in Brazil. Coming from an American university, I also had access to the international scientific literature that many of my colleagues at Brazilian universities lacked. Although this disparity has decreased with electronic libraries and journals, it is still a great advantage to be able to read the international literature in my native language. My own struggle with Portuguese made me appreciate early on the enormity of the barrier that reading in a second language could pose.

My early appreciation for these disparities in access to resources (considering the scientific literature as much of a resource as binoculars) influenced how I set up the Muriqui Project. Specifically, my aim was to provide the students who joined the project with the training to maintain the long-term life history and demography data and to conduct their own studies for their masters or doctoral dissertations. I also provided support for their living expenses, essential equipment and supplies, and access to whatever literature they wanted to read. We

built up a small field library from donated books, reprints of journal articles, journal subscriptions, and copies of dissertations, and for years I sent reprints by mail on request. Our longstanding tradition of providing training and professional advancement for dozens of Brazilian students has been an important contribution of the Project (Mittermeier *et al.,* 2005; Thiago de Mello, 1995).

Increasingly, Brazilian academics and conservationists have traveled and lived abroad and are fluent in English. Some of this reflects the internationalization of science that has accompanied globalization on other fronts, but some is a direct result of Brazilian initiatives. For example, the *Ciência sem Fronteiras* (CSF) program sponsored by CAPES earlier in this decade provided Sérgio and me with research funds and a stipend to cover my living expenses during my time in Brazil. It also permitted me to host our post doc, Carla, and one of Sérgio's doctoral students from UFES, Luana Centoducatte, in my lab at the University of Wisconsin-Madison, providing new opportunities for scientific exchange.

In 2006, prior to the CSF program, Sérgio had spent three months in my lab. I had not realized until then how asymmetrical my relationships with even my closest Brazilian friends and colleagues had been. For decades, I had visited their homes, met their families, and seen what their daily routines were like. By contrast, almost no one from Brazil knew anything about any of these aspects of my Madison life. Dida and his PhD advisor, César Ades, and Jean had also visited on separate occasions, but it was this visit from Sérgio, when he was an active member of my lab, that resonated the most on professional and personal levels.

In October 2012, another muriqui specialist, Fabiano Rodrigues de Melo, came to Madison as my post doc, bringing his family for an entire year. Interacting with Fabiano on a near-daily basis led to many influential conversations for both of us, perhaps in part because the timing of his post doc followed closely on the publication of PAN Muriqui and we were both highly motivated by it. In particular, those conversations expanded my way of thinking about active management initiatives, including translocations, which I have come to see as essential under certain conditions and complementary to the hands-off, *in situ* approach that we have so far adopted in Caratinga.

June 2013 marked the 30th anniversary of the Muriqui Project of Caratinga, and it had been decided that the Muriqui Committee would hold its annual meeting in the city of Caratinga in order to join in the city's commemoration of the project and its own agenda for a sustainable future. Caratinga+30 was modeled after Rio+20, the 20-year follow-up to the first Earth Summit held in Rio de Janeiro in 1992.

The multi-day event brought together a large group of muriqui research and conservation specialists, as well as members of the local government and community. Some prominent participants at Caratinga+30, in addition to the contributors to the Muriqui Action Plan, Russ Mittermeier, and Ramiro Abdalla Passos, were leaders in the Caratinga business and education communities including the president of Doctum Faculdade, Cláudio Leitão, and journalists Miriam Leitão and Sérgio Abranches, both of whom have written a number of articles and essays about muriqui conservation and the Muriqui Project of Caratinga, and continue to be allies in our cause. The event also brought me Honorary Citizenship of Caratinga, and an optimism about the potential future of long-term collaboration on behalf of the muriquis in the region.

Economic and Political Challenges and Future Prospects

The history of the Muriqui Project spans the years of Brazil's transition from military to democratic governance and six different Brazilian currencies. Yet, until recently, I spent most of my time in Brazil in the forest, mostly buffered from the impact of these and other transitions. Instead, I was focused on the muriquis and the students, and on the challenges of maintaining the continuity of the long-term project.

One of the greatest challenges has been related to funding, a universal problem for scientists. In the U.S., as in other countries, funding levels fluctuate from year to year, but losing even one year of funding would result in a significant loss for the Muriqui Project. It is almost impossible to secure funds for the sole purpose of maintaining a long-term study, even though it is their continuity that make the data so valuable. It was necessary to generate new research questions and to navigate across a funding landscape in which the same proposal could be considered too conservation-focused by one agency and too scientific by another. A few decades ago, there was a much less integrated view of the inextricable interdependence between science and conservation than there is today.

The second major challenge pertains to the process of obtaining research permission as a foreign scientist in Brazil. I actually have great appreciation for the rationale behind the requirement of working with a Brazilian counterpart because it has created opportunities for me to interact with some of the most amazing scientists and conservationists in the country. At the same time, however, it is an enormous burden for any Brazilian scientist to serve as coordinator, or "a pessoa responsável" for a foreign colleague. Even now, after training dozens of Brazilian students and decades of collaboration, at two-year intervals my counterpart, Sérgio Mendes generously invests his own time and energy to put together all of the paperwork that only he can submit through his Brazilian institution. Then he has an additional time and energy output to monitor the progression of approvals until the authorization for my research visa is released. Sérgio does all of this on top of all of his other responsibilities, so that the Muriqui Project of Caratinga can continue, and there is no way that I can repay him in kind. Of course, I am very grateful, but it seems particularly cruel because Sérgio is someone with whom I would seek to collaborate, independent any federally-mandated requirement. I wish I could lighten this burden, but sadly, things seem to be moving in the opposite direction (Bockmann *et al.,* 2018).

It goes without saying that there are many uncertainties in the world today, not only for muriquis, but for humans and other primates and the ecosystems that support them. It is easy to become distracted and discouraged, and to think that nothing we can do will make a difference. But then I think about how much one primate, the muriqui, has changed the way we think about primate behavioral diversity and flexibility, and about how much can be accomplished by working together, when scientific and conservation goals coincide… and I am inspired again.

It is all for the muriquis.

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Women in Brazilian mammalogy: the pioneers and the prominent members of the Brazilian Society of Mammalogy

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Abstract: Despite the relatively short history of the Brazilian Society of Mammalogy (SBMz) with its 31 years, some remarkable women made significant contributions, not only to the SBMz, but also to the Brazilian mammalogy in general. Even before the consolidation of the SBMz, several women, regardless of their position in the society and academy, developed and participated in activities that were essential to the current knowledge on Neotropical mammalogy. To highlight the contributions of such women and her successors in Mammalogy, we describe the careers and accomplishments of 21 women in short biographical notes. Our selection includes women that worked from the early 20th century until the beginnings of the 21st century in two categories: SBMz's members and relevant non-members. We shall not forget the Archduchess Leopoldine of Austria, an educated and natural sciences enthusiast that, through her marriage with the Crown Prince D. Pedro I of Brazil, literally brought in her "wedding baggage" the opening to the natural history knowledge of Brazil in early XIX century.

Key-Words: Emilie Snethlage; Leopoldine of Austria; Neotropical mammalogy; Research; 20th century.

Resumo: Mulheres na mastozoologia brasileira: as pioneiras e a Sociedade Brasileira de Mastoozologia. Apesar da Sociedade Brasileira de Mastozoologia (SBMz) ser relativamente nova (31 anos), algumas mulheres notáveis fizeram significativas contribuições, não somente para a SBMz, mas para o estudo de mamíferos no Brasil, porém nunca receberam uma merecida homenagem. Ainda, antes da consolidação da SBMz, algumas delas, a despeito de sua posição na sociedade e na academia, desenvolveram ou participaram de atos que foram essenciais para o que hoje conhecemos sobre a Mastozoologia Neotropical. Para divulgar as contribuições dessas importantes mulheres na mastozoologia, nós elaboramos resumos biográficos de 21 delas, do início do século XX até o ano 2000, separando os registros entre membros da SBMz e aquelas que não são membros. Não podemos nos esquecer da Arquiduquesa Leopoldina da Áustria, uma mulher extremamente culta e interessada em ciências naturais, que no início do século XIX, através de seu casamento com o Príncipe-herdeiro D. Pedro I do Brasil, literalmente trouxe em sua bagagem de núpcias o que seria a abertura do Brasil para o conhecimento científico nas disciplinas da história natural.

Palavras-Chave: Emilie Snethlage; Imperatriz Maria Leopoldina; Mastozoologia Neotropical; Pesquisa; Século XX.

We delineated our essay to include pioneer women dedicated to studies on the Brazilian mammalian fauna and women that contributed to consolidate mammalogy in Brazil (several still contributing to this date). For the latter group, we have arbitrarily included those women with PhD completed until 2000 (four exceptions, being two PhDs, a collection manager and a noblewoman, are explained in the proper sections). Consequently, some important women were excluded, but were not forgotten. Some of the women mentioned herein suffered some kind of prejudice or harassment during their careers, as most women still do in most professions nowadays. In spite of that, they have become examples of successful women and here they are remembered for their great contribution to mammalogy in Brazil. We included, when possible, personal notes from our own experience or the experience of colleagues that have known, lived and/or worked with some of these exceptional women.

The account was organized in chronological order of their graduation. Their professional information was taken from *Plataforma Lattes* (http://buscatextual.cnpq.br/buscatextual), or other sources when specified, and the cut-off date was May 2018, when the first draft of

the text was finalized. The first information between brackets is the year they obtained their bachelor's degree, followed when appropriate by the year of death and the symbol 'ł'. This work was broadly inspired on Stein (1996) and Kaufman *et al.* (1996), who highlighted the contribution of women in the early years of mammalogy in the United States of America and in the development and consolidation of the first 30 years of the American Society of Mammalogists, respectively.

EARLY 20TH CENTURY

Emilie Snethlage (active in Brazil from 1905 to her death in 1929)

The first female who worked with mammals in Brazil was a naturalist, who collected and studied these animals almost a century before the establishment of the Brazilian Society of Mammalogy, in 1985. The German-born Brazilian naturalist Emilie Snethlage (German name Henriette Mathilde Maria Elizabeth Emilie Snethlage) was better known for her studies on birds, but also can easily be considered a mammalogist.

Coming from a Lutheran family, Emilie Snethlage (Figure 1) since an early age was independent and interested in nature (Snethlage, 1930). She had a home education but was approved to be a tutor in high schools (1889) and tutored for 10 years throughout three countries (England, Ireland and Germany). In 1899, she received a small inheritance and could realize her dream of attending higher education (Snethlage, 1930). She was one of the first women to study at the University of Berlin, where she graduated in Natural History (1899). Her PhD degree (1904) in arthropod muscle morphology was developed in two universities, Jena and Freiburg, Germany.

Emilie Snethlage came to Brazil in 1905, invited by Swiss zoologist Emilio Goeldi to work as zoology assistant at *Museu Paraense Emílio Goeldi* – MPEG (that time *Museu Goeldi*), in Belém, Pará State. She was the first woman employed by the government of the State of Pará, where she stayed for 17 years. At MPEG she worked with two directors until 1914, when she was invited to assume the head of the institution. In 1921, the funding for the MPEG decreased with the decline of the regional based economy of latex extraction, and in 1922 Emilie was invited to take a job as a field naturalist at *Museu Nacional,* in Rio de Janeiro State. Emilie conducted fieldwork in several occasions and places during her life as a zoologist in Brazil. Pioneer, one of the most emblematic moments was the expedition throughout an unmapped region between the Xingu and Tapajós Rivers during 1909, in central and western Brazilian Amazonia, on foot and escorted by seven local indigenous people (Junghans, 2008).

Emilie undertook at least 18 large expeditions in Brazil and collected ca. 10.000 birds and mammals, which are deposited in scientific museums of Brazil, Europe and United States (Sanjab *et al.,* 2013; Bezerra, *pers. obs.*). Her last expedition was in 1929 to the Madeira River, in Porto Velho, Rondônia State, when she got sick and passed away at age 61. She had 43 scientific papers published (Junghans, 2008) and among the mammal specimens collected by Emilie, there are several holotypes of species described by Oldfield Thomas (*e.g.,* Thomas, 1910, 1920a, 1920b) and João Moojen (*e.g.,* Moojen, 1948), such as the Pale-brown ghost bat *Diclidurus isabella* (Thomas, 1920) and the Rio Negro brush-tailed rat *Isothrix negrensis* Thomas, 1920. Due to her importance in Brazilian mammalogy she was honored with species named after her, such as the Snethlage's tigrina *Leopardus emiliae* (Thomas, 1914), the tuff-tailed spiny tree rat *Lonchothrix emiliae* Thomas, 1920a (also a new genus), and the Snethlage's marmoset *Mico emiliae* (Thomas, 1920b) (all of them based on specimens collected by her). Animals of other groups have also been

Figure 1: Emilie Snethlage (left) during a fieldwork in Amazon and (right) seated in a chaise in a balcony of *Museu Nacional/Universidade Federal do Rio de Janeiro,* Rio de Janeiro in 1926. Sources: Emil-Heinrich Snethlage, Snethlage Family collection, and *Arquivo Guilherme De La Penha/Museu Paraense Emilio Goeldi,* respectively.

named after her, *e.g.,* the armored catfish *Peckoltia snethlageae* (Steindachner, 1911), the Utinga Surinam toad *Pipa snethlageae* Müller, 1914, the Earth snake *Atractus snethlageae* Cunha and Nascimento, 1983, the lizard *Loxopholis snethlageae* (Avila-Pires, 1995), and the Madeira parakeet *Pyrrhura snethlageae* Joseph and Bates, 2002.

WOMEN IN THE EARLY YEARS OF THE BRAZILIAN SOCIETY OF MAMMALOGY (1985-2000)

Margarete Suñé Mattevi, PhD (1963, 2013†)

Described by her colleagues and friends as a "very enthusiastic, wonderful, and kind professional and person", Margarete Mattevi (Figure 2) had an important role in integrating research and researchers from several academic areas and countries. She pioneered animal cytogenetics in Brazil. Her life was intrinsically linked with the *Universidade Federal do Rio Grande do Sul* – UFRGS, Porto Alegre, Rio Grande do Sul State, where she obtained all degrees and became professor.

She obtained a bachelor's degree in Biology in 1963. During her undergraduate studies, she started to work on human cytogenetics (Salzano, 2014) at the Genetics and Molecular Biology Graduate Program of the UFRGS. There, she carried out her MSc (1970) and PhD (1974) projects for her degrees in Genetics and Molecular Biology.

Margerete was Professor at the Genetics Department of UFRGS (1964-1995) and Professor Emerita at the same department until 2007. After her retirement she also became Professor at the *Universidade Luterana do Brasil* – ULBRA (2001-2011), in Canoas, Rio Grande do Sul State. She worked actively throughout her life; Margarete passed away in 2013 at the age of 72.

A curiosity about the Margarete's MSc: her project on animal cytogenetics was the first MSc thesis finished at the Genetic and Molecular Biology Graduate program of UFRGS. She did it in one month, simultaneously with her PhD in human genetics (Mattevi & Menezes, 2009).

Academic output

Margarete Mattevi was one of the most active Brazilian mammalogists. She had two major research fields, human genetics and mammalian molecular cytogenetics, with a broad network of national and international collaborations. In mammalogy, she worked mainly with Neotropical rodents, marsupials, bats, and ungulates on cytogenetics, mitochondrial and nuclear DNA, and biodiversity. Between 1970 and 2011, she markedly contributed to the knowledge of the Neotropical mammalian cytogenetics and molecular cytogenetics, publishing 79 papers in scientific journals and five book chapters, and was referee at least in 13 scientific journals. She supervised 44 undergraduate students, 22 masters, 14 PhDs, and three postdoctoral fellows. Among her ex-students, several are currently prominent researchers working in universities and research institutes in Brazil.

Service to the Brazilian Society of Mammalogy

Margarete Mattevi was an active member of the Brazilian Society of Mammalogy (SBMz) from 1985 to 2008.

Maria Dalva Antunes de Mello, PhD (1967, 2007†)

Dalva (Figure 2) was one of the first parasitologists with a focus on the Neotropical non-volant small mammals and endemic zoonosis. She was far ahead of her time, and beyond her research and teaching activities she was an art enthusiast, organized art exhibitions, had four photography books published, and managed a bar. She earned her bachelor's degree in Natural History (1967) by *Universidade Federal de Pernambuco* – UFPE, Recife, Pernambuco State, and obtained a specialization in Health Sciences (1968) at the same university. Her master's (1974) and PhD (1980) degrees were in Parasitology from *Universidade Federal de Minas Gerais* – UFMG, Belo Horizonte, Minas Gerais State, and *Universidade de São Paulo* – USP, São Paulo, São Paulo State, respectively.

Dalva was Professor at the Nursing Department of the Health Sciences Faculty of the *Universidade de Brasília* – UnB, Brasília, Federal District (1972-1997), and Collaborator Researcher there until 2005. Actively working throughout most of her life, besides being a researcher, she had excellent administrative skills, demonstrated by her good relationship with governmental health and environmental agencies.

Academic output

Maria Dalva markedly contributed to the knowledge of the Neotropical mammalian parasitology. In her academic life (1967-2005), Maria Dalva edited one book *Roedores da região Neotrópica e patógenos de importância para o Homem* (Mello, 1985), and she has published 22 papers in scientific journals, and three book chapters.

Service to the Brazilian Society of Mammalogy

Dalva was the first female President of the board of directors of SBMz (1991-1994).

Cecília Torres de Assumpção, PhD (1976, 1985†)

Cecília was a great primatologist that worked on ethology and systematics and passed away at a young age. She had a bachelor's degree in Biology from the USP, São Paulo, São Paulo State (1976), and received a

Figure 2: Margarete Mattevi in the laboratory (left) and Dalva Antunes (right), with her former husband Frederico Simões Barbosa. Sources: http://www.ufrgs.br/ppgbmmuseu/index.php/2014-05-23-13-37-21/fotos/item/51-decada-de-1960 and Alessandra S. Barbosa, respectively.

PhD degree (1983) from the University of Edinburgh. Described by colleagues and students as very intelligent, shy, and serious, Cecília (Figure 3) was an Associate Researcher at Biosciences Institute of USP.

Academic output

Cecília's PhD thesis (Torres, 1983) was a very important study on capuchin monkeys (*Sapajus*), comprising 337 pages divided in two research fields, ethology and a systematic revision of the genus. This work has never been published, but a summary paper of her PhD was posthumously published (Rylands *et al.,* 2005; Torres, 1988). Cecília also made the Portuguese translation of the book "Social behaviour of animals" by Deag (1981).

Service to the Brazilian Society of Mammalogy

In 1982, during the Meeting of the Brazilian Society for the Advancement of Science (SBPC) in Campinas, São Paulo State, Cecília, together with Rui Cerqueira and Mario de Vivo, raised the need of surveying the real number of researchers working on mammals in Brazil (Cerqueira, 2005). Cecília made a list of possible mammalogists interested in participating in a future society and Rui contacted them about this idea; in the following two years, the idea of founding a Brazilian Society of Mammalogy emerged. She was present during the SBMz founding meeting in 1985, during the XII Brazilian Zoological Congress held in Campinas, São Paulo State, being also a founder. Cecília was also the 2nd Secretary of the Brazilian Society of Primatology (1985).

Eleonora Trajano, PhD (1977)

Cavernicola and *Universidade de São Paulo* are the two main keywords for Eleonora Trajano. With a degree in Biology (1977) from Biosciences Institute of USP, she developed her entire academic life in that institution, where she also obtained a MSc degree in Zoology (1981) and PhD degree in Biological Sciences (1987). Eleonora (Figure 3) was also a professor in the Zoology Department of USP (1981-2015), having a Full Professor appointment from 2006 to 2012 when she retired and became a Senior Professor until 2015. Currently she is Professor Emerita of the Ecology and Evolutionary Biology Department at *Universidade Federal de São Carlos* – UFSCar and teacher in the Bioethics Postgraduate Program at the *Centro Universitário São Camilo,* Pompéia campus, São Paulo State.

Described by some colleagues as a bulldozer during fieldwork, Eleonora is always very active. Zoologist in essence, Eleonora has an eclectic professional trajectory, working from invertebrates to catfishes and bats, but always with a common denominator, the speleological world.

Academic output

Eleonora Trajano markedly contributed to the knowledge of the Neotropical speleology and subterranean biology. In mammalogy context, her focus was on bat interactions in these ecosystems. She has published up to 87 papers until 2014 in scientific journals, four books, and 24 book chapters, and was referee at least in 11 scientific journals. She supervised five undergraduate students, 12 masters, and 12 PhDs.

Service to the Brazilian Society of Mammalogy

She participated in the founding of the SBMz in 1985.

Vera Maria Ferreira da Silva, PhD (1977)

Vera (Figure 3) is one of the main specialists in Amazonian aquatic mammals, coordinating several projects aimed at the knowledge and conservation of cetaceans and manatees. She earned her bachelor's degree in Biology from UnB (1977), her MSc degree in Fish and Freshwater (1983) from *Instituto Nacional de Pesquisas Amazônicas* – INPA, Manaus, Amazonas State, and the PhD in Mammalian Ecology and Reproduction (1994) from University of Cambridge, England.

Vera is Researcher at INPA since 1981, where she is the leader of the Laboratory of Aquatic Mammals and Assistant Curator of the Mammal Collection. Since 1993 she also coordinates the Boto Project, a large project of population biology, ecology, and behavior of two Amazon dolphins, developed at Mamirauá Sustainable Development Reserve, Amazonas State, Brazil.

Academic output

Vera contributed markedly to the knowledge of Amazonian aquatic mammals, with a focus on conservation and population ecology. Since 1980, she has published 85 papers in scientific journals, five books, and 35 book chapters, was referee in at least five scientific journals and member of the editorial board of three journals. She supervised nine undergraduate students, 28 masters, and six PhDs.

Service to the Brazilian Society of Mammalogy

She was also a founder of SBMz and her name appears in the founding document of SBMz.

Suely Aparecida Marques-Aguiar, PhD (1979)

"Batgirl", is how the gentle Suely (Figure 4) is dubbed by her colleagues from *Museu Paraense Emilio Goeldi* – MPEG. With a bachelor's degree in Biology (1979) from the Bioscience Institute of USP, she pursued her MSc in Biology (Ecology) (1984) at INPA, and her PhD in Biological Sciences (Zoology) (1993) at the George Washington University, United States of America.

Suely worked almost all her professional life at the Section of Mammalogy of MPEG (1983-2016), where she started as a Researcher Fellow and climbed up to Curator in Chief (1985-2014). Retired in 2016, she still works at the same institution as an Associate Researcher. Zoologist in essence, she contributed to the development of what is the third largest scientific mammal collection of Latin America.

Academic output

Her major research interests include systematics, taxonomy, and ecology, with an emphasis on Neotropical bats. An important contribution for the Neotropical mammalogy is Suely's PhD thesis "A systematic review of the large species of *Artibeus* Leach, 1821 (Mammalia: Chiroptera) with some phylogenetic inferences" (Marques-Aguiar, 1994). This work was primordial for the taxonomic acknowledgement of the bat genus *Artibeus* (Phyllostomidae: Stenodermatinae)

Figure 3: Cecília Assumpção teaching (left), Eleonora Trajano in amuse moment with friends (middle), and Vera da Silva in the fieldwork (right). Sources: Eleonora Trajano, Cleyton F. Lino, and http://museunafloresta.weebly.com/vera-da-silva1.html, respectively.

and is mandatory in taxonomic studies of the subfamily Stenodermatinae.

She has published 26 papers in scientific journals and 17 book chapters and edited five books. She has supervised 15 undergraduate students and four masters.

Service to the Brazilian Society of Mammalogy

She was also a founder of SBMz and her name appears in the founding document of SBMz. She is still an active associate member.

Cibele Rodrigues Bonvicino, PhD (1983)

"Multifaceted" could be a good nickname to Cibele Bonvicino (Figure 4), one of the most active Brazilian mammalogists at present. She has two major research fields, human oncology and mammalian systematics, evolution, and conservation. With an insightful and outstanding personality, Cibele has been one of the main contributors to the knowledge of the Neotropical mammalogy. With ca. 1,220 citations of her authored or coauthored papers, she is the researcher who has described more new species of Brazilian mammals in the last 25 years. Besides, she carried out hundreds of field expeditions, mainly in the Cerrado and Amazonia domains, contributing with a large amount of precious material (from mammal specimens to its parasites, tissues and blood samples) to several scientific mammal collections, such as of the *Museu Nacional/Universidade Federal do Rio de Janeiro* – MN/UFRJ, MPEG, UnB, and the *Laboratório de Biologia e Parasitologia de Mamíferos Silvestres Reservatórios* – LABPMR, of *Fundação Oswaldo Cruz* – FIOCRUZ. Her colleagues describe Cibele as a person that lifts you up professionally and personally; she greatly cares for her students and early career colleagues.

Cibele obtained her bachelor's degree in Biology (1983) from the *Universidade Estadual Paulista Júlio de Mesquita Filho* – UNESP, Rio Claro, São Paulo State. She has a MSc degree in Zoology (1988) from the *Universidade Federal da Paraíba* – UFPB, and PhD in Genetics (1994) from the *Universidade Federal do Rio de Janeiro* – UFRJ.

Since 1996, she works as a scientific researcher at *Instituto Nacional de Câncer* – INCa, Rio de Janeiro, and since 2001 is an Associate Researcher at FIOCRUZ, also in Rio de Janeiro. She is moreover the Curator in chief of the Mammalian Reference Collection for zoonotic diseases at LABPMR, FIOCRUZ.

Academic output

Her major areas of research interest include evolution, genetics, systematics, cytogenetics, zoonosis and biogeography of mammals, with emphasis on Neotropical rodents, marsupials and primates, with a broad network of national and international collaborators. Since

Figure 4: Suely Marques-Aguiar in the mammal collection of *Museu Paraense Emilio Goeldi* – MPEG (left) and Cibele Bonvicino teaching at *Sociedade Brasileira de Mastozoologia* meeting (right), at *Pontifícia Univerisdade Católica de Minas,* Belo Horinzonte, Minas Gerais State. Sources: Mammalogy/MPEG and *Sociedade Brasileira de Mastozoologia,* respectively.

her graduation she has published 147 papers in scientific journals, written 19 book chapters, and edited an important book to field studies of Brazilian rodents species, the *Guia dos roedores do Brasil, com chaves para gêneros baseadas em caracteres externos* (Bonvicino *et al.,* 2008), and has been referee in at least 16 scientific journals. She has supervised 42 undergraduate students, 17 masters and 13 PhDs, and supervised eight postdoctoral fellows.

Service to the Brazilian Society of Mammalogy

Cibele is a founder of SBMz and was the vice-president during two terms (2008-2010 and 2010-2012) and the second female President of the board of directors of SBMz in two terms (2012-2014 and 2014-2017).

She actively participated on the dissemination and integration of mammalogy in Brazil and Latin America, organizing three scientific events and two field courses, as follow: I Symposium of Mammalian Evolution (2013), Rio de Janeiro, Rio de Janeiro State; VIII Brazilian Congress of Mammalogy (2015), João Pessoa, Paraíba State; IX Brazilian Congress of Mammalogy (2017), Pirenópolis, Goiás State, and the courses of "Classification and taxidermy of small mammals", in Corumbá, Mato Grosso State (2012), and Ilhéus, Bahia State (2015), respectively. During her terms, she promoted a stronger integration among the mammalogy societies of Latin America.

Helena de Godoy Bergallo, PhD
(1984)

Nena (Figure 5), as she is known among friends and colleagues, who describe her as modest and opened to dialogue, is a very prolific and active Brazilian mammalogist. Her main research field is community ecology, including aspects of natural history, parasitology and demography. In the last 24 years, she has been one of the main contributors to the knowledge of the Neotropical mammalogy, with ca. 1,550 citations of her authored and coauthored papers.

Nena has a bachelor's degree in Biology from the *Universidade do Estado do Rio de Janeiro* – UERJ (1984), and MSc (1991) and PhD (1995) degrees in Ecology from the *Universidade de Campinas* – UNICAMP. Since 1996, Nena is Professor at the Ecology Department of UERJ, where she holds a series of activities participating in committees, councils, projects, and tutoring and supervising students. She has also been linked to several universities and research institutes as Collaborator. She coordinates the *Rede de Pesquisa em Biodiversidade da Mata Atlântica* – PPBio MA (since 2013), an official program of Brazilian Ministry of Sciences, Technology, Innovation, and Communication – MCTIC.

Academic output

Nena's major research interests include community ecology, invasive species, conservation, parasitology, and population ecology of small mammals. Since her graduation, she has published 150 scientific papers and 34 book chapters, edited six books, and has been referee in at least 41 scientific journals. She has supervised almost 100 students, including 31 undergraduates, 34 masters, 22 PhDs, and four postdoctoral fellows.

Service to the Brazilian Society of Mammalogy

Founder of SBMz in 1985, she acted as Second Secretary of the board of SBMz in two terms (1998-2005 and 2005-2008). She organized the IV Brazilian Congress of Mammalogy (2008), in São Lourenço, Minas Gerais state.

Lena Geise, PhD
(1984)

Lena (Figure 5) is a very active Brazilian mammalogist; she is a researcher, professor, and scientific journal editor. Her main research field is taxonomy of small mammals, with other interests including, evolution, biogeography and conservation. Like Cibele, Lena carried on several field expeditions that resulted in the collection of a large number of small mammal specimens. Her fieldwork is focused in the Atlantic Rainforest domain and the material gathered in these expeditions is mostly deposited at *Museu Nacional*/UFRJ, where they are considered always very well prepared and precisely annotated.

She obtained a bachelor's degree in Biology at the *Universidade do Estado do Rio de Janeiro* – UERJ (1984), Rio de Janeiro State, the MSc degree in Biological Sciences (Zoology) at USP (1989) and the PhD in Genetics at UFRJ (1995). Lena held a postdoctoral fellowship (2009-2010) at the Museum of Vertebrate Zoology, University of California, Berkeley, USA.

Since 1996, Lena is Professor at the Zoology Department of UERJ. There she holds a series of activities besides teaching, like participating in committees, councils, projects, and tutoring and supervising students. In more recent years she has also shown to be a very good craftswoman, activity she holds in parallel with teaching and research.

Academic output

Her major research interests include evolution, systematics, biogeography and cytogenetics of mammals, with an emphasis on rodents, marsupials and bats. Since 1987, she has published 69 papers in scientific journals and 10 book chapters; Lena has been member of editorial board of four journals and referee in at least 25 scientific journals. She has supervised 31 undergraduate students, eight MSc, 16 PhDs, and one postdoctoral fellow.

Service to the Brazilian Society of Mammalogy

Founder of SBMz (1985), she acted as First Secretary of the board of SBMz (2005-2008). She organized four SBMz scientific events: I Symposium of Mammalian Evolution (2013), Rio de Janeiro, Rio de Janeiro State; I and II

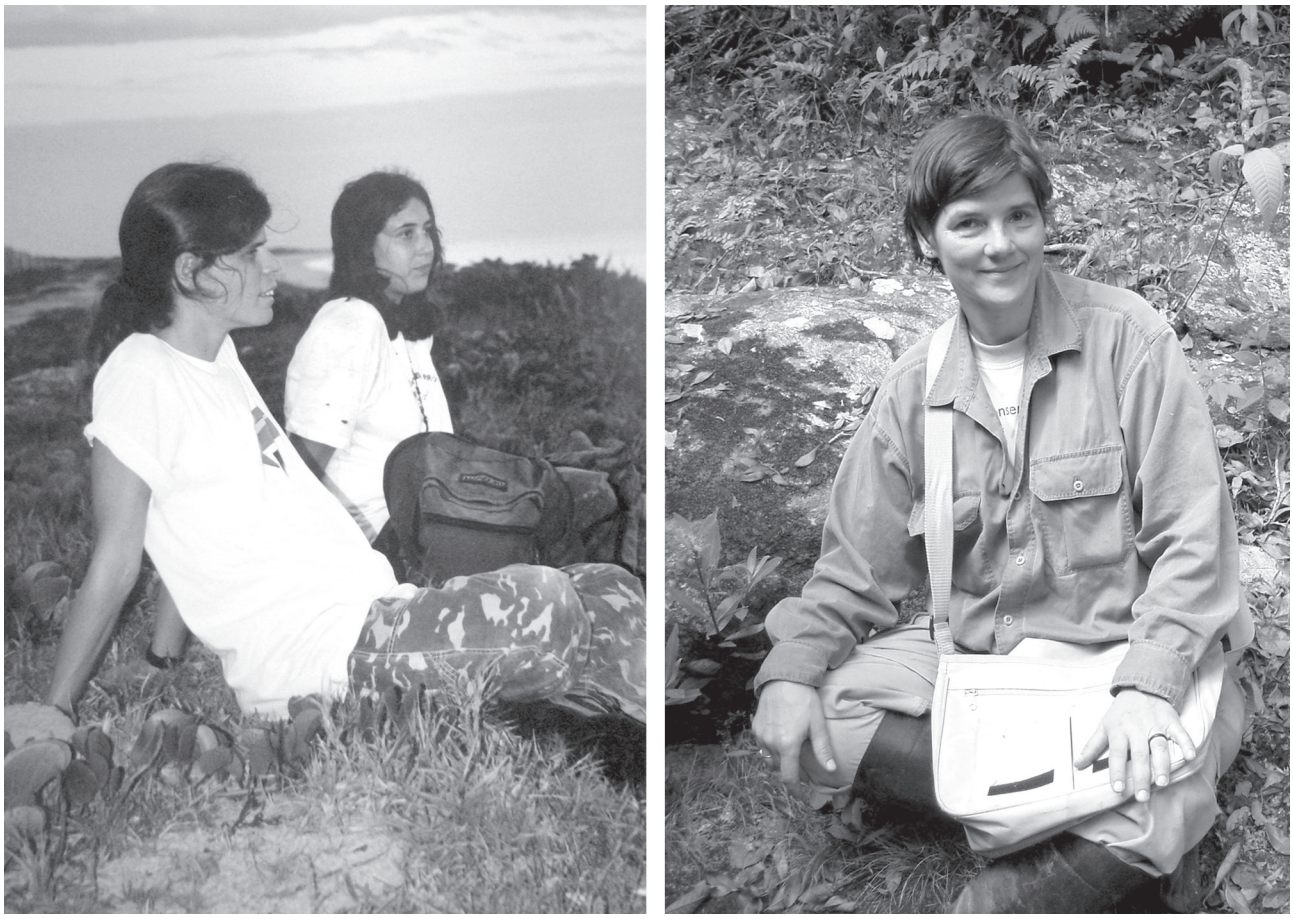

Figure 5: Helena Bergallo (left) and Lena Geise (right) in the fieldworks. Sources: Daniel Raíces and Diego A. Moraes, respectively.

Meeting of mammalogists of Rio de Janeiro State (2012 and 2013), in Teresópolis; and IV Brazilian Congress of Mammalogy (2008), in São Lourenço, Minas Gerais State.

Since 2013 Lena is editor of the Bulletin of the Brazilian Society of Mammalogy, position that she holds with commitment and enthusiasm.

Leila Maria Pessôa, PhD (1985)

Leila (Figure 6) is an enthusiastic mammalogist and passionate teacher. Her main research line is taxonomy and evolution of Brazilian small mammals. She is one of the precursors in high level and complex studies of vertebrate morphometric analysis in Brazil. Very hardworking and professional, sometimes she seems to be a very solemn woman, but in fact is an introspective woman with a big heart.

Leila has a bachelor's degree in Ecology from UFRJ (1985), Rio de Janeiro State, MSc in Biological Sciences (Zoology) from UFRJ (1989) and a PhD from UNESP (1995). She did an internship in Molecular Biology (1993) at University of California, Berkeley and a held a postdoc fellowship (1998) at Texas Tech University, Lubbock, TX, USA.

Since 1993 Leila is Professor at the Zoology Department of UFRJ, Rio de Janeiro, Rio de Janeiro State, where she holds several activities regarding the University, from teaching to participating in committees, councils, and research projects.

Academic output

Her major research lines include ontogeny and morphometrics, cytogenetics, and molecular variability in Brazilian small mammals, with particular interest in bats and echimyid rodents. Since her graduation she has published 67 papers in scientific journals and eight book chapters, edited one book, and has been member of editorial board of eight and referee of nine scientific journals. She has supervised 30 undergraduate, 17 masters, and eight PhDs students.

Service to the Brazilian Society of Mammalogy

She is a founder of SBMz and acted as First Secretary of the board of SBMz (2008-2010). She also edited a book sponsored by SBMz, *Mamíferos de Restingas e Manguezais do Brasil* (Pessôa *et al.,* 2010).

Maria Nazareth Ferreira da Silva, PhD (1985)

Maria Nazareth (Figure 6) is one of the main specialists in Amazonian mammals. She described 11 new species, among primates and rodents, for the Brazilian

Figure 6: Leila Pessôa in amuse moment (left) and Maria Nazareth (right) in the fieldwork. Sources: Leila Pessôa's Facebook® and Carla Bantel.

Amazon, being the second most prolific scientist describing new mammal species in Brazil in the last 25 years.

She has a bachelor's degree in Biology from UnB (1985) and a PhD degree in Zoology (1995) from the University of California, Berkeley. She held a postdoc fellowship in Taxonomy at UNICAMP (2007-2009), São Paulo State, and another one at *Université de Montpellier* (2015), France. Since 1985 she is a Researcher at INPA, where she is also the Curator in Chief of the Mammal Collection.

Academic output

Her major research interests include systematics and taxonomy, with emphasis in morphology and molecular variability of Neotropical rodents and primates. Since her graduation, she has published 38 papers in scientific journals and nine book chapters, and edited one book. She has supervised nine undergraduate students, three masters, and co-supervised 12 masters and five PhDs.

Service to the Brazilian Society of Mammalogy

She is an associate member of SBMz since the beginning.

Stella Maris Franco, BSc
(1985)

Stella (Figure 7) has two bachelor degrees: Biology (1985) from UERJ, Rio de Janeiro, and Psychology (1998) from *Faculdades Integradas Maria Thereza,* Niterói, Rio de Janeiro State. She has also two specializations, one in Clinical Health Psychology in Hospital Context (1999) from *Hospital Getúlio Vargas-Filho,* and another in Psychoanalysis and Mental Health (2002) from UERJ.

She has been Collection Manager (1988-2013) of the Mammalogy Division of *Museu Nacional*/UFRJ – MN/UFRJ, Rio de Janeiro, Rio de Janeiro State. Since 2013 she works as laboratory assistant in the Department of Pharmacy of UFRJ, Macaé campus, Rio de Janeiro State.

Stella was in 1993 my (AMRB) first contact in the Mammal Collection of MN/UFRJ, when I started my first internship. At that time, only she and a professor worked there. Some years later, I heard from her a statement that I will always hold with me: "I love so much working here (MN/UFRJ) that I decided not to apply for a job in psychology which is my profile area." Stella was always diligent and professional in all respects to the mammalian collection there. We (authors) learned so much with Stella as she helped us and all researchers and students that visited the Mammal Collection of MN/UFRJ during those 25 years.

Academic output

Her major research interests include scientific collection management and museums of natural history. Since her bachelor's degree she has published three scientific papers on the Mammal collection of MN/UFRJ in the international journals (Bezerra *et al.,* 2004; Langguth *et al.,* 1997; Oliveira & Franco, 2005), edited one book (Siciliano & Franco, 2005), and presented four communications in scientific meetings.

Service to the Brazilian Society of Mammalogy

She is a founder of SBMz.

Valéria Fagundes, PhD
(1989)

Valéria (Figure 7) is described by her closest colleagues and friends as a very intense professional, with great enthusiasm to organize and implement new projects, besides being a natural leader and manager. She was a pioneer in founding the Animal Genetics Laboratory (LGA) at *Universidade Federal do Espírito Santo* – UFES, and also in helping to implement a new Graduate program in Animal Biology in that university.

Valéria has a bachelor's degree in Biology (1989) from USP, the same university where later she obtained a MSc degree (1993) and a PhD degree (1997), both in Biological Sciences (Genetics). She also held a postdoc fellowship at USP from 1997 to 2000.

Since 2000, Valéria is Professor at the UFES, where she held several coordinator positions, such as Biology Department Director (2008-2010), and Coordinator of Graduate program in Animal Biology (2001-2008; 2016-present). She was also Curator of the UFES´s Vertebrates Tissue and DNA Collection. From 2010 to 2016 she has acted as Technical Scientific Director at the *Fundação de Amparo à Pesquisa e Inovação do Espírito Santo* – FAPES.

Academic output

Her major research interests include vertebrate genetics, encompassing evolutive cytogenetics, conservation genetics, evolution and phylogeography. Since her bachelor's degree she has published 45 papers in national and international journals and two book chapters, and served as referee for seven scientific journals. She has supervised 43 undergraduate, 20 masters, 10 PhD students, and one postdoctoral fellow.

Service to the Brazilian Society of Mammalogy

She is an associate member of SBMz and has organized the III Brazilian Mammalogical Congress in 2005, in Aracruz, Espírito Santo State.

Leonora Pires Costa, PhD
(1990)

Leo (Figure 7), as her closest friends and colleagues know her, is a very enthusiastic, dedicated, free spirited, and proactive mammalogist. She is one of the researchers responsible for establishing an important mammalogical research group in Espírito Santo State. Due to her father's job as Director of university centers in different regions of Brazil, Leo had close experience with nature during her childhood. Together with her family, she lived in Manaus, Amazonas State, for two years and another year in Barreiras, Bahia State, so at age five, she had already had a good glimpse of the Brazilian biodiversity and wildlife!

Leo has a bachelor's degree in Biology (Zoology) (1990) from the UFMG, Belo Horizonte, Minas Gerais State, and a PhD (2001) in Integrative Biology from the University of California (UC), Berkeley. During her PhD, she was curatorial assistant at the Museum of Vertebrate Zoology and manager of the Evolutionary Genetics Laboratory, both at UC.

Since 2005, she is Professor at the UFES and Curator of the Tissue and DNA Collection of the Biological Sciences Department in that institution. She had also been collaborator in several universities and research institutes, including Associate Curator of the Mammal Collection of the Zoology Department at UFMG.

Even though she obtained her PhD in 2001 (one year above the cutoff year established for this essay), Leonora was included here due to the importance of being a pioneer, together with her collaborator, friend, and husband Yuri Leite, in founding research lines and laboratories in a historically deficient region of Brazil. Like Valéria Fagundes some years before, Leonora's laboratory is one of the main contributors to turn the Espírito Santo State into a center of excellence for studies on small mammal evolution. Leo has supervised at least 45 students in the last 13 years and has ca. 1,710 citations of her articles. Her paper, entitled "The historical bridge between the Amazon and the Atlantic Forest of Brazil:

Figure 7: Stella Franco in amuse moment (left), Valéria Fagundes in a meeting (middle), and Leonora Costa (right) in the Amazon. Sources: Stella Franco's *Currículo Lattes,* Roberta Paresque, and Leonora Costa's Facebook®, respectively.

a study of molecular phylogeography with small mammals" (2003) is a seminal contribution to the study of Neotropical phylogeography, with ca. 460 citations.

Academic output

Her major research interests include biogeography, evolution, phylogeography, and taxonomy of small non-volant mammals. Since her graduation she has published 46 scientific papers in national and international journals and 10 book chapters, edited three books, and served as referee for 10 scientific journals. She has supervised 25 undergraduate students, 14 masters, four PhDs students, and two postdoctoral fellows.

Service to the Brazilian Society of Mammalogy

She is an active associate member of SBMz and has organized the III Brazilian Mammalogical Congress in 2005, in Aracruz, Espírito Santo State.

Renata Pardini, PhD
(1992)

Renata (Figure 8) is an ecologist, since her childhood fascinated with the Brazilian forests, which led her to participate in several field expeditions in Amazonia and the Atlantic Forest during her undergraduate years. She published important papers on methodology, which became inspiring to several biologists and students. She has a background in zoology and still participates in fieldwork, collecting and depositing material in scientific collections.

Renata received a bachelor's degree in Biology from USP (1992) and a direct PhD in Zoology (2001) from the same institution, where she pursued a postdoctoral fellowship in Ecology (2003). Since 2003, she is Professor at the Zoology Department of USP. She is also collaborator at the *Universidade Federal da Bahia* – UFBA, Salvador, Bahia State, and UFES. Renata serves as the representative of the Zoology Department on the board of *IB Mulheres* (IB/USP, 2018). The *IB Mulheres* is a non-official committee by the Biosciences Institute of USP that coordinates discussions and mediates conflicts related to gender, stalking and harassment issues.

As Leonora Costa, Renata's higher graduation level was obtained in 2001 (one year above the '2000 year' established for this essay), but she was also included here due to her great academic importance. Her name is never missing from conversations or paper references about community ecology of Atlantic Forest mammals. Renata is very important in her research field, having almost 4,000 citations of her articles.

Academic output

Her major research interests include landscape ecology, community ecology and conservation biology. Recently she is focusing in demography, population genetics and study of diseases to explore the patterns of anthropized landscapes of the Atlantic Forest. Since her graduation, she has published 66 papers in national and international journals and 13 book chapters, and she has been member of the editorial board of three journals and is referee for 30 scientific journals. She has supervised 15 undergraduate students, 20 masters, eight PhDs, and three postdoctoral fellows.

Service to the Brazilian Society of Mammalogy

She is an associate member of SBMz and has organized the V Brazilian Mammalogical Congress (2010) at São Pedro, São Paulo State.

RELEVANT NON-MEMBERS

Alzira Maria Paiva de Almeida, PhD
(1964)

Alzira Almeida (Figure 8) is known by her colleagues as "The Lady of the Plague", due to her importance as specialist in studying the bubonic plague. This respectful and at the same time funny nickname reflects her strong, professional and kind personality. A pioneer, her first contact with the subject was in 1966, when she and her husband, newly married, moved to Exu, Pernambuco State. He was hired by the World Health Organization to help setting up the *Plano Piloto de Peste* (in English, Pilot Plan of Plague). This plan was a field laboratory to investigate the plague ecology, coordinated by the *Institute Pasteur* (France), where studies were carried out during decades. After eight years, Alzira was already in love with Plague studies (Mello, 2018), and today she is an internationally recognized specialist. Many of her papers focus on the role of mammals in the zoonotic cycle of the bubonic plague, representing an important contribution to the knowledge on their biology, ecology and parasitology. She has a very large network of collaborations with researchers and institutes worldwide.

Graduated in Nutrition at UFPE (1964), she has a PhD degree in Microbiology from the *Université Paris 7* (1993). In 1969, she became Full Researcher at *Centro de Pesquisas Aggeu Magalhães,* FIOCRUZ-PE. Retired since 2012, she continues working actively as leader of her research group, coordinator of the "National Reference Service for Plague" and curator of a *Yersinia pestis* culture collection. She is also advisor to the Department of Health Surveillance of the Ministry of Health and Professor Emerita of UFPE.

Alzira teaches field courses in several Brazilian states. These courses aim to train health professionals on epidemiological aspects of rodent-borne diseases, including the adequate methodological procedures for collecting and handling samples for analysis in laboratory.

Academic output

Her major research interests include microbiology and parasitology, with emphasis in applied microbiology,

Figure 8: Renata Pardini (left) and Alzira Almeida (right). Sources: http://www.ib.usp.br/dicom and Alzira Almeida's *Currículo Lattes,* respectively.

working on epidemiology, zoonosis, hosts/reservoirs vectors and diagnosis. Although being retired, she is still publishing and since 1974 she has published 110 papers in national and international journals and 12 book chapters, edited one book, and acted as referee for 19 scientific journals. She has supervised 23 undergraduate students, 20 masters, 17 PhDs, and three postdoctoral fellows.

Yatiyo Yonenaga-Yassuda, PhD (1964)

Yatiyo's (Figure 9) academic history has a close relationship with USP and the molecular cytogenetics. Her main research line is cytogenetics and molecular biology of vertebrates. Precise and visionary, she has kept for a long time a vertebrate cell and tissue bank, the result of years of research and dedication. This is an important material that represents the Neotropical biodiversity and can be used for cytogenetics and molecular studies. In recognition of her contribution to Mammalogy, an echimyid rodent species was named after her, the Yonenaga's Atlantic spiny-rat *Trinomys yonenagae* (Rocha, 1996).

Yatiyo has a bachelor's degree in Natural History (1964) from USP, and MSc (1964) and PhD (1968) degrees in Genetics from that same institution. In 1969, she became Professor at the Biosciences Institute of USP. She is also member of the Academy of Sciences of São Paulo. In 1998, she began to paint, in parallel with the research, starting a new and also successful career.

All colleagues that know and worked sometime with Yatiyo declared she is kind and professional. An example of her professional and kindness was testified by one of the authors. I (AMRB) had the opportunity to work in collaboration with Yatyio in 2013 and, for a particular study, I needed to associate the field number of a specimen to the number on a tube of cell suspension. During months, nobody found these numbers, but Yatiyo searched tirelessly her files (hard copies included) and finally found it! I was so happy that I told her, "I love you!". We did not know each other in person at that time, but her reply was: "I'm going to Rio for the I Symposium of Mammalian Evolution (2013), and I want to meet who made me this lovely declaration."

Academic output

Her major research interests include animal cytogenetics and molecular genetics, including chromosome evolution, rodents and marsupial cytogenetics, and molecular systematics. From 1965 to 2015 she has published 113 papers in national and international journals and three book chapters. Yatiyo, is editorial board member of "Genetics and Molecular Biology Journal" and has acted as referee for five scientific journals. She has supervised eight undergraduate, 13 master, 15 PhD students, and two postdoctoral fellows.

Figure 9: Yatiyo Yonenaga-Yassuda at her office in *Instituto de Biologia/Universidade de São Paulo* (rigth) and Sanae Kashara (left, in middle two students, with Cibele Bonvicino in background) during a cytogenetic course that she done in the *Universidade Federal do Rio de Janeiro,* Rio de Janeiro, in 2009. Sources: Taís Machado and Leila Pessôa, respectively.

Sanae Kasahara, PhD
(1971, 2018†)

Sanae Kasahara (Figure 9) was for 40 years Professor at the UNESP Rio Claro, São Paulo State, working mostly on vertebrate cytogenetics, and was known by her colleagues as a very kind and professional person. She worked on her PhD project under the supervision of Yatiyo Yonenaga-Yassuda and continued working on the same research line thereafter. Sanae had a very important contribution by introducing several mammalogists into cytogenetic studies and by publishing important books about vertebrate cytogenetic methodology.

She obtained her bachelor's degree in Biology from USP (1971), MSc degree in Genetics from USP (1973), and PhD in Genetics also from USP (1979). She pursued a postdoctoral fellowship in Vertebrate Cytogenetics in France (*Commissariat à l'Energie Atomique Fontenay Aux Roses* – 1982/1983).

Besides her position at the UNESP Rio Claro, she has been Research Advisor at several research institutes. Even after retirement (2004), she continued working as an Associate Researcher at UNESP. Sanae passed away in January, 2018.

Academic output

Her major areas of research included chromosome painting and vertebrate cytogenetics, with several studies on rodents. She has published, from 1974 to 2014, 63 papers in national and international journals, three books and one book chapter. She has supervised 16 undergraduate, seven master, four PhD students, and one postdoctoral fellow. She also advised many graduate students (19) in cytogenetic specialization courses, including currently important mammalogists, such as Cibele R. Bonvicino, Leila M. Pessôa, and Lena Geise.

Cleusa Yoshiko Nagamachi, PhD
(active from 1978 to present)

Cleusa Nagamachi's (Figure 10) major research fields are vertebrate cytogenetics and chromosome painting with emphasis in mammals, the same research fields of her PhD advisor Margarete Mattevi. Cleusa, together with her husband Julio C. Pieczarka, was responsible for creating an important research group in mammalian cytogenetics in northern Brazil since she was hired as Professor at the *Universidade Federal do Pará* – UFPA (1983), Belém, Pará State. She is an internationally recognized researcher and has a long-term collaboration with researchers from the University of Cambridge, United Kingdom.

She has a degree in Biomedicine (1978) and a MSc degree in Genetics (1982), both from USP, and a PhD in Genetics and Molecular Biology from UFRGS (1995). She held a postdoctoral fellowship from the University of Cambridge (2004). In 1983, she became Professor at the UFPA and in 2016 became Full Professor at the same university.

Academic output

Since 1978 she has published 117 papers in national and international journals, and three book chapters. Cleusa has served as referee in five scientific journals. She has supervised 34 undergraduate, 18 MSc, and 15 PhD students, and currently supervises two postdoctoral fellows.

Ludmilla Moura de Souza Aguiar, PhD (1987)

Ludmilla Aguiar (Figure 10) is one of the most active Brazilian chiropterologists at present, and recently (2017) was internationally recognized with the Spallanzani Fellow by North American Society for Bat Research – NASBR. She is the third woman to receive this award.

Figure 10: Cleusa Nagamachi (left) and Ludmilla Aguiar (right) working in the laboratory, respectively. Source: Julio C. Pieczarka and http://www.unbciencia.unb.br/biologicas/35-zoologia, respectively.

Her major research field is on population and community ecology of bats.

She has a bachelor's degree in Biology from UFMG (1987), a MSc degree in Ecology, Conservation and Wildlife Management (1994) from the same institution, and a PhD in Ecology from UnB (2000). She pursued a postdoctoral fellowship at the University of Bristol, England (2014).

Between 2001 and 2009 Ludmilla worked as a scientific researcher at *EMBRAPA Cerrados* (2001-2009), Brasília, Federal District. She then (2009) moved for the Zoology Department of UnB as Professor. Ludmilla chose to apply for a job in the academia, so she could focus her research on bats conservation and ecology.

Academic output

Her research focuses on Chiroptera, including different aspects of their biology such as community ecology, conservation, population ecology, and bioacoustics. Since her graduation, she has published 61 papers in scientific journals, and three book chapters. Ludmilla is a member of the editorial board of Chiroptera Neotropical journal and has served as referee in 32 scientific journals. She has supervised 14 undergraduate, 22 master and six PhDs students.

Ludmilla is also a founder of the Brazilian Bat Research Society (2006) and the *Red Latinoamericana y del Caribe para la Conservación de los Murciélagos* – RELCOM (2007). She organized two large events, the XI International Bat Research Conference (1998), at Pirenópolis, Goiás State, and the VII Brazilian Meeting for Bat Study (2013), Brasília, Federal District, Brazil. She also created the Chiroptera Neotropical (1995-2015) and collaborated organizing the first list of Threatened Bats of Brazil (1995).

FINAL CONSIDERATIONS

We could consider the Empress of Brazil, Maria Leopoldina, as the Patroness of Brazilian mammalogy. In early XIX century, the Archduchess Leopoldine of Austria (Figure 11) came to Brazil to join in marriage the Crown Prince Dom Pedro, son of D. João VI, King of the United Kingdom of Portugal, Brazil and the Algarves. Maria Leopoldina, Portuguese name for the German Caroline Josepha Leopoldine Franziska Ferdinanda von Habsburg-Lothringen, was daughter of Franz II, the last Holy Roman Emperor (empire dissolved in 1806) and at that time King of Hungary, Croatia, Bohemia, and Emperor of Austria. Because of this engagement, the then very isolated Brazil started to receive notable young

Figure 11: Archduchess Leopoldine of Austria, by Joseph Kreutzinger, ca. 1815. Source: Schloss Schönbrunn Kultur, Wien.

naturalists from Germany, Austria and, soon after, from other European countries (Hershkovitz, 1987). Among them were important names for Brazilian mammalogy, such as Johann Baptist Ritter von Spix, Alexander Philipp Maximilian zu Wied-Neuwied, Johann Natterer, Peter Wilhelm Lund, and Johannes Theodor Reinhardt (Bezerra, 2015). These naturalists traveled throughout Brazil collecting specimens and ethnographic material, and recording in paintings, drawings and descriptions the sceneries, indigenous people, flora, and fauna of Brazil. The most famous expedition in this period was the 'Austro-German Artistic Mission', which included naturalists that came together with Archduchess Leopoldine to Brazil. A set of material and information never before known to the Brazilian natural sciences, which are the primordial source for the knowledge of several research areas in Brazil. Presently, several mammalian studies could not be complete without consulting the material and publications derived from these expeditions (Bezerra, 2015). Indeed, the arrival of these naturalists in Brazil was not by chance, since Archduchess Leopoldine was a very educated woman, as expected of a child born of the Habsburg House, and was greatly interested in natural sciences, arts, and culture (Ribeiro, 2005).

Our original intent was to survey the history of women with important contributions to Mammalogy in Brazil, but we realized that this would be incomplete without including a noblewoman, the Archduchess Leopoldine of Austria, latterly known as the Empress of Brazil Maria Leopoldina. A woman nevertheless today known by those who are not fully familiar with her history, life and personality, as the "treasured, sad and fragile spouse of D. Pedro I", consequence of her last years of life (Graham, 2010). In fact, Leopoldine was very well educated, impressively intelligent and diligent, who actively took part in politics, the arts and culture of Brazil. Researchers of natural sciences in Brazil were enhanced largely due to her presence here.

Similarly, female scientists (mammalogists in the present scope) were many times viewed only by their looks and/or under a patriarchal point of view, needing to overcome difficulties to work and get recognition by herself and her results. Therefore, we hope that the readers of this essay have learned at least a little more about these wonderful researchers. Finally, we would like to call attention to the large lapse of time between the arrival of the first researchers to Brazil (early 19th century) and the time when women effectively started to work and get recognition in mammalian research (second half of 20th century).

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Are we underestimating the threat status of Brazilian bats?

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Abstract: Current estimates show that most mammals are susceptible to habitat loss. Some authors consider that bats should be particularly vulnerable to anthropogenic land-use changes due to their unique life-history: fast metabolism, low reproductive rates, high longevity, and gregarious behavior in many species. A single event may have long-term consequences, as populations will slowly recover from increased mortality. Considering that the evaluation of a species threat status is the primary step for conservation planning, and that in general we should expect that bats should respond like other mammals due to the massive anthropogenic threats, here we compare bat conservation status with that of the remaining mammals in Brazil, South America and worldwide to evaluate if their perceived level of threat is similar. We also evaluate if knowledge on threatened species in Brazil is balanced among taxa. According to IUCN 21.2% of the world's mammals are globally threatened, while threatened bats represent 14.5% of bats. In South America threatened bats represent just 7%, while in Brazil it goes down to 1% of bats. The number of published papers differs between threatened mammal taxa with five species – from the Carnivora, Cetartiodactyla and Sirenia – corresponding to almost half of the literature. Seeing that Brazil is megadiverse and suffering huge rates of deforestation, our results indicate an unbalanced assessment, with bats (wrongly?) perceived as less threatened than the whole of the other mammals. Finally, considering the lack of robust ecological data on many species we suggest the use of alternative approaches for the redefinition of bat conservation status in Brazil.

Key-Words: Chiroptera; Conservation; IUCN criteria; Mammalia; South America.

Resumo: Estamos subestimando o status de ameaça dos morcegos brasileiros? Estimativas atuais mostram que a maioria dos mamíferos é suscetível à perda de habitat. Alguns autores consideram que os morcegos deverão ser particularmente vulneráveis a mudanças no uso da terra devido à sua história de vida: metabolismo acelerado, baixas taxas reprodutivas, alta longevidade e comportamento gregário em muitas espécies. Um único evento pode ter consequências a longo-prazo, pois as populações se recuperarão lentamente de uma mortalidade acentuada. Considerando que a avaliação do status de ameaça é o primeiro passo no planejamento de conservação e que morcegos responderão de modo geral da mesma forma que outros mamíferos às grandes ameaças antrópicas, comparamos o estado de conservação de morcegos com dos demais mamíferos do Brasil, América do Sul e do mundo para avaliar se o seu nível reconhecido de ameaça é equivalente. Também avaliamos se o conhecimento sobre mamíferos ameaçados no Brasil é análogo entre táxons. Segundo a IUCN, 21,2% dos mamíferos estão ameaçados globalmente, enquanto morcegos ameaçados representam 14,5% dos morcegos. Na América do Sul, morcegos ameaçados representam apenas 7% dos morcegos presentes, enquanto no Brasil esta proporção cai para 1%. Os artigos publicados diferem entre táxons de mamíferos ameaçados com cinco espécies – de Carnivora, Cetartiodactyla e Sirenia – correspondendo a quase metade da literatura. Considerando que o Brasil é megadiverso, e sob elevadíssimas taxas de desmatamento, nossos resultados indicam uma avaliação desequilibrada, com morcegos (erroneamente?) reconhecidos como menos ameaçados do que os restantes mamíferos. Finalmente, considerando a falta de dados ecológicos robustos para muitas espécies, sugerimos o uso de abordagens alternativas para a redefinição do estado de conservação de morcegos no Brasil.

Palavras-Chave: América do Sul; Chiroptera; Conservação; Critérios UICN; Mammalia.

Threats to mammals, big and small…

There is a consensus that native biodiversity is declining at all biological and geographical scales. Recently, Primack *et al.* (2018) discussed the importance of local-scale conservation, not only to guarantee species protection, but also to preserve ecological processes, as well as biodiversity at larger scales (beta and gamma diversity). Another recent study by Wilson *et al.* (2016) showed that research improvement in biodiversity data favors countries that are not megadiverse, thus risking the implementation of proper protection and management of natural ecosystems to mitigate the impacts of the global biodiversity crisis. If we are willing to maintain biodiversity and its associated processes, fulfilling the Convention on Biological Diversity commitment to increase, by 2020, the scientific knowledge regarding biodiversity, its values, functioning, status and the consequences of its lost (CBD, 2010), perhaps the priorities for acquiring scientific data should be upon regions where biodiversity is most diverse.

Brazil is a megadiverse country harboring ~ 14% of the known species of the planet (Lewinsohn & Prado, 2003). At the same time, Brazil is the world's second-largest agricultural producer, with the highest substantial projected increases in agricultural output over the next four decades of any country worldwide (Strassburg *et al.,* 2014). To attend the agricultural global trade, which is the leading threat to biodiversity worldwide Lenzen *et al.* (2012), the nation occupies the first position as deforesting country (55 million hectares over 1990-2010, versus 24 million hectares in the second-placed Indonesia) (FAO, 2010). The Brazilian agribusiness sector has a dubious discourse. Some argue that the existing agrarian lands can sustain production at high levels without the need of further conversion of natural habitats (Strassburg *et al.,* 2014). Others, however, complain that in approximately 70% of the Brazilian territory it is legally forbidden to cultivate the land, as it is occupied by indigenous and *quilombola* people, or harbors permanent preservation areas, conservation units, and legal reserves (Sauer *et al.,* 2016). So, according to this latter view, the Brazilian potential for agriculture and livestock production is somehow limited, even though the existing productive areas are enough to maintain the global importance of Brazilian's food production. While the agricultural sector debates whether to deforest more areas, the conversion of natural ecosystems is ongoing, affecting biodiversity through habitat loss and fragmentation. This jeopardizes the urgency to acquire reliable scientific data necessary to define and implement effective conservation programs and, as stated by Baillie and colleagues, "countries that have the most threatened species tend to be those that are least able to invest significant resources into conservation" (Baillie *et al.,* 2004).

Mammals are one of the groups most directly affected by agricultural activities and the associated deforestation. Native habitat suppression is by far the most critical factor threatening mammals, and it is estimated that 86% of the species are facing the risk of extinction because of this anthropic action (Baillie *et al.,* 2004). Large mammals, especially large predators, frequently prey on cattle while simultaneously requiring habitats with dense vegetation cover, access to water and sufficient natural prey base (Polisar *et al.,* 2003). The less natural habitats and prey are available the more these predators will forage on livestock. So, the loss of natural resources due to habitat conversion for agriculture increases the severity of conflicts between farmers and mammals, and this is presently considered one of the major causes of their decline (Ripple *et al.,* 2014). But large mammals are not the only ones affected by human-wildlife conflicts. Small mammals like bats are also victims of persecution by farmers due to their role as rabies vectors. Current vampire bat management practices have severe impacts on bat populations, vampire and otherwise, by destructing important roosts and directly or indirectly affecting populations of other species that coexist with vampire bat colonies (Aguiar *et al.,* 2010).

In Brazil, bats have a differential distribution across biomes, representing 50.3% of the mammals of Caatinga, 42.5% of the Pantanal, 40.2% of the Cerrado, 37.9% of the Atlantic Forest, 36.5% of the Amazon, and 28.9% of the Pampa. Due to intricate mechanisms of coevolution between bats and plants, there is a strong association of bats with their environments (Muscarella & Fleming 2007). Thus, bats are vital players in ecosystem services like seed dispersal and pollination. Besides that, they play an essential role in predation of insects that are a plague to agriculture (Kunz *et al.,* 2011). However, Amori & Gippoliti (2000) indicate that despite bat's relevant ecosystem services they are poorly represented in conservation papers, which may affect a comprehensive analysis of their conservation status.

The evaluation of the conservation status of a species according to its extinction risk is the primary step for conservation planning (Margules & Pressey, 2000; Rodrigues *et al.,* 2006). The International Union for Conservation of Nature and Natural Resources – IUCN assesses, publishes and periodically updates species' global threat status for over four decades. Although the process has been criticized (de Grammont & Cuaron, 2006) it is, until now, one of the best available ways to evaluate biodiversity conservation status worldwide, allowing comparisons between countries (de Grammont & Cuaron, 2006). For various reasons – for example, phylogenetic proximity to humans, aesthetic standards, conspicuousness (especially in large species) – there is an evident long-term research interest in mammals so mammal species are, overall, well-evaluated conservation-wise; so, they may be used as a proxy group for estimating extinction risk or threats in less-studied taxa on both global and regional scales (McKinney, 1999).

Even considering their ecological and behavioral traits, bats should be responding similarly to other mammals to the above mentioned anthropogenic threats (McKinney, 1999). In general terms, mammal diversity is declining globally and taking an assessment based on the Red List Index, it is observed an expressive reduction

over the last decades (Butchart *et al.,* 2010). Thus, we expected that bats should follow this trend presenting similar percentage of threatened species in comparison to other Mammalia orders. In this context, here we compare the conservation status of bats with that of other mammals to evaluate if their perceived level of threat is similar. We analyzed mammal's data gathered at the global and regional (South America) scales, mainly to compare the Brazilian situation with that of other countries. We hypothesize that South American bats should have similar conservation status to that of other mammals, since human activities, especially large-scale deforestation, should affect most mammals similarly. We also evaluate if knowledge on threatened mammal species in Brazil is balanced among taxa and if it is correlated to their threat status. Our hypothesis is that independently of knowledge and life histories bats are generally considered less threatened than other mammals. Finally, we discuss and question the scenario of evaluation of the conservation status of Brazilian bats and propose measures to improve the current situation.

Threat status of bats: Brazil, South America and worldwide

We accessed the data available at the IUCN webpage (http://www.redlist.org) to download the number of species per endangered category (Critically Endangered, Endangered and Vulnerable) and country of occurrence for all mammalian orders, including the Chiroptera. We compared the observed percentage of threatened bat species in Brazil and other South American countries with that percentage worldwide. We used a test of proportions to test for significant differences in the proportion of threatened bat species between Brazil, South America and the world. All analyses were done in R software v 3.4.4 (R Core Team, 2018). Significance level was set at 0.05.

According to IUCN, 1204 mammals are globally threatened (Critically Endangered, Endangered and Vulnerable), representing 21.20% of the 5674 mammal species recognized to date. Only five orders – Dermoptera, Hyracoidea, Microbiotheria, Notoryctemorphia and Tubulidentata – do not include any threatened species (Table 1). The Chiroptera includes 1241 species evaluated by the IUCN of which 180 (14.50%) are within one of the three threatened categories. If we take the global proportion of threatened mammals and apply it to the Chiroptera, we should expect around 263 species threatened with extinction worldwide. Thus, the current number of globally threatened bats is significantly lower to that of the whole of the remaining mammals ($X^2 = 28.27$, $p < 0.01$).

Of the 1241 bats assessed worldwide, IUCN considers 167 as occurring in Brazil (Table 2); only two species occurring in the country – *Lonchophylla bokermanni* and *L. dekeyseri* – are categorized as threatened worldwide and both with Endangered status. Thus, only about 1% of the bat species present in the country are considered threatened, which is a significantly lower proportion than that of globally threatened bats considering the number of bat species worldwide ($X^2 = 21.99$, $p < 0.01$).

Table 1: Number of IUCN threatened mammal species per order. CR: Critically Endangered; EN: Endangered; VU: Vulnerable; N: total number of species per order; %: percentage of threatened species within each order.

Order	CR	EN	VU	N	%
Afrosoricida	1	7	8	55	29.09
Carnivora	4	31	43	295	26.44
Cetardiodactyla	15	46	58	335	35.52
Chiroptera	23	53	104	1241	14.50
Cingulata	0	0	2	20	10.00
Dasyuromorphia	0	5	5	73	13.70
Dermoptera	0	0	0	2	0.00
Didelphimorphia	2	0	6	98	8.16
Diprotodontia	15	13	24	147	35.37
Euliopotypla	11	40	27	468	16.67
Hyracoidea	0	0	0	5	0.00
Lagomorpha	2	13	5	92	21.74
Macroscelidae	0	1	1	19	10.53
Microbiotheria	0	0	0	1	0.00
Monotremata	2	0	1	5	60.00
Notoryctemorphia	0	0	0	2	0.00
Paucituberculata	0	0	3	7	42.86
Peramelemorphia	0	3	4	22	31.82
Perissodactyla	4	5	3	16	75.00
Pholidota	2	2	4	8	100.00
Pilosa	1	0	2	10	30.00
Primates	64	123	83	440	61.36
Proboscidea	0	1	1	2	100.00
Rodentia	56	131	138	2283	14.24
Scandentia	0	2	0	22	9.09
Sirenia	0	0	4	5	80.00
Tubulidentata	0	0	0	1	0.00
Total	**202**	**476**	**526**	**5674**	

Most South American countries show a similar pattern. Only Chile presents a non-distinct proportion of threatened species to that of globally threatened bats: in Chile two species – *Myotis atacamensis* and *Amorphochilus schnablii* – are classified as Endangered and Vulnerable respectively, which represents 16.6% of the bats occurring in the country. In the remaining South American countries, the proportion of threatened species ranges from 0% (Argentina, Uruguay, Paraguay, and Suriname) to 5.3% (Colombia). Even considering the proportion of threatened bat species in the whole of South America (19 species among 255 species evaluated by IUCN), the proportion of threatened species is just around 7% of the bat species of the region (Table 2).

Distribution of knowledge on Brazilian threatened mammals

The Brazilian Red List of Mammals (Portaria MMA 444, 17 December 2014) categorizes 12 Critically Endangered, 43 Endangered and 54 Vulnerable mammals. We

Table 2: Number of mammals (excluding bats) and bats in South American countries and corresponding threatened species. NMsp: number of mammal species (excluding the Chiroptera); NTsp: number of threatened mammal species (excluding the Chiroptera); CR_T = Critically Endangered, EN_T = Endangered, and VU_T = Vulnerable number of mammal species (excluding the Chiroptera); %TM: percentage of threatened mammal species (excluding the Chiroptera); NBsp: number of bat species; %BM: percentage of bats in relation to the number of mammal species; NTB: number of threatened bat species; CR_B = Critically Endangered, EN_B = Endangered, and VU_B = Vulnerable number of bat species; %TB: percentage of threatened bat species in relation to the total number of bat species.

Country	NMsp	NTsp	CR_T	EN_T	VU_T	%TM	NBsp	%BM	NTB	CR_B	EN_B	VU_B	%TB
Argentina	393	37	6	13	18	9.41	60	15.27	0	0.00	0.00	0.00	0.00
Bolivia	369	20	1	9	10	5.42	119	32.25	1	0.00	1.00	0.00	0.84
Brazil	665	81	11	32	38	12.18	167	25.11	2	0.00	2.00	0.00	1.20
Chile	156	19	1	11	7	12.18	12	7.69	2	0.00	1.00	1.00	16.67
Colombia	453	54	7	14	33	11.92	179	39.51	9	0.00	1.00	8.00	5.03
Ecuador	387	45	2	10	33	11.63	153	39.53	7	0.00	2.00	5.00	4.58
French Guiana	203	8	1	7	0	3.94	104	51.23	0	0.00	0.00	0.00	0.00
Guyana	236	11	0	1	10	4.66	124	52.54	0	0.00	0.00	0.00	0.00
Paraguay	173	10	0	3	7	5.78	54	31.21	0	0.00	0.00	0.00	0.00
Peru	486	50	4	15	31	10.29	159	32.72	6	0.00	3.00	3.00	3.77
Suriname	205	9	0	1	8	4.39	102	49.76	0	0.00	0.00	0.00	0.00
Uruguay	117	10	0	5	5	8.55	20	17.09	0	0.00	0.00	0.00	0.00
Venezuela	374	35	1	11	23	9.36	158	42.25	5	0.00	2.00	3.00	3.16
South America	1311	201	29	73	99	15.33	271	20.67	19	0.00	9.00	10.00	7.01

searched for papers on those Brazilian threatened mammals on the Web of Science database. We used the species names – seven bats and 102 non-chiropteran mammals – as the searching keyword. No date limit was used. To evaluate if the average number of published papers differs between threatened mammalian taxa, considering both family and order levels, we used an ANOVA. All analyses were done in R software v 3.4.4 (R Core Team, 2018) and significance level was set at 0.05.

A total of 7776 papers were recovered in Web of Science dealing with Brazilian threatened mammals (Figure 1). The mean number of papers published per species was 74.3 (sd = 148.8). Five species – *Panthera onca, Puma concolor, Balaenoptera physalus, Physeter microcephalus,* and *Trichechus manatus* – corresponded to 42.3% of the published papers. We found no published information on two Rodentia species (*Euryoryzomys lamia* – EN, and *Microakondontomys transitorius* – EN).

The number of papers published among orders and among families is significantly different ($F_{7,102} = 5.49$, $p < 0.01$; $F_{29,80} = 2.31$, $p < 0.01$, respectively) (Figure 1). Seven of the 30 mammal families represented 72.73% of the papers published: Felidae is the most represented family (1753) followed by Balaenopteridae (983) and Atelide (821) (Figure 1). The Chiroptera accounts for one Endangered and six Vulnerable species (*L. dekeyseri, Lonchorhina aurita, Glyphonycteris behnii, Xeronycteris vieirai, Furipterus horrens, Natalus macrourus, Eptesicus taddeii*); these seven species were referred in a total of 42 papers (Phyllostomidae – 24, Furipteridae – nine, Natalidae – five and Vespertilionidae – four). The number of published papers and species conservation status showed no significant relation ($F = 0.47$, $p = 0.63$) showing that different conservation status is defined independently of the level of knowledge on a specific taxon.

Bats: an unbalanced assessment?

Species tend to have a higher risk of extinction if they occupy small geographical ranges, occur at low densities, and occupy high trophic levels in the food chain (Purvis *et al.,* 2000). Bats are highly diverse, taxonomically and functionally, mirroring the diversity found in the remaining mammals, and including several species with those 'high-risk' characteristics. So, one would expect the proportion of bat species threatened with extinction to be like that of other mammal species, at all spatial scales – global, regional and local. However, our findings indicate that bats are proportionally perceived as less threatened than the whole of the other mammals regardless the number of published papers, suggesting an unbalanced assessment of their threat status. Indeed, almost ¼ of mammals are threatened worldwide due to land-use change and habitat fragmentation, overhunting, introduction of invasive species and pollution (Maxwell *et al.,* 2016; Newbold *et al.,* 2015). Most scenarios (*e.g.,* Pereira *et al.,* 2010; Powell & Lenton, 2013) indicate a trend of continuous decline of biodiversity in the future, and scenarios worsen if the current situation of global agriculture expansion is not halted. The Chiroptera, the second richest mammalian order, even if in a lower proportion, does not escape this fate, with 15% of bat species listed as threatened by the IUCN (2017).

Although responses to land-use changes and other anthropogenic actions are species-specific, all species are negatively affected by habitat loss. Decreased resource availability and distribution, within fragments and the matrix, changes mammal assemblage structure, leading to depleted populations of mammals that are restricted to native fragments and increasing the abundance of those that can use the matrix (Gascon *et al.,* 1999). Bats are no exception to this pattern and many bat species,

dependent on pristine or moderately disturbed environments, are probably as threatened as other mammals in regions that have lost much of their native habitats (Gorresen & Willig, 2004; Lane *et al.,* 2006).

Perspectives on the conservation of Brazilian bats

The Neotropical region has been highly impacted by anthropogenic land-use changes, being one of the regions of the world with higher deforestation rates (FAO, 2010); so there is no reason to suppose that bat species in this region are not responding negatively to those changes. Thus, from our evaluation, we can conclude that something is missing in the South American bat assessment. Even considering that bats are highly mobile, have enormous diversity of feeding habits and occupy a wide range of roosts (Fenton *et al.,* 1992) they are equally suffering from deforestation and habitat fragmentation. Williams-Guillén *et al.* (2016) showed that agricultural intensification has a negative effect on bats in 84% of the studies they analyzed and the implementation of large wind farms in the last decades has becoming a serious concern for bat populations (Barros *et al.,* 2015; Frick *et al.,* 2017). Other studies suggest that local bat abundance is linked to patch size, isolation and vegetation structure that together shape bat assemblages (Estrada-Villegas *et al.,* 2010), and that even moderate land-use changes lead to local extinction of bat species (Ramos Pereira *et al.,* 2018).

Overall, we believe that in Brazil the number of endangered bat species should be higher for the following

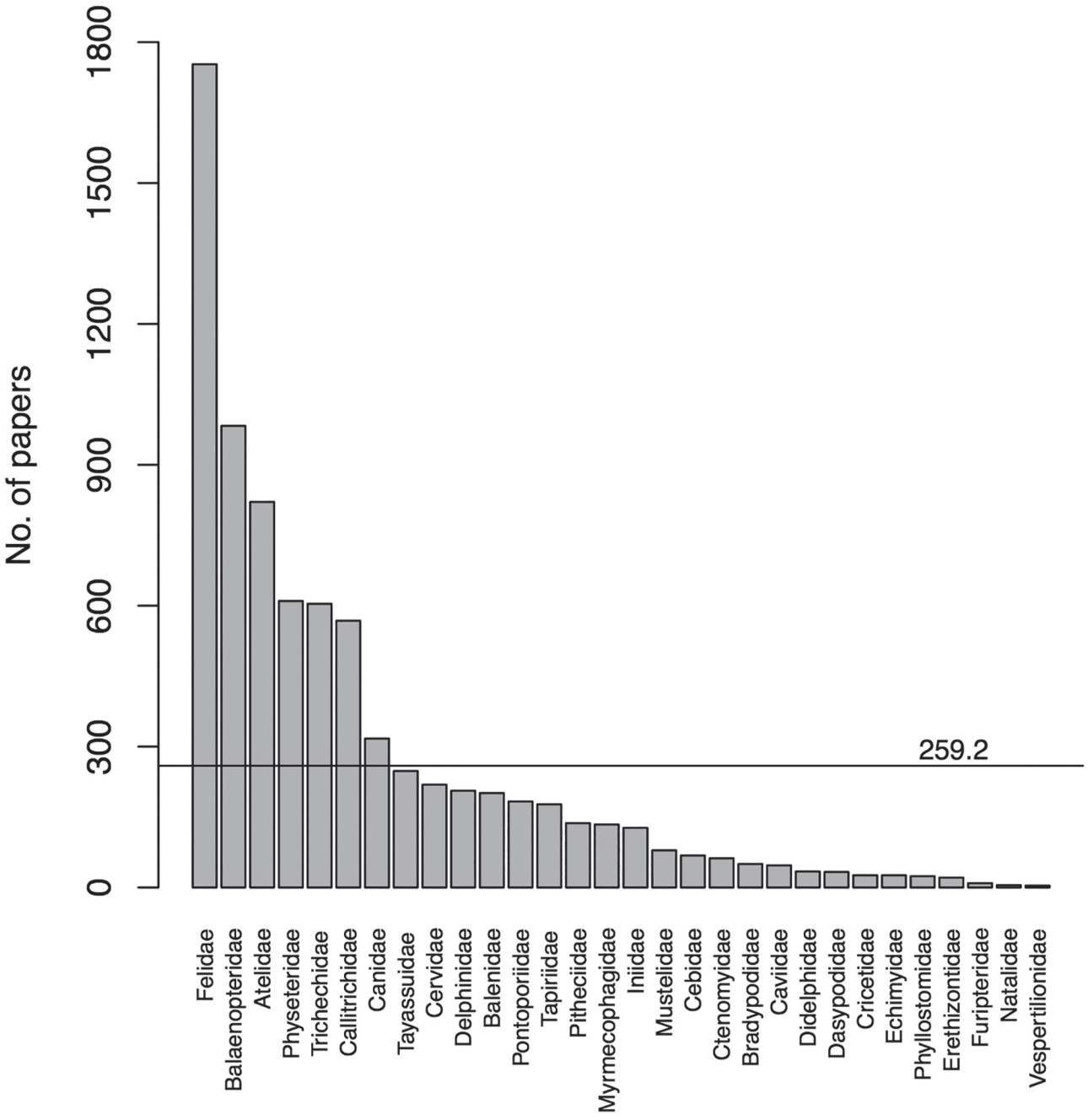

Figure 1: Number of papers by mammalian family retrieved in the Web of Science database showing families above and below the mean number of publications.

reasons: 1. The country is, unfortunately, experiencing high rates of deforestation and two of its biomes are conservation hotspots (Myers *et al.,* 2000); 2. Within the areas suffering high deforestation are located many important caves (hot caves), recognized as home to at least 80 species of bats (Oliveira *et al.,* 2018); 3. Wind farms, known to impact bat populations worldwide (Arnett & Baerwald, 2013), are being licensed and installed without any rigorous impact assessments (Ramos Pereira *et al.,* 2017); 4. There is an undue persecution of bats due to livestock and human rabies outbreaks (Aguiar *et al.,* 2010); 5. All those combined with the expected climatic changes, may lead to increased habitat loss by bats (Aguiar *et al.,* 2016).

In the Brazilian Red List, even if just considering the size of the geographical range, the number of bats threatened with extinction should be higher than that currently observed. For example, *Trinomys yonenagae* (Rodentia) is classified as Endangered (globally and in Brazil) by geographic distribution criteria – B2ab (ii, iii, iv). *Eptesicus taddei,* with the exact same geographic distribution parameters – criteria B2ab (i, ii, iii) – is categorized as Vulnerable in Brazil and as Data Deficient worldwide. *Lasiurus ebenus* is not categorized as threatened, even though it is considered a rare bat, known from only two localities in the Atlantic Forest of the state of São Paulo (Fazzolari-Corrêa, 1994 Claudio *et al.,* 2018) and its geographic range is similar to that of *T. yonenagae* and *E. taddei.* Perhaps with the finding of the species in a third locality, the extension of occurrence of *L. ebenus* could be calculated as well as its category, that will be probably (B2ab (ii, iii, iv) or B2ab (i, ii, iii). Besides geographical distribution, life-history traits deem bats more prone to population decline. Indeed, they may be particularly susceptible to anthropogenic actions mostly due to their unique life-history considering their size: while they are small mammals with high metabolic rates, they are on "the slow side of the slow-fast continuum of life-histories", as they reproduce at a low rate and show high longevity (Barclay & Harder, 2003). Also, many species are gregarious forming colonies of hundreds or thousands of individuals, so a single disturbance event in their roosts may have long-term negative consequences in those populations. This means that most bat populations will slowly, if ever, recover from increased mortality rates (Kingston & Voigt, 2016).

In a country with more than 180 bat species, a more accurate assessment is crucial, especially when a whole set of extinction drivers are knocking at the bat's doors. Certainly, the process of assessing the conservation status of a species depends on the existence of some scientific knowledge to verify how that species fits within the IUCN categories. In their recently edited book "Bats in the Anthropocene – Conservation of Bats in a Changing World", Kingston & Voigt (2016) call for attention to the paucity of ecological studies that can support conservation status assessments. In Brazil, while a small group of threatened species presents a good amount of information, for others, independently of their size, there is not much published. And this is true even for species classified as Critically Endangered in the country. Still, our survey indicates that despite most Brazilian threatened species have very little published knowledge there is no relation between the number of published papers and species conservation status.

Brazilian Red Lists have been increasingly improved, since recently the official national institutions adopted the IUCN criteria and guidelines for application at the regional level. Thus, the assessment process became clearer and, therefore, comparable to other countries. Nevertheless, the Red List Index (Bubb, 2009) still cannot be used for within-country temporal comparisons as the previous official lists did not use the standard criteria.

An interesting point is that, despite this movement and the potential quality increase of the Brazilian Red List, the proportion of endangered bat species is still significantly lower than that expected considering the proportion of endangered bats worldwide. As pointed out by Brito *et al.* (2010) such comparisons between national Red Lists and the IUCN Red List is a high priority both for IUCN and for national Red Listing agencies. Also, and even considering the time necessary for status revisions, the evaluated species list and their distribution is still not consistent with the most updated taxonomic and ecologic information on the group (Nogueira *et al.,* 2014; Paglia *et al.,* 2012). All this indicates that a more detailed assessment is necessary and certainly capable of revealing a situation closer to the conservation reality of Brazilian bats. Our empirical knowledge suggests that many colleagues possess much more data than that immediately available in the literature or shared with conservation authorities, which could support better conservation status assessments. So, we underline the importance of researchers publishing data on bat occurrence, distribution and population ecology that, as demonstrated above, is not only biased towards some species and families, but also still quite scarce; sharing technical reports or even simple datasheets containing bat occurrences in the form of number of individuals per species (when possible) and the respective geographical coordinate with conservation authorities, beyond those mandatory for research done in conservation units, would also very much improve our knowledge and subsidize conservation decisions.

Considering the rate of habitat loss in Brazil, and the indication that obtaining minimum information for bats species would take between 33 and 200 years (Bernard *et al.,* 2011), alternative approaches for the definition of bat conservation status may be necessary. Open source data (*e.g.,* Global Biodiversity Information Facility – GBIF), friendly analytical tools (*e.g.,* ecological niche modeling) and land use maps (from the continental, *e.g.,* Global Land Cover Facility – GLCF, to the regional level, *e.g.,* Mapbiomas project in Brazil – http://www.mapbiomas.org) may contribute towards accurate estimates of distribution areas, areas of potential occurrence in present and future scenarios, as well as rates of habitat loss. As explained by Crooks *et al.* (2017), the proportion of suitable habitat may reflect habitat loss. Though, the

assessment of how remaining habitat is distributed is essential to maintain species in the long term.

The Precautionary Principle[1] should guide this type of analysis because considering a species threatened with extinction has important repercussions on territorial management. This is particularly relevant in environmental licensing, when the potential occurrence of threatened species must be taken into consideration. The identification and the creation of management and conservation units must also consider the occurrence of endangered species, as recommended by the Convention on Biological Diversity (CBD). In the words of Lewinsohn & Prado (2005) "conservation in megadiverse countries must, in a very concrete sense, attempt to avoid losing species that have not even been found".

We believe that the recognition of a species threat status is the first step to its conservation, but certainly not the last. Usually, conservation actions towards these species are related to the definition of priority areas for their conservation and maintenance and management of protected areas. Identification of the most threatened populations of threatened species requires collective efforts to maintain them and should be the practical consequence of the list. It is worth to recall that the Red Lists have a specific rule in the conservation strategy, what means that species can enter and leave the list depending on the success of the conservation actions. It is up to all those involved with biodiversity conservation to surpass this first step and find out how to make such actions possible.

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Lições aprendidas na conservação da anta brasileira e os desafios para mitigar uma de suas ameaças mais graves: o atropelamento em rodovias

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Resumo: A Iniciativa Nacional para a Conservação da Anta Brasileira (INCAB) – Instituto de Pesquisas Ecológicas (IPÊ) atua na pesquisa e desenvolvimento de estratégias de conservação para a espécie. Uma dessas estratégias é a mitigação de ameaças. Entre abril de 2013 e novembro de 2018, foram registrados 470 atropelamentos de anta em 32 rodovias do Mato Grosso do Sul. No mesmo período, 55 pessoas ficaram feridas e 23 vieram a óbito em colisões com antas no estado. Em agosto de 2016, a partir de dados disponibilizados pela INCAB, foi protocolado junto ao Ministério Público Estadual do Mato Grosso do Sul (MPE-MS) um Inquérito Civil para apurar a responsabilidade dos órgãos competentes (AGESUL – Agência Estadual de Gestão de Empreendimentos; IMASUL – Instituto de Meio Ambiente do Mato Grosso do Sul) em não implementar medidas de mitigação na Rodovia MS-040. Desde então, diversas atividades foram realizadas, incluindo a preparação de um Plano de Mitigação para a mencionada rodovia. Em função da morosidade dos órgãos estaduais em implementar as ações propostas, em junho de 2018, o MPE-MS apresentou uma Ação Civil Pública contra AGESUL e IMASUL, através da qual pede indenização de R$ 10 milhões pela morte de animais e acidentes com vítimas humanas na MS-040. No momento, aguardamos deliberações da mencionada ação. Neste ensaio, provemos informações sobre todo o processo desde a instauração do Inquérito Civil, falamos sobre as lições aprendidas e futuros passos, e tecemos recomendações para a solução da problemática dos atropelamentos de fauna no Mato Grosso do Sul.

Palavras-Chave: Ação civil pública; Anta brasileira; Atropelamento; Conservação; Inquérito civil.

Abstract: Lessons learned on lowland tapir conservation and the challenges faced to mitigate one of the species' most severe threats: roadkill. The Lowland Tapir Conservation Initiative (LTCI) – Institute for Ecological Research (IPÊ) applies research data and results for the design of strategies for the conservation of tapirs in Brazil. One of these strategies includes threat mitigation. Between April 2013 and November 2018, 470 lowland tapir carcasses were recorded in 32 highways throughout the state of Mato Grosso do Sul. During the same period, 55 people were injured and 23 died in collisions with tapirs in the state. In August 2016, the Public Prosecutor's Office of the State of Mato Grosso do Sul (MPE-MS) used data provided by the LTCI to file a Civil Inquiry requesting the investigation of the relevant organizations (AGESUL – Development and Infrastructure Department; IMASUL – State Environmental Agency) regarding the lack of roadkill mitigation measures along state highway MS-040. Since then, several activities and discussions took place, including the preparation of a Mitigation Plan for the aforementioned highway. In June 2018, in face of the lack of action on the part of the public bodies to implement the proposed mitigation measures, the MPE-MS filed a lawsuit against AGESUL and IMASUL, requesting compensation in the amount of 10 million Brazilian Reais for the damage to wildlife and loss of human lives along highway MS-040. In this essay, we provide detailed information on the entire process, starting with the establishment of the Civil Inquiry, we discuss the lessons learned and future steps, and we make recommendations about possible solutions for the issue of roadkill in Mato Grosso do Sul.

Key-Words: Conservation; Legal instruments; Lowland tapir; Roadkill.

A anta brasileira, *Tapirus terrestres,* também conhecida como anta sul-americana ou anta de terras baixas, pertence à Família Tapiridae da Ordem Perissodáctila, ordem também representada por cavalos, zebras e rinocerontes. Encontra-se globalmente classificada pela Lista Vermelha da IUCN – *International Union for Conservation of Nature* – como vulnerável à extinção (IUCN – *Red List of Threatened Species*). A Lista Vermelha Nacional do ICMBio – Instituto Chico Mendes de Conservação da Biodiversidade (Medici *et al.,* 2012) classifica o estado de conservação da espécie separadamente por biomas: Amazônia – quase ameaçada; Caatinga – localmente extinta; Cerrado – ameaçada; Mata Atlântica – ameaçada e, Pantanal – quase ameaçada. As principais ameaças para a sobrevivência da espécie incluem perda e fragmentação de habitat, particularmente em função da expansão de fronteiras agropecuárias, atropelamentos em rodovias, contaminação por agrotóxicos e caça.

A espécie tem ampla distribuição geográfica, estendendo-se desde o Norte da Colômbia, à Leste da Cordilheira dos Andes, através de grande parte da América do Sul até o Nordeste da Argentina e Paraguai, em elevações de até dois mil metros (Hershkovitz, 1954; Medici, 2011). Ocorre em 11 países – Argentina, Bolívia, Brasil, Colômbia, Equador, Guiana, Guiana Francesa, Paraguai, Peru, Suriname e Venezuela, e 21 biomas sul-americanos, primordialmente em florestas tropicais baixas e ambientes ripários, mas pode também ser encontrada em habitats mais secos, tais como o Chaco Boliviano e Paraguaio. No Brasil, a espécie é atualmente encontrada nos biomas Amazônia, Cerrado, Mata Atlântica e Pantanal.

A anta é o maior mamífero terrestre da América do Sul. Adultos chegam a pesar 300 quilos, com cerca de um metro de altura e, em alguns casos, mais de dois metros de comprimento. As fêmeas são, em geral, maiores que os machos. Possui uma crina curta e estreita ao longo de todo o pescoço, pelagem acinzentada, curta e áspera. Possui uma probóscide utilizada para a alimentação. É um animal solitário, de hábito noturno-crepuscular.

Sua área de uso é extensa, em média de 500-600 hectares por indivíduo, e movimenta-se a longas distâncias entre fragmentos de habitat (Medici, 2010). Por esta razão, é conhecida como *espécie paisagem.* É um animal herbívoro, alimentando-se, sobretudo, de frutos, brotos e folhas (Medici, 2011). Os frutos consumidos são engolidos inteiros, juntamente com suas sementes. Quando passam pelo trato digestivo do animal, essas sementes têm sua capacidade de germinação potencializada. Desta forma, a anta tem um papel fundamental na dispersão de sementes pela floresta, transportando essas sementes em seu estômago por toda a extensão de sua área de uso. Por esta razão, a anta também é conhecida como a *jardineira da floresta* ou *engenheira de ecossistemas* e desempenha um papel de extrema importância nos processos de formação e manutenção da biodiversidade (Medici, 2011).

Sua reprodução é bastante lenta. Machos e fêmeas atingem a maturidade sexual com cerca de quatro anos de idade e estima-se que vivam de 22 a 24 anos na natureza. A gestação dura de 13 a 14 meses, nascendo um único filhote. Uma fêmea deve produzir um filhote a cada um ano e meio ou até mesmo dois anos. A taxa de mortalidade de filhotes na natureza é alta, sendo que estes estão mais suscetíveis a predadores. Devido às taxas reprodutivas intrinsicamente baixas e baixas densidades populacionais, a recuperação de uma população impactada é bastante lenta (Medici & Desbiez, 2012).

A Iniciativa Nacional para a Conservação da Anta Brasileira

Até 1996, pouco se sabia sobre o *status* de conservação da anta brasileira na natureza. Naquele ano, a pesquisadora e conservacionista Patrícia Medici, uma das fundadoras da organização não governamental IPÊ – Instituto de Pesquisas Ecológicas, estabeleceu um programa pioneiro de pesquisa com a anta no Parque Estadual Morro do Diabo, na região do Pontal do Paranapanema, Município de Teodoro Sampaio, estado de São Paulo. Desta iniciativa, nasceu o Programa Anta Mata Atlântica, iniciando-se a construção do primeiro banco de dados sobre a espécie, incluindo informações valiosas sobre ecologia e biologia do animal, ecologia espacial, demografia, saúde e genética, entre outros parâmetros (Medici, 2010). A principal abordagem do programa foi estudar as antas no contexto de pequenas populações na paisagem fragmentada da Mata Atlântica, usando esses animais como *detetives ecológicos* no processo de identificação e mapeamento das rotas de movimentação de fauna pela matriz de paisagem. As informações geradas foram utilizadas para determinar as áreas potenciais para o estabelecimento de corredores e/ou trampolins ecológicos para o restabelecimento da conectividade do habitat, para influenciar o processo de restauração de áreas importantes para a anta na região, bem como para promover a criação de novas áreas protegidas.

Em 2008, Patrícia Medici decidiu usar a experiência acumulada em 12 anos de trabalho na Mata Atlântica para expandir seus esforços de pesquisa e conservação da espécie para outros biomas brasileiros. Assim, o Programa Anta Mata Atlântica deixou de ser um projeto para tornar-se uma iniciativa em nível de país, a Iniciativa Nacional para a Conservação da Anta Brasileira (INCAB). O próximo alvo foi o Pantanal, a maior planície alagável do planeta e um dos biomas mais importantes para a manutenção de populações viáveis da anta brasileira. O Programa Anta Pantanal foi estabelecido na Fazenda Baía das Pedras, na sub-região da Nhecolândia, no coração do Pantanal Sul, no estado do Mato Grosso do Sul. A meta primordial deste programa, o qual está ainda em andamento, é a obtenção de dados e informações sobre a espécie em um local bem conservado, estudando a anta em condições ideais, uma população controle com a qual todas as demais poderão ser comparadas.

Em 2015, a INCAB expandiu o seu alcance incluindo um novo alvo, o bioma Cerrado, estabelecendo o Programa Anta Cerrado, também no estado do Mato Grosso do Sul. Nesta região altamente antropizada, epicentro do desenvolvimento econômico de nosso país, a meta

principal da INCAB é avaliar o impacto de diferentes ameaças nas populações de anta brasileira e buscar estratégias efetivas para a mitigação dessas ameaças. As ameaças encontradas incluem atropelamentos em rodovias, desmatamento e fragmentação do habitat natural, fogo, caça, expansão do agronegócio, particularmente cana-de-açúcar, soja e milho, consequente contaminação por agrotóxicos, poluição de corpos de água dentre outras.

Através do estabelecimento de programas de pesquisa e conservação da anta em diferentes biomas brasileiros, a INCAB busca criar uma perspectiva comparativa para a conservação da espécie. Através de um profundo entendimento sobre este animal em diferentes contextos de paisagem e sob diferentes níveis de distúrbio ambiental, busca-se avaliar a magnitude e importância dos fatores ecológicos afetando as diferentes populações existentes no país bem como determinar as necessidades da espécie em termos de conservação. Com isso, espera-se ter todas as ferramentas necessárias para promover o desenvolvimento e efetiva implementação de estratégias de conservação e manejo para a anta brasileira em toda a sua área de distribuição na América do Sul.

Especificamente sobre a questão dos atropelamentos, desde 1996, durante a execução do Programa Anta Mata Atlântica no Parque Estadual Morro do Diabo, a INCAB já lidava com a problemática. O parque é cortado pela rodovia SP-613, que conecta os municípios de Teodoro Sampaio e Rosana, e o impacto dos atropelamentos de fauna, com destaque para a anta, era marcadamente crônico, visível e mensurável. Muitos anos se passaram depois do trabalho na Mata Atlântica e foi no bioma Cerrado que os atropelamentos voltaram ao leque de ameaças abordadas pela INCAB. Dirigir nas rodovias que cortam o Cerrado e o Pantanal no Mato Grosso do Sul impressiona pelo altíssimo número de carcaças de animais silvestres. Tão logo o Programa Anta Cerrado foi estabelecido em 2015 observou-se que a magnitude dos atropelamentos de anta na região era infinitamente maior do que no Morro do Diabo e, desta forma, tornou-se prioridade da INCAB avaliar, compreender e mitigar esta ameaça. Neste momento, a pesquisadora Patrícia Medici buscou a experiência da bióloga e especialista em ecologia de rodovias, Fernanda Abra, para auxiliar na mitigação da problemática de atropelamentos de fauna. Assim, as duas conservacionistas tornaram-se grandes parceiras na busca de soluções para os atropelamentos de anta no estado do Mato Grosso do Sul.

Os impactos das rodovias sobre a biodiversidade, segurança humana e economia

Em escala global, as rodovias são conhecidas pelo desenvolvimento social e econômico de regiões trazendo importantes benefícios para a sociedade. No entanto, a construção de novas rodovias, particularmente intensa no último século nos países desenvolvidos e em desenvolvimento, permitiu a expansão da rede viária até as mais remotas áreas naturais remanescentes, resultando muitas vezes na disjunção das relações ecológicas nos ecossistemas por elas cortados (Trocme, 2003). Recentemente, as rodovias também são reconhecidas por representarem uma das maiores ameaças para a conservação biológica (Bond & Jones, 2008; Forman & Alexander, 1998; Trombulak & Frissell, 2000). Para os animais, os efeitos dos impactos das rodovias e do tráfego são variados, envolvendo perda de habitat (Forman *et al.,* 2003), mortalidade direta resultante de colisão com veículo automotor (Fahrig & Rytwinski, 2009; Forman & Alexander, 1998), efeito barreira que consiste no desencorajamento ou impedimento do animal em cruzar a rodovia (Lesbarreres & Fahrig, 2012; Nellemann *et al.,* 2001) e a redução na qualidade do habitat e aumento de perturbações ambientais (*e.g.,* iluminação artificial noturna, poluição, ruído e perturbação visual) (Eigenbrod *et al.,* 2009; Forman *et al.,* 2003; Parris *et al.,* 2009).

Especificamente sobre as colisões envolvendo veículos automotores, a maioria dos estudos aborda mamíferos de médio e grande porte, tanto pela preocupação biológica, uma vez que são os animais mais ameaçados do mundo (Abra *et al.,* 2018; Cardillo, 2005; Rytwinski & Fahrig, 2011), bem como o potencial risco que eles oferecem aos usuários de rodovias (Conover *et al.,* 1995). Na Europa e na América do Norte, o foco está em reduzir colisões com ungulados (Groot Bruinderink & Hazebroek, 1996; Huijser *et al.,* 2009). Na América do Sul, a gravidade das colisões envolve principalmente as capivaras (*Hydrochoerus hydrochaeris*), pela abundância da espécie e pelo hábito de se deslocarem em grupos, e a anta brasileira por ser a espécie com maior tamanho corporal do Brasil (Bueno *et al.,* 2013; Huijser *et al.,* 2013; Medici *et al.,* 2016).

Estima-se que nos Estados Unidos, colisões envolvendo animais em rodovias gerem 211 vítimas humanas fatais, 29 mil vítimas humanas feridas e aproximadamente 6-12 bilhões de dólares de custos econômicos anuais (Conover *et al.,* 1995; Huijser *et al.,* 2007). Na Europa, colisões com ungulados resultam em 300 vítimas humanas fatais, 30 mil vítimas humanas feridas e aproximadamente um bilhão de dólares em perdas materiais anuais (Groot Bruinderink & Hazebroek, 1996).

Na América do Sul, pouca informação está disponível em relação às implicações de colisões envolvendo animais em rodovias na segurança humana e os custos destas colisões para a sociedade. No entanto, em 2014, 3.174 colisões envolvendo animais foram registradas nas Rodovias Federais Brasileiras (IPEA, 2015), representando 1,9% de todos os acidentes rodoviários no período foi calculado (Abra *et al.,* 2018, no prelo).

A problemática dos atropelamentos de anta no MS

A INCAB-IPÊ vem monitorando rodovias federais e estaduais do Mato Grosso do Sul desde abril de 2013. A malha viária do estado é de 62.590 quilômetros (DNIT, 2018), sendo que 87% são estradas rurais (vias não pavimentadas) e apenas 13% são rodovias (vias

pavimentadas). Os biomas representados nas áreas de estudo são o Cerrado e o Pantanal.

Os dados sobre atropelamentos de antas foram coletados de maneira oportunística, através de monitoramento em campo pela equipe da INCAB, informes recebidos através de uma ampla rede de colaboradores via *Whatsapp* (incluindo membros das comunidades locais, motoristas de caminhões, ônibus etc., profissionais das Polícias Rodoviárias Estadual e Federal entre outros), bem como através de pesquisas de inserções de mídia (via *Google search*), bancos de dados das Polícias Rodoviárias Federal e Estadual e DETRAN, e contribuições de informação de outros pesquisadores, projetos de conservação e colaboradores.

De abril de 2013 até o momento da finalização deste ensaio (novembro de 2018, perfazendo um total de 67 meses), foram registradas 470 ocorrências de atropelamento específico de anta brasileira (aproximadamente sete antas por mês) em 32 rodovias da malha viária sul-mato-grossense, incluindo seis rodovias federais (dentre elas as BRs 267 e 262), 24 rodovias estaduais, e duas estradas vicinais. Aqui se faz importante mencionar que é bastante provável que o número de antas atropeladas registradas pela INCAB-IPÊ esteja subestimado, uma vez que muitas carcaças não são detectadas. Existem evidências de que muitos indivíduos atropelados são removidos para consumo da carne e/ou utilização de partes para fins medicinais (patas, pênis). No período do monitoramento, 13 antas foram encontradas carneadas e 11 carcaças foram reportadas por informantes, porém não encontradas pela equipe (EP Medici, comentário pessoal). Adicionalmente, muitos indivíduos são atropelados, porém não vêm a óbito imediatamente na beira da rodovia, mas sim afastados desta, onde não podem ser detectados.

Os dados coletados pela INCAB-IPÊ mostram que dentre todas as rodovias monitoradas, três são campeãs em atropelamentos de anta no Mato Grosso do Sul: BR-267, BR-262 e MS-040. A Rodovia MS-040 conecta as cidades de Campo Grande, capital do estado, e Santa Rita do Pardo, percorrendo um trecho de cerca de 230 quilômetros. É uma rodovia recente, inaugurada em novembro de 2014. Logo após sua liberação para o tráfego, ficou bastante claro que a MS-040 traria um enorme impacto à fauna local. Diversos proprietários de terras ao longo da rodovia, bem como inserções de mídia, passaram a chamar a atenção para a mortalidade de animais. Em resposta, a INCAB iniciou o monitoramento da MS-040 em março de 2015. Demonstra-se o alarmante impacto da MS-040 através de uma rápida comparação desta com a rodovia BR-267. Na BR-267, no trecho entre os municípios de Nova Alvorada do Sul e Bataguassu (220 quilômetros de rodovia), foram detectadas 116 carcaças de anta em 67 meses, enquanto que na MS-040 (cerca de 230 quilômetros, basicamente a mesma extensão), foram detectadas 127 carcaças de anta em 44 meses (março de 2015 a novembro de 2018).

As análises dos dados demonstraram também que alguns trechos dessas rodovias apresentam situações mais críticas de atropelamentos, trechos estes chamados de *hotspots.* A estrutura da paisagem (*e.g.,* presença de corpos d'água, fragmentos florestais, oferta de recursos alimentares etc.) é um fator determinante para que os animais prefiram utilizar certos trechos da rodovia (Ascensão *et al.,* 2017). Consequentemente, demonstra-se maior necessidade de mitigação nesses pontos previamente identificados e cuidadosamente mapeados pela INCAB-IPÊ.

Em julho de 2016, dados preliminares até então coletados pela INCAB foram publicados no relatório "IMPACTO DE ATROPELAMENTOS DE FAUNA, PARTICULARMENTE ANTA BRASILEIRA, EM RODOVIAS ESTADUAIS E FEDERAIS DO ESTADO DO MATO GROSSO DO SUL, BRASIL" (Medici *et al.,* 2016) (Tabela 1). Com base nas informações contidas no relatório, o advogado e ambientalista, Dr. Leonardo Avelino Duarte, apresentou subsídios para a abertura de um Inquérito Civil junto ao Ministério Público do Estado Mato Grosso do Sul (MPE-MS) para investigar a responsabilidade de órgãos ligados ao licenciamento ambiental, fiscalização e empreendimento para o caso específico da Rodovia MS-040.

Foi protocolado o Inquérito Civil (IC) de № 06.2016.00000716-6 com o principal objetivo de apurar o descumprimento da condicionante № 15 da licença ambiental prévia № 102/2013, relativa às obras de pavimentação asfáltica da Rodovia Estadual MS-040, particularmente no que tocava à ausência de medidas mitigadoras de riscos de acidentes automobilísticos envolvendo animais silvestres, com risco à vida e saúde dos usuários da pista e à manutenção da biodiversidade. Embora a alavanca inicial para o IC tenha sido a problemática da mortalidade de antas e consequente perda de biodiversidade, o grande foco do mesmo estava nas perdas humanas. Ao mesmo tempo em que perdemos 436 antas em 64 meses, foram também registradas, no mesmo período, pelo menos 49 pessoas feridas e 23 que vieram a óbito em colisões com antas nas rodovias do estado. Oito dos óbitos ocorreram em uma única colisão na BR-267 em setembro de 2015.

Através do desenvolvimento do IC, foram realizadas reuniões técnicas de discussão e negociação entre o MPE-MS, INCAB-IPÊ e representantes da AGESUL (Agência Estadual de Gestão de Empreendimentos, órgão da SEINFRA – Secretaria de Estado de Infraestrutura) e IMASUL (Instituto de Meio Ambiente do Mato Grosso do Sul, órgão da SEMAGRO – Secretaria de Estado de Meio Ambiente, Desenvolvimento Econômico, Produção e Agricultura Familiar), bem como de outras agências governamentais (Tabela 1). As reuniões foram invariavelmente pautadas por apresentações de dados de atropelamentos levantados pela INCAB-IPÊ, representada por Patrícia Medici, e propostas de mitigação para resolver a problemática, apresentadas por Fernanda Abra. Durante todo o processo do IC, particularmente durante as reuniões técnicas, era perceptível que tanto AGESUL quanto IMASUL compreendem a extensão e magnitude dos impactos dos atropelamentos na MS-040 para a biodiversidade e para a segurança humana, agravados pela ausência total de planejamento de medidas de mitigação do empreendimento. Em algumas situações, inclusive oficialmente, esses órgãos manifestaram deficiência de

conhecimento técnico sobre como lidar com e mitigar esses impactos.

Em algumas oportunidades durante o processo, a AGESUL propôs a instalação de placas de travessia de fauna (placa vertical de advertência modelo A-36) ao longo da MS-040 como estratégia de mitigação para os atropelamentos. De acordo com a literatura, é sabido que a eficiência deste tipo de mitigação é baixíssima (Ritwinski *et al.,* 2016). De maneira geral, os administradores rodoviários preferem estratégias de mitigação que sejam baratas, duradouras e que cubram grandes extensões da rodovia. As placas de sinalização desempenham esse papel, porém são inespecíficas sobre onde, quando e qual animal atravessará a rodovia e, desta forma, os usuários ao lerem as mensagens das placas não apresentam nenhuma mudança comportamental (*e.g.,* aumento da atenção, diminuição de velocidade) durante o seu percurso. A INCAB-IPÊ e o Ministério Público Estadual mantiveram-se irredutíveis nas negociações, sustentando que para a redução dos atropelamentos da MS-040, faz-se imprescindível a adoção de medidas que apresentem alta eficiência, tais como passagens de fauna e cercas (Huijser *et al.,* 2016; Ritwinski *et al.,* 2016).

Desta forma, a INCAB optou por desenvolver e apresentar voluntariamente ao Estado um plano específico de mitigação de atropelamentos de fauna silvestre para a extensão total da Rodovia MS-040. Entre os objetivos deste plano estavam: (1) Levantar e georreferenciar, ao longo de toda a MS-040, toda e qualquer estrutura já existente para travessia de fauna doméstica, drenagem fluvial, pontes e placas de sinalização de travessia de fauna; (2) Determinar as passagens inferiores já existentes que apresentassem potencial para travessia de fauna; (3) Apresentar propostas de cercamento direcional para a fauna em locais estratégicos; (4) Recomendar novos pontos para a instalação de Passagens Inferiores de Fauna (PIFs) adicionais; (5) Sugerir novos modelos de placas de sinalização de travessia de fauna; (5) Sugerir um plano de monitoramento das PIFs com maior potencial para travessia de mamíferos de médio e grande porte.

Em maio de 2017, foi realizado o trabalho de campo de diagnóstico da MS-040, durante o qual foram levantadas as passagens inferiores já existentes com potencial para uso e travessia da fauna. Foram identificadas 47 estruturas incluindo 39 passagens de gado e/ou drenagens fluviais (maiores de 1,5 metros de diâmetro ou largura × altura) e oito pontes (Figura 1). Já durante o primeiro diagnóstico foi observado o uso frequente de muitas dessas estruturas por diversas espécies animais, especialmente pelas antas.

Em junho de 2017, o "PLANO DE MITIGAÇÃO DE FAUNA SILVESTRE ATROPELADA PARA A RODOVIA MS-040" foi entregue ao Ministério Público que o apresentou em seguida aos órgãos de transporte e meio ambiente. O fato de já existirem estruturas potenciais para uso da fauna ao longo da rodovia – estruturas estas não construídas no intuito de funcionar como passagem de fauna – tornou o plano de mitigação proposto extremamente mais exequível do ponto de vista econômico. No plano, ficou demonstrado que a medida mais importante para a Rodovia MS-040 seria a instalação de cercamento de fauna para as estruturas já existentes. Foi recomendado um cercamento de 500 metros para cada lado das estruturas levantadas com *design* e dimensionamento específico para mamíferos de médio e grande porte.

Como complemento ao Plano de Mitigação da MS-040 e no intuito de subsidiar o processo de implementação do mesmo, a INCAB-IPÊ estabeleceu um experimento de monitoramento das passagens inferiores da rodovia localizadas dentro do mais crítico *hotspot* de atropelamentos (entre os quilômetros 100 e 150). A informação principal que se buscava extrair era o número de cruzamentos bem-sucedidos por baixo da rodovia. Entre setembro de 2017 e maio de 2018 (nove meses), 15 passagens foram monitoradas através de armadilhas fotográficas instaladas em seus emboques de forma a registrar o uso das mesmas por animais silvestres, particularmente a anta. Concomitantemente, foi mantido o monitoramento da mortalidade por atropelamento e foi também realizado um monitoramento sistemático do volume de tráfego de veículos pela Rodovia MS-040. Foram registrados 2.818 eventos de animais silvestres, sendo 1.675 eventos de antas (60%). Dentre os eventos de antas, 61% foram travessias completas confirmadas (Figura 2).

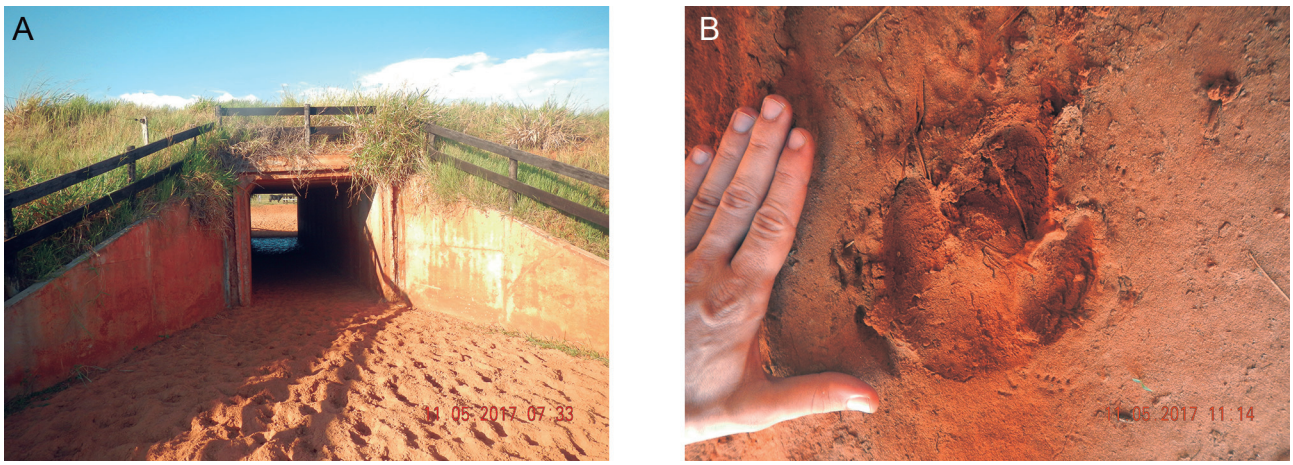

Figura 1: (A) Passagem de gado (Bueiro Simples Celular de Concreto) levantado como estrutura potencial para travessia de fauna na Rodovia MS-040; (B) Pegada de anta brasileira (*Tapirus terrestris*) encontrada no interior da passagem de gado. Crédito: Fernanda D. Abra.

No momento, toda a base de dados está em processo de análise e interpretação para preparo de relatório técnico e publicações científicas. Entretanto, já é possível afirmar que apesar de muitos animais silvestres utilizarem as estruturas inferiores ao longo da rodovia MS-040, os atropelamentos nos mesmos trechos onde as estruturas continuam são altos. O cercamento dessas passagens seria a medida fundamental para o disciplinamento do deslocamento dos animais na paisagem desta rodovia, forçando-os a atravessarem a rodovia por baixo da pista e, assim, seria garantida a segurança tanto dos animais quanto dos usuários.

Em janeiro de 2018, diante da falta de ações por parte das agências governamentais relevantes, a INCAB-IPÊ organizou uma petição pública pedindo o suporte da sociedade civil no processo de pressionar AGESUL e IMASUL para a tomada de providências urgentes. Juntamente com a petição foi lançado o vídeo "Rodovia da Morte" (*Road of Death*). A petição teve mais de cinco mil assinaturas provenientes de todo o mundo. Em fevereiro de 2018, o MPE-MS e a INCAB-IPÊ convocaram uma reunião técnica para apresentar novamente o Plano de Mitigação para AGESUL e IMASUL, entregar as assinaturas da petição pública e tentar avançar no planejamento para a implementação do plano e solução da problemática. A reunião contou com a presença de diversos canais de comunicação e foi amplamente coberta pela mídia. Nessa oportunidade, representantes da AGESUL e IMASUL endossaram o Plano de Mitigação e compromissos para o cumprimento do mesmo foram oficializados com o MPE-MS.

No período entre março e abril de 2018, a AGESUL iniciou um processo de planejamento e cotação de preços para a implementação de parte do Plano de Mitigação, no trecho do *hotspot* mais crítico mencionado anteriormente. A INCAB-IPÊ colaborou com todas as informações técnicas necessárias para esse planejamento, embora estressando frequentemente que o que estava sendo proposto era apenas uma pequena parte do que deveria ser feito para resolver o problema.

As negociações vinham evoluindo vagarosamente quando, em junho de 2018, basicamente dois anos após o início do Inquérito Civil, o MPE-MS apresentou uma Ação Civil Pública contra AGESUL e IMASUL, através da qual o MP pede indenização de R$ 10 milhões pela morte de animais e acidentes com vítimas humanas na Rodovia MS-040. Além do governo do Estado, a ação vai também contra as empresas responsáveis pela construção de partes da rodovia incluindo Cittá Planejamento Urbano e Ambiental, Proteco Construções, Equipav Engenharia, Encalso Construções e CGR Engenharia. As partes teriam também descumprido normativas ambientais, segundo o MP. Até a data de finalização deste ensaio – novembro de 2018 – não houve atualização do andamento da Ação Civil Pública.

LIÇÕES APRENDIDAS

A INCAB-IPÊ vem desempenhando papel fundamental na liderança das discussões acerca da problemática dos atropelamentos de fauna nas rodovias do Mato Grosso do Sul, particularmente na MS-040.

Das lições aprendidas nesse processo, entre o levantamento dos dados de atropelamentos por todo o estado e as iniciativas de influenciar as tomadas de decisão para a efetiva redução dos atropelamentos, podemos afirmar que o envolvimento de diversos atores e conhecimentos multidisciplinares foram fundamentais para que o nosso pleito fosse levado adiante. A INCAB-IPÊ, como projeto de conservação e organização, levantou e

Figura 2: Anta brasileira (*Tapirus terrestris*) utilizando passagem de gado sob a Rodovia MS-040. Crédito: INCAB-IPÊ.

Tabela 1: Cronologia das atividades desenvolvidas no processo de discutir e implementar medidas de mitigação para a problemática dos atropelamentos de fauna na Rodovia MS-040, Mato Grosso do Sul.

Data	Atividade	Comunicação na Mídia
Julho 2016	Publicação do RELATÓRIO PARCIAL "IMPACTO DE ATROPELAMENTOS DE FAUNA, PARTICULARMENTE ANTA BRASILEIRA, EM RODOVIAS ESTADUAIS E FEDERAIS DO ESTADO DO MATO GROSSO DO SUL, BRASIL" (Medici, EP; Abra, FD; Fernandes-Santos, RC; Testa-José, C)	http://ipe.org.br/downloads/Relatorio_Tecnico_Parcial_Atropelamentos_Anta_Brasileira_MS.pdf
Agosto 2016	Protocolo de Subsídio de INQUÉRITO CIVIL junto ao Ministério Público do Estado do Mato Grosso do Sul pelo Advogado Dr. Leonardo Avelino Duarte	—
Novembro 2016	REUNIÃO TÉCNICA para a apresentação do Relatório Parcial "IMPACTO DE ATROPELAMENTOS DE FAUNA, PARTICULARMENTE ANTA BRASILEIRA, EM RODOVIAS ESTADUAIS E FEDERAIS DO ESTADO DO MATO GROSSO DO SUL, BRASIL" (Medici, EP; Abra, FD; Fernandes-Santos, RC; Testa-José, C)	http://www.imasul.ms.gov.br/imasul-recebe-levantamento-sobre-atropelamento-de-animais-silvestres-em-8-rodovias-de-ms
Junho 2017	Entrega do "PLANO DE MITIGAÇÃO DE FAUNA SILVESTRE ATROPELADA NA MS-040" ao Ministério Público do Estado do Mato Grosso do Sul (Equipe técnica envolvida: Abra, FD; Medici, EP; Testa-José, C; Canena, AC; Fernandes-Santos, RC)	
Outubro 2017	Ministério Público do Estado do Mato Grosso do Sul apresenta o "PLANO DE MITIGAÇÃO DE FAUNA SILVESTRE ATROPELADA NA MS-040" para Agência Estadual de Gestão de Empreendimentos (AGESUL) e Instituto de Meio Ambiente do Mato Grosso do Sul (IMASUL) e requer um planejamento de implementação	
Janeiro 2018	INCAB-IPÊ realiza PETIÇÃO ON-LINE para pedir o apoio da sociedade civil no processo de pressionar as organizações responsáveis pela tomada de providências e implementação do Plano de Mitigação/Divulgação de vídeo sobre a problemática dos atropelamentos na MS-040 (Rodovia da Morte)	http://www.change.org/p/pelo-fim-dos-atropelamentos-de-fauna-na-rodovia-ms-040-ms
Fevereiro 2018	REUNIÃO TÉCNICA convocada por MPE-MS e INCAB-IPÊ	http://www.mpms.mp.br/noticias/2018/02/mpms-e-ipe-realizam-reuniao-tecnica-para-discutir-atropelamentos-da-fauna-na-ms-040
Março 2018	Saída de campo da AGESUL e INCAB-IPÊ para vistoriar os locais das passagens de fauna a serem cercadas na Rodovia MS-040	—
Junho 2018	Protocolada a Ação Civil Pública	http://www.mpms.mp.br/noticias/2018/06/mpms-pede-a-condenacao-do-estado-e-instituicoes-devido-a-ausencia-de-plano-de-mitigacao-na-ms-040

disponibilizou os dados necessários que subsidiaram a abertura de um Inquérito Civil. A INCAB-IPÊ esteve presente em absolutamente todas as discussões realizadas durante o processo de instauração do Inquérito Civil e subsequente Ação Civil Pública, provendo informações e assessorando o Ministério Público e os outros órgãos envolvidos em questões técnicas de maneira altamente profissional e responsiva.

Apesar das óbvias falhas no licenciamento ambiental da MS-040 por parte da AGESUL e IMASUL, em momento algum a INCAB-IPÊ deixou de contribuir com esses órgãos da forma mais proativa e colaborativa possível. Prova disso foi o desenvolvimento voluntário de um Plano de Mitigação para a MS-040, plano este extremamente completo e detalhado, visando assessorar o Estado (AGESUL-SEINFRA) no processo de tomada de decisões para mitigação dos atropelamentos de fauna naquela rodovia.

A INCAB-IPÊ levou em conta toda e qualquer infraestrutura já disponível (*e.g.,* pontes, passagens de gado, drenagens fluviais, placas de sinalização de travessia de fauna) ao longo da MS-040 para o desenvolvimento do plano de mitigação, de forma a tornar a implementação do mesmo mais viável para o estado. A experiência da INCAB-IPÊ com a pesquisa e conservação da anta brasileira desde 1996, incluindo a biologia, ecologia e comportamento da espécie, foi fundamental para desenhar o plano de mitigação para a Rodovia MS-040, possibilitando prever os tamanhos mínimos de passagens de fauna, extensões de cercas, presença de aspectos relevantes da paisagem (fragmentos de floresta, corpos de água etc.) entre outros fatores.

Todo o processo jurídico percorrido até o momento pela INCAB-IPÊ, em parceria com o Ministério Público do Estado do Mato Grosso do Sul, envolvendo inicialmente o Inquérito Civil e em um segundo momento a Ação Civil Pública, vem sendo bastante moroso, o que é extremamente frustrante para os envolvidos. Entretanto, gostaríamos de encorajar outros profissionais e organizações da área de pesquisa e conservação a buscar o Ministério Público e utilizar as ferramentas legais como forma de fomentar maiores discussões acerca do atropelamento de fauna em seus municípios, regiões ou estados. O Ministério Público tem a "tração" necessária para trazer para a mesa de negociações as organizações e setores relevantes que de outra forma não estariam necessariamente abertos a discutir com pesquisadores e conservacionistas.

Todo o processo com o qual a INCAB-IPÊ esteve envolvida nos últimos três anos foi muito positivo para ampliar as esferas de discussão sobre atropelamento de fauna no Mato Grosso do Sul, engajando os órgãos de transporte e de meio ambiente, trazendo à tona os aspectos sociais decorrentes das colisões rodoviárias envolvendo fauna e promovendo a causa da conservação da anta brasileira e de outras espécies.

PRÓXIMOS PASSOS

A INCAB-IPÊ visa dar continuidade aos estudos com a anta brasileira nos diferentes biomas brasileiros onde a espécie está presente. Em 2019, será iniciado o Programa Anta Amazônia.

Ainda no bioma Cerrado, será estabelecido novo monitoramento das passagens inferiores da MS-040 uma vez que o cercamento das mesmas seja concluído. Sim, temos certeza absoluta de que nosso trabalho resultará eventualmente na instalação dos cercamentos que pleiteamos! Uma vez que isso aconteça, será necessário comparar o uso das passagens inferiores pela fauna antes e depois do estabelecimento das cercas e avaliar a efetividade dessa medida de mitigação.

Também no Cerrado, os planos incluem desenvolver e negociar planos de mitigação para o atropelamento de fauna silvestre em outras duas rodovias, BR-262 e BR-267, ambas federais, administradas pelo DNIT (Departamento Nacional de Infraestrutura e Transportes). Adicionalmente, a INCAB-IPÊ irá organizar e propor treinamentos técnicos sobre fauna silvestre e ecologia de estradas aos analistas dos órgãos de transporte e de meio ambiente do Mato Grosso do Sul.

Juntamente com o Grupo Especialista de Antas (TSG – *Tapir Specialist Group*) da Comissão de Sobrevivência de Espécies (SSC – *Species Survival Commission*) da União Internacional para a Conservação da Natureza (IUCN – *International Union for the Conservation of Nature*), presidido por Patrícia Medici desde 2000, será elaborado um guia técnico de medidas de mitigação específicas para o atropelamento de antas, contemplando as quatro espécies do mundo.

CONSIDERAÇÕES FINAIS

— A experiência relatada neste ensaio ressalta a necessidade de um esforço multidisciplinar para a solução da problemática dos atropelamentos do Brasil;
— O processo de licenciamento ambiental de empreendimentos rodoviários necessita de fortalecimento. Existe uma carência de formação e capacitação dos técnicos atuantes em órgãos ambientais e de transporte sobre o impacto de rodovias sobre o meio ambiente como um todo, principalmente sobre a fauna silvestre. Pesquisadores e conservacionistas precisam ser mais acessados e aproveitados no treinamento desses profissionais e, mais importante, no processo de desenvolvimento de normativas. Precisamos fazer parte dessas discussões;
— Analistas ambientais do IMASUL precisam estar mais bem preparados tecnicamente para lidar com a problemática dos impactos de rodovias à fauna silvestre, exigindo a instalação de medidas de mitigação eficientes;
— É extremamente importante que o IMASUL desempenhe de maneira mais eficiente o seu papel como fiscalizador sobre o cumprimento de condicionantes ambientais e programas ambientais em empreendimentos rodoviários;
— É igualmente crítico que o corpo técnico da AGESUL inclua em seus novos projetos de rodovias ou duplicações, medidas mitigatórias para o atropelamento de fauna silvestre objetivando aumentar a segurança humana e a conservação da biodiversidade;
— É imprescindível que haja um aumento de iniciativas de pesquisa sobre atropelamento de fauna silvestre, monitoramento de medidas de mitigação e inovações tecnológicas.

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Dinâmica populacional de *Gracilinanus Agilis* (Burmeister, 1854) em um fragmento de Caatinga *strictu sensu,* Serrita, Pernambuco

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Parâmetros demográficos de uma população, tais como densidade, estrutura etária, razão sexual, natalidade, mortalidade e movimentos migratórios, constituem a dinâmica de animais silvestres, e podem se modificar ao longo do tempo, em razão de fatores variados. Avaliar as flutuações desses parâmetros é relacionar, de forma numérica, os elementos que causam essas modificações com os padrões e processos ecológicos que os mantém vivos. Estudar esses mecanismos é também crucial para traçar a história de vida de cada espécie, de suas relações com os mais variados organismos e a persistência em suas populações, além de propiciar a construção de estratégias de manejo e conservação da diversidade biológica. Esse estudo objetivou testar modelos estimativos para analisar as variações nos parâmetros populacionais de *Gracilinanus agilis* (Burmeister, 1854), em função da precipitação em período de seca extrema, na Floresta Nacional de Negreiros, uma Unidade de Conservação Federal, no estado de Pernambuco. As coletas ocorreram entre 2013 e 2015. Foram montadas três grades dentro da área, distantes 2,5 km, com 100 armadilhas em cada grade, colocadas no chão e no estrato arbóreo, que eram abertas no período da manhã e revisadas, diariamente. O método foi captura-marcação-recaptura; para análises de dados foram feitos modelos com sobrevivência (ϕ), recrutamento (ʃ), crescimento populacional (λ), probabilidade de captura (p) e tamanho populacional (N), medidos através do estimador Delineamento Robusto de Pollock (RD, ou Robust Design), com formulação de Pradel, confeccionados no Programa R 3.3.1, com pacotes R MARK®. Foram capturados 187 indivíduos, 540 capturas, 20.980 armadilhas/noite. A sobrevivência e o recrutamento variaram com o grupo etário, em função da precipitação. A probabilidade de captura e o tamanho populacional variaram em cada grupo etário, entre as ocasiões. Foram capturados mais macho do que fêmeas; indivíduos jovens ocorreram principalmente no período chuvoso, época de mais oferta de alimento. O estudo respondeu à hipótese, mostrando que alguns parâmetros variaram em função da precipitação, o que corroborou com trabalhos anteriormente publicados, em outros biomas.

Dieta e padrão de atividade do furão-pequeno *Galictis cuja* (Carnivora: Mustelidae)

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Galictis cuja, um mustelídeo nativo da América do Sul, é uma espécie com pouco conhecimento acerca de sua biologia. Com intuito de melhor compreender aspectos ecológicos da espécie no estado do Rio Grande do Sul, o presente trabalho explorou, em dois capítulos, a dieta da espécie e seu padrão de atividade. Fez-se análise de conteúdo de tratos digestórios de indivíduos encontrados atropelados em todo estado, onde encontrou-se uma grande diversidade de vertebrados, mas uma maior ocorrência de roedores. Segundo o Índice de Levins normalizado, a amplitude de nicho trófico da espécie apresentou um valor intermediário na escala, não podendo, assim, ser considerada especialista ou generalista, porém, pela diversidade de presas consumidas, poderia ser considerado um animal de dieta oportunista. Para examinar o padrão de atividade da espécie utilizou-se registro de suas ocorrências em armadilhas fotográficas instaladas em diversos pontos do Rio Grande do Sul. A espécie apresentou hábito majoritariamente diurno, com pico de atividade durante a manhã e no final da tarde. Comparando a atividade diária entre as estações do ano, verificou-se que durante o outono-inverno, a espécie apresenta maior atividade nas horas de maior temperatura do dia, próximo ao meio-dia, enquanto na primavera-verão a atividade se concentra no início da manhã e no final da tarde, provavelmente evitando os horários de maior calor.

Dieta de *Gracilinanus agilis* em um fragmento de Caatinga *strictu sensu,* Pernambuco

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O estudo da dieta de pequenos mamíferos é uma ferramenta importante para o entendimento das relações ecológicas, tais como da predação e da dispersão de sementes e plântulas, uma vez que estes formam o grupo mais diversificado entre os mamíferos nas florestas tropicais com ocorrência em todos os biomas do Brasil. Com objetivo de identificar os padrões da dieta do marsupial *Gracilinanus agilis* (Didelphidae), foram realizadas análises da dieta e preferência alimentar através do conteúdo fecal do marsupial coletado entre os anos de 2014 e 2015 em capturas mensais na Unidade de conservação Floresta Nacional de Negreiros (FLONA-Negreiros), Caatinga *strictu sensu* no Sertão Pernambucano. Os itens encontrados foram identificados, pesados e classificados em cinco categorias: Mamíferos, répteis, sementes, artrópodes e estruturas vegetais. Foram analisadas 203 amostras, provenientes de 143 indivíduos, classificados de acordo com o sexo, a idade e condições reprodutivas. Foram realizados testes de média (Teste t de Student e ANOVA), para avaliar diferenças entre os consumos dos itens e as variáveis ambientais e intraespecíficas. Uma análise de regressão logística utilizando sexo, estação do ano e condição reprodutiva como preditoras foram realizadas a fim de verificar padrões no consumo das ordens de artrópodes. Por fim foram realizadas análises de preferência através dos índices de Ivlev e do teste de Qui-quadrado residual de Pearson. Como resultados, artrópodes representaram 92,12% das ocorrências, portanto, foi inferido que o *G. agilis* alimenta-se com maior frequência de artrópodes, principalmente da ordem Hymenoptera, apresentando padrão de consumo oportunista quanto à seleção deste item, uma vez que este foi o mais disponível no ambiente. Por outro lado, esse animal se mostrou seletivo para Myriapoda, sendo este o primeiro trabalho a detectar o consumo deste subfilo pelo gênero *Gracilinanus.* Dentre os itens vegetais consumidos na área de estudo, há preferência pelas famílias Bromeliaceae e Cactacea, selecionando estas famílias dentre as disponíveis. Foi verificada a existência de sazonalidade para o consumo de todos os itens, com maior consumo durante a estação chuvosa, principalmente para sementes, que apresentou aumento significativo, indicando um maior consumo de frutos para o período chuvoso, além disso, indivíduos adultos e fêmeas reprodutivas consomem maior biomassa de artrópodes em relação aos demais. Assim nossos dados indicam que o marsupial apresenta alimentação insetívoro-onívoro, com maior consumo de frutos durante a estação chuvosa o que pode colocar o *G. agilis* como dispersor ou predador de sementes, havendo a necessidade de investigações sobre o papel desse animal para as espécies vegetais em áreas de caatinga.

RESUMOS

Lontra longicaudis (Olfers, 1818): revisão do conhecimento existente e análise da influência da qualidade da água sobre a sua ocorrência na bacia do rio dos Sinos, Rio Grande do Sul, Brasil

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A sobre-exploração humana tem causado uma degradação generalizada e perturbação dos ecossistemas de água doce, os mais ameaçados do mundo. A bacia hidrográfica do Rio dos Sinos, no estado do Rio Grande do Sul, é considerada umas mais poluídas do Brasil. Seus cursos d'água estão sob diferentes graus de influência antrópica, bem como seus organismos dependentes. A lontra Neotropical é um mustelídeo semiaquático ameaçado por toda a sua área de distribuição continental onde há conhecimento. Embora a lontra seja um importante organismo para avaliar a qualidade ambiental por apresentar alguma tolerância a ambientes antropizados, pouco se sabe sobre seu status de conservação. Sua biologia, ecologia, comportamento e aspectos populacionais ainda são pouco conhecidos. Considerando isso, uma síntese de aspectos ecológicos e biológicos de *Lontra longicaudis* foi realizada através de extensa revisão bibliográfica. Além disso, avaliada a influência da qualidade da água em regiões com diferentes níveis de influência antrópica, bem como a estrutura da vegetação nas margens de rios, a sazonalidade e a velocidade da correnteza nos rios sobre a ocorrência de *L. longicaudis.* O componente experimental deste projeto foi realizado com base em amostragens mensais de material biológico não invasivo em 16 diferentes regiões da bacia do Rio dos Sinos no Rio Grande do Sul, ao longo de 2016. Ademais, foram realizadas entrevistas com moradores como método complementar para confirmar a presença da espécie. Nove novas áreas de registro de *L. longicaudis* foram confirmadas para o estado. A ocorrência de lontra foi modelada através de modelos lineares generalizados. Áreas com água de melhor qualidade (classes 2 e 3) apresentaram significativamente mais registros que áreas com água de qualidade inferior (classe 4). Adicionalmente, quer a correnteza, quer a época do ano também se mostraram relevantes para explicar os padrões de ocorrência da espécie. Em conclusão, a lontra Neotropical, assim como outros mamíferos semiaquáticos poderão ser utilizados como bioindicadores de qualidade ambiental, especialmente em ambientes antropizados. No futuro, outras variáveis tais como a fisionomia e estágio de sucessão ecológica da vegetação das margens deverão ser considerados para explicar os padrões de ocorrência de lontra, no sentido de contribuir, de forma mais suportada, para a definição de medidas para a sua conservação.

Morcegos insetívoros aéreos Neotropicais: identificação acústica e padrões de estruturação de assembléias

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Os morcegos, ordem Chiroptera, são ecologicamente o grupo mais diverso dos mamíferos e após Rodentia ocupam o segundo lugar em diversidade taxonômica. Devido à sua dramática radiação ecológica e evolutiva, ocupam virtualmente todos os níveis tróficos. No Neotrópico ocorrem nove famílias de quirópteros, das quais oito (excluíndo Phyllostomidae) incluem quase exclusivamente espécies insetívoras que dependem principalmente da ecolocalização para a navegação e aquisição de alimento. A gravação e posterior análise de chamados de ecolocalização emitidos durante a navegação é uma alternativa ou técnica complementar para o estudo deste grupo de morcegos; este método permite identificar muitas espécies com base na estrutura e frequência dos chamados de ecolocalização, otimizando o estudo de associações espécie-habitat dentro das assembleias de morcegos insetívoros. No segundo capítulo desta dissertação intitulado *Who's calling? Acoustic identification of Brazilian bats* é apresentada uma revisão dos estudos relacionados com descrições e identificações acústicas de espécies de morcegos neotropicais que ocorrem no Brasil. No total incluiram-se 47 publicações provenientes de 17 países, para além de dados não-publicados. Das 93 espécies de morcegos não filostomídeos, 65 foram descritas acusticamente, as restantes 28 careceram de informações acústicas. A utilização de monitoramentos acústicos pode ser uma ferramenta fundamental para expandir o nosso conhecimento dos morcegos no Brasil. No terceiro capítulo intitulado *Spatiotemporal patterns of insectivorous bat activity in the Brazilian Cerrado: landscape and microclimate effects* utilizou-se esta técnica para avaliar os padrões espaço-temporais de diversidade e atividade de morcegos insetívoros numa paisagem heterogênea no Cerrado. Os nossos resultados, em concordância com estudos prévios, mostraram que a composição e configuração, em especial a extensão de fitofisionomias bem conservadas, foram fatores importantes para a seleção de hábitat pelos morcegos insetívoros assim como as condições de umidade relativa do ar, particularmente nos meses mais secos. As respostas dos morcegos ante tais fatores variaram com a escala de análise, o grupo funcional e em alguns casos a variação foi espécie-específica. São necessários mais estudos para elucidar como as espécies respondem aos câmbios de origem humana na paisagem e suas possíveis associações com as mudanças climáticas no Cerrado.

RESUMOS

Padrões de atividade de morcegos insetívoros aéreos no limite sul da mata atlântica: influência de variáveis meteorológicas e do habitat

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Resumo: Os padrões de atividade de muitas espécies de morcegos têm sido frequentemente associados à disponibilidade de alimento, à estrutura da vegetação e ao clima. Usualmente há maior atividade em áreas com maior disponibilidade de recursos alimentares e em ambientes que permitem maior facilidade de deslocamento. Em geral, a atividade de morcegos reduz em períodos com temperaturas extremas, sabendo-se que a redução da atividade de morcegos durante períodos frios está relacionada tanto com questões fisiológicas associadas ao balanço entre produção e perda de calor, quanto com ciclos reprodutivos das espécies. Sendo assim, o objetivo geral deste trabalho é avaliar a influência de variáveis meteorológicas e do habitat sobre os padrões de atividade de morcegos em uma região de clima temperado do Brasil. A avaliação da atividade dos morcegos foi realizada entre janeiro e maio de 2016, por meio de monitoramento acústico. Para relacionar a atividade dos morcegos com as condições meteorológicas locais, sensores de temperatura e umidade conectados a data loggers foram instalados perto de cada detector de ultrassom. O número de passagens de morcegos e o número de chamados de alimentação foram comparados entre guildas de uso do espaço – morcegos forrageadores de áreas abertas e morcegos forrageadores de bordas – e entre tamanhos – morcegos pequenos (entre 4 g e 8 g) e morcegos grandes (entre 30 g e 35 g). O local onde se registrou maior atividade de morcegos foi uma área aberta em meio a um contínuo de Floresta Ombrófila Densa, localizado em baixa altitude e maiores níveis de atividade de alimentação foram registrados em locais próximos a fontes de água. O padrão de atividade diferiu significativamente entre as guildas: morcegos forrageadores de espaço aberto apresentaram os maiores níveis de atividade concentrados nas primeiras horas da noite e em temperaturas entre 12°C e 16°C, enquanto os forrageadores de borda mantiveram atividade razoavelmente constante ao longo da noite e entre 16°C e 20°C. Um possível aumento da densidade de insetos em estratos altos ao anoitecer pode otimizar o sucesso de captura dos forrageadores de espaços abertos de tal forma que possibilitaria a concentração da atividade neste período. O padrão de atividade de morcegos grandes e pequenos também diferiu significativamente: a atividade de morcegos grandes ocorreu em temperaturas mais baixas do que a de morcegos pequenos. Como esperado, a temperatura de atividade de morcegos grandes foi mais baixa do que a de morcegos pequenos. Estimou-se, que a temperatura que limita a atividade de morcegos grandes é mais baixa do que a temperatura que limita a atividade dos morcegos pequenos. Isto é uma consequência esperada em razão da maior inércia térmica de animais de maior tamanho corporal, desse modo a temperatura crítica mínima dos morcegos grandes deve ser sempre menor do que a dos morcegos pequenos. A temperatura e o habitat parecem explicar os padrões de atividade tanto de morcegos forrageadores de espaço aberto e de borda, quanto de diferentes tamanhos corporais em um clima temperado mesotérmico no Brasil.

Palavras-Chave: Atividade; Bioclimatologia; Chiroptera; Endotermia; Temperatura; Umidade.

Abstract: The activity patterns of many bat species have often been associated with food availability, vegetation structure and climate. There is usually more activity in areas with higher availability of food resources, and in landscapes that allow greater ease of commuting. The activity is generally reduced in periods with more extreme temperatures, and it is known that the reduction of bat activity during cold periods is related both to physiological issues associated to the balance between production and heat loss, and to the reproductive cycles of the species'. Therefore, the general objective of this work is to evaluate the influence of meteorological and habitat variables on the pattern of bat activity in a temperate region of Brazil. The evaluation of bat activity was carried out between January and May 2016, through acoustic monitoring. To relate bat activity to local weather conditions, temperature and humidity sensors connected to data loggers were installed near each ultrasound detector. The number of bat passes and the number of feeding buzzes were compared between guilds of space use – open and edge foragers bats – and between different body sizes – small bats (between 4 g and 8 g) and large bats (between 30 g and 35 g). The area where the largest bat activity was recorded was a continuous area of Dense Ombrophylous Forest, located at low altitude, and the highest feeding activity was recorded in sites near water sources. The activity pattern differed significantly among guilds: open-space foraging bats registered the

highest activity levels concentrated in the early hours of the night and were active at lower temperatures, while edge--space foragers maintained activity reasonably constant throughout the night, though focusing their activity at higher temperatures. A possible increase in insect density in high strata at dusk can optimize the success of capture of open space foragers in such a way that would allow the concentration of activity in this period. The pattern of activity of large and small bats also differed significantly: large bats were more frequently recorded at lower temperatures than small bats. As expected, the activity of large bats occurred at lower temperatures than that of small bats. It was estimated that the limiting temperature to the activity of the large bats is lower than that to small bats. This is an expected consequence because of the greater thermal inertia of animals of larger body size, thus the minimum critical temperature of large bats should always be smaller than that of small bats. Temperature and habitat seem to explain the activity patterns of both foraging bats of open space and border, and of different body sizes in a temperate mesothermic climate in Brazil.

Key-Words: Activity; Bioclimatology; Chiroptera; Endothermia; Temperature; Humidity.

Perfis Químicos de Amostras Não-Invasivas como Ferramenta para a Identificação de Espécies de Mamíferos

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Resumo: Um crescente interesse no uso de técnicas de monitoramento não-invasivo tem sido observado em trabalhos envolvendo conservação de mamíferos. Dentre uma miríade de técnicas aplicadas com essa finalidade, existe a análise de perfis químicos. Perfis químicos podem ser obtidos de qualquer amostra biológica oriunda de um determinado espécime e possibilitam a obtenção de informações básicas, como, por exemplo, sexo biológico e espécie taxonômica. Tendo isso em vista, este trabalho propõe o uso de perfis químicos obtidos de fezes de mamíferos como ferramenta não-invasiva de identificação de espécies e sexo biológico. Para tanto, cromatografia líquida de alta performance (HPLC) acoplada a um detector de fluorescência induzido por laser (LIF) foi utilizada a fim de obter perfis químicos fecais de machos e fêmeas pertencentes a cinco diferentes espécies de mamíferos: um procionídeo, o quati sul-americano *Nasua nasua,* e quatro felídeos: os felinos neotropicais *Puma concolor, Hepailurus yagouaroundi, Leopardus pardalis,* além do gato doméstico *Felis silvestres.* A obtenção de perfis químicos fecais não só foi possível, como também o foi a identificação de padrões que permitiram a distinção de espécies e sexo biológico. Padrões qualitativos observados nos perfis químicos fecais obtidos cromatograficamente possibilitaram a distinção não ambígua das espécies e o sexo biológico dos indivíduos. Percebe-se, assim, devido aos resultados promissores obtidos, que a metodologia descrita é oportuna para auxiliar a identificação e discriminação de espécies e sexo biológico de indivíduos pertencentes a Carnivora – sendo eficiente, inclusive, em espécies de felídeos filogeneticamente próximas e ecologicamente similares. Investigações adicionais são necessárias, contudo, a fim de se avaliar a aplicabilidade para demais grupos pertencentes a Mammalia em função do poder discriminante do método. Por fim, o potencial do método na verificação de outros aspectos intraespecíficos (como idade e estado de saúde) é uma questão interessante de ser investigada futuramente.

Palavras-Chave: Perfil químico; Análise escatológica; Cromatografia líquida de alta performance; Não-invasivo; Conservação de mamíferos.

Abstract: An increasing interest for the use of non-invasive monitoring techniques has been observed in studies towards mammal conservation. A myriad of non-invasive monitoring techniques exists, being the chemical profile's analysis one of them. Chemical profiles could be obtained from any biological sample belonging to some specimen and through them we can obtain basic information like biological sex and taxonomic identification. In view of that, here we propose the use of chemical profiles of mammalian scats as a non-invasive tool for species and gender discrimination. For such, High-Performance Liquid Chromatography (HPLC) coupled to a Laser-Induced Fluorescence (LIF) detection was used in order to get faecal chemical profiles from females and males belonging to five different mammal species: a procyonid – the South American coati *Nasua nasua* – and four felids – the neotropical felids *Puma concolor, Hepailurus yagouaroundi, Leopardus pardalis* and the domestic cat *Felis silvestris.* Not only we obtained the chemical profiles but also species and gender discrimination. Unambiguous taxonomic identification, as well as gender distinction was achieved thanks to the presence-absence chemical pattern chromatographically observed in the faeces of each analysed specimen. In face of that, it is clear that the method here proposed is extremely promising in discriminating and identifying species and the biological sex of specimens of the Carnivora – even between closely related and ecologically similar felids. Nevertheless, further research is necessary to ascertain the discriminatory power of the method for mammals other than the Carnivora. Other aspect to be investigated is the potential of the method in discriminating other intraspecific traits such as age and health status.

Key-Words: Chemical profile; Scatological analysis; High-Performance Liquid Chromatography; Non-invasive; Mammal conservation.

The use of automated acoustic identification software for bat surveys in the Neotropics: Gaps and Opportunities

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Resumo: As populações de morcegos são conhecidas por serem afetadas por atividades antropogênicas, já que o Chiroptera é um grupo extremamente diverso que ocupa quase todos os nichos disponíveis no meio terrestre. Assim, os morcegos são considerados bons bioindicadores para monitorar mudanças no meio ambiente, mas seu valor como tal também depende da facilidade de monitorar e detectar tendências demográficas em suas populações. O interesse a longo prazo dos pesquisadores na acústica dos morcegos resulta do fato de que é um método não-invasivo e eficiente em termos de tempo para monitorar os padrões espaço-temporais da diversidade e atividade de morcegos. A análise dos sons emitidos pelos organismos tem sido útil para a aquisição de conhecimento sobre as interações bióticas e abióticas específicas de cada espécie, e sua aplicação na conservação. Além das identificações manuais de chamados de morcegos, existe atualmente no mercado um conjunto de programas automatizados de identificação que utilizam bibliotecas regionais e se apresentam como uma ferramenta eficiente no monitoramento de populações de morcegos. A maioria desses programas não foi validada usando dados de campo. Este estudo avalia a confiabilidade de dois softwares automatizados, SonoChiro e Kaleidoscope Pro, em comparação com identificações manuais de dados de campo coletados da região Neotropical. Houve um baixo nível de concordância entre os dois métodos automatizados ao nível das identificações específicas, razoável ao nível do gênero e satisfatório ao nível a família. Houve também uma diferença significativa entre a proporção de chamados corretamente identificados entre os dois programas ao nível específico. Os principais desafios para o uso de software de identificação automatizada incluem a necessidade de bibliotecas de chamados abrangentes da diversidade existente nas regiões em foco dos estudos; as principais oportunidades, por outro lado, incluem a ampla possibilidade de monitorar os padrões espaço-temporais da atividade de morcegos. Existem ainda fortes lacunas que impedem uma aplicação generalizada de programas automatizados em estudos ecológicos e de conservação de morcegos, mas há potencial de melhoria. Considerando as limitações dos programas automatizados, é discutida uma estrutura para aplicação em estudos ecológicos e de conservação.

Palavras-Chave: Bioacústica; Chiroptera; Kaleidoscope; SonoChiro.

Abstract: Bat populations are known to be affected by anthropogenic activities because bats are an extremely diverse group occupying almost all available niches in terrestrial environment. Hence, bats are considered bioindicators to monitor changes in the environment, but their value as such also depends on the ease to monitor and detect demographic trends in their populations. The long-term interest of researchers in the acoustic of bats results from the fact that it is a non-invasive, time-efficient methods to monitor spatiotemporal patterns of bat diversity and activity. The analysis of sounds emitted by organisms has been considered useful to gain insight into species-specific biotic and abiotic interactions, which can further be applied to conservation. Besides manual identifications of bat calls, several automated species identification programs using regional call classifiers have been introduced into the market as an efficient tool in monitoring of bat populations. Most of these programs have not been validated using field data. This study evaluates the reliability of two automated software, SonoChiro and Kaleidoscope Pro, in comparison to manual identifications of field data collected from the Neotropical region. There was low agreement between the two automated methods at the species level, fair agreement at the genus level and moderate agreement at the family level. There was also a significant difference between the proportion of correctly identified calls of the two-automated software at the species level identifications. Major challenges for using automated identification software include the need for comprehensive call libraries of the regions under scope; major opportunities, on the other hand, include the widespread possibility to monitor spatiotemporal patterns of bat activity. Overall, there are serious gaps that preclude a widespread application of automated programs in ecological and conservation studies of bats, but there is a potential for improvement. Considering the limitations of the automated programs, a framework for application in ecological and conservation studies is discussed.

Key-Words: Bioacoustics; Chiroptera; Kaleidoscope; SonoChiro.

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RESUMOS

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