UNIVERSIDADE ESTADUAL PAULISTA
"JÚLIO DE MESQUITA FILHO"
INSTITUTO DE BIOCIÊNCIAS – RIO CLARO

PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA, EVOLUÇÃO E BIODIVERSIDADE

# *REDUCTIO AD ABSURDUM*

# SIMPLIFICATION OF TROPHIC PROCESSES IN TROPICAL FORESTS

FERNANDO SILVA LIMA, M.Sc.

Orientador: Prof. Dr. Milton Cezar Ribeiro

Co-orientador: Dr. Clinton Neil Jenkins

Dezembro - 2020

UNIVERSIDADE ESTADUAL PAULISTA
“JÚLIO DE MESQUITA FILHO”
INSTITUTO DE BIOCIÊNCIAS – RIO CLARO


PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA, EVOLUÇÃO E BIODIVERSIDADE

# *REDUCTIO AD ABSURDUM*

# SIMPLIFICATION OF TROPHIC PROCESSES IN TROPICAL FORESTS


FERNANDO SILVA LIMA, M.Sc.

Orientador: Prof. Dr. Milton Cezar Ribeiro

Co-orientador: Dr. Clinton Neil Jenkins


Tese apresentada ao Instituto de Biociências do Câmpus de Rio Claro, Universidade Estadual Paulista, como parte dos requisitos para obtenção do título de Doutor em Ecologia, Evolução e Biodiversidade.

Dezembro - 2020

L732r

Lima, Fernando Silva
Reductio ad absurdum: simplification of trophic processes in tropical forests / Fernando Silva Lima. -- Rio Claro, 2022
96 f. : il., tabs., mapas

Tese (doutorado) - Universidade Estadual Paulista (Unesp), Instituto de Biociências, Rio Claro
Orientador: Milton Cezar Ribeiro
Coorientador: Clinton Neil Jenkins

1. Animais carnívoros. 2. Predação (Biologia). 3. Animais predadores. I. Título.

Sistema de geração automática de fichas catalográficas da Unesp. Biblioteca do Instituto de Biociências, Rio Claro. Dados fornecidos pelo autor(a).

Essa ficha não pode ser modificada.

UNIVERSIDADE ESTADUAL PAULISTA

**Câmpus de Rio Claro**

## CERTIFICADO DE APROVAÇÃO

TÍTULO DA TESE: **REDUCTIO AD ABSURDUM: SIMPLIFICATION OF TROPHIC PROCESSES IN TROPICAL FORESTS**

**AUTOR: FERNANDO SILVA LIMA**
**ORIENTADOR: MILTON CEZAR RIBEIRO**
**COORIENTADOR: MAURO GALETTI RODRIGUES**
**COORIENTADOR: CLINTON NEIL JENKINS**

Aprovado como parte das exigências para obtenção do Título de Doutor em ECOLOGIA E BIODIVERSIDADE, área: Biodiversidade pela Comissão Examinadora:

Prof. Dr. MILTON CEZAR RIBEIRO (Participaçao Virtual)
Departamento de Biodiversidade / UNESP - Instituto de Biociências de Rio Claro - SP

Prof. Dr. ROGERIO CUNHA DE PAULA (Participaçao Virtual)
Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) / Centro Nacional de Pesquisa e Conservação de Mamíferos Carnívoros - Atibaia/SP

Marcelo Magioli
Prof. Dr. MARCELO MAGIOLI (Participaçao Virtual)
Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) / Centro Nacional de Pesquisas e Conservação de Mamíferos Carnívoros - Atibaia / SP

Prof. Dr. ALEXANDRE CAMARGO MARTENSEN (Participaçao Virtual)
Centro de Ciências da Natureza da UFSCAR / Universidade Federal de São Carlos - Campus Lagoa do Sino - Buri / SP

Marco A. Pizo
Prof. Dr. MARCO AURELIO PIZO FERREIRA (Participaçao Virtual)
Departamento de Biodiversidade / UNESP - Instituto de Biociências de Rio Claro - SP

Rio Claro, 15 de janeiro de 2021

*A minha tia Léa;*

*A meu avô Elon†;*

*A meu pai do mato Cicinho†;*

*e a todos que no fim da jornada podem citar 2 Timóteo 4:7.*

*† in memoriam*

# REFLEXÕES E AGRADECIMENTOS

O que é um doutorado? Nos últimos meses de redação deste documento me vi retornando a esta pergunta inúmeras vezes. Seria uma tese? Um conjunto de artigos publicados? Créditos por disciplinas concluídas? Foi nesse momento que parei para pensar no que fiz nesses anos e somente depois de lembrar o por que decidi fazer doutorado é que consegui me aproximar do que imagino ser uma resposta. Depois de me graduar em 2003 me associei a um instituto de pesquisas e – apesar de ter feito uma especialização na Inglaterra em 2006 – somente em 2007 ingressei no mestrado. Senti que passar um tempo fora da universidade, participando de iniciativas práticas focadas em conservação da biodiversidade me trouxeram uma perspectiva um pouco mais abrangente de atuação como pesquisador. Nesse intervalo tive a oportunidade de estudar e participar de muitos cursos e, assim, compensar algumas não poucas lacunas na minha formação durante a graduação.

O mestrado, em toda a sua intensidade, me trouxe reflexões importantes sobre o por que da pesquisa. Por que coletamos dados? O que fazer com eles? Por que ir para campo coletar dados é só a divertida ponta do iceberg da ciência (não tão divertido da água para baixo). Minha dissertação contestava alguns dos protocolos colocados em prática na pesquisa com felinos selvagens na época e, apesar de severamente contestada em alguns momentos, serviu de referência para a elaboração de desenhos amostrais em diversas iniciativas no país. Fiquei muito feliz em sentir que não seria apenas mais uma encadernação em capa dura arquivada em alguma biblioteca. Enquanto focava em dar continuidade as minhas iniciativas de pesquisa com jaguatiricas no Pontal do Paranapanema e em colaborar com outros grupos Brasil afora – empolgado com as aplicações práticas de meus estudos – uma importante transição acontecia. Os equipamentos para amostragens de fauna, antes restritos a projetos grandes com muito recurso, se tornaram mais acessíveis viabilizando novas iniciativas e amostragens em regiões pouco conhecidas. As abordagens analíticas, antes compartimentadas em softwares específicos, voltaram a raiz da revolução digital quando era necessário digitar linhas de comando com linguagem de programação até para abrir disquetes com 1.44 mb de memória. O desenvolvimento de pacotes analíticos utilizando linguagens de programação em ambientes de código aberto, associado a capacidades de processamento que fazem meu primeiro computador parecer uma calculadora científica, levaram a ecologia enquanto ciência para uma nova era. O céu se tornou o novo limite. Comecei a sentir que precisava me atualizar. Precisava de um momento de imersão na literatura, nas ferramentas e nas novas e cada vez mais sofisticadas linhas de pesquisa. Era hora de fazer doutorado.

No final de 2014 estava procurando uma casa para alugar em Goiânia, onde pretendia me mudar com minha família para iniciar esta nova etapa no PPG em Ciências Ambientais da UFG. Havia sido aprovado em primeiro lugar no processo seletivo com uma bolsa em meu nome. Meses antes havia procurado o Prof. Dr. Milton Ribeiro, que disse que só conversaríamos se o chamasse de Miltinho. Na época de minha primeira visita a Rio Claro, infelizmente Miltinho não tinha mais vagas para orientados. Um tempo depois, enquanto pesquisava por imobiliárias goianas na internet, recebi um e-mail de Miltinho intitulado "interessado no dout ainda?". Fiz a prova sem nenhuma expectativa no dia 21 de Janeiro de 2015, exatos 15 dias depois do nascimento de meu primeiro filho. Passei e decidimos abandonar a idéia de ir para Goiânia. Mesmo tendo prometido a mim mesmo que nunca mais moraria em uma planície depois de 9 anos vivendo em Teodoro Sampaio – extremo oeste do estado de São Paulo - em Maio de 2015 estávamos morando em Rio Claro para avançar com o doutorado.

Foram 3 anos difíceis - principalmente para minha esposa - em uma cidade estranha, sem família ou amigos e um bebê. No entanto, entre todos os desafios típicos da rotina acadêmica, que a tanto tempo não faziam parte de minha vida, uma coisa que nunca pude me queixar foi o apoio incondicional de meu orientador. Em momentos de dificuldades pessoais, financeiras, morais, psicológicas, etc. nunca houve "tempo ruim". Com muito carinho e empatia ele estava sempre lá. Mesmo diante de todas minhas limitações enquanto cientista, nunca pude reclamar dessa parceria e amizade. Sempre com um berimbal debaixo do braço, posso dizer que meu orientador de doutorado foi e é uma das pessoas mais importantes minha formação como ser humano, pai e pesquisador. Mesmo com a atual distância física, serei sempre seu aprendiz. Poderia redigir por horas sobre causos, aventuras, desventuras, aprendizados e mandingas que passei com Miltinho em não poucas viagens pelo Brasil e até no exterior. É com mais de uma lágrima que escrevo essas linhas enquanto lido com uma das maiores pandemias da história da humanidade e finalizo minha tese. Toda honra e toda glória a aquele que nunca se corrompeu pela ilusão dos pequenos poderes da hierarquia acadêmica. Obrigado Miltinho!

Nesse período em Rio Claro descobri uma paixão: o jiu-jitsu. Na década de 90 eu levava o video cassete da casa do meu avô para a casa de um amigo e lá copiavamos fitas VHS dos primeiros UFCs. Criado por Rorion Gracie em 1993, o objetivo do UFC era provar a superioridade do jiu-jitsu brasileiro sobre as outras artes marciais. Fazia isso por que meu tio praticamente me obrigava e achava muito chato um brasileiro com nome estranho (Royce) ficar mais de uma hora agarrado com um lutador no chão até que o "finalizasse". Um dia passando na Rua 5 vi a academia dos Senseis Leandro Brassoloto e Ivan Andrade e parei lá para perguntar. Estava procurando uma atividade física e achei que podia ser interessante. Nessa época minha esposa estava redigindo sua tese de doutorado e eu ficava a maior parte do tempo cuidando do meu filho para que ela pudesse trabalhar. Descer a Av. 14 para o treino das 19:00 era meu ritual diário, meu momento. Durante uma hora e meia só existia o jiu-jitsu. Todas as angústias, dificuldades e ansiedades eram esquecidas. É muito difícil focar nessas coisas quando tem alguém tentando de estrangular. A camaradagem e bom humor no tatame, o bem estar físico e a autoconfiança que o jiu-jitsu me trouxe é o que me fez passar por este período sem me destruir psicologicamente. Agradeço de coração aos meus senseis e irmãos de tatame por me ajudarem a superar os desafios do doutorado. Oss

Quando cheguei no LEEC - Laboratório de Ecologia Espacial e Conservação me senti no mínimo deslocado. Com 38 anos de idade, casado e com um filho me vi cercado de jovens incríveis, no *leading edge* da ecologia de paisagens e no auge de um grande projeto apoiado pela FAPESP em parceria com a Universidade de Helsinki. Aos poucos fui conhecendo as pessoas e processos. Fiz amigos com os quais criei laços invisíveis para a vida toda, embora distantes fisicamente hoje. Nada forja amizades e relações como por perrengues, desafios e batalhas juntos. São nos momentos de dificuldade e necessidade que caem as máscaras que todos nós vestimos diariamente para viver em sociedade e vemos quem é quem. Não foram poucos os desafios e batalhas e encontrei pessoas com códigos de conduta e ética impecáveis na vida pessoal, profissional e acadêmica, outras nem tanto mas mesmo assim tiveram algo a ensinar. Agradeço ao meu amigo Rafael (Urucum), seu jeitão rústico é só uma carapaça para os desavisados. Embaixo dessa casca grossa está

uma das pessoas mais interessantes que tive o prazer de conhecer e conviver nos últimos anos. Agradeço a Renata Muylaert, companheira de não poucas batalhas e desafios. A Milene Eigenheer, a Erison Monteiro, a Natália Stefanini, Paula Montagnana, Cláudia Kanda e Julia Oshima pela amizade, parceria, troca de farpas e discussões sensacionais sobre todo tipo de coisa.

Agradeço a minha alma mater o IPÊ - Instituto de Pesquisas Ecológicas. O IPÊ abriu as portas para mim quando era um biólogo recém formado e ao mesmo tempo me abriu as portas para o mundo. Não tenho palavras para descrever a admiração e gratidão por toda a generosidade de Claudio e Suzana Pádua ao longo destes quase18 anos de convivência. Realmente não tenho palavras, estou há um bom tempo na frente do computador, mas não há formas de expressar o que gostaria através da linguagem escrita. Muito, muito obrigado! Agradeço aos meus amigos e mentores Clinton Jenkins e Alexandre Uezu. Uma das coisas que mais sinto falta no dia-a-dia é de tê-los por perto e poder conversar sobre cultura e ciência com essas mentes brilhantes. Agradeço a minha amiga Angela Pellin, por liderar pelo exemplo e me mostrar o estoicismo na prática. A toda equipe do projeto *Desenvolvimento de novas tecnologias para avaliação dos serviços ambientais em programas de revegetação* IPÊ-CTG, em especial a Williana Marin por todo carinho e atenção na preparação de nossas expedições relâmpagos. Parte desta tese foi viabilizada financeiramente por este projeto e muitos dos resultados dos dados coletados ainda trarão contribuições sobre as estratégias de conexão e padrões de recolonização da fauna em áreas de restauração. A querida Cristina – Tina – Tófoli, minha irmã de coração e toda a equipe do projeto *Monitoramento Participativo da Biodiversidade* IPÊ-ICMBio por renovar minha fé na conservação. A Fabiana Prado por me mostrar o que é liderança e colaboração na prática. Ao time de elite da 2ª Atualização das Áreas Prioritárias da Mata Atlântica IPÊ-MMA: Clinton Jenkins, Angela Pellin, Alexandre Uezu, Alexandre Martensen, Henrique Shirai e Neluce Soares. A equipe e projeto que tenho o maior orgulho e provilégio de ter participado. Agradeço a todo o *staff* do IPÊ por essa jornada em busca de um país mais sustentável. Em especial a Edu Ditt, Andrea Peçanha, Marcela Paolino, Patrícia Medici, Pollyana Lemos, Rafael Chiaravalloti, Simone Tenório, Paula Piccin e a meus irmãos de expedições: José Wilson e Cicinho (*in memoriam*).

Sempre tentei explicar meu trabalho para minha família, as vezes escrevendo, as vezes batendo papo. De fato, desde a graduação quando criei o *fanzine* “Drosophila” há 20 anos atrás, tento falar sobre ecologia e biologia escrevendo. Em 2016 iniciei uma coluna com alguns textos de relativo alcance, mas ainda insipientes. Nessa época, rabisquei em uma prancheta o esboço do que veio a se tornar o DesAbraçando Árvores, projeto lançado em 2018 focado em ecologia e biologia da conservação no formato *podcast*. De lá para cá posso dizer com tranquilidade que este o projeto mudou minha vida e minha carreira. Agradeço ao amigo e padrinho Fabiano Rodrigues de Melo e Rogério Cunha de Paula – meu irmão nerd – que abraçaram a idéia desde o início. A toda a família FIFA pelo suporte e a Paula Piccin, a querida Laís Duarte, a Fernanda Abra, ao maravilhoso Luiz Antônio Gambá, a Lays Parolin, ao Senhor A e a Hugo Fernandes meu eterno obrigado pela amizade e parceria nesse projeto maluco. Nunca imaginei que gravar tudo aquilo que antes fazia as pessoas me rotularem de chato se tornaria um movimento do bem, divulgando projetos e iniciativas importantes de conservação da biodiversidade e o mais importante: quebrando tabus e acabando com *clichês*. Agradeço de coração a cada pesquisador e pesquisadora, cada pessoa que passou pelo podcast e generosamente compartilhou sua jornada conosco e com nossos ouvintes. Esse projeto, por mais que desejássemos dar continuidade, não seria viável sem o apoio de um grupo muito especial de pessoas que se juntaram ao movimento e se dispuseram a contribuir com a *causa*. Obrigado pela confiança, apoio e também pelas críticas. Mas vale sempre a pena lembrar: não nos responsabilizamos por nada!

Agradeço a Ryan Holiday por me apresentar o estoicismo, ao imperador Marcus Aurelius por deixar suas meditações para a posteridade e a Jocko Willink (thanks for your service Sir). Agradeço aos autores Bernard Cornwell, Jim Corbett, Yuval Harari, Cal Newport, Jack Donovan, Dakota Meyer (thanks for your service), Nathan Lents, Matthew Walker, John Stryker Meyer (thanks for your service), John Plaster (thanks for your service), Sean Parnell (thanks for your service), Neil DeGrasse Tyson, Steven Novella, Stephen King, Michael Punke, Ken Follett e David Quammen por me ajudarem a mudar minha visão de mundo nesses últimos anos. Alexandre Ottoni (Joven Nerd), a Deive Pasos (Azaghal), e a Atila Iamarino meu muito obrigado pelas centenas de horas de companhia no Nerdcast.

A Miriam Perilli, minha cara metade, não há como expressar a gratidão por tudo o que vivemos nesses anos e nesta etapa de nossas vidas. Sua paciência, carinho, parceria e cumplicidade trazem sentido e direção a jornada. Esse ciclo se fecha para nós dois e que venham novos desafios! Obrigado por dividir sonhos, sorrisos e lágrimas. Por dividir a vida, o universo e tudo o mais. Aos pequenos Ian e Lis, por me ensinarem a valorizar o que realmente é importante.

Agradeço a minha tia-irmã Leá (tia Cotinha), sem a qual eu não teria feito nem graduação. A minha mãe e a minha querida irmã Cintia. Agradeço também a Dona Miriam Lages, Ana Luiza, Abraão, Maria Regina, Felipe e ao senhor Rômulo Perilli. Obrigado por me receberem de braços abertos na família.

Na reta final das análises e redação tive a ajuda de generosos amigos e cientistas incríveis que me estenderam a mão e tentaram contribuir de todas as formas possíveis. Obrigado Marcelo Magioli, Ronaldo Morato, Elildo Carvalho, Alexandre Martensen, Alexandre Uezu e Milene Eigenheer. Vocês são sensacionais! Desculpem não ter sido o melhor dos aprendizes, mas obrigado por tentarem!

Enfim, voltando a pergunta inicial, essa tese é apenas um fechamento de um processo de formação de um cientista. Li e estudei compulsivamente, elaborei e ministrei disciplinas, contribui com aulas em disciplinas em diversos estados do Brasil e do exterior, participei de discussões acadêmicas em disciplinas, coletei dados, organizei expedições, trabalhei com equipes incríveis, implodi equipes, abandonei equipes, acertei, errei, montei equipes, fechei parcerias nacionais e internacionais. Escrevi projetos de pesquisa, levantei recursos com agências de fomento, institutos de pesquisa e setor privado. Apresentei e discuti meu trabalho com cientistas, governantes, tomadores de decisão e empresários no Brasil e no exterior. Utilizei minha expertise prévia e novas ferramentas aprendidas durante o doutorado para contribuir com planos de ações de espécies ameaçadas, apresentei propostas de soluções para problemas práticos para grandes corporações internacionais e para o governo brasileiro. Mais tarde passei finais de semanas inteiros editando áudio tentando traduzir a importância disso para minha tia e para o público leigo. Colaborei com dezenas de grupos de pesquisa na redação, revisão e análise de dados em artigos publicados nesse período, outros já submetidos e alguns sendo preparados para submissão nesse exato momento. Passei a entender o doutorado como um processo de crescimento e atualização, de formação de um cientista capaz de pensar

em questões teóricas e práticas relevantes para o avanço da ciência e da tecnologia, de fazer parcerias e levantar recursos que viabilizem isso, executar, analisar e reportar. Ser capaz de sintetizar seu conhecimento adquirido e passar adiante. Dificilmente conseguiria resumir esse processo de transformação pessoal e profissional em um documento. Como inúmeros colegas antes de mim, cheguei no final deste processo produzindo uma tese que não correspondeu aos meus anseios no início do processo. Muita coisa ficou para trás por que era ridiculamente inviável desde o início e meu orientador teve a sabedoria de me deixar aprender errando (e para largar de ser teimoso). Outras por falta de organização e outras simplesmente pela dinâmica da vida e mudanças que estão fora do nosso controle. Algumas etapas acabam aqui, algumas vou dar continuidade por que preciso e outras por que quero. Em relação a esta etapa de minha vida posso afirmar que, assim como Paulo, combati o bom combate e terminei minha jornada. O presente trabalho foi realizado com apoio da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Código de Financiamento 001.

So long and thanks for all the fish!

Valar Dohaeris

# Sumário

**APPENDIX I. Produção como discente (2015 – 2020)**

# RESUMO GERAL

A perda e a fragmentação de habitat têm sido descritas mundialmente como as principais ameaças à biodiversidade. Além da redução extrema na densidade e abundância das populações de animais silvestres, esses fenômenos têm implicações nas interações entre as espécies, levando a consequências imprevisíveis. Isso é particularmente sensível quando se trata de interações predador-presa, onde as respostas do predador - ou a ausência dela - às mudanças na paisagem e no habitat podem ter influência direta nas redes alimentares. A importância ecológica dos grandes mamíferos carnívoros (Carnivora) é facilmente reconhecida, pois mesmo poucos indivíduos deste grupo podem exercer um forte controle *top down* sobre as populações de presas e predadores menores. No entanto, não apenas os grandes predadores, mas as populações de grandes mamíferos em geral estão em declínio em todo o mundo. Esse processo de defaunação tende a favorecer espécies de mamíferos de menor massa corporal, alta taxa reprodutiva, onívoros e generalistas, às vezes descrito como “miniaturização da fauna”. Outro fenômeno relacionado à defaunação é a hipótese da liberação do mesopredador. Usado para descrever as irrupções de predadores menores após a extirpação dos maiores. Na Mata Atlântica, um dos hotspots mundiais de biodiversidade, o predador de ápice (onça-pintada) está regionalmente extinto na maior parte do bioma. Além disso, mais de 50% deste bioma está distribuído em um mosaico de manchas florestais menores que 500 ha. A Mata Atlântica combina as principais variáveis associadas a surtos de liberação de mesopredadores. Nesta tese, reuni as principais características da hipótese de liberação do mesopredador adaptada a um contexto regional: a comunidade de mamíferos carnívoros da Mata Atlântica. Inicialmente, proponho um modelo conceitual baseado em hipóteses gerais e resultados esperados apoiados em pesquisa bibliográfica e conhecimento empírico como referência para orientar futuras análises em larga escala sobre esse fenômeno. Seguindo esta discussão, apresento o conjunto de dados *Atlantic-Camtraps*, destinado a apoiar os dados necessários para explorar o fenômeno de liberação de mesopredadores na Mata Atlântica. Por fim, trago um estudo de caso sobre o maior predador da Mata Atlântica em um de seus últimos redutos no bioma. Neste capítulo, eu e meus colegas apresentamos os resultados de cinco anos de monitoramento por telemetria e discutimos a ausência de padrões típicos, como sazonalidade e diferenças no tamanho da área de vida entre machos e fêmeas.

**Palavras-chave**: Animais carnívoros, Predação (Biologia), Animais predadores

# GENERAL ABSTRACT

Habitat loss and fragmentation has been described worldwide as the main threats to biodiversity. Additional to extreme reduction on wildlife populations density and abundance, these phenomena have implications on species interactions, leading to unpredicted consequences. This is particularly sensitive when it comes to predator-prey interactions, where predator responses - or the absence of it – to landscape and habitat changes may have direct influence across food webs. The ecological importance of large mammalian carnivores (Carnivora) is easily recognized since even a few individuals can exert strong top-down control on prey populations and smaller predators. Nevertheless, not only large predators, but large mammal populations in general are in decline worldwide. This shift pattern in mammal species pool towards smaller body mass, highly reproductive rate, omnivorous and generalists caused by defaunation has been described as downsizing. One phenomenon related to defaunation is the mesopredator release hypothesis. It was used to describe smaller predators' irruptions after extirpation of larger ones. In the Atlantic Forest, one of the world's biodiversity hotspots, the apex predator (jaguars) is regionally extinct in most of the biome. Additionally, more than 50% of this biome is distributed in a mosaic of forest patches smaller than 500 ha. The Atlantic Forest combines the key variables associated with mesopredator outbreaks. In this thesis, I put together the key features of the mesopredator release hypothesis adapted to a regional context: the mammal carnivore community of Atlantic Forest. I propose a conceptual model based on general hypothesis and expected results supported by literature research and empirical knowledge as a reference to guide future large-scale analyses on this phenomenon. Following this discussion, I present the dataset Atlantic-Camtraps, originally intended to support the data needed to explore the mesopredator release phenomenon in the Atlantic Forest. Lastly, I bring a study case on the Atlantic Forest apex predator in one of its last strongholds in the biome. In this chapter me and my colleagues present the results of five years of monitoring through telemetry and discuss the absence of typical patterns such as seasonality and differences in home range size between males and females.

**Keywords**: Predation, Carnivora, Predator-prey interaction

# GENERAL INTRODUCTION

Changes in the abundance and persistence of biodiversity, led by the loss and fragmentation of natural habitats has been described worldwide [1–3]. These changes are generally described and/or predicted as negative, tending to focus on single-species and species diversity models. However, this approach may be missing the effects of habitat loss and fragmentation implications on species interactions, leading to unpredicted and misleading results [4,5]. This is particularly sensitive when it comes to predator-prey interactions, where predator responses - or the absence of it – to landscape and habitat changes may have direct influence across food webs [6].

The ecological importance of large mammalian carnivores (*Carnivora*) is easily recognized since even a few individuals can exert strong top-down control on prey populations and smaller predators [4,7–9]. Species with these features occupy an elevated position in the trophic ladder, being classified as *top predators* and their role as ecosystem regulators is now firmly embedded in ecological theory [6,10,11]. Nevertheless, not only large predators, but large mammal populations in general are in decline worldwide and the consequences only recently started to be studied [10]. This shift pattern in mammal species pool towards smaller body mass, highly reproductive rate, omnivorous and generalists caused by defaunation has been described as *downsizing*, with unknown long-term consequences [12,13].

One phenomenon related with defaunation is the mesopredator release hypothesis. It was used to describe smaller predators' irruptions after extirpation of larger ones and first appeared in scientific literature in the late 1980's [14]. In the Atlantic Forest, one of the world's biodiversity hotspots, the apex predator (jaguars) is regionally extinct in most of the biome. Additionally, more than 50% of the biome is distributed in a mosaic of forest patches smaller than 500 ha.

The Atlantic Forest combines the key variables associated with mesopredator outbreaks. Nevertheless, to detect it in regions with high redundancy in ecological functions such as tropical rainforests can become a challenge even to insightful and skilled researchers. However, data availability, dissemination and processing dramatically advance in the last decade. The recent adoption of data sharing policies by journals are an important step towards large scale analysis.

In the first chapter of this thesis, I put together all the key features of mesopredator release hypothesis adapted to a regional context: the mammal carnivore community of Atlantic Forest. I propose a conceptual model based on general hypothesis and expected results supported by literature research and empirical knowledge as a reference to guide future large-scale analyses on this phenomenon.

In the second chapter I present the dataset Atlantic-Camtraps, originally intended to support the data needed to explore the mesopredator release phenomenon in the Atlantic Forest. This data publication was one of the first of a series of datasets combining data mining and raw data from research groups aiming data availability, dissemination, and processing for this biome.

In the third chapter I bring a study case on the Atlantic Forest apex predator in one of its last strongholds in the biome. In this chapter me and my colleagues presents the results of five years of monitoring through telemetry and discuss the absence of typical patterns such as seasonality and differences in home range size between males and females.

REFERENCES

1. Fahrig L. Rethinking patch size and isolation effects: The habitat amount hypothesis. J Biogeogr. 2013;40: 1649–1663. doi:10.1111/jbi.12130

2. Haddad NM, Brudvig L a., Clobert J, Davies KF, Gonzalez A, Holt RD, et al. Habitat fragmentation and its lasting impact on Earth's ecosystems. Sci Adv. 2015;1: e1500052–e1500052. doi:10.1126/sciadv.1500052

3. Jorge MLSP, Galetti M, Ribeiro MC, Ferraz KMPMB. Mammal defaunation as surrogate of trophic cascades in a biodiversity hotspot. Biol Conserv. 2013;163: 49–57. doi:10.1016/j.biocon.2013.04.018

4. Ryall KL, Fahrig L. Response of predators to loss and fragmentation of prey habitat: A review of theory. Ecology. 2006;87: 1086–1093.

5. Valiente-Banuet A, Aizen MA, Alcántara JM, Arroyo J, Cocucci A, Galetti M, et al. Beyond species loss: the extinction of ecological interactions in a changing world. Johnson M, editor. Funct Ecol. 2015;29: 299–307. doi:10.1111/1365-2435.12356

6. Estes J a, Terborgh J, Brashares JS, Power ME, Berger J, Bond WJ, et al. Trophic Downgrading of Planet Earth. Science (80- ). 2011;333: 301–306. doi:10.1126/science.1205106

7. Roemer GW, Gompper ME, Van Valkenburgh B. The Ecological Role of the Mammalian Mesocarnivore. Bioscience. 2009;59: 165–173. doi:10.1525/bio.2009.59.2.9

8. Terborgh J. Ecological Meltdown in Predator-Free Forest Fragments. Science (80- ). 2001;294: 1923–1926. doi:10.1126/science.1064397

9. Soulé ME, Estes JA, Miller B, Honnold DL. Strongly interacting species: Conservation policy, management, and ethics. Bioscience. 2005;55: 168–176. doi:10.1641/0006-3568(2005)055[0168:SISCPM]2.0.CO;2

10. Ripple WJ, Estes J a, Beschta RL, Wilmers CC, Ritchie EG, Hebblewhite M, et al. Status and ecological effects of the world's largest carnivores. Science (80- ). 2014;343: 1241484. doi:10.1126/science.1241484

11. Wallach AD, Izhaki I, Toms JD, Ripple WJ, Shanas U. What is an apex predator? Oikos. 2015;124: 1453–1461. doi:10.1111/oik.01977

12. Cooke RSC, Eigenbrod F, Bates AE. Projected losses of global mammal and bird ecological strategies. Nat Commun. 2019;10: 2279. doi:10.1038/s41467-019-10284-z

13. Young HS, McCauley DJ, Galetti M, Dirzo R. Patterns, Causes, and Consequences of Anthropocene Defaunation. Annu Rev Ecol Evol Syst. 2016;47: 333–358. doi:10.1146/annurev-ecolsys-112414-054142

14. Soulé M., Bolger D., Alberts A., Wright J, Sorice M, Hill S. Reconstructed of Rapid Extinctions of Dynamics Birds in Urban Habitat Islands. Conserv Biol. 1988;2: 75–92. doi:10.1111/j.1523-1739.1988.tb00337.x

# CHAPTER 01

## *REDUCTIO AD ABSURDUM*

## SIMPLIFICATION OF TROPHIC PROCESSES IN TROPICAL FORESTS

*Onçinha pintada*

*Zebrinha listrada*

*Coelhinho peludo*

*Vão se f****!*

*Porque aqui na face da terra*

*Só bicho escroto*

*É que vai ter*

Bichos Escrotos, Titãs.

# ABSTRACT

Changes in the abundance and persistence of biodiversity, led by the loss and fragmentation of natural habitats, have been described worldwide. These changes generally focus on single-species and species diversity models. However, this approach may be missing species interactions leading to misleading results. This is particularly sensitive when it comes to predator-prey interactions, where predator responses or lack of them to landscape and habitat changes may have direct influences across food webs. The decline of large predator populations is indeed a global phenomenon. Meanwhile mesopredators are becoming more abundant in fragmented landscapes. This process, described as the Mesopredator Release Hypothesis, can have profound impacts on biodiversity. In the Atlantic Forest the apex predator is regionally extinct in most of the biome. Additionally, 65% of the remaining forest is distributed in mosaic of forests patches smaller than 2000 ha. This presents a high potential for mesopredator release outbreaks and the outcome is anything but predictable. Here I propose a conceptual model describing how this phenomenon may work in Atlantic Forest.

# INTRODUCTION

Changes in the abundance and persistence of biodiversity, led by the loss and fragmentation of natural habitats has been described worldwide [1–3]. These changes are generally described and/or predicted as negative, tending to focus on single-species and species diversity models. However, this approach may be missing the effects of habitat loss and fragmentation implications on species interactions, leading to unpredicted and misleading results [4,5]. This is particularly sensitive when it comes to predator-prey interactions, where predator responses - or the absence of it – to landscape and habitat changes may have direct influence across food webs [6].

The ecological importance of large mammalian carnivores (*Carnivora*) is easily recognized since even a few individuals can exert strong top-down control on prey populations and smaller predators [4,7–9]. Species with these features occupy an elevated position in the trophic ladder, being classified as *top predators* and their role as ecosystem regulators is now firmly embedded in ecological theory [6,10,11]. Large predators (higher body mass) naturally occur at low density, demands large areas of natural habitat (larger home range size) and stable prey base (larger average prey size) in order to maintain health populations [12,13] (Figure 01). Nevertheless, not only large predators, but large mammal populations in general are in decline worldwide and the consequences only recently started to be studied [10]. This shift pattern in mammal species pool towards smaller body mass, highly reproductive rate, omnivorous and generalists caused by defaunation has been described as *downsizing*, with unknown long-term consequences [14,15] (Figure 01).

## WHAT IS AN APEX PREDATOR?

A recent study proposes that predators above a certain weight threshold and functional features are capable to limit their own population densities – i.e. self-regulation – instead of a bottom-up control determined by prey availability [11]. This feature differentiate this particular group from the general top predator definition and are called apex predators [11]. These species usually presents large body size and have a small chance of been predated by other species [11,16]. Indeed, it is not uncommon to these species to have humans as their unique predator. Top-down control promoted by predators is included as one of the primary forces in ecosystems worldwide. However evolutionary forces led apex predators towards slow reproductive rates, sparsely populated territories, higher rates of infanticide and reproductive suppression as proxies for population densities limits [11].

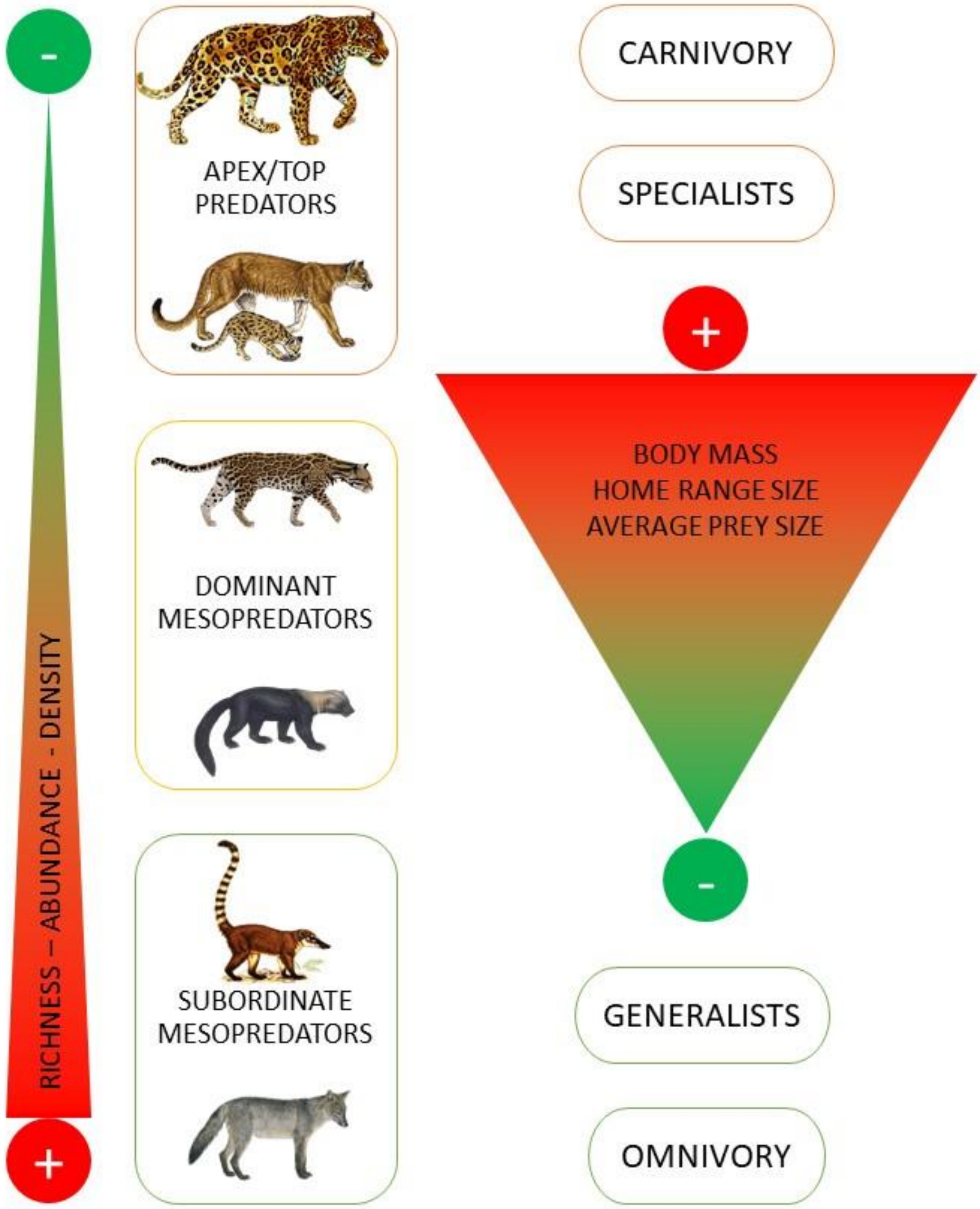



*Figure 1 -Major trends of mammal predators' traits associated with body mass. As body mass decreases, species shifts towards higher reproductive rate, richness, and density; smaller home ranges and average prey sizes; more generalist diet and habitat requirements.*

Different from apex predators top, meso and small predators are unlikely to self-regulate and are instead adapted to extrinsic regulation pressure, as suggested by a higher reproductive rate, lower investment in each offspring and the potential to attain higher densities [11]. This regulation, commonly reported in trophic cascades theory, is essentially an intraguild interaction among predators and can be direct or indirect [17,18]. Direct lethal encounters as predation for food or elimination of an ecological competitor are widespread among mammals and is high enough to promote large demographic effects on mesopredator populations [19,20]. Fear of direct encounters with top and apex predators promotes change in habitat use, altering foraging behavior and activity patterns. In the last instance it affects population growth, reproduction, survival rates and its impact may even be larger than direct kills [18].

## WHAT IS A MESOPREDATOR?

A general definition of mesopredator includes mid-ranking mammalian predators based in weight ranges [21]. Nevertheless this approach does not account for ecological patterns and consequences associated with mesopredator release hypothesis [18]. Indeed, this description fits better the definition of mesocarnivores as a functional group, instead of the actual ecological phenomenon which is not restricted to mammals. According to Prugh et al. (2009):

"*a mesopredator should be defined as any mid-ranking predator in a food web, regardless of its size or taxonomy.*"

It is also important to consider that a mesopredator is a matter of scale. A mesopredator in a system may have the ecological hole of a top predator in another [7,18]. This differentiates the concept of mesopredator from a mesocarnivore in mammal communities. The first more related to the species ecological ranking in a given trophic chain and the latter with its morphological features [18]. Based in these concepts, mesopredator release should be described more broadly, and – paradoxically – more complexly than simple linear smaller predator irruptions after extirpation of larger ones. On the contrary, it is about the expansion in density or distribution, or even the change in behavior of any middle-rank predator as a result from the decline in the density or distribution of an apex predator [17].

## MESOPREDATOR RELEASE HYPOTHESIS

In the late $19^{th}$ century, the United States Government started to develop a formal program aimed to control predators under the Department of Agriculture (USDA) [22]. It later culminated with the Animal Damage Control Act in 1931, establishing a systematic eradication campaign on pumas, wolves, coyotes and bears, among others [23,24]. The later herbivore irruptions caused by eradication of these large predators are very well documented [25,26]. At another scale smaller predators' irruptions after extirpation of larger ones first appeared in scientific literature in the late 1980's and was described as mesopredator release [27]. The term was used to describe a process in which intermediate size predators (i.e. foxes and domestic cats) presented a detectable impact on prey species (birds) in the absence of the local larger predator (coyote) [17,27]. Since then, the Mesopredator Release Hypothesis (MRH) has seen alterations and adjustments on its original description, as well as many misapplications [17]. A common misapplication is to expect a straight cause and effect relation between apex and mesopredators. Negative results reported in the literature often assume that if the apex predator is absent therefore one should expect an immediate and detectable increase in mesopredator abundance.

## PREDATORS IN THE ATLANTIC FOREST

There may be 2 apex predators in Brazil: the jaguar (*Panthera onca*) and the puma (*Puma concolor*). If the latter is an apex predator is a matter of dispute, nevertheless pumas, are certainly top predators in neotropical forests. Not different from other large carnivores around the world, jaguar populations are in decline. Despite its classification as Near Threatened globally its status at regional and local level is critic and it is now actually extinct from regions of previous occurrence [28–30]. This is the actual scenario in the Atlantic Rainforest, where jaguars only occupy 18.4% (37,825 $km^2$) of its remaining [29]. The Atlantic Forest along the coast and interior of South America is among the most threatened tropical forest in the world – one of the world's biodiversity hotspots – and draws a high conservation concern due to its concentration of endemic and small-ranged species [31,32]. Only seven regions in this biome – classified as Jaguar Conservation Units (JCUs) – have records of both males and females [29]. From these, only three JCUs are likely to hold at least 50 individuals (Figure 02) [29].

Despite its critical status in the Atlantic Forest the loss of this specie goes way beyond its regional extinction per se. The loss of jaguar functional hole as the apex predator has profound impacts in the trophic ladder. It is the local representation of a global pattern that predicts a long term shift of mammal species pool towards small, fast-lived, highly fecund, omnivorous, generalists [14].

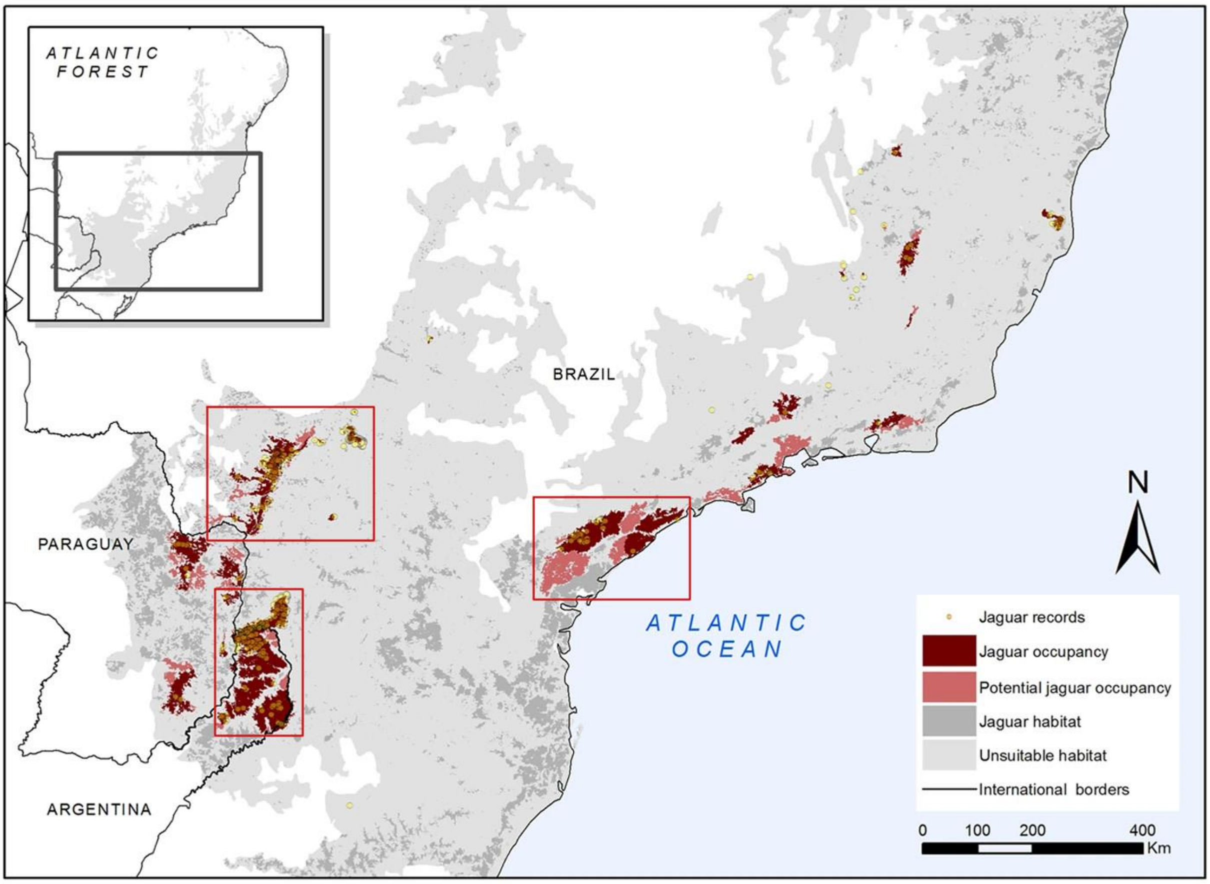



*Figure 2 - Jaguar occurrency in the Atlantic Forest. Red boxes indicate the three Jaguar Conservation Units – JCUs that potentially holds 50 individuals. Adapted from Paviolo et. al. (2016)*

A study evaluating functional diversity of mammals assemblages in the Atlantic Forest found a positive relationship with forest fragment area [33]. Forest patches smaller than the threshold of 60 ha presents a remarkable loss in functional diversity and an important increase is found in patches larger than 2050 ha [33]. However, 65.5% (107,815 km²) of the remaining forest in the biome are distributed in forest patches equal or smaller than 2050 ha. Therefore, most of the Atlantic Forest mammal assemblages are distribute in forest patches with intermediate (60 – 2050 ha) and low functional diversity (≤ 60 ha). In fact it is estimated that 88% of the remaining Atlantic Forest lacks its apex predator (jaguar), its largest herbivore (tapir), its largest seed predator (white-lipped-peccaries) and its largest arboreal seed disperser (muriqui) [3].

As one of the richest biomes of the planet, the Atlantic Forest holds an equally rich community of mesopredators. Some of these species with wide distribution over the biome (Table I). These species occurrence covers nearly every single forest remnant in the Atlantic Forest in contrast with the apex predator (cf. [34]). Based in traits as weight, average prey size, guild and behavior these species can the generally classified as dominant (mesocarnivores), intermediate and subordinate mesopredators (Table I).

## IS MESOPREDATOR RELEASE AN UNDERESTIMATED PHENOMENON IN TROPICAL FORESTS?

Despite significant research interest and conservation relevance unambiguous demonstration of MRH is no trivial task. The fundamental challenge is to rule out alternative explanations for mesopredator overabundance, such as habitat loss that are usually associated with apex predator loss. A major review on the phenomenon state that the main constraint in ecological studies found in the literature is uncontrolled environmental variation [17]. Indeed the probability of mesopredator outbreaks is expected to be higher in fragmented habitats, such as the Atlantic Forest [18].

Improved resource availability and low top-down regulation - as fragmented landscapes typically present - points mesopredator release as a serious and underestimated phenomenon in imbalanced ecosystems. This should indeed be expected in biomes such as the Atlantic Rainforest where most of the original forest is gone, and more than 50% of the remaining forest is distributed in forest fragments smaller than 500 ha [35]. Associated with the absence of jaguars in most of Atlantic Forest, all other variables put together a perfect environment for mesopredator outbreak in this biome. Here I propose a conceptual model describing how this phenomenon may work in Atlantic Forest, using patches sizes thresholds related with functional diversity loss proposed by Magioli *et. al.* (2015) (Figure 03). I built this trophic cascade model based on general hypothesis and expected results supported by literature research and empirical knowledge on mammal carnivore communities in Atlantic Forest.

*Table 1 – Mesopredators with wide occurrence in the Atlantic Forest and potential category of dominance. Some species were not included because their occurrence in the biome is restricted. Average prey size percentage is adapted from Magioli et. al. (2015). Carnivore, terrestrial and social columns are binary (exclusively carnivore or no, exclusively terrestrial or no, social – solitary).*

| | | | | | AVERAGE PREY SIZE % | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FAMILY | SPECIES | IUCN | POTENTIAL CATEGORY | WEIGHT | SMALL | MEDIUM | LARGE | INVERTEBRATES | CARNIVORE | TERRESTRIAL | SOCIAL |
| Canidae | *Cerdocyon thous* | LC | intermediate | 6,1 | 55,20 | 2,56 | 0,17 | 42,08 | n | y | n |
| Felidae | *Leopardus guttulus* | VU | subordinate | 2,1 | 94,40 | 1,40 | 0,20 | 4,00 | y | n | n |
| Felidae | *Leopardus wiedii* | NT | subordinate | 3,2 | 90,90 | 5,80 | 0,00 | 3,30 | y | n | n |
| Felidae | *Herpailurus yagouaroundi* | LC | intermediate | 6,3 | 94,90 | 4,20 | 0,10 | 0,80 | y | n | n |
| Felidae | *Leopardus pardalis* | LC | dominant | 11,5 | 85,80 | 13,70 | 0,50 | 0,00 | y | n | n |
| Mustelidae | *Galictis cuja* | LC | subordinate | 1,8 | 69,60 | 24,60 | 0,30 | 5,50 | y | y | n |
| Mustelidae | *Eira barbara* | LC | dominant | 4,8 | 73,35 | 2,09 | 0,00 | 24,56 | y | n | n |
| Procyonidae | *Nasua nasua* | LC | intermediate | 4,5 | 19,11 | 0,00 | 0,00 | 80,89 | n | n | y |
| Procyonidae | *Procyon cancrivorus* | LC | intermediate | 6 | 35,63 | 0,52 | 0,00 | 63,86 | n | y | n |

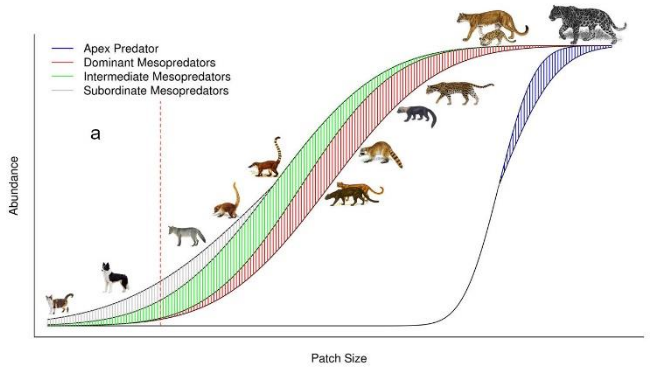
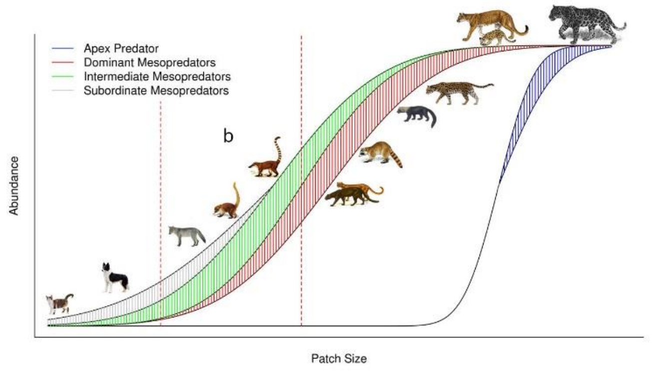
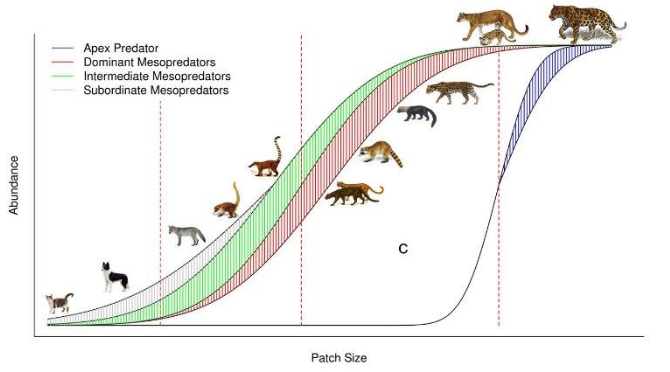
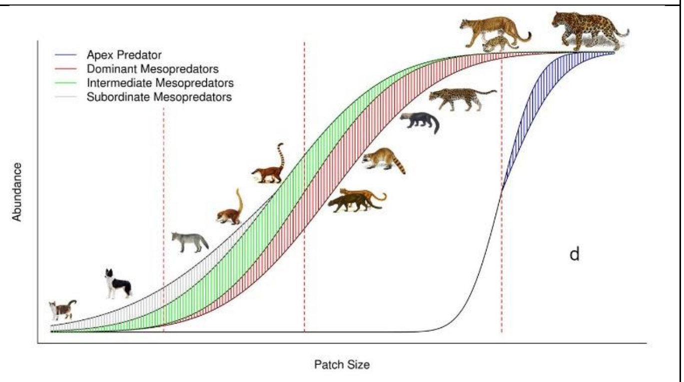
| ASSUMPTIONS | EXPECTED RESULTS | PREDICTIONS |
|---|---|---|
| a) Landscapes composed by small forest patches (<≈ 60 ha) are dominated by SM. | Jaguars are absent;<br>Pumas and DM are rare;<br>IM occurs in specific habitat patches;<br>SM are abundant, including domestic cats and dogs. |  |
| b) Landscapes composed by medium size forest patchs (≈ 60 to ≈ 2000 ha) increases in species richness, functional diversity with increase in dominance by IM and DM. | Jaguar are absent;<br>Pumas and DM occurs and occupy larger patches;<br>IM are more frequent in specific habitat patches;<br>SM are abundant with less influence of domestic cats and dogs. |  |
| c) Landscapes composed by large size forest patchs (≈ 2000 to ≈ 10000 ha) increases species richness and functional diversity with increase in dominance by DM. | Jaguar are rare, mainly dispersing individuals exploring;<br>Pumas and DM are dominant;<br>IM and SM have stable populations.<br>Domestic animals in patches edges and roads. |  |
| d) Landscapes composed by extra large size forest patchs (< 10000 ha) highest species richness and functional diversity with dominance by AP and DM. | Jaguars are present, both sexes present and reproducing in larger areas;<br>Predator community stable;<br>Domestic cats and dogs restricted to areas close to human occupation. |  |

*Figure 3 - Conceptual model on potential mesopredator release outbreak in Atlantic Forest. Forest patches ranges a - c are based on Magioli et. al. (2015).*

# CONCLUSIONS

Apex and top predators require large areas – a result of low densities, need of stable prey populations and large territories – and are more susceptible to habitat loss [36,37]. In addition, this particular group is more likely to be persecuted by humans. As fragmentation and habitat loss intensify, the probability of encounters and killing of domestic animals and livestock also increases [38,39]. Along with these negative effects on apex and top predators, in the opposite direction fragmentation can improve resource availability for mesopredators with the increase of pet food, trash and crop pests (e.g. mices, rats, pigeons) generally associated with regional development [18,40]. The Atlantic Forest presents all the features related with mesopredator outbreaks.

Mesopredator release is quite an intuitive ecological phenomenon. Nevertheless, to detect it in regions with high redundancy in ecological functions such as tropical rainforests can become a challenge even to insightful and skilled researchers. However, data availability, dissemination and processing dramatically advance in the last decade. The recent adoption of data sharing policies by journals are an important step towards large scale analysis. For the Atlantic Forest there are a series of open datasets available on different taxa, including the second chapter of this thesis. In this chapter I put together all the key features of mesopredator release hypothesis adapted to a regional context: the mammal carnivore community of Atlantic Forest. I hope this synthesis and general hypothesis may be a useful reference to guide future large-scale analyses on this phenomenon which the outcome and consequences for biodiversity conservation are anything but predictable.

# REFERENCES

1. Fahrig L. Rethinking patch size and isolation effects: The habitat amount hypothesis. J Biogeogr. 2013;40: 1649–1663. doi:10.1111/jbi.12130

2. Haddad NM, Brudvig L a., Clobert J, Davies KF, Gonzalez A, Holt RD, et al. Habitat fragmentation and its lasting impact on Earth's ecosystems. Sci Adv. 2015;1: e1500052–e1500052. doi:10.1126/sciadv.1500052

3. Jorge MLSP, Galetti M, Ribeiro MC, Ferraz KMPMB. Mammal defaunation as surrogate of trophic cascades in a biodiversity hotspot. Biol Conserv. 2013;163: 49–57. doi:10.1016/j.biocon.2013.04.018

4. Ryall KL, Fahrig L. Response of predators to loss and fragmentation of prey habitat: A review of theory. Ecology. 2006;87: 1086–1093.

5. Valiente-Banuet A, Aizen MA, Alcántara JM, Arroyo J, Cocucci A, Galetti M, et al. Beyond species loss: the extinction of ecological interactions in a changing world. Johnson M, editor. Funct Ecol. 2015;29: 299–307. doi:10.1111/1365-2435.12356

6. Estes J a, Terborgh J, Brashares JS, Power ME, Berger J, Bond WJ, et al. Trophic Downgrading of Planet Earth. Science (80- ). 2011;333: 301–306. doi:10.1126/science.1205106

7. Roemer GW, Gompper ME, Van Valkenburgh B. The Ecological Role of the Mammalian Mesocarnivore. Bioscience. 2009;59: 165–173. doi:10.1525/bio.2009.59.2.9

8. Terborgh J. Ecological Meltdown in Predator-Free Forest Fragments. Science (80- ). 2001;294: 1923–1926. doi:10.1126/science.1064397

9. Soulé ME, Estes JA, Miller B, Honnold DL. Strongly interacting species: Conservation policy, management, and ethics. Bioscience. 2005;55: 168–176. doi:10.1641/0006-3568(2005)055[0168:SISCPM]2.0.CO;2

10. Ripple WJ, Estes J a, Beschta RL, Wilmers CC, Ritchie EG, Hebblewhite M, et al. Status and ecological effects of the world's largest carnivores. Science (80- ). 2014;343: 1241484. doi:10.1126/science.1241484

11. Wallach AD, Izhaki I, Toms JD, Ripple WJ, Shanas U. What is an apex predator? Oikos. 2015;124: 1453–1461. doi:10.1111/oik.01977

12. Balme G a., Hunter LTB, Slotow R. Evaluating Methods for Counting Cryptic Carnivores. J Wildl Manage. 2009;73: 433–441. doi:10.2193/2007-368

13. Paviolo A, De Angelo C, Ferraz KMPMB, Morato RG, Martinez Pardo J, Srbek-Araujo AC, et al. A biodiversity hotspot losing its top predator: The challenge of jaguar conservation in the Atlantic Forest of South America. Sci Rep. 2016;6: 37147. doi:10.1038/srep37147

14. Cooke RSC, Eigenbrod F, Bates AE. Projected losses of global mammal and bird ecological strategies. Nat Commun. 2019;10: 2279. doi:10.1038/s41467-019-10284-z

15. Young HS, McCauley DJ, Galetti M, Dirzo R. Patterns, Causes, and Consequences of Anthropocene Defaunation. Annu Rev Ecol Evol Syst. 2016;47: 333–358. doi:10.1146/annurev-ecolsys-112414-054142

16. Promislow DEL, Harvey PH. Living fast and dying young: A comparative analysis of life-history variation among mammals. J Zool. 1990;220: 417–437. doi:10.1111/j.1469-7998.1990.tb04316.x

17. Brashares JS, Prugh LR, Stoner CJ, Epps CW. Ecological and conservation implications of mesopredator release. Trophic cascades predators, prey, Chang Dyn Nat. 2010; 221–240.

18. Prugh LR, Stoner CJ, Epps CW, Bean WT, Ripple WJ, Laliberte AS, et al. The Rise of the Mesopredator. Bioscience. 2009;59: 779–791. doi:10.1525/bio.2009.59.9.9

19. Palomares F, Caro TM. Interspecific Killing among Mammalian Carnivores. Am Nat. 1999;153: 492–508. doi:10.1086/303189

20. Ritchie EG, Johnson CN. Predator interactions, mesopredator release and biodiversity conservation. Ecol Lett. 2009;12: 982–998. doi:10.1111/j.1461-0248.2009.01347.x

21. Gebrt SD, Clark WR. Raccoons, coyotes, and reflections on the mesopredator

release hypothesis. Wildl Soc Bull. 2003;31: 836–842. doi:10.2307/3784607

22. Bacon T. The Implementation of the Animal Damage Control Act : A Comment on Wildlife Services ' s Methods of Predatory Animal Control. 2012;32.

23. Hawthorne DW. The history of federal and cooperative animal damage control. Sheep Goat Res J. 2004;19: 13–15.

24. Stolzenburg W. Where the wild things were: life, death and ecological wreckage of vanishing predators. 1st ed. Nature. New York: Bloomsbury; 2008.

25. Berger J, Stacey PB, Bellis L, Johnson MP. A mammalian predator-prey imbalance: Grizzly bear and wolf extinction affect avian neotropical migrants. Ecol Appl. 2001;11: 947–960. doi:10.1890/1051-0761(2001)011[0947:AMPPIG]2.0.CO;2

26. Ripple WJ, Wirsing AJ, Wilmers CC, Letnic M. Widespread mesopredator effects after wolf extirpation. Biol Conserv. 2013;160: 70–79. doi:10.1016/j.biocon.2012.12.033

27. Soulé M., Bolger D., Alberts A., Wright J, Sorice M, Hill S. Reconstructed of Rapid Extinctions of Dynamics Birds in Urban Habitat Islands. Conserv Biol. 1988;2: 75–92. doi:10.1111/j.1523-1739.1988.tb00337.x

28. Quigley H, Foster RJ, Petracca L, Payan E, Salom R, Harmsen BJ. Panthera onca. IUCN Red List Threat Species. 2017;8235: 8. Available: http://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T20010A22247615.en

29. Paviolo A, De Angelo C, Ferraz KMPMB, Morato RG, Martinez Pardo J, Srbek-Araujo AC, et al. A biodiversity hotspot losing its top predator: The challenge of jaguar conservation in the Atlantic Forest of South America. Sci Rep. 2016;6: 37147. doi:10.1038/srep37147

30. Paviolo A, De Angelo CD, Di Blanco YE, Di Bitetti MS. Jaguar Panthera onca population decline in the Upper Paraná Atlantic Forest of Argentina and Brazil. Oryx. 2008;42: 554. doi:10.1017/S0030605308000641

31. Myers N, Mittermeier RA, Mittermeier CG, Fonseca GAB, Kent J. Biodiversity hotspots for conservation priorities. Nature. 2000;403: 853–858.

32. Jenkins CN, Alves MAS, Uezu A, Vale MM. Patterns of Vertebrate Diversity and Protection in Brazil. Stow A, editor. PLoS One. 2015;10: e0145064. doi:10.1371/journal.pone.0145064

33. Magioli M, Ribeiro MC, Ferraz KMPMB, Rodrigues MG. Thresholds in the relationship between functional diversity and patch size for mammals in the Brazilian Atlantic Forest. Anim Conserv. 2015; n/a-n/a. doi:10.1111/acv.12201

34. Nagy-Reis M, Oshima JE de F, Kanda CZ, Palmeira FBL, Melo FR, Morato RG, et al. NEOTROPICAL CARNIVORES: a data set on carnivore distribution in the Neotropics. Ecology. 2020;101. doi:10.1002/ecy.3128

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

36. Crooks KR. Relative sensitivities of mammalian carnivores to habitat fragmentation. Conserv Biol. 2002;16: 488–502.

37. De Angelo C, Paviolo A, Rode D, Cullen L, Sana D, Abreu KC, et al. Participatory networks for large-scale monitoring of large carnivores: pumas and jaguars of the Upper Paraná Atlantic Forest. Oryx. 2011;45: 534–545. doi:10.1017/S0030605310000840

38. Cardillo M, Purvis A, Sechrest W, Gittleman JL, Bielby J, Mace GM. Human population density and extinction risk in the world's carnivores. PLoS Biol. 2004;2. doi:10.1371/journal.pbio.0020197

39. Cavalcanti SMC, Gese EM. Kill rates and predation patterns of jaguars (Panthera onca) in the southern Pantanal, Brazil. J Mammal. 2010;91: 722–736. doi:10.1644/09-MAMM-A-171.1

40. Crooks K, Soulé M. Mesopredator release and avifaunal extinctions in a fragmented system. Nature. 1999;400: 563–566. doi:10.1038/23028

# CHAPTER 02

## ATLANTIC CAMTRAPS: a dataset of medium and large terrestrial mammal communities in the Atlantic Forest of South America.

*O senhor saiba: eu toda a minha vida pensei por mim, forro, sou nascido diferente. Eu sou é eu mesmo. Divirjo de todo o mundo... Eu quase que nada não sei. Mas desconfio de muita coisa. O senhor concedendo, eu digo: para pensar longe, sou cão mestre – o senhor solte em minha frente uma idéia ligeira, e eu rastreio essa por fundo de todos os matos, amém!*

Riobaldo Tatarana, Grande Sertão: veredas.

*Ecology*, 98(11), 2017, pp. 2979


# ATLANTIC-CAMTRAPS: a dataset of medium and large terrestrial mammal communities in the Atlantic Forest of South America

Fernando Lima,[1,2,36] Gabrielle Beca,[1] Renata L. Muylaert,[1] Clinton N. Jenkins,[2] Miriam L. L. Perilli,[3] Ana Maria O. Paschoal,[4] Rodrigo L. Massara,[4] Adriano P. Paglia,[4] Adriano G. Chiarello,[5] Maurício E. Graipel,[6] Jorge J. Cherem,[7] André L. Regolin,[1] Luiz Gustavo R. Oliveira Santos,[8] Carlos R. Brocardo,[1,9] Agustín Paviolo,[10,11] Mario S. Di Bitetti,[10,11,12] Leandro M. Scoss,[13] Fabiana L. Rocha,[14] Roberto Fusco-Costa,[15,16] Clarissa A. Rosa,[17] Marina X. Da Silva,[18] Ludmila Hufnagell,[4] Paloma M. Santos,[4] Gabriela T. Duarte,[4] Luiza N. Guimarães,[4] Larissa L. Bailey,[19] Flávio Henrique G. Rodrigues,[4] Heitor M. Cunha,[20] Felipe M. Fantacini,[21] Graziele O. Batista,[22] Juliano A. Bogoni,[23] Marco A. Tortato,[24] Micheli R. Luiz,[25] Nivaldo Peroni,[6] Pedro V. De Castilho,[26] Thiago B. Maccarini,[27] Vilmar Picinatto Filho,[28] Carlos De Angelo,[10,11] Paula Cruz,[10,11] Verónica Quiroga,[10,11] María E. Iezzi,[10,11] Diego Varela,[10,11] Sandra M. C. Cavalcanti,[3] Alexandre C. Martensen,[29] Erica V. Maggiorini,[30] Fabíola F. Keesen,[31] André V. Nunes,[24] Gisele M. Lessa,[32] Pedro Cordeiro-Estrela,[33] Mayara G. Beltrão,[33,34] Anna Carolina F. De Albuquerque,[33,34] Bianca Ingberman,[15] Camila R. Cassano,[35] Laury Cullen Junior,[2] Milton C. Ribeiro,[1,36] and Mauro Galetti[1,36]

*Abstract.* Our understanding of mammal ecology has always been hindered by the difficulties of observing species in closed tropical forests. Camera trapping has become a major advance for monitoring terrestrial mammals in biodiversity rich ecosystems. Here we compiled one of the largest datasets of inventories of terrestrial mammal communities for the Neotropical region based on camera trapping studies. The dataset comprises 170 surveys of medium to large terrestrial mammals using camera traps conducted in 144 areas by 74 studies, covering six vegetation types of tropical and subtropical Atlantic Forest of South America (Brazil and Argentina), and present data on species composition and richness. The complete dataset comprises 53,438 independent records of 83 species of mammals, includes 10 species of marsupials, 15 rodents, 20 carnivores, eight ungulates and six armadillos. Species richness averaged 13 species (±6.07 SD) per site. Only six species occurred in more than 50% of the sites: the domestic dog *Canis familiaris*, crab-eating fox *Cerdocyon thous*, tayra *Eira barbara*, south American coati *Nasua nasua*, crab-eating raccoon *Procyon cancrivorus* and the nine-banded armadillo *Dasypus novemcinctus.* The information contained in this dataset can be used to understand macroecological patterns of biodiversity, community, and population structure, but also to evaluate the ecological consequences of fragmentation, defaunation, and trophic interactions.

*Key words: Atlantic Forest; biodiversity hotspot; camera traps; forest fragmentation; invasive species; mammal communities; neotropical mammals.*

The complete data sets corresponding to abstracts published in the Data Papers section in the journal are published electronically as Supporting Information in the online version of this article at http://onlinelibrary.wiley.com/doi/10.1002/ecy.1998/suppinfo

Manuscript received 5 May 2017; revised 31 July 2017; accepted 16 August 2017. Corresponding Editor: W. K. Michener.
[36] E-mail: pardalismitis@gmail.com

WILEY ECOLOGY

# ATLANTIC-CAMTRAPS: a dataset of medium and large terrestrial mammal communities in the Atlantic Forest of South America



| | |
|---|---|
| Journal: | *Ecology* |
| Manuscript ID | ECY17-0483 |
| Wiley - Manuscript type: | Data Papers |
| Date Submitted by the Author: | 05-May-2017 |





| | |
|---|---|
| Complete List of Authors: | Lima, Fernando; Universidade Estadual Paulista Julio de Mesquita Filho - Campus de Rio Claro, Spacial Ecology and Conservation Lab; Instituto de Pesquisas Ecologicas,<br>Beca, Gabrielle; Universidade Estadual Paulista Julio de Mesquita Filho - Campus de Rio Claro,<br>Muylaert, Renata; UNESP São Paulo State University<br>Jenkins, Clinton; Instituto de Pesquisas Ecologicas<br>Perilli, Miriam; Instituto Pró-Carnívoros,<br>Paschoal, Ana Maria; Universidade Federal de Minas Gerais Instituto de Ciencias Biologicas, Departamento de Biologia Geral<br>Massara, Rodrigo; Universidade Federal de Minas Gerais Instituto de Ciencias Biologicas, Departamento de Biologia Geral<br>Paglia, Adriano; Universidade Federal de Minas Gerais Instituto de Ciencias Biologicas, Departamento de Biologia Geral<br>Chiarello, Adriano; Universidade de Sao Paulo Campus de Ribeirao Preto, Departamento de Biologia, Faculdade de Filosofia, Ciências e Letras<br>Graipel, Maurício; Universidade Federal de Santa Catarina, Ecology and Zoology<br>Cherem, Jorge; Caipora Cooperativa,<br>Regolin, André; Universidade Estadual Paulista Julio de Mesquita Filho - Campus de Rio Claro, Ecology<br>Oliveira Santos, Luiz Gustavo; Rio de Janeiro Federal University<br>Brocardo, Carlos; Universidade Estadual Paulista Julio de Mesquita Filho, Ecology<br>Paviolo, Agustín; National Research Council (CONICET); Instituto de Biologia Subtropical, Facultad de Ciencias Forestales, Universidad Nacional de Misiones<br>Di Bitetti, Mario; National Research Council (CONICET); Instituto de Biologia Subtropical, Facultad de Ciencias Forestales, Universidad Nacional de Misiones<br>Scoss, Leandro; Bicho do Mato Instituto de Pesquisa, Pesquisa<br>Rocha, Fabiana; Universidade Federal da Paraíba. Campus IV - Litoral Norte, Centro de Ciências Aplicadas e Educação - CCAE<br>Fusco-Costa, Roberto; IPeC-Instituto de Pesquisas Cananéia, ; Universidade Federal do Parana, Zoologia, Pós-graduação Ecologia e Conservação |

Rosa, Clarissa; Instituto Alto Montana da Serra Fina,
da Silva, Marina; Parque Nacional do Iguaçu, Projeto Carnívoros do Iguaçu; Parque Nacional do Iguaçu
Hufnagel, Ludmila; Universidade Federal de Minas Gerais, Biologia Geral
Santos, Paloma; Universidade Federal de Minas Gerais Instituto de Ciencias Biologicas, Biologia Geral;
Duarte, Gabriela; Universidade Federal de Minas Gerais Instituto de Ciencias Biologicas,
Guimarães, Luiza; Universidade Federal de Minas Gerais Instituto de Ciencias Biologicas, Instituto de Ciências Biológicas
Bailey, Larissa; Colorado State University, Dept of Fish, Wildlife and Conservation Biology
Guimarães Rodrigues, Flavio Henrique; Universidade Federal de Minas Gerais Instituto de Ciencias Biologicas, Biologia Geral
Cunha, Heitor; Sete Soluções e Tecnologia Ambiental Ltda,
Moreli Fantacini, Felipe; Instituto Ambiental Brüderthal,
Batista, Graziele; Universidade Federal de Santa Catarina, Departamento de Ecologia e Zoologia
Bogoni, Juliano; Universidade Federal de Santa Catarina, Ecologia e Zoologia
Tortato, Marcos; Universidade Federal de Mato Grosso do Sul, Ecology and Conservation Postgraduate Program
Luiz, Micheli; Universidade do Extremo Sul Catarinense, Programa de Pos-Graduacão em Gestão de Recursos Naturais; Instituto Felinos do Aguaí, Pesquisa
Peroni, Nivaldo; Universidade Federal de Santa Catarina, Department of Ecology and Zoology
Volkmer de Castilho, Pedro; Universidade do Estado de Santa Catarina,
Maccarini, Thiago; Corpo de Bombeiros Militar de Santa Catarina,
Picinatto Filho, Vilmar; Universidade Federal do Parana,
De Angelo, Carlos; National Research Council (CONICET); Instituto de Biologia Subtropical, Facultad de Ciencias Forestales, Universidad Nacional de Misiones
Cruz, Maria; Instituto de Biología Subtropical, CONICET-Universidad Nacional de Misiones (UNaM),
Quiroga, Veronica Andrea; Instituto de Biologia Subtropical (IBS) CONICET/UNaM,
Iezzi, Maria; Instituto de Biología Subtropical CONICET and Universidad Nacional de Misiones,
Varela, Diego; Instituto de Biología Subtropical (CONICET-Universidad Nacional de Misiones),
Cavalcanti, Sandra; Instituto Pró-Carnívoros
Martensen, Alexandre; Instituto Nacional de Pesquisas da Amazonia, GCBEv
Maggiorini, Erica Vanessa; Prefeitura da Estância Turística de Salto, Secretaria de Meio Ambiente
Keesen, Fabíola; Universidade Federal de Ouro Preto,
Valle Nunes, André; Universidade Federal de Mato Grosso do Sul, Ecology and Conservation
Lessa, Gisele; Universidade Federal de Vicosa, Biologia Animal
Cordeiro-Estrela, Pedro; Universidade Federal da Paraiba, Departamento de Sistemática e EcologiaCentro de Ciências Exatas e da Natureza
Beltrão, Mayara; Universidade Federal da Paraiba, Ecologia e Evolução
Albuquerque, Anna Carolina; Universidade Federal da Paraiba, Departamento de Sistemática e Ecologia
Ingberman, Bianca; Instituto de Pesquisas Cananéia,
Cassano, Camila; Universidade Estadual de Santa Cruz, Laboratório de Ecologia Aplicada à Conservação
Cullen Jr., Laury; Instituto de Pesquisas Ecologicas
Ribeiro, Milton; UNESP - São Paulo State University, Ecology
Galetti, Mauro; Universidade Estadual Paulista, Ecologia

| | |
|---|---|
| Substantive Area: | Population Ecology < Substantive Area, Data paper < Data < Substantive Area, Community Ecology < Substantive Area |
| Organism: | Mammals < Vertebrates < Animals, Marsupials < Mammals < Vertebrates < Animals, Primates < Mammals < Vertebrates < Animals, Carnivores < Mammals < Vertebrates < Animals, Rodents < Mammals < Vertebrates < Animals |
| Habitat: | Rain Forest < Tropical Zone < Terrestrial < Habitat, Deciduous Forest < Tropical Zone < Terrestrial < Habitat |
| Geographic Area: | Eastern South America (Guyana, Fr. Guiana, Suriname, Brazil) < South America < Geographic Area |
| Additional Keywords: | Atlantic Forest, forest fragmentation, camera traps, neotropical mammals, biodiversity hotspot, mammal communities, invasive species |
| Abstract: | Our understanding of mammal ecology has always been hindered by the difficulties of observing species in closed tropical forests. Camera trapping has become a major advance for monitoring terrestrial mammals in biodiversity rich ecosystems. Here we compile the largest dataset of inventories of terrestrial mammal communities for the Neotropical region based on camera trapping studies. The dataset comprises 170 surveys of medium to large terrestrial mammals using camera traps conducted in 144 areas by 74 studies, covering six vegetation types of tropical and subtropical Atlantic Forests of South America (Brazil and Argentina), and present data on species composition and richness. The complete dataset comprises 53,438 independent records of 83 species of mammals, includes 10 species of marsupials, 15 rodents, 20 carnivores, 8 ungulates and 6 armadillos. Species richness averaged 13 species (± 6.07 SD) per site. Only six species occurred in more than 50% of the sites: the domestic dog Canis familiaris, crab-eating fox Cerdocyon thous, tayra Eira barbara, south American coati Nasua nasua, crab-eating raccoon Procyon cancrivorus and the nine-banded armadillo Dasypus novemcinctus. The information contained in this dataset can be used to understand macroecological patterns of biodiversity, community, and population structure, but also to evaluate the ecological consequences of fragmentation, defaunation, and trophic interactions. |
| | |
| Note: The following files were submitted by the author for peer review, but cannot be converted to PDF. You must view these files (e.g. movies) online. | |
| ATLANTIC_CAMTRAPS_1-0_STUDY.csv<br>ATLANTIC_CAMTRAPS_1-0_LOCATION.csv<br>ATLANTIC_CAMTRAPS_1-0_SURVEY.csv<br>ATLANTIC_CAMTRAPS_1-0_RECORDS.csv<br>ATLANTIC_CAMTRAPS_1-0_SPECIES.csv | |

# ATLANTIC-CAMTRAPS: a dataset of medium and large terrestrial mammal communities in the Atlantic Forest of South America

Fernando Lima[1,2]*, Gabrielle Beca[1], Renata de Lara Muylaert[1], Clinton N. Jenkins[2], Miriam Lucia Lages Perilli[3], Ana Maria de Oliveira Paschoal[4], Rodrigo Lima Massara[4], Adriano Pereira Paglia[4], Adriano Garcia Chiarello[5], Maurício Eduardo Graipel[6], Jorge José Cherem[7], André Luis Regolin[1], Luiz Gustavo Rodrigues Oliveira Santos[8], Carlos Rodrigo Brocardo[1,9], Agustín Paviolo[10,11], Mario S. Di Bitetti[10,11,12], Leandro Moraes Scoss[13], Fabiana Lopes Rocha[14], Roberto Fusco-Costa[15, 16], Clarissa Alves da Rosa[17], Marina Xavier da Silva[18], Ludmila Hufnagel[4], Paloma Marques Santos[4], Gabriela Teixeira Duarte[4], Luiza Neves Guimarães[4], Larissa Lynn Bailey[19], Flávio Henrique Guimarães Rodrigues[4], Heitor Morais Cunha[20], Felipe Moreli Fantacini[21], Graziele Oliveira Batista[22], Juliano André Bogoni[23], Marco Adriano Tortato[24], Micheli Ribeiro Luiz[25], Nivaldo Peroni[6], Pedro Volkmer de Castilho[26], Thiago Bernardes Maccarini[27], Vilmar Picinatto Filho[28], Carlos De Angelo[10,11], Paula Cruz[10,11], Verónica Quiroga[10,11], María Eugenia Iezzi[10,11], Diego Varela[10,11], Sandra Maria Cintra Cavalcanti[3], Alexandre Camargo Martensen[29], Erica Vanessa Maggiorini[30], Fabíola Ferreira Keesen[31], André Valle Nunes[24], Gisele Mendes Lessa[32], Pedro Cordeiro-Estrela[33], Mayara Guimarães Beltrão[33,34], Anna Carolina Figueiredo de Albuquerque[33,34], Bianca Ingberman[15], Camila Righetto Cassano[35], Laury Cullen Junior[2], Milton Cezar Ribeiro[1,*], Mauro Galetti[1,*]

1. Universidade Estadual Paulista (UNESP), Instituto de Biociências, Departamento de Ecologia, CP 199, Rio Claro, SP, 13506-900, Brasil
2. IPÊ – Instituto de Pesquisas Ecológicas, CP 47, Nazaré Paulista, SP, 12960-000, Brasil
3. Instituto para Conservação dos Carnívoros Neotropicais (Pró-Carnívoros), Avenida Horácio Neto, 1030, Atibaia, SP, Brasil
4. Universidade Federal de Minas Gerais, Departamento de Biologia Geral, Avenida Antônio Carlos, nº. 6627, Belo Horizonte, MG, 31270-901, Brasil
5. Universidade de São Paulo, Departamento de Biologia, Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, Avenida Bandeirantes, nº 3900, Ribeirão Preto, SP, 14040-901, Brasil
6. Universidade Federal de Santa Catarina, Departamento de Ecologia e Zoologia, Florianópolis, SC, 88040-900, Brasil
7. Caipora Cooperativa para a Conservação da Natureza, Florianópolis, SC, 88040-400, Brasil
8. Universidade Federal de Mato Grosso do Sul, Instituto de Biologia, Departamento de Ecologia, Av. Costa e Silva s/ nº, Campo Grande, MS, 79070-900, Brasil
9. Instituto Neotropical: Pesquisa e Conservação, Curitiba, PR, Brasil
10. Instituto de Biología Subtropical (IBS), Universidad Nacional de Misiones (CONICET)
11. Asociación Civil Centro de Investigaciones del Bosque Atlántico (CeIBA), Bertoni 85, 3370 Puerto Iguazú, Misiones, Argentina
12. Facultad de Ciencias Forestales, Universidad Nacional de Misiones, Bertoni 124, 3380 Eldorado, Argentina
13. Tropical Ecology Assessment and Monitoring Network, Terrestrial Vertebrate, Site Rio Doce, Bicho do Mato Instituto de Pesquisa, Avenida Cônsul Antônio Cadar, 600, Belo Horizonte, MG, 30360-082, Brasil
14. Universidade Federal da Paraíba, Programa de Pós-Graduação em Ecologia e

Monitoramento Ambiental, Campus IV, Rio Tinto, PB, 58297-000, Brasil
15. Instituto de Pesquisas Cananéia (IPeC), Rua Tristão Lobo, nº 199, Cananéia, SP, 11990-000, Brasil
16. Universidade Federal do Paraná, Programa de Pós-Doutorado em Ecologia e Conservação, CP 19031, Curitiba, PR, 81531-990, Brasil
17. Instituto Alto Montana da Serra Fina, BR 354, Km 768, Bairro Engenho de Serra, Itamonte, MG, 37466-000, Brasil
18. Projeto Carnívoros do Iguaçu, Parque Nacional do Iguaçu, Br 469, Km 22.5, Foz do Iguaçu, PR, 85851-970, Brasil
19. Colorado State University, Department of Fish, Wildlife, and Conservation Biology, 1474 Campus Delivery, 109 Wagar, Fort Collins, CO 80523, USA
20. Sete Soluções e Tecnologia Ambiental, Rua Pernambuco, nº.1000, Belo Horizonte, MG, 30130-151, Brasil
21. Instituto Ambiental Brüderthal, Brusque, SC, 88353-190, Brasil
22. Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis, SCEN Trecho 02, Edifício Sede, Brasília, DF, 70818-900, Brasil
23. Universidade Federal de Santa Catarina, Programa de Pós-Graduação em Ecologia, Florianópolis, SC, 88040-900, Brasil
24. Universidade Federal de Mato Grosso do Sul, Programa de Pós-Graduação em Ecologia e Conservação, Avenida Costa e Silva s/nº, Bairro Universitário, Campo Grande, MS, 79070-900, Brasil
25. Instituto Felinos do Aguaí, Siderópolis, SC, 88860-000, Brasil
26. Universidade do Estado de Santa Catarina, Departamento de Engenharia de Pesca, Laguna, SC, 88790-000, Brasil
27. Rua Martim Stahl, 551, apto 803, Bairro Vila Nova, Jaraguá do Sul, SC, 89259-310, Brasil
28. Universidade Federal do Paraná, Programa de Pós-Graduação em Engenharia Florestal, Curitiba, PR, 80035-050, Brasil
29. Instituto Nacional de Pesquisas da Amazônia (INPA), Programa de Pós-Graduação em Genética, Conservação e Biologia Evolutiva (GCBEv), Avenida André Araújo, 2936, Aleixo, CP 2223, Manaus, AM, 69060-001, Brasil
30. Secretaria de Meio Ambiente, Prefeitura da Estância Turística de Salto, Avenida Nove de Julho, 1053, Salto, SP, 13322-900, Brasil
31. Universidade Federal de Ouro Preto, Programa de Pós-Graduação em Ecologia de Biomas Tropicais, Campus Universitário Morro do Cruzeiro, Ouro Preto, MG, 35400-000, Brasil
32. Universidade Federal de Viçosa, Departamento de Biologia Animal, Laboratório de Mastozoologia, CCB2, 3º andar, Av. P.H. Rolfs s/nº, Campus UFV, Viçosa, MG, 36570-900, Brasil
33. Universidade Federal da Paraíba, Laboratório de Mamíferos, Departamento de Sistemática e Ecologia, CCEN, Jardim Universitário, s/nº, Castelo Branco III, João Pessoa, PB, 58051-900, Brasil
34. Universidade Federal da Paraíba, Programa de Pós-Graduação em Ciências Biológicas (Zoologia)
35. Universidade Estadual de Santa Cruz, Laboratório de Ecologia Aplicada à Conservação, Rodovia Jorge Amado, Km 16, Salobrinho, Ilhéus, BA, 45662-900, Brasil

* Correspondence and requests for materials should be addressed to Fernando Lima (email: pardalismitis@gmail.com), Milton Cezar Ribeiro (mcr@rc.unesp.br) or Mauro Galetti (mgaletti@rc.unesp.br).

## INTRODUCTION

Camera traps have been used in studies of wild animals since the early 20th century (Chapman 1927). From the first attempts by George Shiras III to create self-triggered cameras in the early 1900's, to modern day camera traps, this tool has become essential in wildlife monitoring (Kucera and Barrett 2011). Its vast potential to monitor mammal communities soon became evident, and wildlife researchers realized that photography would be an invaluable aid to study animals in their natural environment. From then on, the development of camera trap technology, associated with a relative reduction in its costs, allowed an exponential increase in studies applying this method, especially with species difficult to observe and detect otherwise (Ahumada et al. 2013, Pimm et al. 2015).

Most terrestrial vertebrates – such as large mammal species – occur at low densities and are very secretive. Consequently, any relevant ecological question at the population or community level requires a huge effort in the field. In addition, with the continuous decline of biodiversity worldwide, many mammal species are becoming increasingly rare in areas with high hunting pressure, habitat loss and habitat fragmentation (Butchart et al. 2010, Ripple et al. 2016). Systematic studies using camera traps over the past decade were aimed mainly at species inventories, activity patterns and estimation of abundance (Tobler et al. 2008a, 2008b). These studies have brought novel information on the distribution and behavior of many species.

Long-term wildlife monitoring programs and online databases, such as the Tropical Ecology Assessment and Monitoring Network, are dealing with an unprecedented amount of species records and data from camera traps surveys (Jansen et al. 2014). However, often information is kept trapped and dispersed in dissertations, reports, and all kinds of gray literature. At another level, wildlife surveys conducted by non-governmental agencies and private consultants are rarely easily accessible. Thus, the potential to detect large scale or global patterns by using this large amount of data is still underutilized due to most of the information being fragmented and inaccessible in regional samplings.

The Atlantic Forest along the coast and interior of South America is among the most threatened tropical forest in the world – one of the world's biodiversity hotspots – and draws a high conservation concern due to its concentration of endemic and small-ranged species (Myers et al. 2000, Jenkins et al. 2015). In this hotspot, where only 12% of original forest still remains, the use of camera traps became increasingly accessible and popular in the early 2000's (Srbek-Araujo and Chiarello 2005, Ribeiro et al. 2009). Here we summarize and make available a database on camera trap studies conducted in the Atlantic Forest hotspot. Data were compiled from the existing literature and through direct contact with research groups and professionals.

This dataset is a large-scale synthesis of studies that used camera traps to sample medium and large terrestrial mammals in a biodiversity hotspot. It is the first joined effort of field researchers and ecologists to organize a large-scale dataset of this kind, and provides an opportunity for understanding macroecological patterns, improving conservation strategies, and new community ecology research. The uniqueness of this dataset is that we were able to gather a large amount of raw and unpublished data through a network of collaborators and within a representative geographic extension of the Atlantic Forest hotspot. It combines 53,438 independent records of 83 mammalian species from 170 surveys conducted in 144 areas by 74 studies.

## METADATA

### CLASS I. DATA SET DESCRIPTORS

**A. Data set identity:** ATLANTIC-CAMTRAPS: a dataset of medium and large terrestrial mammal communities in the Atlantic Forest of South America

**B. Data set identification code:**

(1) ATLANTIC_CAMTRAPS_1-0_STUDY.csv

(2) ATLANTIC_CAMTRAPS_1-0_LOCATION.csv

(3) ATLANTIC_CAMTRAPS_1-0_SURVEY.csv

(4) ATLANTIC_CAMTRAPS_1-0_RECORDS.csv

(5) ATLANTIC_CAMTRAPS_1-0_SPECIES.csv

**C. Data set description:**

**Principal Investigator(s):**

1. Fernando Lima, Renata de Lara Muylaert, Gabrielle Beca, Carlos Rodrigo Brocardo, Mauro Galetti, Milton Cezar Ribeiro
Universidade Estadual Paulista (UNESP), Instituto de Biociências, Departamento de Ecologia, CP 199, Rio Claro, SP, 13506-900, Brasil

2. Fernando Lima, Clinton N. Jenkins, Laury Cullen Jr.
IPÊ – Instituto de Pesquisas Ecológicas, CP 47, Nazaré Paulista, SP, 12960-000, Brasil

3. Miriam Lucia Lages Perilli
Instituto para Conservação dos Carnívoros Neotropicais (Pró-Carnívoros), Avenida Horácio Neto, 1030, Atibaia, SP, Brasil

4. Ana Maria de Oliveira Paschoal, Rodrigo Lima Massara, Adriano Pereira Paglia
Universidade Federal de Minas Gerais, Departamento de Biologia Geral, Avenida Antônio Carlos, nº. 6627, Belo Horizonte, MG, 31270-901, Brasil

5. Adriano Garcia Chiarello
Universidade de São Paulo, Departamento de Biologia, Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, Avenida Bandeirantes, nº 3900, Ribeirão Preto, SP, 14040-901, Brasil

6. Maurício Eduardo Graipel
Universidade Federal de Santa Catarina, Departamento de Ecologia e Zoologia, Florianópolis, SC, 88040-900, Brasil

7. Jorge José Cherem
Caipora Cooperativa para a Conservação da Natureza, Florianópolis, SC, 88040-400, Brasil

8. Luiz Gustavo Rodrigues Oliveira Santos
Universidade Federal de Mato Grosso do Sul, Instituto de Biologia, Departamento de Ecologia, Av. Costa e Silva s/ nº, Campo Grande, MS, 79070-900, Brasil

9. Carlos Rodrigo Brocardo
Instituto Neotropical: Pesquisa e Conservação, Curitiba, PR, Brasil

10. Agustín Paviolo, Mario S. Di Bitetti
Instituto de Biología Subtropical (IBS), Universidad Nacional de Misiones (CONICET)

11. Agustín Paviolo, Mario S. Di Bitetti
Asociación Civil Centro de Investigaciones del Bosque Atlántico (CeIBA), Bertoni 85, 3370 Puerto Iguazú, Misiones, Argentina

12. Mario S. Di Bitetti
Facultad de Ciencias Forestales, Universidad Nacional de Misiones, Bertoni 124, 3380 Eldorado, Argentina

13. Leandro Moraes Scoss
Tropical Ecology Assessment and Monitoring Network, Terrestrial Vertebrate, Site Rio Doce, Bicho do Mato Instituto de Pesquisa, Avenida Cônsul Antônio Cadar, 600, Belo Horizonte, MG, 30360-082, Brasil

14. Pedro Cordeiro-Estrela
Universidade Federal da Paraíba, Laboratório de Mamíferos, Departamento de Sistemática e Ecologia, CCEN, Cidade Universitária, s/nº, Castelo Branco III, João Pessoa, PB, 58051-900, Brasil

15. Roberto Fusco-Costa
Instituto de Pesquisas Cananéia (IPeC), Rua Tristão Lobo, nº 199, Cananéia, SP, 11990-000, Brasil

16. Clarissa Alves da Rosa
Instituto Alto Montana da Serra Fina, BR 354, Km 768, Bairro Engenho de Serra, Itamonte, MG, 37466-000, Brasil

17. Marina Xavier da Silva
Projeto Carnívoros do Iguaçu, Parque Nacional do Iguaçu, Br 469, Km 22.5, Foz do Iguaçu, PR, 85851-970, Brasil

**Abstract:**

Our understanding of mammal ecology has always been hindered by the difficulties of observing species in closed tropical forests. Camera trapping has become a major advance for monitoring terrestrial mammals in biodiversity rich ecosystems. Here we compile the largest dataset of inventories of terrestrial mammal communities for the Neotropical region based on camera trapping studies. The dataset comprises 170 surveys of medium to large terrestrial mammals using camera traps conducted in 144 areas by 74 studies, covering six vegetation types of tropical and subtropical Atlantic Forest of South America (Brazil and Argentina), and present data on species composition and richness. The complete dataset comprises 53,438 independent records of 83 species of mammals, includes 10 species of marsupials, 15 rodents, 20 carnivores, 8 ungulates and 6 armadillos. Species richness averaged 13 species (± 6.07 SD) per site. Only six species occurred in more than 50% of the sites: the domestic dog *Canis familiaris*, crab-eating fox *Cerdocyon thous*, tayra *Eira barbara*, south American coati *Nasua nasua*, crab-eating raccoon *Procyon cancrivorus* and the nine-banded armadillo *Dasypus novemcinctus.* The information contained in this dataset can be used to understand macroecological patterns of biodiversity, community, and population structure, but also to evaluate the ecological consequences of fragmentation, defaunation, and trophic interactions.

**D. Key words:** Atlantic Forest, forest fragmentation, camera traps, neotropical mammals, biodiversity hotspot, mammal communities, invasive species

**E. Description:** The dataset combines 53,438 independent records of 83 species of medium to large terrestrial mammals from 170 surveys using camera traps conducted in 144 areas by 74 studies. We used data exclusively from camera trap surveys as they are ideal to record communities of terrestrial mammals, not selecting a specific group and photographing most species that cross in front of them. For this reason, it is considered the most reliable tool to register the occurrence and ecology of medium to large terrestrial mammals in tropical forests (Tobler et al. 2008a). In addition, it reduces our bias of detecting or missing species when compared with human direct surveys, such as line transect census and track surveys (Silveira et al. 2003). The dataset is restricted to the Atlantic Forest hotspot (Fig. 1).

For the general data analysis, we considered only species that are well detected in camera traps and excluded records considered opportunistic (such as bats, primates, and small mammals). However, we kept the full records of all mammalian species in the database. Specifically, we only evaluated 47 species, from 36 genera, 17 families and 8 orders – hereafter, filtered dataset (Fig. 2). The full dataset has 10 orders, 28 families, 58 genera, and 83 species, of which 10% are classified as Vulnerable (VU) by IUCN, 61% are Least Concern (LC), 2% are Critically Endangered (CR), and 5% are invasive. Both species with CR status are primates (the muriqui *Brachyteles hypoxanthus*, and the buff-headed capuchin *Sapajus xanthosternos*). From the filtered dataset, seven species are classified as Vulnerable (Brazilian dwarf brocket *Mazama nana*, white-lipped peccary *Tayassu pecari*, southern tiger cat *Leopardus guttulus*, giant armadillo *Priodontes maximus*, lowland tapir *Tapirus terrestris*, giant anteater *Myrmecophaga tridactyla*, bristle-spined rat *Chaetomys subspinosus*) and five are Near Threatened (maned wolf *Chrysocyon brachyurus*, bush dog *Speothos venaticus*, margay *Leopardus wiedii*, jaguar *Panthera onca* and the neotropical otter *Lontra longicaudis*) (Fig. 3).

The most frequent species were the nine-banded armadillo *Dasypus novemcinctus*, the south

American coati *Nasua nasua*, and the crab-eating fox *Cerdocyon thous*, occurring in 79, 69, and 58% of all sites, respectively (Fig. 3). Species richness averaged 13 species (± 6.07 SD) per site (Fig. 4). Five species occurred in more than 50% of the sites: the domestic dog *Canis familiaris*, crab-eating fox *Cerdocyon thous*, tayra *Eira barbara*, south American coati *Nasua nasua*, crab-eating raccoon *Procyon cancrivorus*, and the nine-banded armadillo *Dasypus novemcinctus* (Fig. 3). From the full dataset, in the 144 sites, we had 16 species as singletons (i.e. species recorded in only one site). However, in our filtered dataset we had just two singletons: southern naked-tailed armadillo *Cabassous unicinctus* and giant armadillo *Priodontes maximus* (Fig. 3). From all the records, the most frequent species was the Brazilian common opossum *Didelphis aurita* with 1,283 records in a single site. This species alone is represented 10% of overall survey records (2,637 of 25,535), only considering studies that use a minimum one hour interval among records of the same species to allow comparison ($N$ = 71). Among invasive species, the domestic dog was recorded in 56% of the sites and wild boars (*Sus scrofa*) in 16%.

Survey site altitude varied from sea level to 2,791 m (Parque Nacional do Itatiaia) and 67% were conducted in protected areas, adequately representing the broad altitudinal variation of Atlantic forests. On average the surveys used 12 (±12.76 SD) camera traps. As many studies reported that they moved camera traps during the same survey, the average number of sampling points was 16 (±20.77 SD). Distance between sampling stations varied from 100 to 7,192 m. Sampling effort per time, or trap/days, given by the number of survey days multiplied by the number of sampling points, is one of the main factors determining survey success and the number of recorded species (Srbek-Araujo and Chiarello 2007, Tobler et al. 2008a). This pattern was also detected in our dataset, as species richness showed to be correlated to sampling effort (adjusted $R^2$= 0.51, slope=8.18 ±0.66 SE, df=142, p<0.001, Fig. 5). The average effort among studies was 1,185 trap/days (min 40 – max 9,078). The median effort (450 trap/days) is considered adequate to obtain records from the most common species, while a minimum of 900 trap/days would be needed to detected local species efficiently (Tobler et al. 2008b, Si et al. 2014).

Some species can spend several minutes in front of a sampling station and trigger the sensor several times. The same individuals of a given species can also cross at the same sampling station many times in a short period. Also, species that present social behavior such as peccaries and coatis may highly increase the total number of records. To minimize these sources of bias, researchers establish a time interval among consecutive records to determine independence. Most surveys reported one hour minimum interval (42%), while 41 (24%) considered a 24-hour interval as an independent record. Other criteria were: 30 min (7%), 5 min (2%), and 30 seconds (1%). The remaining 24% of studies did not describe any criteria or reported only the total number of records. Only 18% reported having used any kind of baiting to increase detection probability.

In Brazil, most surveys were carried out in São Paulo state (27%) followed by Santa Catarina (21%) and Minas Gerais (18%) states. In Argentina, the surveys are concentrated in Misiones province, the southwestern limit of the Atlantic Forest. Several surveys from this region are raw data from a long term participatory network for carnivore monitoring promoted by Argentine researchers (De Angelo et al. 2011). No surveys in the Atlantic Forest of Paraguay were found during our data compilation process.

## CLASS II. RESEARCH ORIGIN DESCRIPTORS

### A. Overall project description

**Identity:** A database integrating information medium to large terrestrial mammals from camera trap studies in the Atlantic Forest hotspot.

**Period of study:** Raw data range from 1999-2017.

**Objectives:** Our main goals in compiling this dataset were: (1) to summarize information on camera trap inventories conducted in the Atlantic Forest hotspot, (2) to make available data restricted to research groups and/or usually available only to Portuguese and Spanish speakers, and (3) to describe the major patterns in the studies and identify gaps of knowledge and information to guide future sampling and conservation efforts. This dataset follows the ATLANTIC biodiversity series, an effort to compile biodiversity information for the Atlantic Forest (e.g. Bovendorp et al. in press., Bello et al. 2017).

**Abstract:** Same as above.

**Sources of funding:** MLLP, SMCC, ACM and EVM studies were funded by Panthera Foundation and Instituto Pró-Carnívoros. CAR studies were funded by the Tropical Forest Conservation Act – TFCA/FUNBIO. RFC and CRB studies were funded by Fundação Grupo Boticário de Proteção à Natureza; AGC, AMOP, RLM and APP were supported by CNPq, CAPES and FAPEMIG. CRB were granted with CNPq Scholarships, also ALR (153423/2016-1); AP, CA, PC and VQ studies were supported by CONICET, WWF, Fundación Vida Silvestre Argentina, The Rufford Foundation and WCS. MX were supported by Belmont Hotel. MB studies were funded by CONICET, Argentina (PIP nº 112 201101 00616); UCAR, Ministerio de Agroindustria, Argentina - PIA 10102/ 2011; Agencia Nacional de Promoción Científica y Tecnológica, Ministerio de Ciencia Tecnología e Innovación Tecnológica, Argentina - PICT 2013 nº 1904. LS, FFK, AVN and GML surveys were funded by Conservation International, TEAM Network, Gordon and Betty Moore Foundation and Instituto Estadual de Florestas-MG. AVN were associated with Museu de Zoologia João Moojen. PCE, FLR, MDGB and ACFA were funded by Rufford Foundation (Project 20950-1), Idea Wild, Rede BioM.A. Inventários (PPBIO Mata Atlântica/CNPq proc.: 457524/2012-0). MCR, MG, GB were funded by São Paulo Research Foundation FAPESP (Proc 2013/50421-2; 2014/01986-0; 2014/23095-0), as was RLM (Proc 2015/17739-4). FL and LC studies were funded by Fundação Grupo Boticário de Proteção à Natureza, The Scott Neotropical Fund of the Lincoln Park Zoological Society, The Species Survival Fund from Wildlife Trust, IdeaWild Grant Program, WWF/US, WWF-EFN Scholarship Program, DICE Small Grant Program, The Liz Claiborne Art Ortenberg Foundation, The Ashoka Foundation, Conservation, Food and Health Foundation, 100% Fund from Fauna and Flora International, The Woodland Park Zoo, The Whitley Awards, The Rolex Awards, Durrell Wildlife Conservation Trust, The Rufford Small Grants Program and Ridgeway Trust. Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) provided support during ACFA MSc., LC, MGB and FL PhD, and FLR PNPD fellowship. LC, FL, and MLLP received financial support from 2012 – 2015 for data management, curation and analysis from Fundo Brasileiro para a Biodiversidade – Tropical Forest Conservation Act agreement (FUNBio/TFCA). AGC, MG and MCR receive a research fellowship from CNPq. MEG studies were funded by Conservação Internacional do Brasil, CNPq and Ministério da Ciência, Tecnologia e Inovação (MCTI). The funders above had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

**Site description:** Originally, the Atlantic Forest comprised a continuous forest of 150 million ha of evergreen and seasonally-dry forests ranging across a latitudinal gradient of over 3,300 km of the Brazilian Atlantic coast, with extensions in Paraguay and Argentina (Galindo-Leal and Câmara 2003, Tabarelli et al. 2010). The Atlantic Forest is divided into eight biogeographic sub regions, based on endemic species distribution, varying in altitude from sea level to 2,700 m above sea level and annual precipitation up to 4,000 mm/year (Câmara 2003, Silva and Casteleti 2003, Ribeiro et al. 2009).

The Atlantic Forest of South America supports up to 8% of the world's species and has one of the highest rates of endemism in the world (Myers et al. 2000). At least 15,519 plant species (3,343 trees) (Zappi et al. 2015), 891 bird species (Lima 2014), 543 amphibians (Haddad et al. 2013), 200 reptiles (Bérnils and Costa 2015), 350 fishes (MMA 2010), and 298 mammals (Paglia et al. 2012), including 22 species of marsupials (Paglia et al. 2012), and 105 species of rodents (Patton et al. 2015) are known from this ecoregion. The latest national evaluation classified 598 species as threatened in the ecoregion, and 428 of these are endemic (ICMBio 2016).

Its spatial distribution along the Brazilian coast exposed the Atlantic Forest to an intense process of territorial occupation in the past 300 years (Dean 1996). Currently, 88% of its extent has been lost and the remains are divided in more than 200,000 forest fragments (Ribeiro et al. 2009). Nearly 93% of the remaining forest is within one kilometer of a forest edge, and 12 km is the maximum distance from remnants to any non-forested area (Ribeiro et al. 2009, Haddad et al. 2015). Therefore, the Atlantic Forest is among the most threatened of tropical forests, and it draws a high conservation concern due to its high concentration of endemic and small-ranged species (Jenkins et al. 2015).

A major consequence of habitat loss and deterioration is the loss of sensitive species (i.e., rare and with low growth rate), particularly the losses of large vertebrates (Jorge et al. 2013, Galetti et al. 2016a). Among the myriad causes of defaunation, poaching can be considered the main direct threat for medium and large mammals in the remaining forest fragments (Cullen et al. 2000, Canale et al. 2012, Galetti et al. 2016a). Although 88% of the forest cover has been lost, there are no documented extinction of mammal in the last 500 years (Paglia et al. 2012). A few endangered species have recovered after major management and conservation interventions (e.g. the golden lion tamarin, *Leontopithecus rosalia*) (Johnson et al. 2017).

**Data compilation:** We obtained data from three main sources: (i) literature search using Google Scholar, Web of Science, Scielo, Scopus, JStore, and ResearchGate using keywords, (ii) data mining on gray literature, applying the same keywords to look reports, reserve management plans, monographs, unpublished theses, and dissertations, and (iii) contacted with individuals and organizations known to have conducted camera trap surveys in the Atlantic Forest, inviting them to contribute.

**Research Methods:** We divided data acquisition in three stages. First, we conducted a literature search using Google Scholar, Web of Science, Scielo, Scopus, JStore, and ResearchGate using selected keywords (see Section D). Second, we conducted data mining on gray literature, applying the same keywords to look reports, reserves management plans, monographs, unpublished theses, and dissertations.

Even with the increase in scale and popularity of studies using camera traps over the last decade, there is no standard data, metadata, and protocols (Forrester et al. 2016). In order to aggregate data from such a variety of sources, we divided camera trap data in five groups of information: 1) the "study" is a survey or scientific study conducted within a defined location and timeframe;

2) the "location" is a group of general descriptive spatial information, associated with a geographic coordinate of the forest patch(es) or region where the study were conducted; 3) the "survey" is a group of general information that describes the methods, equipment, and protocols used in the study, as well as its timeframe; 4) the "record" contains information associating each record to a species detected during the study as well as number of records or presence/absence data; and 5) the "species" data with taxonomic information of species detected during the study. We organized these groups of information in a relational database structure in Microsoft Access – version 2007-2016 (Fig. 6). For each group of information, we standardized and converted data to fit the dataset structure (Tables 02 to 06). Using this approach we gathered data from Cerveira 2005, Alves and Andriolo 2005, Srbek-Araujo and Chiarello 2005, 2013, Rezini 2007, Kasper et al. 2007, Diniz 2008, Barros 2008, Modesto et al. 2008b, 2008a, Lyra-Jorge et al. 2008, Prado et al. 2008, 2014, Paviolo et al. 2008, 2016, Alves 2009, Lima 2009, 2012, Bastos Neto et al. 2009, Silva and Passamani 2009, Goulart et al. 2009, Abreu Júnior and Köhler 2009, Esteves 2010, Kuhnen 2010, Tonini et al. 2010, de Oliveira 2011, Marques et al. 2011, Norris et al. 2011, Cherem et al. 2011, Espartosa et al. 2011, Falcão et al. 2012, Hortenci 2012, Melo et al. 2012, Motta Lessa 2012, Penido and Zanzini 2012, Paschoal et al. 2012, Nunes et al. 2012, 2013, Cassano et al. 2012, 2014, Brocardo et al. 2012, 2013, de Carvalho et al. 2013, Gomes Albuquerque et al. 2013, Kionka 2013, Pazio 2013, Bogoni et al. 2013, 2016, Carvalho et al. 2013, Costa 2014, Gatti et al. 2014, Soares et al. 2014, Tortato et al. 2014, Talamoni et al. 2014, Rocha-Mendes et al. 2015, Beca et al. 2017.

After the definition of the database structure and organization of the literature data resulting from the two stages of data mining, we observed several spatial gaps of information, i.e. although the search in the literature did not reveal the presence of studies, we knew that some regions had already been sampled by research groups. To fill these gaps, we contacted several individuals and organizations known to have conducted camera trap surveys in the Atlantic Forest, inviting them to contribute.

For each survey, when described otherwise (e.g., trap/hour), we converted the effort to trap/day (number of sampling stations * sampling period). We converted latitudes and longitudes to Geographic Coordinate System WGS 84. Survey sites from the literature were checked and adjusted one by one using Google Earth and we extracted the vegetation type using the classes described in Ribeiro et al. (2009). We standardized the taxonomy of medium to large terrestrial mammals using the Taxize package in R environment (Chamberlain and Szöcs 2013, R Core Team 2016). We used the same package to access species status under the IUCN Red List of Threatened Species, and later verified it on the IUCN website (IUCN 2016). We also added the category IN as a reference to invasive species and feral domestic animals detected in the surveys (i.e. *Sus scrofa, Felis catus, Canis familiaris, Lepus europaeus*). We did not exclude these species because of their high detectability in camera trap studies and because they present feral populations and may have a high impact on the community and disease transmission (Galetti and Sazima 2006, Pedrosa et al. 2015, Paschoal et al. 2016, Galetti et al. 2016b). However, we excluded cattle, horses, and goats, since their presence and absence are related to management and they do not represent feral populations in the Atlantic Forest.

The placement of camera traps near the ground favors terrestrial and scansorial species, thus not being appropriate to register other groups of mammals (Srbek-Araujo and Chiarello 2005). Nevertheless, many studies report opportunistic records of small rodents, primates, and even bats. For the general data description presented here we, excluded records considered opportunistic, but kept the records in the database. The species excluded are presented in Table 1. We also excluded records of genera without a species identification: *Mazama* sp., *Leopardus* sp., *Cabassous* sp. *Dasypus* sp., *Didelphis* sp. *Marmosops* sp., *Cavia* sp., *Dasyprocta* sp., and *Trinomys* sp.

To define Atlantic Forest boundaries, we merged available geographic information from widely used limits along an area that comprises more than 2 million km$^2$: the Brazilian limit provided by government Institutes (IBGE 2004), the limit provided by the Atlantic Forest Law website (MMA 2006), the one available at Ribeiro et al. (2009), and the shapefile reported in Olson et al. (2001) where the categories Atlantic forests and Atlantic dry forests are represented inside and outside Brazil.

**Taxonomy and systematics:** We standardized up to date taxonomy of medium to large terrestrial mammals using the Taxize package in R environment (Chamberlain and Szöcs 2013, R Core Team 2016). We used the same package to access species status under the IUCN Red List of Threatened Species, and later verified it on the IUCN website (IUCN 2016).

**C. Data limitations and potential enhancements:**

We recognize that documenting all species of terrestrial mammals present in megadiverse ecosystems depends on sampling effort, microhabitats sampled, and detectability of each species (Tobler et al. 2008a). Several species occur along water bodies (e.g., *Cuniculus paca, Hydrochoerus hydrochaeris, Lontra longicaudis*) and may not be recorded if this microhabitat is not sampled (Beca et al. 2017). Sampling along roads and large trails can also affect detectability and the species recorded (Harmsen et al. 2010, Bitetti et al. 2014). Some species are too rare (e.g. *Panthera onca, Speothos venaticus*) or move too fast (*Galictis* spp.) and require intensive sampling (Fusco-Costa and Ingberman 2013).

Although this dataset comprises only studies that used camera trapping, most surveys are heterogeneous, with sampling design and efforts highly variable, precluding a more comprehensive diagnosis of diversity throughout the Atlantic Forest. Effort alone has a relevant influence on species richness (adjusted $R^2$= 0.51, slope=8.18 ±0.66 SE, df=142, p<0.001; Fig. 5). Different equipment may influence the capture success of species (Tobler et al. 2008). The use of baits, despite not used in most studies, may also introduce bias in the results. Baits used to improve predator detection have been reported to repel some prey species (Rocha et al. 2016). In addition, the sampling effort length of studies is highly variable, and all them are limited to an 18-year timeframe with most areas sampled only once, limiting the ability to detect long-term population trends.

Another consistent limitation is the uneven sampling throughout the Atlantic Forest, with very few studies in the fragmented forest in north-east of Brazil and none in Paraguay (Fig. 4). The general spatial pattern of survey intensity is biased towards economically developed regions, protected areas, and with close proximity to large cities and universities. It is important to mention that, despite representing the general pattern of survey intensity along the Atlantic Forest, likely not all studies are included here. The data mining process may have overlooked some studies. Also, a few invited research groups and individuals declined to collaborate with unpublished data. Some bioregions where we expect to find highly endemic species were not sampled (e.g. Brejos de Altitude, Ceará). Another limitation is in species identification of some groups (e.g. *Leopardus, Mazama*) where more than one species in the same genera can occur and good photography is needed to identify the correct species.

Despite these limitations, these data represent a massive effort by biologists and ecologists working in this biodiversity hotspot. Collectively, it represents the largest available dataset of the communities of medium and large mammals in tropical and subtropical forests. The results from this dataset can detect gaps to improve the sampling of terrestrial mammals, help identify priority areas for conserving endangered species and populations, aid in understanding community composition and potential trophic cascades mediated by mammals (Jorge et al. 2013), and help to understand the impact and occurrence of invasive species (Pedrosa et al. 2015, da Rosa et al. 2017).

## CLASS III. DATA SET STATUS AND ACCESSIBILITY

### A. Status

**Latest update:** May 2017

**Latest archive date:** May 2017

**Metadata status:** Last updated May 2017, version submitted

**Data verification:** We verified the data at distinct levels. We converted all latitudes and longitudes to Geographic Coordinate System WGS 84, and checked and adjusted one by one when necessary using Google Earth. We searched for extreme values, transcription errors, and excluded all diacritic marks to avoid encoding problems. See Research Methods section for further details.

### B. Accessibility

**Storage location and medium:** In addition to Ecological Society of America Data Registry, our dataset – which was structured as a relational database in Microsoft Access – will also be available at http://www.leec.eco.br/data.html (Spatial Ecology and Conservation Lab repository).

**Contact person(s):** Fernando Lima (pardalismitis@gmail.com), Mauro Galetti (mgaletti@rc.unesp.br), Milton Cezar Ribeiro (mcr@rc.unesp.br)

**Copyright restrictions:** None

**Proprietary restrictions:** Please cite this data paper if the data are used in publications. We intend to keep it up to date as novel studies become available (server link above).

**Costs:** None

## CLASS IV. Data structural descriptors

### A. Data set file

**Identity:** (1) ATLANTIC_CAMTRAPS_1-0_STUDY.csv

(2) ATLANTIC_CAMTRAPS_1-0_LOCATION.csv

(3) ATLANTIC_CAMTRAPS_1-0_SURVEY.csv

(4) ATLANTIC_CAMTRAPS_1-0_RECORDS.csv

(5) ATLANTIC_CAMTRAPS_1-0_SPECIES.csv

**Size:** (1) ATLANTIC_CAMTRAPS_1-0_STUDY.csv, 74 studies, 16 KB;

(2) ATLANTIC_CAMTRAPS_1-0_LOCATION.csv, 144 communities, 18 KB;

(3) ATLANTIC_CAMTRAPS_1-0_SURVEY.csv, 170 surveys, 25 KB;

(4) ATLANTIC_CAMTRAPS_1-0_RECORDS.csv, 14.110 entries, 614 KB;

(5) ATLANTIC_CAMTRAPS_1-0_SPECIES.csv, 83 species, 8 KB.

**Format and storage mode:** available as comma-separated values (*.csv), and stored in a relational Microsoft Access database (*.accdb)

**Alphanumeric attributes:** Mixed

**Data anomalies:** If no information is available for a given record the field is empty.

## TABLES

**Table 1.** Species detected in camera trap surveys in Atlantic Forest considered opportunistic records. These species were not accounted in data description, but the records are kept in the database.

| ORDER | FAMILY | GENUS | SPECIES | IUCN STATUS |
|---|---|---|---|---|
| Artiodactyla | Bovidae | Bos | *Bos taurus* | - |
| Chiroptera | Phyllostomidae | Sturnira | *Sturnira lilium* | LC |
| Didelphimorphia | Didelphidae | Gracilinanus | *Gracilinanus agilis* | LC |
| | | | *Gracilinanus microtarsus* | LC |
| | | Marmosa | *Marmosa murina* | LC |
| | | Marmosops | *Marmosops incanus* | LC |
| | | Metachirus | *Metachirus nudicaudatus* | LC |
| | | Monodelphis | *Monodelphis scalops* | LC |
| | | Philander | *Philander frenatus* | LC |
| | | | *Philander opossum* | LC |
| Pilosa | Bradypodidae | Bradypus | *Bradypus torquatus* | VU |
| Primates | Atelidae | Alouatta | *Alouatta caraya* | LC |
| | | | *Alouatta guariba* | LC |
| | | Brachyteles | *Brachyteles hypoxanthus* | CR |
| | Callitrichidae | Callithrix | *Callithrix geoffroyi* | LC |
| | | | *Callithrix kuhlii* | NT |
| | | | *Callithrix penicillata* | LC |
| | | Leontopithecus | *Leontopithecus chrysomelas* | EN |
| | Cebidae | Sapajus | *Sapajus nigritus* | NT |
| | | | *Sapajus xanthosternos* | CR |
| | Pitheciidae | Callicebus | *Callicebus melanochir* | VU |
| Rodentia | Cricetidae | Juliomys | *Juliomys pictipes* | LC |
| | | Nectomys | *Nectomys squamipes* | LC |
| | | Sooretamys | *Sooretamys angouya* | LC |
| | Echimyidae | Trinomys | *Trinomys dimidiatus* | LC |
| | | | *Trinomys iheringi* | LC |
| | Myocastoridae | Myocastor | *Myocastor coypus* | LC |
| | Sciuridae | Sciurus | *Sciurus aestuans* | LC |

**Table 2. Studies information**: Description of the fields related with the study sites information – file ATLANTIC_CAMTRAPS_1-0_STUDY.csv

| FIELD | DESCRIPTION | LEVELS | EXAMPLE |
|---|---|---|---|
| **study_id** | Identification code for each study | 1001 - 1074 | 1001 |
| **study** | Citation of the study | | Paschoal, A. M. O., R. L. Massara, J. L. Santos, and A. G. Chiarello. 2012. Is the domestic dog becoming an abundant species in the Atlantic forest? A study case in southeastern Brazil. Mammalia 76:67–76 |
| **ref_obs** | Any observation regarding the study | | Unpublished data |

**Table 3. Location information:** Description of the fields related with the location of each study sites – file ATLANTIC_CAMTRAPS_1-0_LOCATION.csv

| FIELD | DESCRIPTION | LEVELS | EXAMPLE |
|---|---|---|---|
| **location_id** | Identification code for the location of the study | 1001 – 1144 | 1001 |
| **site** | Local name of the study area | | Estacao Ecologica Mico-leao-preto Tucano |
| **municipality** | Municipality of the study | | Euclides da Cunha |
| **state** | State or province of the study | | Sao Paulo |
| **country** | Name of the country | | Brazil |
| **X** | Longitude in decimal degrees (GCS - WGS 84) | | -52,46820 |
| **Y** | Latitude in decimal degrees (GCS - WGS 84) | | -22,48010 |
| **altitudeMin** | Minimum altitude of study area when described | 0 – 1450 | 0 |
| **altitudeMax** | Maximum altitude of study area when described | 20 – 2791 | 20 |
| **vegetation_type** | Atlantic Forest Vegetation type according to Ribeiro et al. (2009) | Deciduous Forest<br>Dense Ombrophilous Forest<br>Mixed Ombrophilous Forest<br>Semideciduous Forest<br>Steppe | Deciduous Forest |
| **PA** | If the study or part of it was conducted in a protected area | yes - no (y - n) | Y |

**Table 4. Survey information**: Description of the fields related with each survey – file ATLANTIC_CAMTRAPS_1-0_SURVEY.csv

| FIELD | DESCRIPTION | LEVELS | EXAMPLE |
|---|---|---|---|
| **study_id** | Identification code for each study (one-to-many relationship link to STUDY Table) | 1001 – 1074 | 1001 |
| **location_id** | Identification code for the location of the study (one-to-many relationship link to LOCATION Table) | 1001 – 1144 | 1001 |
| **survey_id** | Identification code for each survey | 1001 – 1170 | 1001 |
| **monthstart** | month of the start of the survey | 01 – 12 | 10 |
| **yearstart** | year of the start of the survey | 1999 – 2017 | 2016 |
| **monthfinish** | month of the end of the survey | 01 – 12 | 10 |
| **yearfinish** | year of the end of the survey | 2002 – 2017 | 2017 |
| **Effort** | Sampling Effort: number of sampling stations * sampling period (trap/days) | 35 - 9078 | 500 |
| **n_cameras** | Number of camera traps used in the study | 01 - 72 | 50 |
| **cam_type** | Type or brand of Camera Traps used | | LeafRiver |
| **design** | Protocol used to distribute sampling points | grid,<br>transect,<br>points (opportunistic) | Grid |
| **n_points** | Number of sample points | 01 - 184 | 50 |
| **cam_spacing** | Average distance between sample points | 100 - 7192 | 500 |
| **cam_spacing_obs** | Observation about camera trap spacing | | min 1000; max 01500 |
| **baiting** | If any kind of baiting was used in the survey | yes - no (y - n) | y |
| **records_obs** | Observation about records. Independence among records criteria | | independent record = 24 hour interval |

**Table 5. Records information**: Description of the fields related with the records of medium and large terrestrial mammal each survey – file ATLANTIC_CAMTRAPS_1-0_RECORDS.csv

| FIELD | DESCRIPTION | LEVELS | EXAMPLE |
|---|---|---|---|
| **record_id** | Identification code for each record | 10001 - 14110 | 10001 |
| **survey_id** | Identification code for each survey (one-to-many relationship link to SURVEY Table) | 1001 - 1170 | 1001 |
| **species_id** | Identification code for each survey (one-to-many relationship link to SPECIES Table) | 1001 - 1083 | 1001 |
| **species_code** | Code composed of 4 characters for species genus followed by 4 characters for species scientific name | | Leop_pard |
| **record** | Number of records of each species during the survey | 1 - 14110 | 55 |
| **presence_absence** | presence-absence data of species (1-0) | 1<br>0 | 1 |

545

**Table 6. Species information**: Description of the fields related with the species of medium and large terrestrial mammal detected by camera traps in each survey – file ATLANTIC_CAMTRAPS_1-0_SPECIES.csv

| FIELD | DESCRIPTION | LEVELS | EXAMPLE |
|---|---|---|---|
| **species_id** | Identification code for each species (one-to-many relationship link to SPECIES Table) | 1001 - 1083 | 1001 |
| **order** | Order of the species | Artiodactyla<br>Chiroptera<br>Carnivora<br>Cingulata<br>Didelphimorphia<br>Lagomorpha<br>Perissodactyla<br>Pilosa<br>Primates<br>Rodentia | Carnivora |
| **family** | Family of the species | | Felidae |
| **genus** | Genus of the species | | Leopardus |
| **species** | Species name | | pardalis |
| **species_name** | Scientific name of the species | | Leopardus pardalis |
| **species_code** | Code composed by 4 characters of species genus followed by 4 characters for species scientific name | | Leop_pard |
| **iucn_status** | IUCN status of the species (accessed April 2017). Critically endangered (CR), Data Deficient (DD), Endangered (EN), Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Invasive (IN) | CR<br>DD<br>EN<br>LC<br>NT<br>VU<br>IN | LC |
| **records (survey_id)** | Each of the next columns are named with a code from survey_id (one-to-one relationship link to SURVEY table). Data in these columns correspond to the number of records of each species during the survey. In presence/absence surveys records are filled as "y" | 1 - ... Or "y" | 55 |

**ACKNOWLEDGMENTS:** We thank Fundação José Pedro de Oliveira for sending information from Mata de Santa Genebra. We also thank to Renato Rizzaro owner of Reserva Particular do Patrimônio Natural Rio das Furnas, who kindly permitted data from this area to be used. We thank Viviane Brito for data organization services. To Carolina Bello and the ATLANTIC team, thanks for the invaluable help with programming and your many valuable insights. We also thank Denis Sana, Kauê Abreu, Fred Lemos, Fernanda Azevedo, Fabiano Melo and Analice Calaça who were readily available to contribute with their datasets, even if it was not possible to include them at the end. This work is dedicated to those who spent weeks – often months – struggling in the jungles in order to bring light on medium and large terrestrial mammal ecology.

**Figure captions:**

**Fig. 1. Distribution of the camera trap surveys of medium and large terrestrial mammal communities within the Atlantic Forest extent**. Gray shows the Atlantic Forest extent with remaining forest patches in green (*sensu* Ribeiro et al. 2009). Blue dots show the geographic locations of studies.

**Fig. 2**. **Taxonomic information levels of medium and large terrestrial mammal species recorded in camera trap surveys within the Atlantic Forest.** Only species considered well detected by camera traps are listed. From the 83 species reported in the database, 8 are not listed because the identification is at genera level. Another 28 species are not listed because they were considered opportunistic records of species not usually detected by camera traps (primates, bats, small rodents, and small marsupials).

**Fig. 3. Distribution of frequencies of occurrence of the main species evaluated in ATLANTIC-CAMTRAPS, and their status in the 2017 IUCN Red list of threatened species.** LC = least concern, NT = near threatened, VU = vulnerable, EN = endangered, CR = critically endangered, DD = data deficient, and IN = invasive species (not an IUCN category).

**Fig. 4. Distribution of taxonomic richness and sampling effort across Atlantic Forest sites where camera traps were used for sampling of medium and large terrestrial mammal species.** Opportunistic records (see the text) were removed from this analysis.

**Fig. 5. Positive effect of sampling effort on observed taxonomic richness of ATLANTIC-CAMTRAPS database.** Predictor of linear regression was log transformed (adjusted $R^2$= 0.51, slope=8.18 ±0.66 SE, df=142, p<0.001). Gray dashed lines represent 95% confidence intervals of predicted values.

**Fig. 6 Standardized layout of the database ATLANTIC-CAMTRAPS.** Guideline to the correlational structure in order to inform how the database is organized.

**Literature cited**


Abreu Júnior, E. F. De, and A. Köhler. 2009. Mastofauna de médio e grande porte na RPPN da UNISC, RS, Brasil. Biota Neotropica 9:169–174.

Ahumada, J. A., J. Hurtado, and D. Lizcano. 2013. Monitoring the Status and Trends of Tropical Forest Terrestrial Vertebrate Communities from Camera Trap Data: A Tool for Conservation. PLoS ONE 8:e73707.

Alves, L. C. P. D. S., and A. Andriolo. 2005. Camera traps used on the mastofaunal survey of Araras Biological Reserve, IEF-RJ. Revista Brasileira de Zoociências 7:231–246.

Alves, T. R. 2009. Diversidade de mamíferos de médio e grande porte e sua relação com o mosaico vegetacional na fazenda experimental Edgárdia, UNESP, Botucatu/SP. UNIVERSIDADE ESTADUAL PAULISTA "JÚLIO DE MESQUITA FILHO."

De Angelo, C., A. Paviolo, D. Rode, L. Cullen, D. Sana, K. C. Abreu, M. Xavier da Silva, A.-S. Bertrand, T. Haag, F. Lima, A. R. Rinaldi, S. Fernàndez, F. Ramírez, M. Velàzquez, C. Corio, E. Hasson, and M. S. Di Bitetti. 2011. Participatory networks for large-scale monitoring of large carnivores: pumas and jaguars of the Upper Paraná Atlantic Forest. Oryx 45:534–545.

Barros, R. S. M. 2008. Levantamento e estimativas populacionais de mamíferos de médio e grande porte num fragmento de mata atlântica em área urbana no sudeste do Brasil. Universidade Federal de Juiz de Fora, Juiz de Fora, Minas Gerais - Brasil.

Bastos Neto, O. J. R., E. G. de Oliveira, D. P. de Souza, B. F. Mello, T. O. Simoes Amorim, K. C. Pedretti Gomes, and A. Andriolo. 2009. Mammals of particular periurban forest fragment in Juiz de Fora, Minas Gerais, Brazil. Revista Brasileira de Zoociencias.

Beca, G., M. H. Vancine, C. S. Carvalho, F. Pedrosa, R. S. C. Alves, D. Buscariol, C. A. Peres, M. C. Ribeiro, and M. Galetti. 2017. High mammal species turnover in forest patches immersed in biofuel plantations. Biological Conservation.

Bello, C., M. Galetti, D. Montan, M. A. Pizo, T. C. Mariguela, L. Culot, F. Bufalo, F. Labecca, F. Pedrosa, R. Constantini, C. Emer, W. R. Silva, F. R. da Silva, O. Ovaskainen, and P. Jordano. 2017. ATLANTIC-FRUGIVORY: A plant-frugivore interaction dataset for the Atlantic Forest. Ecology:1–49.

Bérnils, R. S., and H. C. Costa. 2015. Répteis brasileiros: lista de espécies. Herpetologia Brasileira.

Bitetti, M. S. Di, A. Paviolo, and C. De Angelo. 2014. Camera trap photographic rates on roads vs. off roads: location does matter. Mastozoología Neotropical 21:37–46.

Bogoni, J. A., T. C. Bogoni, M. E. Graipel, and J. R. Marinho. 2013. The Influence of Landscape and Microhabitat on the Diversity of Large- and Medium-Sized Mammals in Atlantic Forest Remnants in a Matrix of Agroecosystem and Silviculture. ISRN Forestry 2013:1–13.

Bogoni, J. A., J. J. Cherem, E. L. Hettwer Giehl, L. G. Oliveira-Santos, P. V. de Castilho, V. Picinatto Filho, F. M. Fantacini, M. A. Tortato, M. R. Luiz, R. Rizzaro, and M. E. Graipel. 2016. Landscape features lead to shifts in communities of medium- to large-bodied mammals in subtropical Atlantic Forest. Journal of Mammalogy 97:713–725.

Bovendorp, R. S., V. Nacho, E. Abreu-Júnior, C. Bello, A. L. Regolin, A. Percequillo, and M.

Galetti. (n.d.). ATLANTIC-SMALL MAMMALS: A dataset of communities of rodents and marsupials of the Atlantic Forests of South America. Ecology.

Brocardo, C. R., R. Rodarte, R. D. S. Bueno, L. Culot, and M. Galetti. 2012. Mamíferos não voadores do Parque Estadual Carlos Botelho, Continuum florestal do Paranapiacaba. Biota Neotropica 12:198–208.

Brocardo, C. R., V. B. Zipparro, R. A. F. de Lima, R. Guevara, and M. Galetti. 2013. No changes in seedling recruitment when terrestrial mammals are excluded in a partially defaunated Atlantic rainforest. Biological Conservation 163:107–114.

Butchart, S. H. M., M. Walpole, B. Collen, A. van Strien, J. P. W. Scharlemann, R. E. A. Almond, J. E. M. Baillie, B. Bomhard, C. Brown, J. Bruno, K. E. Carpenter, G. M. Carr, J. Chanson, A. M. Chenery, J. Csirke, N. C. Davidson, F. Dentener, M. Foster, A. Galli, J. N. Galloway, P. Genovesi, R. D. Gregory, M. Hockings, V. Kapos, J.-F. Lamarque, F. Leverington, J. Loh, M. A. McGeoch, L. McRae, A. Minasyan, M. H. Morcillo, T. E. E. Oldfield, D. Pauly, S. Quader, C. Revenga, J. R. Sauer, B. Skolnik, D. Spear, D. Stanwell-Smith, S. N. Stuart, A. Symes, M. Tierney, T. D. Tyrrell, J.-C. Vie, and R. Watson. 2010. Global Biodiversity: Indicators of Recent Declines. Science 328:1164–1168.

Câmara, I. de G. 2003. Brief history of conservation in the Atlantic Forest. Pages 31–42*in* C. Galindo-Leal and I. De Gusmão Câmara, editors.The Atlantic Forest of South America : biodiversity status, threats, and outlook. Island Press, Washington, D.C.

Canale, G. R., C. A. Peres, C. E. Guidorizzi, C. A. F. Gatto, and M. C. M. Kierulff. 2012. Pervasive defaunation of forest remnants in a tropical biodiversity hotspot. PLoS ONE 7.

Carvalho, W., C. Adania, and C. Esbérard. 2013. Comparison of two mammalian surveys made with camera traps in southeastern Brazil, focusing the abundance of wild mammals and domestic dogs. Brazilian Journal of Biology 73:29–36.

de Carvalho, W. D., M. S. de M. Godoy, C. H. Adania, and C. E. L. Esbérard. 2013. Assembleia de mamíferos não voadores da Reserva Biológica Serra do Japi, Jundiaí, São Paulo, Sudeste do Brasil. Bioscience Journal 29:1369–1386.

Cassano, C. R., J. Barlow, and R. Pardini. 2012. Large Mammals in an Agroforestry Mosaic in the Brazilian Atlantic Forest. Biotropica 44:818–825.

Cassano, C. R., J. Barlow, and R. Pardini. 2014. Forest loss or management intensification? Identifying causes of mammal decline in cacao agroforests. Biological Conservation 169:14–22.

Cerveira, J. 2005. Mamíferos silvestres de médio e grande porte no Planalto Meridional: suas relações com a fragmentação da paisagem e a presença do gado. Universidade Federal do Rio Grande do Sul, Porto Alegre.

Chamberlain, S. a, and E. Szöcs. 2013. taxize: taxonomic search and retrieval in R. F1000Research.

Chapman, F. M. 1927. Who treads our trails? A camera trapper describes his experiences on an island in the canal zone, a natural-history laboratory in the American tropics. National Geographic.

Cherem, J. J., M. E. Graipel, M. A. Tortato, S. L. Althoff, F. Brüggemann, J. Z. Matos, J. C. Voltolini, R. R. de Freitas, R. Illenseer, F. Hoffmann, I. R. Ghizoni-Jr., A. Bevilacqua, R.

Reinicke, C. H. S. de Oliveira, A. Filippini, N. Furnari, K. Abati, M. Moraes, T. T. Moreira, L. G. R. Oliveira-Santos, V. V. Kuhnen, T. B. Maccarini, F. V. B. Goulart, H. B. Mozerle, F. M. Fantacini, D. Dias, R. Penedo-Ferreira, B. P. Vieira, and P. C. Simões-Lopes. 2011. Mastofauna terrestre do Parque Estadual da Serra do Tabuleiro, Estado de Santa Catarina, sul do Brasil. Biotemas 24:73.

Costa, R. F. 2014. Distribuição e monitoramento de mamíferos de médio e grande porte em áreas protegidas na Floresta Atlântica Costeira, Estado do Paraná, Sul do Brasil. Tese de Doutorado. Universidade Federal do Paraná, Curitiba.

Cullen, L., R. E. Bodmer, and C. Valladares Pádua. 2000. Effects of hunting in habitat fragments of the Atlantic forests, Brazil. Biological Conservation 95:49–56.

Dean, W. 1996. With broadax and firebrand: The Destruction of the Brazilian Atlantic Forest. University of California Press, Berkeley.

Diniz, T. R. 2008. Influência do uso de iscas na amostragem da riqueza e frequência de captura de mamíferos de médio e grande porte utilizando armadilhas fotográficas. Trabalho de Conclusão de Curso. Universidade Estadual Paulista “Júlio de Mesquita Filho,” Rio Claro, São Paulo.

Espartosa, K. D., B. T. Pinotti, and R. Pardini. 2011. Performance of camera trapping and track counts for surveying large mammals in rainforest remnants. Biodiversity and Conservation 20:2815–2829.

Esteves, C. F. 2010. Influência antrópica na distribuição espacial da comunidade de mamíferos no Parque Estadual da Ilha Anchieta, SP. Dissertação de Mestrado. Universidade Estadual Paulista “Júlio de Mesquita Filho,” Rio Claro, São Paulo.

Falcão, F. D. C., D. H. A. Guanaes, and A. Paglia. 2012. Medium and large-sized mammals of RPPN Estação Veracel, southernmost Bahia, Brazil. Check List 8:929–934.

Fusco-Costa, R., and B. Ingberman. 2013. Records of the bush dog Speothos venaticus in a continuous remnant of coastal Atlantic Forest in southern Brazil. Oryx 47:105–108.

Galetti, M., C. R. Brocardo, R. A. Begotti, L. Hortenci, F. Rocha-Mendes, C. S. S. Bernardo, R. S. Bueno, R. Nobre, R. S. Bovendorp, R. M. Marques, F. Meirelles, S. K. Gobbo, G. Beca, G. Schmaedecke, and T. Siqueira. 2016a. Defaunation and biomass collapse of mammals in the largest Atlantic forest remnant. Animal Conservation.

Galetti, M., F. Pedrosa, A. Keuroghlian, and I. Sazima. 2016b. Liquid lunch - vampire bats feed on invasive feral pigs and other ungulates. Frontiers in Ecology and the Environment 14:505–506.

Galetti, M., and I. Sazima. 2006. Impact of feral dogs in an urban Atlantic forest fragment in southeastern Brazil. Natureza & Conservação 4:146–151.

Galindo-Leal, C., and I. G. Câmara. 2003. Atlantic Forest hotspots status: an overview. Pages 3–11*in* C. Galindo-Leal and I. De Gusmão Câmara, editors.The Atlantic Forest of south america: biodiversity status, threats, and outlook. Island Press, Washington; D.C.

Gatti, A., B. Segatto, C. C. Carnelli, and D. Moreira. 2014. Mamíferos de médio e grande porte da Reserva Biológica Augusto Ruschi, Espírito Santo. Natureza Online 12:61–68.

Gomes Albuquerque, H., P. Ferreira Martins, F. Soares Pessôa, T. Carvalho Modesto, J. Lins Luz,

D. S. L. Raíces, N. Carneiro Ardente, I. C. Motta Lessa, N. Attias, T. Jordão-Nogueira, M. Carlota Enrici, and H. de Godoy Bergallo. 2013. Mammals of a forest fragment in Cambuci municipality, state of Rio de Janeiro, Brazil. Check List 9:1505–1509.

Goulart, F. V. B., N. C. Cáceres, M. E. Graipel, M. A. Tortato, I. R. Ghizoni, and L. G. R. Oliveira-Santos. 2009. Habitat selection by large mammals in a southern Brazilian Atlantic Forest. Mammalian Biology - Zeitschrift für Säugetierkunde 74:182–190.

Haddad, C. F. B., L. F. Toledo, C. P. A. Prado, D. Loebmann, J. L. Gasparini, and I. Sazima. 2013. Guia dos Anfíbios da Mata Atlântica - Diversidade e Biologia. Anolis Books, São Paulo.

Haddad, N. M., L. a. Brudvig, J. Clobert, K. F. Davies, A. Gonzalez, R. D. Holt, T. E. Lovejoy, J. O. Sexton, M. P. Austin, C. D. Collins, W. M. Cook, E. I. Damschen, R. M. Ewers, B. L. Foster, C. N. Jenkins, a. J. King, W. F. Laurance, D. J. Levey, C. R. Margules, B. a. Melbourne, a. O. Nicholls, J. L. Orrock, D.-X. Song, and J. R. Townshend. 2015. Habitat fragmentation and its lasting impact on Earth’s ecosystems. Science Advances 1:e1500052–e1500052.

Harmsen, B. J., R. J. Foster, S. C. Silver, L. E. T. Ostro, and C. P. Doncaster. 2010. Differential use of trails by forest mammals and the implications for camera-trap studies: A case study from Belize. Biotropica 42:126–133.

Hortenci, L. 2012. Defaunação e efeitos-cascata sobre a diversidade vegetal em uma ilha “semi - defaunada” na Floresta Atlântica:75.

IBGE. 2004. Biomas (MMA-IBGE). <http://mapas.mma.gov.br/i3geo/datadownload.htm>. Downloaded on 15 March 2017.

ICMBio. 2016. Livro Vermelho da Fauna Brasileira Ameaçada de Extinção - Sumário Executivo. Instituto Chico Mendes de Conservação da Biodiversidade.

IUCN. 2016. The IUCN Red List of Threatened Species. Version 2016-3. <http://www.iucnredlist.org>. Downloaded on 23 Abril 2017.

Jansen, P., and al et. 2014. TEAM: a standardised camera trap survey to monitor terrestrial vertebrate communities in tropical forests. Pages 263–270Camera trapping: wildlife management and research. CSIRO Publishing.

Jenkins, C. N., M. A. S. Alves, A. Uezu, and M. M. Vale. 2015. Patterns of Vertebrate Diversity and Protection in Brazil. PLOS ONE 10:e0145064.

Johnson, C. N., A. Balmford, B. W. Brook, J. C. Buettel, M. Galetti, L. Guangchun, and J. M. Wilmshurst. 2017. Biodiversity losses and conservation responses in the Anthropocene. Science 356:270–275.

Jorge, M. L. S. P., M. Galetti, M. C. Ribeiro, and K. M. P. M. B. Ferraz. 2013. Mammal defaunation as surrogate of trophic cascades in a biodiversity hotspot. Biological Conservation 163:49–57.

Kasper, C. B., F. D. Mazim, J. B. G. Soares, T. G. De Oliveira, and M. E. Fabián. 2007. Composição e abundância relativa dos mamíferos de médio e grande porte no Parque Estadual do Turvo, Rio Grande do Sul, Brasil. Revista Brasileira de Zoologia 24:1087–1100.

Kionka, D. C. O. 2013. Mastofauna não-voadora em fragmentos florestais nativos circundados por uma matriz agrícola e de pastagem em Palmeira das Missões, RS, Brasil. Dissertação de Mestrado. Centro Universitário Univates, Lajeado.

Kucera, T. E., and R. H. Barrett. 2011. A history of camera trapping. Page Camera Traps in Animal Ecology: Methods and Analyses.

Kuhnen, V. V. 2010. DIVERSIDADE DE MAMÍFEROS E A ESTRUTURA DO HÁBITAT: Estudo da composição da mastofauna terrestre em diferentes estágios sucessionais de regeneração da Floresta Ombrófila Densa, Santa Catarina, Brasil. Universidade Federal de Santa Catarina.

Laurance, W. F. 2009. Conserving the hottest of the hotspots. Biological Conservation 142:1137.

Lima, E. F. de. 2012. Estrutura da comunidade de mamíferos de médio e grande porte em uma paisagem fragmentada com matriz de eucalipto, Capão Bonito e Buri, SP. Universidade de São Paulo.

Lima, F. 2009. Estimativas de abundância e densidade populacional da jaguatirica através de modelos de marcação-recaptura: estudo de caso nos remanescentes florestais do Pontal do Paranapanema, São Paulo. Pontifícia Universidade Católica de Minas Gerais, Belo Horizonte.

Lima, L. M. 2014, January 21. Aves da Mata Atlântica: riqueza, composição, status, endemismos e conservação. Universidade de São Paulo, São Paulo.

Lyra-Jorge, M. C., G. Ciocheti, and V. R. Pivello. 2008. Carnivore mammals in a fragmented landscape in northeast of São Paulo State, Brazil. Biodiversity and Conservation 17:1573–1580.

Marques, R. V., C. Vargas, and S. Missel. 2011. Mastofauna no Planalto das Araucárias, Rio Grande do Sul, Brasil. Revista Brasileira de Biociências 9:278–288.

Melo, G. L., J. Sponchiado, and N. C. Cáceres. 2012. Use of camera-traps in natural trails and shelters for the mammalian survey in the Atlantic Forest. Iheringia, Série Zoologia, Porto Alegre, 102:88–94.

MMA. 2006. MMA Lei n° 11.428, de 22 de dezembro de 2006. <http://www.mma.gov.br/biomas/mata-atlantica/mapa-da-area-de-aplicacao>. Downloaded on 15 March 2017.

Modesto, T. C., F. S. Pessôa, M. C. Enrici, N. Attias, T. Jordão-Nogueira, L. de M. Costa, H. G. Albuquerque, and H. de G. Bergallo. 2008a. Mamíferos do Parque Estadual do Desengano, Rio de Janeiro, Brasil. Biota Neotropica 8:0–0.

Modesto, T. C., F. S. Pessôa, T. Jordão-Nogueira, M. C. Enrici, L. M. Costa, N. Attias, J. Almeida, D. S. L. Raíces, H. G. Albuquerque, B. C. Pereira, C. E. L. Esbérard, and H. G. Bergallo. 2008b. Mammals, Serra da Concórdia, state of Rio de Janeiro, Brazil. Check List 4:341–348.

Motta Lessa, I. C. 2012. Os mamíferos de médio porte e suas respostas à fatores ambientais, físicos e antrópicos, sobre diferentes perspectivas, no Parque Estadual da Ilha Grande - RJ. Universidade do Estado do Rio de Janeiro.

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.

Norris, D., J. M. Ramírez, C. Zacchi, and M. Galetti. 2011. A survey of mid and large bodied mammals in Núcleo Caraguatatuba, Serra do Mar State Park, Brazil. Biota Neotropica 12:1–9.

Nunes, A. V., L. Moraes Scoss, and G. Mendes Lessa. 2012. Composição e abundância relativa dos mamíferos terrestres de médio e grande porte do Parque Estadual da Serra do Brigadeiro, Minas Gerais, Brasil. Biotemas 25:205–216.

Nunes, A. V., L. M. Scoss, M. R. Prado, and G. M. Lessa. 2013. Survey of large and medium-sized terrestrial mammals in the Serra do Brigadeiro State Park, Minas Gerais, Brazil. Check List 9:240–254.

de Oliveira, G. 2011. Mamíferos de maior porte en paisagens tropicais alteradas: seu papel em cascatas tróficas e fatores que determinam sua distribuiçao.

Olson, D. M., E. Dinerstein, E. D. Wikramanayake, N. D. Burgess, G. V. N. Powell, E. C. Underwood, J. A. D'amico, I. Itoua, H. E. Strand, J. C. Morrison, C. J. Loucks, T. F. Allnutt, T. H. Ricketts, Y. Kura, J. F. Lamoreux, W. W. Wettengel, P. Hedao, and K. R. Kassem. 2001. Terrestrial Ecoregions of the World: A New Map of Life on Earth.

Paglia, A. P., G. A. B. da Fonseca, A. B. Rylands, G. Herrmann, L. M. S. Aguiar, A. G. Chiarello, Y. L. R. Leite, L. P. Costa, S. Siciliano, M. C. M. Kierulff, S. L. Mendes, V. da C. Tavares, R. A. Mittermeier, and J. L. Patton. 2012. Lista Anotada dos Mamíferos do Brasil 2ª Edição. Page Occasional Papers in Conservation Biology.

Paschoal, A. M. O., R. L. Massara, L. L. Bailey, W. L. Kendall, P. F. D. Jr, A. Hirsch, A. G. Chiarello, and A. P. Paglia. 2016. Use of Atlantic Forest protected areas by free- - ranging dogs : estimating abundance and persistence of use. Ecosphere 7:1–15.

Paschoal, A. M. O., R. L. Massara, J. L. Santos, and A. G. Chiarello. 2012. Is the domestic dog becoming an abundant species in the Atlantic forest? A study case in southeastern Brazil. Mammalia 76:67–76.

Patton, J. L., U. F. J. Pardiñas, and G. D''Elía. 2015. Mammals of South America, Volume 2: Rodents. Page University of Chicago Press.

Paviolo, A., C. D. De Angelo, Y. E. Di Blanco, and M. S. Di Bitetti. 2008. Jaguar Panthera onca population decline in the Upper Paraná Atlantic Forest of Argentina and Brazil. Oryx 42:554.

Paviolo, A., C. De Angelo, K. M. P. M. B. Ferraz, R. G. Morato, J. Martinez Pardo, A. C. Srbek-Araujo, B. de M. Beisiegel, F. Lima, D. Sana, M. Xavier da Silva, M. C. Velázquez, L. Cullen, P. Crawshaw Jr, M. L. S. P. Jorge, P. M. Galetti, M. S. Di Bitetti, R. C. de Paula, E. Eizirik, T. M. Aide, P. Cruz, M. L. L. Perilli, A. S. M. C. Souza, V. Quiroga, E. Nakano, F. Ramírez Pinto, S. Fernández, S. Costa, E. A. Moraes Jr, and F. Azevedo. 2016. A biodiversity hotspot losing its top predator: The challenge of jaguar conservation in the Atlantic Forest of South America. Scientific Reports 6:37147.

Pazio, D. D. 2013. Inventariamento de mamíferos terrestres de médio e grande porte em áreas de recuperação do Parque Estadual Lago Azul, Paraná, Brasil. Universidade Tecnológica Federal do Paraná.

Pedrosa, F., R. Salerno, F. V. B. Padilha, and M. Galetti. 2015. Current distribution of invasive feral pigs in Brazil: economic impacts and ecological uncertainty. Natureza & Conservação 13:84–87.

Penido, G., and A. C. S. Zanzini. 2012. Checklist of large and medium-sized mammals of the Estação Ecológica Mata do Cedro, an Atlantic forest remnant of central Minas Gerais, Brazil. Check List 8:712–717.

Pimm, S. L., S. Alibhai, R. Bergl, A. Dehgan, C. Giri, Z. Jewell, L. Joppa, R. Kays, and S. Loarie. 2015. Emerging Technologies to Conserve Biodiversity. Trends in Ecology & Evolution xx:1–12.

Prado, H., R. S. Murrieta, C. Adams, and E. Brondizio. 2014. Local and scientific knowledge for assessing the use of fallows and mature forest by large mammals in SE Brazil: identifying singularities in folkecology. Journal of Ethnobiology and Ethnomedicine 10:7.

Prado, M. R. do, E. C. Rocha, and G. M. L. del Giudice. 2008. Mamíferos de médio e grande porte em um fragmento de mata atlântica, Minas Gerais, Brasil. Revista Árvore 32:741–749.

R Core Team. 2016. R: A language and environment for statistical computing. Page R Development Core Team.

Rezini, J. A. 2007. Mamíferos de médio e grande porte em propriedades particulares no Baixo Vale do Itajaí , SC. Universidade Regional de Blumenau.

Ribeiro, M. C., J. P. Metzger, A. C. Martensen, F. J. Ponzoni, and M. M. Hirota. 2009. The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. Biological Conservation 142:1141–1153.

Ripple, W. J., K. Abernethy, M. G. Betts, G. Chapron, R. Dirzo, M. Galetti, T. Levi, P. A. Lindsey, D. W. Macdonald, B. Machovina, T. M. Newsome, C. A. Peres, A. D. Wallach, C. Wolf, and H. Young. 2016. Bushmeat hunting and extinction risk to the world's mammals. Royal Society Open Science 3:160498.

Rocha-Mendes, F., C. L. Neves, R. de A. Nobre, R. M. Marques, G. V. Bianconi, and M. Galetti. 2015. Non-volant mammals from Núcleo Santa Virgínia, Serra do Mar State Park, São Paulo, Brazil. Biota Neotropica 15.

Rocha, D. G., E. E. Ramalho, and W. E. Magnusson. 2016. Baiting for carnivores might negatively affect capture rates of prey species in camera-trap studies. Journal of Zoology 300:205–212.

da Rosa, C. A., N. H. de Almeida Curi, F. Puertas, and M. Passamani. 2017. Alien terrestrial mammals in Brazil: current status and management. Biological Invasions.

Si, X., R. Kays, and P. Ding. 2014. How long is enough to detect terrestrial animals? Estimating the minimum trapping effort on camera traps. PeerJ 2:e374.

Silva, J. M. C. da, and C. H. M. Casteleti. 2003. Status of the biodiversity of the Atlantic Forest of Brazil. Pages 43–59The Atlantic Forest of South America: biodiversity status, threats, and outlook.

Silva, L. D., and M. Passamani. 2009. Mamíferos de médio e grande porte em fragmentos florestais no município de Lavras, MG Lourdes Dias da Silva[1] & Marcelo Passamani[1] [1]. Ecologia 11:137–144.

Silveira, L., A. T. A. Jácomo, and J. A. F. Diniz-Filho. 2003. Camera trap, line transect census and track surveys: a comparative evaluation. Biological Conservation 114:351–355.

Soares, C. S., L. F. Faneca, R. M. Fonseca Barreto, and M. R. Del Valle Alvarez. 2014. Levantamento de mamíferos de maior porte em seringais e florestas do sul da Bahia (Brasil) utilizando armadilhas fotográficas. Revista de Biologia Neotropical 10:36–45.

Srbek-Araujo, A. C., and A. G. Chiarello. 2005. Is camera-trapping an efficient method for surveying mammals in Neotropical forests? A case study in south-eastern Brazil. Journal of Tropical Ecology 21:121–125.

Srbek-Araujo, A. C., and A. G. Chiarello. 2007. Armadilhas fotográficas na amostragem de mamíferos: considerações metodológicas e comparação de equipamentos. Revista Brasileira de Zoologia 24:647–656.

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 13:51–62.

Tabarelli, M., A. V. Aguiar, M. C. Ribeiro, J. P. Metzger, and C. A. Peres. 2010. Prospects for biodiversity conservation in the Atlantic Forest: Lessons from aging human-modified landscapes. Biological Conservation 143:2328–2340.

Talamoni, S., B. Amaro, D. Cordeiro-Júnior, and C. Maciel. 2014. Mammals of Reserva Particular do Patrimônio Natural Santuário do Caraça, state of Minas Gerais, Brazil. Check List 10:1005–1013.

Tobler, M. W., S. E. Carrillo-Percastegui, R. Leite Pitman, R. Mares, and G. Powell. 2008a. An evaluation of camera traps for inventorying large- and medium-sized terrestrial rainforest mammals. Animal Conservation 11:169–178.

Tobler, M. W., S. E. Carrillo-Percastegui, R. Leite Pitman, R. Mares, and G. Powell. 2008b. Further notes on the analysis of mammal inventory data collected with camera traps. Animal Conservation 11:187–189.

Tonini, J. F. R., L. D. M. Carão, I. deSouza Pinto, J. L. Gasparini, Y. L. R. Leite, and L. P. Costa. 2010. Non-volant tetrapods from Reserva Biológica de Duas Bocas, State of Espírito Santo, Southeastern Brazil. Biota Neotropica 10:339–351.

Tortato, F. R., A. F. Testoni, and S. L. Althoff. 2014. Mastofauna terrestre da Reserva Biológica Estadual do Sassafrás, Doutor Pedrinho, Santa Catarina, Sul do Brasil. Biotemas 27:123.

Zappi, D. C., F. L. R. Filardi, P. Leitman, V. C. Souza, B. M. T. Walter, J. R. Pirani, M. P. Morim, L. P. Queiroz, T. B. Cavalcanti, V. F. Mansano, R. C. Forzza, M. C. Abreu, P. Acevedo-Rodríguez, M. F. Agra, E. B. Almeida Jr., G. S. S. Almeida, R. F. Almeida, F. M. Alves, M. Alves, A. Alves-Araujo, M. C. E. Amaral, A. M. Amorim, B. Amorim, I. M. Andrade, R. H. P. Andreata, C. O. Andrino, E. A. Anunciação, L. Y. S. Aona, Y. Aranguren, J. L. M. Aranha Filho, A. O. Araújo, A. A. M. Araújo, D. Araújo, M. M. Arbo, L. Assis, M. C. Assis, V. A. Assunção, S. M. Athiê-Souza, C. O. Azevedo, J. B. Baitello, F. F. V. A. Barberena, M. R. V. Barbosa, F. Barros, L. A. V. Barros, M. J. F. Barros, J. F. A. Baumgratz, L. C. Bernacci, P. E. Berry, N. C. Bigio, L. Biral, V. Bittrich, R. A. X. Borges, R. L. C. Bortoluzzi, C. P. Bove, M. G. Bovini, J. M. A. Braga, D. M. Braz, J. B. A. Bringel Jr., C. P. Bruniera, C. V. Buturi, E. Cabral, F. N. Cabral, M. K. Caddah, C. S. Caires, L. S. B. Calazans, M. F. Calió, R. A. Camargo, L. Campbell, T. S. Canto-Dorow, J. P. P. Carauta, J. M. Cardiel, D. B. O. S. Cardoso, L. J. T. Cardoso, C. R. Carneiro, C. E. Carneiro, D. S. Carneiro-Torres, T. T. Carrijo, M. B. R. Caruzo, M. L. S. Carvalho, M. Carvalho-Silva, A. C. D. Castello, L. Cavalheiro, A. C. Cervi, R. G. Chacon, A. Chautems, B. Chiavegatto, N. S. Chukr, A. A. O. P. Coelho, M. A. N. Coelho, R.

L. G. Coelho, I. Cordeiro, E. Cordula, X. Cornejo, A. L. A. Côrtes, A. F. Costa, F. N. Costa, J. A. S. Costa, L. C. Costa, M. B. Costa-e-Silva, J. L. Costa-Lima, M. R. C. Cota, R. S. Couto, D. C. Daly, R. D. De Stefano, K. De Toni, M. Dematteis, G. A. Dettke, F. R. Di Maio, M. C. Dórea, M. C. Duarte, J. H. A. Dutilh, V. F. Dutra, L. Echternacht, L. Eggers, G. Esteves, C. Ezcurra, M. J. A. Falcão Junior, F. Feres, J. M. Fernandes, D. M. C. Ferreira, F. M. Ferreira, G. E. Ferreira, P. P. A. Ferreira, S. C. Ferreira, M. S. Ferrucci, P. Fiaschi, T. S. Filgueiras, M. Firens, A. S. Flores, E. Forero, W. Forster, A. P. Fortuna-Perez, R. H. Fortunato, C. N. Fraga, F. França, A. Francener, J. Freitas, M. F. Freitas, P. W. Fritsch, S. G. Furtado, A. L. Gaglioti, F. C. P. Garcia, P. Germano Filho, L. Giacomin, A. S. B. Gil, A. M. Giulietti, S. A.P.Godoy, R. Goldenberg, G. A. Gomes da Costa, M. Gomes, V. L. Gomes-Klein, E. G. Gonçalves, S. Graham, M. Groppo, J. S. Guedes, L. R. S. Guimarães, P. J. F. Guimarães, E. F. Guimarães, R. Gutierrez, R. Harley, G. Hassemer, E. K. O. Hattori, S. M. Hefler, G. Heiden, A. Henderson, N. Hensold, P. Hiepko, A. S. S. Holanda, J. R. V. Iganci, D. C. Imig, A. Indriunas, E. L. Jacques, J. G. Jardim, H. M. Kamer, C. Kameyama, L. S. Kinoshita, M. Kirizawa, B. B. Klitgaard, I. Koch, C. Koschnitzke, N. P. Krauss, R. Kriebel, J. Kuntz, J. Larocca, E. S. Leal, G. P. Lewis, C. T. Lima, H. C. Lima, I. B. Lima, L. F. G. Lima, L. C. P. Lima, L. R. Lima, L. F. P. Lima, R. B. Lima, E. J. Lírio, R. M. Liro, E. Lleras, A. Lobão, B. Loeuille, L. G. Lohmann, M. I. B. Loiola, J. A. Lombardi, H. M. Longhi-Wagner, R. C. Lopes, T. S. Lorencini, R. B. Louzada, J. Lovo, E. D. Lozano, E. Lucas, R. Ludtke, C. L. Luz, P. Maas, A. F. P. Machado, L. Macias, J. R. Maciel, M. A. G. Magenta, M. C. H. Mamede, E. A. Manoel, M. S. Marchioretto, J. S. Marques, N. Marquete, R. Marquete, G. Martinelli, R. C. V. Martins da Silva, Â. B. Martins, E. R. Martins, M. L. L. Martins, M. V. Martins, R. C. Martins, L. Q. Matias, C. A. Maya-L., S. Mayo, F. Mazine, D. Medeiros, E. S. Medeiros, H. Medeiros, J. D. Medeiros, J. E. Meireles, R. Mello-Silva, A. Melo, A. L. Melo, E. Melo, J. I. M. Melo, C. G. Menezes, L. Menini Neto, L. A. Mentz, A. C. Mezzonato, F. A. Michelangeli, M. A. Milward-de-Azevedo, S. T. S. Miotto, V. F. O. Miranda, C. A. Mondin, M. Monge, D. Monteiro, R. F. Monteiro, M. D. Moraes, P. L. R. Moraes, S. A. Mori, A. C. Mota, N. F. O. Mota, T. M. Moura, M. Mulgura, J. N. Nakajima, C. Nardy, J. E. Nascimento Júnior, L. Noblick, T. S. Nunes, N. O'Leary, A. S. Oliveira, C. T. Oliveira, J. A. Oliveira, L. S. D. Oliveira, M. L. A. A. Oliveira, R. C. Oliveira, R. S. Oliveira, R. P. Oliveira, B. Paixão-Souza, L. R. Parra, E. Pasini, J. F. B. Pastore, M. Pastore, J. Paula-Souza, L. C. Pederneiras, A. L. Peixoto, G. Pelissari, M. O. O. Pellegrini, T. Pennington, R. O. Perdiz, A. C. M. Pereira, M. S. Pereira, R. A. S. Pereira, C. Pessoa, E. M. Pessoa, M. C. R. Pessoa, L. J. S. Pinto, R. B. Pinto, T. A. Pontes, G. T. Prance, C. Proença, S. R. Profice, A. C. Pscheidt, G. A. Queiroz, R. T. Queiroz, A. Quinet, H. Rainer, E. Ramos, J. G. Rando, A. Rapini, M. Reginato, I. P. Reis, P. A. Reis, A. R. O. Ribeiro, J. E. L. S. Ribeiro, R. Riina, M. R. Ritter, F. Rivadavia, A. E. S. Rocha, M. J. R. Rocha, I. M. C. Rodrigues, K. F. Rodrigues, R. S. Rodrigues, R. S. Rodrigues, V. T. Rodrigues, W. Rodrigues, S. Romaniuc Neto, G. O. Romão, R. Romero, N. Roque, P. Rosa, L. Rossi, C. F. C. Sá, M. M. Saavedra, M. Saka, C. M. Sakuragui, R. M. Salas, M. F. Sales, F. R. G. Salimena, D. Sampaio, G. Sancho, P. T. Sano, A. Santos, É. P. Santos, J. S. Santos, M. R. Santos, A. P. Santos-Gonçalves, F. Santos-Silva, W. São-Mateus, D. P. Saraiva, D. P. Saridakis, Â. L. B. Sartori, V. R. Scalon, Â. Schneider, R. Sebastiani, R. S. Secco, L. Senna, L. Senna-Valle, R. T. Shirasuna, P. J. S. Silva Filho, A. S. Silva, C. Silva, G. A. R. Silva, G. O. Silva, M. C. R. Silva, M. J. Silva, M. J. Silva, O. L. M. Silva, R. A. P. Silva, S. R. Silva, T. R. S. Silva, K. C. Silva-Gonçalves, C. L. Silva-Luz, R. Simão-Bianchini, A. O. Simões, B. Simpson, C. M. Siniscalchi, J. A. Siqueira Filho, C. E. Siqueira, J. C. Siqueira, N. P. Smith, C. Snak, R. L. Soares Neto, K. P. Soares, M. V. B. Soares, M. L. Soares, P. N. Soares, M. Sobral, R. C. Sodré, G. V. Somner, C. A. Sothers, D. J. L. Sousa, E. B. Souza, É. R. Souza, M. Souza, M. L. D. R. Souza, F. O. Souza-Buturi, A. P. Spina, M. N. S. Stapf, M. V. Stefano, J. R. Stehmann, V. Steinmann, C. Takeuchi, C. M. Taylor, N. P. Taylor, A. M. Teles, L. G. Temponi, M. H. Terra-Araujo, V. Thode, W. W.

Thomas, M. L. Tissot-Squalli, B. M. Torke, R. B. Torres, A. M. G. A. Tozzi, R. J. Trad, R. Trevisan, M. Trovó, J. F. M. Valls, A. M. S. F. Vaz, L. Versieux, P. L. Viana, M. D. M. Vianna Filho, A. O. S. Vieira, D. D. Vieira, M. Vignoli-Silva, T. Vilar, F. Vinhos, B. Wallnöfer, M. G. L. Wanderley, D. Wasshausen, M. T. C. Watanabe, M. Weigend, C. A. D. Welker, E. Woodgyer, C. C. Xifreda, K. Yamamoto, A. Zanin, R. D. Zenni, and C. S. Zickel. 2015. Growing knowledge: an overview of Seed Plant diversity in Brazil. Rodriguésia 66:1085–1113.

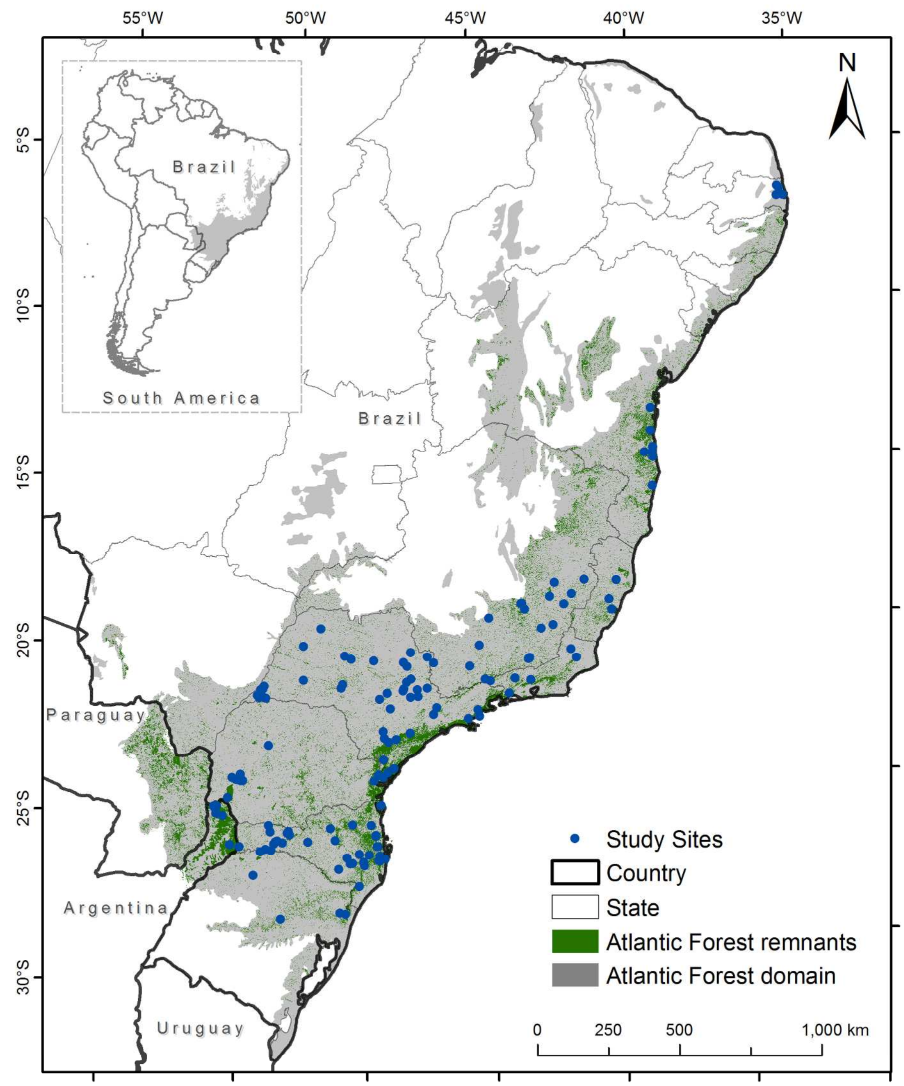



Fig. 1. Distribution of the camera trap surveys of medium and large terrestrial mammal communities within the Atlantic Forest extent. Gray shows the Atlantic Forest extent with remaining forest patches in green (sensu Ribeiro et al. 2009). Blue dots show the geographic locations of studies.

210x256mm (300 x 300 DPI)

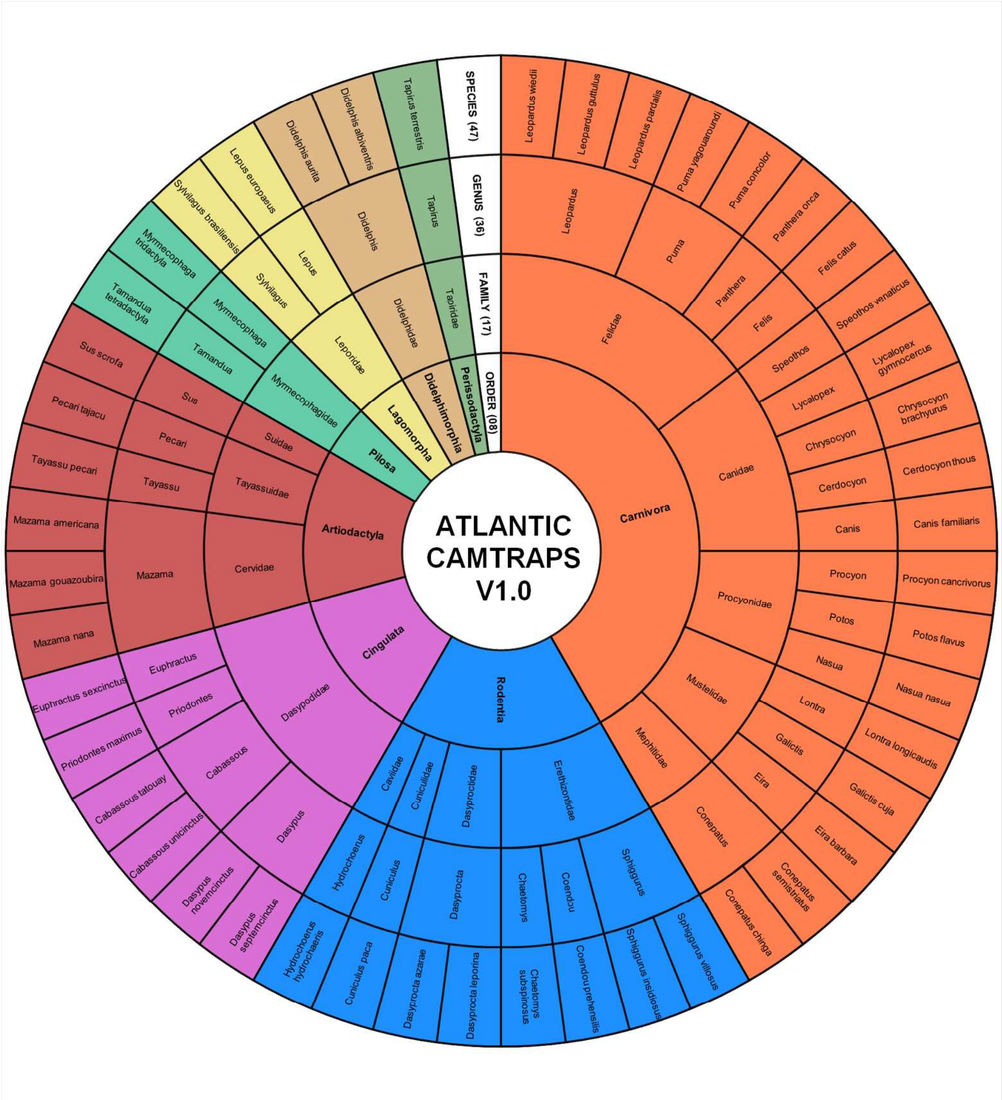



Fig. 2. Taxonomic information levels of medium and large terrestrial mammal species recorded in camera trap surveys within the Atlantic Forest. Only species considered well detected by camera traps are listed. From the 83 species reported in the database, 8 are not listed because the identification is at genera level. Another 28 species are not listed because they were considered opportunistic records of species not usually detected by camera traps (primates, bats, small rodents, and small marsupials).

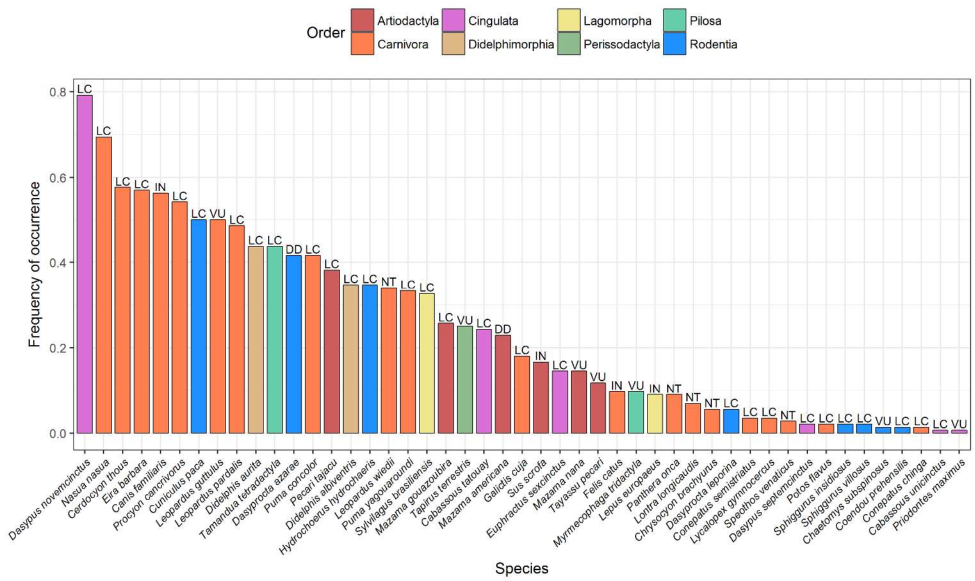



Fig. 3. Distribution of frequencies of occurrence of the main species evaluated in ATLANTIC-CAMTRAPS, and their status in the 2017 IUCN Red list of threatened species. LC = least concern, NT = near threatened, VU = vulnerable, EN = endangered, CR = critically endangered, DD = data deficient, and IN = invasive species (not an IUCN category).

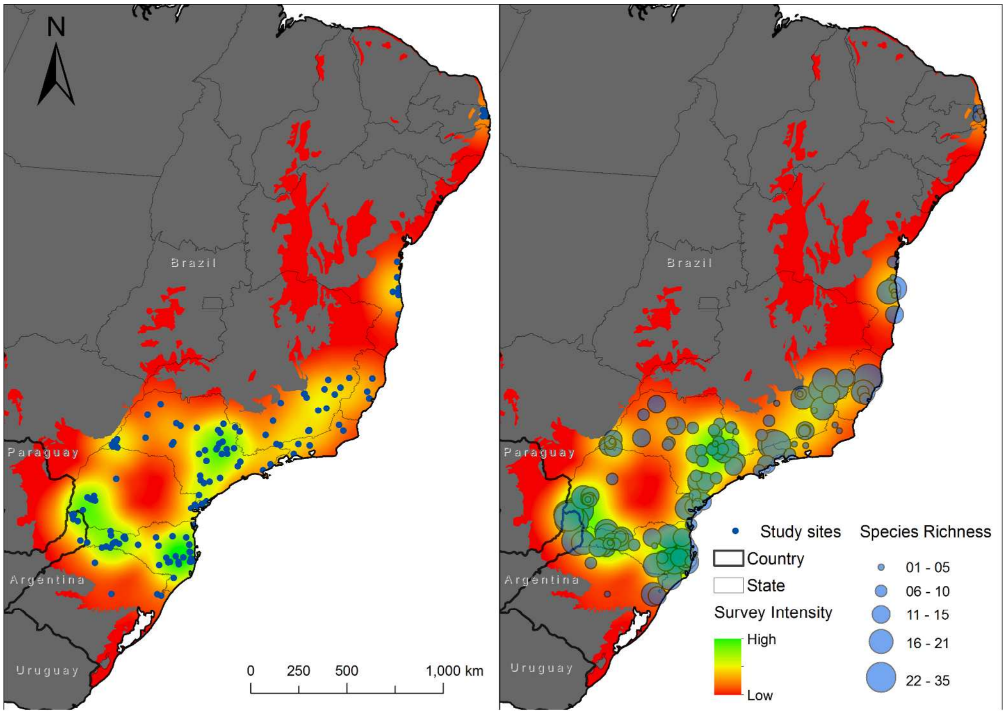



Fig. 4. Distribution of taxonomic richness and sampling effort across Atlantic Forest sites where camera traps were used for sampling of medium and large terrestrial mammal species. Opportunistic records (see the text) were removed from this analysis.

297x210mm (300 x 300 DPI)

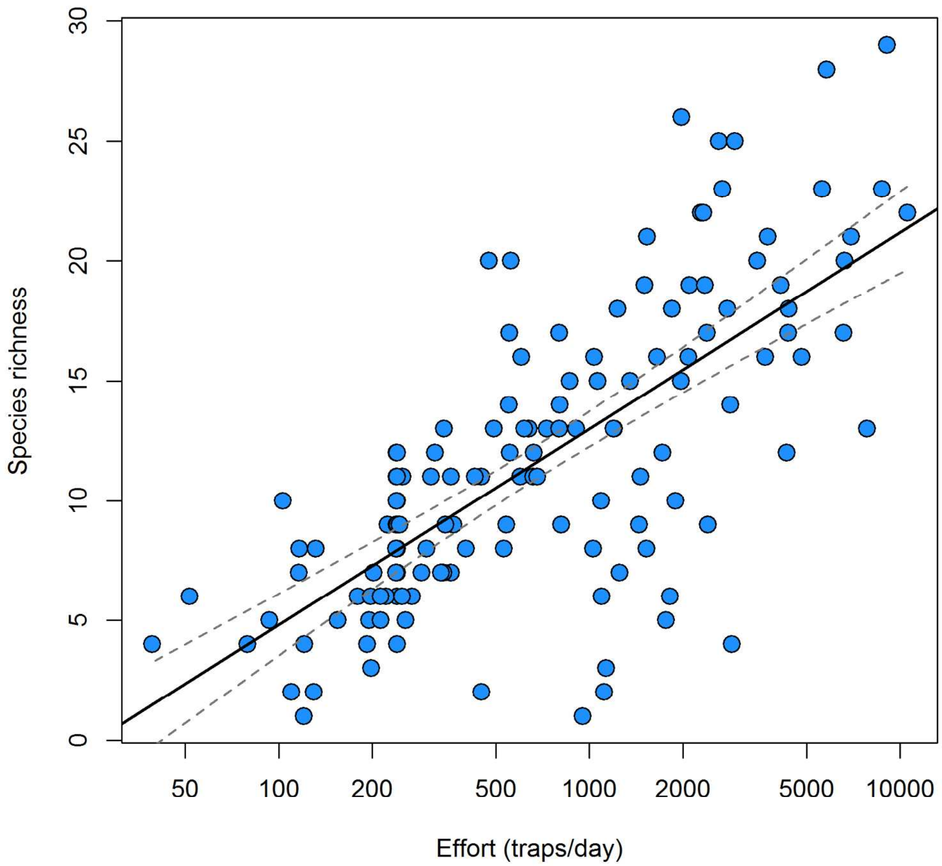



Fig. 5. Positive effect of sampling effort on observed taxonomic richness of ATLANTIC-CAMTRAPS database. Predictor of linear regression was log transformed (adjusted R2= 0.51, slope=8.18 ±0.66 SE, df=142, p<0.001). Gray dashed lines represent 95% confidence intervals of predicted values.

169x169mm (300 x 300 DPI)

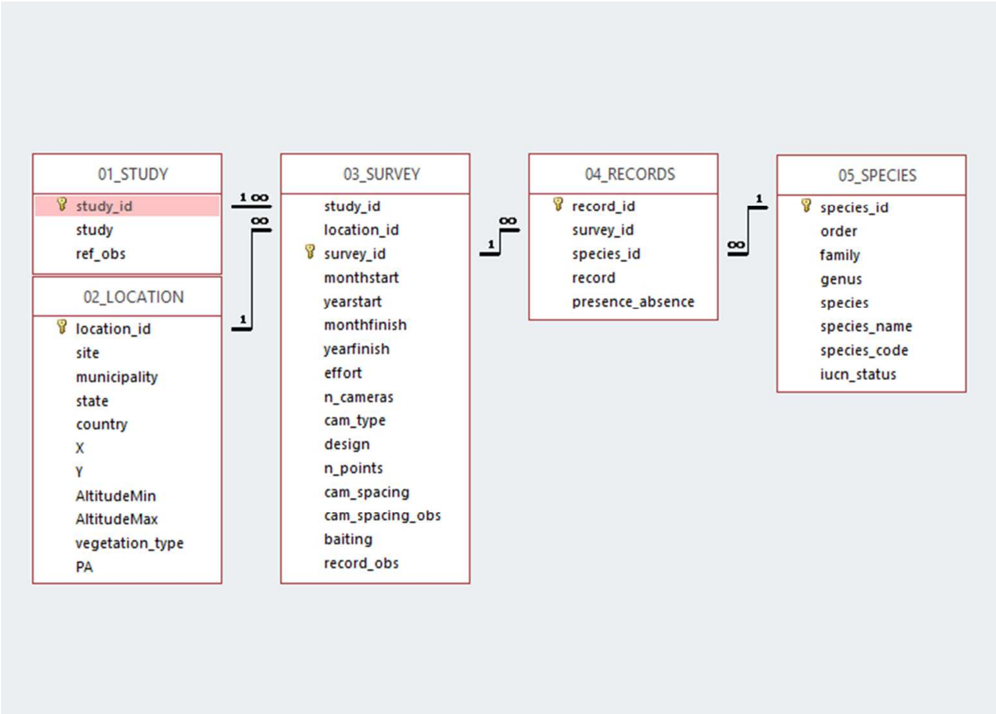



Fig. 6. Standardized layout of the database ATLANTIC-CAMTRAPS. Guideline to the correlational structure in order to inform how the database is organized.

# CHAPTER 03

## HOME RANGE AND MOVEMENT PATTERNS OF JAGUARS IN THE ATLANTIC FOREST OF SOUTH AMERICA

*NECESSE TIBI EST PANTHERAM TUAM IPSAM ESSE*

Fernando Lima

# HOME RANGE AND MOVEMENT PATTERNS OF JAGUARS IN THE ATLANTIC FOREST OF SOUTH AMERICA

**Fernando Lima [1, 2,*], Miriam L. L. Perilli[3], Denis Sana[3,4], Milton Cezar Ribeiro[2], Laury Cullen Jr.[1]**

[1] IPÊ – Instituto de Pesquisas Ecológicas, Nazaré Paulista, São Paulo, Brazil

[2] Programa de Pós-graduação em Ecologia e Biodiversidade, Instituto de Biociências, Universidade Estadual Paulista – UNESP, Rio Claro, São Paulo, Brazil

[3] Instituto para Conservação dos Carnívoros Neotropicais - Instituto Pró-Carnívoros, Atibaia, São Paulo, Brazil

[4] Programa de Pós-graduação em Ecologia, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil

* Corresponding author

E-mail: pardalismitis@gmail.com (FL)

# ABSTRACT

The jaguar (*Panthera onca*) is the apex predator of neotropical forests. Like many other large predator species, it demands its population are in decline. Most previous studies have reported that males have larger home ranges than females and have observed seasonal variation in home range size. In this study we describe the home range estimates and movement patterns of 10 jaguars in one of the three regions of the Atlantic Forest with potential to maintain long term populations. Our results showed that jaguar home ranges and movement patterns does not vary seasonally neither between male and females as a general rule.

# INTRODUCTION

The jaguar (*Panthera onca*) historically ranged from the far southwestern United States to southern Argentina [1]. Like most large carnivore species, jaguars have been regionally extirpated from parts of their historic range [2]. Nevertheless, jaguars still persist in a wide array of habitats, from tropical moist forests, to xeric shrub lands, to tropical dry forests, to grasslands, and savannas [3]. In the Atlantic Forest – one of the world's biodiversity hotspots – the species persists in only 18.4% of the remaining forest [4,5]. The main causes of the continuing decline of jaguar populations in this hotspot are poaching, over exploitation of its prey, habitat loss, and roadkill [4,6].

Wide-ranging carnivores with large home ranges, such as jaguars, demand a stable prey population and large continuous habitat patches [7,8]. Under high human interventions, apex predators are generally the first species to be locally or regionally extirpated. Additionally, most protected areas do not hold suitable habitat patches large enough to support functional populations of wide-ranging species [4,9,10]. For these species, functional landscape connectivity among suitable patches to connect populations and guarantee genetic flow is as important as reserve establishment [4,11–15].

To understand jaguar habitat use, home range and movements is essential for managing jaguar attacks on cattle stock [16], to mitigate the impacts of habitat fragmentation [17], and for developing habitat suitability models for large scale conservation [18]. Selected areas of concentrated use by an individual within home ranges are often denoted as core areas, implying that these selected areas are of greater significance to the animals [19]. Most previous studies have reported that males have larger home ranges than females and have observed seasonal variation in home range size [16,20–22]. In this study we describe that - despite great variation throughout its distribution - jaguar home ranges and movement patterns does not vary seasonally neither between male and females as a general rule.

# MATERIALS AND METHODS

## STUDY SITES

This study was carried out in the Morro do Diabo State Park (MDSP – 35,000 ha) in the State of São Paulo and in Ivinhema State Park (ISP – 73,000 ha) in the State of Mato Grosso do Sul (Figure 1), Brazil. These reserves are the core of the Upper Paraná Paranapanema Jaguar Conservation Unit (JCU) [4].This is one of the three JCUs with higher probability of long-term population persistence identified in the Atlantic Forest [4].

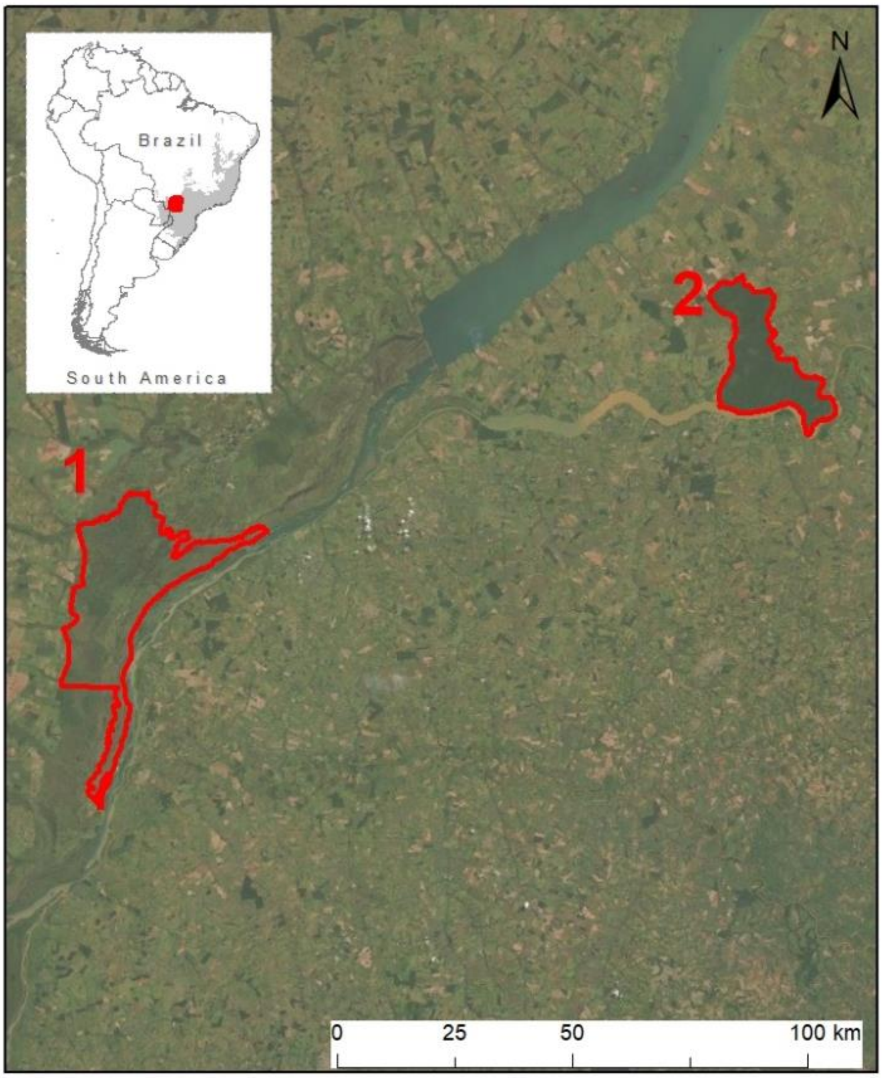



*Figure 1 - Location of the two reserves where jaguars were monitored. 1 - Morro do Diabo State Park, São Paulo state; 2 - Ivinhema State Park, Mato Grosso do Sul state.*

The forests of Morro do Diabo are considered a transitional ecosystem, bordered by tropical evergreen broadleaf forest to the east and the dry cerrado vegetation to the north and west [23]. The ISP, is located 150 km southwest of Morro do Diabo and comprises several former cattle ranches.

The landscape can be characterized as a complex mosaic of forest patches and open areas. In both study areas, the climate is markedly seasonal, and most of the 1,450 mm average annual precipitation falls between early October and late March.

## TELEMETRY AND HOME RANGE ESTIMATES

Between April 1998 and August 2005, 10 adult jaguars (> 2 years old) were captured, radio-collared, and monitored, with seven at the Morro do Diabo State Park (MDSP) and three at Ivinhema State Park (ISP). Individuals were captured using custom-made iron box-traps baited with live bait or treed by trained dogs and chemically restrained with Zoletil® (tiletamina-zolazepan). The sedative was administered intramuscularly using a dart fired from a $CO_2$ pistol or rifle. Capture and handling protocols were permitted by the Brazilian Institute of Environment and Natural Resources and accompanied by a veterinary *in loco*. The first two jaguars captured at MDSP and the first jaguar captured at ISP were fitted with conventional VHF radio collars made by (Telonics®). VHF radio-collared jaguars were located approximately once a week. The remaining jaguars were fitted with Televilt Global Positioning Systems (GPS) satellite collars to increase the number of locations for each jaguar home range and to reduce costs of aerial monitoring. GPS collars were programmed for three locations/day.

Home range size and movements were analyzed separately for the dry season (April-September), the wet season (October-March), and for both seasons combined. Data were pooled across >1 year of observation. Thus, a dry season home range includes locations for two or more seasons for a particular animal. We adjusted all locations to the same projection (Transverse Mercator) and datum (SIRGAS 2000) in ArcCatalog 10.4.1 before uploading it to the Movebank.org repository.

To estimate annual and seasonal home ranges we used the continuous-time movement modelling (*ctmm*) package developed for *R* environment [24,25]. This approach fits a continuous-time stochastic movement model to animal tracking data and accounts for serial autocorrelation that can be present [26]. In addition, have the ability to handle irregular sampling schedules (including gaps in data sampling) and identify important features such as range residency [24]. As autocorrelation can persist for days, weeks or even years we first estimated semi-variance (function *variogram*) as a function of time lag to visually inspect the autocorrelation structure of the location data. At zero to short time lags, uncorrelated velocity is represented by a linear increase in the semi-variance and suggest movement models such as *Brownian motion* (BM) or *Ornstein-Uhlenbeck* (OU) [24,27]. Upward curvature indicates autocorrelation suggesting movement models such as integrated OU or OU with foraging.

To inspect space use we investigated the behavior across longer time lags. To any given individual be considered range-resident its variogram is expected to reach an asymptote, that would correspond to its home range size. If its variogram did not reach the asymptote, it was not considered a resident and thus discharged (e.g. not monitored for enough time, a migrating or dispersing individual) [24]. We then proceed fitting the models via maximum likelihood (function *ctmm.fit*) and compared the concurrent models using AIC (function *ctmm.select*). Finally, we estimated 50%, 85% and 95% home range conditional on the fitted, selected model for each individual using the *akde* function.

We report the 50% home range as an area of core utilization and the 85% home range as an area of ecological importance for a jaguar. We also report the 95% home range as a commonly referenced contour. Seasonal home ranges were calculated for all individuals, but for comparisons we used only individual adult jaguars which had ≥ 30 locations in the season. For both sexes, we calculated overlap among annual 85% home ranges. Linear distances between locations were used to calculate the mean and maximum distance moved by the animals. After variogram inspection, we considered all individuals to be resident of the study areas. For general comparisons among seasons and gender we used Wilcoxon’s test after the Shapiro-wilk test to check for normality.

# RESULTS

In Morro do Diabo, the annual 85% home range averaged 267 km$^2$ ± 192.5 *SD* for males and 96 km$^2$± 62.3 *SD* for females (Table 1, Fig 2). For the wet season both males and females presented similar home ranges (145 ±114 *SD* – 118 km² ± 112 *SD*). In Ivinhema State Park, the only male monitored had a yearly 85% home range of 325 km$^2$, while for the two females yearly home ranges averaged 312 km$^2$ ± 217 *SD.* For both areas combined, dry season 85% home ranges averaged 299 km$^2$ ± 200 *SD* for males and 158 km² ± 131 *SD* for females and during the wet season 217 km² ± 148 *SD* for males and 116 km² ± 90 *SD* for females (Table 1, Fig 2).

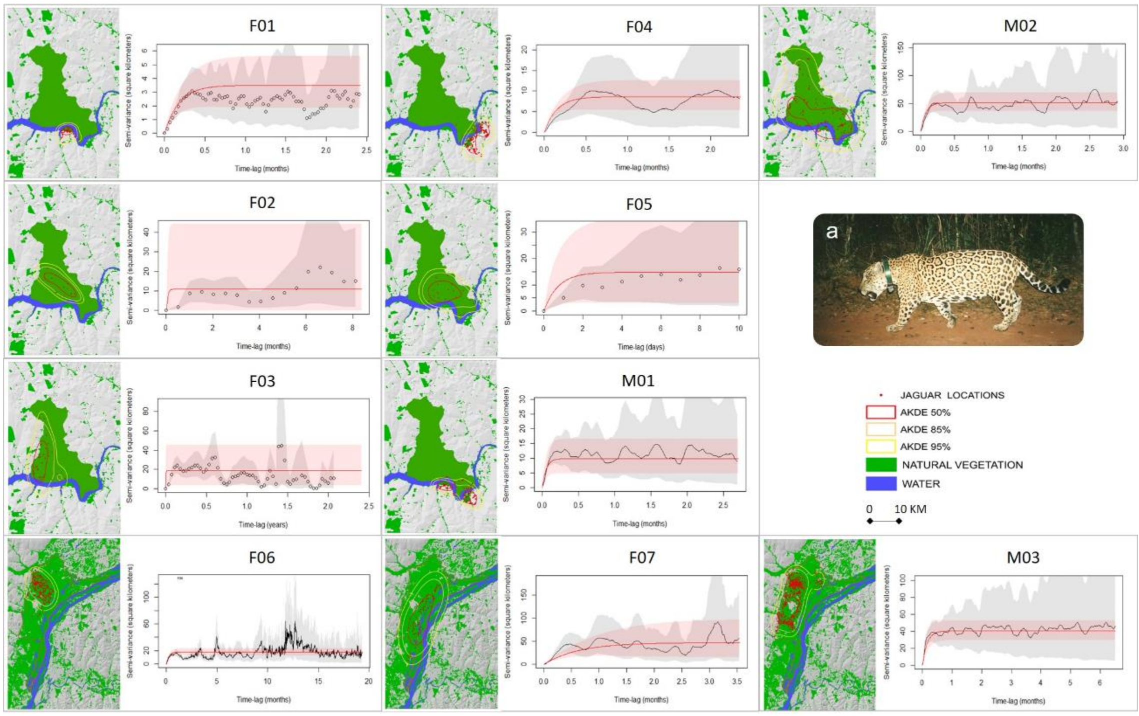



*Figure 2 - Annual and seasonal home range areas (in km2) for three adult males (M1 to M3) and seven adult female jaguars (F1 to F7) in Morro do Diabo State Park/São Paulo state and Ivinhema State Park/Mato Grosso do Sul state, Brazil. The variograms were used for visual inspection for range-residency. Red line represents the fitted movement model and the red shading corresponds to 95% CI. Home ranges were estimated using Autocorrelated Kernel Density Estimator (AKDE). The jaguar picture is from Male 02 (M2) detected during a simultaneous camera-trap survey.*

*Table 1 - Annual and seasonal 85% home range areas (km² ±95% CI) for 10 adult jaguars (3 males and 7 females) in Morro do Diabo State Park (MDSP) and Ivinhema State Park (ISP). Movement models corresponds to Ornstein-Uhlenbeck (OU) and OU with foraging*

| Animal ID | Years tracked | Annual home range | | | | Dry-season home range | | | | Wet-season home range | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. loc. | 50% | 85% | 95% | No. loc. | 50% | 85% | 95% | No. loc. | 50% | 85% | 95% |
| | | | | | | **Morro do Diabo State Park** | | | | | | | |
| M1 | 1 | 159 | 28 (22 - 35) | 74 (59 - 92) | 110 (87 - 136) | 87 | 34 (24 - 46) | 85 (60 - 114) | 124 (87 - 166) | 72 | 27 (19 - 35) | 64 (50 - 92) | 105 (75 _139) |
| M2 | 1 | 156 | 177 (133 - 227) | 459 (345 - 588) | 672 (506 - 862) | 138 | 188 (139 - 244) | 480 (354 - 624) | 700 (516 - 911) | 18 | 85 (38 - 152) | 226 (99 - 402) | 329 (146 - 586) |
| F1 | 1 | 92 | 8 (5 - 13) | 29 (17 - 43) | 50 (31 - 75) | 58 | 3 (2 - 4) | 11 (7 - 15) | 16 (11 - 22) | 34 | 33 (7 - 79) | 98 (20 - 235) | 161 (34 - 384) |
| F2 | 2 | 17 | 36 (21 - 57) | 51 (89 - 138) | 129 (73 - 201) | - | - | - | - | 17 | 36 (21 - 57) | 51 (89 - 138) | 129 (73 - 201) |
| F3 | 5 | 35 | 54 (36 - 75) | 159 (106 - 224) | 242 (160 - 339) | 24 | 40 (24 - 62) | 111 (65 - 169) | 172 (100 - 262) | 11 | 108 (46 - 198) | 282 (119 - 513) | 417 (177 - 758) |
| F4 | 2 | 211 | 21 (31 - 44) | 75 (50 - 106) | 112 (75 - 157) | 170 | 31 (20 - 45) | 77 (50 - 109) | 115 (75 - 164) | 88 | 16 (10 - 23) | 41 (26 - 60) | 62 (39 - 90) |
| F5 | 1 | 18 | 63 (33 - 102) | 164 (87 - 266) | 244 (129 - 394) | 18 | 63 (33 - 102) | 164 (87 - 266) | 244 (129 - 394) | - | - | - | - |
| Male mean | | 158 | 103 | 267 | 391 | 113 | 111 | 283 | 412 | 45 | 56 | 145 | 217 |
| Female mean | | 75 | 36 | 96 | 155 | 68 | 34 | 91 | 137 | 38 | 48 | 118 | 192 |
| | | | | | | **Ivinhema State Park** | | | | | | | |
| M3 | 2 | 797 | 119 (94 - 147) | 325 (258 - 399) | 499 (396 - 614) | 399 | 118 (80 - 164) | 333 (226 - 461) | 542 (367 - 749) | 398 | 136 (100 - 177) | 360 (267 - 469) | 528 (390 - 685) |
| F6 | 4 | 326 | 58 (43 - 75) | 158 (118 - 204) | 250 (186 - 323) | 148 | 67 (43 - 96) | 192 (124 - 274) | 302 (195 - 431) | 178 | 58 (38 - 82) | 149 (98 - 211) | 232 (152 - 329) |
| F7 | 1 | 183 | 179 (73 - 331) | 466 (191 - 860) | 712 (292 - 1316) | 154 | 142 (54 - 272) | 392 (149 - 750) | 607 (232 - 1159) | 29 | 29 (4 - 77) | 75 (10 - 201) | 116 (16 - 310) |
| Male mean | | 797 | 119 | 325 | 499 | 399 | 118 | 333 | 542 | 398 | 136 | 360 | 528 |
| Female mean | | 255 | 119 | 312 | 481 | 151 | 105 | 292 | 455 | 104 | 44 | 112 | 174 |

For six females, mean overlap was 35%, and the two males overlapped 47%. In Ivinhema State Park the overlap in yearly 85% home ranges for the two neighboring adult females monitored was 29%.

The mean straight-line distance between locations for all 10 individuals studied averaged 3 km (range = 1.11–5.88 km; Table 2). The distances that jaguars moved between consecutive locations in the wet season (3.07 km, ±2.17 *SD*) did not differ from the pattern identified in the dry season (2.57 km ±1.50 *SD*, $W = 36$, $p = 0.7$). The maximum distance moved by all jaguars between consecutive locations averaged 13.18 km. The maximum distance moved by jaguars between consecutive locations in the wet season (11.58 km ±5.76 *SD*) was similar when compared to the dry season (11.37 km, ±5.22 *SD*). Males and females moved similar distances between consecutive locations ($W = 7$, $p = 0.516$). The maximum distance recorded for consecutive locations was for a male (M1) at MDSP (20.46 km).

*Table 2 - Straight-line distances moved by jaguars (yearly, dry and wet seasons) in Morro do Diabo State Park (MDSP) and Ivinhema State Park (ISP), Brazil. Number of locations are indicated within parenthesis.*

| Animal ID | Telemetry Type | Mean Distanced Moved (km) | | | Maximum Distance Moved (km) | | |
|---|---|---|---|---|---|---|---|
| | | Yearly (n) | Dry (n) | Wet (n) | Yearly (n) | Dry (n) | Wet (n) |
| **Morro do Diabo State Park** | | | | | | | |
| M1 | GPS | 5.22 (159) | 5.22 (87) | 4.51 (72) | 20.46 (159) | 20.46 (87) | 15.10 (72) |
| M2 | GPS | 2.50 (156) | 2.48 (138) | 2.49 (18) | 12.36 (156) | 11.19 (138) | 12.36 (18) |
| F1 | GPS | 1.11 (92) | 1.02 (58) | 1.30 (34) | 4.98 (92) | 3.47 (58) | 4.98 (34) |
| F2 | VHF | 5.88 (17) | - | 5.88 (17) | 13.02 (17) | - | 13.02 (17) |
| F3 | GPS | 4.77 (35) | 3.53 (24) | 6.89 (11) | 17.00 (35) | 12.29 (24) | 17.06 (11) |
| F4 | GPS | 1.27 (211) | 1.31 (170) | 1.20 (88) | 4.75 (211) | 4.75 (170) | 4.59 (88) |
| F5 | VHF | 4.46 (18) | 4.46 (18) | - | 11.97 (18) | 11.97 (18) | - |
| Mean Male | | 3.86 | 3.85 | 3.50 | 16.41 | 15.83 | 13.73 |
| Mean Female | | 3.50 | 2.58 | 3.88 | 9.54 | 8.12 | 9.90 |
| **Ivinhema State Park** | | | | | | | |
| M3 | GPS | 2.41 (797) | 2.17 (399) | 2.68 (398) | 18.16 (797) | 13.13 (399) | 18.16 (398) |
| F6 | GPS | 1.64 (326) | 1.75 (148) | 1.61 (178) | 15.87 (326) | 15.87 (148) | 15.63 (178) |
| F7 | GPS | 1.31 (183) | 1.27 (154) | 1.10 (29) | 13.26 (183) | 9.17 (154) | 3.32 (29) |
| Mean Male | | 2.41 | 2.17 | 2.68 | 18.16 | 13.13 | 18.16 |
| Mean Female | | 1.48 | 1.01 | 1.36 | 14.57 | 12.52 | 9.47 |

# DISCUSSION

Male and female jaguars presented great variation in home range sizes in both study sites. Large home range size, lower density and small overlap are factors normally associated with low carrying capacity and low prey biomass. This association might explain the larger home range and the smaller overlaps observed for female jaguars in Ivinhema when compared to those of Morro do Diabo. Ivinhema State Park was recently established (1998), and most of its mosaic is still composed of abandoned and regenerating pastures. Moreover, winter fires are common and might deplete jaguar prey and lower carrying capacity. For example, in August 2002 and again in February 2006 nearly 500 $km^2$, which represents 65% of Ivinhema Park was burnt, mostly in seasonally flooded marshlands and abandoned pasture.

Crawshaw and Quigley showed that jaguar home ranges were larger during the dry season [22]. In contrast, the results of this study showed no difference in jaguar home ranges between the seasons. Flooding in the wet season is the major ecological event in the protected marshes of the Upper Paraná River. The availability of dry land fluctuates with the water level. Much of the seasonally-flooded lowland savannas and seasonally-flooded semi-deciduous forests (alluvial forests) are under more than 1 m of water during the wet season. For most terrestrial mammals, this drastically reduces the effective area available for foraging. For example, averages annual home ranges for female jaguars in Ivinhema were 112 $km^2$ in the wet season and 292 $km^2$ in the dry season. In flooded habitat, variation in home range size of jaguars during the wet season probably reflects the concentration of their food resource on the remaining higher ground. In the dry season by contrast, prey disperses. Previous studies on jaguar ecology have also reported that home range sizes for male jaguars were larger than those of females because of their polygynous breeding system. The large size of their home ranges may reflect limited competition from other males in this isolated and fragmented area.

Our estimates of jaguar home range size were generally larger than other studies in the Neotropics, partly because the adjust for autocorrelated telemetry data provided by the AKDE home range estimation. For example, in Belize, home ranges of four males varied from 28-40 km$^2$, with a mean of 33.4 km$^2$ [21]. This is about nine times smaller than the average home range for males in Morro do Diabo and Ivinhema. In the same study in Belize, two females had ranges of 10 and 11 km$^2$. In contrast to this study, the home range of the two females did not overlap in Belize, but those of the males overlapped extensively. At Iguaçu National Park, in southern Brazil, home range estimates (Minimum Convex Polygon) varied considerably, from 8.8 km$^2$ (female) to 138 km$^2$ (male) [28]. In the Brazilian Pantanal, the average home range size for five animals studied by Schaller and Crawshaw in 1980 was 42 km$^2$ [20]. In a second Pantanal study, 20 years later, Cavalcanti and Gese, concluded that 90% kernel home ranges varied among animals and seasons (range: 34-262.9 km$^2$) [16].

The larger home ranges associated with lower jaguar densities in both of our study sites could also be attributed to the lower carrying capacities of semi-deciduous habitats. Morro do Diabo State Park is located right on the edge of the *Cerrado* and, accordingly, the best classification of Morro do Diabo forest would be an “upland semideciduous Atlantic Forest interspersed with some areas of Cerradão” [29]. In these habitats, primary productivity is lower and more erratic than in moister forests, while water availability is lower [30]. Similarly, large home range areas were reported for jaguars in the Cerrado of central Brazil, where average home range for males was 161 km$^2$ [31]. The moist tropical forests and the alluvial marshlands of tropical South America, such as the “Llanos” in Venezuela and the “Pantanal” in Brazil, probably correspond to the upper limit of jaguar densities, whereas the semideciduous habitats and *Cerrado* vegetation may correspond to the lower limits. Wide ranging movements and long dispersal distances are key attributes for large mammals’ species. Long distance dispersal was not observed by any studied individuals. However, adult jaguars showed long distance movements within their home range, of up to 30 km in 3-4 days. They also moved through gallery forests as travel routes and showed the ability to traverse long distances in open pastures and to cross relatively wide rivers. Nevertheless, these are basically digressions on what may or may not help to explain this output.

Not different from other large carnivores around the world, jaguar populations are in decline. Despite its classification as Near Threatened globally its status at regional and local level is critic and it is now actually extinct from regions of previous occurrence [32–34]. This is the actual scenario in the Atlantic Rainforest, where jaguars only occupy 18.4% (37,825 km²) of its remaining [33]. Only seven regions in this biome – classified as Jaguar Conservation Units (JCUs) – have records of both males and females [33]. From these, only three JCUs are likely to hold at least 50 individuals and the Upper Paraná is one of those [33]. The loss of this specie in the Atlantic Forest goes way beyond its regional extinction per se. The loss of jaguar functional hole as the apex predator has profound impacts in the trophic ladder. It is the local representation of a global pattern that predicts a long term shift of mammal species pool towards small, fast-lived, highly fecund, omnivorous, generalists and its consequences for wildlife and biodiversity are far from predictable [35].

## ACKNOWLEDGEMENTS

We thank Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) and Instituto Florestal de São Paulo for the institutional support provided during field studies in Morro do Diabo State Park, and Secretaria de Estado do Meio Ambiente do Mato Grosso do Sul (SEMA- MS) for the support during the field work in Ivinhema State Park. MCR is funded by FAPESP (2013/50421-2) and receives research grant from CNPq (312045/2013-1 and 312292/2016-3).

## REFERENCES

1. Guggisberg CAW. Wild cats of the world. David & Charles; 1975.

2. Sanderson EW, Redford KH, Vedder A, Coppolillo PB, Ward SE. A conceptual model for conservation planning based on landscape species requirements. Landsc Urban Plan. 2002;58: 41–56.

3. Paula RC De, Desbiez A, Cavalcanti SMC. Plano Nacional para a

Conservação da Onça-Pintada. 2013.

4. Paviolo A, De Angelo C, Ferraz KMPMB, Morato RG, Martinez Pardo J, Srbek-Araujo AC, et al. A biodiversity hotspot losing its top predator: The challenge of jaguar conservation in the Atlantic Forest of South America. Sci Rep. 2016;6: 37147. doi:10.1038/srep37147

5. Myers N, Mittermeier RA, Mittermeier CG, Fonseca GAB, Kent J. Biodiversity hotspots for conservation priorities. Nature. 2000;403: 853–858.

6. Cullen L, Stanton JC, Lima F, Uezu A, Perilli MLL, Akçakaya HR. Implications of Fine-Grained Habitat Fragmentation and Road Mortality for Jaguar Conservation in the Atlantic Forest, Brazil. Banks SC, editor. PLoS One. 2016;11: e0167372. doi:10.1371/journal.pone.0167372

7. Woodroffe R, Ginsberg JR. Conserving the African wild dog Lycaon pictus. II. Is there a role for reintroduction? Oryx. 1999;33: 143–151. doi:10.1046/j.1365-3008.1999.00053.x

8. Ripple WJ, Estes J a, Beschta RL, Wilmers CC, Ritchie EG, Hebblewhite M, et al. Status and Ecological Effects of the World’s Largest Carnivores. Science (80- ). 2014;343: 1241484–1241484. doi:10.1126/science.1241484

9. Ortega-Huerta MA, Medley KE. Landscape analysis of jaguar (Panthera onca) habitat using sighting records in the Sierra de Tamaulipas, Mexico. Environ Conserv. 1999;26: S0376892999000387. doi:10.1017/S0376892999000387

10. Woodroffe R. Edge Effects and the Extinction of Populations Inside Protected Areas. Science (80- ). 1998;280: 2126–2128. doi:10.1126/science.280.5372.2126

11. McCullough DR. Spatially structured populations and harvest theory. J Wildl Manage. 1996;60: 1–9.

12. Brooker L, Brooker M, Cale P. Animal dispersal in fragmented habitat: Measuring habitat connectivity, corridor use, and dispersal mortality. Ecol Soc. 1999;3.

13. South A. Dispersal in Spatially Explicit Population Models. Conserv Biol. 1999;13: 1039–1046. doi:10.1046/j.1523-1739.1999.98236.x

14. Novaro AJ, Redford KH, Bodmer RE. Effect of hunting in source-sink systems in the Neotropics. Conservation Biology Jun, 2000 pp. 713–721. doi:10.1046/j.1523-1739.2000.98452.x

15. HAAG T, SANTOS AS, SANA DA, MORATO RG, CULLEN JR L, CRAWSHAW JR PG, et al. The effect of habitat fragmentation on the genetic structure of a top predator: loss of diversity and high differentiation among remnant populations of Atlantic Forest jaguars (Panthera onca). Mol Ecol. 2010;19: 4906–4921. doi:10.1111/j.1365-294X.2010.04856.x

16. Cavalcanti SMC, Gese EM. Spatial Ecology and Social Interactions of Jaguars (Panthera Onca) in the Southern Pantanal, Brazil. J Mammal. 2009;90: 935–945. doi:10.1644/08-MAMM-A-188.1

17. Cullen Jr. L, Abreu KC de, Sana DA, Nava AFD. Jaguars as landscape detectives for the upper Paraná River corridor, Brazil. Nat Conserv. 2005;3:

43–58.

18. Akçakaya HR. Using models for species conservation and management: an introduction. In: Akçakaya HR, Burgman MA, Kindvall O, editors. 2004.

19. Kaufmann JH. Ecology and Social Behavior of the Coati, Nasua narica on Barro Colorado Island Panama. Univ Calif Publ Zool. 1962;60: 95–222.

20. Schaller GB, Crawshaw PG. Movement Patterns of Jaguar. Biotropica. 1980;12: 161–168.

21. Rabinowitz AR, Nottingham, Jr. BG. Ecology and bahaviour of the Jaguar (Panthera onca) in Belize, Central America. J Zool. 1986;210: 149–159.

22. Crawshaw PG, Quigley HB. Jaguar spacing, activity and habitat use in a seasonally flooded environment in Brazil. J Zool. 1991;223: 357–370. Available: http://doi.wiley.com/10.1111/j.1469-7998.1991.tb04770.x

23. Ab'Saber AN. Os domínios morfoclimáticos na América do Sul: primeira aproximação. Geomorfologia. 1977;52: 1–22.

24. Calabrese JM, Fleming CH, Gurarie E. ctmm : an r package for analyzing animal relocation data as a continuous-time stochastic process. Freckleton R, editor. Methods Ecol Evol. 2016;7: 1124–1132. doi:10.1111/2041-210X.12559

25. Fleming CH, Calabrese JM. ctmm: Continuous-Time Movement Modeling. R package version 0.3.4. [Internet]. CRAN; 2016. Available: http://cran.jellyfish.lol/web/packages/ctmm/index.html.

26. Fleming CH, Fagan WF, Mueller T, Olson KA, Leimgruber P, Calabrese

JM, et al. Rigorous home range estimation with movement data: A new autocorrelated kernel density estimator. Ecology. 2015;96: 1182–1188. doi:10.1890/14-2010.1.sm

27. Fleming CH, Calabrese JM, Mueller T, Olson KA, Leimgruber P, Fagan WF. From Fine-Scale Foraging to Home Ranges: A Semivariance Approach to Identifying Movement Modes across Spatiotemporal Scales. Am Nat. 2014;183: E154–E167. doi:10.1086/675504

28. Crawshaw PG, Mähler JK, Indrusiak C, Cavalcanti SMC, Leite-Pitman MRP, Silvius KM. Ecology and Conservation of the Jaguar (Panthera onca) in Iguaçu National Park. People Nat Wildl Conserv South andCentral Am. 2004;3: 271–285.

29. Baitello JB, Pastore JA, Aguiar OT De, Serio FC, Eduardo C. A vegetação do Parque Estadual do Morro do Diabo, município de Teodoro Sampaio, Estado de São Paulo. Acta Bot Bras. 1988;230: 221–230.

30. Cullen, Bodmer, Valladares-Padua. Ecological consequences of hunting in Atlantic forest patches, Sao Paulo, Brazil. Oryx. 2001;35: 137–144. doi:10.1046/j.1365-3008.2001.00163.x

31. Silveira L, Marinho-Filho J. Ecologia comparada e conservação da onça-pintada (Panthera onca) e onça-parda (Puma concolor), no Cerrado e Pantanal. Leandro Silveira–2004. 2004; 1–61.

32. Quigley H, Foster RJ, Petracca L, Payan E, Salom R, Harmsen BJ. Panthera onca. IUCN Red List Threat Species. 2017;8235: 8. Available: http://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T20010A22247615.en

33. Paviolo A, De Angelo C, Ferraz KMPMB, Morato RG, Martinez Pardo J, Srbek-Araujo AC, et al. A biodiversity hotspot losing its top predator: The challenge of jaguar conservation in the Atlantic Forest of South America. Sci Rep. 2016;6: 37147. doi:10.1038/srep37147

34. Paviolo A, De Angelo CD, Di Blanco YE, Di Bitetti MS. Jaguar Panthera onca population decline in the Upper Paraná Atlantic Forest of Argentina and Brazil. Oryx. 2008;42: 554. doi:10.1017/S0030605308000641

35. Cooke RSC, Eigenbrod F, Bates AE. Projected losses of global mammal and bird ecological strategies. Nat Commun. 2019;10: 2279. doi:10.1038/s41467-019-10284-z

# CONSIDERAÇÕES FINAIS

Apesar do significativo interesse enquanto tópico de pesquisa e relevância para a conservação, a demonstração inequívoca da hipótese da liberação do mesopredador não é uma tarefa trivial. O desafio fundamental é descartar explicações alternativas para a superabundância de mesopredadores, como mudanças de habitat que geralmente estão associadas à perda de predadores de ponta. Neste trabalho, reuni as principais características da hipótese de liberação do mesopredador adaptada à comunidade de mamíferos carnívoros da Mata Atlântica. Propus ainda um modelo conceitual baseado em hipóteses gerais e resultados esperados apoiados em pesquisa bibliográfica e conhecimento empírico como referência para orientar futuras análises em larga escala sobre esse fenômeno. Seguindo esta discussão, apresentei o conjunto de dados Atlantic-Camtraps, originalmente destinado a apoiar os dados necessários para explorar o fenômeno de liberação de mesopredadores na Mata Atlântica. Por fim, trouxe um estudo de caso sobre o ápice predador da Mata Atlântica em um de seus últimos redutos no bioma. Neste capítulo, eu e meus colegas apresentamos os resultados de cinco anos de monitoramento por telemetria e discutimos a ausência de padrões típicos, como sazonalidade e diferenças no tamanho da área de vida entre machos e fêmeas. Com este trabalho, espero chamar a atenção para este fenômeno nas florestas tropicais e orientar futuros estudos sobre o tema.

# APPENDIX I

# PRODUÇÃO COMO DISCENTE

# 2015 - 2020

# PRODUÇÃO COMO DISCENTE

## COLABORAÇÕES EM ARTIGOS PUBLICADOS

### QUALIS A1 - BIODIVERSIDADE

1. Perilli MLL, Lima F, Rodrigues FHG, Cavalcanti SMC. Can Scat Analysis Describe the Feeding Habits of Big Cats? A Case Study with Jaguars (Panthera onca) in Southern Pantanal, Brazil. Crowther MS, editor. PLoS One. 2016;11: e0151814. doi:10.1371/journal.pone.0151814
   **Colaboração:** análises; redação e revisão do texto.

2. Cullen L, Stanton JC, Lima F, Uezu A, Perilli MLL, Akçakaya HR. Implications of Fine-Grained Habitat Fragmentation and Road Mortality for Jaguar Conservation in the Atlantic Forest, Brazil. Banks SC, editor. PLoS One. 2016;11: e0167372. doi:10.1371/journal.pone.0167372
   **Colaboração:** coleta e sistematização de dados; geoprocessamento; análises; redação e revisão do texto.

3. Morato RG, Stabach JA, Fleming CH, Calabrese JM, De Paula RC, Ferraz KMPM, et al. Space Use and Movement of a Neotropical Top Predator: The Endangered Jaguar. Stöck M, editor. PLoS One. 2016;11: e0168176. doi:10.1371/journal.pone.0168176
   **Colaboração:** coleta (parcial) e sistematização de dados (parcial); revisão do texto.

4. Lima F, Beca G, de Lara Muylaert R, Jenkins CN, Perilli MLL, de Oliveira Paschoal AM, et al. ATLANTIC-CAMTRAPS: a dataset of medium and large terrestrial mammal communities in the Atlantic Forest of South America. Ecology. 2017 [cited 4 Sep 2017]. doi:10.1002/ecy.1998
   **Colaboração:** coleta (parcial) e sistematização de dados; articulação com grupos de pesquisa; geoprocessamento; análises; redação e revisão do texto.

5. Morato RG, Thompson JJ, Paviolo A, de La Torre JA, Lima F, McBride RT, et al. Jaguar movement database: a GPS-based movement dataset of an apex predator in the Neotropics. Ecology. 2018;99. doi:10.1002/ecy.2379
   **Colaboração:** idealização; coleta (parcial) e sistematização de dados (parcial); geoprocessamento; revisão do texto.

6. Morato RG, Connette GM, Stabach JA, De Paula RC, Ferraz KMPM, Kantek DLZ, et al. Resource selection in an apex predator and variation in response to local landscape characteristics. Biol Conserv. 2018;228: 233–240. doi:10.1016/j.biocon.2018.10.022
   **Colaboração:** coleta (parcial) e sistematização de dados (parcial); revisão do texto.

7. Culot L, Pereira LA, Agostini I, de Almeida MAB, Alves RSC, Aximoff I, et al. ATLANTIC-PRIMATES: a dataset of communities and occurrences of primates in the Atlantic Forests of South America. Ecology. 2019;100. doi:10.1002/ecy.2525
   **Colaboração:** coleta (parcial) e sistematização de dados (parcial).

8. Marjakangas EL, Abrego N, Grøtan V, de Lima RAF, Bello C, Bovendorp RS, et al. Fragmented tropical forests lose mutualistic plant–animal interactions. Divers Distrib. 2020;26: 154–168. doi:10.1111/ddi.13010
   **Colaboração:** coleta (parcial) e sistematização de dados (parcial).

9. Rosa CA da, Ribeiro BR, Bejarano V, Puertas FH, Bocchiglieri A, Barbosa AL dos S, et al. NEOTROPICAL ALIEN MAMMALS: a data set of occurrence and abundance of alien mammals in the Neotropics. Ecology. 2020;101. doi:10.1002/ecy.3115
   **Colaboração:** coleta (parcial) e sistematização de dados (parcial).

## QUALIS B1 - BIODIVERSIDADE

10. Paviolo A, De Angelo C, Ferraz KMPMB, Morato RG, Martinez Pardo J, Srbek-Araujo AC, et al. A biodiversity hotspot losing its top predator: The challenge of jaguar conservation in the Atlantic Forest of South America. Sci Rep. 2016;6: 37147. doi:10.1038/srep37147

    **Colaboração:** coleta (parcial) e sistematização de dados (parcial); redação (parcial) e revisão do texto.

## QUALIS B3 - BIODIVERSIDADE

11. Melo FR, Lima F, Ferraz DS, Faria MB, Oliveira PA de, Soares PC, et al. Primates of the valleys of the Rios Jequitinhonha and Mucuri, Brazil: occurrence and distribution. Primate Conserv. 2018;32: 95–108. Available: http://static1.1.sqspcdn.com/static/f/1200343/28066358/1548525267613/PC32_Melo_et_al_Primates_Jequitinhonha__Mucuri_Brazil.pdf?token=8im83LEbb11vbeuHBqPeU%2F9GjTQ%3D

    **Colaboração:** coleta e sistematização de dados; geoprocessamento; redação e revisão do texto.

# CITAÇÕES NO GOOGLE SCHOLAR (2015 – 2020)

https://scholar.google.com.br/citations?user=Ct3qk9MAAAAJ&hl=pt-BR

Citações: 356

Índice h: 11

Índice i10: 11

# TEXTOS DE DIVULGAÇÃO CIENTÍFICA

Lima, Fernando. **A estranha jornada acadêmica.** Disponível em https://www.desabrace.com.br/1093-2/ Acesso em 22 de dezembro de 2020.

Lima, Fernando. **O caminho do monge guerreiro: a falsa dicotomia entre campo e laboratório.** Disponível em https://www.desabrace.com.br/o-caminho-do-monge-guerreiro-a-falsa-dicotomia-entre-campo-e-laboratorio/ Acesso em 22 de dezembro de 2020.

Lima, Fernando. **Selfies na floresta: armadilhas fotográficas e os novos caçadores.** Disponível em https://www.desabrace.com.br/selfies-na-floresta-armadilhas-fotograficas-e-os-novos-cacadores/ Acesso em 22 de dezembro de 2020.

Lima, Fernando. **O encontro de Goethe e The Doors.** Disponível em https://www.desabrace.com.br/o-encontro-de-goethe-e-the-doors/ Acesso em 22 de dezembro de 2020.

Lima, Fernando. **Wilsinho e a onça.** https://www.desabrace.com.br/wilsinho-e-a-onca/ Acesso em 22 de dezembro de 2020.

Lima, Fernando. **Jim Corbett e o tigre capeta de Champawat.** Disponível em https://www.desabrace.com.br/jim-corbett-e-o-tigre-capeta-de-champawat/ Acesso em 22 de dezembro de 2020.

# PROJETOS DE DIVULGAÇÃO CIENTÍFICA

### DesAbraçando Árvores Podcast (2018 – atual)

Idealizador, produtor, editor e apresentador

### Que bicho é esse? (2018 – atual)

Idealizador, produtor e editor

### Que bicho é esse, crianças? (2020 – atual)

Idealizador, produtor, editor e apresentador