CLARISSA ALVES DA ROSA

MAMÍFEROS EXÓTICOS INVASORES NO BRASIL:

SITUAÇÃO ATUAL, RISCOS POTENCIAIS E IMPACTOS DA INVASÃO DE PORCOS SELVAGENS EM FLORESTAS TROPICAIS

LAVRAS – MG

2016

CLARISSA ALVES DA ROSA

MAMÍFEROS EXÓTICOS INVASORES NO BRASIL: SITUAÇÃO ATUAL, RISCOS POTENCIAIS E IMPACTOS DA INVASÃO DE PORCOS SELVAGENS EM FLORESTAS TROPICAIS

Tese apresentada à Universidade Federal de Lavras, como parte das exigências do Programa de Pós-Graduação em Ecologia Aplicada, área de concentração em Ecologia e Monitoramento de Ecossistemas Sob Interferência Antrópica, para a obtenção do título de Doutor.

Orientador

Dr. Marcelo Passamani

LAVRAS – MG

2016

Ficha catalográfica elaborada pelo Sistema de Geração de Ficha Catalográfica da Biblioteca Universitária da UFLA, com dados informados pelo(a) próprio(a) autor(a).

Rosa, Clarissa Alves da.
Mamíferos exóticos invasores no Brasil: situação atual, riscos potenciais e impactos da invasão de porcos selvagens em florestas tropicais / Clarissa Alves da Rosa. – Lavras : UFLA, 2016.
160 p.

Tese(doutorado)–Universidade Federal de Lavras, 2015.
Orientador(a): Marcelo Passamani.
Bibliografia.

1. Javali. 2. *Sus scrofa*. 3. *Tayassu pecari*. 4. Mata Atlântica. 5. Araucária. I. Universidade Federal de Lavras. II. Título.

CLARISSA ALVES DA ROSA

MAMÍFEROS EXÓTICOS INVASORES NO BRASIL: SITUAÇÃO ATUAL, RISCOS POTENCIAIS E IMPACTOS DA INVASÃO DE PORCOS SELVAGENS EM FLORESTAS TROPICAIS

Tese apresentada à Universidade Federal de Lavras, como parte das exigências do Programa de Pós-Graduação em Ecologia Aplicada, área de concentração em Ecologia e Monitoramento de Ecossistemas Sob Interferência Antrópica, para a obtenção do título de Doutor.

APROVADA em 27 de Novembro de 2015.

Dr. Bernard Josiah Barlow Lancaster University

Dr. Fernando Cesar Cascelli de Azevedo UFSJ

Dr. Luiz Fernando Silva Magnago UFLA

Dr. Paulo dos Santos Pompeu UFLA

Orientador Dr. Marcelo Passamani

LAVRAS – MG

2016

AGRADECIMENTOS

Agradeço primeiramente a vida e todas suas oportunidades. À minha família de sangue, sobretudo minha mãe Maria Luiza, que sempre me apoiou e me deixou livre para fazer todas as minhas escolhas. À companheira de todas as aventuras Cris, por seu apoio, dedicação e compreensão. Aos meus afilhados Matias e Stela. À família de coração que são aqueles que alguns chamam de amigos e, que embora sejam muitos para nomear e correndo o risco de esquecer alguém, existem aqueles que merecem destaque: Quelen por sua amizade de mais de década e seu ombro amigo e apoio nos momentos mais difíceis; Chaim, Juliano(s), Bodinho, Marina, Tobias e Lele por todos anos de amizade, risadas e aventuras lavrenses.

A toda equipe do Laboratório de Ecologia e Conservação Ambiental, especialmente Fernando Puertas, companheiraço de campo e de trabalho. Ao meu orientador Marcelo Passamani que me recebeu de braços abertos, apoiou e deixou livre para trilhar meu caminho ao longo deste doutorado. Não poderia deixar de lembrar do Gabriel, Luciano e Éder, também companheiros ao longo dos intensos trabalhos de campo. É por causa dessa equipe maravilhosa que essa tese foi toda escrita se referindo ao NOSSO trabalho, pois esse nunca foi um trabalho só meu.

Ao Programa de Pós-Graduação de Ecologia Aplicada por esses sete anos de aprendizado e convivência, especialmente aos professores Paulo Pompeu, Julio Louzada e Carla Ribas, além do meu orientador já citado. Aos membros da banca, Jos, Fernando, Luiz e Paulo por caitarem o convite para participar da banca de defesa desta tese. A CAPES pela bolsa de estudos e ao TFCA/Funbio pelo custeio do projeto que resultou nessa tese. À Associação de

Pós Graduandos da UFLA, gestão 2014 e 2015, onde e quando aprendi que unidos podemos fazer a diferença e que Pós-Graduação se trata também de pessoas e não somente de aulas e projetos de pesquisa.

A toda equipe do “Projeto Javali na Mantiqueira”, Instituto Alto Montana, Parque Nacional do Itatiaia, ICMBio, Prefeitura Municipal de Itamonte e Embrapa, todos parceiros desse projeto. Ao Zé Cristiano e todos os produtores e caçadores do município de Itamonte, sobretudo os últimos com quem aprendi sobre comportamento e ecologia animal mais do que qualquer ecóloga(o) ou texto de ecologia poderia me ensinar.

E finalmente agradeço a Natureza, que faz parte de nós e da qual fazemos parte. É no Templo Natureza onde sempre recarreguei minhas energias e encontrei motivações para continuar, mesmo quando parar fosse o mais fácil.

Muito obrigada a todos!

RESUMO

A invasão de espécies exóticas está entre as principais causas de perda de biodiversidade no mundo. Espécies de vertebrados invasores são reconhecidos como importantes predadores e competidores, podendo afetar diretamente a fauna e flora nativas. Além disso, alguns vertebrados são importantes engenheiros de ecossistemas capazes de alterar características físicas e químicas do ambiente, resultando na criação, modificação ou manutenção de habitats para si e outras espécies. O Brasil não possui uma sistematização das informações sobre espécies exóticas de vertebrados e suas populações ferais em território nacional e tão pouco conhecimento do impacto causado por essas espécies. Diante disso esta tese de doutorado tem o objetivo de sistematizar as informações referentes aos mamíferos exóticos que possuem populações ferais estabelecidas e invasoras no Brasil e avaliar os impactos do *Sus scrofa*, uma das espécies invasoras de vertebrados com maior potencial de alteração de ecossistemas. No primeiro capítulo apresentamos um levantamento bibliográfico dos mamíferos exóticos que ocorrem no Brasil, suas características ecológicas e biológicas relacionados ao sucesso de invasão, impactos conhecidos e distribuição atual no Brasil. Neste capítulo realizamos também uma análise de risco de invasão para espécies de mamíferos exóticos vendidos como animais de estimação e que inda não ocorrem em vida livre no Brasil. Todas as espécies exóticas que ocorrem no Brasil, bem como as espécies vendidas como animais de estimação, possuem alto risco de invasão e alto potencial de impacto nos ecossistemas brasileiros. No segundo capítulo avaliamos o uso de córregos no Parque Nacional do Itatiaia por porcos selvagens invasores (*Sus scrofa*) e pela espécie nativa queixada (*Tayassu pecari*). Observamos que os porcos selvagens invasores possuem uma capacidade de alterar a integridade física dos córregos em maior intensidade que o queixada. Os córregos usados por porcos selvagens apresentam o talude escavado e o curso d'água sedimentado, resultando em córregos mais largos e rasos. Finalmente no terceiro capítulo apresentamos o papel dos mamíferos nativos e de porcos selvagens invasores na remoção de sementes (pinhão) da *Araucaria angustifolia*, espécie de árvore ameaçada de extinção no Brasil. Nossos resultados mostraram que a remoção de pinhões em áreas com a presença de porcos selvagens é alta, mas que os mamíferos nativos são os principais removedores do pinhão, não havendo distinção entre pequenos, médios ou grandes mamíferos ou mesmo entre porcos selvagens e espécies nativas. Esperamos que os resultados dessa tese auxiliem no entendimento da ecologia e impacto de mamíferos exóticos em ambientes tropicais, bem como políticas públicas e legislações de controle de espécies exóticas invasoras que objetivem reduzir o impacto destas nos ecossistemas brasileiros.

Palavras-chave: Javali. *Sus scrofa*. *Tayassu pecari*. Mata Atlântica, Araucária.

GENERAL ABSTRACT

The invasion of exotic species is among the leading causes of biodiversity loss worldwide. Invasive species of vertebrates are recognized as important predators and competitors, and can directly affect native flora and fauna. In addition, some vertebrates are important ecosystem engineers capable of altering physical and chemical characteristics of the environment, resulting in the creation, modification or maintenance of habitats for themselves and other species. Brazil lacks information systematization regarding exotic vertebrate species and their feral populations in the country, not to mention an extreme lack of knowledge of the impact caused by these species. Therefore the present doctoral thesis aims to systematize the information regarding exotic mammals that have established feral and invasive populations in Brazil and assess the impacts of *Sus scrofa*, one of the invasive vertebrate species with the greatest potential for ecosystem alteration. In the first chapter we present a literature review of exotic mammals that occur in Brazil, their ecological and biological characteristics related to the success of invasion, known impacts and current distribution in Brazil. This chapter also contains a risk invasion analysis of exotic mammal species sold as pets and that still do not occur in the wild in Brazil. All the exotic species that occur in Brazil, as well as the species sold as pets, have a high invasion risk and high potential impact on Brazilian ecosystems. In the second chapter we evaluate the use of streams in Itatiaia National Park by invasive wild pigs (*Sus scrofa*) and the white-lipped peccary native species (*Tayassu peccary*). We note that the invasive wild pigs have an ability to alter the physical integrity of streams at a higher intensity than the white-lipped peccary. The streams used by wild pigs present an excavated embankment and sedimented water course, resulting in broader, shallower streams. Finally in the third chapter we present the role of native mammals and invasive wild pigs in the removal of *Araucaria angustifolia* seed (pine nuts), a species of endangered tree in Brazil. Our results showed that the removal of pine nuts in areas with the presence of wild pigs is high, but that native mammals are the main pine nut removers, with no distinction between small, medium or large mammals or even between wild pigs and native species. We hope the results of this thesis assist in understanding the ecology and impact of exotic mammals in tropical environments, as well as with public policies and control legislation for invasive alien species that aim to reduce their impact on Brazilian ecosystems.

Key-words: Wild boar. *Sus scrofa*. *Tayassu pecari*. Brazilian Atlantic Forest. Brazilian Pine.

SUMÁRIO

PRIMEIRA PARTE

INTRODUÇÃO E REFERENCIAL TEÓRICO

1 INTRODUÇÃO

Em 2006 nas Terras Altas da Mantiqueira, próximo aos municípios de Itamonte e Itanhandu, ambos em Minas Gerais, seis indivíduos da espécie *Sus scrofa* foram soltos e estabeleceram população feral na região, segundo relatos de moradores locais. Pouco mais de cinco anos depois, muitos produtores rurais passaram a ter problemas com porcos selvagens, sobretudo relacionados ao ataque a hortas e cultivos agrícolas. Da mesma forma, grupos de porcos selvagens passaram a ocupar Unidades de Conservação na região como o Parque Nacional do Itatiaia e a RPPN Alto Montana. Nesse contexto, uma parceria entre o ICMBio, Parque Nacional do Itatiaia (PNI), Embrapa Suínos e Aves, Instituto Alto Montana, Prefeitura Municipal de Itamonte e a Universidade Federa de Lavras (UFLA), deu origem ao "Projeto Javali na Mantiqueira", financiado pelo TFCA/FUNBIO e FAPEMIG, o qual foi executado de julho de 2013 a setembro de 2015.

O "Projeto Javali na Mantiqueira" conta com várias linhas de ação voltadas para avaliação dos impactos sociais, ambientais, sanitários e controle dos porcos selvagens no município de Itamonte, segundo Instrução Normativa (IN) do IBAMA Nº 03/2013, de 31 de janeiro de 2013. O objeto dessa tese é a avaliação dos impactos dos porcos selvagens nos ecossistemas da Serra da Mantiqueira. No Brasil as populações ferais do *Sus scrofa* são conhecidos popularmente como javali ou javaporco. Nesta tese vamos utilizar o termo "porco selvagem" que se refere a qualquer forma asselvajada do *Sus scrofa*, javali europeu e seus híbridos, que viva em populações ferais.

Como uma espécie exótica, eu acredito que a melhor forma de avaliar um efeito alóctone ao ecossistema é compara-lo com efeitos similares causados por espécies ou processos nativos, por isso essa tese tem como foco a avaliação dos efeitos causados pelo porco selvagem em comparação ao seu equivalente ecológico nativo, o queixada *Tayassu pecari*. Essa comparação foi possível devido haver uma grande porção do PNI no município de Itatiaia (RJ) onde só ocorre o queixada, sem registros de porcos selvagens, e outras áreas no PNI e RPPN Alto Montana, ambos em Itamonte (MG), onde ocorrem somente porcos selvagens e sem registros recentes do queixada (Figuras 1, 2 e 3).

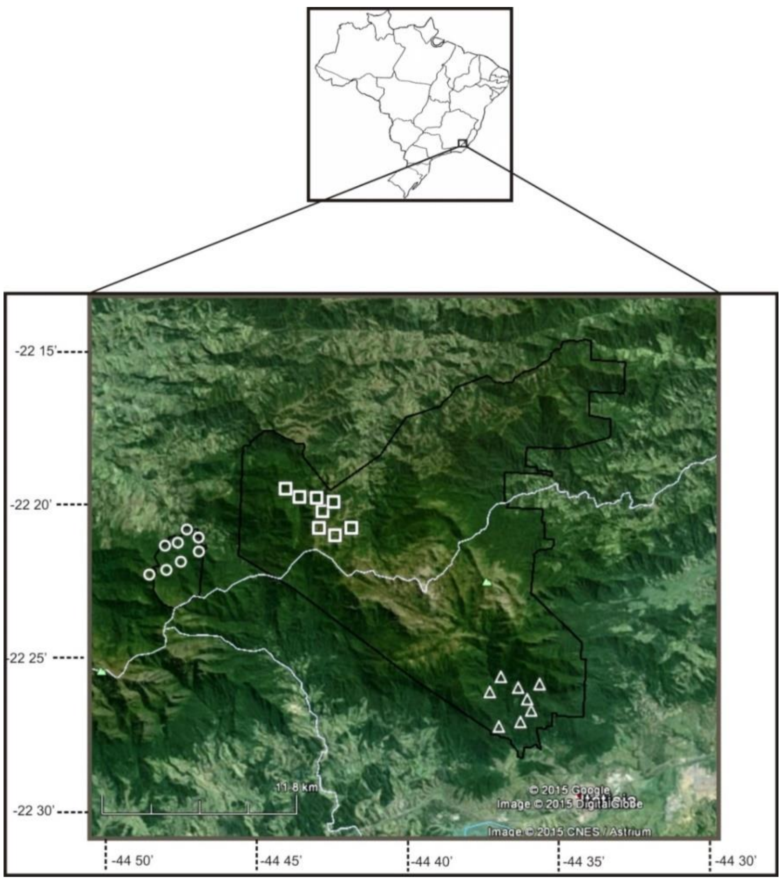


Figura 1 Mapa mostrando os limites do Parque Nacional do Itatiaia (PNI) e RPPN Alto Montana. Os círculos representam os pontos de estudo na RPPN, os quadrados os pontos de estudo na Parte Alta do PNI e os triângulos os pontos de estudo na Parte Baixa do PNI.

Figura 2 Porco selvagem *Sus scrofa* fotografado em 2014 na RPPN Alto Montana, município de Itamonte (MG).

Figura 3 Queixada *Tayassu pecari* fotografado em 2014 no Parque Nacional do Itatiaia, município de Itatiaia (RJ).

O primeiro capítulo dessa tese contou com a colaboração de mais dois pesquisadores, além do meu orientador. Neste capítulo contextualizamos a invasão de espécies de mamíferos no território brasileiro, buscando sistematizar as informações ecológicas e biológicas dessas espécies, bem como a atualização dos mapas de distribuição no Brasil e avaliação de riscos potenciais de invasões de outras espécies de mamíferos exóticos que ainda não possuem populações ferais estabelecidas no Brasil. Esse capítulo foi formatado segundo as normas da revista *Biological Invasions*.

No segundo capítulo, realizado em parceria com o Prof. Dr. Paulo Pompeu, nosso objetivo foi avaliar os efeitos dos porcos selvagens sobre a integridade física de córregos no Parque Nacional do Itatiaia (Áreas 2 e 3 na Figura 1), comparando com os efeitos do queixada. Ambas espécies modificam córregos no PNI (Figura 4 e 5), porém nossos resultados mostram que os porcos selvagens causam o alargamento e assoreamento dos córregos em proporções maiores que o queixada e por isso, recomendamos uma avaliação dos efeitos causados por porcos selvagens sobre as comunidades biológicas que vivem nesses córregos. Esse capítulo já foi encaminhado para publicação na *Journal of Wildlife Management* e se encontra em revisão desde maio de 2015.

Figura 4 Córrego afetado por porcos selvagens *Sus scrofa* no Parque Nacional do Itatiaia, município de Itamonte, MG.

Figura 5 Córrego afetado pelo queixada *Tayassu pecari* no Parque Nacional do Itatiaia, município de Itatiaia, RJ.

O terceiro capítulo avalia os efeitos dos porcos selvagens sobre a remoção de sementes da Araucária *Araucaria angustifolia*, recurso chave para a fauna das Terras Altas da Mantiqueira. Comparamos a remoção de sementes em áreas ocupadas somente por porcos selvagens e somente por queixadas (Áreas 1 e 3 na Figura 1) e a relação entre taxas de remoção e abundância relativa de removedores de sementes (porcos selvagens, queixadas e pequenos roedores, Figuras 6, 7, 8 e 9). Neste trabalho foi possível observar que a remoção de sementes de Araucária está associada, sobretudo, a abundância relativa de pequenos roedores e que a taxa de remoção é semelhante entre áreas onde ocorre o porcos selvagens e o queixada. Embora não haja aparente impacto sobre as populações de Araucária, neste capítulo abordamos os potenciais impactos dos porcos selvagens sobre os pequenos roedores nativos devido a competição pelas sementes de Araucária; alémdo porco selvagem como um potencial substituto das funções ecológicas do queixada, sobretudo em ambientes da Mata Atlântica que já foram modificadas por outras atividades humanas. Esse capítulo foi formatado segundo as normas da revista *Biotropica*.

Figura 6 Porco selvagem *Sus scrofa* consumindo pinha de *Araucaria angustifolia* na RPPN Alto Montana em 2014.

Figura 7 Sementes de *Araucaria angustifolia* predadas por porco selvagem *Sus scrofa* na RPPN Alto Montana em 2014.

Figura 8 Queixada *Tayassu pecari* consumindo sementes de *Araucaria angustifolia* durante experimento realizado no Parque Nacional do Itatiaia para o terceiro capítulo dessa tese.

Figura 9 Pequeno roedor consumindo sementes de *Araucaria angustifolia* na RPPN Alto Montana.

Em abril de 2014, resultados preliminares do “Projeto Javali na Mantiqueira”, que incluem também essa tese, foram apresentados no “I Workshop sobre Controle do Javali na Serra da Mantiqueira”, realizado na sede no Instituto Alto Montana em Itamonte (MG), que contou com a participação da comunidade local, pesquisadores das mais variadas áreas do conhecimento e regiões brasileiras e órgãos públicos municipais, estaduais e federais. Neste Workshop se discutiu a problemática de expansão da distribuição da invasão dos porcos selvagens na Serra da Mantiqueira, pontuando os problemas ambientais, sociais e econômicos para a região e a importância da aliança entre pesquisa, comunidade local e órgãos públicos para a eficiência da avaliação do status de invasão e controle populacional dos porcos selvagens. A exemplo do I Workshop e para a finalização do projeto, foi realizado em setembro de 2015 o “II Workshop sobre Controle do Javali na Serra da Mantiqueira”, onde os atores envolvidos discutiram os resultados do projeto e puderam expor os avanços e dificuldades em todos os níveis de organização (pesquisa, gestão pública e comunidade local), criando o “Plano de Ação para Controle do Javali nas Terras Altas da Mantiqueira”, mostrando a importância e relação direta desse projeto e tese com políticas públicas de conservação de ecossistemas tropicais.

Além dos objetivos relacionados às espécies-foco (*Sus scrofa* e *Tayassu pecari*), durante a execução dessa tese foi possível realizar a formação de novos pesquisadores, uma vez que foi desenvolvido com o envolvimento direto desta doutoranda e com dados coletados no “Projeto Javali na Mantiqueira”, sete trabalhos apresentados em eventos científicos nacionais e internacionais com alunos de iniciação científica, e dois Trabalhos de Conclusão de Curso de Graduação. Além disso, foram publicados os artigos (1) “Rosa CA, Santos KK, Faria GMM, Puertas FH, Passamani M. 2015. Note on dietary of *Chrysocyon* *brachyurus* (Illiger 1815) and the record of predation to *Crypturellus obsoletus* in Serra da Mantiqueira Mountain, Southeastern Brazil. Boletim da Sociedade Brasileira de Mastozoologia 72: 7-10", que trás observações inéditas da dieta do lobo-guará na Mata Atlântica; (2) e "Faria GMM, Rosa CA, Correa GLC, Puertas F, Jiménez KMO, Perillo LN, Maia LHRD, Leles B, Paula RC, Rodriques FHGR, Passamani M. 2015. Geographic Distribution of the European hare (*Lepus europaeus*) in Brazil and new records of occurrence for the Cerrado and Atlantic Forest biomes. Mammalia: *in press*." com autores de diferentes instituições do Brasil, onde se avaliou o status atual da invasão da lebre europeia e estimativa de velocidade de expansão da distribuição da espécie no Brasil.

2 REFERENCIAL TEÓRICO

2.1 Mamíferos exóticos invasores

Desde que o ser humano passou a descobrir e colonizar novos territórios tem levado consigo as mais variadas espécies da fauna e flora selvagem e domesticada. Algumas dessas espécies acabam, de forma intencional ou acidental, sendo introduzidas em territórios onde não são nativas e cuja dispersão não seria possível sem a ajuda do ser humano (BLACKWELL, 2005). Quando a colonização é um sucesso para as espécies exóticas, essas estabelecem populações que podem se tornar invasoras e causar severos impactos em ecossistemas e espécies nativas, como alteração das relações de predação e competição, alteração da estrutura de habitats e dos serviços ambientais (SINGER et al., 1984; NOVILLO e OJEDA, 2008; SCHÜTTLER et al., 2008; ESTES et al., 2011). Espécies exóticas invasoras variam de microorganismos a vertebrados (e.g. *Plasmodiom relictum* Grassi & Feletti 1891, *Lates niloticus* Linnaeus 1758 e *Psidium cattleianum* Sabine 1821) e são atualmente uma das maiores causas de perda de biodiversidade (SCHÜTTLER et al., 2008).

Os mamíferos foram os primeiros organismos intencionalmente introduzidos ao redor do mundo para caça, comercialização, domesticação, criação comercial, animais de estimação e para controlar outras espécies invasoras (LONG, 2003; BLACKWELL, 2005; CLOUT e RUSELL, 2008). Espécies de mamíferos invasores possuem grande plasticidade ecológica que permitem um alto sucesso de estabelecimento e dispersão para áreas além de suas distribuições naturais (LONG, 2003; CLOUT e RUSELL, 2008). Na América do Sul existem vários exemplos de mamíferos introduzidos que se tornaram invasores e causam impactos econômicos, ambientais e na saúde pública, como o *Antilope cervicapra* Linnaeus 1758, *Castor canadensis* Kuhl 1820 e *Sus scrofa* Linnaeus 1758 (NOVILLO e OJEDA, 2008; PEDROSA et al,. 2015).

No Brasil as informações sobre mamíferos exóticos invasores ainda são restritas a registros pontuais de ocorrência (ex. PETERS et al., 2009; COSTA e FERNANDES, 2010), impactos locais (HEGEL e MARINI, 2013) e banco de dados digitais (IABIN, Inter-American Biodiversity Information Network), sem avaliações dos efeitos dos mamíferos exóticos invasores sobre os ecossistemas tropicais ou mesmo uma sistematização do status atual das invasões (ex. NOVILLO e OJEDA, 2008).

2.2 O porco selvagem *Sus scrofa* como espécie exótica invasora

A espécie *Sus scrofa* conhecida como javali europeu é nativa da Eurasia e um dos primeiros organismos intencionalmente introduzidos ao redor do mundo para caça, comercialização, domesticação e criação comercial (LONG, 2003; CLOUT e RUSELL, 2008). Por se tratar da mesma espécie doméstica utilizada em criações comerciais de suínos, o javali europeu pode reproduzir com o porco doméstico. O cruzamento entre javalis europeus e porcos domésticos resulta em diferentes linhagens de porcos selvagens que são hoje uma das 100 piores espécies invasoras do mundo segundo o Invasive Species Specialist Group (http://www.issg.org).

Na América do Sul os porcos foram introduzidos pela primeira vez no final do século XV junto com a colonização europeia e continuam sendo introduzido até hoje para fins de caça e criação (OLIVEIRA, 2012). Em algumas regiões, como a Amazônia, a introdução de porcos selvagens não evoluiu para a fase mais grave de invasão (OLIVEIRA, 2012; PEDROSA et al,. 2015), enquanto em outros locais do Brasil e na Argentina a invasão ocorreu rapidamente gerando conflitos a partir dos primeiros três anos da introdução da espécie (OLIVEIRA, 2012). Atualmente no Brasil um dos principais problemas são as criações clandestinas, onde ocorre o cruzamento entre o porco selvagem e o porco doméstico, aumentando ainda mais a capacidade reprodutiva da espécie, cujos efeitos genéticos e ecológicos são ainda desconhecidos (BARRIOS-GARCIA e BALLARI, 2012; OLIVEIRA, 2012). Com isso, os porcos selvagens passaram a ter uma das maiores distribuições entre os mamíferos terrestres, e a ser um dos mais graves problemas econômicos, sociais e ambientais causados por espécies exóticas invasoras em muitos países (MAYER e BRISBIN, 1991; CHOQUENOT et al., 1996; LOWE et al., 2000; ATKINSON, 2006; PEDROSA et al., 2015).

Os impactos dos porcos selvagens nos ecossistemas estão diretamente ligados a sua biologia e ecologia. O porco selvagem é um ungulado com alta capacidade reprodutiva, podendo reproduzir ao longo de todo o ano, tendo até duas ninhadas por ano, com uma média de quatro filhotes por ninhada (FERNÁNDEZ-LLARIO e MATEOS-QUESADA, 1998). Sua área de vida pode variar entre 80 e 1.600 ha, dependendo da distribuição e disponibilidade de recursos (KEULING et al., 2008) e pode variar sazonalmente devido a dois fatores principais: temperatura e recursos alimentares. Porcos selvagens não possuem glândulas sudoríporas e por isso preferem lugares com temperaturas frias (< 10ºC) ou ambientes protegidos do calor (BARRETT, 1978; COBLENTZ e BABER, 1986; CUEVAS et al., 2012). Sendo assim, esses animais costumam ser mais abundantes em áreas florestais e nas estações mais quentes, é comum se concentrarem em áreas de alta altitude, próximas a corpos d'água e com alta cobertura vegetal de espécies herbáceas e arbustivas (BARRETT, 1982; COBLENTZ e BABER, 1986; CAHILL et al., 2012). Possuem uma dieta muito plástica, consumindo principalmente matéria vegetal (> 90%), embora possam consumir fungos, invertebrados e vertebrados. Para forragear possuem o hábito de chafurdar o solo e as raízes das plantas. O período de atividade é variável, podendo ser ativo a qualquer momento do dia e da noite, sendo que apresentam uma atividade noturna mais intensa em altas temperaturas ou em área com elevada concentração de atividades humanas, sobretudo onde ocorre atividade de caça (BARRIOS-GARCIA e BALLARI, 2012).

O porco selvagem é classificado como um engenheiro de ecossistemas, que são espécies que, de forma direta ou direta, regulam a disponibilidade de recursos e alteram características físicas e químicas do ambiente, resultando na criação, modificação ou manutenção de habitats para si e outras espécies (JONES et al., 1994). No caso do porco selvagem, essa característica tem gerado inúmeros conflitos e impactos aos ecossistemas. O principal conflito entre ser humano-porco selvagem é a utilização das culturas agrícolas pelos animais como fonte de recurso alimentar, em alguns casos destruindo lavouras inteiras (PEDROSA et al., 2015). Os impactos em lavouras são mais significativos quando estas se encontram próximas a bordas de florestas (THURFJELL et al., 2009; BARRIOS-GARCIA e BALLARI, 2012; LI et al., 2013).

Já os estudos quanto aos impactos do porco selvagem nos ecossistemas são concentrados em ambientes temperados (Europa e Estados Unidos) e subtropicais (Austrália). De forma geral podemos citar os seguintes impactos aos ecossistemas terrestres: alteração da estrutura e processos do solo devido o chafurdamento do solo e raízes, causando perda de nutrientes e lixiviação, tal qual um cultivo agrícola mecanizado (SINGER et al., 1984; CUEVAS et al., 2012); o chafurdamento causa também diminuição da cobertura vegetal, decréscimo da riqueza de espécies e alteração da composição de espécies e da regeneração vegetal, sobretudo herbáceas e arbustos (CUEVAS et al., 2012), além de abrir pequenas clareiras na vegetação que levam a colonização de plantas exóticas invasoras (BARRIOS-GARCIA e BALLARI, 2012); atua como dispersor de gramíneas exóticas, principalmente aquelas dispersadas por epizoocoria (SANGUINETTI e KITZBERGER, 2010; DOVRAT et al., 2012); reduz a regeneração florestal através da predação direta de sementes, pisoteamento de plântulas ou através da redução, alteração e homogeneização da estrutura do banco de sementes, devido a exposição das sementes às condições de germinação antes do tempo (ICKES et al., 2001; WEBBER et al., 2010; BUENO et al., 2011).

Quanto aos ecossistemas aquáticos não há estudos quanto aos impactos dos porcos selvagens na estrutura física destes. Porém sabe-se que o porco selvagem causa alteração na comunidade de plantas aquáticas, mudança na qualidade química da água e dispersão de plantas, animais, doenças e patógenos entre sistemas isolados (DOUPÉ et al., 2010).

Os impactos sobre a fauna nativa estão relacionados a predação de inúmeras espécies de vertebrados, destruição de habitats e ninhos e competição. Porcos selvagens destroem microhabitats levando a exclusão de algumas espécies, como pequenos mamíferos que dependem da serapilheira e estrato arbustivo-herbáceo como habitat (SINGER et al., 1984). O porco selvagem aparentemente não compete com taiaçuídeos brasileiros (*Tayassu pecari* e *Pecari tajacu*), porém ocupa facilmente as paisagens fragmentadas onde as populações das espécies nativas já foram reduzidas ou eliminadas (OLIVEIRA, 2012).

Alguns estudos têm apontado impactos positivos da introdução de porcos selvagens, como a inclusão destes na cadeia trófica como presa para médios e grandes carnívoros; dispersão de sementes de espécies nativas, embora possa dispersar as exóticas também (PEREDO et al., 2013); substituição das funções ecológicas de espécies nativas e processos extintos, como o pastejo e pisoteamento realizado por ungulados nativos e ursos; além da criação de distúrbios originalmente realizados pelo fogo que é atualmente suprimido em algumas regiões (SANDOM et al., 2013). Destaca-se também seu valor econômico para carne e caça recreativa substituindo inclusive a caça de espécies nativas no Pantanal (DESBIEZ et al., 2011).

2.3 Porcos selvagens e floresta ombrófila mista

Especificamente no Brasil, o porco selvagem ocorre em todos os biomas (PEDROSA et al., 2015) e tem sido comum na Mata Atlântica em áreas de Floresta Ombrófila Mista (FOM) onde seu principal recurso alimentar são as sementes de Araucária (*Araucaria angustifolia* (Bertol.) Kuntze) (OLIVEIRA, 2012). A *Araucaria angustifolia* é uma gimnosperma nativa do Brasil, única representante no país da Família Araucariaceae, e está distribuída no sul e sudeste do país. Cresce em florestas subtropicais de solos ácidos com no mínimo 500 metros de altitude. (MANTOVANI et al., 2004). Devido a sua distribuição naturalmente restrita, fragmentação da FOM, exploração madeireira e defaunação que atinge os principais dispersores de suas sementes (VELOSO et al., 1991; FRAGOSO et al., 2011), as populações de Araucária se encontram em declínio e a espécie é ameaçada de extinção na categoria “criticamente em perigo” da IUCN (THOMAS, 2013). O pinhão, nome popular da semente de Araucária, é um recurso chave consumido por uma ampla gama de mamíferos, desde pequenos roedores (< 200g) até queixadas maiores que 30 kg, e os pequenos roedores são reconhecidamente os principais dispersores das sementes (SOLÓRZANO-FILHO, 2001; IOB e VIEIRA, 2008). A Araucária é protegida por leis nacionais e, com o corte proibido no Brasil (CONAMA, 2001), houve uma redução da exploração madeireira da espécie que continua a ser uma importante fonte de renda das populações locais das FOMs devido a exploração econômica das suas sementes, com um extrativismo estimado em 6000 toneladas ao ano (IBGE, 2006).

Apesar do status de ameaça e importância ecológica e social das Araucárias, não há estudos avaliando os efeitos da invasão dos porcos selvagens nas FOMs brasileiras. Na Argentina, em áreas com *Araucaria araucana*, sabe-se que os porcos selvagens predam os pinhões, deixando estes indisponíveis aos roedores de pequeno porte, reduzindo a oferta alimentar das espécies nativas (competição por exploração) e a sobrevivência das sementes, e por consequência alterando os processos de dispersão (SANGUINETTI e KITZBERGER, 2010; SHEPHERD e DITGEN, 2012).

2.4 Porcos selvagens e a Serra da Mantiqueira

A Serra da Mantiqueira possui relevantes fragmentos florestais e é considerada prioritária para a conservação do Bioma Mata Atlântica e insubstituível para a biodiversidade do mundo, devido a alta biodiversidade, incluindo inúmeras espécies de mamíferos de médio e grande porte ameaçadas de extinção (ex. *Tayassu pecari*, *Puma concolor*, etc.) (DRUMOND, 2005; LE SAOUT et al., 2013). A Serra da Mantiqueira abriga inúmeras nascentes, pequenos córregos e rios fundamentais para os processos ecológicos do ecossistema em questão e que abastecem inúmeras bacias hidrográficas e municípios inseridos dentro do seu limite. Além disso, a Serra da Mantiqueira é o limite norte da distribuição da Araucária, cujas sementes (pinhão) se tornam o principal recurso alimentar das espécies da fauna, sobretudo nos meses mais frios, quando o recurso é escasso.

O município de Itamonte, em Minas Gerais, se destaca na conservação da Serra da Mantiqueira. O município é dominado pela Floresta Estacional Semidecidual Montana (VELOSO et al., 1991) e abriga as cabeceiras da bacia hidrográfica do rio Verde, estando inserida na Área de Proteção Ambiental Serra da Mantiqueira e no entorno imediato do Parque Nacional do Itatiaia (22% do território do município, 9.818 ha) e do Parque Estadual da Serra do Papagaio (15% do território do município, 6.482 ha). Devido sua localização e presença de importantes Unidades de Conservação, o município de Itamonte apresenta relevante importância na preservação e conservação dos remanescentes de Mata Atlântica, evidenciada pela atual cobertura vegetal original do Bioma que representa cerca de 37% da área total do município (SOSMA/INPE, 2010).

Dentre as Unidades de Conservação do município de Itamonte destacam-se a Reserva Particular do Patrimônio Natural (RPPN) Alto-Montana, no município de Itamonte (22°21S e 44°47W) e o Parque Nacional do Itatiaia, nos municípios de Itamonte (MG) e Itatiaia (RJ) (22º15'e 22º30'S; 44º30'e 44º45'W), que são foco dos estudos realizados nesta tese. A RPPN possui 672 ha, uma altitude entre 1500 e 2500 metros e está localizada na porção superior do município de Itamonte. Já o Parque Nacional do Itatiaia (PNI) possui em torno de 28.000 hectares e uma altitude entre 600 a 2.791 metros. Em ambas UCs predomina a Floresta Estacional Semidecidual Montana caracterizada pela presença da Araucária e campos de altitude caracterizados pela distribuição descontínua de indivíduos de Araucária (URURAHY et al., 1983; OLIVEIRA-FILHO e FONTES, 2000), com exceção das porções mais baixas do PNI (< 1.600 metros) onde predomina a Floresta Ombrófila Densa.

Atualmente são estimadas densidades de 8,5 e 15,8 ind./km^2 vivendo de forma feral no Parque Nacional do Itatiaia e RPPN Alto Montana, respectivamente (PUERTAS, 2015). Por esses motivos, a avaliação da ecologia dos porcos selvagens nos ecossistemas da Serra da Mantiqueira se torna urgente. A região onde foram realizados os estudos desta tese proporciona também uma oportunidade ímpar de experimentação, uma vez que possui uma grande área dentro dos limites do Parque Nacional do Itatiaia (altitudes abaixo de 1.600 metros) onde não foi detectado a presença do porco selvagem e a espécie nativa queixada *Tayassu pecari* ocorre em altas densidades (ROSA, PUERTAS e PASSAMANI, dados não publicados).

2.5 A espécie nativa queixada *Tayassu pecari* como equivalente ecológico do porco selvagem

O queixada *Tayassu pecari* é uma espécie da família Tayassuidae e endêmica da região neotropical, distribuída desde o sudeste do México até o norte da Argentina e Sul do Brasil (SOWLS, 1984). No entanto, seus limites de distribuição diminuíram muito ao longo de toda sua distribuição original (REYNA-HURTADO et al., 2009; 2010; ALTRICHTER et al., 2012), devido sobretudo a fragmentação e caça furtiva (REYNA-HURTADO et al., 2009; 2010; ALTRICHTER et al., 2012).

Devido suas semelhanças de comportamento e uso do habitat, o queixada pode ser considerado o equivalente ecológico nativo do porco selvagem conforme já destacado por Novillo e Ojeda (2008). O queixada é um dos maiores mamíferos neotropicais, podendo atingir até 40 kg e 150 cm de comprimento (FRAGOSO, 1999). Embora prefira florestas tropicais úmidas, habita uma variedade de ambientes como planícies secas e alagadas, florestas tropicais secas e regiões costeiras (MAYER e BRANDT, 1982; SOWLS, 1984; DESBIEZ et al., 2009). É um animal onívoro que vive em grupo de dezenas a centenas de indivíduos e se alimentam de tubérculos, sementes, invertebrados, pequenos vertebrados, carcaças, fungos, frutos, etc. Por isso é um dos principais dispersores de sementes, além de importante presa para grandes carnívoros como *Panthera onca* e *Puma concolor*, contribuindo para a estruturação e manutenção de comunidades biológicas (SOWLS, 1984; MAYER e WETZEL, 1987; REIS et al., 2011). Além disso, é responsável pela formação de habitats para outras espécies, caracterizando-se como um engenheiro de ecossistema (BECK et al., 2010).

Sendo assim os artigos apresentados nessa tese tiveram seus dados coletados no Parque Nacional do Itatiaia e RPPN Alto Montana onde eu e meus colaboradores buscamos avaliar a ecologia do porco selvagem na Serra da Mantiqueira comparando com a ecologia do queixada. Eu acredito que os resultados dessa tese irão contribuir com o conhecimento individual de ambas espécies foco (*Sus scrofa* e *Tayssu pecari*), cuja ecologia é atualmente incipiente no Brasil e ambientes tropicais, além de auxiliar no planejamento e execução de estratégias de manejo de fauna que visem o controle populacional de espécies exóticas invasoras.

REFERÊNCIAS

ALTRICHTER, M. et al. Range-wide declines of a key Neotropical ecosystem architect, the Near Threatened white-lipped peccary *Tayassu pecari*. **Oryx**, Oxford, v. 46, n. 1, p. 87–98, 2011.

ATKINSON, I. A. E. Introduced mammals in a new environment. In: ALLEN, R. B.; LEE W. G. (Eds.). **Biological Invasions in New Zealand**. Berlin/Heidelberg: Springer-Verlag, 2006. p. 49-66.

BARRETT, R. H. The feral hog at Dye Creek Ranch, California. **Hilgardia,** Davis, v. 46, p. 283–355, 1978.

BARRETT, R. H. Habitat preferences of feral hogs, deer, and cattle on a Sierra foothill range. **Journal of Range Management**, Tucson, v. 35, p. 342–346, 1982.

BARRIOS-GARCIA, M.; BALLARI, S.A. Impact of wild boar *(Sus scrofa*) in its introduced and native range: a review. **Biological Invasions,** Dordrecht, v. 14, p. 2283-2300, 2012.

BECK, H.; THEBPANYA, P.; FILIAGGI, M. Do Neotropical pecari species (Tayassuidae) function as ecosystem engineers for anurans? **Journal of Tropical Ecology**, New York, v. 26, p. 407-414, 2010.

BLACKWELL, G. L. Another World: The composition and consequences of the Introduced Mammal fauna of New Zealand. **The Australian Zoologist**, Sydney, v. 33, n. 1, p. 108-118, 2005.

BUENO, C. G. et al. Effects of large wild boar disturbances on alpine soil seed banks. **Basic and Applied Ecology,** Jena, v. 12, p. 125-133, 2011.

CAHILL, S. et al. Characteristics of wild boar (*Sus scrofa*) habituation to urban areas in the Collserola Natural Park Barcelona) and comparison with other locations. **Animal Biodiversity and Conservation,** Spain, v. 35, n. 2, p. 221-233, 2012.

CHOQUENOT, D.; MCILROY, J.; KORN, T. **Managing vertebrate pests: feral pigs**. Canberra: Bureau of Resource Sciences/Australian Government Publishing Service, 1996.

CLOUT, M. N.; RUSSELL, J. C. The invasion ecology of mammals: a global perspective. **Wildlife Research**, Collingwood, v. 35, p. 180–184, 2008.

COBLENTZ, B. E.; BABER, D. W. Biology and control of feral pigs on Isla Santiago, Galapagos, Ecuador. **Journal of Applied Ecology**, London, v. 24, p. 403–418, 1987.

CONAMA (Conselho Nacional do Meio Ambiente). Resolução nº 278, de 24 de maio de 2001. Diário Oficial da União, Poder Executivo, Brasília, DF, 19 jul. 2001. p. 51-52.

COSTA, M. D.; FERNANDES, F. A. B. Primeiro registro de *Lepus europaeus* Pallas, 1778 (Mammalia, Lagomorpha, Leporidae) no sul do Estado de Minas Gerais e uma síntese dos registros conhecidos para o sudeste do Brasil. **Revista Brasileira de Zoociências**, Juiz de Fora, v. 1778, n. 3, p. 311–314, 2010.

CUEVAS, M. F. et al. Effects of wild boar disturbance on vegetation and soil properties in the Monte Desert, Argentina. **Mammalian Biology**, Berlin, v. 77, p. 299–306, 2012.

DESBIEZ, A. L. J.; BODMER, R. E.; SANTOS, S. A. Wildlife habitat selection and sustainable resource management in a Neotropical wetland. **International Journal of Biodversity and Conservation,** Cairo, v. 1, n. 1, p. 11-20, 2009.

DESBIEZ, A. L. J. et al. Invasive species and bushmeat hunting contributing to wildlife conservation: the case of feral pigs in a Neotropical wetland. **Oryx**, Oxford, v. 45, n. 1, p. 78-83, 2011.

DOUPÉ, R. G. et al. Efficacy of exclusion fencing to protect ephemeral floodplain lagoon habitats from feral pigs (*Sus scrofa*). **Wetlands Ecology and Management,** Berlin, v. 18, p. 69-78, 2010.

DOVRAT, G.; PEREVOLOTSKY, A.; NE’EMAN, G. Wild boars as seed dispersal agents of exotic plants from agricultural lands to conservation areas. **Journal of Arid Environments,** London, v. 78, n. 49-54, 2012.

DRUMOND, G. M. **Biodiversidade em Minas Gerais: um Atlas para sua conservação**. Belo Horizonte: Fundação Biodiversitas, 2005.

ESTES, J. A. et al. Trophic Downgrading of Planet Earth. **Science**, New York, v. 333, n. 6040, p. 301-306, 2011.

FERNÁNDEZ-LLARIO, P.; MATEOS-QUESADA, P. Body size and reproductive parameters in the wild boar *Sus scrofa*. **Acta Theriologica**, Bialystok, v. 43, n. 4, p. 439-444, 1998.

FRAGOSO, J. M. V. Perception of scale and resource partitioning by peccaries: behavioral causes and ecological implications. **Journal of Mammalogy**, Lawrence, v. 80, n. 3, p. 993-1003, 1999.

FRAGOSO, R. O.; DELGADO, L. E. S.; LOPES, L. M. Aspectos da atividade de caça no Parque Nacional do Iguaçu – PR. **Revista de Biologia Neotropical**, Goiânia, v. 8, n. 1, p. 41-52, 2011.

HEGEL, C. G. Z.; MARINI, M. A. Impacto do javali europeu, *Sus scrofa*, em um fragmento da Mata Atlântica brasileira. **Neotropical Biology and Conservation**, São Leopoldo, v. 8, n. 1, p. 17–24, 2013.

ICKES, K.; DEWALT, S. J.; APPANAH, S. Effects of native pigs (*Sus scrofa*) on woody understorey vegetation in a Malaysian lowland rain forest. **Journal of Tropical Ecology**, New York, v. 17, p. 191-206, 2001.

IOB, G.; VIEIRA E. M. Seed predation of *Araucaria angustifolia* (Araucariaceae) in the Brazilian Araucaria Forest: influence of deposition site and comparative role of small and 'large' mammals. **Plant Ecology**, Heidelberg, v.198, p. 185-196, 2008.

JONES, C. G.; LAWTON, J. H.; SHACHAK, M. Organisms as ecosystem engineers. **Oikos,** Lund, v. 69, p. 373–386, 1994.

KEULING, O.; STIER, N.; ROTH, M. How does hunting influence activity and spatial usage in wild boar *Sus scrofa* L.? **European Journal of Wildlife Research,** New York, v. 54, p. 729-737, 2008.

KEULING, O.; STIER, N.; ROTH, M. Annual and seasonal space use of different age classes of female wild boar *Sus scrofa* L. **European Journal of Wildlife Research,** New York, v. 54, p. 403-412, 2008.

LE SAOUT, S. et al. Protected areas and effective biodiversity conservation. **Science,** New York, v. 342, artigo 803, 2013.

LI, L. et al. Factors influencing wild boar damage in Taohongling National Nature Reserve in China: a model approach. **European Journal of Wildlife Reasearch**, New York, v. 59, p. 179-184, 2013.

LONG, J. L. **Introduced mammals of the world: their history distribution and influence**. Collingwood: CSIRO, 2003.

LOWE, S. et al. **100 of the world's worst invasive alien species: a selection from the global invasive species database**. Gland: The Invasive Species Specialist Group (ISSG)/World Conservation Union, 2000.

MANTOVANI, A.; MORELLATO, L. P. C.; REIS, M. S. Fenologia reprodutiva e produção de sementes em *Araucaria angustifolia* (Bert.) O. Kuntze. **Revista Brasileira de Botânica**, São Paulo, v. 27, n. 4, p. 787-796, 2004.

MAYER, J. J.; BRISBIN, I. L. **Wild Pigs in the United States: the history, comparative morphology and current status**. Athens: University of Georgia Press, 1991.

MAYER, J. J., BRANDT, P. N**. Identity, distribution, and history of the peccaries, Tayassuidae**. Em: MARES, M. A.; GENOWAYS, H. H. (Eds.). Mammalian Biology in South America, p. 433-455. Pittsburgh: Pymatuning Laboratory of Ecology, University of Pittsburgh, , 1982.

MAYER, J. J.; WETZEL, R. M. *Tayassu pecari*. **Mammalian Species**, Lawrence, v. 293, p. 1-7, 1987.

NOVILLO, A.; OJEDA, R. A. The exotic mammals of Argentina. **Biological Invasions**, Dordrecht, v. 10, n. 8, p. 1333–1344, 2008.

OLIVEIRA, C.H.S. **Ecologia e Manejo de javali (*Sus scrofa* L.) na América do Sul**. 2012. Tese de Doutorado, Programa de Pós Graduação em Ecologia da Universidade Federal do Rio de Janeiro, Rio de Janeiro, 152 p. 2012.

OLIVEIRA-FILHO, A. T.; FONTES, M. A. L. Patterns of floristic differentiation among Atlantic Forests in Southeastern Brazil and the influence of climate. **Biotropica**, Hoboken, v. 32, n. 4b, p. 793-810, 2000.

PEDROSA, F. et al. Current distribution of invasive feral pigs in Brazil: economic impacts and ecological uncertainty. **Brazilian Journal of Nature Conservation**, Rio de Janeiro, v. 13, p. 84-87, 2015.

PEREDO, A. et al. Mammalian seed dispersal in Cantabrian woodland pastures: Network structure and response to forest loss. **Basic and Applied Ecology**, Jena, v. 14, p. 378-386, 2013.

PETERS, F. B. et al. Predação de *Lepus europaeus* (Lagomorpha: Leporidae) por *Bubo virginianus* (Stringiformes: Stringidae) no Sul do Brasil. **Biodiversidade Pampeana**, Porto Alegre, v. 7, n. 1, p. 31–34, 2009.

PUERTAS, F.H. **A invasão do javali na Serra da Mantiqueira: aspectos populacionais, uso do habitat e sua relação com o Homem**. 2015. Dissertação de Mestrado, Programa de Pós-Graduação em Ecologia Aplicada da Universidade Federal de Lavras, Lavras, 97p. 2015.

REIS, N. R. et al. **Mamíferos do Brasil**. Londrina: Nélio Reis, 2011.

REYNA-HURTADO, R. Conservation status of the White-lipped pecari (*Tayassu pecari*) outside the Calakmul Biosphere Reserve in Campeche, Mexico: a synthesis. **Tropical Conservation Science**, Menlo Park, v. 2, p. 159-172, 2009.

REYNA-HURTADO, R. et al. Hunting and the conservation of a social ungulate: the white-lipped pecari T*ayassu pecari* in Calakmul, Mexico. **Oryx**, Oxford, v. 44, n. 1, p. 89-96, 2010.

SANDOM, C. J.; HUGUES, J.; MACDONALD, D. W. Rewilding the Scottish Highlands: Do Wild Boar, *Sus scrofa*, use a suitable foraging strategy to be effective ecosystem engineers? **Restoration Ecology,** Malden, v. 21, n. 3, p. 336-343, 2013.

SANGUINETTI, J.; KITZBERGER, T. Factors controlling seed predation by rodents and non-native *Sus scrofa* in *Araucaria araucana* forests: potential effects on seedling establishment. **Biological Invasions**, Dordrecht, v. 12, p. 689-706, 2010.

SCHÜTTLER, E.; CÁRCAMO, J.; ROZZI, R. Diet of the American mink *Mustela vison* and its potential impact on the native fauna of Navarino Island, Cape Horn Biosphere Reserve, Chile. **Revista Chilena de História Natural,** Santiago, v. 81, p. 585–598, 2008.

SHEPHERD, J. D.; DITGEN, R.S. Rodent handling of *Araucaria araucana* seeds. **Austral Ecology**, Windsor, v. 38, p. 23-32, 2012.

SINGER, F. J.; SWANK, W. T.; CLEBSCH, E. E. C. Effects of wild pig rooting in a deciduous forest. **Journal of Wildlife Management,** London, v. 48, p. 464–473, 1984

SOLÓRZANO-FILHO, J. A. **Demografia, fenologia e ecologia da dispersão de sementes de *Araucaria angustifolia* em uma população relictual em Campos do Jordão, SP.** 2001. Dissertação de Mestrado, Programa de Pós-Graduação da Universidade de São Paulo, São Paulo. 2001

SOSMA/INPE. **Atlas dos Remanescentes de Mata Atlântica.** Disponível em: <http://mapas.sosma.org.br/>. Acesso em: 01 novembro 2013.

SOWLS, L. K. **The Peccaries**. Tucson: The University of Arizona Press, 1984.

THOMAS, P. 2013. ***Araucaria angustifolia*.** The IUCN Red List of Threatened Species. Disponível em: <www.iucnredlist.org>. Acesso em 26 de junho de 2015.

THURFJELL, H. et al. Habitat use and spatial patterns of wild boar *Sus scrofa* (L.): agricultural fields and edges. **European Journal of Wildlife Research,** New York, v. 55, p. 517-523, 2009.

URURAHY, J. C. et al. **Vegetação**. Levantamento dos Recursos Naturais 32. Rio de Janeiro/Vitória: RADAMBRASIL, Folhas SF 23/24, 1983. p. 553-623

VELOSO, H. P.; RANGEL FILHO, A. L. R.; LIMA, J. C. A. **Classificação da vegetação brasileira, adaptada a um sistema universal**. Rio de Janeiro: Instituto Brasileiro de Geografia e Estatística, 1991

WEBBER, B.; NORTON, B. A.; WOODROW, I. E. Disturbance affects spatial patterning and stand structureof a tropical rainforest tree. **Austral Ecology,** Windsor, v. 35, p. 423-434, 2010.

SEGUNDA PARTE
ARTIGOS

ARTIGO 1

Preparado segundo as normas da revista *Biological Invasions*

Alien terrestrial mammals in Brazil: current status and invasive risk assessment

Clarissa Alves da Rosa[1,2], Nelson Henrique de Almeida Curi[1], Fernando Henrique Puertas[1], Marcelo Passamani[1]

[1]Laboratório de Ecologia e Conservação de Mamíferos, Setor de Ecologia, Departamento de Biologia, Universidade Federal de Lavras, Campus Universitário, 37200-000, Lavras, Minas Gerais, Brazil

Corresponding Author[2]: Telephone +55 35 38291922; E-mail alvesrosa_c@hotmail.com

Acknowledgments: We would like to thank CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) and FAPEMIG (Fundação de Amparo à Pesquisa do Estado de Minas Gerais) for financial support. We also thank Ziller S for her backing to the risk assessment analysis.

Abstract

The invasion of exotic species is an important cause of biodiversity loss worldwide and exotic-mammal invaders are recognized for having the greatest potential for ecosystem alteration. Our aim was, from the literature available, to systematize the information regarding exotic mammals that have established feral populations in Brazil and carry out a risk assessment for the possibility of invasion by other exotic mammal species sold as pets in Brazil. We found nine species of exotic mammals living in the wild in Brazil, highlighting *Lepus europaeus* and *Sus scrofa* which have the largest distribution in Brazilian territory and continue expanding their distribution. In addition, we call attention to the invasion of *Bubalus bubalis*, a large species that still thrives as isolated populations, but is also expanding its distribution. We conducted risk assessments of eight exotic mammal species sold as pets in Brazil and all of them showed high risk of invasion. Finally, we recommend a series of actions for the control of existing exotic populations and policies to prevent the invasion by new mammal species in Brazil.

Key-Words: Exotic, Biological Invasions, Introduced mammals, Traits of invasiveness, Protected areas.

Introduction

Biodiversity loss is currently one of the most important societal concerns worldwide, and it is caused mainly by habitat loss and fragmentation, biological invasions and climate change (Vitousek et al. 1996). Invasive alien species often disrupt ecosystem processes by negatively affecting native species through direct, indirect or apparent (parasite-mediated) competition, predation, habitat modification and alteration of nutrient and water cycles (Long 2003; Blackwell 2005; Mooney et al. 2005; Clout and Rusell 2007). Other impacts involve human and domestic animal health concerns and economic losses (Mooney et al. 2005).

Despite most of the studies reporting negative effects, some report positive effects and interactions with native species. For instance, exotic *Casuarina* plants provide refuge for native snails against exotic rats on Japanese islands (Chiba 2010). Another positive aspect of biological invasions is the opportunity to study species attributes and ecological aspects of the invasion itself (aiming towards future control strategies), which also provide insights on population and community ecology and ecosystem structure and function (see Novel Ecosystem concept in Hobbs et al 2006 and Hobbs et al. 2009).

Species life history traits (e.g. body mass, reproductive rate, diet breadth, home range and behavior) and both native and invasive habitat characteristics (e.g. size, topography, resource diversity, climate, and vacant niches) complementarily drive invasion success or failure (Sakai et al. 2001; Mooney et al. 2005). These traits act in each step of the invasion process (transport, establishment and spread) through effects on survival and reproduction of invading individuals and populations (Sakai et al. 2001). Different combinations of these factors have led to several introductions worldwide, and the problem is so critical that in many countries organizations are engaged to minimize or solve the threat, such as the IUCN/SSC Invasive Species Specialist Group (ISSG) and their Global Invasive Species Database. One of the strategies to combat biological invasion is the creation of risk assessment protocols of potentially invasive species. These protocols consider issues related to ecology and biology of the species, biogeographic aspects, associated risk factors (e.g. commercial interest, availability of efficient control methods), among others, and can be adapted to different geographic realities (e.g. Bomford 2008; Pereira and Ziller 2008; Nentwig et al. 2010).

Because of their reproductive output and wider physiological tolerance range, several mammal species are considered successful invaders overall, and their impacts can be extremely strong and detrimental to native habitats and their biotas. In addition, large mammals tend to have a high capability of habitat modification, and are referred to as ecosystem engineers (Jones et al. 1994). Mammals were the first organisms to be intentionally introduced around the world for reasons including hunting game, commercialization, domestication as livestock or pets and to control the adverse effects of other invasive species (Long 2003; Clout and Rusell 2007).

South America has faced many introductions of mammals since European colonization, and currently at least 25 species (e.g. Wild pigs *Sus scrofa*, European hare *Lepus europaeus*, American beaver *Castor canadensis*) of 37 introduced are successfully thriving as feral populations (Long et al. 2003). The status of exotic invader mammals is well documented in some countries such as Chile (Iriarte et al. 2005) and Argentina (Novillo and Ojeda 2008). Unfortunately in Brazil, the largest South American country, several mammal species that have been introduced were reported by the grey literature and many scientific publications have arisen, but the information is mostly scarce and scattered.

Our aim, therefore, is to review the status of invader mammal species in Brazil, the history of invasions, their biological and ecological attributes, impacts, distribution maps, as well as to identify potential invader mammals using a risk assessment protocol adapted to Brazilian environmental condition. Such information is crucial for conservation and economic issues since it guides exotic species management, control and research efforts.

Methods

We performed a literature search from various types of sources including textbooks (Lowe et al. 2000; Long 2003), scientific literature articles, the internet databases Global Invasive Species Database (GISD's) of IUCN/SSC and Inter-American

Biodiversity Information Network (IABIN) and reports from experts. Only non-native mammals living in feral state without intentional human assistance were included. Domestic animals such as cows, cats and dogs were excluded as there is little data on their populations in feral state in Brazil (but see Paschoal et al. 2012 and related papers on feral dogs). From the literature, we listed the history of invasions, biological and ecological attributes of invaders that can be used as surrogates of invasive potential (Williamson 1996), and Brazilian geographic ranges of invaders. Wild pig and European hare geographic ranges in Brazil were collected from the recently works of Pedrosa et al. (2015) and Faria et al. (2015), respectively. We plotted the geographic range of invasive species with the distribution of Brazilian Protected Areas available in ICMBio (2016).

We believe that the major actual risk for new mammal invaders in Brazil is the pet trade source since it is a common source of invasive species in many countries (Long 2003) and Brazil do not have a national pet trade control policy. Being such, we searched the internet for non-native mammal species for sale in pet stores in Brazilian state capitals. We considered potential invader species those that already have alien and feral populations established in other countries by Long (2003). For these species we conducted a Risk Assessment Protocol used by the Horus Institute (Pereira and Ziller 2008) to access the potential risk of invasion in Brazilian territory. The protocol has 39 questions related to four categories: (1) species biological and ecological characteristics, (2) biogeographic aspects, (3) social and economic aspects and (4) risk potentiating characteristics (Appendix I). The results of the protocol are considered valid if approximately 70% of the questions are answered yes/no for each category. The potential risk is divided into five intensities: very low (values less than 11 points), low (values between 11 and 32 points), moderate (values between 32 and 45 points), high (between 45 and 65 points) and very high (values above 65 points and a maximum of 150 points) (Pereira and Ziller 2008).

Results

Feral populations of nine species of exotic mammals from Eurasia and Africa occur in Brazil (Table 1). Native species from Brazil also become invasive in Brazilian territory, such as the Rock cavy, *Kerodon rupestris,* a rodent from the Brazilian Caatinga that is invasive on Fernando de Noronha Island, and three Callitrichid primate species from Brazilian Caatinga, Cerrado and Atlantic Forest that are invaders in different places, including the Brazilian Cerrado and Atlantic Forest (Fig. 1). Most introductions are mainly from the second and first half of the 19th and 20th centuries with the purpose of human activities (i.e. sport hunting, food and fur industry, and for ornamental purposes), and hitchhiker species (i.e. old world mice and rats through ships) (Table 1). Nearly all of the introductions began with accidental escapes or intentional release into the wild. The majority of the feral population occurred in south and southeast of Brazil, between latitudes 15 and 35 SL and with exception of the Indian sambar *Cervus unicolor*, all the invasive species occurs in Brazilian Protected areas (Fig.1).

The invasive mammal species in Brazil are represented by small (< 1 kg), medium and large sized species. All the medium and large sized invasive mammal species in Brazil are from Eurasia and Africa, while the Brazilian species (Rock cavy and Callitrichid primates) are all small sized species. The invasive mammal species living in feral population in Brazil have high reproductive rates (more than three cubs per female per year), broad omnivorous or herbivorous-omnivorous diets and large displacement capacity (more than 10 km/day) . A summarized account of invasive mammal species living in feral population in Brazil, their historic invasion, potential impacts and ecological attributes are shown in Tables 1 and 2.

Besides the invasive mammal species that already occurs in Brazilian territory, we found eight potential invader mammal species for pet sale and with no established feral populations in Brazil but with historic of invasion in other countries. Among these, two already had the risk assessment protocol (European polecat *Mustela putorius* and Wild rabbit *Oryctolagus cuniculus*) carried out by the Horus Institute and six were evaluated for this study (Hedgehog *Erinaceus europaeus*, Skunk *Mephitis mephitis*, Gerbil *Meriones unguiculatus*, *Petaurus breviceps*, Chipmunk *Tamias sibiricus* and Stoat *Mustela erminea*) (Table 3). All the eight potentially invasive species showed very high invasion risk and the lagomorphs and rodents had the highest risk values (Table 3).

Risk assessment for species analyzed in this study and the literature related is available as part of the on-line article (Appendix A).

Discussion

Exotic and invasive terrestrial mammals in Brazil

We provide the first global assessment of the status and distribution of the exotic and invasive mammals in Brazil. The number of exotic mammal species with feral population established in Brazil represents 1% of the mammal species in Brazil (Paglia et al. 2012), below the level found in other South-American countries (Jacksic 1998; Jaksic et al. 2002; Novillo and Ojeda 2008).

The distribution of invasive mammals in Brazil is concentrated in the South, Southeast and Midwest regions, where are located the Brazilian Atlantic Forest and Cerrado, the two Brazilian biodiversity hotspot and priority for conservation (Myers et al. 2000). Most invasive mammals from Eurasia occupy ecoregions similar to their native ranges, and some species with broad niche have experienced a range expansion to new habitat types (e.g. European hare and Wild pig) (Novillo and Ojeda 2008). Moreover, some of the invasive species still remain as small populations with restricted distributional ranges (e. g. Indian sambar and Feral Goat). Also the Rocky cave expanded their ranges from original semi-arid habitats to forestry habitats (Pimentel 2011), while the invaded ecoregions by callitrichid primates match with original biome and ecological attributes of species (Rylands and Mendes 2008a, 2008b; Rylands et al. 2008a) but because of the lack of studies and the unknown historic of invasions the invasion range of callitrichid primates is probably subestimated in our study.

Ehrlich (1989) listed 11 attributes (e.g. broad diet and habitat, association with humans, high reproductive and dispersal capacity) as predictors of invasion successfully by terrestrial vertebrates and at least six invasive species in Brazil (Wild pigs, Feral goats, European hare, Swamp buffalo and Old world rats) encompass most, if not all, of these traits. Furthemore, four of these invader mammals (House rat, House mouse, Wild pigs and Feral Goat) are among the 100 worst invasive species of the world (Lowe et al. 2000). Beside the attributes of species, both habitat area and conditions are also important attributes to invasion susceptibility (Hobbs 2001; Graham et al. 2012; Gibson 2013). Smaller fragments and islands are often more prone to invasive species (Hobbs 2001; Duncan and Forsyth 2006, Howald et al. 2007) and the habitat loss and isolation of patches are responsible for improve biological invasions, including extinctions of endemic species (e.g. Graham et al. 2012; Gibson 2013), especially when the landscape is dominated by cropping and near human occupations (Graham et al. 2012; Frigeri et al. 2014). Gibson (2013) estimated catastrophic extinctions of small mammals by an invasive rat species after the isolation of areas no more than 56 ha driven by an artificial reservoir. Because of that the mostly preoccupant issue is the biological invasions encompassing Brazilian Protected areas and islands of Brazilian Atlantic Forest and Cerrado since both are located in one of the most populated Brazilian region and the Brazilian Atlantic Forest is one of the most endangered tropical forests worldwide, with only 12% of remaining original cover area represented mostly by fragments with less than 50 ha (Ribeiro et al. 2009).

Exotic and invasive terrestrial mammal account and impacts

Old World Rats

The small cosmopolitan rodents from Eurasia, House rat *Rattus rattus*, House mouse *Mus musculus* and Brown rat *Rattus norvegicus*, were unintentionally introduced in the South America during the discovery and colonization period in the 16th century (Pimentel 2011). The three species occur throughout Brazil where they have expanded their ranges in conjunction with human settlements, urban and agricultural areas but also in preserved environments, including protected areas (Long 2003; Olifiers et al. 2005; Junior and Leite 2007; Lambert et al. 2008; Passamani and Fernandez 2011; Pimentel 2011; Kajdacsi et al. 2013).

With a high ecological plasticity (Long 2003, Lambert et al. 2008, Bramley 2014), the old world rats are a threat to human health, since they are hosts of many diseases such as Trichinosis, Typhus, Rat Bite Fever, Bubonic Plague and Leptospirosis (Webster and Macdonald 1995; Himsworth et al.2013; Kosoy et al.2010). Furthermore they are responsible for the destruction of crops and predation of native species, from invertebrates to reptiles, birds and mammals (Zepellini et al. 2007; Masi et al. 2010; Kajdacci et al. 2013; Sarmento et al. 2014), including rare species like the Red-billed tropicbird *Phaethon aethereus*, which has restricted distribution in Brazil and whose eggs and juveniles are predated by rodents (Sarmento et al. 2014).

Large ungulates

Both Feral Goats *Capra hircus* and Wild horses *Equus caballus* were intentionally introduced in Brazil during the discovery and colonization period in the 16th century (Long 2003; Pimentel 2011). Feral Goats were introduced mainly raised for food, and have formed some feral populations in South and Southeast states of Brazil, including islands (Pimentel 2011; I3N Brasil 2015) (Fig. 1). Despite their potential for altering vegetation and transmitting diseases (Long 2003), no study has assessed this issue to date. Wild horses occur in open areas of Savanna vegetation in Amazon Biome and their impacts are also unknown where they live as free-roaming or feral animals.

The other two invasive ungulate species, Indian sambar and Swamp buffalo *Bubalus bubalis*, were intentionally introduced in Brazil in the 19 and 20th century. Two isolated feral population of Indiam sambar are known to be introduced in São Paulo State for sport hunting and no events of dispersion to other sites or ecological problems have been reported (Pimentel 2011; I3N Brasil 2015). Finally, the Swamp buffalo is the largest ungulate living in feral populations in Brazil and were first introduced on Marajo Island for work animal purpose. Currently the Swamp buffalo is showing an expansion of the distribution area in Brazil territory by means of natural dispersal and voluntary introductions for livestock and hunting (personal observation). There are official records in at least 10 Brazilian states (Pimentel 2011; I3N Brazil 2015), but some feral groups have been seen recently in other states, like Acre (Charneca F, personal communication), Tocantins and Goiás (Furtado C, personal communication). The impacts of Swamp buffalo in Brazil are unknown but because of overgrazing and trampling, the Swamp buffalo have a huge potential to damage flood plain and pasture environments by altering vegetation structure, tramping of wildlife nests and soil erosion (Stocker 1971;

Georges and Kennett 1989). Swamp buffalo are also a risk to livestock production acting as reservoirs of bovine tuberculosis (Garine-Wichatitsky et al. 2010).

Lepus europaeus

The European hare, native on grasslands of Eurasia, arrived to South American in late 19th century from Germany to Argentina and Chile to serve as hunting game and spread into southern Brazil in the 50s by means of natural dispersal across the border with Uruguay and through voluntary introductions (Grigera and Rapoport 1983, Long 2003, Costa and Fernandes 2010). Because of its high degree of ecological plasticity, the range of the European hare in Brazil continues to expand at a rate of 45.35 km/year (Faria et al. 2015) and they use mainly pastures, *Pinus* spp. and *Eucalyptus* spp. plantations and other agricultural areas that are typical of South and Southeast Brazil (Auricchio and Olmos 1999).

The unregulated practice of hunting certain species of potential predators, such as wild canids and felids (De La Sancha et al. 1999), and the transformation of forested areas into monocultures, which also serve as an abundant food resource for European hares, may have a combined effect that has facilitated the species invasion in southern Brazil and Paraguay (De La Sancha et al. 1999; Bonino et al. 2010). The ecological impacts of European hare in tropical environments are unknown, but it can put native species at risk acting as vectors of diseases, such as European Brown Hare Syndrome, Pseudotuberculoses, and Coccidiosis (Novillo and Ojeda 2008), and parasites, such as *Fasciola hepatica* (Grigera and Rapoport 1983; Auricchio and Olmos 1999; Edwards et al. 2000; Kleiman et al. 2004).

Sus scrofa

The wild pigs, native to Eurasia and northwestern Africa, are one of the oldest species intentionally introduced by humans (Courchamp et al. 2003, Long 2003). Wild pigs arrived in South America and Brazil in the 16th century for meat consumption of discovers and colonizers, and in late 20th century wild pigs arrived from Uruguay to south of Brazil and several introductions were made for all of the country for meat production and hunting (Oliveira 2012). Now they occur in all Brazilian political regions (Pedrosa et al. 2015). With a broad diet (Spitz 1986; Oliver 1993; Long 2003) and a rooting and wallowing behavior wild pigs are recognized as an important alien ecosystem engineers (Cuevas et al. 2012).

Wild pigs have the capacity to changing the soil structure (Singer et al. 1981; Cuevas et al. 2012), vegetation cover through suppression of native species (Barrios-Garcia and Ballari 2012; Cuevas et al. 2012) and alteration in the seed bank structure (Ickes et al. 2001; Webber et al. 2010). With the recent invasion boom in late 20th century, many works are arising concerning the effects of wild pigs in Brazilian environemnts. In the Brazilian Pantanal they occur sympatrically with native tayassuidae species (Desbiez et al 2009; Desbiez et al 2011) but because the differences in cranial anatomy, wild pigs root and graze to a greater extent than do peccaries (Ilse and Hellgren 1995; Sicuro and Oliveira 2002). In the Brazilian Atlantic Forest they disrupt streams and become a potential risk to biodiversity and water resource quality (Rosa et al., in press).

Kerodon rupestris

The Rock cavy is a native rodent from the Brazilian Caatinga biome and in 1967 the species was introduced in the Fernando de Noronha Archipelago by military personnel as hunting game (Pimentel 2011). In their original environment the individuals typically use the rocky areas with little vegetation, using cracks as shelter, and are threatened by illegal hunting, due to the large size when compared to other rodents and their meat quality (Streilen 1982). The species is herbivorous-omnivorous and outside of their original habitat they can compete with native animals for food (fruits and roots) and disperse seeds that can lead to vegetation changes (I3N Brasil 2015). There are no systematic studies about the effect of the Rocky cavy in Fernando de Noronha Archipelago, but is known that the habit of biting the base of trees can cause their death and treefall, eventually exposing soils to erosion and leading to degradation of natural environments and supression of vegetation (I3N Brasil 2015). However, due to the lack of knowledge about the ecology of the species, it is not possible to conclude if it has a high invasive potential or if the environmental features of small islands, such as Fernando de Noronha, have facilitated the invasion process.

Callitrichid Primates

The callitrichid primates were introduced in different places of Brazil due to collection as pets and misguided release of confiscated animals. The Common Marmoset *Callithrix jacchus* naturally occurs in the Scrub Forest of the Caatinga and Atlantic forest of north-eastern Brazil (Rylands et al. 2008a). Recent invasive populations in Brazil were reported in different Brazilian Atlantic Forest environments, including islands and Protect areas (Coimbra-Filho 1984; Alonso et al. 1987; Ruiz-Miranda et al. 2000; Santos et al. 2005; Rylands et al. 2008a). This species is very adaptable and currently has a cosmopolitan range, being present in urban parks, gardens, rural villages and even in the core of many urban centers (Rylands et al. 2008a). The Black-tufted-ear Marmoset *Callithrix penicilatta* has a wide natural distribution in Southeast, Northeast and Midwest of Brazil (Hershkovitz 1977), occurring in gallery forests, dry forests and forest patches in the Brazilian Cerrado. Invasions have been reported in Brazilian Atlantic Forest environments of South and Southeast of Brazil (Coimbra-Filho 1984; Vivo 1991; Santos et al. 2005; Rylands and Mendes 2008a). Finally, the Geoffroy's Marmoset (*Callithrix geoffroyi*) occurs naturally in Espirito Santo, Minas Gerais and Bahia states (Ávila-Pires 1969; Hershkovitz 1977; Coimbra-Filho 1984; Rylands et al. 1988) and was introduced to the south of Brazil in Santa Catarina state (Santos et al. 2015).

All three species have a varied diet, including fruits, flowers, animal prey (including frogs, snails, lizards, spiders and insects) and gum from trees (Coimbra-Filho 1972; Rylands 1984; Rylands and Mendes 2008a,b). The impacts of these species in alien environments are poorly known. It is believed that the invasive populations may be displacing, competing and hybridizing with the Buffy-headed Marmoset *Callithrix flaviceps* and Buffy-tufted-ear Marmoset *Callithrix aurita* in their respective native ranges (Mendes and Melo 2007; Rylands and Mendes 2008b,c). Additionally, the three invasive species occur in sympatry in Santa Catarina state with risks of hybridization between them (Santos et al. 2005).

Risk Assessment of exotic mammals in Brazil

The Horus Institute conducted risk assessments for 29 mammal species (I3N Brasil 2015). Of these, 28% had low risk, 7% had high risk including the already invasive Indian sambar, Wild horse, Rock cavy and Black-tufted-ear Marmoset, and 41% had very high risk as all other invasive species in Brazil (I3N Brasil 2015). Mammal pet species sold in Brazil are a potential risk to biodiversity conservation and native ecosystems since they have high risk assessment values, similar to species that are already invasive in Brazil (I3N Brasil 2015). As the invasive species with feral populations established in Brazilian territory, the potential invaders exhibit ecological attributes considered as predictors of successful invaders (Ehrlich 1989; Rejmanek and Richardson 1996; Williamson 1996; Kolar and Lodge 2001; Clout and Rusell 2007).

Because the species in Table 3 do not occur in Brazil we could not discuss the effects of their invasions in Brazilian environments. But the effects of rodents, lagomorphs and carnivores invaders are well known worldwide. First, all species for sale in Brazilian pet shops may be carriers of important zoonoses and diseases that may eventually affect humans, native species and livestock (Long 2003; Barton et al. 2010; Pimentel 2011; Burrells et al. 2013; Krawczyket al. 2015). Rodents and lagomorphs have high reproductive capacity and omnivorous and generalist habits (Long 2003; Jones et al. 2005; Jones and Norbury 2011) which ensure a high capacity for occupation in different habitats with great variation in temperature and food resources (Fowler and Racey 1987; Long 2003; Anufriev and Arkhipov 2004; Faria et al. 2015). Carnivorous species have lower reproductive capacity when compared to rodents and lagomorphs (King 2002; Long 2003), but have a high displacement capacity (King 1983; Long 2003; Neiswenter et al. 2010; Veale et al. 2012), enhancing the spreading and establishing of invasive populations. The lack of natural predators and the generalist habits makes the introduction of predator as Skunk *Mephitis mephitis* and Stoat *Mustela erminea* a risk for Brazilian biodiversity conservation, since both prey different species of small to medium-sized vertebrates (Long 2003; Edwards and Forbes 2003; Azevedo et al. 2006; Alvarez et al. 2014), and some Brazilian environments (e.g. Brazilian Atlantic Forest) already suffer with defaunation of large predators and the release of domestic mesopredators such as dogs (*Canis familiaris*) (Paschoal et al. 2012).

The illegal fauna trade, especially for pet use, is common in South American (e.g. Bager et al. 2009; Alves et al. 2013; Bermudez et al. 2014) and to avoid new biological invasions we need to struggle it. For birds is known that at least 23% of Brazilian species are illegally sold as pets (Alves et al. 2013) and the five genera of turtles with occurrence in Colombia are known to be illegally sold in many countries (Bermudez et al. 2014). But, for mammals, little is known about which species are the main target of the trade and the pet trafficking route. The pet trafficking is expanding because of the increasing demand for unusual and wild animals to keep in human households that is expanding the number of species affected and is facilitated by internet where the most pet trafficking is reportedly done nowadays (Lavorgna 2015). The wildlife trafficking is international regulated by the Convention on the International Trade in Endangered Species 1975 (CITES), however the illegal pet trade is superficially discussed by conservation science and their targets, routes and effects need to be studied for allow environmental policies of regulation and control of wildlife trade.

Final considerations

Brazil has a diversity of unique ecosystems and endemic species (Myers et al. 2000) but has no policy to prevent biological invasions. Brazilian law and public opinion results in great limitations to lethal control of vertebrate populations and there are no public and private investments for the control of invasive vertebrates. The creation of Law 9605/1998, regulating conduct and activities harmful to the environment, and IBAMA Normative 93/1998, that regulates the importation and exportation of native and exotic wildlife were the first steps to prevent introductions of alien species in Brazil, but better tools to improve the control of invasive species are needed. Following the strategy of official lists of endangered species, we recommend a creation of a list of alien for

Brazilian territory with the possibility to update species records and associated ecological information.

In 2013, with the IBAMA Normative 03/2013, wild pigs were the first Brazilian experience of population control regulation of invasive vertebrates nationwide. Currently there are at least 7,000 Brazilian citizens licensed to voluntary control wild pigs and an average of 20 animals being killed per person/year (Rosa CA, unpublished data) with positives effects to populations of native species (Desbiez et al. 2011). We believe that this strategy that consists in a partnership between government and the population, need to be expanded to control of European hare and Swamp buffalo since their current distribution is expanding in Brazil with potential risks to native ecosystem.

Control techniques are more effective and less costly when performed on species that have established populations in small territories or that are found early in their invasion process, removing them faster than they reproduce and preventing re-invasion (Clout and Veitch 2002; Morrison et al. 2007). For Feral Goats, which have small and isolated populations established and a history of ecological impacts (Long 2003), we recommend the population eradication. For Rock cavy, which is threatened by hunting and fragmentation in their native habitat (Streilen 1982), we recommend a program with capture in Fernando de Noronha Island, where it is invasive, and reintroduction into their native habitat, after quarantine and other protocols to avoid parasite introduction and other possible adverse effects of such intervention. These can be made by a collective effort of the federal government and researchers. For the Callitrichids species, a collective effort with the population where these species are alien is necessary, due to their proximity with urban areas; usually the population itself perpetuates the invasive species by feeding them. In addition, in areas where there is another primate species that can be put in risk, eradication efforts must be considered.

The fauna of alien mammals of Brazil represents an enormous opportunity for research, so a national research program focused on understanding the ecological dynamics of alien species, especially in Protected Areas and islands would have a great positive impact. Understanding these factors may clarify the species selection strategies and habitat use in the different environments that are being colonized, helping the creation of more effective conservation planning against and to manage alien species in Brazil.

Bibliographic References

Alonso C, Faria DS, Langguth A, Santee DF (1987) Variação da pelagem na área de integração entre *Callithrix jacchus* e *Callithrix penicillata*. Rev Bras Biol 47(4):465-470

Alvarez JA, Davidson KA, Foster AM (2014) *Actinemys marmorata* (Western Pond Turtle) Nest Predation Association. Herpetol Rev 45(2):307-308

Alves RRN, Lima JRF, Araujo HFP (2013) The live bird trade in Brazil and its conservation implications: an overview. Bird Conserv Int 23:53-65. doi: :10.1017/S095927091200010X

Anufriev AI, Arkhipov GG (2004) Influence of body weight and size on the mode of wintering in hibernators of the Family Sciuridae in Northeastern Russia. Russ J Ecol 35(3):189–193. doi: 10.1023/B:RUSE.0000025970.36575.13

Auricchio P, Olmos F (1999) Northward Range Extension for the European Hare, *Lepus europaeus* Pallas, 1778 (Lagomorpha-Leporidae) in Brazil. Publicações Avulsas do Instituto Pau Brasil 2(1): 1-5

Ávila-Peres FD (1969) Taxonomia e zoogeografia do gênero *Callithrix* Erxleben, 1777 (Primates, Callitrichidae). Rev Bras Biol 29(1):46

Azevedo FCC, Lester V, Gorsuch W, Larivière S, Wirsing AJ, Murray D (2006) Dietary breadth and overlap among five sympatric prairie Carnivores. J Zool 269:127-135. doi: 10.1111/j.1469-7998.2006.00075.x

Bager A, Rosa CA, Piedras SRN (2009) Substrate and diet effects in *Trachemys dorbigni* (Testudines – Emydidae) hatchlings during the first 6 months of life. R Bras Agrociência 15(1-4):89-93.

Barrios-Garcia M, Ballari AS (2012) Impact of Wild boar (*Sus scrofa*) in its introduced and native range: a review. Biol Invasions 14: 2283-2300. doi: 10.1007/s10530-012-0229-6

Barton H D, Gregory AJ, Davis R, Hanon CA, Wisely SM (2010) Contrasting landscape epidemiology of two sympatric rabies virus strains. Mol Ecol 19:2725–2738. doi: 10.1111/j.1365-294X.2010.04668.x

Bermudez FJA, Goyneche OYR, Gómez MAB, Heredia RGH (2014) Illegal Trade of Tortoises (Testudinata) in Colombia: A Network Analysis Approach. Acta Biol Colomb 19(3):381-392. doi: 10.15446/abc.v19n3.41590

Blackwell GL (2005). Another World: The composition and consequences of the Introduced Mammal fauna of New Zealand. Aust Zool 33(1):108-118. doi: 10.7882/AZ.2005.008

Bomford M (2008) Risk assessment models for the establishment of exotic vertebrates in Australia and New Zealand: validating and refining risk assessment models. Invasive Animals Cooperative Research Centre, Canberra.

Bonino N, Cossíos D, Menegheti J (2010) Dispersal of the European hare, *Lepus europaeus* in South America. Folia Zool 59(1):9–15

Bramley GN (2014) Home ranges and interactions of kiore (*Rattus exulans*) and Norway rats (*R. norvergicus*) on Kapiti Island, New Zealand. N Z J Ecol 38(2): 328-334.

Burrells A, Bartley PM, Zimmer IA, Roy S, Kitchener AC, Meredith A, Wright SE, Innes EA, Katzer F (2013) Evidence of the three main clonal *Toxoplasma gondii* lineages from wild mammalian carnivores in the UK. Parasitology 140:1768–1776. doi: 10.1017/S0031182013001169

Chiba S (2010) Invasive non-native species' provision of refugia for endangered native species. Conserv Biol 24(4):1141-1147. doi: 10.1111/j.1523-1739.2010.01457.x

Clout MN, Russell JC (2007) The invasion ecology of mammals: a global perspective. Wildl Res 35:180–184. doi: 1035-3712/08/030180

Clout MN, Veitch CR (2002) Turning the tide of biological invasion: the potential for eradicating invasive species. In: Veitch CR, Clout MN (eds). Turning the tide: the eradication of invasive species (proceedings of the international conference on eradication of island invasives). Occasional Paper of the IUCN Species Survival Commission 27, *Gland, Switzerland*, pp 1-3.

Coimbra-Filho AF (1972) Aspectos inéditos do comportamento de sagüis do gênero *Callithrix* (Callithricidae, Primates). Rev Brasil Biol 32:505–512.

Coimbra-Filho AF (1984) Situação atual dos calitriquídeos que ocorrem no Brasil (Callitrichidae-Primates). In: de Mello MT (ed). A Primatologia no Brasil. Sociedade Brasileira de Primatologia, Brasília, pp 15-33.

Costa MD, Fernandes FAB (2010) Primeiro registro de *Lepus europaeus* Pallas, 1778 (Mammalia, Lagomorpha, Leporidae) no sul do Estado de Minas Gerais e uma síntese dos registros conhecidos para o sudeste do Brasil. Rev Bras Zoociências 1778(3):311–314.

Courchamp F, Chapuis JL, Pascal M (2003) Mammal invaders on islands: impact, control and control impact. Biol Rev 78:347–383. doi: 10.1017/S1464793102006061

Cuevas MF, Mastrantonio L, Ojeda RA, Jaksic FM (2012) Effects of Wild boar disturbance on vegetation and soil properties in the Monte Desert, Argentina. Mamm Biol 77(1):299–306. doi: 10.1016/j.mambio.2012.02.003

De la Sancha N, Mantilla-Meluk H, Ramirez F, Perez P, Mujica N, Troche A, Gimenez M (2009) Notes on geographic distribution. Mammalia, Lagomorpha, Leporidae, *Lepus europaeus*, Pallas, 1778: Distribution extension, first confirmed record for Paraguay. Check List 5:428-432

Desbiez ALJ, Bodmer RE, Santos SA (2009) Wildlife habitat selection and sustainable resource management in a Neotropical wetland. Int J Biodvers Conserv 1(1):11-20

Desbiez ALJ, Keuroghlian A, Piovezan U, Bodmer RE (2011) Invasive species and bushmeat hunting contributing to wildlife conservation: the case of feral pigs in a Neotropical wetland. Oryx 45(1): 78-83. doi: 10.1017/S0030605310001304

Duncan RP, Forsyth DM (2006) Modelling population persistence on islands: mammal introductions in the New Zealand archipelago. Proc R Soc B 273:2969–2975. doi: 10.1098/rspb.2006.3662

Edwards PJ, Fletcher MR, Berny P (2000) Review of the factors affecting the decline of the European brown hare, *Lepus europaeus* (Pallas, 1778) and the use of wildlife incident data to evaluate the significance of paraquat. Agric Ecosyst Environ 79:95–103. doi: 10.1016/S0167-8809(99)00153-X

Edwards MA, Forbes GJ (2003) Food habits of Ermine, *Mustela erminea*, in a forested landscape. Can Field Nat 117:245-248

Ehrlich PR (1989) Attributes of invaders and invading processes: vertebrates. In: Drake J, di Castri F, Groves R, Kruger R, Mooney HA, Rejmanek M, Williamson M (eds) Biological invasions: a global perspective, Wiley, USA, pp 315–328

Eisenberg JF, Redford KH (1999) Mammals of the neotropics the central neotropics. Vol.3. University of Chicago Press., Chicago, pp 93-94.

Faria GMM, Rosa CA, Correa GLC, Puertas F, Jiménez KMO, Perillo LN, Maia LHRD, Leles B, Paula RC, Rodriques FHGR, Passamani M (2015) Geographic Distribution of the European hare (*Lepus europaeus*) in Brazil and new records of occurrence for the Cerrado and Atlantic Forest biomes. Mammal doi: 10.1515/mammalia-2015-0036

Frigeri E, Cassano CR, Pardini R (2014) Domestic dog invasion in an agroforestry mosaic in southern Bahia, Brazil. Trop Conserv Sci 7(3):508-528.

Fowler PA, Racey PA (1987) Relationship between body and testis temperatures in the European hedgehog, *Erinaceus europaeus*, during hibernation and sexual reactivation. J Reprod Fert 81:567-573. doi: 10.1530/jrf.0.0810567

Garine-Wichatitsky M, Caron A, Gomo C, Foggin C, Dutlow K, Pfukenyi D, Lane D, Bel SL, Hofmeyr M, Hlokwe T, Michel A (2010) Bovine Tuberculosis in Buffaloes, Southern Africa. Emerg Infect Dis 16(5):884-885. doi: 10.3201/eid1605.090710

Georges A, Kennett R (1989) Dry-season distribution and ecology of *Carettochelys insculpta* (Chelonia: Carettochelydidae) in Kakadu National Park, northern Australia. Aust Wildl Res 16:323–35. doi: 10.1071/WR9890323

Gibson L, Lynam AJ, Bradshaw CJA, He F, Bickford DP, Woodruff DS, Bumrungsri S, Laurance WF (2013) Near-Complete Extinction of Native Small Mammal Fauna 25 Years After Forest Fragmentation. Science 341:1508-1510. doi: 10.1126/science.1240495

Graham CA, Maron M, MacAlpine CA (2012) Influence of landscape structure on invasive predators: feral cats and red foxes in the brigalow landscapes, Queensland, Australia. Wildlife Res 39(8): 661-676. doi: 10.1071/WR12008

Grigera DE, Rapoport EH (1983) Status and Distribution of the European Hare in South America. J Mammal 64(1):163–166. doi: 10.2307/1380771

Hershkovitz P (1977) Living New World monkeys (Platyrrhini), with an introduction to Primates. University of Chicago Press, Chicago.

Himsworth CG, Parsons KL, Jardine C, Patrick DM (2013) Rats, cities, people, and pathogens: a systematic review and narrative synthesis of literature regarding the ecology of rat-associated zoonoses in urban centers. Vector-Borne and Zoonotic Dis 13:349–359. doi: 10.1089/vbz.2012.1195

Hobbs RJ (2001) Synergisms among habitat fragmentation, livestock grazing, and iotic invasions in Southwestern Australia. Conserv Biol 15(6):1522-1528. doi: 10.1046/j.1523-1739.2001.01092.x

Hobbs RJ, Arico S, Aronson J, Baron JS, Bridgewater P, Cramer VA, Epstein PR, Ewel JJ, Klink CA, Lugo AE, Norton D, Ojima D, Richardson DM, Sanderson EW, Valladres F, Vilà M, Zamora R, Zobel M (2006) Novel ecosystems: theoretical and management aspects of the new ecological world order. Global Ecol Biogeogr 15:1–7. doi: 10.1111/j.1466-822X.2006.00212.x

Hobbs RJ, Higgs E, Harris JA (2009) Novel ecosystems: implications for conservation and restoration. Trends Ecol Evol 24(11). doi: 10.1016/j.tree.2009.05.012

Howald G, Donlan CJ, Galván JP, Russell JC, Parkes J, Samaniego A, Wang Y, Veitch D, Genovesi P, Pascal M, Saunders A, Tershy B (2007) Invasive Rodent eradication on Islands. Conserv Biol 21(5):1258-1268. doi: 10.1111/j.1523-1739.2007.00755.x

I3N Brasil. Base de dados nacional de espécies exóticas invasoras. IABIN – Rede Inter Americana de Informação sobre Biodiversidade Instituto Hórus de Desenvolvimento e Conservação Ambiental, Florianópolis – SC. http://i3n.institutohorus.org.br/www. Accessed 26 June 2015.

Ickes K, Dewalt SJ, Appanah S (2001) Effects of native pigs (*Sus scrofa*) on woody understory vegetation in a Malaysian lowland rain forest. J Trop Ecol 17(1):191-206. doi: 10.1017/S0266467401001134

ICMBio Instituto Chico Mendes para a Conservação da Biodiversidade (2016) Mapa temático e dados geoestatísticos das unidades de conservação federais. http:// http://www.icmbio.gov.br/portal/servicos/geoprocessamento/51-menu-servicos/4004-mapa-tematico-e-dados-geoestatisticos-das-ucs.html. Accessed 05 January 2016.

Ilse LM, Hellgren EC (1995) Resource partitioning in sympatric populations of Collared Peccaries and Feral Hogs in Southern Texas. J Mammal 76(3): 784-799. doi: 10.2307/1382747

Iriarte JA, Lobos GA, Jaksic FM (2005) Especies de vertebrados invasores en Chile y su control y monitoreo por agencias gubernamentales. Rev Chilena de Hist Nat 78:143–154. doi: 10.4067/S0716-078X2005000100010

Jaksic FM (1998) Vertebrate invaders and their ecological impacts in Chile. Biodiv Conserv 7:1427–1445. doi: 10.1023/A:1008825802448

Jaksic FM, Iriarte JA, Jimenez JE, Martinez DR (2002) Invaders without frontiers: cross-border invasions of exotic mammals. Biol Invas 4:157–173. doi: 10.1023/A:1020576709964

Jones CG, Lawton JH, Shachak M (1994) Organisms as ecosystem engineers. Oikos 69(3):373-386. doi: 10.1007/978-1-4612-4018-1_14

Jones C, Moss K, Sanders M (2005) Diet of hedgehogs (*Erinaceus europaeus*) in the upper Waitaki Basin, New Zealand: Implications for conservation. N Z J Ecol 29(1):29-35

Jones C, Norbury G (2011) Feeding selectivity of introduced hedgehogs *Erinaceus europaeus* in a dryland habitat, South Island, New Zealand. Acta Theriol 56:45–51. doi: 10.1007/s13364-010-0009-6

Junior VC, Leite YLR (2007) Uso de habitats por pequenos mamíferos no Parque Estadual da Fonte Grande, Vitória, Espírito Santo, Brasil. Bol Mus Biol Mello Leitão 21:57-77

Kajdacsi B, Costa F, Hyseni C, Porter F, Brown J, Rodrigues G, Farias H, Reis MG, Childs JE, Ko AI, Caccone A (2013) Urban population genetics of slum-dwelling rats (*Rattus norvegicus*) in Salvador, Brazil. Molecular Ecology 22:5056-5070. doi: 10.1111/mec.12455

King CM (1983) Mustela erminea. Mamm Species 195:1-8. doi: 10.2307/3503967

King CM (2002) Cohort variation in the life-history parameters of stoats *Mustela erminea* in relation to fluctuating food resources: a challenge to boreal ecologists. Acta Theriol 47(3):225–244. doi: 10.1007/BF03194145

Kleiman F, González N, Rubel D (2004) *Fasciola hepatica* (Linnaeus, 1758) en liebres europeas (*Lepus europaeus*, Pallas 1778) (Lagomorpha, Leporidae) en la región Cordillerana Patagónica, Chubut, Argentina. Parasitol Latinoam 59:68–71

Kolar CS, Lodge DM (2001) Progress in invasion biology: predicting invaders. Trends Ecol Evol 16(4):199-204. doi: 10.1016/S0169-5347(01)02101-2

Kosoy M, Bai Y, Sheff K, Morway C, Baggett H, Maloney SA, Boonmar S, Bhengsri S, Dowell SF, Sitdhirasdr A, Lerdthusnee K, Richardson J, Peruski LF (2010) Identification of Bartonella infections in febrile human patients from Thailand and their potential animal reservoirs. Am J Trop Med Hyg 82:1140–1145. doi: 10.4269/ajtmh.2010.09-0778.

Krawczyket A, van Leeuwen AD, Jacobs-Reitsma W, Wijnands LM, Bouw E, Jahfari S, van Hoek AHAM, der Giessen JWB, Roelfsema JH, Kroes M, Kleve J, Dullemont Y, Sprong H, de Bruin A (2015) Presence of zoonotic agents in engorged ticks and hedgehog faeces from *Erinaceus europaeus* in (sub) urban areas. Parasit Vectors 8: 210. doi: 10.1186/s13071-015-0814-5.

Lambert MS, Qhy RJ, Smith RH, Cowan DP (2008) The effect of habitat management on home-range size and survival of rural Norway rat populations. J Appl Ecol 45:1753-1761. doi: 10.1111/j.1365-2664.2008.01543.x

Lavorgna A (2015). The social organization of pet trafficking in cyberspace. Eur J Crim Policy Res 21: 353-370. doi: 10.1007/s10610-015-9273-y

Long JL (2003) Introduced Mammals of the World -Their History, Distribution and Influence. Csiro Publishing, Collingwood.

Lowe S, Browne M, Boudjelas S, De Poorter M (2000) 100 of the World's worst invasive Alien species a selection from the Global Invasive Species Database. Published by The Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN), *Gland, Switzerland.*

Masi E, Pino FA, Santos MG, Genehr L, Albuquerque JOM, Bancher AM, Alves JCM (2010) Socioeconomic and environmental risk factors for urban rodent infestation in Sao Paulo, Brazil. J Pest Sci 83:231–241. doi: 10.1111/j.1365-2664.2008.01543.x

Mendes CSL, De Melo FR (2007) Situação atual do sagüi-da-serra (*Callithrix flaviceps*) em fragmentos florestais na Zona da Mata de Minas Gerais. In: Bicca-Marques JC (ed) A Primatologia no Brasil. Vol.10, Guapimirim, pp 163-180.

Mooney HA, Mack RN, McNeely JA, Neville LE, Schei PJ, Waage JK (2005) Invasive alien species: a new synthesis. Island Press; Washington.

Morrison SA, Macdonald N, Walker K, Lozier L, Shaw R (2007) Facing the dilemma at eradication's end: uncertainty of absence and the Lazarus effect. Front Ecol Environ 5:271-276. doi: 10.1890/1540-9295(2007)5[271:FTDAEE]2.0.CO;2

Myers N, Mittermeier RA, Mittermeier CG, Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403:853-858. doi: 10.1038/35002501

Nentwig W, Kühnel E, Bacher S (2010) A Generic Impact-Scoring System Applied to Alien Mammals in Europe. Conserv Biol 24(1):302-311. doi: 10.1111/j.1523-1739.2009.01289.x

Novillo A, Ojeda RA (2008) The exotic mammals of Argentina. Biol. Invasions 10(8):1333–1344. doi: 10.1007/s10530-007-9208-8

Olifiers N, Gentile R, Fiszon JT (2005) Relation between small-mammal species composition and anthropic variables in the Brazilian Atlantic Forest. Braz J Biol 65(3):495-501. doi: 10.1590/S1519-69842005000300015

Oliveira CHS (2012) Ecologia e Manejo de javali (*Sus scrofa* L.) na América do Sul. Dissertation, Universidade Federal do Rio de Janeiro.

Paglia AP, Fonseca GAB, Rylands AB, Herrmann G, Aguiar LMS, Chiarello AG, Leite YLR, Costa LP, Siciliano S, Kierulff MCM, Mendes SL, Tavares V, Mittermeier RA, Patton JL (2012) Annotated Checklist of Brazilian Mammals. Occasional Papers in Conservation Biology No. 6, Conservation International, Arlington.

Paschoal AMO, Massara RL, Santos JL, Chiarello AG (2012). Is the domestic dog becoming an abundant species in the Atlantic forest? A study case in southeastern Brazil. Mammal 76: 67-76. doi: 10.1515/mammalia-2012-0501

Passamani M, Fernandez FAS (2011) Abundance and richness of small mammals in fragmented Atlantic Forest of southeastern Brazil. J Nat Hist 45(9):553-565. doi: 10.1080/00222933.2010.534561

Pedrosa F, Salerno R, Padilha FVB, Galetti M (2015) Current distribution of invasive feral pigs in Brazil: economic impacts and ecological uncertainty. Braz J Nat Conserv 13:84-87. doi: 10.1016/j.ncon.2015.04.005

Pereira LA, Ziller SR (2008) Manual de Análise de Risco para Vertebrados. Cinco Reinos/Instituto Horus/The Nature Conservancy. Florianópolis.

Pimentel D (2011) Biological Invasions: Economic and Environmental Cost of Alien Plant, Animal and Microbe Species. Second Edition. CRC Press, Taylor & Francis Group, Boca Raton, Florida.

Rejmanek M, Richardson DM (1996) What attributes make some plant species more invasive? Ecology 77:1655–166. doi: 10.2307/2265768

Ribeiro MC, Martensen JP, Ponzoni AC, Hirota MM (2009) The Brazilian Atlantic Forest: how much is left, and how is the remaining forest distributed? Implications for conservation. Biol Conserv 142: 1141-1153. doi: 10.1016/j.biocon.2009.02.021

Ruiz-Miranda CR, Affonso AG, Martins A, Beck B (2000) Distribuição do sagüi (*Callithrix jacchus*) nas áreas de ocorrência do mico-leão-dourado (*Leontopithecus rosalia*) no estado do Rio de Janeiro. Neotrop Primates 8(3): 98-101.

Rylands AB (1984) Exudate-eating and tree-gouging by marmosets (Callitrichidae, Primates). In: Chadwick AC, Sutton SL (eds) Tropical Rain Forest: The Leeds Symposium. Leeds Philosophical and Literary Society, Leeds, pp 155–168.

Rylands AB, Mendes SL (2008a) *Callithrix penicillata*. The IUCN Red List of Threatened Species. Version 2015.2. http://www.iucnredlist.org. Accessed 09 October 2015.

Rylands AB, Mendes SL (2008b) *Callithrix geoffroyi*. The IUCN Red List of Threatened Species. Version 2015.2. http://www.iucnredlist.org. Accessed 09 October 2015.

Rylands AB, Mittermeier RA, de Oliveira MM, Kierulff MCM (2008a) *Callithrix jacchus*. The IUCN Red List of Threatened Species. Version 2015.2. http://www.iucnredlist.org. Accessed 09 October 2015.

Rylands AB, Ferrari SF, Mendes SL (2008b) *Callithrix flaviceps*. The IUCN Red List of Threatened Species. Version 2015.2. http://www.iucnredlist.org. Accessed 09 October 2015.

Rylands AB, Kierulff MCM, Mendes SL, de Oliveira MM (2008c) *Callithrix aurita*. The IUCN Red List of Threatened Species. Version 2015.2. http://www.iucnredlist.org. Accessed 09 October 2015.

Rylands AB, Spironelo WR, Tornisielo VL, Lemos de Sá RM, Kierulff MCM, Santos IB (1988) Primates of the Rio Jequitinhonha Valley, Minas Gerais, Brazil. Primate Conserv 9:100-109

Sakai AK et al (2001) The population biology of invasive species. Ann Rev Ecol Syst 32:305–332. doi: 10.1146/annurev.ecolsys.32.081501.114037

Santos CV, Luz KP, Sant'anna FS (2005) As três espécies de primates do gênero *Callithrix* (*C. jacchus*, *C. penicillata* e *C. geoffroyi*) introduzidos na Ilha de Santa Catarina – SC: A importância de pesquisa na implantação do manejo. Porto Alegre, pp 13-18.

Sarmento R, Brito D, Ladle RJ, Leal GR, Efe MA (2014) Invasive house (*Rattus rattus*) and brown rats (*Rattus norvegicus*) threaten the viability of red-billed tropic bird (*Phaethon aethereus*) in Abrolhos National Park, Brazil. Trop Conserv Sci 7(4):614-627

Sicuro FL, Oliveira LFB (2002) Coexistence of peccaries and feral hogs in the Brazilian Pantanal wetland: an ecomorphological view. J Mammal 83(1): 207-217. doi: 10.1093/jmammal/83.1.207

Singer FJ, Otto DK, Tipton AR, Hable CP (1981) Home ranges, movements and habitat use of European Wild boar in Tennessee. J Wildl Manage 45:343–353

Spitz F (1986) Current state of knowledge of wild boar biology. Pig news and information 7(2):171-175

Stocker GC (1971) Water buffaloes and conservation in the Northern territory. Wildlife in Australia 8:10-12

Streilei KE (1982) Ecology of small mammals in the semiarid Brazilian Caatinga. IV. Habitat selection. Ann Carnegie Mus 51:331-343

Veale AJ, Clout MN, Gleeson DM (2012) Genetic population assignment reveals a long-distance incursion to an island by a stoat (*Mustela erminea*). Biol Invasions 14:735–742. doi: 10.1007/s10530-011-0113-9

Vitousek PM, D'Antonio CM, Loope LL, Westbrooks R (1996) Biological invasions as global environmental change. Am Sci 84:468–478.

Vivo M (1991) Taxonomia de Callithrix Erxleben, 1777 *(Callitrichidae, Primates)*. Fundação Biodiversitas para Conservação da Diversidade Biológica, Belo Horizonte, Brazil.

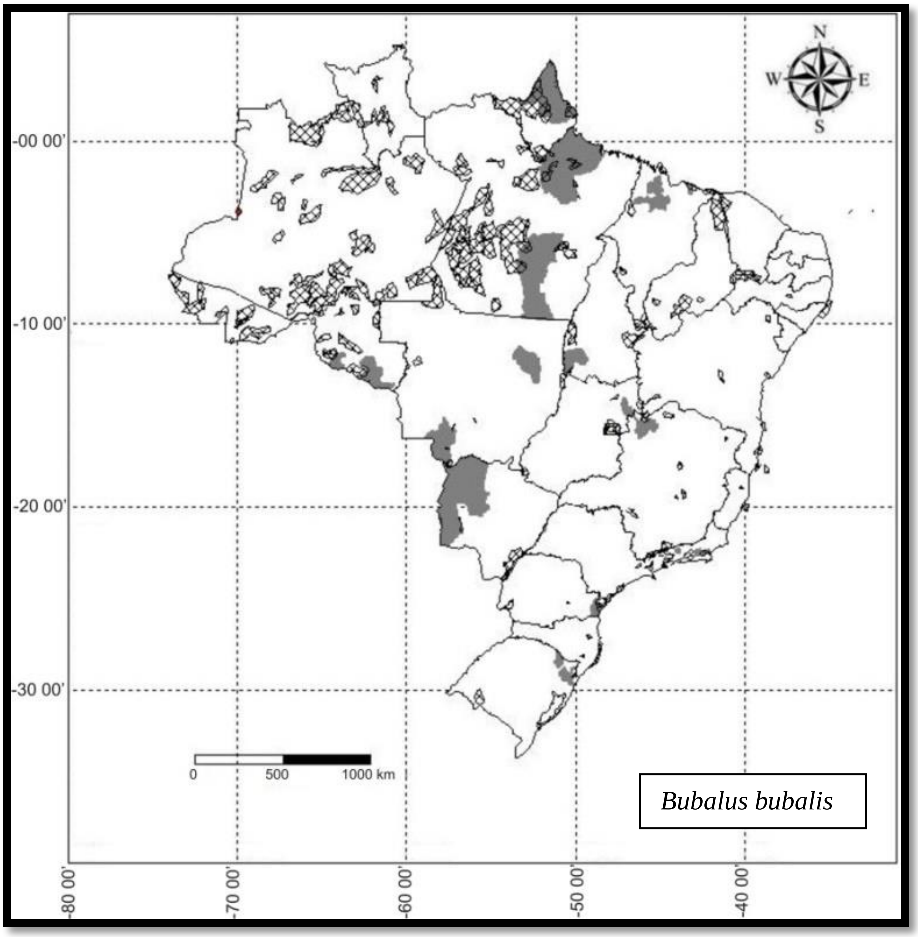
Webber B, Norton BA, Woodrow IE (2010) Disturbance affects spatial patterning and stand structure of a tropical rainforest tree. Austral Ecol 35(1):423-434. doi: 10.1111/j.1442-9993.2009.02054.x

Webster JP, Macdonald DW (1995) Parasites of wild brown rats (*Rattus norvegicus*) on UK farms. Parasitology 111:247–255. doi: 10.1017/S0031182000081804

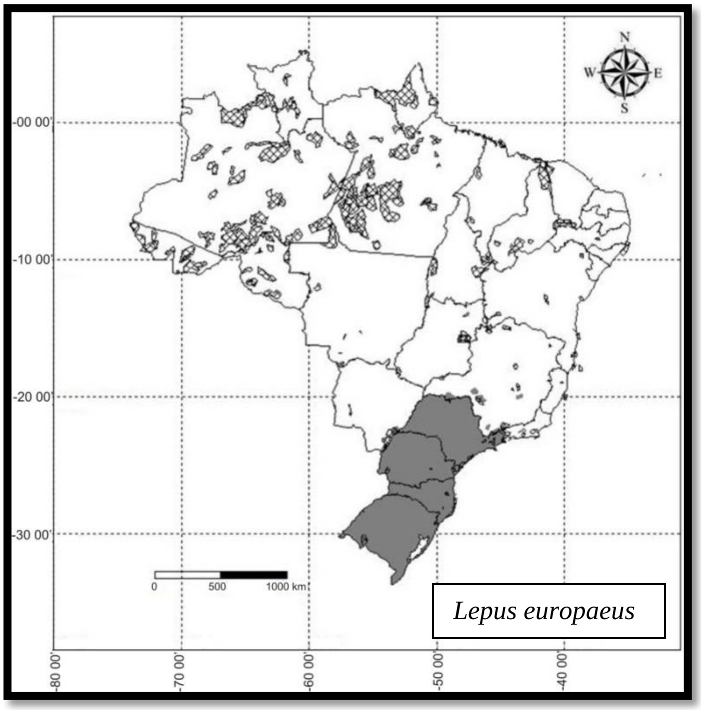
Williamson M (1996) Biological invasions. Chapman and Hall, USA

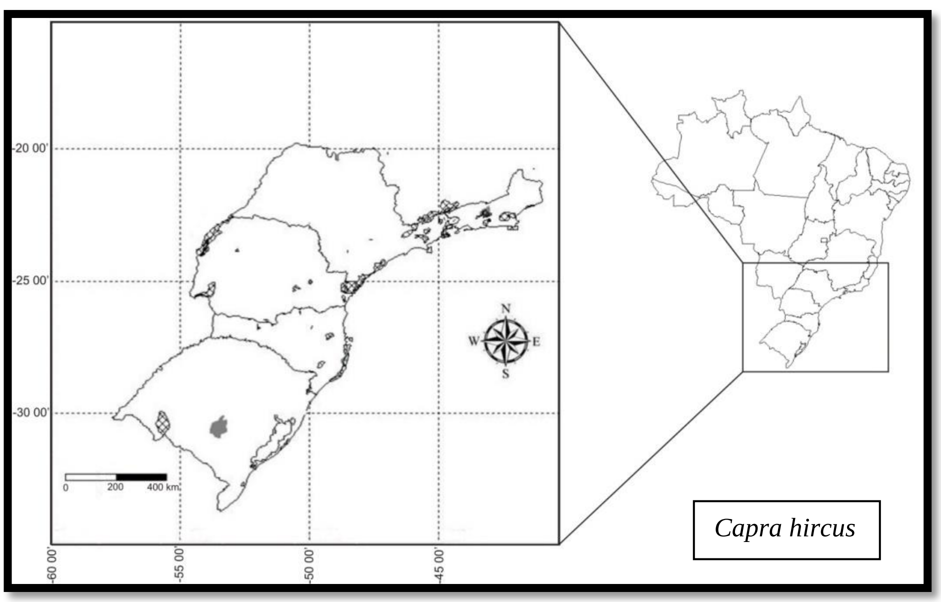
Zepellini D, Mascarenhas R, Meier GG (2007) Rat Eradication as Part of a Hawksbill Turtle (*Eretmochelys imbricata*) Conservation Program in an Urban Area in Cabedelo, Paraíba State, Brazil. Marine Turtle Newsletter 117:5-7.

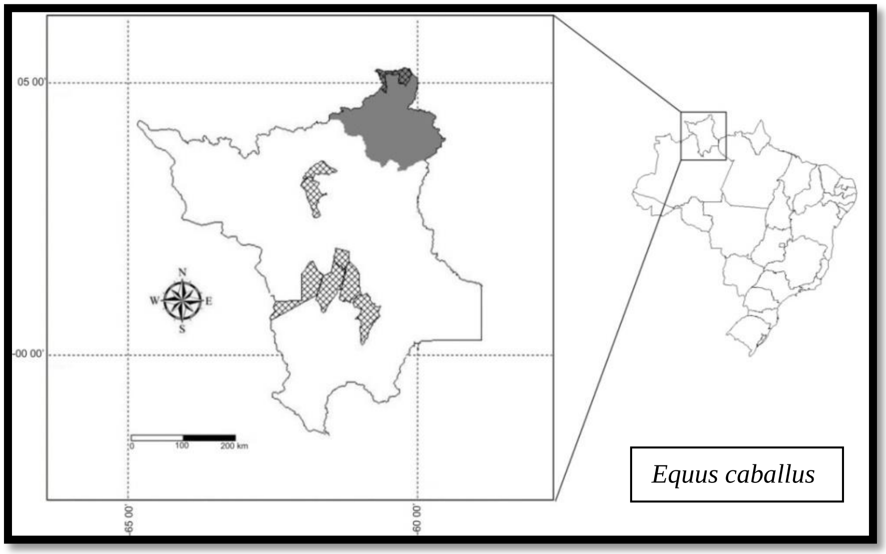
FIGURES


N
W
E
S
-00 00'
-10 00'
-20 00'
-30 00'
0
500
1000 km
Bubalus bubalis
-80 00'
-70 00'
-60 00'
-50 00'
-40 00'

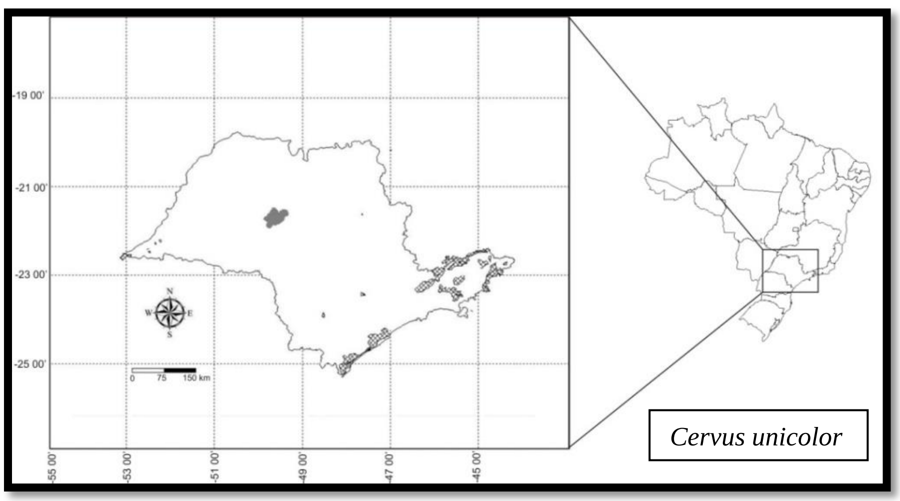

N
W
E
S
-00 00'
-10 00'
-20 00'
-30 00'
0
500
1000 km
Sus scrofa
-80 00'
-70 00'
-60 00'
-50 00'
-40 00'


-00 00'
-10 00'
-20 00'
-30 00'
-80 00'
-70 00'
-60 00'
-50 00'
-40 00'
N
S
W
E
0
500
1000 km
Lepus europaeus

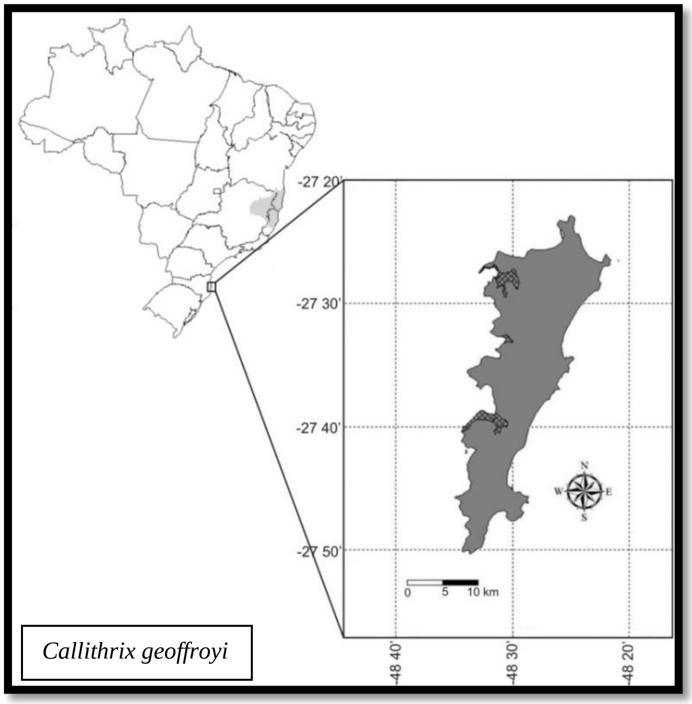

-20 00'
-25 00'
-30 00'
-60 00'
-55 00'
-50 00'
-45 00'
N
S
W
E
0
200
400 km
Capra hircus

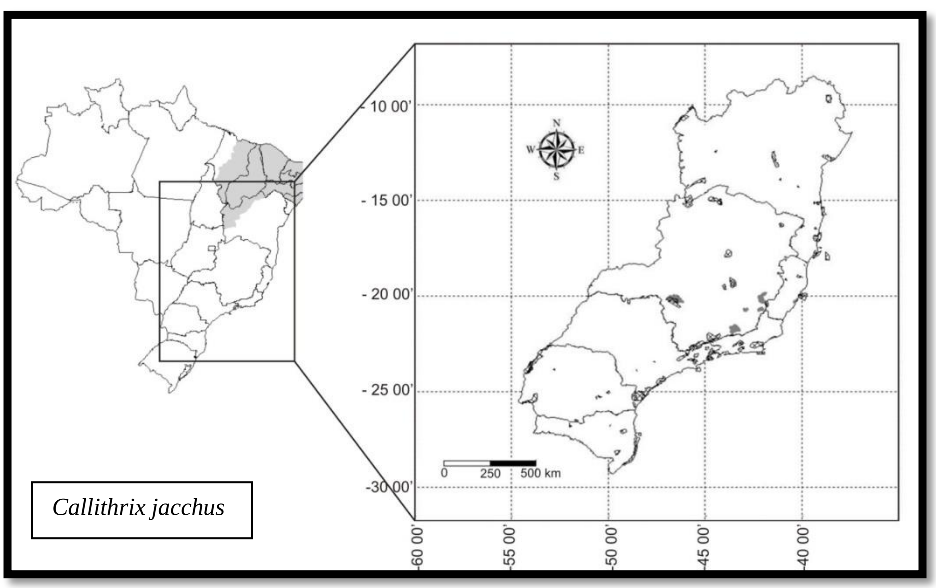


05 00'
-00 00'
-65 00'
-60 00'
N
S
W
E
0
100
200 km
Equus caballus



-19 00'
-21 00'
-23 00'
-25 00'
-55 00'
-53 00'
-51 00'
-49 00'
-47 00'
-45 00'
N
S
W
E
0
75
150 km
Cervus unicolor


-27 20'
-27 30'
-27 40'
-27 50'
0 5 10 km
N
W E
S
-48 40'
-48 30'
-48 20'
Callithrix geoffroyi


- 10 00'
- 15 00'
- 20 00'
- 25 00'
-30 00'
N
W E
S
0 250 500 km
-60 00'
-55 00'
-50 00'
-45 00'
-40 00'
Callithrix jacchus

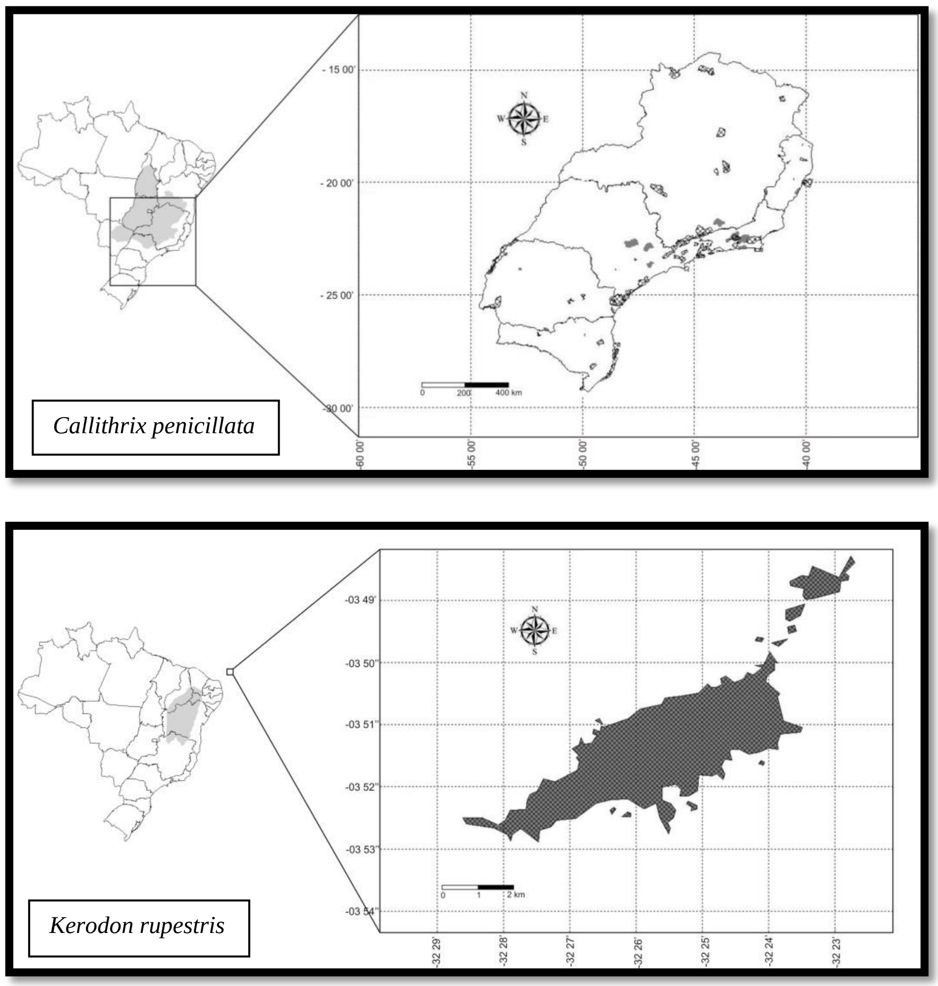


Fig 1: Current Distribution of invasive mammals in Brazil. For all species, the dark gray indicates the current distribution of invasive feral populations in Brazil. The hatching indicates the location of protected areas. For Brazilian species (*Callithrix geoffroyi*, *Callithrix jacchus*, *Callithrix penicillata* e *Kerodon rupestris*), light gray on the map of Brazil indicates the native distribution. The distribution of *Sus scrofa* was made using the work of Pedrosa et al. (2015) and distribution of *Lepus europaeus* was made using the work of Faria et al. (2015).

TABLES

Table 1: Invasion history, origin and current occurrence of invasive mammals in Brazil. 1: Information from Long (2003); 2: Information from Pimentel et al. (2011). 3: Information from Rylands and Mendes (2008a); 4: Information from Rylands et al. (2008a); 5: Information from Rylands and Mendes (2008b); 6: I3N Brasil 2015; 7: Pedrosa et al. (2015).

Species	Common Name	Origin	Introduction Year	Introduction Reason	Current Invasive Distribution in Brazil
Rattus rattus[1,2]	House rat	Asia	~1500	Portuguese colonization	All Brazilian regions
Rattus norvegicus[1,2]	Brown rat	Eurasia	~1500	Portuguese colonization	All Brazilian regions
Mus musculus[1,2]	House mouse	Eurasia	~1500	Portuguese colonization	All Brazilian regions
Lepus europaeus[1,2]	European hare	Eurasia	~1900	Hunt, arrive by Uruguay	South, Southeast and Midwest
Sus scrofa[1,2,7]	Wild pig	Eurasia and Africa	~1500	Hunt, Feeding	All Brazilian regions
Capra hircus[1,2,6]	Feral goat	Eurasia	1500's	Food source	South and Southeast
Bubalus bubalis[1,2]	Swamp buffalo	Asia	1895	Food and animal	All Brazilian regions

				work	
Equus cabalus[1,2,6]	Wild horse	Eurasia	1540	Portuguese colonization	Roraima state
Cervus unicolor[1,2,6]	Indian sambar	Asia	1980	Hunting	São Paulo state
Kerodon rupestris[2]	Rocky cave	Brazilian Caatinga	1967	Hunt by military	Fernando de Noronha Island
Callithrix jacchus[3]	Common Marmoset	Brazilian Atlantic Forest	NA	Pet release	South, Southeast and Northeast
Callithrix penicillata[4]	Black-tufted-ear Marmoset	Brazilian Atlantic Forest and Cerrado	NA	Pet release	Southeast
Callithrix geoffroyi[5]	Geoffroy's Marmoset	Brazilian Atlantic Forest and Cerrado	NA	Pet release	Florianopolis Island

Table 2: Ecological and biological characteristics of invasive mammals in Brazil. NA: No information available; 1: Information from Long (2003); 2: Information from Pimentel (2011); 3: Information from Eisenberg and Redford (1999); 4: Information from Rylands and Mendes (2008a); 5: Information from Rylands et al. (2008a); 6: Information from Rylands and Mendes (2008b).

Scientific Name	Weight (Kg)	Reprodutivy Rate (cub/female/year)	Diet	Social Behavior	Daily Movement (Km)
Rattus rattus[1]	0.09 to 0.35	5 to 72	Omnivorous	Group	up to 0.2
Rattus norvegicus[1]	0.12 to 0.9	30 to 132	Omnivorous	Colonial	0.5 to 3.3
Mus musculus[1]	0.01 to 0.04	6 to 84	Omnivorous	Solitary or Group	0.004 to 0.02
Lepus europaeus[1]	2 to 5	2 to 28	Herbivorous	Solitary	1.8 to 15
Sus scrofa[1]	15 to 190	2 to 24	Omnivorous	Group	0.5 to 15
Capra hircus[1]	15 to 79	1 to 2	Herbivorous	Group	20
Bubalus bubalis[1]	250 to 1200	1	Herbivorous	Group	3 to 10
Equus cabalus[1]	200 to 300	1 to 2	Herbivorous	Group	100
Cervus unicolor[1]	200 to 320	1	Herbivorous	Group	30
Kerodon rupestris[2,3]	0.7 to 0.9	4.5	Herbivorous, Omnivorous	NA	NA
Callithrix jacchus[4]	0.35 to 0.45	4	Insetivorous, Frugivorous, Gumivorous	Group	5 to 10

Callithrix penicillata[5]	0.35 to 0.45	4	Insetivorous, Frugivorous, Gumivorous	Group	5 to 10
Callithrix geoffroyi[6]	0.35 to 0.45	4	Insetivorous, Frugivorous, Gumivorous	Group	5 to 10

Table 3: Risk assessment for mammal species sold in Brazilian that are potential invasive species in Brazilian territory. The potential risk is classified in: very low (less than 11 points), low (between 11 and 32 points), moderate (between 32 and 45 points), high (between 45 and 65 points) and very high (above 65 points and a maximum of 150 points) (Pereira and Ziller 2008).

Species	Questions Answered	Points	Source	Risk Assessment
Mustela putorius	28	68.5	Instituto Horus (2015)	Very high
Meriones unguiculatus	34	88.5	This work	Very high
Oryctolagus cuniculus	33	95.5	Instituto Horus (2015)	Very high
Erinaceus europaeus	34	81.5	This work	Very high
Petaurus breviceps	34	71	This work	Very high
Tamias sibiricus	33	82.5	This work	Very high
Mephitis mephitis	31	79	This work	Very high
Mustela erminea	31	73	This work	Very high

Appendix A: Electronic Supplementary Material

Questions used in the Terrestrial Vertebrate Risk Assessment Analysis from Pereira and Ziller (2008) (Table 1) and analysis of *Erinaceus europaeus* (Table 2), *Tamias sibiricus* (Table 3), *Meriones unguiculatus* (Table 4), *Petaurus breviceps* (Table 5), *Mephitis mephitis* (Table 6) and *Mustela erminea* (Table 7).

Table 1: Protocol for Invasive Risk Assessment from Pereira and Ziller (2008)

HÓRUS INSTITUTE FOR ENVIRONMENTAL DEVELOPMENT AND CONSERVATION			
Terrestrial Vertebrates Risk Assessment Analysis			
Section	**Group**		**Question**
Biological and ecological characteristics			
A	Reproductive Mechanisms	1.01	Does the taxon present parental care (parents care for the young)?
		1.02	Is the taxon able to reproduce in a short time (less than 1 year)?
		1.03	Does the taxon reproduces throughout the year??
		1.04	Does the taxon produce a large number of progeny or offspring in each reproductive cycle (more than three)?
	Food Group	2.01	Is the taxon a carnivore?
		2.02	Is the taxon able to spend long periods without food?
		2.03	Does the taxon feed on or degrade vegetation (for example, conducts compactation)?
		2.04	Is the taxon omnivorous or generalist (eats more than one food item)?
	Ecological Interactions	3.01	Is the taxon aggressive or does it prey on other animals?
		3.02	Does the taxon defend the resources (nest or food) in its territory?
		3.03	Are their any effective natural predators of the

			taxon present in the region?
		3.04	Does the taxon use any resources (food, space, shelter) which causes some kind of competition with the native fauna?
		3.05	Does the taxon have some adversity resistance strategy (hibernation, reproduction early, change of fur or feather in winter)?
	Habitat	4.01	Can the taxon can travel long distances?
		4.02	Is the taxon is able to live in anthropogenic habitats (such as in gardens or among crops)?
		4.03	Is the taxon is able to live in environments with wide variations in temperature, humidity or endure stress?
Biogeographic aspects			
B	Occurrence	5.01	Does the taxon have a history of repeated introductions outside its natural range - **intentional introductions**?
		5.02	Are there recored of the taxon beimg established outside of its natural historically known range?
		5.03	Does the taxon present endemism in its region of origin?
		5.04	Are there old records of occurrence of this taxon in captivity outside its natural range?
		5.05	Are there records that the taxon is invasive in environments outside its natural range?
Social and economic aspects			
C	Economic importance of the taxon	6.01	Can the taxon be (or is) used in animal production, breeding or in rearing?
		6.02	Does the taxon have some ornamental attraction that could encourage its rearing or breeding in captivity?
		6.03	Is there occurrence of this taxon in environments

			close to their rearing area (or are there records of its escape from rearing - **unintentional introductions**)?
	Risk to People	7.01	Is the taxon aggressive with people or are there any records of accidents?
		7.02	Is the taxon is able to inoculate toxins or have some kind of poison that can affect people?
		7.03	Can the rearing of this taxon be harmful to public health or put people at risk (either through escape or animal waste)?
Risk potentiating characteristics			
D	Contamination by Pathogens and Parasites	8.01	Is the taxon susceptible to, or could it transmit some disease or parasite to other species of native fauna?
		8.02	Are there records of epidemics in this taxon (or genus) caused by viruses, protozoa, fungi or other parasites in other regions?
	Persistence Attributes	9.01	Is the taxon a mammal, bird, amphibian or reptile?
		9.02	Does some wild population of the species feed on or cause damage to agricultural production? (including pollution damage with feces and urine or nesting activities)
		9.03	Could the taxon disperse weeds or invasive plants?
		9.04	Is the taxon is used for human consumption?
		9.05	Could the taxon deform or cause physical damage to buildings or structures (fences, houses, water and electrical systems, other equipment)?
		9.06	It is possible and easy to find a form of effective control at a reasonable cost?
	Social Actors Involved	10.01	Are there breeders or stores that legally sell this taxon?
		10.02	Are there a large number of people who sell, use

			or raise this taxon in the country (including trafficking in animals)?
		10.03	Is the issue of animal transport guides easy for owners of breedering establishments?
		10.04	Are there government incentives for raising or marketing of this taxon?

Table 2: Invasive Risk Assessment for the Hedgehog *Erinaceus europaeus*

HÓRUS INSTITUTE FOR ENVIRONMENTAL DEVELOPMENT AND CONSERVATION				
RESULT				
Pontuation: 81.5			**Valid Avaliation (>70% of answers)**	**High Risk**
Terrestrial Vertebrates Risk Assessment Analysis				
Section	**Group**		**Answers *Erinaceus europaeus***	**References**
Biological and ecological characteristics				
A	Reproductive Mechanisms	1.01	Yes	(Long 2003)
		1.02	Yes	(Long 2003; Bunnell 2009)
		1.03	No	(Long 2003)
		1.04	Yes	(Long 2003)
	Food Group	2.01	No	(Long 2003)
		2.02	Yes	(Fowler and Racey 1987; Fowler and Racey 1990; Long 2003)
		2.03	No	(Jones and Norbury 2011)
		2.04	Yes	(Jones et al. 2005)
	Ecological Interactions	3.01	Yes	(Jackson and Green 2000; Long 2003; Jackson et al. 2004;

				Pimentel 2011; Kross et al. 2013; Hagman et al. 2015)
		3.02	No	(Moss and Sanders 2001; Rondinini 2007; Hof and Bright 2010)
		3.03		
		3.04	Yes	(Campbell 1973)
		3.05	Yes	(Fowler and Racey 1987; Fowler and Racey 1990; Long 2003)
	Hábitat	4.01	No	(Morris et al. 1992; Moss 1999; Moss and Sanders 2001; Long 2003; Riber 2006)
		4.02	Yes	(Long 2003; Baker and Harris 2007; Haigh et al. 2009; Dowding et al. 2010)
		4.03	Yes	(Fowler and Racey 1987; Fowler and Racey 1990; Long 2003)
Biogeographic aspects				
B	Occurrence	5.01	Yes	(Long 2003)
		5.02	Yes	(Long 2003)
		5.03	No	(Long 2003; Amori et al. 2008)
		5.04	Yes	(Long 2003)
		5.05	Yes	(Long 2003; Amori et al. 2008; DAISIE 2015)
Social and economic aspects				

C	Economic importance of the taxon	6.01	No	We did not found reasons (the. Meat consumption) encouraging the creation of this taxon
		6.02	Yes	(Long 2003)
		6.03	Yes	(Long 2003)
	Risk to People	7.01	No	There is no record
		7.02	No	There are no records of toxins inoculated by this species
		7.03	Yes	(English and Morris 1969; Long 2003; Cirak et al. 2010; Pimentel 2011; Krawczyket al. 2015)
Risk potentiating characteristics				
D	Contamination by Pathogens and Parasites	8.01	Yes	(English and Morris 1969; Long 2003; Cirak et al. 2010; Pimentel 2011; Krawczyket al. 2015)
		8.02		
	Persistence Attributes	9.01	Mammal	(Long 2003)
		9.02	No	(Moss and Sanders 2001)
		9.03		
		9.04	No	We did not find usage records for human consumption
		9.05		
		9.06	No	(Griffiths et al. 2015)

	Social Actors Involved	10.01	No	IBAMA information
		10.02		
		10.03	Yes	Only need waybill issued by any vet without restriction
		10.04	No	IBAMA information

Table 3: Invasive Risk Assessment for the Chipmunk *Tamias sibiricus*

HÓRUS INSTITUTE FOR ENVIRONMENTAL DEVELOPMENT AND CONSERVATION				
RESULT				
Pontuation: 82.5		**Valid Avaliation (>70% of answers)**		**High Risk**
Terrestrial Vertebrates Risk Assessment Analysis				
Section	**Group**		**Answers *Tamias sibiricus***	**References**
Biological and ecological characteristics				
A	Reproductive Mechanisms	1.01	Yes	(Long 2003)
		1.02	Yes	(Long 2003; DAISIE 2015)
		1.03	No	(NNSS 2015)
		1.04	Yes	(Long 2003; DAISIE 2015)
	Food Group	2.01	No	(Long 2003)
		2.02	Yes	(Long 2003; DAISIE 2015)
		2.03		
		2.04	Yes	(Long 2003)
	Ecological Interactions	3.01	Yes	(Forstmeier and Weiss 2004; NNSS 2015)
		3.02		
		3.03	Yes	(NNSS 2015)

		3.04	Yes	(Pimentel 2011; DAISIE 2015; NNSS 2015)
		3.05	Yes	(Anufriev and Arkhipov 2004; Long 2003; DAISIE 2015)
	Hábitat	4.01	No	(Marmet et al. 2009; Marmet et al. 2011; DAISIE 2015; NNSS 2015)
		4.02	Yes	(Long 2003; DAISIE 2015)
		4.03	Yes	(Fløjgaard et al. 2009; NNSS 2015)
Biogeographic aspects				
B	Occurrence	5.01	Yes	(Long 2003; NNSS 2015)
		5.02	Yes	(Long 2003; Benassi and Bertolino 2011)
		5.03	No	(Long 2003; Tsytsulina et al. 2008)
		5.04	Yes	(Long 2003)
		5.05	Yes	(Long 2003; Tsytsulina et al. 2008)
Social and economic aspects				
C	Economic importance of the taxon	6.01	No	We did not found reasons (the. Meat consumption) encouraging the creation of this taxon
		6.02	Yes	Sold in pet stores throughout Brazil

		6.03	Yes	(Long 2003; DAISIE 2015; NNSS 2015)
	Risk to People	7.01	No	There are no records of accidents and aggression
		7.02	No	There are no records of toxins inoculated by this species
		7.03	Yes	(Bonnet et al. 2015; NNSS 2015)
Risk potentiating characteristics				
D	Contamination by Pathogens and Parasites	8.01	Yes	(Kim et al. 2011; Marsot et al. 2011; Klein et al. 2015; NNSS 2015)
		8.02	No	There is no epidemic events
	Persistence Attributes	9.01	Mammal	(Long 2003)
		9.02	Yes	(Long 2003; DAISIE 2015; NNSS 2015)
		9.03	Yes	(Yi et al. 2015)
		9.04	No	We did not find usage records for human consumption
		9.05		
		9.06		
	Social Actors Involved	10.01	No	IBAMA information
		10.02		
		10.03	Yes	Only need waybill issued by any vet without restriction
		10.04	No	IBAMA information

Table 4: Invasive Risk Assessment for the Gerbil *Meriones unguicuatus*

HÓRUS INSTITUTE FOR ENVIRONMENTAL DEVELOPMENT AND CONSERVATION				
RESULT				
Pontuation: 88.5		**Valid Avaliation (>70% of answers)**		**High Risk**
Terrestrial Vertebrates Risk Assessment Analysis				
Section	**Group**		**Answers** ***Merioness unguiculatus***	**References**
Biological and ecological characteristics				
A	Reproductive Mechanisms	1.01	Yes	(Prates and Guerra 2005)
		1.02	Yes	(Gulotta 1971; Long 2003)
		1.03	Yes	(Gulotta 1971; Long 2003)
		1.04	Yes	(Gulotta 1971; Long 2003)
	Food Group	2.01	No	(Gulotta 1971; Long 2003)
		2.02		
		2.03	Yes	(Gulotta 1971; Agren et al. 1989)
		2.04	Yes	(Gulotta 1971; Long 2003)
	Ecological Interactions	3.01	No	(Long 2003)
		3.02		
		3.03	Yes	(Long 2003)
		3.04	Yes	(Scheiber et al. 2005; Scheibler and Wollnik 2009)

		3.05	Yes	(Li et al. 2001; Li and Wang 2005)
	Hábitat	4.01	No	(Long 2003)
		4.02	Yes	(Zhong et al. 1985; Wang and Zhong 1998; Scheiber et al. 2005)
		4.03	Yes	(Gulotta 1971; Scheiber et al. 2005)
Biogeographic aspects				
B	Occurrence	5.01	Yes	(Long 2003)
		5.02	Yes	(Long 2003)
		5.03	No	(Long 2003; Batsaikhan and Tsytsulina 2008)
		5.04	Yes	(Long 2003)
		5.05	Yes	(Long 2003; DAISIE 2015)
Social and economic aspects				
C	Economic importance of the taxon	6.01	Yes	(Gulotta 1971)
		6.02	Yes	Sold in pet stores throughout Brazil
		6.03	Yes	(Long 2003)
	Risk to People	7.01	No	(Gulotta 1971)
		7.02	No	There are no records of toxins inoculated by this species
		7.03	Yes	(Gaastra et al. 2009)
Risk potentiating characteristics				

D	Contamination by Pathogens and Parasites	8.01	Yes	(Langey and Gray 1987; Durbey and Lindsey 2000)
		8.02	No	(Gulotta 1971)
	Persistence Attributes	9.01	Mammal	(Long 2003)
		9.02	No	(Agren et al. 1989)
		9.03		
		9.04	No	We did not find usage records for human consumption
		9.05		
		9.06		
	Social Actors Involved	10.01	No	IBAMA information
		10.02	Yes	Common in pet stores and with large numbers of pets supporters in Brazil
		10.03	Yes	Only need waybill issued by any vet without restriction
		10.04	No	IBAMA information

Table 5: Invasive Risk Assessment for the Sugar glider *Petaurus breviceps*

HÓRUS INSTITUTE FOR ENVIRONMENTAL DEVELOPMENT AND CONSERVATION		
RESULT		
Pontuation: 71	**Valid Avaliation (>70% of answers)**	**High Risk**

Terrestrial Vertebrates Risk Assessment Analysis				
Section	**Group**		**Answers** *Petaurus breviceps*	**References**
Biological and ecological characteristics				
A	Reproductive Mechanisms	1.01	Yes	(Smith 1973; Long 2003)
		1.02	Yes	(Long 2003)
		1.03	Yes	(Smith 1973; Jackson 2000)
		1.04	No	(Long 2003; Smith 1973)
	Food Group	2.01	No	(Long 2003; Smith 1973; Smith 1982)
		2.02		
		2.03	No	(Smith 1973; Smith 1982)
		2.04	Yes	(Smith 1973; Smith 1982; Long 2003)
	Ecological Interactions	3.01	Yes	(Stojanovic et al. 2014; Heinsohn et al. 2015)
		3.02	No	(Schultze-Westrum 1969; Smith 1973)
		3.03		
		3.04	Yes	(Smith 1973; Lindenmayer and Cunningham 1997; Booth 2003)
		3.05	Yes	(Geiser 2004; Geiser et al. 2007; Quin et al. 2010)
	Hábitat	4.01	No	(Jackson 2000; Caryl et al. 2013; Taylor and

				Rohweder 2013)
		4.02	Yes	(Smith 1973; Caryl et al. 2013)
		4.03	Yes	(Geiser 2004; Geiser et al. 2007; Quin et al. 2010)
Biogeographic aspects				
B	Occurrence	5.01	Yes	(Long 2003)
		5.02	Yes	(Long 2003; Stojanovic et al. 2014; Heinsohn et al. 2015)
		5.03	No	(Smith 1973)
		5.04	Yes	(Booth 2003)
		5.05	Yes	(Long 2003)
Social and economic aspects				
C	Economic importance of the taxon	6.01	No	We did not found reasons (the. Meat consumption) encouraging the creation of this taxon
		6.02	Yes	Sold in pet stores throughout Brazil
		6.03	No	(Long 2003)
	Risk to People	7.01	No	(Booth 2003)
		7.02	No	There are no records of toxins inoculated by this species
		7.03	Yes	(Smith 1973; Nichols et al. 2015)
Risk potentiating characteristics				
D	Contamination by Pathogens	8.01	Yes	(Smith 1973; Holz and Graham 2008; Nichols

	and Parasites			et al. 2015)
		8.02	No	There is no epidemic events
	Persistence Attributes	9.01	Mammal	(Long 2003)
		9.02	No	(Smith 1973; Smith 1982)
		9.03		
		9.04	No	(Smith 1973)
		9.05		
		9.06		
	Social Actors Involved	10.01	No	IBAMA information
		10.02		
		10.03	Yes	Only need waybill issued by any vet without restriction
		10.04	No	IBAMA information

Table 6: Invasive Risk Assessment for the Skunk *Mephitis mephitis*

HÓRUS INSTITUTE FOR ENVIRONMENTAL DEVELOPMENT AND CONSERVATION				
RESULT				
Pontuation: 79		**Valid Avaliation (>70% of answers)**		**High Risk**
Terrestrial Vertebrates Risk Assessment Analysis				
Section	**Group**		**Answers *Mephitis mephitis***	**References**
Biological and ecological characteristics				
A	Reproductive Mechanisms	1.01	Yes	(Long 2003)
		1.02	No	(Long 2003)
		1.03	No	(Long 2003; Johnson-Delaney 2014)

		1.04	No	(Long 2003)
	Food Group	2.01	Yes	(Long 2003)
		2.02	Yes	(Aleksiuk and Stewart 1977; Mustonen et al. 2013)
		2.03	No	Taxon is carnivorous and there are no records of consumption or vegetation compression for any species of *Mephitis* sp.
		2.04	Yes	(Long 2003)
	Ecological Interactions	3.01	Yes	(Long 2003; Azevedo et al. 2006; Harrison et al. 2011; Alvarez et al. 2014)
		3.02		
		3.03		
		3.04		
		3.05	Yes	(Aleksiuk and Stewart 1977; Mustonen et al. 2013)
	Hábitat	4.01	Yes	(Rosatte et al. 1992; Larivière and Messier 1998; Long 2003; Neiswenter et al. 2010; Brashear et al. 2015)
		4.02	Yes	(Kowalski 2003; Harrison et al. 2011; Lesmeister et al. 2015)
		4.03	Yes	(Mustonen et al. 2013)
Biogeographic aspects				
B	Occurrence	5.01	Yes	(Long 2003)

		5.02	Yes	(Long 2003)
		5.03	No	(Long 2003; Reid and Helgen 2008b)
		5.04	Yes	(Long 2003)
		5.05	Yes	(Long 2003; DAISIE 2015)
Social and economic aspects				
C	Economic importance of the taxon	6.01	No	We did not found reasons (the. Meat consumption) encouraging the creation of this taxon
		6.02	Yes	(Long 2003)
		6.03	Yes	(Long 2003)
	Risk to People	7.01	Yes	(Johnson-Delaney 2014)
		7.02		
		7.03	Yes	(Dubey and Jones 2008; Barton et al. 2010; Gajadhar and Forbes 2010; Brown et al. 2014)
Risk potentiating characteristics				
D	Contamination by Pathogens and Parasites	8.01	Yes	(Dubey and Jones 2008; Barton et al. 2010; Gajadhar and Forbes 2010; Brown et al. 2014)
		8.02	Yes	(Brashear 2013; Brown et al. 2014)
	Persistence Attributes	9.01	Mammal	(Long 2003)
		9.02	No	There are no records of direct (consumption) or indirect (feces, urine, etc.) damage to agriculture
		9.03		

		9.04	No	We did not find usage records for human consumption
		9.05		
		9.06		
	Social Actors Involved	10.01	No	IBAMA information
		10.02		
		10.03	Yes	Only need waybill issued by any vet without restriction
		10.04	No	IBAMA information

Table 7: Invasive Risk Assessment for the Stoat *Mustela erminea*

HÓRUS INSTITUTE FOR ENVIRONMENTAL DEVELOPMENT AND CONSERVATION				
RESULT				
Pontuation: 68.5			**Valid Avaliation (>70% of answers)**	**High Risk**
Terrestrial Vertebrates Risk Assessment Analysis				
Section	**Group**		**Answers *Mustela erminea***	**References**
Biological and ecological characteristics				
A	Reproductive Mechanisms	1.01	Yes	(Long 2003)
		1.02	No	(King 2002; Queensland Government 2010)
		1.03	No	(King and Moody 1982; King 2002; Queensland Government 2010)
		1.04	Yes	(King 2002; Queensland Government 2010)
	Food Group	2.01	Yes	(Long 2003)
		2.02	No	(Harris and Yalden 2008)

		2.03	No	(Hoset et al. 2014)
		2.04	Yes	(Martinoli et al. 2001; King et al. 2003; Long 2003; Remonti et al. 2007)
	Ecological Interactions	3.01	Yes	(Edwards and Forbes 2003; Long 2003; Moorhouse et al. 2003; Elmeros 2006)
		3.02		
		3.03		
		3.04	Yes	(Erlinge 1983)
		3.05		
	Hábitat	4.01	Yes	(King 1983; Samson and Raymond 1995; Long 2003; Gillies et al. 2007; Reid and Helgen 2008; Veale et al. 2012)
		4.02	Yes	(Klemola et al. 1999; Ratz 2000; Smith et al. 2007; Queensland Government 2010; Cervinka et al. 2013)
		4.03		
Biogeographic aspects				
B	Occurrence	5.01	Yes	(Long 2003)
		5.02	Yes	(Long 2003)
		5.03	No	(Long 2003; Reid and Helgen 2008)
		5.04	Yes	(Long 2003)
		5.05	Yes	(Long 2003; Reid and Helgen 2008)

Social and economic aspects				
C	Economic importance of the taxon	6.01	No	We did not found reasons (the. Meat consumption) encouraging the creation of this taxon
		6.02	Yes	Sold in pet stores throughout Brazil
		6.03	No	(Long 2003)
	Risk to People	7.01		
		7.02	No	There are no records of toxins inoculated by this species
		7.03	Yes	(Queensland Government 2010; Burrells et al. 2013)
Risk potentiating characteristics				
D	Contamination by Pathogens and Parasites	8.01	Yes	(Pavlacik et al. 2007; Queensland Government 2010; Stuart et al. 2012; Burrells et al. 2013; Dubay et al. 2014; Oltean et al. 2014)
		8.02		
	Persistence Attributes	9.01	Mammal	(Long 2003)
		9.02	No	There are no records of direct (consumption) or indirect (feces, urine, etc.) damage to agriculture
		9.03		
		9.04	No	(Reid and Helgen 2008; Queensland Government 2010)
		9.05	No	(Queensland Government

				2010)
		9.06	No	(Queensland Government 2010; King et al. 2009)
	Social Actors Involved	10.01	No	IBAMA information
		10.02		
		10.03	Yes	Only need waybill issued by any vet without restriction
		10.04	No	IBAMA information

Bibliographic References

Agren G, Zhou Q, Zhong W (1989) Ecology and social behaviour of the Mongolian gerbil, *Meriones unguicalatus* at Xilinhot, inner Mongolia, China. Anim Behav 37:11–27. doi: 10.1016/0003-3472(89)90002-X

Aleksiuk M, Stewart AP (1977) Food intake, weight changes and activity of confined striped skunks (*Mephitis mephitis*) in winter. Am Midl Nat 98:331–342. doi: 10.2307/2424307

Alvarez JA, Davidson KA, Foster AM (2014) *Actinemys marmorata* (Western Pond Turtle) Nest Predation Association. Herpetol Rev 45(2):307-308.

Amori G, Hutterer R, Kryštufek B, Yigit N, Mitsain G, Palomo LJ (2008) *Erinaceus europaeus*. The IUCN Red List of Threatened Species 2008: http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T29650A9508219.en. Accessed 09 October 2015.

Anufriev AI, Arkhipov GG (2004) Influence of body weight and size on the mode of wintering in hibernators of the family Sciuridae in Northeastern Russia. Russ J Ecol35(3): 189–193. doi: 1067-4136/04/3503-0189

Azevedo FCC, Lester V, Gorsuch W, Lariviere S, Wirsing AJ, Murray DL (2006) Dietary breadth and overlap among five sympatric prairie carnivores. J Zool 269:127–135. doi: 10.1111/j.1469-7998.2006.00075.x

Baker P, Harris S (2007). Urban mammals: what does the future hold? An analysis of the factors affecting patterns of use of residential gardens in Great Britain. Mammal Rev 37 (4):297–315. doi: 10.1111/j.1365-2907.2007.00102.x

Barton HD, Gregory AJ, Davis R, Hanlon CA, Wisely SM (2010) Contrasting landscape epidemiology of two sympatric rabies virus strains. Mol Ecol 19:2725–2738. doi: 10.1111/j.1365-294X.2010.04668.x.

Batsaikhan N, Tsytsulina K (2008) *Meriones unguiculatus*. The IUCN Red List of Threatened Species 2008: http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T13171A3418036.en. Accessed 09 October 2015.

Benassi G, Bertolino S (2011) Distribution and activity of the introduced *Tamias sibiricus* (Laxmann, 1769) in an urban park in Rome, Italy. Mammal 75:87–90. doi: 10.1515/mamm.2010.066

Bonnet S, Choumet V, Masseglia S, Cote M, Ferquel E, Lilin T, Marsot M, Chapuis J, Vourch G (2015) Infection of Siberian chipmunks (*Tamias sibiricus barberi*) with *Borrelia* sp. reveals a low reservoir competence under experimental conditions. Ticks Tick Borne Dis 6: 393–400. doi: 10.1016/j.ttbdis.2015.03.008

Booth R (2003) Sugar Gliders. Sem Avian Exot Pet 12(4): 228-231.

Brashear WA (2013) An assessment of the genetic structure of a striped skunk (M*ephitis mephitis*) population across an urban landscape. Dissertation, Angelo State University.

Brashear WA, Ammerman LK, Dowler RC (2015). Short-distance dispersal and lack of genetic structure in an urban striped skunk population. J Mammal 96(1):72–80. doi: 10.1093/jmamma/gyu004

Brown LJ, Rosatte RC, Fehlner-Gardiner C, Ellison JA, Jackson FR, Bachmann P, Taylor JS, Franka R, Donovan D (2014) Oral vaccination and protection of striped skunks (*Mephitis mephitis*) against rabies using ONRAB ®. Vaccine 32:3675–3679. doi: 10.1016/j.vaccine.2014.04.029

Bunnell T (2009) Growth rate in early and late litters of the European hedgehog (*Erinaceus europaeus*). Lutra 52(1):15-22.

Burrells A, Bartley PM, Zimmer IA, Roy S, Kitchener AC, Meredith A, Wright SE, Innes EA, Katzer F (2013) Evidence of the three main clonal *Toxoplasma gondii* lineages from wild mammalian carnivores in the UK. Parasitology 140:1768–1776. doi:10.1017/S0031182013001169

Campbell PA (1973) The feeding behaviour of the Hedgehog (*Erinaceus europaeus*) in pasture land in New Zealand. Proc New Zeal Ecol Soc 20:35-40.

Caryl FM, Thomson K, Van Der Ree R (2013). Permeability of the urban matrix to arboreal gliding mammals: Sugar gliders in Melbourne, Australia. Austral Ecol 38:609–616. doi: 10.1111/aec.12006

Cervinka J, Sálek M, Padysáková E, Smilauer P (2013) The effects of local and landscape-scale habitat characteristics and prey availability on corridor use by carnivores: A comparison of two contrasting farmlands. J Nat Conserv 21:105–113. doi: 10.1016/j.jnc.2012.11.004

Cirak VY, Senlik B, Aydogdu A, Selver M, Akyol V (2010) Helminth parasites found in hedgehogs (*Erinaceus concolor*) from Turkey. Prev Vet Med 97:64–66. doi: 10.1016/j.prevetmed.2010.07.007

DAISIE (2015). Delivering Alien Invasive Species Inventories for Europe. http://www.europe-aliens.org/. Accessed 29 June 2015.

Dowding CV, Harris S, Poulton S, Baker PJ (2010). Nocturnal ranging behaviour of urban hedgehogs, *Erinaceus europaeus*, in relation to risk and reward. Animal Behaviour 80:13-21. doi: 10.1016/j.anbehav.2010.04.007

Dubay S, Buchholz MJ, Lisiecki R, Huspeni T, Ginnett T, Haen L, Borsdorf P (2014) Prevalence and intensity of nematode parasites in Wisconsin Ermine. J Parasitol 100(5):616-622. doi: 10.1645/13-486.1

Dubey JP, Jones JL (2008) *Toxoplasma gondii* infection in humans and animals in the United States. Int J Parasitol 38:1257–1278. doi: 10.1016/j.ijpara.2008.03.007

Dubey JP, Lindsay DS (2000) Gerbils (*Meriones unguiculatus*) are highly susceptible to oral infection with *Neospora caninum* oocysts. Parasitol Res 86:165-168. doi: 10.1007/s004360050027

Edwards MA, Forbes GJ (2003) Food Habits of Ermine, *Mustela erminea*, in a Forested Landscape. Can Field Nat 117:245-248.

Elmeros M (2006) Food habits of stoats *Mustela erminea* and weasels *Mustela nivalis* in Denmark. Acta Theriol 51(2):179–186. doi: 10.1007/BF03192669

English MP, Morris P (1969) *Trichophyton mentagrophytes* var *erinacei* in hedgehog nests. Sabouraudia 7:118-121. doi:

Erlinge S (1983) Demography and dynamics of a Stoat *Mustela erminea* population in a diverse community of vertebrates. J Anim Ecol 52(3): 705-726. doi: 10.2307/4449

Fløjgaard C, Morueta-Holme N, Skov F, Madsen AB, Svenning J (2009). Potential 21st century changes to the mammal fauna of Denmark – implications of climate change, land-use, and invasive species. Earth Environ Sci 8:1-17.

Forstmeier W, Weiss I (2004) Adaptive plasticity in nest-site selection in response to changing predation risk. Oikos 104: 487-499. doi: 10.1111/j.0030-1299.1999.12698.x

Fowler PA, Racey PA (1987) Relationship between body and testis temperatures in the European hedgehog, *Erinaceus europaeus*, during hibernation and sexual reactivation. J Reprod Fert 81:567-573. doi: 10.1530/jrf.0.0810567

Fowler PA, Racey PA (1990). Daily and seasonal cycles of body temperature and aspects of heterothermy in the hedgehog *Erinaceus europaeus.* J Comp Physiol B 160:299-307. doi: 10.1007/BF00302596

Gaastra W, Boot R, Ho HTK, Lipman LJA (2009) Rat bite fever. Vet Microbiol 133:211–228. doi: 10.1016/j.vetmic.2008.09.079

Gajadhar AA, Forbes LB (2010) A 10-year wildlife survey of 15 species of Canadian carnivores identifies new hosts or geographic locations for Trichinella genotypes T2, T4, T5, and T6. Vet Par 168:78–83. doi: 10.1016/j.vetpar.2009.10.012

Geiser F (2004) metabolic rate and body temperature reduction during hibernation and daily torpor. Annu Rev Physiol 66:239–74. doi: 10.1146/annurev.physiol.66.032102.115105

Geiser F, Holloway JC, Körtner G (2007) Thermal biology, torpor and behaviour in sugar gliders: a laboratory-Weld comparison. J Comp Physiol B 177:495–501. doi: 10.1007/s00360-007-0147-6

Gillies CA, Graham PJ, Clout MN (2007) Home ranges of introduced mammalian carnivores at Trounson Kauri Park, Northland, New Zealand. N Z J Zool 34:317-333. doi: 10.1080/03014220709510091

Griffiths R, Buchanan F, Broome K, Neilsen J, Brown D, Weakley M (2015) Successful eradication of invasive vertebrates on Rangitoto and Motutapu

Islands, New Zealand. Biol Invasions 17:1355–1369. doi: 10.1007/s10530-014-0798-7

Gulotta (1971) *Meriones unguiculatus*. Mamm Species 3: 1-5. doi: 10.2307/3503988

Hagman M, Löwenborg K, Shine R (2015) Determinants of anti-predator tactics in hatchling grass snakes (*Natrix natrix*). Behav Process 113:60–65. doi: 10.1016/j.beproc.2015.01.009

Haigh A, Butler F, O'Riordan RM (2012) Habitat use by the European hedgehog (*Erinaceus europaeus* L., 1758) in an Irish rural landscape. In: Butler F., Kelleher C (eds) All-Ireland Mammal Symposium 2009, Irish Naturalists' Journal, Belfast, pp 23-30.

Harris S, Yalden D (2008). Mammals of the British Isles (4th Revised ed.). Mammal Society. Coalville.

Harrison SWR, Cypher BL, Bremner-Harrison S, Job CLVH (2011) Resource use overlap between urban carnivores: Implications for endangered San Joaquin kit foxes (*Vulpes macrotis mutica*). Urban Ecosyst 14:303–311. doi: 10.1007/s11252-011-0155-x

Heinsohn R, Webb M, Lacy R, Terauds A, Alderman R, Stojanovic D (2015) A severe predator-induced population decline predicted for endangered, migratory swift parrots (*Lathamus discolor*). Biol Conserv 186:75–82. doi: 10.1016/j.biocon.2015.03.006

Hof AR, Bright PW (2010) The value of agri-environment schemes for macro-invertebrate feeders: hedgehogs on arable farms in Britain. Anim Conserv 13:467–473. doi: 10.1111/j.1469-1795.2010.00359.x

Holz PH, Graham KJ (2008) Neurological bacterial diseases in possums and gliders: a review of eight cases. Aust Vet J 86(8):302-302. doi: 10.1111/j.1751-0813.2008.00316.x

Hoset KS, Kyrö K, Oksanen T, Oksanen L, Olofsson J (2014) Spatial variation in vegetation damage relative to primary productivity, small rodent abundance and predation. Ecography 37: 894–901. doi: 10.1111/ecog.00791

Jackson SM (2000) Population dynamics and life history of the mahogany glider, *Petaurus gracilis*, and the sugar glider, *Petaurus breviceps*, in north Queensland. Wildl Res 27(1):21-37. doi: 10.1071/WR98044

Jackson DB, Green RE (2000) The importance of the introduced hedgehog (*Erinaceus europaeus*) as a predator of the eggs of waders (Charadrii) on machair in South Uist, Scotland. Biol Conserv 93:333-348. doi: 10.1016/S0006-3207(99)00135-4

Jackson DB, Fuller RJ, Campbell ST (2004) Long - term population changes among breeding shorebirds in the Outer Hebrides, Scotland, in relation to introduced hedgehogs (*Erinaceus europaeus*). Biol Conserv 117:151–166. doi: 10.1016/S0006-3207(03)00289-1

Johnson-Delaney C (2014) Pet Virginia opossums and skunks. J Exot Pet Med 23:317–326. doi: 10.1053/j.jepm.2014.07.011

Jones C, Norbury G (2011) Feeding selectivity of introduced hedgehogs *Erinaceus europaeus* in a dryland habitat, South Island, New Zealand. Acta Theriol 56:45–51. doi: 10.1007/s13364-010-0009-6

Jones C, Moss K, Sanders M (2005) Diet of hedgehogs (*Erinaceus europaeus*) in the upper Waitaki Basin, New Zealand: Implications for conservation. N Z J Ecol 29(1):29-35.

Kim HC, Han SH, Chong ST, Klein TA, Choi C, Nam H, Chae H, Lee H, Ko S, Kang J, Chae J (2011) Ticks Collected from Selected Mammalian Hosts Surveyed in the Republic of Korea During 2008-2009. Korean J Parasitol 49(3): 331-335. doi: 10.3347/kjp.2011.49.3.331

King CM, Moody JE (1982) The biology of the stoat (*Mustela erminea*) in the National Parks of New Zealand IV. Reproduction. N Z J Zool 9:103-118. doi: 10.1080/03014223.1982.10423840

King CM (1983). Mustela erminea. Mamm Species 195:1-8. doi: 10.2307/3503967.

King CM (2002) Cohort variation in the life-history parameters of stoats *Mustela erminea* in relation to fluctuating food resources: a challenge to boreal ecologists. Acta Theriol 47(3):225–244. doi: 10.1007/BF03194145

King CM, White PCL, Purdey DC, Lawrence B (2003) Matching productivity to resource availability in a small predator, the stoat (*Mustela erminea*). Can J Zool 81(4):662–669. doi: 10.1139/z03-042

King CM, McDonald RM, Martin RD, Dennis T (2009) Why is eradication of invasive mustelids so difficult? Biol Conserv 142:806-816. doi: 10.1016/j.biocon.2008.12.010

Klein TA, Kim HC, Chong S, Kim K, Lee S, Kim W, Nunn PV, Song J. 2015. Hantaan virus surveillance targeting small mammals at nightmare range, a high elevation military training area, Gyeonggi Province, Republic of Korea. Plos One 10(4):1-14. doi:10.1371/journal.pone.0118483

Klemola T, Korpimäki E, Norrdahl K, Tanhuanpää M, Koivula M (1999) Mobility and habitat utilization of small mustelids in relation to cyclically fluctuating prey abundances. Ann Zool Fenn 36:75–82.

Kowalski BL (2003) Effects of landscape covariates on the distribution and detection probabilities of mammalian carnivores on the former fortord, California. Dissertation, California State University Monterey Bay.

Krawczyket A, van Leeuwen AD, Jacobs-Reitsma W, Wijnands LM, Bouw E, Jahfari S, van Hoek AHAM, der Giessen JWB, Roelfsema JH, Kroes M, Kleve J, Dullemont Y, Sprong H, de Bruin A (2015) Presence of zoonotic agents in engorged ticks and hedgehog faeces from *Erinaceus europaeus* in (sub) urban areas. Parasit Vectors 8: 210. doi: 10.1186/s13071-015-0814-5.

Kross SM, Mcdonald PG, Nelson XJ (2013) New Zealand Falcon nests suffer lower predation in agricultural habitat than in natural habitat. Bird Conserv Int 23(4):512-519. doi: 10.1017/S0959270913000130

Langey RJ, Gray JS (1987) Age-related susceptibility of the Gerbil, *Meriones unguiculatus*, to the Bovine Parasite, *Babesia divergens*. Exp Parasitol 64:466-473. doi: 10.1016/0014-4894(87)90061-0

Larivière S, Walton LR, Messier F (2006) Summer movements and impact of individual Striped Skunks, *Mephitis mephitis* on duck nests in Saskatchewan. Can Field Nat 120(3):342–346.

Lesmeister D B, Nielsen CK, Schauber EM, Hellgren EC (2015) Spatial and temporal structure of a mesocarnivore guild in midwestern North America. Wildlife Monogr 191:1-61. doi: 10.1002/wmon.1015

Li XH, Wang D (2005) Seasonal adjustments in body mass and thermogenesis in Mongolian gerbils (*Meriones unguiculatus*): the roles of short photoperiod and cold. J Comp Physiol B 175:593–600. doi: 10.1007/s00360-005-0022-2

Li Q, Sun R, Huang C, Wang Z, Liu X, Hou J, Liu J, Cai L, Li N, Zhang S, Wang Y (2001) Cold adaptive thermogenesis in small mammals from different geographical zones of China. Comp Biochem Phys A 129:949-961.

Lindenmayer DB, Cunningham RB (1997) Patterns of co-occurrence among arboreal marsupials in the forests of central Victoria, southeastern Australia. Aust J Ecol 22:340-346. doi: 10.1111/j.1442-9993.1997.tb00680.x

Long JL (2003) Introduced Mammals of the World -Their History, Distribution and Influence. Csiro Publishing, Collingwood.

Marmet J, Pisanu B, Chapuis J (2009) Home range, range overlap, and site fidelity of introduced Siberian chipmunks in a suburban French Forest. Eur J Wildl Res 55:497–504. doi: 10.1007/s10344-009-0266-3

Marmet J, Pisanu B, Chapuis J (2011). Natal dispersal of introduced Siberian chipmunks, *Tamias sibiricus*, in a suburban forest. J Ethol 29:23–29. doi: 10.1007/s10164-010-0215-3

Marsot M, Sigaud M, Chapuis J, Ferquel E, Cornet M, Vourch G (2011) Introduced siberian chipmunks (*Tamias sibiricus barberi*) harbor more-diverse B*orrelia burgdorferi* sensu lato genospecies than native bank voles (M*yodes glareolus*). Appl Environ Microb 77(16):5716–5721. doi: 10.1128/AEM.01846-10

Martinoli A, Preatoni DG, Chiarenzi B, Wauters LA, Tosi G (2001) Diet of stoats (*Mustela erminea*) in an Alpine habitat: The importance of fruit consumption in summer. Acta Theriol 22:45−53. doi: 10.1016/S1146-609X(01)01102-X

Moorhouse R, Greene T, Dilks P, Powlesland R, Moran L, Taylor G, Jones A, Knegtmans J, Wills D, Pryde M, Fraser I, August A, August C (2003) Control of introduced mammalian predators improves kaka *Nestor meridionalis* breeding success: reversing the decline of a threatened New Zealand parrot. Biol Conserv 110:33–44. doi: 10.1016/S0006-3207(02)00173-8

Morris PA, Munn S, Craig-Wood S (1992) The effects of releasing captive hedgehogs (*Erinaceus europaeus*) into the wild. Field Stud 8:89-99.

Moss KA (1999) Diet, nesting behaviour, and home range size of the European hedgehog (*Erinaceus europaeus*) in the braide drivers of the Mackenzie Basin, New Zealand. Dissertation, University of Canterbury.

Moss K, Sanders M (2001) Advances in New Zealand mammalogy 1990–2000: Hedgehog. J Roy Soc New Zeal 31(1): 31-42. doi: 10.1080/03014223.2001.9517637. 10.1080/03014223.2001.9517637

Mustonen A, Bowman J, Sadowski C, Nituch LA, Bruce L, Halonen T, Puukka K, Rouvinen-Watt K, Aho J, Nieminen P (2013) Physiological adaptations to prolonged fasting in the overwintering striped skunk (*Mephitis mephitis*). Comp Biochem Phys A 166:555–563. doi: 10.1016/j.cbpa.2013.08.008

Neiswenter SA, Dowler RC, Young. JH (2010) Activity patterns of two sympatric species of Skunks (*Mephitis mephitis* and *Spilogale gracilis*) in Texas. Southwestern Nat 55(1):16-21. doi: 10.1894/PS-51.1

Nichols M, Takacs N, Ragsdale J, Levenson D, Marquez C, Roache K, Tarr CL (2015) *Listeria monocytogenes* infection in a Sugar Glider (*Petaurus breviceps*)–New Mexico, 2011. Zoonoses and Public Health 62:254–257. doi: 10.1111/zph.12134

NNSS (2015) Great Britain non-native species secretariat. http://www.nonnativespecies.org. Accessed 29 June 2015.

Pavlacik L, Celer V, Koubek P, Literak I (2007) Prevalence of canine distemper virus in wild mustelids in the Czech Republic and a case of canine distemper in young stone martens. Vet Med-Czech 52(2):69–73.

Pereira LA, Ziller SR (2008) Manual de Análise de Risco para Vertebrados. Cinco Reinos/Instituto Horus/The Nature Conservancy. Florianópolis.

Pimentel D (2011) Biological Invasions: Economic and Environmental Cost of Alien Plant, Animal and Microbe Species. Second Edition. CRC Press, Taylor & Francis Group, Boca Raton, Florida.

Prates EJ, Guerra RF (2005) Parental care and sexual interactions in Mongolian gerbils (*Meriones unguiculatus*) during the postpartum estrus. Behav Process 70:104–112. doi: 10.1016/j.beproc.2005.04.010

Queensland Government (2010) Pest risk assessment: Stoat (*Mustela erminea*). Department of Employment, Economic Development and Innovation Biosecurity Queensland, Queensland.

Quin DG, Riek A, Green S, Smith AP, Geiser F (2010) Seasonally constant field metabolic rates in free-ranging sugar gliders (*Petaurus breviceps*). Comp Biochem Phys A 155:336–340. doi: 10.1016/j.cbpa.2009.11.014

Ratz H (2000) Movements by stoats (*Mustela erminea*) and ferrets (*M. furo*) through rank grass of yellow-eyed penguin (*Megadyptes antipodes*) breeding areas. J Zool 27(1):57-69. doi: 10.1080/03014223.2000.9518210.

Reid F, Helgen K (2008a) *Mustela erminea*. The IUCN Red List of Threatened Species 2008. http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T29674A9523078.en. Accessed 09 October 2015.

Reid F, Helgen K (2008b) *Mephitis mephitis*. The IUCN Red List of Threatened Species 2008. http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T41635A10524738.en. Accessed 09 October 2015.

Remonti L, Balestrieri A, Prigioni C (2007) Role of fruits in the diet of small mustelids (*Mustela sp*.) from the western Italian Alps. Eur J Wildl Res 53: 35–39. doi: 10.1007/s10344-006-0058-y

Riber AB (2006) Habitat use and behaviour of European hedgehog *Erinaceus europaeus* in a Danish rural area. Acta Theriol 51(4): 363–371. doi: 10.1007/BF03195183

Rosatte R, Power M, MacInnes C, Campbell J (1992) Trap-vaccinate-release and oral vaccination for rabies control in urban skunks, raccoons and foxes. J Wildl Dis 28:562-571. doi: 10.7589/0090-3558-28.4.562

Samson C, Raymond M (1995) Daily activity pattern and time budget of stoats (*Mustela erminea*) during summer in southern Quebec. Mammal 59(4):501-510. doi: 10.1515/mamm.1995.59.4.501

Scheibler E, Liu W, Weinandy R, Gattermann R (2005) Burrow systems of the Mongolian gerbil (Meriones unguiculatus Milne Edwards, 1867). Mammal Biol 71(3): 178-182. doi:10.1016/j.mambio.2005.11.007

Scheibler E, Wollnik F (2009) Interspecific contact affects phase response and activity in Desert hamsters. Physiol Behav 98:288–295. doi: 10.1016/j.physbeh.2009.06.001

Schultze-Westrum TG 1969. Social communications by chemical signals in flying phalangers (*Petaurus breviceps papuanus*). In: Ptaffmann C (ed) Olfaction and taste. Rockefeller University Press, New York, pp. 268-277.

Smith MS (1973) *Petaurus breviceps*. Mamm Species 30:1-5. doi: 10.2307/3503785

Smith AP (1982) Diet and feeding strategies of the marsupial Sugar Glider in temperate Australia. J Anim Ecol 51(1):149-166. doi: 10.2307/4316

Smith DHV, Wilson DJ, Moller H, Murphy EC, van Heezik Y (2007) Selection of alpine grasslands over beech forest by stoats (*Mustela erminea*) in montane southern New Zealand. N Z J Ecol 31(1):88-97.

Stuart P, Zintl A, de Waal T, Mulcahy G, Hawkins C, Lawton C (2013) Investigating the role of wild carnivores in the epidemiology of bovine neosporosis. Parasitology 140:296–302. doi: 10.1017/S0031182012001588

Taylor BD, Rohweder D (2013) Radio-tracking three Sugar Gliders using forested highway median strips at Bongil Bongil National Park, north-east New South Wales. Ecol Manage Res 14(3):228-230. doi: 10.1111/emr.12063

Tsytsulina K, Formozov N, Shar S, Lkhagvasuren D, Sheftel B (2008) *Tamias sibiricus*. The IUCN Red List of Threatened Species 2008. http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T21360A9275610.en. Accessed 09 October 2015.

Veale AJ, Clout MN, Gleeson DM (2012) Genetic population assignment reveals a long-distance incursion to an island by a stoat (*Mustela erminea*). Biol Invasions 14:735–742. doi: 10.1007/s10530-011-0113-9

Wang GM, Wang ZW, Zhou QQ, Zhong WQ (1999) Relationship between species richness of small mammals and primary productivity of arid and semi-arid grasslands in northern China. J Arid Enrion 43:467–475.

Yi X, Wang Z, Liu C, Liu G (2015) Seed trait and rodent species determine seed dispersal and predation: evidences from semi-natural enclosures. iForest 8:207-213. doi: 10.3832/ifor1185-008

Zhong WQ, Zhou QQ, Sun CL (1985) The basic characteristics of the rodent pests on the pasture in Inner Mongolia and its ecological strategies of controlling. Acta Theriologica Sinica 5:242–249.

ARTIGO 2

Preparado segundo as normas da revista *Journal of Wildlife Management*

5-25-2015
Clarissa Alves da Rosa
Laboratório de Ecologia e Conservação de Mamíferos, Setor de Ecologia, Departamento de Biologia, Universidade Federal de Lavras
Campus Universitário, 37200-000, Lavras, Minas Gerais, Brazil
Phone +55 35 3829-1922
alvesrosa_c@hotmail.com

RH: Rosa et al. • Wild pigs and streams

Differential effects of exotic Eurasian wild pigs and native peccaries on physical integrity of streams in the Brazilian Atlantic Forest

CLARISSA ALVES DA ROSA, Laboratório de Ecologia e Conservação de Mamíferos, Setor de Ecologia, Departamento de Biologia, Universidade Federal de Lavras, Campus Universitário, 37200-000, Lavras, Minas Gerais, Brazil

MARCELO PASSAMANI, Laboratório de Ecologia e Conservação de Mamíferos, Setor de Ecologia, Departamento de Biologia, Universidade Federal de Lavras, Campus Universitário, 37200-000, Lavras, Minas Gerais, Brazil

PAULO SANTOS POMPEU, Laboratório de Ecologia e Conservação de Peixes, Universidade Federal de Lavras, Campus Universitário, 37200-000, Lavras, Minas Gerais, Brazil

ABSTRACT

Wild pigs (*Sus scrofa*) native to Eurasia and Africa, are one of the world's most widely distributed invasive species. Their impacts on terrestrial environments have been well documented, however little is known about effects on aquatic environments. We used standardized physical habitat surveys to compare the use of streams by invasive wild pig and native white-lipped peccaries (*Tayassu pecari*) and their effects on the physical structure of four first-order streams in the Brazilian Atlantic Forest. Two of the streams were used solely by wild pigs and two by peccaries. Each stream was subdivided by cross-sectional transects into continuous sections, each 10 m in length, where we measured the intensity of use of species and different variables related to the stream physical habitat. Although both species used the streams, wild pigs altered physical and environmental parameters more, and with greater intensity, than the native peccaries. Wild pigs decreased the stream bank angle and the riparian ground cover, leading to local erosion, increase of fine sediments and wet width, and a decrease in stream depth. We recommend studies to evaluate the biological consequences of the alterations caused by introduced wild pigs that should be conducted with population control plans in environments where the pig is invasive.

KEY-WORDS: *Sus scrofa, Tayassu pecari,* Ecosystem Engineer, Feral Hogs, Hotspot, water.

The physical and chemical features of streams are good indicators of stream ecological integrity and their biological condition (Casatti et al. 2006). Activities that disrupt stream physical structure may impact aquatic biota diversity and ecosystem processes (Gorman and Karr 1978, Resh et al. 1988). Many of the disruptions in stream physical habitat characteristics have been caused by anthropogenic land use change (e.g., Wang et al. 2003, Kaufmann and Hughes 2006). However, other organisms can also disrupt the habitat of streams and affect aquatic community structure (Meysman et al. 2006).

In fresh water, various vertebrates, called ecosystem engineers (Jones et al. 1994), can promote alterations in physical habitats and water quality, including native (e.g., Tiegs et al. 2009, Hogg et al. 2014) and introduced fish species (e.g., Bain 1993), but also mammals (Butler and Malanson 1995, Coronato et al. 2003, Anderson and Rosemond 2007, Beck et al. 2010, Doupé et al. 2010).

In temperate zones the American beaver (*Castor canadensis*) cuts down trees to build dams, altering the physical structure of rivers, changing water dynamics and homogenizing the substrate. In the Neotropics, the white-lipped peccary (*Tayassu pecari*) may modify streams creating microhabitats for species (Beck et al. 2010). However when the use of streams by exotic species results in alterations, it can lead to negative consequences to the environment by disrupting the trophic dynamics, habitat structure, and/or the frequency and intensity of disturbances and geochemical cycles (Simberloff 2011).

The wild pigs (*Sus scrofa*), native to Eurasia and northwestern Africa (Long 2003), are one of the oldest species intentionally introduced by humans (Courchamp et al. 2003, Long 2003). Wild pigs are recognized as an important alien ecosystem engineer, changing the soil structure (Singer et al. 1981, Cuevas et al. 2012), vegetation cover by suppression of native species (Barrios-Garcia and Ballari 2012, Cuevas et al. 2012), causing alteration in the structure of the seed bank (Ickes et al. 2001, Bueno et al. 2011) and the spread of exotic grasses (Sanguinetti and Kitzberger 2010, Dovrat et al. 2012). However, there is no consensus about the effects of wild pigs on aquatic environments.

Doupé et al. (2010) reported negative changes in the aquatic plant community and water quality and Arrington et al. (1999) observed an increase in the aquatic plant diversity in water bodies used by wild pigs. Therefore their foraging behavior, which consists of rooting (Barrios-Garcia and Ballari 2012), and their need for body temperature regulation, promotes the formation of large bogs in water bodies (Barrett 1978, Coblentz and Baber 1987, Cuevas et al. 2013).

In the Neotropics the white-lipped peccary *Tayassu pecari* can be considered the native ecological equivalent of the wild pig (Novillo and Ojeda 2008). The white-lipped peccary is one of the largest Neotropical mammals (Fragoso 1999) and in their natural range the populations are declining due to habitat fragmentation and poaching (Reyna-Hurtado et al. 2009, Reyna-Hurtado et al. 2010, Altrichter et al. 2012). However unlike wild pig, the white-lipped peccary does not seem to have become a problematic invasive species where it has been introduced (Mayer and Wetzel 1987).

The Serra da Mantiqueira is a mountain range extending for 500 km along southeastern Brazil and one of more important areas of the Brazilian Atlantic Forest Biome, considered to be an area of global importance for biodiversity conservation (Myers et al. 2000, Le Saout et al. 2013). According to local residents, in 2006, six individuals of pigs that had been kept enclosed on a commercial breeding site, were intentionally introduced next to Itatiaia National Park (INP), one of the largest protected areas of the Serra da Mantiqueira. The pigs established feral populations that now have a population in the Serra da Mantiqueira estimated at 199±1.38 individuals with a density of 15,8 ind./km² (Puertas 2015) and no control effort have been made.

Both the wild pig and white-lipped peccary use streams in their daily activities and have rooting and wallowing behavior and the potential to alter the stream physical habitat structure of streams (Arrington et al. 1999, Beck et al. 2010, Doupé et al. 2010). To better understand the potential effect of wild pigs on aquatic environments of Brazilian Atlantic Forest, we compared the use of streams by the alien wild pig and the native white-lipped peccary and their consequences on the physical structure of first-order streams. We hypothesized that stream use by wild pigs may potentially cause a harmful disturbance to the aquatic ecosystem of the Brazilian Atlantic Forest because such use have a potential to disrupt the physical structure of streams more intensely than the use by white-lipped peccaries

STUDY AREA

The Itatiaia National Park (INP) is the most representative of a patchwork of protected areas in the Serra da Mantiqueira. The INP has a lower region (22°26'14"S/44°36'3"W), between 600 and 1,500 m of altitude, locally called the Lower Part (LP) which has a Cwb climate type, mesothermal with a rainy season in summer (Köppen 1936); and the other (22°20'23"S/44°43'17"W) between 1,500 and 2,791 m called the Higher Part (HP) which has a Cfb climate type, mesothermal without a dry season (Köppen 1936). The area covered by INP has 12 important regional watersheds that drain into two main basins: the Grande River, a tributary of the Paraná River, and the Paraíba do Sul River.

Since 2013 we have been conducting a continuous monitoring program of the mammal's activities in our study area with automatic cameras and there has been no evidence of sympatry between white-lipped peccary and wild pig. The wild pig occurs only in the HP while the white-lipped peccary occurs only in the LP (C. A. Rosa, F. H. Puertas and M. Passamani and Rosa, unpublished data). Thus, we selected four headwater streams (first and second orders); two in the LP areas and two in the HP areas (Fig. 1). Their riparian vegetation cover was represented by forest in advanced succession stage, with canopy height between 15 and 20 meters.

METHODS

Data Collection

To determine the use of streams by wild pigs and peccaries and the consequences on the physical structure of first-order streams we carried out an observational study during the dry season between October and November 2013. For this we performed a standardized physical habitat survey adapted from the methodology of Peck et al. (2006) and Hughes and Peck (2008) that uses physical, chemical and biological variables to assess the integrity of streams.

We surveyed four streams used by the species; two in the LP area (with peccaries and without wild pigs) and two in the HP area (with wild pigs and without peccaries) (Fig. 1). Each stream was subdivided by cross-sectional transects into continuous sections of 10 m in length each (Fig. 2) as recommended by Peck et al. (2006) and Hughes and Peck (2008). Both species occurred over the area sampled, thus we could not find streams that are not used by at least one species in all their extension. But we could find stream sections with different use intensities (eg, footprints, rooting), or even without use by the species. To set the control points and evaluate how different use intensities of species can alter the physical integrity of streams, we employed a use intensity score from the presence or absence of footprints and rooting every 1 meter in each 10m section. Each 1 meter accounted for 10% of the total 10 m section, resulting in a use intensity ranging from 0 to 100% in each 10m section (Fig. 2). The control sections were those in which the use intensity scores were 0%. In total we measured in HP 16 sections used by wild pigs and 12 control sections, and in LP 13 sections used by white-lipped peccaries and 24 control sections.

To measure the effects of use intensity of species in stream conditions in each 10m-section we measured physical variables associated with morphology and type of substrate of streams that could be altered by ecological engineers such as wild pigs and peccaries from previous field observations. At each of the cross-sectional transects we measured depth (DEPTH) and visually examined substrate type (bedrock, concrete, boulders, cobbles, coarse gravel, fine gravel, sand, silt and clay, hardpan, fine litter, coarse litter, wood, roots) along five equidistant points. Based on substrate type we calculated the mean substrate diameter (SIZE_CLS), the percentage of substrate smaller than fine gravel (SEDIMENT) and larger than boulder (LARGER). Transect characterization also included bank full width (BANKWID), mean wetted width (WT_WID), undercut bank distance (UNDERCUT), and bank angle (ANGLE). We assessed habitat complexity at each transect in 10 m length plots inside the stream channel, using semi-quantitative visual estimates (%) of the surface cover of leaf packs, roots, large woody debris >30cm diameter, brush and small woody debris, overhanging vegetation <1 m above the water surface, undercut banks, boulders, and artificial structures. These variables were used to estimate the number of woody debris pieces (PIECES), riparian ground cover (RIP_GC) and shelter for aquatic organisms (SHELTER).

Data Analysis

We divided the sampled sections into four groups: (1) points in HP not used by wild pigs (control points); (2) points in the HP used by wild pings; (3) points in LP not used by peccaries (control points); and (4) points in LP used by peccaries. The variables describing the stream conditions were examined using principal component analysis (PCA). Differences among the four groups were tested by discriminant correspondence analysis (DCA) using the software Statistica 6 (StatSoft Inc. 2001).

For each stream variable we tested normality using the Shapiro-Wilk test and compared its mean values between Groups 1 and 2 and between Groups 3 and 4, using the Kruskal-Wallis test for non-normal data and the Student's t-test for normal data using the software Bioestat 5.0 (Ayres et al. 2007).

RESULTS

We recorded differences of stream physical characteristics in sampled sections used by wild pigs and peccaries. When ordered, these differences were most evident along the first axis of the PCA (Fig. 3). In general both species were associated with shallower stream depths (DEPTH), and replacement of the larger substrate (LARGER) by fine gravel (SEDIMENT) (Table 1). However, while all sections with any use intensity by wild pigs showed these characteristics, only those with high use intensity values by peccaries (>50% of use intensity) followed this pattern. In sections used by wild pigs, stream characteristics related to the second axis of the PCA were altered (Fig. 3), in particular by reducing the undercut bank distance (UNDERCUT) (Table 1).

When evaluated on its own set of variables, the four groups differed ($p < 0.05$), mainly due to the amount of larger substrate (LARGER) and riparian ground cover (RIP_GC) (Table 2). In stream sections used by either species, we noted the cover of large substrate by silt and removal of riparian ground cover.

In sections used by wild pig the bank distance (UNDERCUT), mean wetted width (WT_WID), woody debris pieces (PIECES) and shelter (SHELTER), did not differ between control and streams-section used by species (Fig. 4c and 4f). However, bank angle (ANGLE), sediment larger than boulder (LARGER), riparian ground cover (RIP_GC), mean substrate diameter (SIZE_CLS), fine gravel

(SEDIMENT) and bank full width (BANKWID) were altered (Fig. 4a, 4b, 4d, 4e and 4g). In areas were white-lipped peccaries occurred, bank distance (UNDERCUT), mean wetted width (WT_WID), woody debris pieces (PIECES) and shelter (SHELTER), also did not differ between control and stream sections used by species (Fig. 4c and 4f). However, bank angle (ANGLE), sediment larger than boulder (LARGER), depth (DEPTH) and riparian ground cover (RIP_GC) were altered (Fig. 4d, 4e, 4g and 4h).

DISCUSSION

In sections used by wild pigs or peccaries, the physical structures of streams were altered. The main effect included decreasing stream depth by sedimentation due to replacement of the larger substrate by fine gravel. The fact that both species are associated with fine sediments could demonstrate a habitat preference. However, since our control sections presented larger substrates and the sections with predominance of fines were always associated with the bank collapse, these section features must be related to the use by one of the two species

Even with abundance six times lower than white-lipped peccaries (C. A. Rosa, F. H. Puertas and M. Passamani and Rosa, unpublished data), any use intensity of streams by wild pigs caused bank erosion, reflecting also in a decrease of the stream bank angle and the riparian ground cover. These results support our hypothesis that wild pigs change the physical structure of streams more intensely than peccaries, characterizing them as an agent of alien disturbance to the aquatic ecosystem of the Brazilian Atlantic Forest.

Significant effects of wild pigs on the physical structure of the soil, leaf litter, seed and land plants in terrestrial environments have previously been reported (e.g., Bueno et al. 2011, Wirthner et al. 2011, Cuevas et al. 2012). Their rooting behavior makes the soil less compact and wetter, which reduces the vegetative cover making the soil more susceptible to wind erosion (Cuevas et al. 2012). Such rooting can also reduce ground vegetative cover and leaf litter, which in turn eliminates the presence of some small mammal species that are dependent upon those microhabitat parameters of the forest floor for their survival (Singer et al. 1984).

We found no studies that had evaluated the use of wild pigs or white-lipped peccaries and their effects on stream physical habitats structure . However, Beck et al. (2010) showed that pools created and maintained by white-lipped peccaries are wider and hydrologically more stable over time than other pools, especially during times of drought, increasing the diversity of anurans. For wild pigs, Doupé et al. (2010) noted increased turbidity, changes in chemical composition and reduction of macrophyte coverage on an ephemeral flood plain lagoon used by species. Arrington et al. (1999) did not assess the effect of wild pigs on the physical structure of wetlands, but noted increased vegetation in these areas due to the creation of microhabitats for this species. These authors point out that because of the wet ground, the ability of wild pigs to modify wetlands in wet periods is limited, providing an opportunity for the vegetation to recover, leading to an increase in plant species diversity in these areas.

In the terrestrial environment, wild pigs root and graze to a greater extent than do peccaries because of differences in cranial anatomy of the species (Ilse and Hellgren 1995, Sicuro and Oliveira 2002). In the Brazilian Pantanal, where peccaries and wild pigs coexist, morphological differences between the species have been related to a higher soil rooting performance by the wild pigs that allows soil excavation up to 50 times deeper than peccaries (Sicuro and Oliveira 2002. We believe that these same cranial differences can have a relation to the wild pig's ability to modify aquatic environments.

Where it is an invasive species, the wild pig create new habitats for exotic species increasing their diversity (Kotanen 1995, Cushman et al. 2004). However, where it is native, it is possible to observe resiliency in the native herbaceous plant community, probably due to their mutual evolutionary history (Dovrat et al. 2014). The same occurs with the white-lipped peccary through its wallowing behavior that creates pools that are used for reproduction by different frog species, leading to an increased density and diversity of frogs in the Peruvian Amazon (Beck et al. 2010). Native or exotic ecosystem engineers can alter the frequency regime of disturbances (e.g., grazing and fire), as well as being the source of disturbance itself (Crooks 2002), and this may increase the alpha (Arrington et al. 1999) and beta diversity (Astorga et al. 2014). Thus, the effects of ecosystem engineers are a matter of scale and context, depending on the landscape and the regional species pool in which the activity is located. The effects on species diversity vary depending on the scale of influence on the resource and its influence on the increase or decrease in diversity as the heterogeneity is reduced or increased (Crooks 2002). Thus, the ecosystem engineers may be crucial for maintaining biodiversity in some landscapes, especially those where the disturbances regime and frequency have been altered due to other human activities (Badano and Cavieres 2006).

In the case of wild pigs, our study shows that the presence of an exotic ecosystem engineer modifies the physical structure of streams; however, we do not know the ultimate consequences. Although the disturbance can increase the number of habitats, we must remember that in tropical environments heterogeneity of substrates is critical for fish diversity, including sympatric congeners (Leal et al. 2010), and we do not know the consequences of stream physical habitat changes caused by wild pigs on fish and other aquatic organisms

The Itatiaia National Park is recognized as a fundamental area for water resources and biodiversity preservation, but suffers with domestic and exotic species such as wild pigs, feral dogs, cattle and domestic horses, whose synergy can enhance the impact of each species individually (Simberloff 2011). As an immediate solution to reduce the effects of wild pigs on streams, the fencing of streams can be carried out, which has already proved to be a success in Australia (Doupé et al. 2010). However, without a wild pig population control program, the fencing of streams would be a palliative solution.

Brazilian law results in great limitations for wildlife management strategies, mainly regarding the lethal control of populations. Recently, wild pigs were recognized as a risk for the Brazilian economy and biodiversity, and their population control by hunting techniques has been allowed (Instrução Normativa Ibama 03/2013). Therefore we recommend that Protected Areas include the control of this invasive exotic species in their management plans, and that the control techniques and management of exotic species must be extended to the surrounding area and be strategically evaluated in conjunction with the local community.

ACKNOWLEDGMENTS

We thank Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG) and Tropical Forest Conservation Act (TFCA/FUNBIO) for the financial resources that led to realization of this project. M. Passamani and P.S. Pompeu receive a CNPq fellowship. We thank the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), the administration of the Itatiaia National Park and the Alto Montana Institute for logistical support during this study. To F. H. Puertas, E. Carvalho and L. Oliveira for their help in data collection and analysis.

LITERATURE CITED

Altrichter, M., A. Taber, H. Beck, R. Reyna-Hurtado, L. Lizarraga, A. Keuroghlian, and E. W. Sanderson. 2012. Range-wide declines for a key Neotropical ecosystem architect, the White-lipped peccary *Tayassu pecari*. Oryx 46(1):87-98.

Anderson, C.B., and A. D. Rosemond. 2007. Ecosystem engineering by invasive exotic beavers reduces in-stream diversity and enhances ecosystem function in Cape Horn, Chile. Oecologia 154:141-153.

Arrington, D.A., L. A. Toth, and J. W. Koebel Jr. 1999. Effects of rooting by feral hogs *Sus scrofa* L. on the structure of a foodplain vegetation assemblage. Wetlands 19(3):535-544.

Astorga, A., R. Death, F. Death, R. Paavola, M. Chakraborty,and T. Muotka. 2014. Habitat heterogeneity drives the geographical distribution of beta diversity: the case of New Zealand stream invertebrates. Ecology and Evolution 4(13):2693-2702.

Ayres, M., M. Ayres Jr., D.L. Ayres, and A. S. Santos. 2007. Bioestat 5.0 - aplicações estatísticas nas áreas das ciências biológicas e médicas. Sociedade Civil Mamirauá, Belém, Pará, Brasil. [in Portuguese]

Badano, E. I., and L. A. Cavieres. 2006. Impacts of ecosystem engineers on community attributes: effects of cushion plants at different elevations of the Chilean Andes. Diversity and Distribution 12:388–396.

Bain, M. B. 1993. Assessing impacts of introduced aquatic species: grass carp in large systems. Environmental Management 17:211–224.

Barrett, R. H. 1978. The feral hog on the Dye Creek Ranch, California. Hilgardia 46:283–355.

Barrios-Garcia, M., and A. S. Ballari. 2012. Impact of wild boar (*Sus scrofa*) in its introduced and native range: a review. Biological Invasions 14:2283-2300.

Beck, H., P. Thebpanya, and M. Filiaggi. 2010. Do Neotropical peccary species (Tayassuidae) function as ecosystem engineers for anurans? Journal of Tropical Ecology 26:407-414.

Bueno, C. G., R. Reiné, C. L. Alados, and D. Gómez-García. 2011. Effects of large wild boar disturbances on alpine soil seed banks. Basic Applied Ecology 12:125-133.

Butler, D. R., and G. P. Malanson. 1995. Sedimentation rates and patterns in beaver ponds in a mountain environment. Geomorphology 13:255–269.

Casatti, L., Langeani, F., and C. P. Ferreira. 2006. Effects of physical habitat degradation on the stream fish assemblage structure in a pasture region. Environmental Management 38:974–982.

Coblentz, B.E., and D. W. Baber. 1987. Biology and control of feral pigs on Isla Santiago, Galapagos, Ecuador. Journal of Applied Ecology 24:403–418.

Coronato, A., J. Escobar, C. Mallea, C. Roig, and M. Lizarralde. 2003. Características geomorfológicos de rios de montaña colonizados por *Castor canadensis* em Tierra Del Fuego, Argentina. Ecología Austral 13:15–26.

Courchamp, F., J. L. Chapuis, and M. Pascal. 2003. Mammal invaders on islands: impact, control and control impact. Biological Reviews 78:347–383.

Crooks, J. A. 2002. Characterizing ecosystem-level consequences of biological invasions: the role of ecosystem engineers. Oikos 97:153–166.

Cuevas, M. F., L. Mastrantonio, R. A. Ojeda, and F. M. Jaksic. 2012. Effects of wild boar disturbance on vegetation and soil properties in the Monte Desert, Argentina. Mammalian Biology 77(1):299–306.

Cuevas, M. F., R. A. Ojeda, and F. M. Jaksin. 2013. Multi-scale patterns of habitat use by wild boar in the Monte Desert of Argentina. Basic Applied Ecology 14:320-328.

Cushman, J. H., T. A. Tierney, and J. M. Hinds. 2004. Variable effects of feral pig disturbances on native and exotic plants in a California grassland. Ecological Applications 14(6); 1746-1756.

Doupé, R. G., J. Mitchell, M. J. Knott, A. M. Davis, and A. J. Lymbery. 2010. Efficacy of exclusion fencing to protect ephemeral floodplain lagoon habitats from feral pigs (*Sus scrofa*). Wetlands Ecology and Management 18:69–78.

Dovrat, G., Perevolotsky, A., and G. Ne'eman. 2012. Wild boars as seed dispersal agents of exotic plants from agricultural lands to conservation areas. Journal of Arid Environments 78(1):49-54.

Dovrat, G., Perevolotsky, A., and G. Ne'eman. 2014. The response of Mediterranean herbaceous community to soil disturbance by native wild boars. Plant Ecology 215:531-541.

Fragoso, J. M. V. 1999. Perception of scale and resource partitioning by peccaries: behavioral causes and ecological implications. Journal of Mammalogy 80(3):993-1003.

Gorman, O. T., and J. R. Karr. 1978. Habitat structure and stream fish communities. Ecology 59(3):507-515.

Hogg, R. S., S. M. Coghlan, J. Zydlewski, and K. S. Simon. 2014. Anadromous sea lampreys (*Petromyzon marinus*) are ecosystem engineers in a spawning tributary. Freshwater Biology 59(6):1294–1307

Hughes, R. M., and D. V. Peck. 2008. Acquiring data for large aquatic resource surveys: the art of compromise among science, logistics, and reality. Journal of the North American Benthological Society 27 (4):837-859.

Ickes, K., S. J. Dewalt, and S. Appanah. 2001. Effects of native pigs (*Sus scrofa*) on woody understory vegetation in a Malaysian lowland rain forest. Journal of Tropical Ecology 17(1):191-206.

Ilse, L. M., and E. C. Hellgren. 1995. Resource partitioning in sympatric populations of Collared Peccaries and Feral Hogs in Southern Texas. Journal of Mammalogy 76(3): 784-799.

Jones, C. G., J. H. Lawton, and M. Shachak. 1994. Organisms as ecosystem engineers. Oikos 69:373-386.

Kaufmann, P. R., and R. M. Hughes. 2006. Geomorphic and anthropogenic influences on fish and amphibians in Pacific Northwest coastal streams. Pages 429-455. *in* Hughes, R. M., L. Wang, and P. W. Seelbach, editors. Landscape influences on stream habitat and biological assemblages, American Fisheries Society, Symposium 48, Maryland, USA.

Köppen, W. 1936. Das geographisca System der Klimate. Pages 1-44 *in* W. Koppen and R. Geiger, editor. Klimatologie. Gebr, Borntraeger, Germany. [in German]

Kotanen, P. M. 1995. Responses of vegetation to a changing regime of disturbance: effects of feral pigs in a California coastal prairie. Ecography 18: 190-199.

Le Saout, S., M. Hoffmann, Y. Shi, A. Hughes, C. Bernard, T. M. Brooks, B. Bertzky, S. H. M. Butchart, S. N. Stuart, T. Badman, and A. S. L. Rodrigues. 2013. Protected areas and effective biodiversity conservation. Science 342:803.

Leal, C. G., N. T. Junqueira, and P. S. Pompeu. 2010. Morphology and habitat use by fishes of the Rio das Velhas basin in southeastern Brazil. Environmental Biology of Fishes 90(2):143-157.

Long, J. L. 2003. Introduced mammals of the world: their history distribution and influence. CSIRO, Collingwood, USA.

Mayer, J. J., and R. M. Wetzel. 1987. *Tayassu pecari*. Mammalian Species 293:1-7.

Meysman, F. J., J. J. Middelburg, and C. H. Heip. 2006. Bioturbation: a fresh look at Darwin's last idea. Trends in Ecology and Evolution 21:688–695.

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. Fonseca, and J. Kent. 2000. Biodiversity hotspots for conservation priorities. Nature 403:853-858.

Novillo, A. and R. A. Ojeda. 2008. The exotic mammals of Argentina. Biological Invasions 10(8):1333–1344.

Peck, D. V., A. T. Herlihy, B. H. Hill, R. M. Hughes, P. R. Kaufmann, D. J. Klemm, J. M. Lazorchak, F. H. McCormick, S. A. Peterson, P. L. Ringold, T. Magee, and M. Cappaert. 2006. Environmental Monitoring and Assessment Program-Surface Waters Western Pilot Study: Field Operations Manual for Wadeable Streams, EPA/620/R-06/003, Environmental

Protection Agency, Office of Research and Development, Washington, USA.

Puertas, F. H. 2015. A Invasão do Javali na Serra da Mantiqueira: Aspectos populacionais, uso do habitat e sua relação com o Homem. Dissertation, Universidade Federal de Lavras, Lavras, Brazil. [in Portuguese]

Resh, V. H., A. V. Brown, A. P. N. Covich, M. E. Gurtz, H. W. Li, G. W. Minshall, S. R. Reice, A. L. Sheldon, J. B. Wallace, and R. Wissmar. 1988. The role of disturbance in stream ecology. Journal of the North American Benthological Society 7:433-455.

Reyna-Hurtado, R. 2009. Conservation status of the white-lipped peccary (*Tayassu pecari*) outside the Calakmul Biosphere Reserve in Campeche, Mexico: a synthesis. Tropical Conservation Science 2:159-172.

Reyna-Hurtado, R., E. Naranjo, C. A. Chapman, and G. W. Taner. 2010. Hunting and the conservation of a social ungulate: the white-lipped peccary T*ayassu pecari* in Calakmul, Mexico. Oryx 44(1):89-96.

Sanguinetti, J., and T. Kitzberger. 2010. Factors controlling seed predation by rodents and non-native *Sus scrofa* in *Araucaria araucana* forests: potential effects on seedling establishment. Biological Invasions 12:689-706.

Sicuro, F. L., and L. F. B. Oliveira. 2002. Coexistence of peccaries and feral hogs in the Brazilian Pantanal wetland: an ecomorphological view. Journal of Mammalogy 83(1): 207-217.

Simberloff, D. 2011. How common are invasion-induced ecosystem impacts? Biological Invasions 13:1255-1568.

Singer, F. J., D. K. Otto, A. R. Tipton, and C. P. Hable. 1981. Home ranges, movements and habitat use of European Wild boar in Tennessee. Journal of Wildlife Management 45:343–353.

Singer, F. J., W. T. Swank, and E. E. C. Clebsch. 1984. Effects of wild pig rooting in a deciduous forest. Journal of Wildlife Management 48:464–473.

Statsoft Inc. 2004. Statistica: data analysis software system, Computer Program Manual, Version 6, Tulsa, USA.

Tiegs, S. D., E. Y. Campbell, P. S. Levi, J. Rüegg, M. E. Benbow, D. T. Chaloner, R. W. Merritt, J. L. Tank, and G. A. Lamberti. 2009. Separating physical disturbance and nutrient enrichment caused by Pacific salmon in stream ecosystems. Freshwater Biology 54:1864–1875.

Wang, L., J. Lyons, P. Rasmussen, P. Seelbach, T. Simon, M. Wiley, P. Kanehl, E. Baker, S. Niemela, and P. M. Stewart. 2003. Watershed, reach, and riparian influences on stream fish assemblages in the Northern Lakes and Forest Ecoregion, U.S.A. Cannadian Journal of Fisheries and Aquatic Sciencies 60:491–505.

Wirthner, S., B. Frey, M. D. Busse, M. Schütz, and A. C. Risch. 2011. Effects of wild boar (*Sus scrofa* L.) rooting on the bacterial community structure in mixed-hardwood forest soils in Switzerland. European Journal of Soil Biology 47:296-302.

FIGURES CAPTIONS

Figure 1. Study area showing the sampled streams in the Higher Part (square), the *Sus scrofa* area, and in the Lower Part (circle), the *Tayassu pecari* area, of Itatiaia National Park. The line indicates the division of the Brazilian states where the Higher Part (Minas Gerais) and Lower Part (Rio de Janeiro) of Itatiaia National Park are located.

Figure 2. Sampling design showing the 10m-section used to measure the use of streams by *Sus scrofa* and *Tayassu pecari*.

Figure 3. PCA showing the effects of *Sus scrofa* (in black) and *Tayassu pecari* (in gray) in the sampled points. Black crosses indicate the control points of *Sus scrofa* area (Group 1); black balls indicate points used by *Sus scrofa* (Group 2); Gray crosses indicate the control points of *Tayassu pecari* area (Group 3); gray balls indicate points used by *Tayassu pecari* (Group 4). The bubbles represent the use intensity (%) of each species, where the larger the ball, the higher the use intensity of the species.

Figure 4. Mean, standard deviation and maximum and minimum values of the physical streams variables measured in the sampled streams (1) control points of *Sus scrofa* area; (2) points used by *Sus scrofa*; (3) control points of *Tayassu pecari* area; (4) points used by *Tayassu pecari.* Different letters indicate significant differences ($P < 0.05$), with *a* and *b* representing the Groups 1 and 2 and *c* and *d* for Groups 3 and 4.

FIGURES

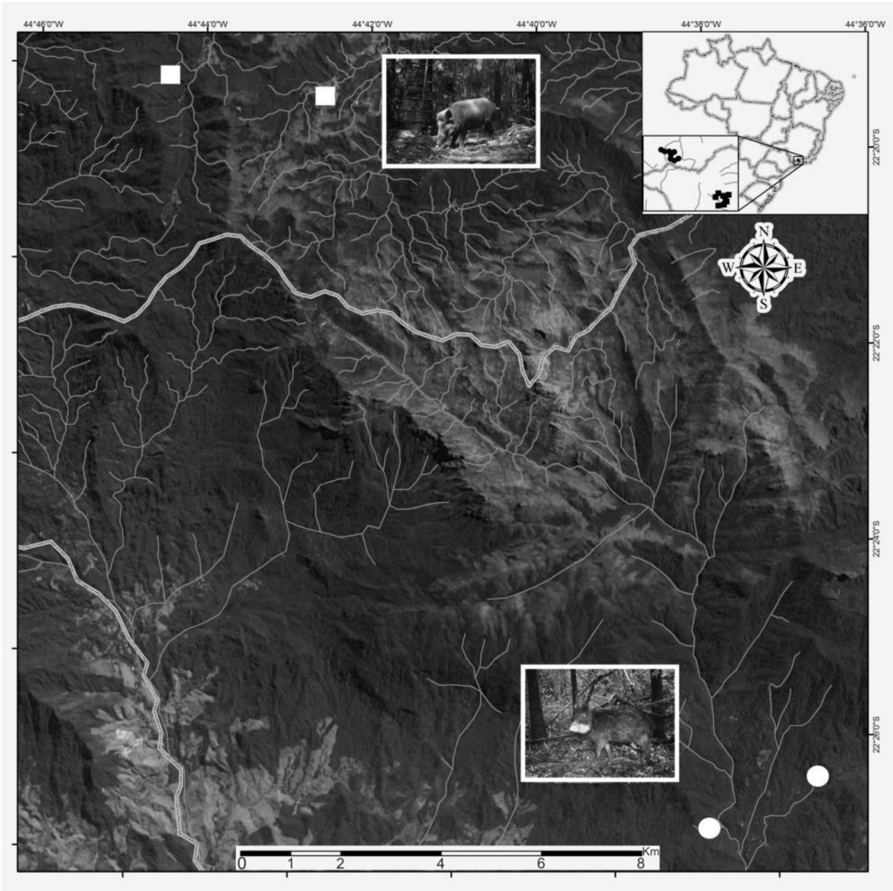


FIGURE 1

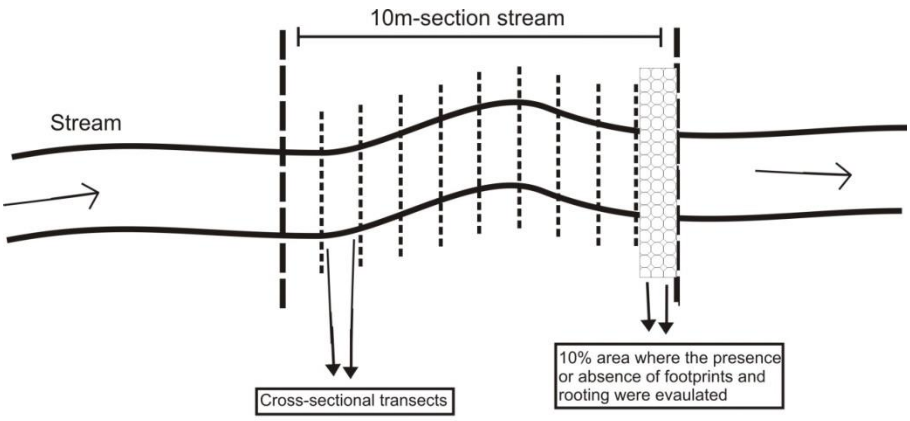


FIGURE 2

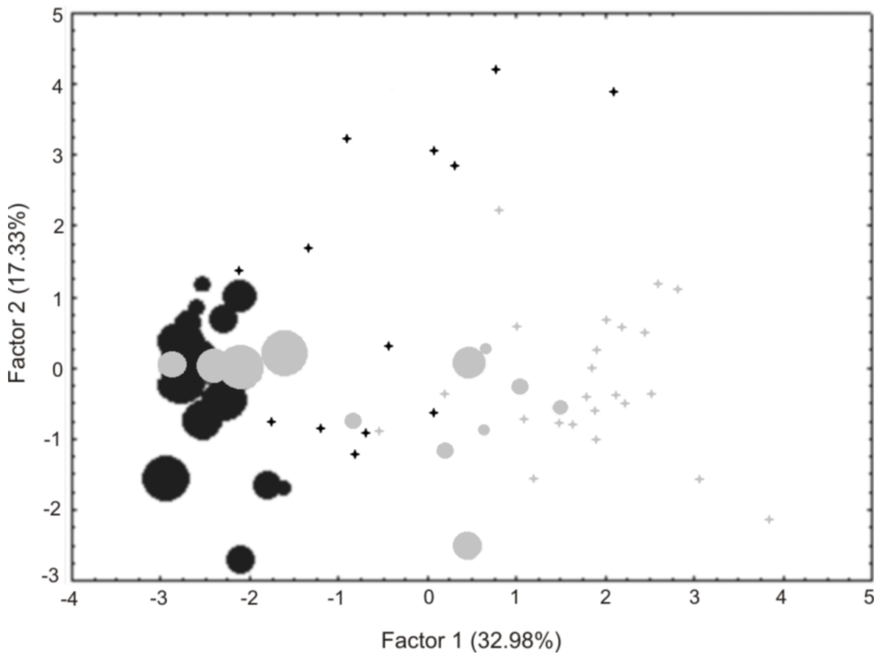


FIGURE 3

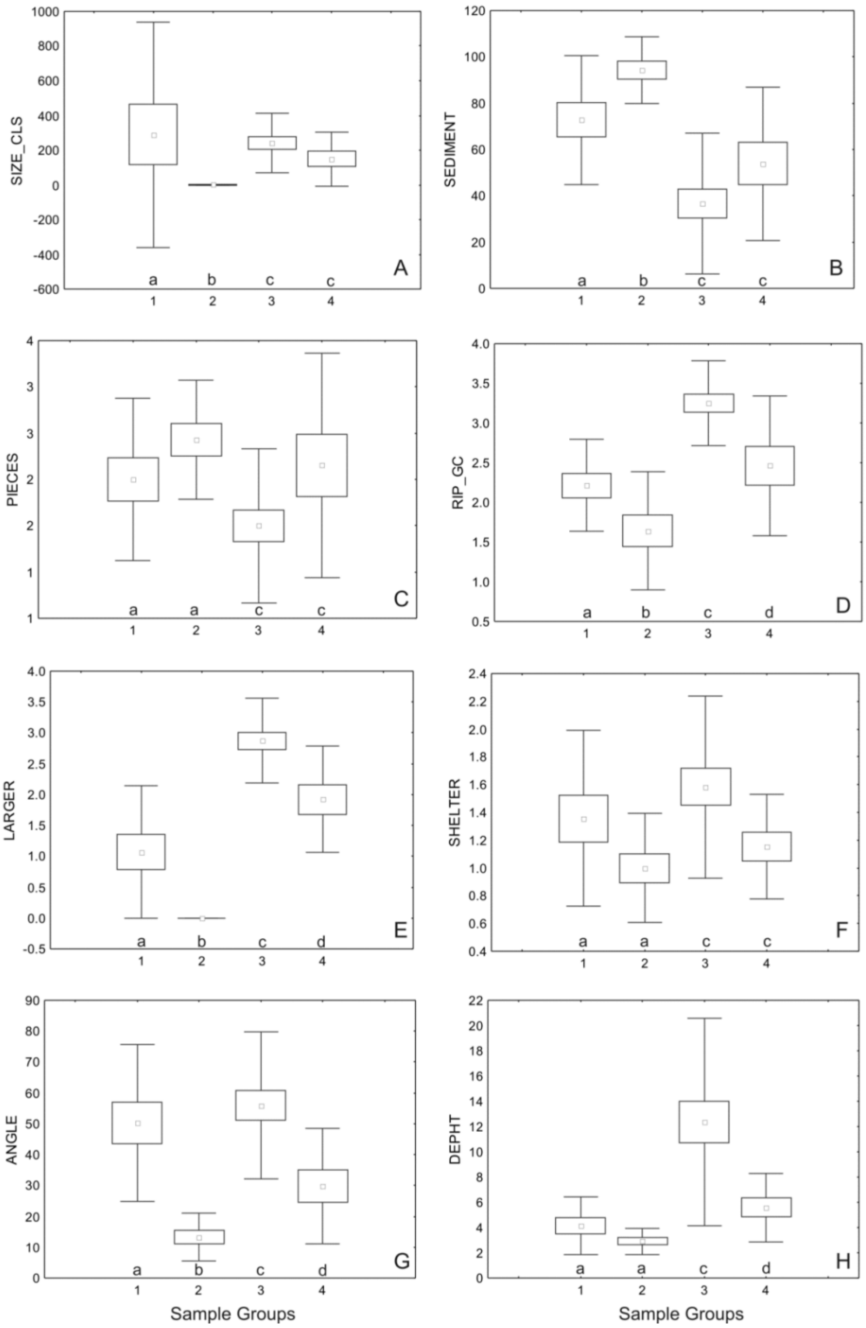

SIZE_CLS
a b c c
1 2 3 4
A
SEDIMENT
a b c c
1 2 3 4
B
PIECES
a a c c
1 2 3 4
C
RIP_GC
a b c d
1 2 3 4
D
LARGER
a b c d
1 2 3 4
E
SHELTER
a a c c
1 2 3 4
F
ANGLE
a b c d
1 2 3 4
G
Sample Groups
DEPHT
a a c d
1 2 3 4
H
Sample Groups

FIGURE 4

TABLES

Table 1. Stream attributes, PCA scores and contribution to the first three PCA components of the variables measured in streams used by *Tayassu pecari* and *Sus scrofa*. Highest scores of each axis are in bold and scores between -0.3 and 0.3 are presented only with a positive or negative sign.

	PCA 1	PCA 2	PCA 3
DEPTH	**0.74**	-	-0.31
SIZE_CLS	0.46	0.39	0.32
SEDIMENT	**-0.71**	+	-0.52
ANGLE	0.64	0.32	-
WT_WID	0.51	-0.44	-0.49
BANKWID	-	-0.69	-0.32
SHELTER	0.48	0.30	-0.57
PIECES	-0.51	-	+
RIP_GC	0.69	-0.41	+
UNDERCUT	+	**0.77**	-
LARGER	**0.83**	-0.19	+
Eigenvalues	3.63	1.91	1.34
Variance explained (%)	32.99	17.33	12.14
Cumulative variance (%)	32.99	50.31	62.45

Table 2. F and exit values of the model and tolerance of the discriminant correspondence analysis, and p value for variance analysis of variables measured in streams used by *Tayassu pecari* and *Sus scrofa*.

	F-exit	Tolerance	P (DCA)	P (variance)
DEPTH	1.30	0.65	0.2844	<0.0001
SIZE_CLS	2.13	0.67	0.1082	<0.0001
SEDIMENT	1.83	0.60	0.1530	<0.0001
ANGLE	1.99	0.71	0.1267	<0.0001
WT_WID	1.39	0.57	0.2560	0.0395
BANKWID	2.31	0.53	0.0877	0,0218
SHELTER	1.76	0.60	0.1657	0.0152
PIECES	0.50	0.82	0.6823	0.0158
RIP_GC	3.03	0.68	**0.0378**	<0.0001
UNDERCUT	0.44	0.65	0.7237	0.2260
LARGER	6.63	0.76	**0.0007**	<0.0001

ARTIGO 3

Preparado segundo as normas da revista *Biotropica*

Rosa, Querido, and Passamani

Removal Rate of *Araucaria angustifolia* Seeds

The Role of Mammals in *Araucaria angustifolia* Seed Removal (Araucariacea): Is the *Sus Scrofa* (Suidae) a Threat to the Brazilian Araucaria Forest?

[1,2] Clarissa Alves da Rosa, [1]Luciano Carramaschi de Alagão Querido, [1]Marcelo Passamani

[1]Laboratório de Ecologia e Conservação de Mamíferos, Setor de Ecologia, Departamento de Biologia, Universidade Federal de Lavras, Campus Universitário, 37200-000, Lavras, Minas Gerais, Brazil

Corresponding Author[2]: Telephone +55 35 38291922; E-mail alvesrosa_c@hotmail.com

Abstract

The *Sus scrofa* is an invasive pig that is expanding its territory throughout the Araucaria Forest, one of the most threatened environments of the Brazilian Atlantic Forest. Our aim is to understand the role of wild pig and native mammals in the seed removal of Brazilian pine, the characteristic tree species of Araucaria Forest. We tested the hypothesis that the seed removal in areas with wild pigs would be greater than the seed removal in areas without the invasive pig. We made a seed removal experiment in eight points of two different areas (with and without the wild pig); the experiment was divided into four different treatments that segregate the mammal species with access to seeds. In each point we installed one camera-trap to register the seed removal events and relative abundance of seed removers. The seed removal do not differ among small, medium and large mammals, even in areas with wild pig; and the relative abundance of all native seed removers play an important role in the seed removal, especially the small rodents. The seed removal events were also conducted mainly by small rodents in both areas (> 80%). We believe that wild pig do not affect the recruitment of Brazilian pine and more studies are necessary to evaluate the potential of wild pigs to replace ecological functions in fragmented areas where native large mammals species were ecological extinct.

Key-word: Brazilian Atlantic Forest; Brazilian pine; Feral hog; Rodents; Wild boar

SEED PREDATION AND SEED DISPERSAL BY ANIMALS ARE KEY PROCESSES DETERMINING THE SPATIAL STRUCTURE OF PLANT POPULATIONS (SCHUPP 1988, WANG & SMITH 2002). For seeds that are dispersed by gravity and secondarily by terrestrial mammals, dispersal success is influenced by the behavior of seed removers (Shepherd & Ditgen 2012) and plant reproductive strategy. These mechanisms are essential for reproductive success of the Brazilian pine (*Araucaria angustifolia* (Bertol.) Kuntze) (Mantovani *et al.* 2004, Ribeiro & Vieira 2014).

The Brazilian pine has large seeds (6.5 to 7 g) that are produced in great abundance (Mantovani *et al.* 2004), and this therefore increases the probability of seed survival following the predator-satiation hypothesis where the plant produces more seeds than the predators are capable of consuming (Crawley & Long 1995, Brewer & Rejmánek 1999). This synchronous production of seeds is predictable seasonally, happening at a time of relative scarcity of food resources in the Araucaria Forests (Mantovani *et al.* 2004, Paise & Vieira 2005, Souza *et al.* 2010), being a key resource for local fauna (Kristosch & Marcondes-Machado 2001, Iob & Vieira 2008, Ribeiro & Vieira 2014).

The seed removal dynamics depends on intra- and interspecific relationships to determine the reproductive success of tree species, the dispersion processes and the forest regeneration (Janzen 1970, Janzen 1971, Silman *et al.* 2003). There is a tendency towards increased seed removal in areas with greater abundance of seed removers and higher plant density (Janzen 1970, Janzen 1971). For Brazilian pine, small (e.g. *Akodon azarae*, <200g, Vieira *et al.* 2011) to medium-sized rodents (ex. *Dasyprocta azarae*, up to 3.5 kg, Ribeiro & Vieira 2014) are the main seed removers and act as both seed predators and dispersers (Solórzano-Filho 2001, Iob & Vieira 2008, Vander Wall 2010, Vieira *et al.* 2011, Ribeiro & Vieira 2014).

Recently, the Araucaria Forests has undergone the addition of a further component to its dynamics, the presence of the alien and invasive species *Sus scrofa* L. (wild pig), which also consumes seeds of the Brazilian pine (Deberdt & Scherer 2007). The seed dispersal by wild pigs is concentrated to seeds with epizoochory strategy and therefore concentrated on exotic and herbaceous grasses (Dovrat *et al.* 2012, Oconnor & Kelly 2012). In areas with *Araucaria araucana* (Monkey Puzzle) in Argentina, the wild pigs prey on seeds reducing the food supply of native species and seed survival (Sanguinetti & Kitzberger 2010, Shepherd & Ditgen 2012). Wild pigs are recognized as an important alien ecosystem engineer with high ecological plasticity, changing the soil, seed bank structure (Singer *et al.* 1981, Ickes *et al.* 2001, Webber *et al.* 2010, Cuevas *et al.* 2012) and vegetation cover by suppression of native species (Barrios-Garcia & Ballari 2012, Cuevas *et al.* 2012). However, there is no study evaluating the relationship between wild pigs and Brazilian pine seed removal.

To better understand the potential of Brazilian pine seed removal by wild pigs, we compared the seed removal in areas of Brazilian Atlantic Forest were occurs only wild pigs and areas were occurs only their equivalent native species, the white-lipped peccary (*Tayassu pecari*). The white-lipped peccary (*Tayassu pecari*) is recognized as an important seed removal in tropical forests (Galetti *et* *al.* 2015a,b) and there is no information available about their potential of Brazilian pine seed removal.

We build a block experiment with Brazilian pine seeds in treatments with free access, access only to small mammals and only to medium and large mammals. Because of the potential of seed removal by wild pigs (Sanguinetti & Kitzberger 2010), our hypothesis was that in areas with wild pigs the seed removal would be greater in the medium and large mammals treatment, whereas in the area without wild pigs, the seed removal would be greater in the treatment with access only to small mammals, as they are recognized as the main removers of Brazilian pine seeds (Iob & Vieira 2008). We also investigated the effects of the relative abundance of seed removers on seed removal.

METHODS

STUDY AREA

This study was carried out in the Parque Nacional do Itatiaia (PNI) (22°26'14"N, 44°36'3"W), Brazil's first National Park created in 1937 and expanded in 1982, and in the Reserva Particular do Patrimônio Natural Alto Montana (RPPN) (22º21'08 "N, 44º48'04" W), both located in southeastern Brazil (Fig. 1). The protected areas have 28084 (PNI) and 672 (RPPN) ha of the Brazilian Atlantic Forest domain, specifically in the Serra da Mantiqueira Mountain, which is considered to be an area of global importance for biodiversity conservation (Myers *et al.* 2000) and recently considered an irreplaceable protected area in the world (Le Saout *et al.* 2013).

The PNI altitude range between 600 and 2791 meters and our study was conducted in the Lower Part of the PNI between 600 and 1600 m, which has a Cwb climate type, mesothermal with a rainy season in summer (Köppen 1936). The RPPN is continuous to PNI with 1500 and 2500 m of altitude and has a Cfb climate type, mesothermal, without a dry season (Köppen 1936). Both areas are located in the municipality of Itamonte, Minas Gerais, Brazil. The RPPN is dominated by a mixture of seasonal semideciduous montane forest and high altitude fields characterized by the presence of Brazilian pine while the lower part of PNI is dominated by tropical rain forest with few disperse individuals of Brazilian pine (Ururahy *et al.* 1983, Oliveira-Filho & Fontes 2000).

According to local residents, in 2006 six individuals of pigs that were kept enclosure by a commercial breeding, were intentionally released next to RPPN and established feral populations that have now a population estimated in 140±2.37 individuals at RPPN area (Puertas 2015). In order to segregate the areas used by wild pigs and white-lipped peccaries we obtained information for our laboratory team from a continuous monitoring program with automatic cameras traps in our study area since 2013. There is no evidence that wild pigs occur in the Lower Part of PNI. The white-lipped peccary occurs in the Lower Part of PNI, but there are no recent records of this species in the RPPN, indicating a probable local extinction in this region (C. A. Rosa, F. H. Puertas & M. Passamani, unpublished data).

THE BRAZILIAN PINE *ARAUCARIA ANGUSTIFOLIA*

The Brazilian pine is the sole representative of Araucariaceae family in Brazil and is distributed in the South and Southeast of the country. It grows in subtropical forests of acid soils with a minimum of 500 meters of altitude. The seed cones begin to mature two years after pollination, and the complete cycle from primitive carpel to seed takes about four years. Young trees begin to set seeds between 12 and 15 years of age (Bittencourt 2007, Thomas 2013) and normally seeds are dispersed from March to June (Mantovani *et al.* 2004).

Due to its restricted distribution, habitat fragmentation, logging and defaunation of the main seed dispersers (Veloso *et al.* 1992, Fragoso *et al.* 2011), Brazilian pine populations are declining and the species is listed as "critically endangered" by the IUCN Red List (Thomas 2013). This species is protected by national laws and its cut prohibited in Brazil (Brasil 2008; CONAMA 2001), however the seeds continue to be exploited by local residents that use them for subsistence and commercial human feeding.

Data Collection

For assessing the seed removal of Brazilian pine we conducted an experiment from April to May 2014 during the fruiting of the Brazilian pine in the sampled areas (PNI and RPPN). In this period, the experiment was repeated three times at intervals of 15 days. Within each area we selected eight sampling points around 1 km distant from each other (Fig. 1). Each point is a block with four different treatments to segregate the species with access to seeds (Mileri *et al.* 2012, Ribeiro & Vieira 2014). The treatments were arranged two meters apart, with 10 seeds in each treatment: (1)

Control: seeds arranged in the ground with free access to all animals; (2) Small: seeds placed inside PVC pipes with 75 mm thickness, accessible only for species of small mammals; (3) Large: seeds disposed within a basin 15 cm above the ground, allowing access only to medium and large mammals; (4) Closed: seeds arranged inside a PVC pipe with 25 mm thickness, inaccessible to any mammal.

To assess the relative abundance of seed removers we conducted a camera trapping effort of 960 camera-nights during the experiment with one camera-trap in each point sampled. We used motion-activated digital cameras (Bushnell HD, ©Bushnell Outdoor Products, California, USA) set to take three photos every 30 seconds. The traps were installed on trails used by mammal species. No bait was used. The camera traps were kept in continuous operation during the two months of data collection. Since the cameras can run automatically over such period, we did not check them to avoid unnecessary disturbance. At the end of sampling, memory cards were recovered and species were identified by the image records. We pooled all species of small rodents, including squirrels, into a single category because no reliable identification at species level was possible from the pictures. Each pictures of each species that occurred within one hour were considered an independent registration (Srbek-Araujo & Chiarello 2013) and the sum of independent registrations represent the relative abundance of species during the experiment. We count only for white-lipped peccaries, wild pigs and small rodents because to the low occurrence of others granivore/herbivore mammals during our study. Camera trapping also allowed us to identify seed removal events and we consider one seed removal event when we identified the manipulation of seeds by any species and their disappearance in the sequential photographic records.

DATA ANALYSIS

To test our hypothesis we consider each block as a replica and the number of seeds removed as the response variable. We compared seed removal between treatments using Kruskal-Wallis with Dunn as a *posteriori* due to non-normality of the data by Shapiro-Wilk test. The analysis was performed for the two areas together (RPPN and PNI), and for each area separately.

To single out the seed removers species that exert the most important influence on the seed removal of Brazilian pine, we used Generalized Linear Mixed Models (GLMM) with poisson distribution in 'lme4' packages in R Studio Version 0.99.473(Bolker *et al.* 2009, R Core Team 2013) allowing us to account for non-normal data and spatial correlations (Zuur *et al.* 2009). We considered the area (RPPN and PNI), the relative abundance of wild pigs, white-lipped peccaries and small rodents as fixed effects and each block (point sampled) as random effect. We also test models with the sum of all seed removers. For these we used the sum of relative abundance of all seed removers and area as fixed effects and each block (point sampled) as random effect. We used the 'dredge' function from the 'MuMIn' package in R Studio (R Core Team 2013) to test models defined by all possible variable combinations and then ranked them by their AICc-based model weight and selected the preferred model by the lowest AICc score and a cut-off of 2 AICc (Burnham & Anderson 2002).

RESULTS

From a total of 1920 seeds available in all treatments 57% were removed, being 20% removed in the Closed treatment, 63% in the Large treatment, 73% in the Control treatment and 74% in the Small treatment (Fig. 2). When we excluded the Closed treatment the seed removal reaches 70% of a total of 1440 seeds. The seed removal were different between treatments for the two areas together (PNI an RPPN) ($H = 30.0197$; $p <0.0001$) and when analyzed separately for each area (RPPN: $H = 12.9199$; $p = 0.0048$; PNI : $H = 17.6086$; $p = 0.0005$). But, in both cases, these differences is carried out by the Closed treatment that had the lowest seed removal when compared with all the other treatments ($p < 0.05$) (Fig. 2).

The relative abundance of wild pigs in RPPN was 143 individuals, while in PNI the relative abundance of white-lipped peccaries was 318 individuals; there were 75 and 122 registrations of small rodents in the RPPN and PNI respectively. For the removal events recorded by camera traps, 85% were carried out by small rodents. In RPPN, 24% of removal events were made by wild pigs and 68% by small mammals, while in PNI 4% of removal events were by white-lipped peccaries and 93% by small mammals. In our photographic records we can see that all seed removal events made by wild pigs in Large and Control treatments was carried out in a single event by one individual, and the seed removal carried out by small rodents in Small and Control treatments was gradual, with one seed being removed daily. Also we observed two more removal events by

Black-horned capuchin (*Sapajus nigritus*) and red brocket (*Mazama americana*).

The GLMMs showed that all species are important removers of Brazilian pine seeds, especially the small rodents that appear in the best model when considering the seed removers separately. Also there was no effect of wild pigs and area on seed removal when considering the seed removers separately (Table 1).

DISCUSSION

The Brazilian pine seed removal did not differ between treatments with access to small, medium and large mammals, which rejects our hypothesis that seeds are removed mainly by medium and large mammals in areas with wild pigs. Our models show that small rodents play an important role in Brazilian pine seed removal, like verified by Vieira et al. (2011). However because of white-lipped peccaries also appeared in the best models, our result showed that all native granivore mammals play an important role in seed removal. Furthermore, because of the low weight of models and the null model as the second best model, we believe that are other factors acting on the Brazilian pine seed removal (e.g. other seed removers not detected by cameras Franz *et al.* 2014, differences in Brazilian pine seeds production between points sampled).

The Araucaria forest has a history of human occupation that makes it one of the most fragmented ecosystems in Brazil (Ribeiro *et al.* 2009) and defaunated mainly of medium and large mammals (Iob & Vieira 2008, Vieira *et al.* 2011, Ribeiro &Vieira 2014). Therefore, it is expected that small rodents were the main removers of Brazilian Pine seeds as observed by many studies (e.g. Solórzano-Filho 2001, Iob & Vieira 2008). Our study is the first to access the seed removal of Brazilian pine by white-lipped peccaries and wild pigs and we showed that the white-lipped peccary have the greater relative abundance of the seed removers in our study area and also play an important role in seed removal of Brazilian pine. This is in line with the results of Galetti *et al.* (2015a) that observed that in defaunated Brazilian Atlantic Forests (without white-lipped peccaries) the predation of seeds is mostly done by small rodents (98.3%) while in non-defaunated sites they were responsible for the predation of 63.5% of the seeds. It is also interestingly that in the defaunated areas of Galetti *et al.* (2015a) the seed removal is similar to our results at PNI without wild pigs, while the seed removal in RPPN is similar to that of non-defaunated areas, suggesting that wild pigs and white-lipped peccaries can be ecological equivalents.

In RPPN, the wild pigs remove three times fewer Brazilian pine seeds than small rodents, as observed by Sanguinetti & Kitzberger (2010) for Monkey Puzzle in Argentina. Because of that, wild pigs do not appear to be a threat to seed removal dynamics of Brazilian pine, however we emphasize that wild pig invasion is recent in our study areas (under 10 years), and their effects still cannot be observed. Also, Sanguinetti & Kitzberger (2010) observed that both wild pigs and small rodents feeds on Monkey Puzzle seeds and, even with lower seed removal rates, the wild pig can be altering the resources available for the native fauna. Therefore, in our experiment we observed that wild pigs removed seeds in a single event in Control treatment which also can lead to a significant reduction in Brazilian pine seeds that is available to small native rodents.

Although the wild pig seed removal events were lower than those of the small rodents, our estimates of seed removing by wild pig is 24-fold greater than for the oak (*Quercus* spp.) in Mediterranean forests, where the species is native (Gomez *et al.* 2003). Furthermore our results show that, even with a small relative abundance, seed removal events by wild pigs were six times higher than the seed removal by the native species white-lipped peccaries.

We do not know the effects of seed removal made by large granivorous in Brazilian pine populations. In tropical forests the white-lipped peccary is recognized as an ecosystem engineers capable of changing the structure of *Astrocaryum murumuru* plant populations through cascading effects caused by the seed predation and changing in scattered hoading behavior of small mammals, changing the quantity and distribution of palm seedlings and leading to an aggregate population structure (Silman *et al.* 2003). The probability of survival of the seedlings in tropical forests is mainly determined by the distance that the seed will be from the parent plant (Janzen 1970, Connell 1971, Janzen 1971, Willson & Whelan 1990). The extinction of native predators and seed dispersers, such as peccaries and tapirs, can change the structure of plant populations directly by changing the seed removal rates and indirectly due to release of competition from other seed predators (Galetti *et al.* 2001, Fleury & Galetti 2006, Galetti *et al.* 2015a,b). The extinction of large granivorous is a problem in Brazil where the loss of large mammals by fragmentation and poaching is still present in all biomes (Cullen Jr. *et al.* 2000, Parry *et al.* 2009, Treves & Bruskotter 2014) and where native species habitat restoration and reintroduction programs are scarce.

In some landscapes, especially those where the regime and frequency of disturbances have been changed due to other human activities (Badano & Cavieres 2006), exotic ecosystem engineers, like wild pigs, could eventually replace ecological functions of native ecosystem engineers that are locally extinct (see Novel Ecosystem concept in Hobbs et al 2006 and Hobbs et al. 2009). However, it is important to advance in response to questions related to the biological consequences of ecosystem modification, social impacts and economic losses in tropical zones by wild pigs. Finally, we suggest a continuous monitoring program of wild pig invasion in Araucaria forests to evaluate the possible long term effects of the wild pig in tropical ecosystems.

ACKNOWLEDGMENTS

We would like to thank Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for fellowship to C. A. Rosa, and Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG), Tropical Forest Conservation Act and Fundo Brasileiro Para a Biodiversidade (TFCA/FUNBIO) for the financial resources. M. Passamani received a CNPq fellowship. We thank the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), the administration of the Parque Nacional do Itatiaia nd the Instituto Alto Montana for logistical support during this study. We thank F. H. Puertas for the field support.

LITERATURE CITED

BADANO, E. I., AND L. A. CAVIERES. 2006. Impacts of ecosystem engineers on community attributes: effects of cushion plants at different elevations of the Chilean Andes. Diversity and Distribution 12: 388–396.

BARRIOS-GARCIA, M., AND A. S. BALLARI. 2012. Impact of Wild boar (*Sus scrofa*) in its introduced and native range: a review. Biological Invasions 14: 2283-2300.

BITTENCOURT, J. V. M. 2007. *Araucaria angustifolia*- its geography and ecology. University of Reading. CIDADE, PAÍS.

BOLKER, B. M., M. E. BROOKS, C. J. CLARK, S. W. GEANGE, J. R. POULSEN, M. H. H. STEVENS, AND J.S. WHITE. 2009. Generalized linear mixed models: a practical guide for ecology and evolution. Trends in Ecol Evol 24(3): 127-135

BRASIL. 2008. Lista Oficial das Espécies da Flora Brasileira Ameaçadas de Extinção. Ministério do Meio Ambiente, Brasília, Brasil.

BREWER, S., AND M REJMANEK. 1999. Small rodents are significant dispersers of tree seeds in a Neotropical forest. J Veg Sci 10: 206-21

BURNHAM, K. P., AND D. R. ANDERSON. 2002. Model selection and inference: A Practical Information-theoretic. Springer-Verlag , New York, EUA.

CONAMA, CONSELHO NACIONAL DO MEIO AMBIENTE. 2001. Resolução Nº 278 de 24 de maio de 2001. Diário Oficial da União 138: 51-52.

CONNELL, J. H. 1971. On the role of natural enemies in preventing competitive exclusion in some marine animals and in rain forest trees. In P. J. Den Boer, and G. Gradwell (Eds.). Dynamics of populations, p. 298–312. PUDOC, Wageningen. UR.

CRAWLEY M.J., AND C. R. LONG. 1995. Alternate Bearing, Predator Satiation and Seedling Recruitment in Querrcus-Robur L. J Ecol 83: 683-69

CUEVAS, M. F., L. MASTRANTONIO, R. A. OJEDA, AND F. M. JAKSIC. 2012. Effects of Wild boar disturbance on vegetation and soil properties in the Monte Desert, Argentina. Mamm Biol 77(1): 299–306.

CULLEN JR., L., R. E, BODMER, AND C. VALLADARES-PÁDUA. 2000. Effects of hunting in habitats fragments of the Atantic forest, Brazil. Biol Conserv 95: 49-56.

DEBERDT, A.J., AND S. B. SCHERER. 2007. O javali asselvajado: ocorrência e manejo da espécie no Brasil. Natureza e Conservação, 5:31-44

DOVRAT, G., A. PEREVOLOTSKY, AND G. NE'EMAN. 2012. Wild boars as seed dispersal agents of exotic plants from agricultural lands to conservation areas. J Arid Environ 78(1): 49-54.

FLEURY, M., AND M. GALETTI. 2006. Forest fragment size and microhabitat effects on palm seed predation. Biol Conserv 131: 1-13.

FRAGOSO, R. O., L. E. S. DELGADO, AND L. M. LOPES. 2011. Aspectos da atividade de caça no Parque Nacional do Iguaçu – PR. Revista de Biologia Neotropical 8(1): 41-52.

FRANZ, I., M. P. BARROS, L. CAPPELATTI, R. B. DALA-CORTE, P. H. OTT. 2014. Birds of two protected areas in the southern range of the Brazilian Araucaria forest. Papéis Avulsos de Zoologia 54(10): 111-127.

GALETTI, M., R. S. BOVENDORP, AND R. GUEVARA. 2015a. Defaunation of large mammals leads to an increase in seed predation in the Atlantic forests. Global Ecology and Conservation 3: 824-830.

GALETTI, M., R. GUEVARA, C. L. NEVES, R. R. RODARTE, R. S. BOVENDORP, M. MOREIRA, J. B. HOPKINS III, AND J. YEAKEL. 2015b. Defaunation affect population and diet of rodents in Neotropical rainforests. Biol Conserv 190: 2-7.

GALETTI, M., A. KEUROPHLIAN, L. HANADA,, AND M. I. MORATO. 2001. Frugivory and Seed Dispersal by the Lowland Tapir (*Tapirus terrestris*) in Southeast Brazil1. Biotropica 33(4): 723-726.

GOMEZ, J. M., D. GARCIA, AND R. ZAMORA. 2003. Impact of vertebrate acorn- and seedling-predators on a Mediterranean *Quercus pyrenaica* forest. For Ecol Manag 180: 125–134.

HOBBS, R. J., S. ARICO, J. ARONSON, J. S. BARON, P. BRIDGEWATER, V. A. CRAMER, P. R. EPSTEIN, J. J. EWEL, C. A. KLINK, A. E. LUGO, D. NORTON, D. OJIMA, D. M. RICHARDSON, E. W. SANDERSON, F. VALLADRES, M. VILÀ, R. ZAMORA, AND M. ZOBEL. 2006. Novel ecosystems: theoretical and management aspects of the new ecological world order. Global Ecol Biogeogr 15:1–7.

HOBBS, R. J., E. HIGGS, J. A. HARRIS. 2009. Novel ecosystems: implications for conservation and restoration. Trends Ecol Evol 24(11).

ICKES, K., S. J. DEWALT, AND S. APPANAH. 2001. Effects of native pigs (*Sus scrofa*) on woody understory vegetation in a Malaysian lowland rain forest. J Trop Ecol 17(1):191-206.

IOB, G., AND E. M. VIEIRA. 2008. Seed predation of *Araucaria angustifolia* (Araucariaceae) in the Brazilian Araucaria Forest: influence of deposition site and comparative role of small and 'large' mammals. Plant Ecol 198: 185-196.

JANZEN, D. H. 1970. Herbivores and the number of tree species in tropical forests. The Am Nat 104(940): 501-528

JANZEN, D. H. 1971. Seed predation by animals. Annu Rev Ecol Syst 2: 465-492.

KÖPPEN, W. 1936. Das geographisca System der Klimate. *In* W. Koppen, and R. Geiger (Eds.). Klimatologie, p. 298–312. Gebr, Borntraeger, Germany.

KRISTOSCH, G. C., AND L. O. MARCONDES-MACHADO. 2001. Diet and feeding behavior of the Reddish-Bellied Parakeet (*Pyrrhura frontalis*) in an Araucaria forest in Southeastern Brazil. Ornitologia Neotropical 12: 215-223.

LE SAOUT, S., M. HOFFMANN, Y. SHI, A. HUGHES, C. BERNARD, T. M. BROOKS, B. BERTZKY, S. H. M. BUTCHART, S. N. STUART, T. BADMAN, AND A. S. L. RODRIGUES. 2013. Protected areas and effective biodiversity conservation. Science 342: 803.

MANTOVANI, A., L. P. C. MORELLATO, AND M. S. REIS. 2004. Fenologia reprodutiva e produção de sementes em *Araucaria angustifolia* (Bert.) O. Kuntze. Rev Bras Bot 27(4): 787-796.

MILERI, M., M. PASSAMANI, F. EUTRÓPIO, AND A. OLIVEIRA. 2012. Removal of Seeds of Exotic Jackfruit Trees (*Artocarpus heterophyllus*, Moraceae) in Native Forest Areas with Predominance of Jackfruit Trees in the Duas Bocas Biological Reserve, Southeastern Brazil. International Journal of Ecosystem 2(5): 93-98.

MYERS, N., R. A. MITTERMEIER, C. G. MITTERMEIER, G. A. B. FONSECA, AND J. KENT. 2000. Biodiversity hotspots for conservation priorities. Nature 403: 853-858.

OCONNOR, S. J., AND D. KELLY. 2012. Seed dispersal of matai (*Prumnopitys taxifolia*) by feral pigs (*Sus scrofa*). New Zeal J Ecol 36(2): 228-231.

OLIVEIRA-FILHO, A. T., AND M. A. L. FONTES. 2000. Patterns of floristic differentiation among Atlantic Forests in Southeastern Brazil and the influence of climate. Biotropica 32(4b): 793-810.

PAISE, G., AND E. M. VIEIRA. 2005. Produção de frutos e distribuição espacial de angiospermas com frutos zoocóricos em uma Floresta Ombrófila Mista no Rio Grande do Sul, Brasil. Rev BrasBot 28(3): 615-625.

PARRY, L., J. BARLOW, AND C. PERES. 2009. Hunting for Sustainability in Tropical Secondary Forests. Conserv Biol 23(5): 1270–1280.

PUERTAS, F. H. 2015. A Invasão do Javali na Serra da Mantiqueira: Aspectos populacionais, uso do habitat e sua relação com o Homem. MSc Dissertation. Universidade Federal de Lavras, Lavras. Brazil.

R CORE TEAM. 2013. A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna.

RIBEIRO, J. F. AND E. M. VIEIRA. 2014. Interactions between a seed-eating neotropical rodent, the Azara's agouti (*Dasyprocta azarae*), and the Brazilian 'pine' *Araucaria angustifolia*. Austral Ecol 39: 279-287.

RIBEIRO, M. C., J. P. MARTENSEN, A. C. PONZONI, AND M. M. HIROTA. 2009. The Brazilian Atlantic Forest: how much is left, and how is the remaining forest distributed? Implications for conservation. Biol Conserv 142: 1141-1153.

SANGUINETTI, J., AND T. KITZBERGER. 2010. Factors controlling seed predation by rodents and non-native *Sus scrofa* in *Araucaria araucana* forests: potential effects on seedling establishment. Biol Invasions 12: 689-706.

SCHUPP E. W. 1988. Factors affecting post-dispersal seed survival in a tropical forest. Oecologia 76: 525–530.

SHEPHERD, J. D., AND R. S. DITGEN. 2012. Rodent handling of *Araucaria araucana* seeds. Austral Ecol 38(1): 23-32.

SILMAN, M. R., J. W. TERBORGH, AND R. A. KILTIE. 2003. Population regulation of a dominant rain forest tree by a major seed predator. Ecology 84(2): 431-438.

SINGER, F. J., D. K. OTTO, A. R. TIPTON, AND C. P. HABLE. 1981. Home ranges, movements and habitat use of European Wild boar in Tennessee. Journal of Wildlife Management 45: 343–353.

SOLÓRZANO-FILHO, J. A. 2001. Demografia, fenologia e ecologia da dispersão de sementes de *Araucaria angustifolia* em uma população relictual em Campos do Jordão, SP. MSc Dissertation. Universidade de São Paulo, São Paulo.

SOUZA, A. F., D. UARTE DE MATOS, C. FORGIARINI, AND J. MARTINEZ. 2010. Seed crop size variation in the dominant South American conifer Araucaria angustifolia. Acta Oecol 36: 126–134

SRBEK-ARAUJO, A. C., AND A. G. CHIARELLO. 2013. Influence of camera-trap sampling design on mammal species capture rates and community structures in southeastern Brazil. Biota Neotropica 13(2): 51-62.

THOMAS, P. 2013. *Araucaria angustifolia*. The IUCN Red List of Threatened Species. Version 2015.2. <www.iucnredlist.org>. Downloaded on 26 June 2015.

TREVES, A., AND J. BRUSKOTTER. 2014. Tolerance for predatory wildlife. Science 344: 476-477.

URURAHY, J. C., J. E. R. COLLARES, M. M. SANTOS, AND R. A. A. BARRETO. 1983. *In* RADAMBRASIL, Vegetação, Levantamento dos Recursos Naturais 32, Folhas SF 23/24. Rio de Janeiro/Vitória, Brasil.

VANDER WALL, S.B. 2010. How plants manipulate the scatter-hoarding behaviour of seed-dispersing animals. Phil. Trans. R. Soc. B 365: 989–997.

VELOSO, H. P., A. L. R. RANGEL FILHO, AND J. C. A. LIMA. 1992. Classificação da vegetação brasileira, adaptada a um sistema universal. Instituto Brasileiro de Geografia e Estatística. Rio de Janeiro, Brasil.

VIEIRA, E. M, J. F. RIBEIRO, AND G. IOB. 2011. Seed predation of *Araucaria angustifolia* (Araucariaceae) by small rodents in two areas with contrasting seed densities in the Brazilian Araucaria forest. J Nat Hist 45 (13-14): 843-854.

WANG, L., J. LYONS, P. RASMUSSEN, P. SEELBACH, T. SIMON, M. WILEY, P. KANEHL, E. BAKER, S. NIEMELA, AND P. M. STEWART. 2003. Watershed, reach, and riparian influences on stream fish assemblages in the Northern Lakes and Forest Ecoregion, U.S.A. Cannadian Journal of Fisheries and Aquatic Sciencies 60: 491–505.

WEBBER, B., B. A. NORTON, AND I. E. WOODROW. 2010. Disturbance affects spatial patterning and stand structure of a tropical rainforest tree. Austral Ecol 35(1):423-434.

WILLSON, M. F., AND C. J. WHELAN. 1990. Variation in postdispersal survival of vertebrate-dispersed seeds: effects of density, habitat, location, season, and species. Oikos, 57 (2): 191-198.

ZUUR, A. F., E. N. IENO, N. J. WALKER, A. A. SAVELIEV, AND G. M. SMITH. 2009. Mixed Effects Models and Extensions in Ecology with R. Springer, New York, EUA.

Table 1. Ranking of the best Generalized Linear Mixed Models with poisson distribution and significance of fixed effects in each model for predicting the effects of area and seed removers in the Brazilian Pine seed removal at Brazilian Atlantic Forest, southeastern Brazil.

Best Generalized Linear Mixed Models for seed removal taxa					
Models	**df**	**AICc**	**Δ AICc**	**Wi**	**Cumulative Wi**
Models with different seed removals					
Rodents	3	322.9	0	0.181	0.181
Null	2	323.1	0.2	0.164	0.345
Peccaries + Rodents	4	323.8	0.9	0.116	0.461
Peccaries	3	324.6	1.69	0.078	0.539
Models with the sum of all seed removals					
Seed removers	3	322.5	0	0.424	0.424
Null	2	232.1	0.6	0.314	0.738
Area + Seed removers	4	324.5	1.95	0.160	0.898

FIGURE LEGENDS

Figure 1: Study area showing the sampled points (blocks) in RPPN Area (circle), the *Sus scrofa* area, and Parque Nacional do Itatiaia (triangle), the *Tayassu pecari* area. The gray line is the division of the Brazilian states where the RPPN (Minas Gerais) and Parque Nacional do Itatiaia (Rio de Janeiro) are located.

Figure 2: Mean, standard and maximum and minimum deviation of seed removal in each treatment.

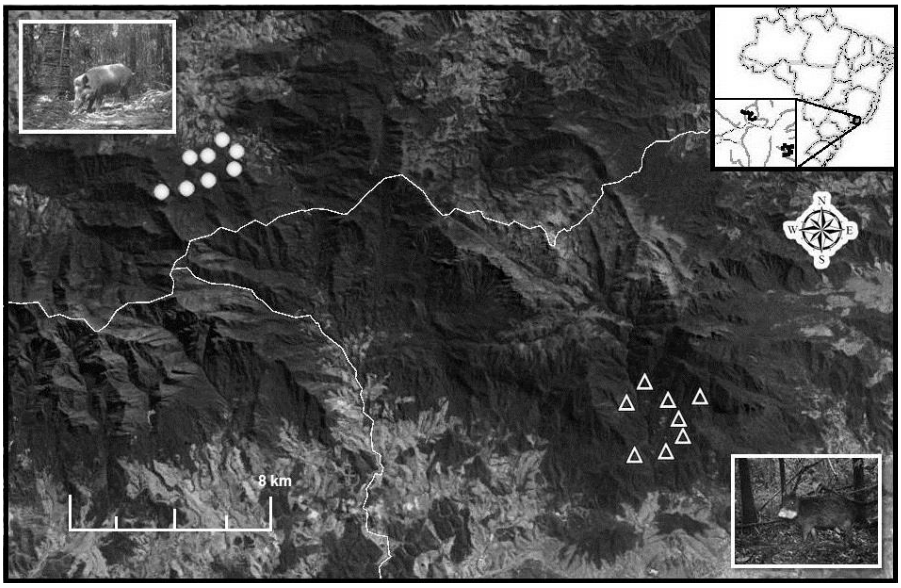


Figure 1

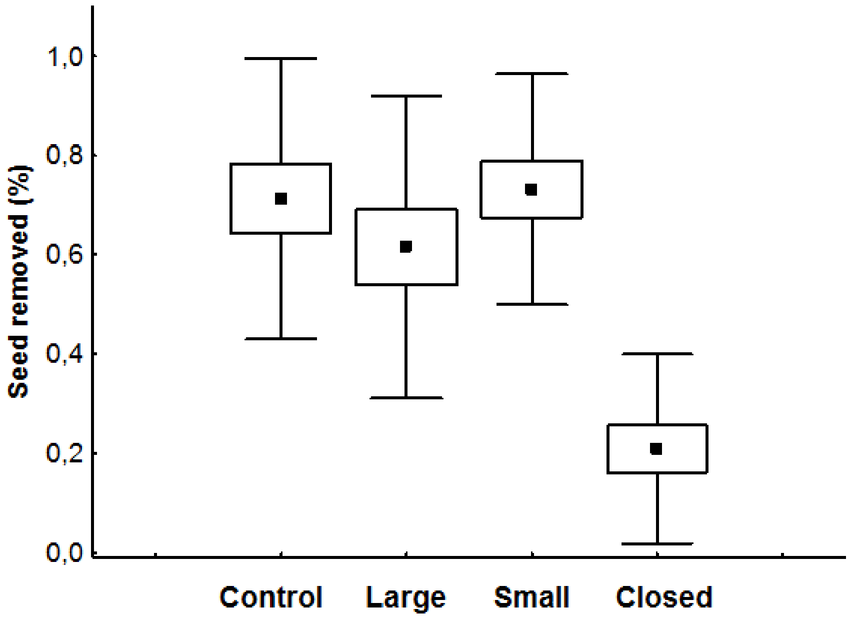


Figure 2