UNIVERSIDADE ESTADUAL DO MARANHÃO
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RENATA SORAYA DOS SANTOS PEREIRA

# ABUNDÂNCIA RELATIVA E FATORES AMBIENTAIS PREDISPONENTES À OCORRÊNCIA DE ANIMAIS DOMÉSTICOS NO PARQUE ESTADUAL DO MIRADOR, MARANHÃO

Área: Reprodução e Conservação Animal

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Dissertação apresentada à Universidade Estadual do Maranhão, como parte das exigências do Programa de Pós-Graduação em Ciência Animal, para obtenção do título de Mestre.

Orientador: Prof. Dr. Tadeu Gomes de Oliveira

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Aprovada em ____/____/_____

Banca de defesa de mestrado

_____
Prof. Dr. Tadeu Gomes de Oliveira (Orientador)
Universidade Estadual do Maranhão (UEMA)

_____
1ª Examinador

_____
2ª Examinador

Dedico esta obra à minha mãe,
que sempre me apoiou e estimula
a vencer todos os desafios.

## AGRADECIMENTOS

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A vida é uma jornada, ela não leva a um destino
exatamente, mas a uma transformação.

## RESUMO

O Parque Estadual do Mirador é uma Unidade de Conservação do bioma Cerrado considerada a segunda maior do país na qual existem cerca de 1.000 residentes e agregados a eles suas criações de animais domésticos. Diante disso, objetivou-se avaliar a incidência de animais domésticos no Parque Estadual do Mirador e verificar quais parâmetros influenciam sua ocorrência. Para tanto, foram instaladas as armadilhas fotográficas em distâncias entre si de 500-800 m levando em consideração nas análises a espécie, o horário, data, o número de indivíduos para cálculo da abundância dessas espécies. Além disso, foram obtidos dados dos parâmetros ambientais e criado o histórico de detecção referente aos anos de 2014-2015 e 2018 de modo a fazer as análises de ocupação. De acordo com o registrado pelas armadilhas fotográficas, os suínos foram os animais domésticos mais abundantes (8,42 ind/100 armadilhas-dia) durante o período de 2014-2015 e asininos (4,01 ind/100 armadilhas-dia) durante o ano de 2018. A distância para a água foi a variável que mais influenciou a ocupação dos animais domésticos, seguida da variável distância para casas.



**Palavras-chave:** Monitoramento, espécies invasoras, Parque Estadual do Mirador, variáveis ambientais, ocupação.


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## ABSTRACT

The Mirador State Park is a Conservation Unit of the Cerrado biome considered the second largest in the country in which there are about 1,000 residents and added to them their domestic animal breeding. The objective of this study was to evaluate the incidence of domestic animals in Mirador State Park and to verify which parameters influence its occurrence. For this purpose, the photographic traps were installed at distances of 500-800 m, considering the species, time, date and number of individuals to calculate the abundance of these species. In addition, data were obtained from the environmental parameters and the detection history for the years 2014-2015 and 2018 was created in order to perform the occupancy analyzes. According to photographic traps, pigs were the most abundant domestic animals (8.42 ind / 100 day traps) during the period 2014-2015 and asinines (4.01 ind / 100 day traps) during the year of 2018. The distance to water was the variable that most influenced the occupation of domestic animals, followed by the variable distance to houses.



**Keywords:** Monitoring, invasive species, Mirador State Park, environmental variables, occupancy.

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### CHAPTER 1



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## 1 INTRODUÇÃO

O Cerrado, com aproximadamente 2 milhões km², é o segundo maior bioma brasileiro. Apresenta elevado percentual de endemismo e intenso processo de perda de habitat por meio da expansão agrícola tornando-o um *hotspot* internacional (ROSA, 2007). O bioma apresenta somente 8,6% de sua área protegida por unidades de conservação, destes, 3,1% se encontra na forma de UC de proteção integral que é o caso do Parque Estadual do Mirador. O Cerrado perdeu de sua cobertura quase um milhão de quilômetros quadrados e no período de 2010-2011 no estudo mais recente realizado pelo Ministério do Meio Ambiente, mostrou que a área desmatada foi de aproximadamente 7.247 km$^2$ desse total, 1.310,62 km² localizou no Maranhão. O estados como principais responsáveis por esse desmatamento são: Maranhão, Tocantins, Piauí e Bahia representados pela sigla MATOPIBA (MMA, 2015).

No Parque Estadual do Mirador existe registros de aproximadamente 1000 residentes distribuídos em 61 povoados com habitações que se encontram ao longo dos rios Alpercatas e Itapecuru. A presença de residentes permitiu a detecção de diversos problemas na Unidade de Conservação, sendo eles: caça, queimadas, exploração predatória de recursos e presença de animais domésticos (OLIVEIRA, ARAÚJO, LACERDA, 2014). Em situação de pobreza e como principal fonte de renda voltada para criações dos animais domésticos, os moradores causam mais impactos visando alimentação destes ocasionando queimadas para renovação de pastoreio de seus animais. Possibilitando, portanto, maiores índices de queimadas as quais já mostraram-se críticas no ano de 2014.

Sua biota ainda é pouco conhecida, mas verificou-se a presença de espécies que estão ameaçadas de extinção, como *Leopardus tigrinus* e *Leopardus colocola*. A forte pressão sobre o cerrado maranhense, associado ao escasso conhecimento da diversidade, torna o PEM prioritário para levantamentos e conservação (OLIVEIRA et al., 2014).

A introdução ou invasão de espécies exóticas tem causado grandes transtornos aos ecossistemas naturais. Pode acontecer desses animais predarem outros vertebrados de pequeno a grande porte, afetando inclusive a biodiversidade da área (GALETTI, SAZIMA, 2006).

A atividade humana resulta em diversos impactos, tais como desmatamento, exploração de madeira, alteração do habitat, caça predatória e também a proximidade

humana. Como são fatores muito frequentes em qualquer região, destaca-se a proximidade humana como grande ameaça devido ao impacto de potenciais doenças que os animais domésticos podem transmitir aos silvestres, além de alteração comportamental e predação propriamente dita sendo os cães e gatos os principais causadores desses impactos (WESTON et al., 2014, BESSA et al., 2018, GATTI et al., 2018, MCCOMB et al., 2018). Nesse contexto, o Parque Estadual do Mirador apresenta situação precária mediante a ocorrência desses impactos (OLIVEIRA, 2007).

Os casos de predação variam desde o aumento da pressão de predação em pequenos mamíferos e ungulados (YOUNG et al., 2011) até casos extremos de um único cão que depletou populações de animais selvagens nativos em mais de 55% (TABORSKY, 1988). A transmissão da doença inclui o vírus da cinomose canina (CDV), parvovírus e raiva, com casos documentados de morte de animais silvestres devido a essas doenças em áreas protegidas (ROELKE-PARKER et al., 1996, KOCK et al., 1998, WOODROFFE, 1999).

Além dos impactos causados pela proximidade humana ocorre também o processo inverso, que é a possibilidade de transmissão de doenças aos humanos, como por exemplo a raiva. Segundo Arruda et al. (2008), a raiva possui diversos reservatórios, sendo a raposa e o morcego hematófago destacados como importantes no Maranhão. Além desses animais silvestres, os domésticos também são importantes formas de transmissão da raiva. Sendo considerada, dessa forma, perigo constante para o homem. Os animais silvestres passam a se aproximar mais das habitações atacando as criações, transmitindo, assim, a doença. Os bovinos seriam os mais afetados na América do Norte e Europa (GOMES, 2004).

Esta proximidade entre as habitações humanas e suas criações com as espécies nativas poderia também resultar em predação que, por sua vez, pode levar à caça como forma de retaliação causando impactos de todas as formas possíveis (AZEVEDO, 2006, PETERS et al., 2017). O inverso também é passível de acontecer, de animais domésticos predarem animais silvestres devido ao constante contato entre ambos (CAMPOS, 2004, METZGER et al., 2006). O motivo para tal acontecimento seria a falta de alimento aos domésticos que é provido pelos próprios seres humanos e/ou a sua livre circulação pelo habitat natural, fato semelhante ao que ocorre no Parque Estadual do Mirador.

## 2 REVISÃO BIBLIOGRÁFICA

A introdução ou invasão de espécies exóticas como porcos (*Sus scrofa domesticus*), bois (*Bos taurus*), cavalos (*Equus caballus*), cães (*Canis lupus familiares*), gatos (*Felis catus*) e jumentos (*Equus africanus asinus*) têm causado grandes transtornos aos ecossistemas naturais. Isto também pode ser ocasionado por animais ferais, que são animais domésticos que voltaram a uma vida selvagem em habitats naturais (GALETTI, SAZIMA, 2006).

Os cães vivem em proximidade aos humanos desde que foram domesticados a cerca de 15.000 anos (DRISCOLL, MACDONALD, 2010). Sua presença em UCs é preocupante, pois podem influenciar na abundância e distribuição das espécies nativas (ZAPATA-RÍOS, BRANCH, 2016). Os efeitos são significantes quando ocorrem espécies endêmicas e em áreas com espécies ameaçadas. São ainda potenciais transmissores de doenças, têm capacidade de predarem animais silvestres e são competidores por recursos alimentares (PRADO et al., 2008, QUEIROGAS et al., 2010, ZAPATA-RÍOS, BRANCH, 2016).

No Pará houve declínio populacional de carnívoros silvestres devido à transmissão de cinomose canina via cães domésticos, tal efeito ocorreu dentro de uma área protegida também de proteção integral. Espécies como onças (vermelha e pintada), quatis, gato maracajá tiveram contato direto com os canídeos que realizavam caças nas áreas naturais (WHITEMAN et al., 2007). O mesmo ocorreu na Bolívia dentro de um Parque Nacional em que os cães apresentaram altos níveis de exposição para cinomose e parvovirose (FIORELLO et al., 2004, UHART et al., 2012).

É importante destacar que os suínos não impactam somente a vegetação, os mesmos podem ainda ser reservatório de doenças como a Peste Suína Africana (KUKIELKA et al., 2016a) e a Hepatite E (que é zoonose) que pode ainda ser transmitida aos animais silvestres (TAKAHASHI et al., 2004, KUKIELKA et al., 2016b, CARUSO et al., 2017).

Os gatos domésticos são considerados grandes vilões no que diz respeito à conservação de espécies silvestres (KAYS, DEWAN, 2004). Estão entre as 100 piores espécies piores espécies invasoras (LOWE et al., 2000) e são responsáveis pela morte de cerca de 1,3 – 4,0 bilhões e 6,3 – 22,3 bilhões de aves e mamíferos respectivamente (BAKER et al., 2005, LOSS et al., 2012). Existem situações de felinos domésticos que têm donos, obtêm alimento nas residências e ainda caçam garantindo-lhes vantagens

sobre as espécies nativas em relação à competição por recurso (WOODS et al., 2003, BIRÓ et al., 2005).

A problemática é ainda maior em ilhas agravando os impactos conforme mostrado por Medina et al. (2011) que constataram impactos sobre 175 taxa dos quais consistiam répteis, aves e mamíferos referente à levantamento global. Os gatos são também potenciais transmissores de doenças como larva migrans cutânea, toxoplasmose e doenças transmitidas por vetores. Outra zoonose transmitida é a raiva, que apesar do que se tem conhecimento, os índices de detecção são maiores em felinos do que em cães domésticos (GERHOLD, JESSUP, 2012).

A expansão humana invadindo áreas nativas abre caminhos para uma maior interação entre essas espécies, transformando suas criações em presas às espécies nativas (LOVERIDGE et al., 2010, ATHREYA et al., 2016, RECIO et al., 2015). Bem como a redução de suas presas por meio da caça predatória, desmatamento e/ou transmissão de doenças são situações que permitem a busca de alimentos por parte das espécies nativas em criações (AZEVEDO, CONFORTI, 2002). O conflito existente entre pessoas e animais silvestres, o qual tem como consequência a caça retaliatória, ocorre basicamente devido a ataques às criações, destruição de lavouras e risco de transmissão de doenças (CAVALCANTI, 2006, INSKIP, ZIMMERMANN, 2009, MCMANUS et al., 2015), tornando esses conflitos uma questão de crescente interesse para os conservacionistas.

Soluções possíveis ou propostas mitigadoras seriam a caça liberada desses animais, o abate e envenenamento. Porém são ideias que devem ser minuciosamente analisadas, pois não devem ser executadas de forma indiscriminada (BALLARI et al., 2014, RUSSEL et al., 2018). Havendo a possibilidade de remoção da espécie invasora que está impactando as demais ocorre uma modificação na pirâmide ecológica que é o aumento (proliferação) de suas presas/espécies influenciadas pela sua presença, conforme mostrado por Stokeld et al. (2018) que realizaram um experimento com répteis em meio livre e isolado de gatos ferais.

Existem programas de remoção desses invasores para esterilização e castração “Armadilha-Neutra-Liberação” (TNR) que consiste em capturar os animais selvagens para a realização desses procedimentos e por fim serem devolvidos ao meio natural. Esta prática é executada principalmente por instituições privadas que não utilizam a prática do abate, porém ainda é perigosa visto que há o contato com o meio externo

podendo assim haver a contaminação de espécies silvestres através do contato (GERHOLD, JESSUP, 2012).

## 3 OBJETIVOS

### 3.1 Geral

Avaliar a incidência de animais domésticos no Parque Estadual do Mirador, Maranhão – PEM.

### 3.2 Específicos

- Quantificar a ocorrência de animais domésticos em diferentes áreas do Parque através do armadilhamento fotográfico;

- Monitorar a abundância de animais domésticos em diferentes áreas do Parque através do armadilhamento fotográfico;

- Verificar a intensidade de uso das áreas naturais pelas espécies domésticas;

- Identificar quais variáveis estariam influenciando a ocorrência de animais domésticos no PEM.

## CHAPTER 1

### Abundance of domestic animals and their influence on the native species of Mirador State Park, Maranhão[1]

Renata Soraya dos Santos Pereira[1], Breno Campelo Lima[1] & Tadeu Gomes de Oliveira[1,2]

1 Mestranda em Ciência Animal da Universidade Estadual do Maranhão, Cidade Universitária Paulo VI, Av. Lourenço Vieira da Silva, nº 1000 - Bairro: Jardim São Cristóvão CEP: 65055-310 – São Luís – MA. E-mail: renatasoraya.p@gmail.com;

2 Departamento de Química e Biologia, Universidade Estadual do Maranhão, Cidade Universitária Paulo VI, Av. Lourenço Vieira da Silva, nº 1000 - Bairro: Jardim São Cristóvão CEP: 65055-310 – São Luís – MA.

**ABSTRACT**

Mirador State Park is the second largest conservation unit in the Cerrado. Besides its large surface it is home of several threatened species, notably the Northern Tiger Cat *Leopardus tigrinus*. Notwithstanding there is also a wide array of domestic animals living within the park. In this context, the current research was done to quantify and monitor these animals through camera traps. A total of 45 camera traps were installed in three areas of the park and spaced by distances of 500-800 m. In order to calculate species abundance, we identified each species, and gather data on date, time, and number of individuals. With a trapping effort of 5,030 trap nights, we obtained 606 independent records of domestic animals in our study areas. Our results indicated that pigs were the most abundant domestic animal (8,42 indiv./100 trap-nights) for the period 2014-2015 and donkeys were the most abundant (4,01 indiv./100 trap nights) during 2018. The data show large occurrence of domestic animals in natural areas of Mirador State Park and contributes effectively to the creation of management actions for the park that needs adequate management to deal with the presence of domestic animals and their potential negative impacts to its biodiversity.

**Key words:** Monitoring; camera traps; invasive species; conservation; Cerrado.

[1] Artigo a ser submetido na revista Perspectives on Ecology and Conservation. Fator de Impacto: 2.49

**INTRODUCTION**

Mirador State Park (MSP) is a fully protected conservation unit which, given its wildlife component, it should be considered one of the highest priority areas of conservation in the Brazilian Cerrado. However the park suffers from several environmental problems, among them the presence of domestic animals within park limits. This tends to cause impacts on the local fauna and flora (Macdonald, Thom, 2001, Paschoal et al., 2016).

The presence of exotic animals in a natural environment produces negative interactions for the biodiversity. Disease transmission, hybridization, competition and predation lead to the decline of wildlife populations, altering the ecosystem dynamics in its most varied levels (Wayne, Brown, 2001, Craft et al., 2017, Richardson, 2011, Doherty et al., 2017).

Currently, disease transmission between domestic animals and wildlife is an issue of great concern for conservation biologists. Domestic dogs for example are responsible for approximately 4,5 % of vertebrates modern extinctions due to disease transmission (Doherty et al., 2017).

In the current scenario, rabies, canine cinomose, parvovirus and leishmaniasis are considered large threats to wildlife populations, particularly for carnivores (Lessa et al., 2016). Several works have already shown precisely the proportion of pathogen exposure for both wild and domestic animals (Curi et al., 2016). Courtenay et al. (2001) found 91 domestic canids (cubs and adults) seropositive for both parvovirus and cinomose. The conservation threat is illustrated by the fact that 92% of monitored crab-eating foxes, *Cerdocyon thous*, would roam close to human settlements thereby increasing the risk of disease transmission. In some situations, both domestic and wild animals obtained the same exposure rate to the parvovirus (Cleaveland et al., 2006, Fiorello, 2006, Furtado et al., 2016). The threatened species present at MSP that would be sensible to these impacts include the hoary fox *Lycalopex vetulus* and Northern tiger cat *Leopardus tigrinus*, as well as the most abundant species recorded in this conservation unit, the crab-eating fox (*C. thous*).

High densities of exotic animals in protected areas could also lead to competition for space and resource, leading to considerable impacts to the native wildlife (Campos et al., 2007, Espartosa, 2009, Doherty et al., 2016a, Lessa et al., 2016,

Doherty et al., 2017). Domestic dogs and cats could kill, even without posterior consumption, a considerable amount of the local wildlife, resulting even in local extinctions (Sampaio, Schimidt, 2013, Doherty et al., 2017).

This work is very relevant since is the first research done in Brazil dealing with demographic aspects of domestic animals in a conservation unit. We seeked to describe the domestic species present in MSP by quantifying occurrence and abundance of these animals in the park through camera trapping.

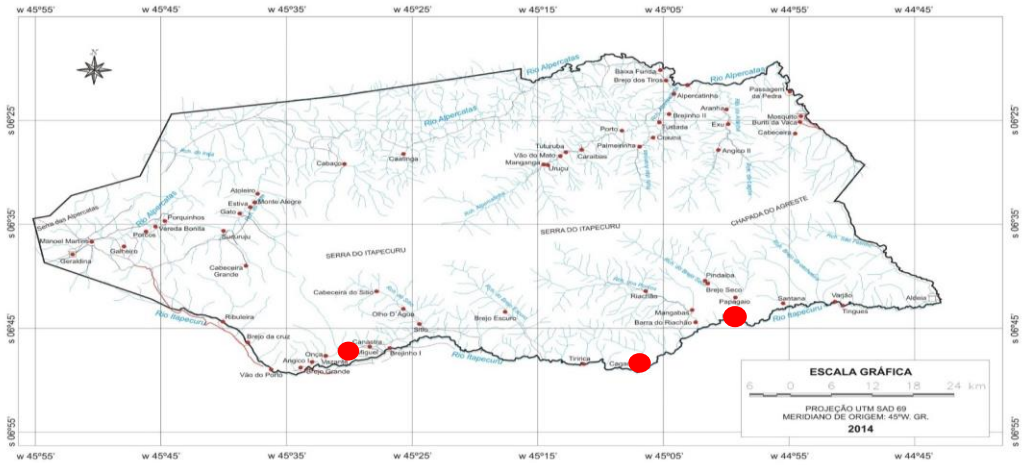
## MATERIALS AND METHODS

*Study site:*

Mirador State Park (MSP) is located in the Cerrado biome between the following coordinates 06°10'06°42'' S and 44°43'45°54'' W. The climate is dry and sub-humid with an annual pluviometric precipitation of 1,200 mm and two well defined seasons, a dry one from June through September and a wet season from December to April. Mean maximum temperature ranges from 32°C-34°C and minimum of 18°-20.5°C (Araújo, Lopes, Calvacante, 2014). The park includes the regions of the Chapadões and the Planaltos. Vegetation cover is represented mainly by open savannas, woodland savannas and gallery forests (Rodrigues, Conceição, 2014). The state's Cerrado biome includes several savanna formation with varying degrees of tree density (Muniz et al., 2014).

With approximately 5,000 km², MSP is the second largest conservation unit in the Brazilian Cerrado (Conceição, Castro, 2009). Our study was conducted at three of the park's outposts: Mel, Zé Miguel, and Cágados (Figure 1). The outposts differ in their vegetation composition with dense woodland savannas at Mel, open savannas in Zé Miguel, and semi-open savannas at Cágados. Study sites were chosen on the basis of detecting wildlife with a particular focus on areas in which felids had been detected historically. Besides this, we took into account easiness of access in order to install the cameras.

Figure 1: Map of Mirador State Park, Maranhão, with the three study sites (red dots)




Source: Oliveira, Araújo, Lacerda, 2014

*Data collection and analysis*

We used camera traps Bushnell Trophy Cam HD, Reconyx PC850, ScoutGuard SG565, and Browning. Camera trapping has been a particularly effective method for both recording and monitoring wildlife, since it allows the detection of several species, including rare ones and those that are hard to detect. All of this in a short span of time, as long as the number of camera traps deployed is well fitted for the study purposes (Karanth, 1995, Carbone et al., 2001, Karanth, Nichols, 2002, Oliveira, 2007, 2011).

Trapping stations were defined as one camera unit, and were spaced by distances of 0.5-1.0 km. The cameras were installed at a height of 30 cm in areas with high potential for felid detection, such as trails and natural walkways (Oliveira, Cassaro 2005, Oliveira, 2011). Data collection at Mel occurred between January 2014 and July 2015 as well as between May-August 2018. At Zé Miguel the survey period was from August 2014 to July 2015. Finally at Cágados data collection occurred from May-August 2018.

For every photographic record we collected the species, time, date, and number of individuals. These data allowed us to analyze how these species use the study sites, with which frequency and how do they distribute their activities throughout the day. We analyzed the intensity of habitat use by domestic species and compared it to that of the native wildlife.

Relative Abundance Indexes (RAI) were used as a proxy for species abundance, since RAI is correlated with true species abundance (Carbone et al., 2001, O'Brien et al., 2003). For this study we considered the number of individuals as well as the number of independent records. The latter were defined as either records from the same species in which the interval between pictures/videos is greater than one hour or records less than 1 hour from different individuals of the same species (O'Brien et al., 2003). This means that there were two RAI formulas: $RAI1 = (Sr/N)\ x\ 100$trap-nights, where *Sr* is the number of independent records and *N* is the survey effort. $RAI2 = (Si/N)\ x\ 100$trap-nights, where *Si* is the number of individuals and *N* is the survey effort.

We run normality tests in order to determine the appropriate statistical test. We applied a *t-test* in order to compare the study sites and survey periods. When the *t-test* was rejected we used a *Mann-Whitney Rank Sum Test*. Paired data was compared through Analysis of Variance (ANOVA). All tests were carried out on SigmaPlot© version 14.0.

**RESULTS**

Total survey effort was 5,030 trap-nights of which 1,495 of which were for 2018 and 3,535 were for 2014-2015 (Table 1). For the period 2014-2015 we obtained 456 independent records of domestic animals, while in 2018 we obtained 150 records (Table 2). There was a significant difference in the number of records for 2014-2015 and 2018 at Mel (t = 40.000; *P* = 0.008). Overall there was a significant difference between both monitoring period (t = 37.500; *P* = 0.032).

Table 1: Survey effort at Mirador State Park

| **2014/15** | | **2018** | |
|---|---|---|---|
| Mel<br>2730 | Zé Miguel<br>805 | Mel<br>711 | Cágados<br>784 |
| **Total: 3.535** | | **Total: 1.495** | |

Table 2: Number of individuals and independent records obtained during monitoring at Mirador State Park

| **2014-2015** | | **2018** | |
|---|---|---|---|
| Records | Nº individuals | Records | Nº individuals |
| 456 | 1.032 | 150 | 248 |
| **TOTAL: 1886** | | | |

In just 4 months of surveys at the Cágados outpost we obtained the same number of records of donkeys as in the whole 2014-2015 survey period (Figure 2). Records distributions throughout the period 2014-2015 were proportional among the species, except for pigs (Figure 3). There were significant differences between the three sites (H = 9.125; gl = 2; *P* = 0.01), as well as between Cágados and Mel (H = 4.811; gl = 1; *P* = 0.032).

Figure 2: Number of independent records at Mel and Cágados outposts, Mirador State Park, Maranhão, 2018

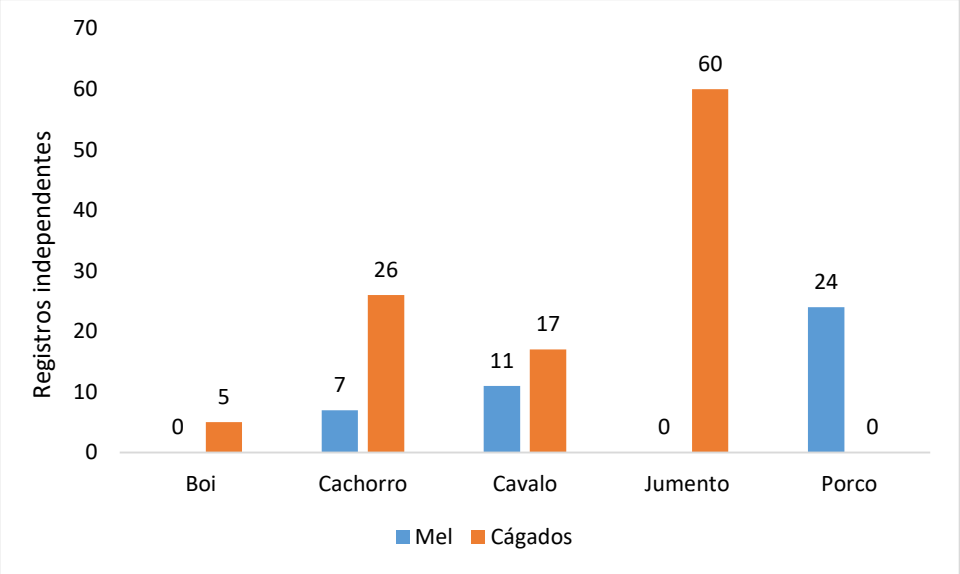
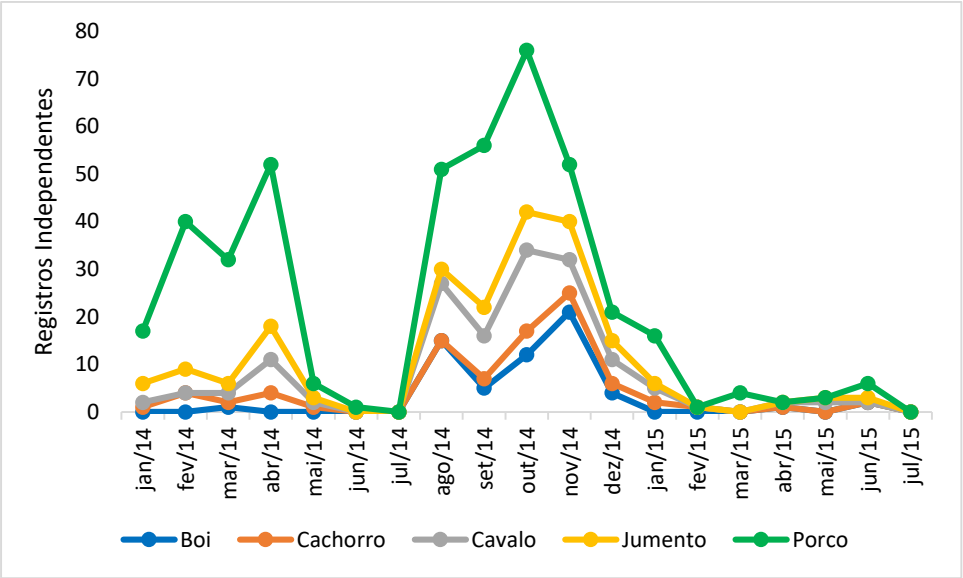


Figure 3: Number of independent records at Mel outpost, Mirador State Park, Maranhão, 2014-2015




When comparing the same survey period between 2014 and 2018 we did not detect a significant difference (t = 0.776; gl = 8; *P* = 0.46). There was no significant difference either when comparing the dry and rainy seasons (t = 33.000; *P* = 0.31). With regards to the RAI in terms of both number of independent records and number of individuals for 2018, there were contrasts for donkeys and horses (Figure 4). On the other hand, the RAI based on the number of independent records was high for pigs in 2014-2015 (Figure 5).

Figure 4: Relative abundance index based on number of independent records (blue) and number of individuals (orange) in Mirador State Park, 2018

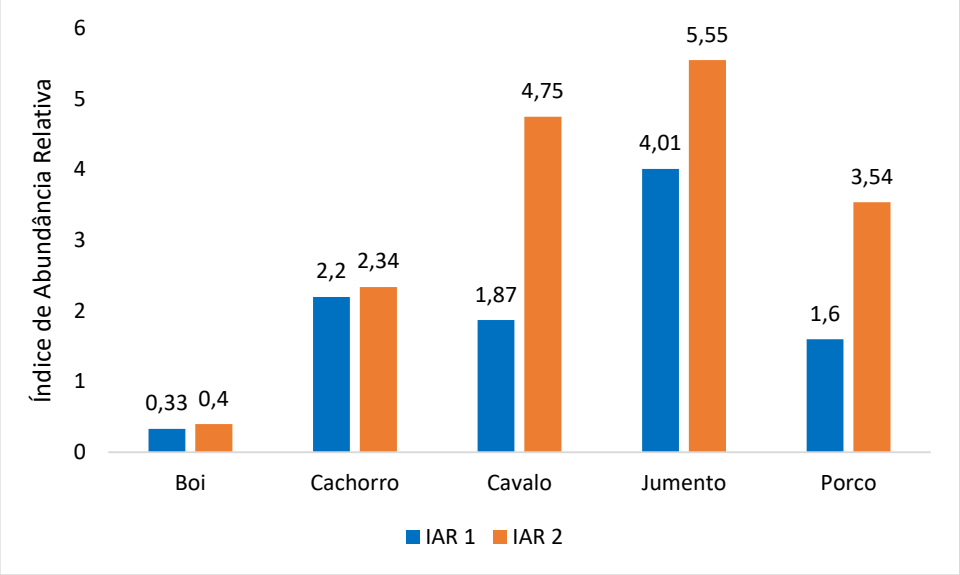
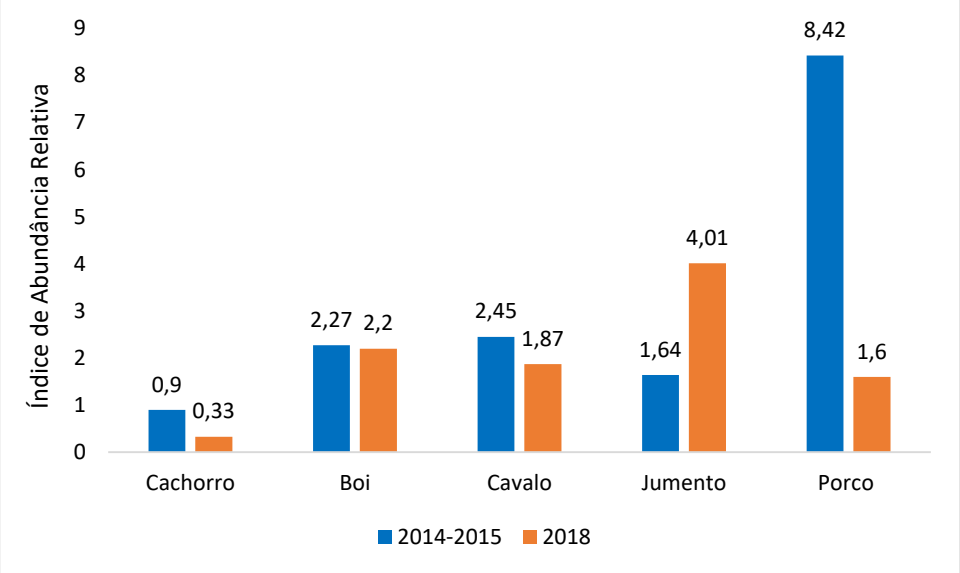



Figure 5: Comparison of relative abundance index between survey periods 2014/2015 and 2018 in Mirador State Park



## DISCUSSION

The number of domestic animals - be it by species amount or independent records - is high for a conservation unit and this is a concern for the populational aspects of threatened wildlife, particularly carnivores *Puma concolor*, *Lycalopex vetulus*, *Leopardus colocola* e *Leopardus tigrinus* (ICMBio, 2016, IUCN, 2018). Large population declines were reported for Africa, Europe, and the United States (Wierzbowska et al., 2016) caused particularly by antagonistic interactions with exotic species.

The high number of records at Mel could be due to different survey efforts in the two periods (2014/2015 and 2018), as sampling was carried out there since the very beginning of the study in 2014. The greatest number of donkey records comes from Cágados, and this could be the results of deliberate releases in areas adjacent to the park (Oliveira, Araújo, Lacerda, 2014) and the high number of individuals observed in the years 2004-2008 (T.G. de Oliveira, per. obs.).

The distribution of records among species (Figure 3) is not related to the site's climate, since according to the statistical analysis, there was no difference between wet and dry seasons. This even matched what was found in previous monitoring in 2014.

The domestic species recorded were mostly livestock such as pigs, horses, cattle, and donkeys. Worldwide, pigs, domestic cats, and exotic rodents are the invasive species that pose the greatest threat to endangered vertebrates (Doherty et al., 2016a) with many effects in several taxonomic groups (Bellard et al., 2016). Pigs are responsible for impacts such as predation, habitat loss, competition, and disease transmission (Braysher, 2004, Bengsen et al., 2014, Engeman et al., 2016, Jones et al., 2017), resulting in anywhere from 9 to 11 species extinctions (Doherty et al., 2016a). There was a decline in the number of pig captures between the two survey periods, we believe that this is related to the selling of animals by their owners.

Intensive livestock raising within conservation units has many impacts, particularly when the animals raised are ungulates (Vijayan et al., 2017). At Cágados there was the highest abundance of donkeys, and there is evidence of indiscriminate releases of donkeys within park limits, which raises the possibility of these animals being established in the park (Oliveira, Araújo, Lacerda, 2014), thereby directly influencing the observed results. These animals contribute to a myriad of impacts to the

native biodiversity with the simple act of feeding and displacing in search of food (Miranda, Muniz, 2009). Stomping and grazing can lead to delays in the ecological succession process. Another possibility is that exotic species disperse seeds from agricultural areas outside the park, through feces (Silva et al., 2013).

There are other domestic animals in MSP which were estimated by the local population at 6,300 individuals, including chickens (more than 5,000), domestic dogs, and cats. Besides the species mentioned and recorded, there is also a presence of goats, buffaloes, and sheep inside the park (Oliveira, Araújo, Lacerda, 2014). This information compliments our results and raise an alert for the environmental problems caused by the presence of these species in the park.

The presence of these invasive species greatly impact the natural environment, particularly the native species, as it results in competition and disease transmission. Competition can occur in disputes for territory or resources, as found by Aliaga-Rossel et al. (2012) with domestic dogs fighting with Andean condors and foxes over carcasses in Bolivia. In this case the dogs would form packs and often would dominate the wild scavengers over the carcasses, in some cases even attacking them. Besides competition, there are also cases of attacks and predation on native species of small and medium size (Gatti et al., 2018, McComb et al., 2018).

Domestic dogs and cats were the species most commonly cited in the exotic/invasive species lists of Brazilian federal conservation units, with the domestic cat being one of the worst ones worldwide (Sampaio, Schimidt, 2013, Doherty et al., 2016a). Domestic cats are a particularly bad problem in Australia, where they have lead to the extinctions of birds, reptiles, and mammals (Davies et al., 2016, Doherty et al., 2016a,b, Woinarski et al., 2017a,b).

With regards to domestic dogs, they are as impactful as the domestic cats, and even being responsible for the extinction of several species. Gatti et al. (2018) verified attacks of domestic dogs on wild lowland tapirs (threatened species at the Brazilian level) in a conservation unit in Espírito Santo state. The population of tapirs in the area is not high enough for long-term survival, thus continued dog attacks could result in the local extinction of the tapir (*Tapirus terrestris*). The main form of impact is predation and the most affected taxonomic group is that of the mammals (Doherty et al., 2017). Domestic dogs are a strong threat to the native wildlife of Australia and New Zealand,

leading to the establishment of eradication programs in these two countries (Lessa et al., 2016, Roy, 2016).

As it has been shown, the issue of domestic animals in conservation units has gained amplitude and interest by the scientific community has grown, particularly in the area of conservation medicine due to zoonotic diseases (Wiethoelter et al., 2015).

Domestic dogs in the park showed signs of disease that were visible through camera trapping; these free roaming dogs could enter in contact with native species. This is of great concern, given the possibility of disease transmission, as we saw in foxes that showed signs of potential dermatofitosis (Figure 6). Besides this, we also observed some individuals with symptoms of cinomose. This disease affects the gastrointestinal and respiratory systems, as well as the nervous system, and is very common in domestic dogs. It is transmitted through direct contact between individuals and thus it raises concerns for the cases of sick animals in MSP (Acosta-Jamett et al., 2015, Viana et al., 2015, Kim et al., 2018). A study done in Emas National Park, also in the Cerrado biome, showed that most wildlife species as well as domestic dogs from nearby areas had been exposed to cinomose. This also occurred with parvovirus, which affected both domestic dogs and native wildlife (Curi et al., 2016, Furtado et al., 2016).

Figure 6: Records of animals showing signs of disease (foxes and domestic dogs)


There is a large occurrence of domestic animals in natural areas of MSP and need to continued monitoring and if possible, expansion of such monitoring to new

areas of the park in order to verify the presence of invasive species and their intensity of habitat use. The data shown contributes effectively to the creation of management actions for the park that needs adequate management to deal with the presence of domestic animals and their potential negative impacts to the park's biodiversity.

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## REFERENCES

Acosta-Jamett, G., Surot, D., Cortés, M. et al. (2015) Epidemiology of canine distemper and canine parvovirus in domestic dogs in urban and rural areas of the Araucanía region in Chile. *Veterinary Microbiology*, 178(3-4): 260-264.

Aliaga-Rossel, E., Ríos-Uzeda, B., Ticona, H. (2012) Amenazas de perros domésticos en la conservación del cóndor, el zorro y el puma en las tierras altas de Bolivia. *Revista Latinoamericana de Conservación*, 2(1): 78-81.

Araújo, E. P., Lopes, J. R., Cavalcante, E. P. A. (2014) Mapeamento do uso e cobertura da terra do Parque Estadual do Mirador no Estado do Maranhão. In: *Programa de Gestão Compartilhada do Parque Estadual do Mirador*. Pró-Vida Brasil/ SEMA, p. 28-50. Relatório de pesquisa.

Bellard, C., Cassey, P., Blackburn, T. M. (2016) Alien species as a driver of recent extinctions. *Biology Letters*, 12: 20150623.

Bengsen, A. J., Gentle, M. N., Mitchell, J. L. et al. (2014) Impacts and management of wild pigs *Sus scrofa* in Australia. *Mammal Review***,** 44: 135–147.

Braysher, M. (2004). *Threat abatement plan for predation, habitat degradation, competition and disease transmission by feral pigs*. Australian Department of Environment and Heritage, Canberra.

Campos, C. B., Esteves, C. F., Ferraz, K. M. P. M. B. et al. (2007) Diet of free-ranging cats and dogs in a suburban and rural environment, south-eastern Brazil. *Journal of Zoology*, 273(1): 14-20.

Carbone, C., Christine, S., Conforti, K. et al. (2001) The use of photographic rates to estimate densities of tigers and other cryptic mammals. *Animal Conservation***,** 4: 75-79.

Cleaveland, S., Laurenson, K., Funk, F., Packer, C. (2006) Impact of viral infections in wild carnivore populations. In: Morato, R.G. (Org.) et al. *Manejo e conservação de carnívoros neotropicais*. 2. ed. São Paulo: Ibama, p. 325-349.

Conceição, G. M., Castro, A. A. J. F. (2009) Fitossociologia de uma área de cerrado marginal, Parque Estadual do Mirador, Mirador, Maranhão. *Scientia Plena*, 5(10).

Courtenay, O, Quinell, R. J., Chalmers, W. S. K. (2001) Contact rates between wild and domestic canids: no evidence of parvovirus or canine distemper virus in crab-eating fox. *Veterinary Microbiology*, 81: 9-19.

Craft, M.E., Vial, F., Miguel, E. et al. (2017) Interactions between domestic and wild carnivores around the greater Serengeti ecosystem. *Animal Conservation*, 20: 193-204.

Curi, N. H. A., Massara, R. L., Paschoal, A. M. O. et al. (2016) Prevalence and risk factors for viral exposure in rural dogs around protected areas of the Atlantic forest. *BMC Veterinary Research*, 12(21).

Davies, H. F., McCarthy, M. A., Firth, R. S. C. et al. (2016) Top-down control of species distributions: feral cats driving the regional extinction of a threatened rodent in northern Australia. *Diversity and Distributions*, 23(3): 272-283.

Doherty, T. S., Glen, A. S. Nimmo, D. G. et al. (2016a) Invasive predators and global biodiversity loss**.** *Proceedings of the National Academy of Sciences of the United States of America*, 113(40): 11261–11265.

Doherty, T. S., Dickman, C. R., Johnson, C. N. et al. (2016b) Impacts and management of feral cats *Felis catus* in Australia. *Mammal Review*, 47(2): 83-97.

Doherty, T. S., Dickman, C. R., Glen, A. S. et al. (2017) The global impacts of domestic dogs on threatened vertebrates. *Biological Conservation*, 210: 56-59.

Engeman, R. M., Orzell, S. L., Felix, R. K. et al. (2016) Feral swine damage to globally imperiled wetland plant communities in a significant biodiversity hotspot in Florida. *Biodiversity and Conservation*, 25(10): 1879–1898.

Espartosa, K. D. (2009) *Mamíferos Terrestres de maior porte e a invasão de cães domésticos em remanescentes de uma paisagem fragmentada de Mata Atlântica: avaliação da eficiência de métodos de amostragem e da importância de múltiplos fatores sobre a distribuição das espécies*. 2009. 127f. Dissertação (Mestrado em Ciências) – Instituto de Biociências, Universidade de São Paulo, São Paulo.

Fiorello, C. V. (2006) A review of ecological aspects of disease spillover in carnivores, and possibilities for intervention in the Bolivian Chaco. In: MORATO, R.G. (Org.) et al. *Manejo e conservação de carnívoros neotropicais*. 2. ed. São Paulo: Ibama, p. 367-395.

Furtado, M. M., Hayashi, E. M. K., Allendorf, S. D. et al. (2016) Exposure of free-ranging wild carnivores and domestic dogs to Canine Distemper Virus and Parvovirus in the Cerrado of Central Brazil. *EcoHealth*, 13(3): 549-557.

Gatti, A., Seibert, J. B., Moreira, D. O. (2018) A predation event by free–ranging dogs on the lowland tapir in the Brazilian Atlantic Forest. *Animal Biodiversity and Conservation*, 41(2): 311-314.

ICMBio. Instituto Chico Mendes de Conservação da Biodiversidade. (2016) <http://www.icmbio.gov.br/portal/images/stories/comunicacao/publicacoes/publicacoes-diversas/dcom_sumario_executivo_livro_vermelho_ed_2016.pdf>. Acesso em 27 de agosto de 2018.

IUCN. The IUCN Red List of Threatened Species. (2018) < http://www.iucnredlist.org/search>. Acesso em 27 de agosto de 2018.

Jones, K. C., Gorman, T. A., Rincon, B. K. et al. (2017) Feral swine *Sus scrofa*: a new threat to the remaining breeding wetlands of the vulnerable reticulated flatwoods salamander *Ambystoma bishopi*. *Oryx*, 52(4): 669-676.

Karanth, K. U. (1995) Estimating tiger *Panthera tigris* populations from camera trap data using capture-recapture models. *Biological Conservation*, 71: 333-338.

Karanth, K. U., Nichols, J. D. (org.). (2002) *Monitoring tigers and their prey*. Centre for Wildlife Studies, Bangalore, India.

Kim, H-H., Yang, D-K., Seo, B-H., Cho, I-S. (2018) Serosurvey of rabies virus, canine distemper virus, parvovirus, and influenza vírus in military working dogs in Korea. *The Journal of Veterinary Medical Science*, 80(9): 1424-1430.

Lessa, I., Guimarães, T. C. S., Bergallo, H. de G. et al. (2016) Domestic dogs in protected areas: a threat to Brazilian mammals? *Natureza & Conservação*, 14(2): 46-56.

Macdonald, D. W., Thom, M. D. (2001) Alien carnivores: unwelcome experiments in ecological theory. In: Gittleman, J. L. et al. *Carnivore Conservation*. Cambridge University Press, p. 93-122.

McComb, L. B., Lentini, P. E., Harley, D. K. P. et al. (2018) Feral cat predation on Leadbeater's possum (*Gymnobelideus leadbeateri*) and observations of arboreal hunting at nest boxes. *Australian Mammalogy*.

Miranda, M. C. P. C., Muniz, F. H. (2009) Impacto do gado bovino sobre os ecossistemas do Parque Estadual do Mirador – PEM. *Pesquisa em Foco***,** 17(1): 31-42.

Muniz, F.H., Santos, P.M., Pinheiro, R.S., et al. (2014) Vegetação. In: *Programa de Monitoramento de fauna e flora do Parque Estadual do Mirador do Programa de Gestão Compartilhada do Parque Estadual do Mirador*. Pró-Vida Brasil/ SEMA, p. 60-80. Relatório de pesquisa.

O'Brien, T.G., Kinnaird, M.F. Wibisono, H.T. (2003) Crouching tigers, hidden prey: Sumatran tiger and prey populations in a tropical forest landscape. *Animal Conservation*, 6(2): 131–139.

Oliveira, T. G. de, Cassaro, K. (2005) *Guia de campo dos felinos do Brasil*. Instituto Pró-Carnívoros/Fundação Parque Zoológico de São Paulo/Sociedade de Zoológicos do Brasil/Pró-Vida Brasil, São Paulo, SP.

Oliveira, T. G. de. et al. (2007) Mamíferos do Cerrado Norte do Brasil. In: BARRETO, L. (Org.). *Cerrado Norte do Brasil*. Pelotas: USEB, p. 261-271.

Oliveira, T.G. de. (2011) *Ecologia e conservação de pequenos felinos no Brasil e suas implicações para o manejo*. 2011. Tese de Doutorado. Universidade Federal de Minas Gerais.

Oliveira, T. G. de, Araújo, L. P., Lacerda, M. G. (2014) Diagnóstico do Parque Estadual do Mirador**.** In: *Programa de Gestão Compartilhada do Parque Estadual do Mirador*. PRÓ-VIDA BRASIL/ SEMA. PRÓ-VIDA BRASIL/ SEMA. p. 3-28. Relatório de pesquisa.

Paschoal, A. M. O., Massara, R. L., Bailey, L. L. et al. (2016) Use of Atlantic Forest protected areas by free-ranging dogs: estimating abundance and persistence of use. *Ecosphere*, 7(10): 1-15.

Richardson, D.M. (2011) *Fifty Years of Invasion Ecology: The Legacy of Charles Elton*.

Wiley-Blackwell, Wales.

Rodrigues, M. S., Conceição, G. M. (2014) Diversidade florística das diferentes fisionomias de Cerrado do Parque Estadual do Mirador, Maranhão, Brasil. *Brazilian Geographical Journal: Geosciences and Humanities research medium*, 5(1): 139-156, jan./jun.

Roy, E. A. (2016) No more rats: New Zealand to exterminate all introduced predators. Disponível em: <https://www.theguardian.com/world/2016/jul/25/no-more-rats-new-zealand-to-exterminate-all-introduced-predators?CMP=fb_gu>. Acesso em: 31 de out. 2016.

Sampaio, A. B., Schimidt, I. B. (2013) Espécies Exóticas Invasoras em Unidades de Conservação Federais do Brasil. *Biodiversidade Brasileira*, 3(2): 32-49.

Silva, A. C. C., Prata, A. P. N., Souto, L. S., Mello, A. A. (2013) Aspectos de ecologia de paisagem e ameaças à biodiversidade em uma unidade de conservação na Caatinga, em Sergipe. *Revista Árvore*, 37(3): 479-490.

Viana, M., Cleaveland, S., Matthiopoulos, J. et al. (2015) Dynamics of a morbillivirus at the domestic–wildlife interface: Canine distemper virus in domestic dogs and lions. *Proceedings of the National Academy of Sciences of the United States of America*, 112(5): 1464–1469.

Vijayan, S., Morris, D. W., McLaren, B. E., Mukherjee, S. (2017) Domestic ungulates in protected areas and the potential for indirect interactions via shared predation. *Biodiversity*, 18(4): 129-136.

Wayne, R. K., Brown, D. M. (2001) Hybridization and conservation of carnivores. In: Gittleman, J. L. et al. *Carnivore Conservation*. Cambridge University Press, p. 145-162.

Wierzbowska, I.A., Hędrzak, M., Popczyk, B. et al. (2016) Predation of wildlife by free-ranging domestic dogs in Polish hunting grounds and potential competition with the grey wolf. *Biological Conservation*, 201: 1–9.

Wiethoelter, A. K., Beltrán-Alcrudo, D., Kock, R., Mor, S. M. (2015) Global trends in infectious diseases at the wildlife–livestock interface. *Proceedings of the National Academy of Sciences of the United States of America*, 112(31): 9662–9667.

Woinarski, J.C.Z., Woolley, L. A., Garnett, S. T. et al. (2017a) Compilation and traits of Australian bird species killed by cats. *Biological Conservation*, 216: 1-9.

Woinarski, J. C. Z., Murphy, B. P., Legge, S. M. et al. (2017b) How many birds are killed by cats in Australia? *Biological Conservation*, 214: 76-87.

## CHAPTER 2

# Environmental Parameters and Occupancy of Domestic Animals in Mirador State Park, Maranhão, Brazil[2]

Renata Soraya dos Santos Pereira[1], Lester Alexander Fox-Rosales[1,2] & Tadeu Gomes de Oliveira[1,3]

1 Mestranda em Ciência Animal da Universidade Estadual do Maranhão, Cidade Universitária Paulo VI, Av. Lourenço Vieira da Silva, nº 1000 - Bairro: Jardim São Cristóvão CEP: 65055-310 – São Luís – MA. E-mail: renatasoraya.p@gmail.com;

2 Workgroup Endangered Species Conservation. Georg-August Universtität, Bürgerstrasse 50, 37073, Göttingen, Germany;

3 Departamento de Química e Biologia, Universidade Estadual do Maranhão, Cidade Universitária Paulo VI, Av. Lourenço Vieira da Silva, nº 1000 - Bairro: Jardim São Cristóvão CEP: 65055-310 – São Luís – MA.

## ABSTRACT

Mirador State Park is the second largest conservation unit in the Brazilian Cerrado. Its landscape is shared between the native wildlife, human settlements, and domestic animals both feral and owned. These animal pose a threat to the native wildlife in the park. The purpose of this study was to verify which environmental variables influence the occurrence of domestic animals in the Park. In order to do so, we installed camera traps at three outposts within the park: Mel, Cágados, and Zé Miguel. In addition, we gather data on four environmental variables that were hypothesized to affect domestic animals occupancy. The distance to water was the variable that most influenced the occupation of cattle, canines and pigs. Equine and asinine animals were influenced by distance to houses. Occupancy at Mel and Cágados in 2018 was similar, but cattle and donkeys were more common in Cágados and pigs were more so in Mel. Overall these results could potentially guide management and mitigation actions at the park.

**Key words:** Invasive species, Environmental Parameters, Occupancy, Conservation Units.

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## INTRODUCTION

The presence of domestic animals in conservation units has become a global problem, affecting different countries and with many different impacts, that even lead to species extinctions (Mugume et al., 2015, Doherty et al., 2016a, Home et al., 2017). The impacts include competition, disease transmission, hybridization, and predation (Doherty et al., 2016b).

The high density of exotic animals making use of natural areas can lead to competition for resources and space, which may result in considerable impacts to the native wildlife (Campos et al., 2007, Espartosa, 2009). On the other hand, the invasion of protected areas by human populations can lead to wildlife predation on livestock and domestic animals (Athreya et al., 2016), thus giving rise to human-wildlife conflict and retaliatory killing of predators (Azevedo, 2006, Peters et al., 2017).

Furthermore, domestic dogs (*Canis lupus familiaris*) have already caused the extinctions of 11 vertebrate species basically through direct predation and or disease transmission, besides being considered a serious threat for an additional 200 vertebrate species worldwide (Doherty et al., 2017). Domestic dog presence in conservation units is of high concern because they can influence the abundance and distribution of native species. Such influences have been observed by Zapata-Ríos and Branch (2016), in Andean regions in which domestic dogs were roaming freely, native species would either be absent or would alter their activity patterns in order to avoid encounters with dogs.

The presence of invasive species can also lead to the circulation of pathogens within protected areas, as well as disease transmission to native wildlife (Santos et al., 2017). Curi et al. (2016) found that exposure to pathogens was related to the circulation around the environment, verified through tests for parvovirus, adenovirus, and cinomosis. Disease transmission was more likely to occur in areas near human settlements, and when these settlements were found around protected areas and dogs were free roaming the probability for disease transmission was higher.

In contrast with dogs, domestic cats (*Felis catus*) have greater movement restrictions in natural areas, using open and flat areas (Hohnen et al., 2016). Domestic cats are among the worst invasive species (Lowe et al., 2000) and are responsible for the

extinctions of 63 species, of which 40 were birds, 21 were mammals, and 2 were reptiles (Doherty et al., 2016a).

Domestic cats have been particularly harmful in Australia, which is where most of the studies on domestic cat impacts have been conducted (Doherty et al., 2016b, Woinarski et al., 2017a,b, McComb et al., 2018, Stokeld et al., 2018), there they cause high impacts on bird populations. Brazil also suffers from these impacts, notably on the Fernando de Noronha Island with about 1,300 domestic cats (Dias, et al., 2017, Russel et al., 2018).

Agrarian activities have deleterious effects in wildlife species occupancy, resulting in the movement of such species in order to avoid contact with humans (Vijayan et al., 2017, Karimov et al., 2018). Through occupancy analysis prior studies have shown that domestic animals negatively influence the presence of native wildlife, displacing them from their natural habitat (Zapata-Ríos, Branch, 2018). The same effect has also been documented on ocelots (*Leopardus pardalis*) which are vulnerable not only to habitat loss but also to the presence of domestic animals (Cruz et al., 2018).

With approximately 5,000 km², Mirador State Park (MSP) is the second largest Conservation Unit of the Cerrado, the Brazilian savannas biome. It also contains the source of the Itapecurú river, which supplies several cities, including São Luís, reinforcing its ecological and economic importance (Conceição, Castro, 2009). In addition, its enormous areas and fauna composition make it one of the priority areas for conservation in the Brazilian Cerrado.

Taking all this into consideration, this study had the goal of identifying which environmental parameters would be influencing the occupancy of domestic animals in Mirador State Park, as well as identifying the intensity of habitat use by these species with the goal of enhancing mitigation actions.

## METHODS

*Study Site:*

The study was carried out in Mirador State Park (MSP) located between the coordinates 06°10’06°42” S and 44°43’45°54” W in the central-southern portion of Maranhão state, Northeast Brazil (Figure 1A). It is part of the Cerrado biome and the

vegetation includes woodland savannas, open savannas, and gallery forests along rivers (Rodrigues, Conceicão, 2014).

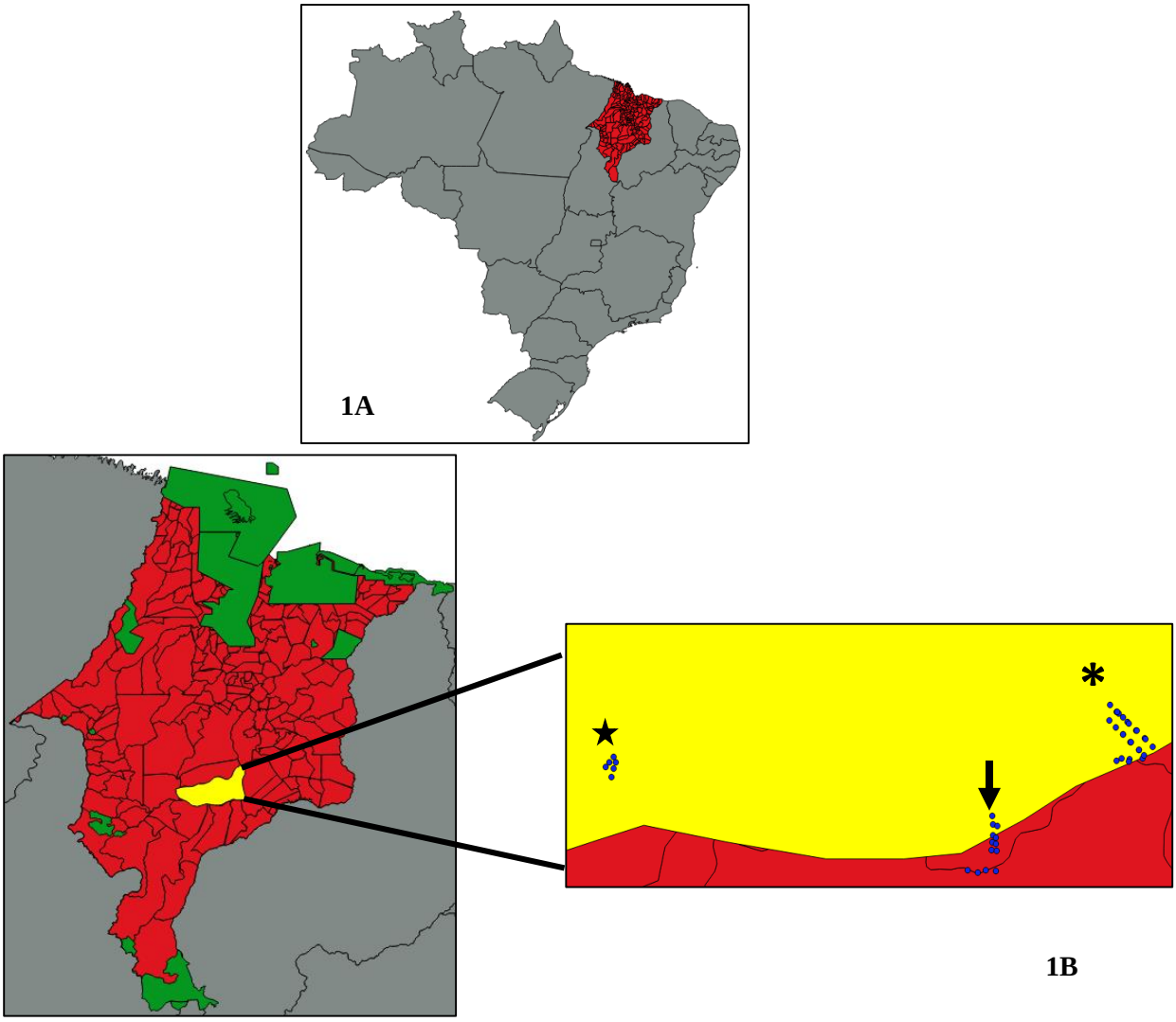
*Camera Trapping Protocol*

Camera traps were installed around three different outposts in MSP: Mel, Zé Miguel, and Cágados (Figure 1B). Camera traps were deployed with the goal of detecting wild felids, which had been detected in these areas in prior studies. The vegetation varies between the outposts, with Mel having dense woodland savanna, fairly open savannas in Zé Miguel and semi open vegetation at Cágados.

Camera traps were spaced by 0.5-1.0 km apart, they were installed at a height of 30 cm in areas with high potential for mammal and wild felid detection such as trails (Oliveira, Cassaro, 2005, Oliveira, 2011). The cameras functioned 24 hours a day. Data collection was carried out between January 2014 and July 2015 and between May and August 2018 at Mel outpost. In Zé Miguel data was collected between August 2014 and July 2015. While at Cágados data collection was done between May and August 2018. For the period 2014-2015 we used 19 trapping stations while in 2018 we used 26, in both cases a trapping station was defined as one single camera. All cameras were georeferenced by means of GPS.

Figure 1: Location of Mirador State Park in Maranhão, Brasil

1A: Location of Maranhão State; 1B: Location of Mirador State Park (yellow) and layout of the camera traps (blue dots). Legend: Star – Zé Miguel; Arrow – Cágados; Asterisk – Mel.




*Occupancy Modeling:*

Occupancy probability (ψ) is defined as the probability that at site *i* the target species is present, while detection probability (p) is the probability of detecting the target species at site *i* at occasion *t* given that the species is present. Both parameters can be modeled as functions of covariates (MacKenzie et al., 2002). Covariates were defined as the environmental variables that could influence the detection and occupancy of domestic animals, considering that these animals depend on human populations. The variables chosen were: forest cover, elevation, distance to nearest household, and distance to nearest body of water (Table 1). We obtained the measurements using the Eucledian Distance function in Quantum GIS ver 2.18.27 (The Quantum GIS Project).

Table 1: Environmental variables and predicted effects on domestic species occupancy

| Covariate | Description | Predicted effect |
|---|---|---|
| Tree Cover | Percentage of 30x30 m pixels with a tree cover greater than 25% (height > 5m) in a 300-m buffer | Occupancy increases with tree cover due to higher food availability |
| Elevation | Elevation above sea level in m | Occupancy increases with lower elevation due to higher accessibility |
| Distance to water | Linear distance to nearest water body | Occupancy increases with proximity to water |
| Distance to human settlements | Linear distance to nearest inhabited household | Occupancy increases with proximity to houses |

A presence-absence detection history matrix (1 – species is present; 0 – species is absent) was done for each of the species recorded in the study. Because the sampling period was not continuous we decided to model 2014-2015 and 2018 through different approaches. Multi-season occupancy models were used for the 2014-2015 period using a total of three survey periods of 11, 28 of 12 days each; these models assume static occupancy within surveys but allow for changes in occupancy (colonization and extinction) between surveys, these changes can also be modeled as covariates. Single season occupancy models were used for 2018, in periods of 7 occasions of 12 days each, these models assume no changes in occupancy occur during the study period. The sampling period for 2018 was less than 3 months, which is short enough to guarantee static occupancy at the sampling sites.

In both the multi-season and single-season analysis we acknowledge that detection is imperfect, therefore by taking into account the detection probability we make better occupancy estimates (MacKenzie et al., 2002).

*Data analysis:*

We standardized all covariates, as they were continuous. We run Spearman correlations in order to test for normality among the four covariates, we did this in R ver. 3.5.0 (R Development Core Team, 2018). Maximum likelihood inference was used

for the occupancy models following a logit-link function. We followed a stepdown or *ad-hoc* approach for modeling purposes, that is we modeled occupancy as a function of each of the covariates while leaving the detection constant and vice versa. We used Akaike Information Criterion (AIC) to rank the models. We considered those models with a change in AIC $\leq 2$ from the top model as the best models, and their respective covariates as possibly important for predicting the target species detection and occupancy probabilities (Burnham, Anderson, 2002). For the multi-season analysis we also obtained estimates of colonization and extinction. All analyses were carried out in the program PRESENCE ver. 12.24 (Hines, 2006).

**RESULTS**

We obtained 606 independent records of domestic animals in MSP with an effort of 5,030 trap-nights. We detected presence of cattle (*Bos taurus*), domestic dogs (*Canis lupus familiaris*), donkeys (*Equus asinus*), horses (*Equus caballus*), and pigs (*Sus scrofa domesticus*). The number of independent records per species was 67 for cattle, 64 for domestic dogs, 120 for donkeys, 101 for horses, and 254 for pigs. Naïve occupancy percentages ranged between 15-46% (Table 2). It represents the proportion of sites where the species were detected at least once.

Table 2: Percentage of sites in which each species was recorded in MSP, 2018

| **Species** | **Naïve *occupancy*** |
|---|---|
| *Bos taurus* - cattle | 0.1538 |
| *Canis lupus familiaris* – dog | 0.4231 |
| *Equus caballus* – horse | 0.3462 |
| *Equus asinus* – donkey | 0.4615 |
| *Sus scrofa domesticus* - pig | 0.3462 |

*Occupancy models*

The Spearman correlations showed that neither of the variables were highly correlated (see Table 1 Supplemental Information). For the single season analysis of 2018, the environmental variable that influenced domestic animal occupancy the most was distance to water bodies, followed by distance to human settlements. Detection probability was constant in the best models for all species, except horses. Cattle occupancy was most influenced by distance to water bodies (Table 3), with increasing distance to water cattle occupancy declines (Table 5).

With regards to domestic dogs, distance to water bodies was the most important covariate for occupancy, with dog occupancy decreasing with increasing distance to water. Horse occupancy was positively influenced by elevation and to a lesser extend ($\beta = 1.259540 \pm 4.036532$) by forest cover, while its detection probability was negatively correlated with forest cover. Donkey occupancy was influenced by all four covariates, negatively by forest cover, distance to water, and distance to houses, and positively by elevation. Finally, pig occupancy had a positive correlation with distance to water bodies.

Single season occupancy modeling for pigs showed that distance to water had a positive influence in their occupancy probability (Table 4) and that distance to human settlements had a negative effect on the detection probability ($\beta = -0.000817 \pm 0.000281$) which possibly means that these animals are independent in relation to human households and roam freely. This variable was absent in the multi-season analysis (Table 3), in which distance to water continued to influence occupancy and detection positively (Table 5). Colonization did not seem to be affected by any of the covariates. Extinction probability was also negatively affected by distance to water.

The multi-season occupancy analysis for 2014-2015 showed different results for the five species, but in almost all cases the best models had a constant detection probability except for pigs (Table 4). Cattle occupancy increased with increasing forest cover, elevation, and distance to households, while it declined with increasing distance to water (Table 6). Domestic dog occupancy was negatively correlated with elevation, while its colonization probability of new sites increased with elevation. For horses occupancy was positively correlated with distance to houses, while colonization of new sites was negatively correlated with elevation. Donkey occupancy and colonization had

a negative correlation with distance to water bodies. As for pigs, the best model had constant occupancy, colonization, and extinction probabilities, as well as detection probability negatively affected by all covariates except distance to houses, which had a positive correlation.

The estimated occupancy of dogs and horses was similar between Cágados and Mel in 2018. Nevertheless cattle and donkeys were far more common at Cágados ($\psi$ = 0,3) while pigs were more common in Mel ($\psi$ = 0,77), these results were recurring throughout the study period (Figure 2).

Table 3: Ranking of single season occupancy models for domestic animals in MSP

$\psi$ = Occupancy probability; p = detection probability; Wgt = model weight. Variables - Forest: forest cover; Water: distance to nearest water body; Elev: Elevation above sea level; House: distance to nearest human settlement.

| Model | AIC | ΔAIC | AIC wgt |
|---|---|---|---|
| **Cattle** | | | |
| $\psi$(Water), p(.) | 39.32 | 0.00 | 0.3323 |
| $\psi$(Forest+Water), p(.) | 39.99 | 0.67 | 0.2377 |
| **Dog** | | | |
| $\psi$(Water), p(.) | 130.84 | 0.00 | 0.3516 |
| $\psi$(Forest), p(.) | 132.80 | 1.96 | 0.1320 |
| $\psi$(Water+Forest), p(.) | 132.83 | 1.99 | 0.1300 |
| **Horse** | | | |
| $\psi$(Elev), p(Forest) | 101.00 | 0.00 | 0.1925 |
| $\psi$(Elev), p(.) | 101.57 | 0.57 | 0.1447 |
| $\psi$(Forest), p(Forest) | 101.64 | 0.64 | 0.1398 |
| $\psi$(.), p(Forest) | 101.72 | 0.72 | 0.1343 |
| **Donkey** | | | |
| $\psi$(Forest+Water+Elev+Houses), p(.) | 118.89 | 0.00 | 0.7018 |
| **Pig** | | | |
| $\psi$(Water), p(.) | 89.68 | 0.00 | 0.7405 |

Table 4: Ranking of multi-season occupancy models of domestic animals in MSP

ψ = Occupancy probability; p = detection probability; Wgt = model weight. Variables - Forest: forest cover; Water: distance to nearest water body; Elev: Elevation above sea level; House: distance to nearest human settlement.

| Model | AIC | ΔAIC | AIC wgt |
|---|---|---|---|
| **Cattle** | | | |
| ψ(Forest+Water+Elev+Houses), γ(.), ε(.), p(.) | 205.46 | 0.00 | 0.4558 |
| ψ(Forest+Water), γ(.), ε(.), p(.) | 206.72 | 1.26 | 0.2428 |
| ψ(.), γ(Forest+Water+Elev+Houses), ε(.), p(.) | 207.08 | 1.62 | 0.2028 |
| **Dog** | | | |
| ψ(Elev), γ(Elev), ε(.), p(.) | 186.85 | 0.00 | 0.2430 |
| ψ(Elev), γ(.), ε(.), p(.) | 188.03 | 1.18 | 0.1347 |
| **Horse** | | | |
| ψ(House), γ(Elev), ε(.), p(.) | 263.40 | 0.00 | 0.7429 |
| **Donkey** | | | |
| ψ(Water), γ(Water), ε(.), p(.) | 225.92 | 0.00 | 0.2923 |
| ψ(Forest+Water+Elev+Houses), γ(.), ε(.), p(.) | 226.16 | 0.24 | 0.2593 |
| ψ(.), γ(Water), ε(.), p(.) | 226.82 | 0.90 | 0.1864 |
| **Pig** | | | |
| ψ(.), γ(.), ε(.), p(Forest+Water+Elev+Houses) | 318.15 | 0.00 | 0.4048 |
| ψ(Forest), γ(.), ε(.), p(Forest+Water+Elev+Houses) | 318.19 | 0.04 | 0.3967 |

## DISCUSSION

Though we had expected that distance to water was going to be an important covariate for occupancy, we had hypothesized that distance to settlements was going to be the most important variable given domestic animals dependence on humans. In the single season analysis distance to houses was not present in the best model for any species. For the multi-season distance to houses was only present for cattle and horses, and only in the latter did it have a negative correlation (suggesting that horses during 2014-2015 were indeed more abundant near human settlements). These findings suggest that some of the animals captured were feral, there are reports of donkeys being released in the park by local inhabitants (Oliveira, Araújo, Lacerda, 2014). Another possible explanation is that some of the animals, particularly cattle and pigs, are privately owned by people and are let to roam freely during the day and or night. Therefore, they are

more likely to be detected in areas away from the households when they are foraging or travelling.

An interesting finding of this study, are the changes in the most important covariates for species occupancy between 2014/2015 and 2018. While in 2014/2015 each species occupancy was influenced by a different covariate, in 2018 distance to water was present in the best model of each species, but horses. Horse occupancy went from being dependent on distance to houses to being more affected by elevation in the 2018 single season analysis. Though these differences could have been due to survey design (longer sampling period during 2014/2015 for example), they could also be suggestive of other issues.

The multi-season analysis of 2014/2015 showed that for most species colonization and extinction were constant and not dependent on environmental covariates. However we acknowledge that this is likely due to the fact that there were very few colonization and extinction events during the survey period. Due to the length of the study, we believe that the lack of changes in occupancy for all species is indicative of high adaptability and resilience. This is worrisome as it could potentially mean that some of these animals could establish themselves in the park and form populations on the medium and long term.

The high occupancy probability of dogs in 2018 (>45% at most of the sampling sites, Figure 2) is worrisome because of the potential impacts to native wildlife. Zapata-Ríos and Branch (2018) looked at which factors influence the presence of wild carnivores in Ecuador, and one of these factors was the presence of domestic dogs. The variable presence of dogs had negatively affected wild carnivore occupancy. Free roaming domestic dogs could be potential prey for large carnivores as shown by Athreya et al. (2016) who found that domestic dogs and cats made up 87% of the biomass consumed by leopards (*Panthera pardus*) in India. The preference for this food source laid in the high availability and easiness of killing. In MSP a potential predator for domestic dogs would be the puma (*Puma concolor*), which has been detected in the park recently (de Oliveira per. comm.). Domestic dogs could also be a potential predator for smaller carnivores such as the Northern tiger cat (*Leopardus tigrinus*) and both fox species.

Not only domestic cats and dogs impact wildlife, other non-native species may cause indirect effects. Karimov et al. (2018) showed through occupancy modeling that distance to areas with cattle negatively affected the occupancy of large mammals (gray wolf, snow leopard, brown bear, and ungulates), displacing them to other areas. Cattle had a high estimated occupancy in the park on both 2014/2015 and 2018 periods, so they are likely indeed affecting and displacing wildlife in the park. More research such look specifically at cattle-wildlife interactions in the park.

Donkeys represent an interesting case. While in 2014/2015 donkey occupancy was only influenced by distance to water sources, in 2018 it was influenced by all four covariates. In the 2018 survey donkeys were detected at all sampling stations in Cágados and none in Mel (Figure 2). This could explain why such a huge difference in the occupancy models of both periods. As stated before, there are reports of donkeys being released into the park by humans. Their high occupancy at Cágados could be due to the fact that they are being released there, since the best model estimated at 0 the probability of occupancy at every single site in Mel. The fact that donkeys roam freely in the park is concerning since it increases the probability of disease transmission such as equine infectious anemia (Oliveira, Araújo, Lacerda, 2014).

Horses were the only species whose occupancy was solely affected by elevation in 2018 and by distance to households in 2014/2015. There were very few detections of horses with riders or people nearby, hence it is quite possible that at least some of the individuals were feral. The correlation between elevation and horse occupancy in 2018 was positive.

Table 5: Beta estimates for each of the best models for single season occupancy in MSP.

| Models | Beta estimates (SD) |
|---|---|
| **Cattle** | |
| ψ(Water), p(.) | -3.261431 (6.357158) |
| **Dog** | |
| ψ(Water), p(.) | -0.667642 (0.478039) |
| **Horse** | |
| ψ(Elev), p(Forest) | 0.766896 (0.908314) / -8.246738 (1.853573) |
| **Donkey** | |
| ψ(Forest+Water+Elev+Houses), p(.) | -61.334048 (5508069.042806) / -192.863856 (-) / 115.168843 (-) / -3.773449 |

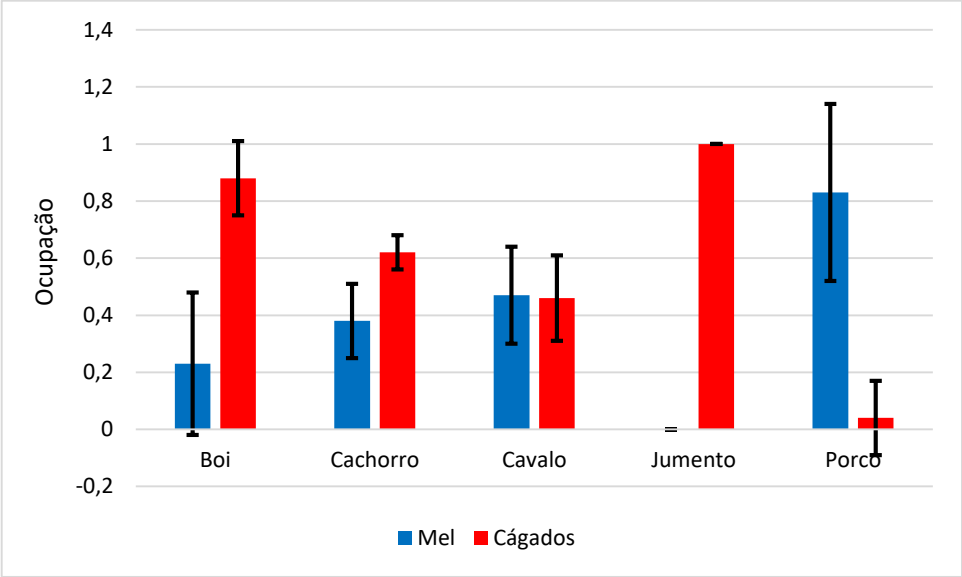
| | |
|---|---|
| | (820772.197931) |
| **Pig** | |
| ψ(Water), p(.) | 7.836261 (6.385147) |

Table 6: Beta estimates of the best models for the multi-season occupancy analysis in MSP

| Models | Beta estimates (SD) |
|---|---|
| **Cattle** | |
| ψ(Forest+Water+Elev+Houses), γ(.), ε(.), p(.) | 452.984551 (-) / -791.082806 (-) / 959.811363 (-) / 420.358251 (-) |
| **Dog** | |
| ψ(Elev), γ(Elev), ε(.), p(.) | -4.110310 (3.226428) / 550.402959 (7053826.367659) |
| **Horse** | |
| ψ(House), γ(Elev), ε(.), p(.) | 1.680645 (0.877323) / -2.915635 (2.576367) |
| **Donkey** | |
| ψ(Water), γ(Water), ε(.), p(.) | -0.580344 (0.608662) / 165.633094 (10.000000) |
| **Pig** | |
| ψ(.), γ(.), ε(.), p(Forest+Water+Elev+Houses) | -5.117957 (0.808307) / -0.095485 (0.177742) / -1.582202 (0.291461) / 0.016654 (0.217161) |

The positive influence of increasing distance to water on pig occupancy in 2018 (Table 5) was highly unexpected, as pigs are ecologically very dependent on water sources. A possible explanation is that some of these animals are owned, they could be released by their owners in the morning, and they probably spend the day foraging away from the houses and water bodies. Pig presence in conservation units causes negative impacts during foraging (Bengsen et al., 2014), affecting ecological succession (Silva et al., 2013) and destroying the riparian vegetation. It is worth noting that pigs are reservoirs of diseases such as African swine flu (Kukielka et al., 2016a) and Hepatitis E, which can be transmitted to the native wildlife (Takahashi et al., 2004, Kukielka et al., 2016b, Caruso et al., 2017). These factors combined with the pigs' high adaptability to different environments, make their presence at MSP a serious conservation issue.

Figure 2: Occupancy estimation for Mel and Cágados in 2018




Occupancy analysis can be used to guide programs of invasive species removal, by finding in which areas these species are more likely to occur and which environmental variables affect their presence (Cove et al., 2018, Davis et al., 2018). Overall the results of this project can be used for management purposes. For feral individuals management possibilities include translocation, eradication, and population control. Translocation is a very expensive measure and likely not viable for MSP. Eradication is also cost-intensive and it might be difficult to fully accomplish. Population control on the other hand can be achieved through the culling of different individuals. On the long term population control of feral domestic animals could make them ecologically extinct in the park. Potential culling campaigns of feral domestic animals at MSP should be concentrated near water bodies, as those are the areas with greater domestic animal occupancy.

Domestic animals that are owned should be dealt with in a different manner. Steps should be taken in order to minimize the contact between those animals and wildlife. For cattle for example, large enclosures could be built near human settlements, so that the cattle can be kept at night. Domestic dogs could be kept indoors and not allowed to roam freely without human presence. All these measures require cooperation with the local human population. Environmental education programs could be a way to accomplish this. These programs could teach local people how to take care of their

animals and how not to let them roam freely inside the park. Lastly future research should concentrate on the epidemiological profile of these animals in order to evaluate the risk they may pose to the park's wildlife.

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**REFERENCES**

Athreya, V., Odden, M., Linnell, J. D. C., Krishnaswamy, J., Karanth, K. U. (2016) A cat among the dogs: leopard *Panthera pardus* diet in a human-dominated landscape in western Maharashtra, India. *Oryx*, 50(1), p. 156–162.

Azevedo, F. C. C. de. (2006) The impact of domestic animal predation by large carnivores. How does this affect the conservation of keystone species? In: Morato, R.G. (Org.) et al. *Manejo e conservação de carnívoros neotropicais*. 2. ed. São Paulo: Ibama, p. 169-182.

Bengsen, A. J., Gentle, M. N., Mitchell, J. L. et al. (2014) Impacts and management of wild pigs *Sus scrofa* in Australia. *Mammal Review***,** 44, p. 135–147.

Burnham, K. P., Anderson, D. R. (2002) *Model Selection and Inference: A Practical Information-Theoretic Approach*. 2nd Edition, Springer-Verlag, New York.

Campos, C. B.; Esteves, C. F.; Ferraz, K. M. P. M. B. et al. (2007) Diet of free-ranging cats and dogs in a suburban and rural environment, south-eastern Brazil. *Journal of Zoology*, v.273, n.1, p.14-20.

Caruso, C., Peletto, S., Rosamilia, A. et al. (2017) Hepatitis E Virus: A cross-sectional serological and virological study in pigs and humans at zoonotic risk within a high-density pig farming area. *Transboundary and Emerging Diseases*, v. 64, p. 1443-1453.

Conceição, G. M., Castro, A. A. J. F. (2009) Fitossociologia de uma área de cerrado marginal, Parque Estadual do Mirador, Mirador, Maranhão. *Scientia Plena*, 5(10).

Cove, M. V., Gardner, B., Simons, T. R., O'Connell, A. F. (2018) Co-occurrence dynamics of endangered Lower Keys marsh rabbits and free-ranging domestic cats: Prey responses to an exotic predator removal program. *Ecology and Evolution*, 8(8):4042–4052.

Cruz, P., Iezzi, M. E., De Angelo, C. (2018) Effects of human impacts on habitat use, activity patterns and ecological relationships among medium and small felids of the Atlantic Forest. *Plos One*, 13(8).

Curi, N. H. A., Massara, R. L., Paschoal, A. M. O. et al. (2016) Prevalence and risk factors for viral exposure in rural dogs around protected areas of the Atlantic forest. *BMC Veterinary Research*, 12(21).

Davis, A. J., McCreary, R., Psiropoulos, J. et al. (2018) Quantifying site-level usage and certainty of absence for an invasive species through occupancy analysis of camera-trap data. *Biological Invasions*, 20(4): 877-890.

Dias, R. A., Abrahão, C. R., Micheletti, T. (2017) Prospects for domestic and feral cat management on an inhabited tropical island. *Biological Invasions*, 19(8): 2339-2353.

Doherty, T. S.; Glen, A. S.; Nimmo, D. G.; Ritchie, E. G.; Dickman, C. R. (2016a) Invasive predators and global biodiversity loss. *Proceedings of the National Academy of Sciences of the United States of America*, 113(40): 11261–11265.

Doherty, T. S.; Dickman, C. R.; Johnson, C. N.; Legge, S. M.; Ritchie, E. G.; Woinarski, J. C. Z. (2016b) Impacts and management of feral cats *Felis catus* in Australia. *Mammal Review*, 47(2): 83-97.

Doherty, T. S., Dickman, C. R., Glen, A. S. et al. (2017) The global impacts of domestic dogs on threatened vertebrates. *Biological Conservation*, 210: 56-59.

Espartosa, K. D. (2009) *Mamíferos Terrestres de maior porte e a invasão de cães domésticos em remanescentes de uma paisagem fragmentada de Mata Atlântica: avaliação da eficiência de métodos de amostragem e da importância de múltiplos fatores sobre a distribuição das espécies*. 2009. 127f. Dissertação (Mestrado em Ciências) – Instituto de Biociências, Universidade de São Paulo, São Paulo.

Hines, J. E. (2006) PRESENCE-software to estimate patch occupancy and related parameters . USGS-PWRC. http://www.mbr- pwrc.usgs.gov/software/presence.shtml.

Hohnen, R., Tuft, K., McGregor, H. W. et al. (2016) Occupancy of the Invasive Feral Cat Varies with Habitat complexity. *Plos One*, 11(9).

Home, C., Bhatnagar, Y. V., Vanak, A. T. (2017) Canine Conundrum: domestic dogs as an invasive species and their impacts on wildlife in India. *Animal Conservation*, 21(4): 275-282.

Karimov, K., Kachel, S. M., Hacklander, K. (2018) Responses of snow leopards, wolves and wild ungulates to livestock grazing in the Zorkul Strictly Protected Area, Tajikistan. *Plos One*, 13(11).

Kukielka, E. A., Jori, F., Martínez-López, B., et al. (2016a) Wild and Domestic Pig interactions at the Wildlife–livestock interface of Murchison Falls National Park, Uganda, and the Potential association with african swine Fever Outbreaks. *Frontiers in Veterinary Science*, 3(31).

Kukielka, D., Rodriguez-Prieto, V., Vicente, J., Sanchez-Vizcaíno, J. M. (2016b) Constant Hepatitis E Virus (HEV) Circulation in Wild Boar and Red Deer in Spain: an increasing Concern Source of HEV Zoonotic Transmission. *Transboundary and Emerging Diseases*, 63: 360-368.

Lowe, S., Browne, M., Boudjelas, S., De Poorter, M. (2000) *100 of the world's worst invasive alien species A selection from the global invasive species database*. Published by The Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN), p. 12.

MacKenzie, D. I., Nichols, J. D., LacHman, G. D. et al. (2002) Estimating site occupancy rates when detection probabilities are less than one. *Ecology*, 83(8): 2248–2255.

McComb, L. B.; Lentini, P. E.; Harley, D. K. P. et al. (2018) Feral cat predation on Leadbeater's possum (*Gymnobelideus leadbeateri*) and observations of arboreal hunting at nest boxes. *Australian Mammalogy*.

Mugume, S., Isabirye-Basuta, G., Otali, E. et al. (2015) How do human activities influence the status and distribution of terrestrial mammals in forest reserves? *Journal of Mammalogy*, 96(5): 998–1004.

Oliveira T. G. de, Cassaro, K. (2005) *Guia de campo dos felinos do Brasil*. Instituto Pró-Carnívoros/Fundação Parque Zoológico de São Paulo/Sociedade de Zoológicos do Brasil/Pró-Vida Brasil, São Paulo, SP.

Oliveira, T.G. de. (2011) *Ecologia e conservação de pequenos felinos no Brasil e suas implicações para o manejo*. 2011. Tese de Doutorado. Universidade Federal de Minas Gerais.

Oliveira, T. G. de, Araújo, L. P., Lacerda, M. G. (2014) Diagnóstico do Parque Estadual do Mirador**.** In: *Programa de Gestão Compartilhada do Parque Estadual do Mirador*. PRÓ-VIDA BRASIL/ SEMA. PRÓ-VIDA BRASIL/ SEMA. p. 3-28, 2014. Relatório de pesquisa.

Peters, F. B., Mazim, F. D., Favarini, M. O. et al. (2017) Cacería vengativa de felinos por humanos en el extremo sur de Brasil. In: *II. Conflicto entre felinos y humanos en América Latina* (C. Castaño-Uribe, C. A. Lasso, R. Hoogesteijn, E. Payán-Garrido),

Serie Editorial Fauna Silvestre Neotropical. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH), Bogotá, D. C., Colombia. p. 481.

Rodrigues, M. S., Conceição, G. M. (2014) Diversidade florística das diferentes fisionomias de Cerrado do Parque Estadual do Mirador, Maranhão, Brasil. *Brazilian Geographical Journal: Geosciences and Humanities research medium*, 5(1): 139-156.

Russell, J. C.; Abrahão, C. R.; Silva, J. C.R.; Dias, R. A. (2018) Management of cats and rodents on inhabited islands: An overview and case study of Fernando de Noronha, Brazil. *Perspectives in Ecology and Conservation*, v. 16, n. 4, p. 193-200.

Santos, C. L. A. dos, Silva, A. P., Santos, S. B. dos. et al. (2017) Dog invasion in agroforests: The importance of households, roads and dog population size in the surroundings. *Perspectives in Ecology and Conservation*, 15: 221–226.

Silva, A. C. C., Prata, A. P. N., Souto, L. S., Mello, A. A. (2013) Aspectos de ecologia de paisagem e ameaças à biodiversidade em uma unidade de conservação na Caatinga, em Sergipe. *Revista Árvore*, 37(3): 479-490.

Stokeld, D., Fisher, A., Gentles, T. et al. (2018) Rapid increase of Australian tropical savanna reptile abundance following exclusion of feral cats. *Biological Conservation*, 225: 213–221.

Takahashi, K., Kitajima, N., Abe, N., Mishiro, S. (2004) Complete or near-complete nucleotide sequences of hepatitis E virus genome recovered from a wild boar, a deer, and four patients who ate the deer. *Virology*, 330: 501– 505.

Vijayan, S., Morris, D. W., McLaren, B. E., Mukherjee, S. (2017) Domestic ungulates in protected areas and the potential for indirect interactions via shared predation. *Biodiversity*, 18(4).

Woinarski, J.C.Z., Woolley, L. A., Garnett, S. T. et al. (2017a) Compilation and traits of Australian bird species killed by cats. *Biological Conservation*, 216: 1-9.

Woinarski, J. C. Z., Murphy, B. P., Legge, S. M. et al. (2017b) How many birds are killed by cats in Australia? *Biological Conservation*, 214: 76-87.

Zapata-Ríos, G.; Branch, L. C. (2016) Altered activity patterns and reduced abundance of native mammals in sites with feral dogs in the high Andes. *Biological Conservation*, 193: 9–16.

Zapata-Ríos, G., Branch, L. C. (2018) Mammalian carnivore occupancy is inversely related to presence of domestic dogs in the high Andes of Ecuador. *Plos One*, 13(2).

## CONCLUSÃO

O presente trabalho realça a problemática existente no Parque Estadual do Mirador por meio de evidências como a abundância destas espécies invasoras, bem como as áreas naturais que utilizam. Em posse dessas informações é possível desenvolver estratégicas de manejo e mitigação do problema.

Além disso, este trabalho se mostra importante para a comunidade científica e conservacionistas, pois são apresentados dados de monitoramento de cinco espécies domésticas em Unidade de Conservação algo ainda não realizado para tal quantitativo. Dessa forma chamando atenção para o PEM, visto que esta deveria ser uma área prioritária para conservação.

## REFERÊNCIAS BIBLIOGRÁFICAS

ARRUDA, R. C. N.; GOULART, C. S.; MARQUES, G. H. F.; et al. Raiva em ruminantes domésticos no maranhão: uma análise da Percepção de médicos veterinários oficiais. **Pesquisa em Foco**, v. 16, n. 1, p. 1-6, 2008.

ATHREYA, V.; ODDEN, M.; LINNELL, J. D. C.; KRISHNASWAMY, J.; KARANTH, K. U. A cat among the dogs: leopard *Panthera pardus* diet in a human-dominated landscape in western Maharashtra, India. **Oryx**, v.50, n. 1, p. 156–162, 2016.
AZEVEDO, F. C. C. DE.; CONFORTI, V. A. Fatores predisponentes à predação. In: PITMAN, M. R. P. L. (Org.) et al. **Manual de identificação, prevenção e controle de predação por Carnívoros**. Brasília: IBAMA, p. 83, 2002.

AZEVEDO, F. C. C. DE. The impact of domestic animal predation by large carnivores. How does this affect the conservation of keystone species?. In: Morato, R.G. (Org.) et al. **Manejo e conservação de carnívoros neotropicais**. 2. ed. São Paulo: Ibama, p. 169-182, 2006.

BAKER, P. J.; BENTLEY, A. J.; ANSELL, R. J.; HARRIS, S. Impact of predation by domestic cats *Felis catus* in an urban area. **Mammal Review**, *v.* 35, n. 3, p. 302–312, 2005.

BALLARI, S. A.; CUEVAS, M. F.; CIRIGNOLI, S.; VALENZUELA, A. E. J. Invasive wild boar in Argentina: using protected areas as a research platform to determine distribution, impacts and management. **Biological Invasions, v.**17, p. 1595-1602, 2014.

BESSA, E.; BLUMSTEIN, D. T.; SAMIA, D. S. M.; GEFFROY, B. Pets at ecotourism estinations: cute mascot or trojan horse? **Current Issues in Tourism**, 2018.

BIRÓ, ZS; LANSZKI, J.; SZEMETHY, L. Feeding habits of feral domestic cats (*Felis catus*), wild cats (*Felis silvestris*) and their hybrids: trophic niche overlap among cat groups in Hungary. **Journal of Zoology**, v. 266, p. 187-196, 2005.

CAMPOS, C. B. DE. **Impacto de cães (*Canis familiaris*) e gatos (*Felis catus*) errantes sobre a fauna silvestre em ambiente peri-urbano**. 2004. 71 f. Dissertação (Mestrado em Ecologia de Agroecossistemas) – Universidade de São Paulo, Piracicaba, 2004.

CARUSO, C.; PELETTO, S.; ROSAMILIA, A. et al. Hepatitis E Virus: A cross-sectional serological and virological study in pigs and humans at zoonotic risk within a high-density pig farming area. **Transboundary and Emerging Diseases**, v. 64, p. 1443-1453, 2017.

CAVALCANTI, S. M. C. Aspects of livestock depredation by jaguars in the southern Pantanal, Brasil. In: Morato, R.G. (Org.) et al. **Manejo e conservação de carnívoros neotropicais.** 2. ed. São Paulo: Ibama, p. 215-228, 2006.

DRISCOLL, C. A.; MACDONALD, D. W. Top dogs: wolf domestication and wealth. **Journal of Biology**, v. 9, n. 2, 10, 2010.

FIORELLO, C. V.; DEEM, S. L.; GOMPPER, M. E.; DUBOVI, E. J. Seroprevalence of pathogens in domestic carnivores on the border of Madidi National Park, Bolivia. **Animal Conservation**, v. 7, p. 45–54, 2004.

GALETTI, M.; SAZIMA, I. Impacto de cães ferais em um fragmento urbano de Floresta Atlântica no sudeste do Brasil. **Natureza & Conservação,** v. 4, n. 1, p. 58-63, abr. 2006.

GATTI, A.; SEIBERT, J. B.; MOREIRA, D. O. A predation event by free–ranging dogs on the lowland tapir in the Brazilian Atlantic Forest. **Animal Biodiversity and Conservation**, v. 41, n.2, 2018.

GERHOLD, R. W.; JESSUP, D. A. Zoonotic Diseases Associated with Free-Roaming Cats. **Zoonoses and Public Health**, v. 60, n. 3, p. 189-195, 2012.

GOMES, A. A. B. **Epidemiologia da raiva: caracterização de vírus isolados de animais domésticos e silvestres do semi-árido paraibano da região de Patos, Nordeste do Brasil**. 2004. 107f. Tese (Doutorado em Medicina Veterinária) – Faculdade de Medicina Veterinária e Zootecnia, Universidade de São Paulo, São Paulo, 2004.

INSKIP, C.; ZIMMERMANN, A. Human-felid conflict: a review of patterns and priorities worldwide. **Oryx**, v. 43, n. 1, p. 18–34, 2009.

KAYS, R. W.; DEWAN, A. A. Ecological impact of inside/outside house cats around a suburban nature preserve. **Animal Conservation**, v. 7, p. 273-283, 2004.

KOCK, R.; CHALMERS, W. S. K.; MWANZIA, J. et al. Canine distemper antibodies in lions of the Masai Mara. **Veterinary Record**, v. 142, p. 662-665, 1998.

KUKIELKA, E. A.; JORI, F.; MARTÍNEZ-LÓPEZ, B., et al. Wild and Domestic Pig interactions at the Wildlife–livestock interface of Murchison Falls National Park, Uganda, and the Potential association with african swine Fever Outbreaks. **Frontiers in Veterinary Science**, v., 3, n. 31, 2016a.

KUKIELKA, D.; RODRIGUEZ-PRIETO, V.; VICENTE, J.; SANCHEZ-VIZCAÍNO, J. M. Constant Hepatitis E Virus (HEV) Circulation in Wild Boar and Red Deer in Spain: an increasing Concern Source of HEV Zoonotic Transmission. **Transboundary and Emerging Diseases**, v. 63, p. 360-368, 2016b.

LOSS, S. R.; WILL, T.; MARRA, P. P. The impact of free-ranging domestic cats on wildlife of the United States. **Nature Communications**, v. 4, p. 1396, 2012.

LOVERIDGE, A. J., WANG, S. W., FRANK, L. G.; SEIDENSTICKER, J. People and wild felids: conservation of cats and management of conflicts. In **Biology and Conservation of Wild Felids** (eds D.W. MACDONALD; A.J. LOVERIDGE), p. 161–195. Oxford University Press, Oxford, UK, 2010.

LOWE, S., BROWNE, M., BOUDJELAS, S., DE POORTER, M. **100 of the world's worst invasive alien species A selection from the global invasive species database.** Published by The Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN), p. 12, 2000.

MCCOMB, L. B.; LENTINI, P. E.; HARLEY, D. K. P.; LUMSDEN, L. F. et al. Feral cat predation on Leadbeater's possum (*Gymnobelideus leadbeateri*) and observations of arboreal hunting at nest boxes. **Australian Mammalogy**, 2018.

MCMANUS, J. S.; DICKMAN, A. J.; GAYNOR, D. et al. Dead or alive? Comparing costs and benefits of lethal and non-lethal human–wildlife conflict mitigation on livestock farms. **Oryx**, v. 49, n. 4, p. 687–695, 2015.

MEDINA, F. M.; BONNAUD, E.; VIDAL, E. et al. A global review of the impacts of invasive cats on island endangered vertebrates. **Global Change Biology**, 17, p. 3503–3510, 2011.

METZGER, J. P; ALVES, L. F.; PARDINI, R. et al. Características ecológicas e implicações para a conservação da Reserva Florestal do Morro Grande. **Biota Neotropica**, v. 6, n. 2, 2006.

MINISTÉRIO DO MEIO AMBIENTE (MMA). **Monitoramento do desmatamento nos biomas brasileiros por satélite. Cerrado 2010-2011**. Brasília - DF, 2015.

OLIVEIRA, T. G. DE. Carnívoros do Maranhão: preliminares sobre a distribuição, composição das comunidades e conservação no meio-norte do Brasil. In: SILVA, A. C. DA. (Org.); FORTES, J. L. O (Org.). **Diversidade biológica, uso e conservação de recursos naturais do Maranhão: projetos e ações: em Biologia e Química Vol II**. São Luís: UEMA, p. 347-366, 2007.

OLIVEIRA, T. G. DE.; ARAÚJO, L. P.; LACERDA, M. G. Diagnóstico do Parque Estadual do Mirador**.** In: **Programa de Gestão Compartilhada do Parque Estadual do Mirador.** PRÓ-VIDA BRASIL/ SEMA. PRÓ-VIDA BRASIL/ SEMA. p. 3-28, 2014. Relatório de pesquisa.

OLIVEIRA, T. G. DE.; VIEIRA, O. Q.; CAVALCANTI, G. N. et al. Mamíferos. In: **Programa de Monitoramento de fauna e flora do Parque Estadual do Mirador do Programa de Gestão Compartilhada do Parque Estadual do Mirador.** PRÓ-VIDA BRASIL/ SEMA. p. 150-181, 2014. Relatório de pesquisa.

PETERS, F. B.; MAZIM, F. D.; FAVARINI, M. O. et al. Cacería vengativa de felinos por humanos en el extremo sur de Brasil. In: **II. Conflicto entre felinos y humanos en América Latina** (C. CASTAÑO-URIBE, C. A. LASSO, R. HOOGESTEIJN, E. PAYÁN-GARRIDO), Serie Editorial Fauna Silvestre Neotropical. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH), Bogotá, D. C., Colombia. P. 481, 2017.

PRADO, M. R.; ROCHA, E. C.; GIUDICE, G. M. L. Mamíferos de médio e grande porte em um fragmento de Mata Atlântica, Minas Gerais, Brasil. **Revista Árvore**, Viçosa-MG, v.32, n.4, p.741-749, 2008.

QUEIROGAS, V. L.; OLIVEIRA, L. M.; MARQUES, R. L. et al. Carrapatos (Acari: Ixodidae) em cães domésticos no Parque Estadual Serra de Caldas Novas, Goiás: considerações epidemiológicas. **Biota Neotropica**, v.10, n.1, p. 347-349, 2010.

RECIO, M. R.; ARIJA, C. M.; CABEZAS-DÍAZ, S.; VIRGÓS, E. Changes in Mediterranean mesocarnivore communities along urban and ex-urban gradients. **Current Zoology**, v. 65, n. 1, p. 793–801, 2015.

ROELKE-PARKER, M. E.; MUNSON, L.; PACKER, C. et al. A canine distemper virus epidemic in Serengeti lions (*Panthera leo*). **Nature**, 379, 441-445, 1996.

ROSA, M. R. **Áreas Prioritárias Para Conservação, Uso Sustentável E repartição de benefícios da biodiversidade brasileira: Atualização - Portaria MMA n° 9, de 23 de janeiro de 2007.** Ministério do Meio Ambiente, Secretaria de Biodiversidade e Florestas. Brasília: MMA, p. 55- 62, 2007.

RUSSELL, J. C.; ABRAHÃO, C. R.; SILVA, J. C.R.; DIAS, R. A. Management of cats and rodents on inhabited islands: An overview and case study of Fernando de Noronha, Brazil. **Perspectives in Ecology and Conservation**, v. 16, n. 4, p. 193-200, 2018.

STOKELD, D.; FISHER, A.; GENTLES, T. et al. Rapid increase of Australian tropical savanna reptile abundance following exclusion of feral cats. **Biological Conservation**, v. 225, p. 213–221, 2018.

TABORSKY, M. Kiwis and dog predation: observations in Waitangi State Forest. **Notornis**, v. 35, n. 3, p. 196-202, 1988.

TAKAHASHI, K.; KITAJIMA, N.; ABE, N.; MISHIRO, S. Complete or near-complete nucleotide sequences of hepatitis E virus genome recovered from a wild boar, a deer, and four patients who ate the deer. **Virology**, v. 330, p. 501– 505, 2004.

UHART, M. M.; RAGO, M. V.; MARULL, C. A. Exposure to selected pathogens in geoffroy's cats and domestic carnivores from central Argentina. **Journal of Wildlife Diseases**, v. 48, n. 4, p. 899–909, 2012.

WESTON, M. A.; FITZSIMONS, J. A.; WESCOTT, G. et al. Bark in the Park: A Review of Domestic Dogs in Parks. **Environmental Management**, v. 54, p. 373–382, 2014.

WHITEMAN, C. W.; MATUSHIMA, E. R.; CONFALONIERI, U. E. C. et al. Human and domestic animal populations as a potential threat to wild carnivore conservation in a fragmented landscape from the Eastern Brazilian Amazon. **Biological Conservation**, v. 138, p. 290–296, 2007.

WOODROFFE, R. Managing disease threats to wild mammals. In **Animal Conservation forum**. Cambridge University Press, 1999.

WOODS, M.; MCDONALD, R. A.; HARRIS, S. Predation of wildlife by domestic cats *Felis catus* in Great Britain. **Mammal Review**, v. 33, n. 2, p. 174–188, 2003.

YOUNG, J. K.; OLSON, K. A.; READING, R. P. et al. Is wildlife going to the dogs? Impacts of feral and free-roaming dogs on wildlife populations. **BioScience**, v. 61, n. 2, 125-132, 2011.

ZAPATA-RÍOS, G.; BRANCH, L. C. Altered activity patterns and reduced abundance of native mammals in sites with feral dogs in the high Andes. **Biological Conservation**, v. 193, p. 9–16, 2016.