

BRENO CAMPELO LIMA

**A REFINED POPULATION AND OCCUPANCY ASSESSMENT
OF TWO ENDANGERED FELIDS: NORTHERN TIGER CAT
(*Leopardus tigrinus*) AND PAMPAS CAT (*Leopardus colocola*) IN
THE NORTHERN SAVANNAS OF BRAZIL**



SÃO LUÍS

2020

BRENO CAMPELO LIMA

**A REFINED POPULATION AND OCCUPANCY
ASSESSMENT OF TWO ENDANGERED FELIDS:
NORTHERN TIGER CAT (*Leopardus tigrinus*) AND PAMPAS
CAT (*Leopardus colocola*) IN THE NORTHERN SAVANNAS
OF BRAZIL**

Dissertação de Mestrado apresentada ao Programa de Pós-Graduação em Ciência Animal PPGCA/UEMA, como parte dos requisitos para obtenção do título de Mestre em Ciência Animal, área de concentração em Reprodução e Conservação Animal

Orientador: Prof. Dr. Tadeu Gomes de Oliveira

SÃO LUÍS

2020

Lima, Breno Campelo.

A refined population and occupancy assessment of two endangered felids: northern tiger cat (*Leopardus tigrinus*) and pampas cat (*Leopardus colocola*) in the northern savanas of Brazil / Breno Campelo Lima. – São Luís, 2020.

96 f

Dissertação (Mestrado) – Curso de Ciência Animal, Universidade Estadual do Maranhão, 2020.

Orientador: Prof. Tadeu Gomes de Oliveira.

1.*Leopardus tigrinus*. 2.*Leopardus colocola*. 3.Domestic dogs. 4.Occupation models. 5.Viability Analysis.6.Population density analysis.
I.Título

CDU: 636.8(213.54)



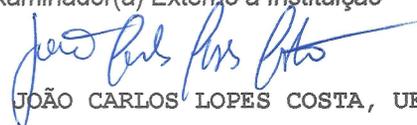
Universidade Estadual do Maranhão
PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIA ANIMAL

ATA Nº 45

Aos dezesseis dias do mês de março de dois mil e vinte, às quinze horas, compareceu à Sala de Aula da Pós-Graduação PPGCA-LAMP/UEMA, o Pós-Graduando Breno Campelo Lima, para apresentar e defender a dissertação intitulada "Parâmetros ecológicos-ambientais e status populacional de espécies ameaçadas: Leopardus tigrinus e Leopardus colocola no Parque Estadual do Mirador - MA", perante a Banca Examinadora de dissertação abaixo relacionada. Após a apresentação e arguição pelos membros da Banca, o pós-graduando foi considerado (aprovado/reprovado), APROVADO, conferindo-o o título de "Mestre em Ciência Animal", conforme as normas vigentes na Universidade Estadual do Maranhão-UEMA. Encerrados os trabalhos foi lavrado a presente ATA que, eu, professor Dr. Tadeu Gomes de Oliveira (Orientador), li e após aprovada, recebeu a assinatura dos membros da Banca. A versão final da Dissertação deverá ser entregue ao Programa, no prazo de 60 dias, contendo as modificações sugeridas pela banca examinadora e constante na folha de correção anexa.


Dr. (a) ADRIANI HASS, UFMA

Examinador(a) Externo à Instituição


Dr. (a) JOÃO CARLOS LOPES COSTA, UEMA

Examinador(a) Externo à Instituição


TADEU GOMES DE OLIVEIRA, UEMA

Presidente(a)


BRENO CAMPELO LIMA

Mestrando(a)

AGRADECIMENTOS

Ao meu tripé vital: meus pais, meus avós e minha madrinha por todo amor e compreensão. Esse sentimento me inspira, motiva e me faz querer sempre mais. Todos os meus sacrifícios são para vocês e por vocês. Obrigado por tudo! Em especial, queria externalizar toda gratidão do mundo a minha mãe. Eu me inspiro nessa sua vontade de viver. Mesmo com todas as dificuldades nunca mediu esforços para me proporcionar o melhor. Por isso eu luto todo dia para retribuir todo esse sacrifício. Eu te amo mãe e é pela senhora que tento melhorar.

Ao Prof. Dr. Tadeu Gomes de Oliveira, pela orientação. Obrigado pela oportunidade e por todos os conselhos que levarei para vida pessoal e profissional. Agradeço-lhe pelo estímulo e confiança. Enfim, independente do caminho que a vida me levar, sempre direi que tive um Paizão na ciência. Sou seu fã!

Ao meu amigo Odgley Quixaba. Serei eternamente grato pelos conselhos nos bastidores e pelos momentos de descontração. Aproveito esse momento para agradecer aos meus cúmplices Mastozoologia: Vítor Emanuel, Renata Soraya, Rayana Diniz, Laís Everton, Diogo Silva e Lester Fox. Vocês foram minha segunda família nesses dois anos de mestrado. Com vocês passei por momentos felizes, tristes e tensos. Com vocês compartilhei frustrações, conquistas e aprendi muita coisa. Compartilhamos segredos e criamos uma cumplicidade vital para sobreviver aos dias difíceis. Muito obrigado!

Aproveito esse espaço para agradecer especialmente a uma pessoa que passei a considerar como um irmão - meu amigo Lester Fox. “Sio” é até difícil escrever um agradecimento diante das inúmeras situações que passamos. Obrigado pelas aulas de programação e pelos macetes na estatística. Além disso, nunca conheci ninguém mais humilde, responsável e parceiro como você. Obrigado por ser esse baita amigo. Tu fazes parte da família e espero ainda compartilhar muitas histórias contigo. Tu és meu irmão na ciência e de estrada. Sou teu fã!

. Não tem como deixar passar meu trio da graduação. Minhas irmãs Eudeanny Maria, Isabel Jansen e Mariana Farias que sempre apoiaram meu desenvolvimento profissional e estiveram presentes nos momentos mais importantes durante toda essa jornada. Eu amo cada uma de vocês e espero que nossa amizade seja eterna. Guardo todos os nossos momentos com muito carinho.

Aos amigos de toda vida Lucas de Lima, Felipe Garreto e Wilber Presley. Devo muitas coisas a vocês. Não tem como explicar nossa amizade, mas tem como comemorar a existência dela. Fico extremamente feliz por crescer ao lado de vocês, por compartilhar momentos bons. Eu amo cada um de vocês.

Almerinda Medeiros, eu te agradeço por ressurgir na minha vida em um momento vital. Agradeço pelo companheirismo, pela paciência e pelos inúmeros conselhos. Tu és uma baita profissional e é na tua jornada que me espelho. Obrigado por sonhar meus sonhos, amo-te.

Agradeço a todo corpo docente do PPGCM e em especial a Prof^a Dr. Allana Lislea e a nossa especial Fran. Sou eternamente grato pelos conselhos e pela ajuda durante essa caminhada. Aproveito para agradecer a Universidade Estadual do Maranhão por toda a contribuição na minha formação e pela FAPEMA pela concessão da bolsa de pesquisa.

“O homem nunca tem o bastante sem ter em demasia”
(James Lovelock)

SUMÁRIO

APRESENTAÇÃO.....	6
--------------------------	----------

CAPÍTULO 1

A refined population and conservation assessment of the elusive and endangered northern tiger cat (<i>Leopardus tigrinus</i>) in its key worldwide conservation area in Brazil.....	9
--	----------

CAPÍTULO 2

Of small cats and dogs: Interspecific relationships of wild and domestic carnivores in the northern savannas of Brazil.....	63
--	-----------

APRESENTAÇÃO

O Brasil é considerado como um dos países de maior diversidade biológica por abrigar mais de 10% das formas viventes no planeta (MYERS et al., 2000) que estão distribuídas nos mais variados ambientes. Nesse contexto, encontra-se o Cerrado, também chamado de savana brasileira. Esse bioma ocupa o ranking de segundo maior bioma brasileiro, ocupando uma área com mais 2 milhões de km², equivalente a 23% do território brasileiro (EITEN 1972, AB'SABER, 1977).

Também reconhecido como hotspot, o Cerrado padece com um intenso processo de conversão da cobertura vegetal por atividades produtivas, tendo perdido mais de 51% da sua cobertura original. Dentre as regiões apontadas como prioritárias para conservação da biodiversidade do Cerrado, encontra-se a segunda maior Unidade de Conservação (UC) do Cerrado – o “Parque Estadual do Mirador” (PEM).

O PEM apresenta uma importância singular para conservação da biodiversidade. Apesar disso, estudos preliminares apontam uma grande riqueza dos mais variados grupos, especialmente para a mastofauna. Dados pretéritos, sugerem o PEM como uma importante UC na conservação de espécies mundialmente ameaçadas, como os felinos *Leopardus tigrinus* (Schreber, 1775) (gato-do-mato/gato-pintado) e *Leopardus colocola* (Molina, 1782) (gato-palheiro). Diante do exposto, o PEM passou a ser considerado pela IUCN como uma das áreas mais importantes para a conservação ao nível mundial desses felinos ameaçados.

Esta dissertação abordará aspectos ecológicos e conservacionistas de duas espécies de felinos ameaçados *Leopardus tigrinus* e *Leopardus colocola* na porção norte do Cerrado brasileiro. O manuscrito foi dividido em dois capítulos que estarão estruturados de acordo com as normas das revistas de interesse para publicação.

Capítulo I - A refined population and conservation assessment of the elusive and endangered northern tiger cat (*Leopardus tigrinus*) in its key worldwide conservation area in Brazil

Neste capítulo é apresentado a primeira estimativa de densidade publicada para *Leopardus tigrinus*. Também foi realizado uma Análise de Viabilidade Populacional (PVA) e avaliado o impacto de cães domésticos na população do gato-do-mato do Parque.

Adicionalmente, extrapolamos as análises de densidade para outras áreas que compõem o corredor na porção norte da Reserva da Biosfera do Cerrado.

As estimativas de densidade de gato-do-mato foram de 0,12 e 0,25 indivíduos / km² (através da análise não-espacial) ou 0,087 e 0,11 indivíduos / km² (na análise espacial), enquanto as abundâncias relativas variaram de 0,124-2,168 indivíduos/100 noites de armadilha. A população foi estimada em 522 indivíduos, o PVA estimou uma probabilidade de extinção de 0% nos próximos 100 e 1.000 anos, em cenários de surtos leves a inexistentes de doença. Ao extrapolar as análises para a Reserva da Biosfera, os resultados indicaram que a população é de aproximadamente 700 indivíduos no complexo de áreas protegidas que compõem a porção norte da Reserva da Biosfera e de 2000 a 3000 indivíduos em toda área considerada habitável pela espécie na Reserva. Artigo publicado na Revista Global Ecology and Conservation em janeiro de 2020 (<https://doi.org/10.1016/j.gecco.2020.e00927>).

Capítulo II - Of small cats and dogs: Interspecific relationships of wild and domestic carnivores in the northern savannas of Brazil

Neste capítulo abordamos a influência de variáveis ambientais e antrópicas nos mecanismos de exploração espaço-temporal dos pequenos felinos *Leopardus tigrinus* e *Leopardus colocola* no Parque Estadual do Mirador. Utilizamos Modelos Lineares Generalizados (GLM) e Modelos de Ocupação (OM) para estimar a influência das covariáveis nos padrões de uso do habitat, também extrapolamos seus efeitos para os locais amostrados. Adicionalmente, analisamos padrões de atividade para ambas as espécies.

Os registros foram obtidos entre maio de 2018 e março de 2019 com 30 armadilhas fotográficas instaladas em duas áreas dentro do parque, totalizando 4.312 armadilhas. Obtivemos uma taxa de ocupação natural de 0,23 e 0,50 para *L. colocola* e *L. tigrinus*, respectivamente. A detectabilidade de ambas as espécies foi afetada diretamente pela estrutura da vegetação, enquanto as análises de seleção de habitat mostraram que *L. tigrinus* evitava áreas próximas a assentamentos humanos e com alta intensidade de uso por cães domésticos; por outro lado, a seleção do habitat de *L. colocola* foi influenciada principalmente pela estrutura da vegetação. As espécies de gatos e os cães domésticos apresentaram um grau moderado de sobreposição temporal, enquanto houve uma segregação temporal significativa entre os dois felídeos; o maior nível de sobreposição

de atividades foi observado entre *L. tigrinus* e *Cerdocyon thous*. O artigo foi estruturado de acordo com as normas da Revista de interesse para publicação – Perspectives in Ecology and Conservation.

CAPITULO I

Artigo publicado na Global Ecology and Conservation

Doi: <https://doi.org/10.1016/j.gecco.2020.e00927>

1 **A refined population and conservation assessment of the elusive and endangered**
2 **northern tiger cat (*Leopardus tigrinus*) in its key worldwide conservation area in**
3 **Brazil**

4

5 Tadeu G. de Oliveira^{1a,2}, Breno C. Lima^{1b}, Lester Fox-Rosales³, Renata S. Pereira^{1c}, Elienê
6 Pontes-Araújo⁴ and Alana L. de Sousa^{1d}

7 1. Programa de Pós-Graduação em Ciência Animal, Universidade Estadual do Maranhão (UEMA),
8 Campus Paulo VI, Av. Lourenço Vieira da Silva 1000, Jardim São Cristóvão, São Luís, MA, 65055-310,
9 Brazil.

10 a. tadeu4@yahoo.com <http://orcid.org/0000-0002-8760-3159> (Corresponding author)

11 b. brenocampelolima@hotmail.com <http://orcid.org/0000-0003-3327-4676>

12 c. renatasoraya.p@gmail.com <http://orcid.org/0000-0002-4894-839X>

13 d. alislea@hotmail.com <http://orcid.org/0000-0002-0920-2560>

14 2. Instituto Pró-Carnívoros, Av. Horácio Neto 1030, Parque Edmundo Zaroni, Atibaia, SP 12945-010,
15 Brazil.

16 3. Workgroup Endangered Species Conservation. Georg-August Universität, Bürgerstrasse 50, 37073
17 Göttingen, Germany. lesteral94@hotmail.com <http://orcid.org/0000-0003-0582-284X>

18 4. Núcleo Geoambiental/Laboratório de Geoprocessamento, UEMA, Campus Paulo VI, Av. Lourenço
19 Vieira da Silva 1000, Jardim São Cristóvão, São Luís, MA, 65055-310, Brazil.
20 elienepontes@yahoo.com.br <http://orcid.org/0000-0002-4768-7722>

21

22

23

24

25 **Abstract**

26 The northern tiger cat (*Leopardus tigrinus*) is one of Brazil's least studied felids, with no
27 published population density estimates. A potential key conservation unit for the species
28 is Mirador State Park (MSP) in NE Brazil, an area that also hosts humans and domestic
29 dogs. Therefore, we assessed the park's importance in terms of tiger cat conservation and
30 whether domestic dogs present a threat to the survival of this species. We established 52
31 camera trap stations at three sites and monitored them for a total of 5,030 trap-days. We
32 calculated population densities using spatial and nonspatial methods and relative
33 abundances in MSP and extrapolated these results to the other protected areas and corridor
34 that comprise the northern portion of the Cerrado Biosphere Reserve. We conducted a
35 population viability analysis for tiger cats in the park and assessed the potential impact of
36 domestic dogs. The tiger cat density estimates were 0.12 and 0.25 individuals/km²
37 (nonspatial) and 0.087 and 0.11 individuals/km² (spatial), whereas the relative
38 abundances ranged from 0.124-2.168 individuals/100 trap-nights. The tiger cat
39 population was estimated at 287 individuals, with 0% extinction probability within the
40 next 100 and 1,000 years, but only in scenarios of mild to no disease outbreaks. Large
41 outbreaks or habitat loss will be detrimental to species survival in the area. Domestic dogs
42 were detected at 80% of the stations where tiger cats were observed. The threat of disease
43 transmission by domestic dogs potentially impacts 65% of the park and seems to be the
44 primary threat for the species there. The northern tiger cat population was estimated at
45 approximately 700 individuals in the entire protected area of the northern savannas, which
46 together with the additional corridor of the Cerrado Biosphere Reserve could yield up to
47 2,000-3,000 individuals. Our results provide the first published density estimates of tiger
48 cats and confirm the potential threat of domestic dogs to this felid in Mirador, thereby
49 confirming the park's importance as a key area for tiger cat conservation and the need for

50 conservation actions. Given its density and abundance of tiger cats, as well as its area
51 size, compared to other locations in the northern savannas, MSP may be the most
52 important site for the worldwide, long-term conservation of *Leopardus tigrinus*.

53

54

55 **Keywords:** *Leopardus tigrinus*; northern savannas of Brazil; Northern tiger cat;
56 population and conservation assessments; population viability analysis; spatial and
57 nonspatial density.

58

59 **Highlights:**

- 60 ➤ The first density estimates for *Leopardus tigrinus* are reported.
- 61 ➤ This is the first PVA analysis conducted for a small cat in tropical America.
- 62 ➤ Populations will be viable with mild-disease but nonviable with a large outbreak
63 or habitat loss.
- 64 ➤ Disease transmission by domestic dogs is the primary threat for the species in
65 MSP.
- 66 ➤ MSP is the most important site for the long-term conservation of *Leopardus*
67 *tigrinus*.

68

69

70 **1. Introduction**

71 Conservation often requires population estimates to improve or identify a proper course
72 of action, information that is lacking for most species of small cats (< 15 kg). Because of
73 advances in methods and programs pertaining to camera trapping (e.g., Sollman et al.,
74 2011; Tobler and Powell, 2013), this scenario is beginning to change for the smaller and
75 lesser-known species of Felidae (Caruso et al., 2012; Mohamed et al., 2013; Naing et al.,
76 2017). The northern tiger cat (*Leopardus tigrinus*) is a small-sized felid (ca. 2.4 kg; Figure
77 1) whose currently recognized range from Costa Rica to central Brazil is still being
78 defined (Payan and de Oliveira, 2016; de Oliveira et al. unpubl. data). There is a very poor
79 understanding of the demography, ecology and natural history of *L. tigrinus*, with very
80 few available estimates of abundance and occupancy (Oliveira, 2011; Marinho et al.,
81 2017; Oliveira, 2018; Dias et al., 2019). Furthermore, most ecological studies conducted
82 before the species split investigated what is now considered *Leopardus guttulus* (e.g.,
83 Tortato and Oliveira, 2005; Oliveira-Santos et al., 2012). Only recently has *L. tigrinus*
84 become the subject of long-term studies (Oliveira et al., 2008, 2018; Oliveira, 2011;
85 Marinho et al., 2017; Oliveira, 2018; Dias et al., 2019). This species is the only carnivore
86 listed as Endangered in Brazil and as Vulnerable worldwide (Oliveira et al., 2018a; Payan
87 and de Oliveira, 2016).



88

89 Figure 1. Northern tiger cat (*Leopardus tigrinus*) in its key worldwide conservation area
90 at Mirador State Park in the threatened northern/MATOPIBA savanna of Brazil.

91 It is increasingly known that the impacts of nonnative animals on native wildlife might
92 be much greater than expected. Exotic carnivores can affect wild populations through
93 direct predation, behavioral alteration, and disease transmission to other animals and
94 humans (Weston et al., 2014; Doherty et al., 2017). The effects of predation and diseases
95 of domestic dogs in natural areas are well documented (Young et al., 2011; Doherty et
96 al., 2017). Transmitted diseases include canine distemper virus, parvovirus, and rabies,
97 with cases of wildlife die-off due to these diseases documented within protected areas
98 (Roelke-Parker et al., 1996; Woodroffe, 1999). Therefore, even in fully protected areas,
99 wildlife may still be at risk if domestic dogs are present within them or in adjacent areas.

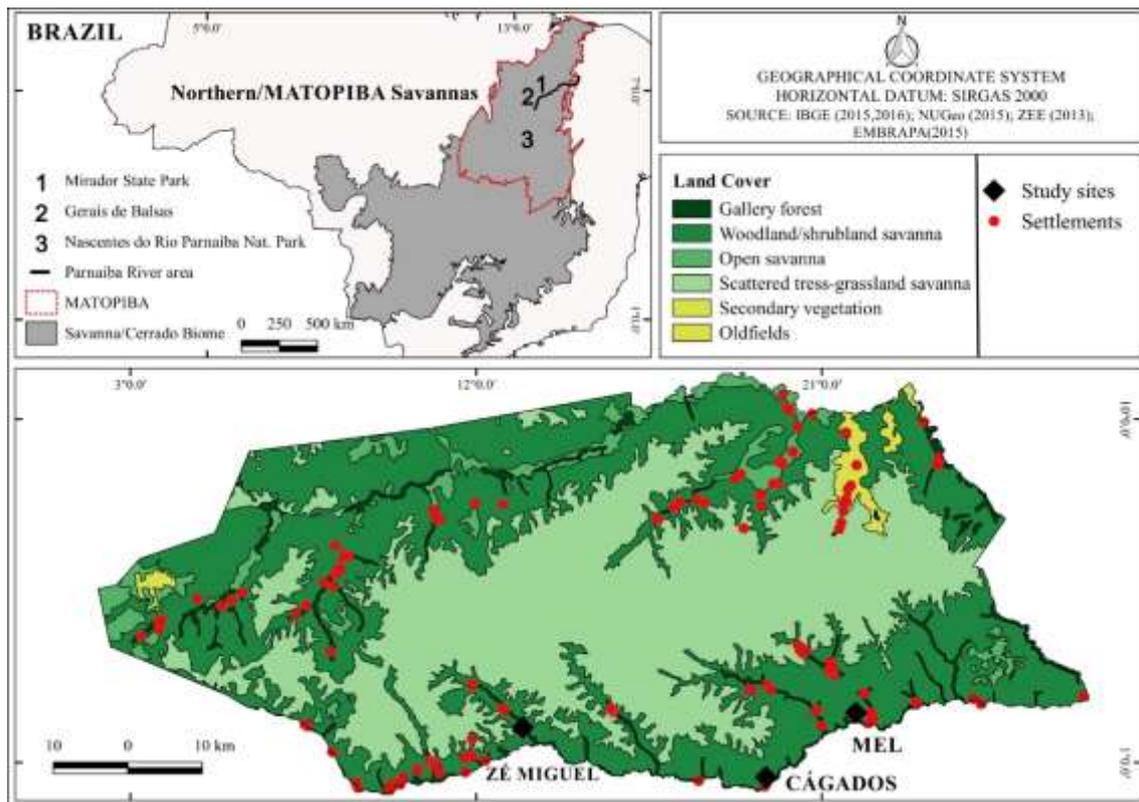
100 This raises the question as to whether certain key conservation units are indeed effectively
101 protecting threatened wildlife.

102 The savannas of the Cerrado biome, a biodiversity hotspot, are currently facing the
103 greatest threats related to habitat loss in Brazil; an annual loss rate of ca. 0.44% has been
104 observed, with >51% of the biome having already been removed and only 8% off limits
105 for development (IBAMA, 2015; NASA, 2018). Current removal is concentrated in the
106 MATOPIBA region (an acronym for the states of Maranhão, Tocantins, Piauí and Bahia),
107 Brazil's new agricultural frontier, where agricultural lands increased by 87% between
108 2000 and 2014 (IBAMA, 2015; NASA, 2018). This area comprises the northern savannas,
109 which are the country's most extensive savannas, and areas of the highest conservation
110 priority, including the entire remaining nonagricultural area surrounding Mirador State
111 Park (MSP; MMA, 2017). This park hosts an impressive number of threatened species
112 and faces several environmental problems (Oliveira, 2014). Among these is the very high
113 presence of domestic animals, including domestic dogs. The tiger cat has long been found
114 to live in the park (Oliveira, 1996), and given some abundance estimates, the park was
115 noted as a possible key worldwide conservation area for the species in the IUCN Red List
116 assessment (Payan and de Oliveira, 2016). Therefore, we asked two main questions: does
117 MSP represent a key conservation area for the endangered northern tiger cat? Could the
118 domestic dogs in the area pose a threat to this species? To answer these questions, the
119 main goals of the current study were to provide estimates of the density and abundance
120 of the population of northern tiger cats in MSP, and assess the role of the park in the long-
121 term conservation and persistence of this species.

122

123 **2. Study Area**

124 MSP is a fully protected conservation area in the Brazilian mid-north (Figure 2). At 5,008
125 km² in size, MSP is the second largest protected area in the Brazilian Cerrado. The park
126 encompasses a series of savanna formations, from open to forested, and includes gallery
127 forests composed mostly of palms (see Rodrigues and Conceição, 2014 for a detailed
128 description). The climate is subhumid, with an annual precipitation of 1,200 mm and
129 mean maximum and minimum temperatures of 31.4-33.0°C and 19.5-21.0°C,
130 respectively (Rodrigues and Conceição, 2014). Preliminary assessments indicated the
131 presence of 28 species of mammals of conservation interest, making MSP a key
132 biodiversity area (Oliveira, 2014). The study sites within MSP were established within
133 three outposts: Mel, Cágados and Zé Miguel (Supplementary Material Fig. S1). Mel and
134 Zé Miguel contain settlements, whereas Cágados does not. The vegetation structure is
135 mostly dense woodland savannas at Mel, semiopen to dense woodland savannas at
136 Cágados, and mostly open savannas at Zé Miguel. Wild and human-induced fires are the
137 only impacts to the vegetation at the sites. Human slash-burn agriculture at the park is
138 conducted mostly near the watersheds, away from the sampling sites. Thus, we
139 considered all sampling sites to be representative of the area's natural vegetative
140 conditions, regardless of their proximity to human settlements.



141

142 Figure 2. Locations of the study sites in the northern savannas of Brazil and the camera-
 143 trapping sites and human settlements in Mirador State Park.

144

145 3. Methods

146 3.1. Camera trapping protocol

147 We deployed passive detection camera traps, the infrared Bushnell Trophy Cam HD
 148 (Bushnell Outdoor Products, Overland Park/Kansas), and the white-flash ScoutGuard
 149 SG565 (Boly Inc., Santa Clara/California) and Reconyx PC850 (Reconyx Inc.,
 150 Holmen/Wisconsin). Typically, >19 camera stations consisting of one unit each were
 151 used in each sampling area (Mel, Cágados). Camera placement followed the same
 152 protocol at all sites, always targeting small felids. All cameras were spaced from 0.5 km
 153 to 1 km apart to guarantee that no animals would have a zero detection probability based
 154 on the known minimum home range size of tiger cats and other Neotropical felids and the

155 typical distance moved by these animals (e.g., Michalski et al., 2006; Oliveira et al., 2010;
156 Kasper et al., 2016). The camera traps were typically placed 20-30 cm high along trails
157 and at other sites with high potential for felid detection. This protocol has been very
158 effective for the detection of felids (Oliveira et al., 2008). Overall, camera trapping was
159 conducted from January 2014 to August 2018 (Table 1). For abundance comparisons, we
160 also used data from four months of sampling in 2005 conducted with the same protocol
161 and at the same sampling site in the Cágados area by the lead author. To assess the extent
162 of dog use (ray of action), we determined the minimum and maximum distance moved
163 from a camera location to the nearest and farthest households at the sites. A detailed study
164 of the health of domestic carnivores is being conducted at the sites.

165

166 *3.2. Population parameters*

167 To determine relative abundance, consecutive photographic records of the same species
168 were defined as independent occurrences when the individual(s) could be unambiguously
169 distinguished or if the interval between records was >1 hour. Individual tiger cat
170 identification was based on their characteristic spot patterns, body markings and other
171 individual features (i.e., scars).

172 Population estimation was conducted using the traditional mark-recapture method with
173 the *Rcapture* package (Baillargeon and Rivest, 2007) in R version 3.5.1 (R Development
174 Core Team, 2016). Best-fit models were evaluated based on Akaike information criterion
175 (AIC) values. We favored heterogeneity models (M_h), as they are widely considered to
176 be more biologically appropriate for felids than other models because of the variation in
177 capture probability among individuals (Chao et al., 2000). For capture probability (p^{\wedge})
178 and closure tests, we used the program Capture (White et al., 1978) because *Rcapture*

179 does not provide these calculations. The camera polygon plus a buffer of the mean
180 maximum distance moved by individuals (MMDM) (Dillon and Kelly, 2007; Maffei and
181 Noss, 2008) were used to determine the effectively trapped area. We applied the same
182 buffer for both trapping sites. We conducted density estimation at the Mel site for 11
183 months and six months, while density estimation was conducted for three months at the
184 Cágados site. Trapping occasions (six for Mel and eight for Cágados) were implemented
185 to minimize the number of sessions with zero captures and increase recaptures following
186 the recommendations of Otis et al. (1978).

187 We also estimated tiger cat density through spatially explicit capture-recapture models
188 (SECR) in a maximum likelihood framework (Borchers and Efford, 2008). SECR models
189 assume that the population is closed during the survey period, that each individual has a
190 fixed and circular home range and that the encounter rate of an individual decreases with
191 distance from its home range center following a specific detection function. For this, we
192 used a half-normal function with two parameters: the encounter rate at the home range
193 center, g_0 , and the scale parameter, σ , which describes the inverse relationship
194 between the detection probability and distance from the home range center (Tobler et al.,
195 2013; Jedrzejewski et al., 2017). For buffer width, we assumed that 95% of the activity
196 in a circular bivariate normal home range is concentrated within a circle of radius 2.45σ
197 (Petit et al., 2018). We divided the study period into 24-h capture occasions because short
198 sampling intervals can improve the precision of SECR estimates for felids (Goldberg et
199 al., 2015). All SECR analyses were performed using the *secr* package version 3.2 (Efford,
200 2019) in R.

201 To estimate the size of the adult tiger cat population at MSP and the population's long-
202 term viability, we used a digitized shapefile of vegetation formations and land use at the
203 park determined on the basis of detailed satellite images (Landsat8-TM) that were

204 georeferenced, field proofed, and analyzed in Q-GIS ver.3.4.7 LTR (Q-GIS Development
205 Team, 2019). To define the available area, we excluded all unsuitable nonspecific
206 vegetative formations, settlements and cultivated areas. Then, we applied density
207 estimates (mean, minimum and maximum) to all areas deemed suitable. For areas close
208 to households/settlements, we applied a buffer of 800 m in which we considered density
209 to be 60% of the average values used elsewhere and 80% in areas of secondary/disturbed
210 vegetation. We based this on the difference between the SECR density results between
211 the two sites. This slight reduction was appropriate because preliminary occupancy
212 estimates at MSP showed a probability of absence of 80% at that distance (Lima, 2019;
213 Supplementary Material Fig. S2). Marinho et al. (2017) also showed that proximity to
214 settlements affected the occupancy of northern tiger cats.

215 For the other protected areas of the MATOPIBA savannas, we used shapefiles of suitable
216 and unsuitable habitats to estimate the tiger cat population size (Project MapBiomias,
217 2019). We applied the minimum and maximum known density estimates for small
218 Neotropical cats (0.01-0.25 ind./km²; Oliveira 2011; Oliveira et al., 2018a, b). For their
219 expected population size, we made an assumption based on their abundance proportions
220 in comparison to those of MSP estimates of approximately 60%. Thus, for sites other than
221 MSP, expected population sizes were calculated using a density of 0.06 indiv./km².
222 Lastly, we also estimated the population for the MATOPIBA portion of the buffer zone
223 of the Cerrado Biosphere Reserve, which serves as a potential corridor for the protected
224 areas in the region. We assessed habitat suitability within the reserve by excluding
225 agricultural areas and vegetation types not used by the species. We performed the analysis
226 using land use and vegetation maps from the Brazilian Institute of Geography and
227 Statistics – IBGE (2018). Then we applied the minimum density values of Neotropical
228 cats (0.01 – 0.02 indiv./km²; Oliveira, 2011; Oliveira et al., 2018b) to all areas of suitable

229 habitat within the biosphere reserve. We chose to be conservative because buffer zones
230 are not strictly protected and there have been no camera trapping surveys done in this part
231 of the region.

232 In this analysis, we calculated both the total (N) and effective population sizes (N_e),
233 considered as $0.2N$, following the genetically based recommendations for risk
234 assessments and red list criteria adjustments (Frankham et al., 2014).

235 The potential impact of domestic dogs and human settlements on tiger cat density was
236 estimated through the Heat Map plugin in QGIS. The estimate was made through a Kernel
237 interpolation function, which expresses the density based on the number of points in a
238 location and the overlap of the different layers (Bailey and Gatrell, 1995; Oliveira et al.,
239 2015, 2016). The ray of potential dog impact was based on the mean maximum distance
240 moved by dogs during the survey period (6 km; Supplementary Material Table S3), while
241 the ray of human settlements influence was calculated based on tiger cat occupancy
242 probabilities as a function of distance to human settlements (see “Population Viability
243 Assessment”).

244 *3.2.1. Population viability analysis*

245 For the population viability analysis (PVA), we used the software VORTEX version
246 10.3.3 (Miller and Lacy, 2005), which has been widely used to model wildlife populations
247 and, when tested against long-term field study datasets, was found to provide accurate
248 predictions (Brook et al., 2000). For a detailed explanation of VORTEX and its use in
249 PVA, see Miller and Lacy (2005). Literature on tiger cats and unpublished data on their
250 natural history and ecology, complemented with data on other species of felids (notably
251 jaguar and ocelot) as well as personal communications and best guesses offered by cat
252 specialists, provided data on the life history parameters necessary for the population

253 models (Supplementary Material Table S5). We used the baseline 100 iterations for a
254 short-term scenario (100 years) and long-term scenario (1,000 years), which, with a 5-
255 year generation length, represented 20 and 200 tiger cat generations, respectively. The
256 initial population size was based on the average density of the more conservative
257 estimates of the spatially explicit capture-recapture models for MSP, whereas, for
258 carrying capacity (K), we added 20%. The main threat modeled was disease. Disease
259 outbreak prevalence was established at 14% per generation, or 2.8% per year, based on
260 felid data provided by Reed et al. (2003). We tested both a mild and strong outbreak
261 scenario, in which survivorship percentages were 85% and 60% of the normal survival
262 values, respectively. Given the predictions of habitat loss for the MSP area (Ferreira et
263 al., 2013), we considered an annual loss of approximately 1.2% per year (for about 100
264 years). We also tested this threat separately and considering both scenarios of disease
265 outbreaks for the short term only. We also tested the scenario of a 30% loss in K. This
266 change in K is likely to occur if land use changes take place or if the populations of ocelots
267 or other competitors increase, as seen in another tiger cat population in southern Brazil
268 (Oliveira et al., 2010).

269

270 **4. Results**

271 *4.1. Population parameters*

272 We identified 21 individual northern tiger cats (98% of the species' photographs) over a
273 trapping effort of 5,030 trap-days for MSP in 2014-15 and 2018 (Table 1), with an average
274 relative abundance of 1.014 ind./100 trap-days. The different sites at the park showed
275 different abundances, with higher abundances in the mostly dense formations and very
276 low abundances in the predominantly open areas (0.124-2.168 ind./100 trap-days, Table

277 1). At Mel, the relative abundance was the same in 2014/15 and 2018, with ca. 1 tiger cat
 278 per 100 trap-days during both time periods. Interestingly, a 13-year comparison of the
 279 abundance at a single trapping site at Cágados showed a dramatic difference, from 0.00
 280 to 2.168 ind./100 trap-days in 2005 and 2018, respectively. The abundance in the other
 281 study areas in the northern savannas also varied (mean: 0.368 ind./100 trap-days, range:
 282 0.222-0.481 ind./100 trap-days) but was less than half of the MSP abundance on average.

283 Table 1. Relative abundances (number of individuals \times 100 trap-days) of northern tiger
 284 cats in the northern savannas of Brazil.

Site	Sampling effort (trap-days)	Individuals/100 trap-days	Habitat type/integrity
MSP – Mel (01/2014-07/2015) ¹	2,729	0.953	Pristine/lightly disturbed dense savanna
– Mel (05-08/2018) ¹	711	0.985	
– Mel (01/2014-08/2018) ¹	3,440	0.959	
MSP – Zé Miguel (08/2014-07/2015) ¹	806	0.124	Pristine/lightly disturbed mostly open savanna
MSP – Cágados 2005 ²	450	0.000	Pristine/lightly disturbed moderately open to dense savanna
– Cágados (05-08/2018) ¹	784	2.168	
Mirador State Park (2014/2018) ¹	5,030	1.014	
Parnaíba River area ²	1,580	0.400	Pristine to disturbed dense savanna
Gerais de Balsas ²	450	0.222	Pristine/lightly disturbed dense savanna
Nascentes do Rio Parnaíba Nat. Park (MA/TO/PI) ³	4,154	0.481	Pristine/lightly disturbed dense savanna

285 1. This study, 2. Oliveira et al. (2008), 3. Lima (2009)

286

287 At Mel, six different individuals (2 males, 2 females, 2 unidentified sex) were recorded
 288 26 times in 2014. For a six-month period, this yielded a population estimate (M_h , M_0) of
 289 5.3 ± 0.7 individuals (5.0-7.5) (Table 2). At Cágados, eight individuals were identified (3
 290 males, 2 females, 3 unidentified sex) and recorded 16 times in a three-month period,
 291 which led to a population estimate (M_h , M_0) of 10.4 ± 2.4 individuals (8.0-17.9). The
 292 capture probability (p^{\wedge}) was estimated at 35.7% and 50.0% (M_h , M_0 , respectively) at Mel
 293 and 21.9% and 18.7% (M_h , M_0) at Cágados. The MMDM for the park was 2.4 ± 1.05 km

294 (range: 0.87-3.3 km). The effective trapped area was 45.1 km² for Mel and 41.9 for
 295 Cágados, which led to estimated densities of 12 ind./100 km² (13-19 ind./100 km²) and
 296 25 ind./100 km² (19-38 ind./100 km²), respectively. Assessments for an 11-month period
 297 at Mel were similar (Supplementary Material Table S6). The densities estimated from the
 298 SECR models were smaller and were 8.68 ± 3.9 (3.75-20.1) ind./100 km² for the Mel site
 299 and 11.3 ± 5 ind./100 km² (5.0-25.5) for the Cágados site (Table 3).

300 Table 2. Abundance models for the northern tiger cat in Mirador State Park, Brazil, by
 301 means of traditional nonspatial methodology.

Site/Model	Abundance	SE ±	95% CI	Density (per km ²)	SE ±	95% CI	AIC
Mel							
M ₀	5.3	0.7	5.0-7.0	0.12	0.016	0.11-0.16	39.137
M _t	5.0	0.0	5.0-5.7	0.11	0.00	0.11-0.13	34.486
M _h Chao	7.3	4.2	5.0-21.9	0.16	0.093	0.11-0.49	39.433
M _h Poisson	5.3	0.7	5.0-7.5	0.13	0.016	0.11-0.17	41.137
Cágados							
M ₀	10.4	2.4	9.0-17.7	0.25	0.057	0.21-0.42	52.280
M _t	10.0	2.2	8.0-16.5	0.24	0.053	0.19-0.39	58.272
M _h Chao	10.4	2.4	8.0-17.9	0.25	0.057	0.19-0.43	52.280
M _h Poisson	8.5	1.2	8.0-12.1	0.20	0.024	0.19-0.29	52.918

302

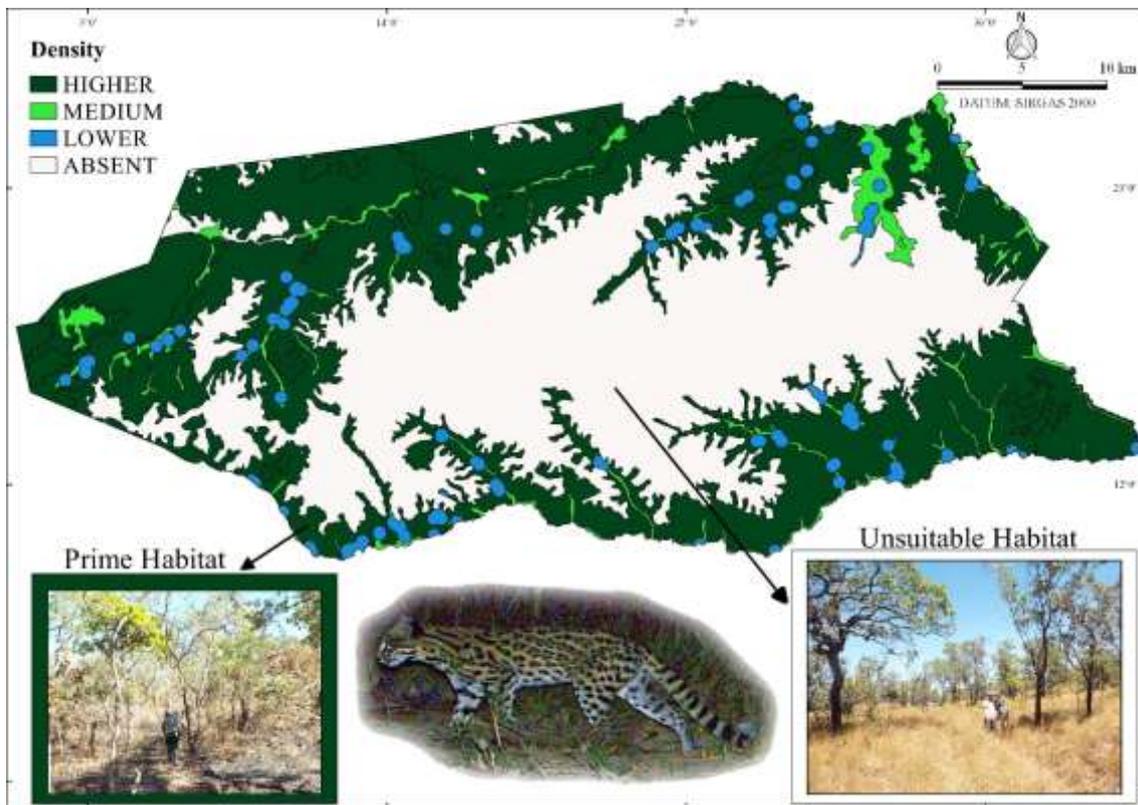
303 Table 3. Density estimates of northern tiger cats in Mirador State Park, Brazil, by means
 304 of spatially explicit capture-recapture models.

Parameter	Mel	Cágados
Buffer (2.45*RPSV km)	3.37	3.56
D (+/- SE) per 1 km ²	0.087 ± (0.039)	0.11 ± (0.049)
95% CI	0.038-0.20	0.05-0.25
Sigma (km)	1.93	4.40
g ₀	0.0061	0.0025

305

306 The total area of the park with habitat suitable for northern tiger cats is 2,629.12 km²
 307 (52.5% of the park – Figure 3.). This leads to an estimated population of 537 (464-827)

308 or 287 (127-661) individuals according to nonspatial models or SECR models,
309 respectively. Thus, the effective population size (N_e) would be 107 individuals (93-165)
310 nonspatially or 57 individuals (25-132) spatially.

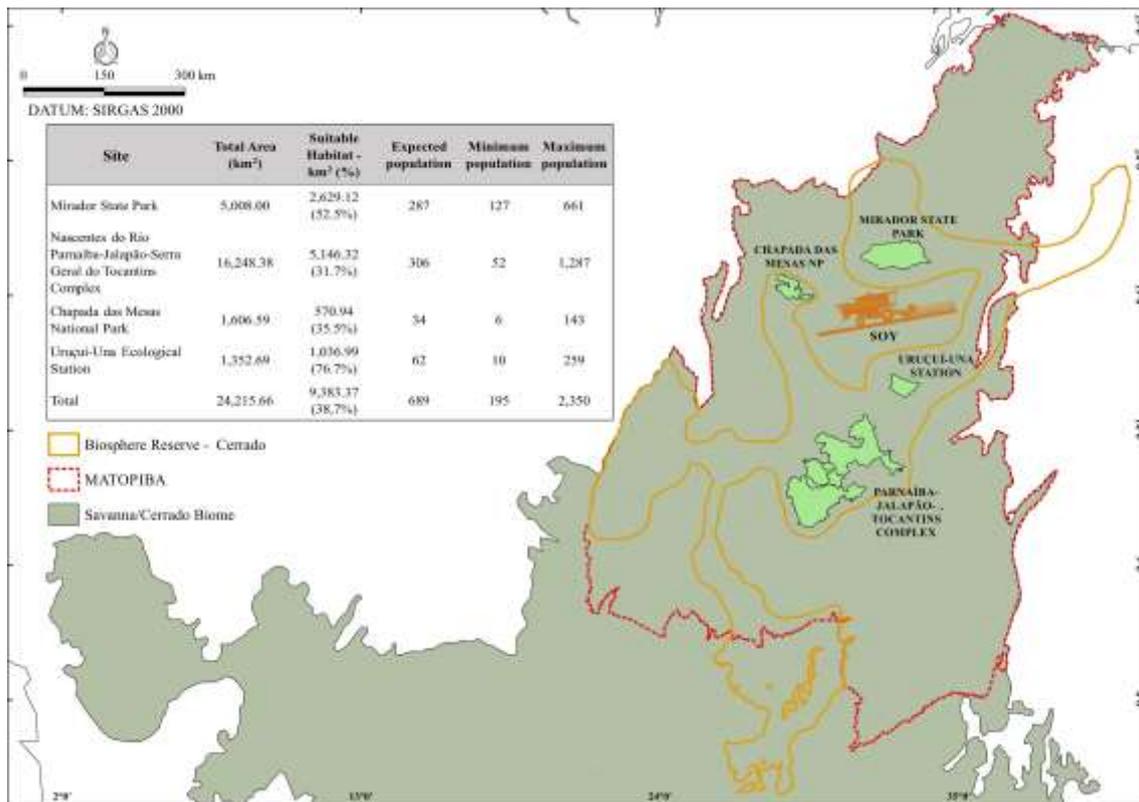


311

312 Figure 3. Expected density map of the northern tiger cat in its key worldwide
313 conservation area in Mirador State Park in the northern savannas of the Cerrado
314 biodiversity hotspot.

315

316 The expected population sizes in other protected areas within the MATOPIBA savannas
317 varied (34-306 Figure 4) and were either equal or smaller than those of MSP. The total
318 population for the protected area system was approximately 700 adult northern tiger cats
319 (200-2,350). For the buffer zone of the Cerrado Biosphere Reserve in the MATOPIBA,
320 the expected population size was 1,302-2,064 individuals (Supplementary Material Fig.
321 S4). This means that the total expected tiger cat population for the whole MATOPIBA
322 region could potentially reach 2,000 or 3,000 individuals.



323

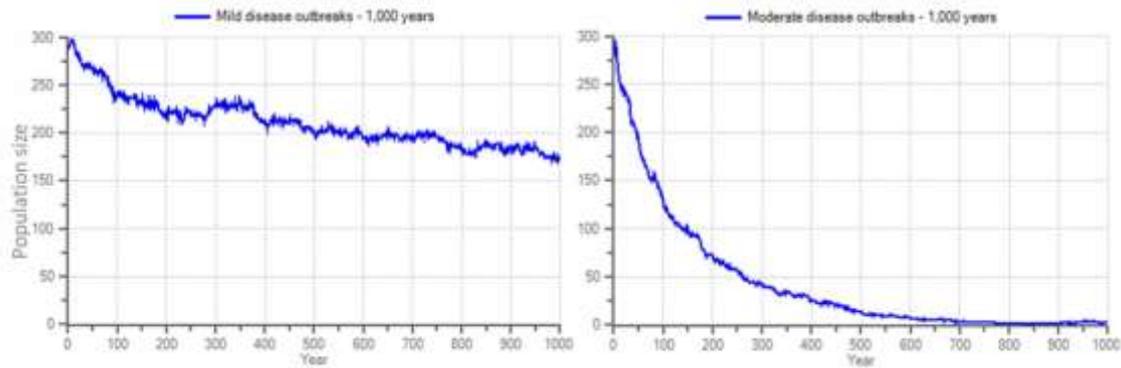
324 Figure 4. Expected northern tiger cat population size based on habitat suitability for the
 325 protected areas of the MATOPIBA savannas and the corridor of the Cerrado Biosphere
 326 Reserve, whose shape is highly influenced by the soy belt.

327

328 4.2. Population viability assessment

329 With an estimated initial population of 287 animals and carrying capacity of 359
 330 individuals, the tiger cat population would not go extinct in either a 100-year or 1,000-
 331 year period under catastrophe-free conditions, even if the carrying capacity decreased by
 332 30% (Figure 5, Supplementary Material Table S7). The same would apply in a mild
 333 disease outbreak scenario or even with a stronger disease threat over the short term (100
 334 years). However, over the long term (1,000 years), if the outbreaks resulted in
 335 survivorship of 60% of the regular values, the population would go extinct. The effect of
 336 habitat loss in the short-term scenario is also devastating in MSP. Considering the
 337 effective population size, the outcome is grim. In the short-term scenarios, the extinction

338 probability ranges from 3% (no catastrophes) to 100% (e.g., moderate disease outbreaks,
339 habitat loss). In the long-term scenario and in all simulations and with habitat loss, the
340 average probability of extinction in all the scenarios is 88.6% (53-100% - Supplementary
341 Material Table S7 and Fig. S8).

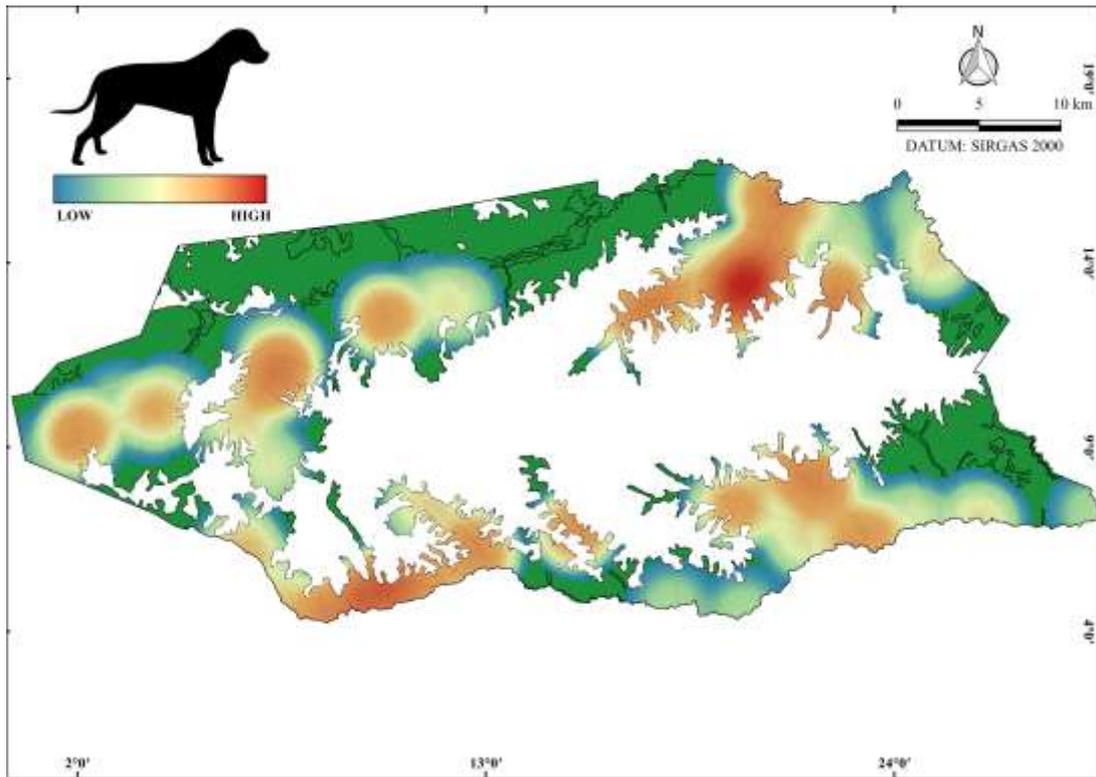


342
343 Figure 5. Long-term outcomes of northern tiger cat population viability analyses in
344 Mirador State Park under scenarios of mild and moderate disease outbreaks.

345

346 4.3. Assessing domestic dog potential impact

347 Non-feral domestic dogs were identified in all studied areas in the park; there were 15
348 individuals at Mel and seven at Cágados (Supplementary Material Table S3). The
349 distances moved by domestic dogs were 1.4-2.5 km for the Mel area and 8.0-11.2 km for
350 the Cágados area. They appeared on 80% of all cameras that recorded tiger cats. Given
351 the ray of action of dogs (6 km), the area of tiger cat suitable habitat potentially impacted
352 by dogs is 1,815.24 km² (65.1%, Figure 6). Interviews and clinical evaluations conducted
353 at the study sites on the health assessment of domestic carnivores showed dermatologic
354 disorders (mange, dermatophytosis, mycosis), as well as unspecific clinical signs of
355 anorexia, coughing, and apathy in all 50 dogs evaluated (Albuquerque et al., unpubl. data).
356 Of very high concern were the neurologic signs indicating the presence of canine
357 distemper virus in these free-ranging dogs in the park (Albuquerque et al., unpubl. data).



358

359 Figure 6. The area of suitable tiger cat habitats potentially impacted by domestic dogs in
 360 Mirador State Park is about 65%.

361

362 5. Discussion

363 5.1. Population assessment

364 The density estimates provided here represent the first estimates published for this
 365 species. The estimates are robust, with a higher-than-average likelihood of capture (p^{\wedge})
 366 and a narrower 95% confidence interval than those provided by several density estimate
 367 studies of felids, where p^{\wedge} is typically $<15\%$ and the CI is very broad (Karanth and
 368 Nichols, 1998; Silver et al., 2004; Kolowski and Alonso, 2010). Higher recapture rates
 369 are key for robust estimates (Sollmann et al., 2011). Nevertheless, spatial and nonspatial
 370 estimates differ, with spatially explicit estimates always being lower in studies that
 371 compared both methods (Sollmann et al., 2011; Tobler et al., 2013; Ávila-Nájera et al.,

372 2015). Overall, our SECR estimates showed greater errors and wider confidence intervals
373 than the traditional estimates. However, they were still in the same range or better than
374 estimates from other felid studies conducted elsewhere (Sollman et al., 2011; Mohamed
375 et al., 2013; Naing et al., 2017). The differences between the two sites could be related to
376 slight differences in resource availability or to the fact that the Mel site is close to human
377 settlements, whereas Cágados is not. Marinho et al. (2017) showed that proximity to
378 settled areas decreased occupancy by northern tiger cats.

379 Unpublished estimates of northern tiger cat populations exist for two sites in the savannas
380 of the Grande Sertão Veredas/Peruaçu National Parks conservation mosaic area. The
381 reported densities, 9.1 ind./100 km² and 4.5 ind./100 km², were lower than those in MSP
382 (Oliveira, 2018). The highest density reached by the smaller (< 6 kg) tropical species of
383 Neotropical felids is 25 ind./100 km² and is only attained where ocelots are rare or absent,
384 with an average high density of 10-15 ind./100 km²; where such species are rare, the
385 densities are typically < 1-5 ind./100 km² (Oliveira et al., 2010, 2018a, b; Oliveira, 2011).
386 Other authors (Oliveira-Santos et al., 2012; Caso, 2013; Kasper et al., 2016; Oliveira,
387 2018) have corroborated these findings. Ocelots, the ecologically dominant
388 mesopredators in the area, reach much higher densities, with an average density of 30
389 ind./100 km², but are able to reach densities of up to 80-100 ind./100 km² under favorable
390 conditions (Kolowski and Alonso, 2010; Oliveira et al., 2010). All reported estimates for
391 northern tiger cats are similar to the values of the other relatively small species of tropical
392 America (1-25 ind./100 km² – Supplementary Material Fig S9; Oliveira, 2011, unp. data;
393 Oliveira-Santos et al., 2012; Caso, 2013; Kasper et al., 2016; Oliveira, 2018; Oliveira et
394 al., 2018b). This indicates that tiger cat densities at MSP are high for Neotropical felid
395 standards, signifying the importance of the park.

396 Our data show that the northern tiger cat population at MSP is robust and more than twice
397 abundant than that in other Brazilian mid-north savanna areas (Oliveira et al., 2008; Lima,
398 2009) and considerably higher than that in other savannas throughout Brazil. In the
399 predominantly open savanna at Emas National Park, assessments conducted from 2001-
400 2011 over 30,798 trap-days did not record the species (Giozza et al., 2017), even though
401 one individual was trapped and radio-collared outside the park (Oliveira et al., 2010). The
402 abundance at semiarid Caatinga scrub sites in NE Brazil was similar (0.036-0.493
403 ind./100 trap-days; Oliveira, 2011). Only at some sites in the semiarid Caatinga in Rio
404 Grande do Norte were abundance estimates higher or equivalent to those at MSP (0.6-4.1
405 ind./100 trap-days; Marinho, 2015).

406 A rather startling finding was the difference in the abundance in the Cágados area between
407 2005 and 2018, where records went from 0.0 to 2.2 ind./100 trap-days, or from
408 momentarily absent to 25 tiger cats per 100 km². Considerable population fluctuations
409 have been noted to occur for Pampas cats (*Leopardus colocola*) and other carnivores in
410 Emas National Park (Giozza et al., 2017). Changes in the abundance of northern tiger cats
411 have also been reported in a Caatinga scrub/savanna mosaic in the Caetité area of Bahia
412 state, where the population dropped by 25.9% between 2012 and 2015 (Meira et al. unp.
413 data) and for several populations of the southern tiger cat and other felids in SE Asia (de
414 Oliveira et al., 2016; Naing et al., 2017). Three nonexclusive hypotheses could be invoked
415 to explain the findings: 1) conditions changed between the two survey periods, 2)
416 differences in habitat or prey availability occurred, or 3) other factors, such as the
417 occurrence of disease transmitted from dogs, caused the differences. The area sampled
418 and camera protocol remained the same, as did the vegetation structure and integrity. This
419 means that whatever caused the disappearance of tiger cats from the area in the 2005
420 catchment was not related to habitat integrity or methodology. The temporal change

421 hypothesis associated with changes in prey availability seems to be an unlikely
422 explanation, as Pampas cats and other mesocarnivores were relatively common at that
423 time at the same site (Oliveira et al., 2008). The most plausible and compelling hypothesis
424 is that a disease outbreak affected the species at the time, which has serious inherent
425 implications for conservation. In the late 1980s and early 1990s, there was a crash in the
426 fox population at the park, which was likely due to diseases transmitted by domestic dogs
427 (Oliveira, 1996). We speculate that the same might have happened with tiger cats. In
428 2005, while tiger cats were absent, dogs were recorded on cameras. Unquestionable signs
429 of the current and former occurrence of canine distemper were found in the domestic dogs
430 observed in this study, and this disease is well known to cause serious impacts to
431 carnivores worldwide (Woodroffe, 1999; Jorge et al., 2010).

432 What would make the tiger cat abundance twice as high in MSP than in other savannas?
433 Small-mammal trapping showed a healthy prey base but nothing exceptional that could
434 explain such differences (Oliveira, 2014, unp. data). MSP experiences multiple
435 anthropogenic impacts, which should actually have a negative impact on this species. A
436 possible explanation associated with prey availability could be the near absence of ocelots
437 at this location. It has been documented that ocelots negatively affect the abundance of
438 smaller competitors through interspecific killing, also known as the “ocelot effect”
439 (Oliveira et al., 2010; Oliveira, 2011). Ocelots are present in MSP, but their abundance
440 in the monitored areas is extremely low (0.020 ind./100 trap-days; Supplementary
441 Material Table S10). With the camera-trapping rarity defined at 0.300 ind./100 trap-days
442 (see de Oliveira et al., 2018), ocelots are exceedingly rare at the park, which could allow
443 higher numbers of tiger cats to occur (Fig.7). This is in line with the intraguild hostility
444 hypothesis (Maran et al., 1998). Oliveira et al. (2010) showed that where ocelot densities
445 are higher than 15 ind./100 km², smaller felids are very low in abundance or absent. Other

446 felids present in MSP (Supplementary Material Table S10) would also be considered rare
 447 according to camera-trapping efforts in Neotropical America (de Oliveira et al., 2018),
 448 which would suggest low competition and predation pressure for tiger cats at MSP, as has
 449 been observed to explain the leopard cat (*Prionailurus bengalensis*) abundance in Borneo
 450 (Mohamed et al., 2013). Notwithstanding, small Neotropical cats (< 6 kg) do not seem to
 451 negatively affect each other's numbers (Oliveira, 2011).



452 Figure 7. A healthy prey base with the near absence of the ocelot, the dominant
 453 mesopredator of tropical America and the tiger cat's interspecific killer, allows for the
 454 relatively high densities of *Leopardus tigrinus* found in Mirador State Park.
 455

456 5.2. Northern tiger cat long-term conservation at the park and the northern savannas

457 Tiger cat populations in the MATOPIBA protected area system are much smaller than
 458 expected given their total area size due low levels of habitat suitability, which when
 459 combined represented only 39%. This is especially true for the largest area of them all,
 460 the Nascentes do Parnaíba-Jalapão-Serra Geral de Tocantins complex, which, at 16,248
 461 km², has only 31.7% suitable habitat and, being three times larger than MSP, has the same
 462 expected population size.

463 The total number of northern tiger cats expected in the MATOPIBA protected area
 464 (approximately 700) is still below that proposed by Frankham et al. (2014) for the
 465 maintenance of evolutionary potential, even though its upper limits could fulfill the
 466 criterion. However, despite the rampant rates of habitat loss (IBAMA, 2015) in every
 467 direction due to the agricultural frontier, there are still extensive amounts of savannas

468 that, if properly managed within the concept of biosphere reserves, could host
469 approximately 1,300-2,000 individuals for total population size of 2,000-3,000 mature
470 individuals and also maintain gene flow.

471 The results of the PVA suggest that short-term viability would be guaranteed for the tiger
472 cat populations above 200 individuals at MSP. However, over the long term (1,000 years),
473 stronger disease outbreaks would cause extinction if the population became isolated. In
474 this scenario, over the long term, the probability of extinction increases sharply to 96%.
475 Given the geography of MSP, local outbreaks are more likely than one simultaneously
476 affecting the entire 5,008 km² area. Although mild-outbreak scenarios could predominate,
477 severe disease outbreaks remain a clear and present danger at MSP.

478 In the N_e scenario PVA showed an unviable result. This striking difference in the PVA
479 outcome of N and N_e raises serious concern. Frankham et al. (2014) stressed that, for the
480 retention of evolutionary potential, the population would need to be > 1,000 individuals
481 and to avoid inbreeding depression, >100 individuals. In a scenario of isolation, only
482 short-term inbreeding depression could be avoidable at MSP. Thus, for the effective
483 population to remain viable, maintenance of connectivity is vital. If properly managed,
484 the established Cerrado Biosphere Reserve (MMA, 2016) could fulfill this need.

485 In most PVAs of other Neotropical hypercarnivores (jaguar, ocelot, bush-dog),
486 survivorships were found to be considerably lower than those for the tiger cats in Mirador
487 (Haines et al., 2006; Desbiez et al., 2013; Godoy et al., 2015). In fact, the PVAs using
488 spatially explicit estimates for population size reflected the biological potential of the
489 tiger cat population in the park. Thus, considering the total population size, MSP should
490 indeed be considered a key conservation area for northern tiger cats.

491 In the other areas of the northern savannas, the data suggests smaller population sizes
492 than those found in MSP. However, given the size and theoretical protection of the
493 Nascentes do Rio Parnaíba National Park-Jalapão-Serra Geral de Tocantins protected area
494 complex, even only half the abundance of individuals in MSP should be very important
495 for the long-term species conservation. This is especially true considering the integration
496 of the Cerrado Biosphere Reserve (MMA, 2016), which might prove needed for
497 maintaining connectivity, gene flow and viability under the severe pressure of the
498 agricultural frontier. In the scenario of connectivity, the PVA for the MATOPIBA
499 Biosphere Reserve ($N = 3,000$; $N_e = 750$) suggests that the population would be self-
500 sustaining over 1,000 years, with zero probability of extinction, even with moderate
501 disease outbreaks.

502

503 *5.3. Potential impact of dogs and park conservation issues*

504 MSP hosts an estimated population of approximately 1,000 people in 61 small
505 settlements, with 201 households and 201 families (1-18 families per settlement; Oliveira,
506 2014). Although poaching is a problem at MSP, we could not find evidence that it affects
507 tiger cats. Habitat loss and conversion within the park boundaries do not pose a threat yet,
508 although there are predictions that this might become a threat in the future (Ferreira et al.,
509 2013). Dogs, on the other hand, could be a potential threat to tiger cats. At Mel, where
510 settlements occur, dogs travelled 2.5 km away from their households, similar to the 3 km
511 reported in the literature (Lessa et al., 2016), as opposed to 11 km at Cágados, where there
512 are no settlements. Dogs roaming longer distances into the natural areas of MSP than
513 regularly indicated by the literature increase the threat of disease transmission.
514 Furthermore, domestic dogs were detected at 80% of the trapping stations at which tiger

515 cats were also observed. Thus, these species overlap spatially in the study areas, which
516 leads to the potential for disease transmission or even predation. The extensiveness of
517 settlements throughout the park suggests that the area potentially impacted by dogs is
518 widespread in MSP, especially in suitable tiger cat habitats.

519 Although laboratorial confirmation of the diseases affecting domestic carnivores in MSP
520 has not yet been conducted, the neurologic signs of canine distemper virus found in the
521 free-ranging dogs along with their high area of overlap with tiger cats makes us consider
522 that dogs may pose a serious threat to the population of this felid at MSP. The overlap of
523 the home ranges of dogs and wild carnivores provides an easy pathway for disease
524 transmission and is a great zoonotic threat (Curi et al., 2010; Lessa et al., 2016).

525 Given the high potential threat of disease to tiger cats, actions should be taken to reduce
526 the presence of domestic dogs in the park. Unfortunately, the literature offers few
527 solutions for conservation issues involving dogs and wildlife interactions (Hughes and
528 Macdonald, 2013). Domestic dog management in protected areas is socially complex and
529 often opposed by people, making eradication attempts unsuccessful (WHO, 2005;
530 Dorresteijn et al., 2015; Doherty et al., 2017). It requires management actions of control,
531 restraint and eradication to reduce contact and the subsequent risk of disease transmission
532 (Lessa et al., 2016).

533

534 *5.4. Concluding Remarks*

535 MSP harbors an important population of the endangered northern tiger cat in the
536 threatened MATOPIBA savannas of northern Brazil. This species reaches high densities
537 in the park that allow for a viable population to be maintained over the long term. This
538 confirms that the park is a key conservation area for this felid. However, the high

539 incidence of dogs, as well as signs of the highly dangerous canine distemper virus, and
540 the association of dogs with extensive human settlements suggests that dogs pose a
541 conservation threat to the local population of *L. tigrinus*, which will require serious
542 conservation actions.

543 The data shows that without a refined analysis of habitat suitability, population estimates
544 would be much higher than they actually are. Thus, integrating a refined population
545 assessment proved to be very helpful and important for accurate and proper assessments
546 of population size and viability; this information is of great importance for conservation
547 planning and decision-making for managing threatened species.

548

549 Author contributions:

550 Study design and fieldwork: TGO, BL, LFR, RP; data analysis: TGO, BL, LFR, RP, EPA;
551 article writing: all authors.

552

553 Acknowledgements: This paper is a contribution of the research and conservation
554 program “Projeto Gatos do Mato – Brasil” (Project Wild Cats of Brazil). Funding was
555 provided by Maranhão State Environmental Secretariat (SEMA) through Pró-Vida Brasil
556 (tp#001/2013/SEMA) and grants from FAPEMA (#016314/2017) and The Mohamed bin
557 Zayed Species Conservation Fund (#182517790), which we acknowledge and thank. We
558 are also grateful for the support provided by Biofaces. Tadeu de Oliveira received a
559 research productivity fellowship from UEMA, Breno Lima and Renata Pereira received
560 graduate student fellowships from FAPEMA and CAPES, respectively, and Lester Fox-
561 Rosales received a DAAD Stipendienvereinbarung (grant) from Georg-August

562 Universität, Göttingen. Several people have helped with fieldwork throughout the years
563 at Mirador State Park, particularly Gitana Cavalcanti, Vítor Moura, Diogo Silva, and Laís
564 Everton. Soraia Albuquerque is conducting the portion of the study related to disease. We
565 also thank Fernanda Michalski, Ronaldo Morato, Fernando Azevedo and Fábio Mazim
566 for their insight and comments regarding earlier versions of the manuscript.

567

568 Conflicts of interest: None.

569

570 Ethical standards: This research complies with GECCO's Code of Conduct.

571

572 **References**

573 Ávila-Nájera, D.M., Chávez, C., Lazcano-Barrero, M.A., Pérez-Elizalde, S., Alcántara-
574 Carbajal, J.L., 2015. Estimación poblacional y conservación de felinos (Carnivora:
575 Felidae) en el norte de Quintana Roo, México. *Revista de Biología Tropical*. 63, 799.

576 Baillargeon, S., Rivest, L.P., 2007. Rcapture: loglinear models for capture-recapture in
577 R. *J. Statistical Softw.* 19 (5), 1-31. <https://doi.org/10.18637/jss.v019.i05>.

578 Bailey, T., Gatrell A.C., 1995. *Interactive Spatial Data Analysis*. Longman Scientific &
579 Technical, Malaysia.

580 Beuchle, R., Grecchi, R.C., Shimabukuro, Y.E., Seliger, R., Eva, H.D., Sano, E., Achard,
581 F., 2015. Land cover changes in the Brazilian Cerrado and Caatinga biomes from 1990
582 to 2010 based on a systematic remote sensing sampling approach. *Appl. Geogr.* 58, 116–
583 127. <https://doi.org/10.1016/j.apgeog.2015.01.017>.

584 Borchers, D.L., Efford, M.G., 2008. Spatially explicit maximum likelihood methods for
585 capture–recapture studies. *Biometrics*. 64 (2), 377-385. [https://doi.org/10.1111/j.1541-](https://doi.org/10.1111/j.1541-0420.2007.00927.x)
586 [0420.2007.00927.x](https://doi.org/10.1111/j.1541-0420.2007.00927.x).

587 Brook, B.W., O'Grady, J.J., Chapman, A. P., Burgman, M. A., Akcakaya, H. R.,
588 Frankham, R., 2000. Predictive accuracy of population viability analysis in conservation
589 biology. *Nature*. 404 (6776), 385. <https://doi.org/10.1038/35006050>.

590 Caruso, N., Manfredi, C., Vidal, E.M.L., Casanaveo, E.B., Lucherinio, M., 2012. First
591 density estimation of two sympatric small cats, *Leopardus colocolo* and *Leopardus*
592 *geoffroyi*, in a shrubland area of central Argentina. *Annales Zoologici Fennici*. 49, 181-
593 191. <https://doi.org/10.5735/086.049.0306>.

594 Caso, A., 2013. Spatial differences and local avoidance of ocelot (*Leopardus pardalis*)
595 and jaguarundi (*Puma yagouaroundi*) in northeast Mexico. PhD thesis. Texas A&M
596 University-Kingsville.

597 Chao, A., Chu, W., Hsu, C.H., 2000 Capture–recapture when time and behavioral
598 response affect capture probabilities. *Biometrics*. 56 (2), 427-433.
599 <https://doi.org/10.1111/j.0006-341X.2000.00427.x>.

600 Craft, M.E., Vial, F., Miguel, E., Cleaveland, S., Ferdinands, A., Packer, C., 2017.
601 Interactions between domestic and wild carnivores around the greater Serengeti
602 ecosystem. *Anim. Conserv.* 20, 193-204. <https://doi.org/10.1111/acv.12305>.

603 Curi, N.H., Araújo, A.S., Campos, F.S., Lobato, Z.I.P., Gennari, S.M., Marvulo, M.F.V.,
604 Silva, J.C.R., Talamoni, S.A., 2010. Wild canids, domestic dogs and their pathogens in
605 Southeast Brazil: disease threats for canid conservation. *Biodiv. Conserv.* 19, 3513–3524.
606 <https://doi.org/10.1007/S11531-010-9911-0>.

607 de Oliveira, T., Trigo, T., Tortato, M., Paviolo, A., Bianchi, R., Leite-Pitman,
608 M.R.P., 2016. *Leopardus guttulus*. The IUCN Red List of Threatened Species 2016
609 e.T54010476A54010576.[http://dx.doi.org/10.2305/IUCN.UK.2016-](http://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T54010476A54010576.en)
610 [2.RLTS.T54010476A54010576.en](http://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T54010476A54010576.en). (accessed 04 May 2019).

611 de Oliveira, T., Michalski, F., Botelho, A., Michalski, L., Calouro, A., Desbiez, A., 2018.
612 How rare is rare? Quantifying and assessing the rarity of the bush dog *Speothos venaticus*
613 across the Amazon and other biomes. *Oryx*. 52, 98-
614 107. <https://doi.org/10.1017/S0030605316000624>.

615 Desbiez, A., Paula, R.C., Cavalcanti, S., 2013. Plano de ação nacional para a conservação
616 da onça-pintada. Instituto Chico Mendes de Conservação da Biodiversidade (ICMBIO),
617 MMA. 1-384.

618 Dias, D.M., Massara, R.L., de Campos, C.B., Rodrigues, F.H.G., 2019. Feline predator–
619 prey relationships in a semi-arid biome in Brazil. *J. Zool.* 307 (4), 282-291.
620 <https://doi.org/10.1111/jzo.12647>.

621 Dillon, A., Kelly, M.J., 2007. Ocelot *Leopardus pardalis* in Belize: the impact of trap
622 spacing and distance moved on density estimates. *Oryx*. 41 (4), 469-477.
623 <https://doi.org/10.1017/S0030605307000518>.

624 Doherty, T.S., Glen, A.S., Nimmo, D.G., Ritchie, E.G., Dickman, C.R., 2016. Invasive
625 predators and global biodiversity loss. *Proc. Natl. Acad. Sci.* 113, 11261-11265.
626 <https://doi.org/10.1073/pnas.1602480113>.

627 Doherty, T.S., Dickman, C.R., Glen, A.S., Newsome, T.M., Nimmo, D.G., Ritchie, E.G.,
628 Vanak, A.T., Wirsing, A.J., 2017. The global impacts of domestic dogs on threatened
629 vertebrates. *Biol. Conserv.* 210, 56-59. <https://doi.org/10.1016/j.biocon.2017.04.007>.

630 Dorresteijn, I., Schultner, J., Nimmo, D.G., Fischer, J., Hanspach, J., Kuemmerle, T.,
631 Kehoe, L., Ritchie, E.G., 2015. Incorporating anthropogenic effects into trophic ecology :
632 Predator - Prey interactions in a human-dominated landscape. Proc. Royal Society B. 1–
633 8. <https://doi.org/10.1098/rspb.2015.1602>.

634 Efford, M., 2019. secr 3.2-spatially explicit capture–recapture in R. Retrieved from:
635 <https://cran.r-project.org/web/packages/secr/vignettes/secr-overview.pdf>. (accessed 30
636 January, 2019).

637 Frankham, R., Bradshaw, C.J.A, Brook, D.W., 2014. Genetics in conservation
638 management: revised recommendations for the 50/500 rules, red list criteria and
639 population viability analyses. Biol. Conserv. 170, 53-63.
640 <https://doi.org/10.1016/j.biocon.2013.12.036>

641 Ferreira, M.E., Ferreira Jr, L. G., Miziara, F., Soares-Filho, B.S., 2013. Modeling
642 landscape dynamics in the central Brazilian savanna biome: future scenarios and
643 perspectives for conservation. J. Land Use Sci. 8 (4), 403-421.
644 <https://doi.org/10.1080/1747423X.2012.675363>.

645 Giozza, T.P., Jácomo, A.T.D.A., Silveira, L., and Torres, N.M., 2017. Riqueza e
646 abundância relativa de mamíferos de médio e grande porte na região do Parque Nacional
647 das Emas-GO. Revista Brasileira de Zootecias 18 (3), 71-87.

648 Godoy, S., Desbiez, A.L.J., Miller, P., 2015. Bush Dog Population Viability Workshop.
649 IUCN/SSC Conservation Breeding Specialist Group (CBSG), Atibaia, Brazil.

650 Goldberg, J.F., Tempa, T., Norbu, N., Hebblewhite, M., Mills, L.S., Wangchuk, T.R.,
651 Lukacs, P., 2015. Examining temporal sample scale and model choice with spatial

652 capture-recapture models in the common leopard *Panthera pardus*. PloS ONE.
653 <https://doi.org/10.1371/journal.pone.0140757>.

654 Haines, A. M., Tewes, M. E., Laack, L. L., Horne, J. S., Young, J. H., 2006. A habitat-
655 based population viability analysis for ocelots (*Leopardus pardalis*) in the United
656 States. Biol. Conserv. 132 (4), 424-436. <https://doi.org/10.1016/j.biocon.2006.04.035>.

657 Hughes, J., Macdonald, D.W., 2013. A review of the interactions between free-roaming
658 domestic dogs and wildlife. Biol. Conserv. 157, 341-351.
659 <https://doi.org/10.1016/j.biocon.2012.07.005>.

660 IBAMA, 2015. Monitoramento do desmatamento nos biomas brasileiros por satélite:
661 Cerrado 2010-2011. Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais
662 Renováveis (IBAMA), Brasília, Brazil.

663 IBGE, 2018. Monitoramento da Cobertura e Uso da Terra do Brasil 2014-2016. Instituto
664 Brasileiro de Geografia e Estatística (IBGE). Rio de Janeiro. Brazil.
665 https://www.ibge.gov.br/apps/monitoramento_cobertura_uso_terra/v1/ (Accessed 15th
666 July, 2019).

667 Jędrzejewski, W., Puerto, M.F., Goldberg, J.F., Hebblewhite, M., Abarca, M., Gamarra,
668 G., Robinson, H.S., 2017. Density and population structure of the jaguar (*Panthera onca*)
669 in a protected area of Los Llanos, Venezuela, from 1 year of camera trap
670 monitoring. Mamm. Res. 62 (1), 9-19. <https://doi.org/10.1007/s13364-016-0300-2>.

671 Jorge, R.S.P., Rocha, F.L., May, J.A., Morato, R.G., 2010. Ocorrência de patógenos em
672 carnívoros selvagens brasileiros e suas implicações para a conservação e saúde pública.
673 Oecologia Australis. 14, 686–710.

674 Karanth, K.U., Nichols, J.D., 1998. Estimation of tiger densities in India using
675 photographic captures and recaptures. *Ecology*. 79 (8), 2852-2862.
676 [https://doi.org/10.1890/0012-9658\(1998\)079\[2852:EOTDII\]2.0.CO;2](https://doi.org/10.1890/0012-9658(1998)079[2852:EOTDII]2.0.CO;2).

677 Kasper, C.B., Schneider, A., Oliveira, T.G., 2016. Home range and density of three
678 sympatric felids in the Southern Atlantic Forest, Brazil. *Braz. J. Biol.* 76, 228-232.
679 <http://dx.doi.org/10.1590/1519-6984.19414>.

680 Kolowski, J.M., Alonso, A., 2010. Density and activity patterns of ocelots (*Leopardus*
681 *pardalis*) in northern Peru and the impact of oil exploration activities. *Biol. Conserv.* 143,
682 917-925. <https://doi.org/10.1016/j.biocon.2009.12.039>.

683 Lessa, I., Guimarães, T.C.S., Bergallo, H. G., Cunha, A., Vieira, E.M., 2016. Domestic
684 dogs in protected areas: a threat to Brazilian mammals? *Natureza e Conservação*. 14, 46-
685 56. <https://doi.org/10.1016/j.ncon.2016.05.001>.

686 Lima, M.G.M. 2009. Mamíferos de médio e grande porte do Parque Nacional das
687 Nascentes do Rio Parnaíba, Brasil. MS thesis. Universidade Federal do Pará, Belém, Pará.

688 Lima, B.C., 2019. Parâmetros ecológicos-ambientais e status populacional de espécies
689 ameaçadas: *Leopardus tigrinus* e *Leopardus colocola* no Parque Estadual do Mirador.
690 Semiannual Technical Report. Universidade Estadual do Maranhão (UEMA). São Luís,
691 Brazil.

692 Maffei, L., Noss, A. J., 2008. How small is too small? Camera trap survey areas and
693 density estimates for ocelots in the Bolivian Chaco. *Biotropica*, 40 (1), 71-75.
694 <https://doi.org/10.1111/j.1744-7429.2007.00341.x>

695 Maran, T., Macdonald, D. W., Kruuk, H., Sidorovich, V., V.V. Rozhnov, 1998. The
696 continuing decline of the European mink, *Mustela lutreola*: evidence for the intra-guild

697 aggression hypothesis. Symposia. Zool. Soc. London. 71, 297–324.
698 <https://doi.org/10.1017/CBO9780511721830.018>.

699 Marinho, P.H.D., 2015. Gato-do-mato-pequeno (*Leopardus tigrinus*) na Caatinga:
700 ocupação e padrão de atividade de um felídeo ameaçado e pouco conhecido na floresta
701 tropical seca do Nordeste do Brasil. MS thesis. Universidade Federal do Rio Grande do
702 Norte, Rio Grande do Norte.

703 Marinho, P.H., Bezerra, D., Antongiovanni, M., Fonseca, C.R., Venticinque, E.M., 2017.
704 Estimating occupancy of the Vulnerable northern tiger cat *Leopardus tigrinus* in Caatinga
705 drylands. Mamm. Res. 63 (1), 33-42. <https://doi.org/10.1007/s13364-017-0330-4>.

706 Michalski, F., Crawshaw, P.G., de Oliveira, T.G., Fabián, M.E., 2006. Notes on home
707 range and habitat use of three small carnivore species in a disturbed vegetation mosaic of
708 southeastern Brazil. Mamm. 70 (1-2), 52-57. <https://doi.org/10.1515/MAMM.2006.004>.

709 Miller, P.S., Lacy, R.C., 2005. VORTEX. A stochastic simulation of the extinction
710 process. Version 9.50 user's manual. Conservation Breeding Specialist Group
711 (IUCN/SSC). Apple Valley, Minnesota.

712 MMA, 2007. Áreas Prioritárias para Conservação, Uso Sustentável e Repartição de
713 Benefícios da Biodiversidade Brasileira: Atualização - Portaria MMA nº9, de 23 de
714 janeiro de 2007.

715 MMA, 2016. Rede Brasileira de Reservas da Biosfera, Brasília, Brasil.
716 [https://www.mma.gov.br/areas-protegidas/instrumentos-de-gestao/reserva-da-](https://www.mma.gov.br/areas-protegidas/instrumentos-de-gestao/reserva-da-biosfera.html)
717 [biosfera.html](https://www.mma.gov.br/areas-protegidas/instrumentos-de-gestao/reserva-da-biosfera.html). (accessed 24 March, 2019).

718 MMA, 2017. 2ª Atualização das Areas Prioritárias para Conservação da Biodiversidade.
719 2018.

720 <http://areasprioritarias.mma.gov.br/images/mapas/mapaBioamas/CerradoPantal.bmp>.
721 (accessed 16 March, 2019).

722 Mohamed, A., Sollmann, R., Bernard, H., Ambu, L.N., Lagan, P., Mannan, S., Hofer, H.,
723 Wilting, A., 2013. Density and habitat use of the leopard cat (*Prionailurus bengalensis*)
724 in three commercial forest reserves in Sabah, Malaysian Borneo. J. Mammal. 94, 82-89.
725 <https://doi.org/10.1644/11-MAMM-A-394.1>.

726 Naing, H., Ross, J., Burnham, D., Htun, S., Macdonald, D.W., 2017. Population density
727 estimates and conservation concern for clouded leopard *Neofelis nebulosa*, marbled cats
728 *Pardofelis marmorata* and tigers *Panthera tigris* in Htamanthi Wildlife Sanctuary,
729 Sagaing, Myanmar. Oryx. 1-9. <https://doi.org/10.1017/S0030605317001260>.

730 NASA, 2018. Converting Savannahs into Soybeans.
731 <https://earthobservatory.nasa.gov/images/92717/converting-savannahs-into-soybeans>
732 (accessed 12 September, 2018).

733 O'Brien, T.G., Kinnaird, M.F., Wibisono, H.T., 2003. Crouching tigers, hidden prey:
734 Sumatran tiger and prey populations in a tropical forest landscape. Anim. Conserv. 6,
735 131-139. <https://doi.org/10.1017/S1367943003003172>.

736 Oliveira, T.G., 1996. A situação dos mamíferos brasileiros ameaçados de extinção do
737 Parque Estadual de Mirador, Maranhão: problemas e perspectivas. Pesquisa em Foco, 4,
738 62-70.

739 Oliveira, T.G., Kasper, C.B., Tortato, M.A., Marques, R.V., Mazim, F.D. Soares, J.B.G.,
740 2008. Aspectos ecológicos de *Leopardus tigrinus* e outros felinos de pequeno-médio
741 porte no Brasil, in: Oliveira, T.G. (Eds.), Plano de ação para a conservação de *Leopardus*

742 *tigrinus* no Brasil., Instituto Pró-Carnívoros/Fundo Nacional do Meio Ambiente, pp. 37-
743 105.

744 Oliveira, T.G., Tortato, M.A., Silveira, L., Kasper, C.B., Mazim, F.D., Lucherini, M.,
745 Jácomo, A.T., Soares, J.B.C., Marques, R.V., Sunquist, M.E., 2010. Ocelot ecology and
746 its effect on the small-felid guild in the lowland Neotropics, in: Macdonald, D.W.,
747 Loveridge, A.J. (Eds.) *Biology and Conservation of Wild Felids*, Oxford University
748 Press, Oxford, UK, pp. 563–574.

749 Oliveira, T.G., 2011. *Ecologia e conservação de pequenos felinos no Brasil e suas*
750 *implicações para o manejo*. PhD thesis. Universidade Federal de Minas Gerais, Belo
751 Horizonte, Brazil.

752 Oliveira, T.G., 2014. Programa de Gestão Compartilhada do Parque Estadual do Mirador,
753 Pró-Vida Brasil/SEMA (Secretaria de Estado do Meio Ambiente e Recursos Naturais).

754 Oliveira, U., Brescovit, A. D., Santos, A. J., 2015. Delimiting areas of endemism through
755 kernel interpolation. *PloS one*. 10 (1), 1-18.
756 <https://doi.org/10.1371/journal.pone.0116673>.

757 Oliveira, U., Paglia, A. P., Brescovit, A. D., de Carvalho, C. J., Silva, D. P., Rezende, D.
758 T., Leite F.S.F, Batista, J. A. N., Barbosa, J.P.P.P, Stehmann, J. R., Ascher, J.S.,
759 Vasconcelos, M. F., Marco Jr, P.M., Löwenberg-Neto, P., Dias, P.G., Ferro, V.G., Santos,
760 A.J., 2016. The strong influence of collection bias on biodiversity knowledge shortfalls
761 of Brazilian terrestrial biodiversity. *Divers. Distrib.* 22 (12), 1232-1244.
762 <https://doi.org/10.1111/ddi.12489>.

763 Oliveira, T.G., Trigo, T.C., Tortato, M.A., Almeida, L.B., Campos, C.B., Beisiegel, B.M.,
764 2018a. *Leopardus tigrinus* (Schreber, 1775), in: Livro Vermelho da Fauna Brasileira
765 Ameaçada de Extinção: Mamíferos. ICMBio, Brasília, DF, v.II, pp. 344-348.

766 Oliveira, T.G., Mazim, F.D., Fox-Rosales, L.A., Peters, F.B., Marques, R.V., Lima, B.C.,
767 Marinho, P.H.D., Meira, L.P., Pereira, A., Silva, D.G., Favarini, M.O., Soares, J.B.G.,
768 2018b. Assessing small cats abundance in Brazil: camera trapping summary report –
769 2018, Project Wild Cats of Brazil. Instituto Pró-Carnívoros/Instituto Pampa, Atibaia, SP.,
770 9p. [http://procarnivoros.org.br/wp_ipc/wp-content/uploads/2015/01/Gatos-do-Mato-](http://procarnivoros.org.br/wp_ipc/wp-content/uploads/2015/01/Gatos-do-Mato-Brasil-CamTrap-report-2018.pdf)
771 [Brasil-CamTrap-report-2018.pdf](http://procarnivoros.org.br/wp_ipc/wp-content/uploads/2015/01/Gatos-do-Mato-Brasil-CamTrap-report-2018.pdf) (accessed 10 January, 2019).

772 Oliveira, M.J., 2018. Coocorrência espacial e temporal de mamíferos de médio e grande
773 porte do Cerrado – competição interespecífica e predação. PhD thesis. Universidade
774 Federal de Minas Gerais, Belo Horizonte, Brazil.

775 Oliveira-Santos L.G.R, Graipel, M.E., Tortato, M.A., Zucco, C.A. Cáceres, N.C.,
776 Goulart, F.V., 2012. Abundance changes and activity flexibility of the oncilla, *Leopardus*
777 *tigrinus* (Carnivora: Felidae), appear to reflect avoidance of conflict. *Zoologia*, 29 (2),
778 115-120. <http://dx.doi.org/10.1590/S1984-46702012000200003>.

779 Otis, D. L., Burnham, K. P., White, G. C., Anderson, D. R., 1978. Statistical inference
780 from capture data on closed animal populations. *Wildlife monographs*. 62, 3-135.

781 Payan, E., de Oliveira, T., 2016. *Leopardus tigrinus*. The IUCN Red List of Threatened
782 Species 2016 e.T54012637A50653881. [http://dx.doi.org/10.2305/IUCN.UK.2016-](http://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T54012637A50653881.en)
783 [2.RLTS.T54012637A50653881.en](http://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T54012637A50653881.en).

784 Petit, M., Denis, T., Rux, O., Richard-Hansen, C., Berzins, R., 2018. Estimating jaguar
785 (*Panthera onca*) density in a preserved coastal area of French Guiana. *Mammalia*. 82 (2),
786 188-192. <https://doi.org/10.1515/mammalia-2016-0150>.

787 Project MapBiomas, 2019. Collection [v.3.1.] of Brazilian Land Cover & Use Map Series.
788 <http://mapbiomas.org/map#coverage> (accessed 24 April, 2019).

789 QGIS Development Team, 2019. QGIS A Free and Open Source Geographic Information
790 System. <https://www.qgis.org/en/site/> (accessed 01 February, 2019).

791 R Development Core Team, 2016. R: A Language and Environment for Statistical
792 Computing. Vienna, Austria. R Foundation for Statistical Computing. Retrieved from
793 <https://www.r-project.org/> (accessed 02 September, 2018).

794 Reed, D. H., O'Grady, J. J., Ballou, J. D., Frankham, R., 2003. The frequency and severity
795 of catastrophic die-offs in vertebrates. *Anim. Conserv. Forum*. 6, 109-114.
796 <https://doi.org/10.1017/S1367943003003147>.

797 Rodrigues, M.S., Conceição, G.M., 2014. Diversidade florística das diferentes
798 fisionomias de Cerrado do Parque Estadual do Mirador, Maranhão, Brasil. *Brazilian*
799 *Geograph. J.: Geosci. Humanit. Res. Medium*. 5 (1), 139-156.

800 Roelke-Parker, M.E., Munson, L., Packer, C., Kock, R., Cleaveland, S., Carpenter, M.,
801 O'Brien, S.J., Pospischil, A., Hofmann-Lehmann, R., Lutz, H., Mwamengele, G.L.,
802 Mgasa, M.N., Machange, G.A., Summers, B.A., Appel, M.J., 1996. A canine distemper
803 virus epidemic in Serengeti lions (*Panthera leo*). *Nature*. 379, 441-445.
804 10.1038/379441a0.

805 Silver, S.C., Ostro, L.E.T., Marsh, L.K., Maffei, L., Noss, A.J., Kelly, M.J., Wallace,
806 R.B., Gómez, H., Ayala, G., 2004. The use of camera traps for estimating jaguar *Panthera*

807 *onca* abundance and density using capture/recapture analysis. *Oryx*. 38, 148-154.
808 <https://doi.org/10.1017/S0030605304000286>.

809 Sollmann, R., Furtado, M.M., Gardner, B., Hofer, H., Jácomo, A.T., Tôrres, N.M.,
810 Silveira, L., 2011. Improving density estimates for elusive carnivores: accounting for sex-
811 specific detection and movements using spatial capture–recapture models for jaguars in
812 central Brazil. *Biol. Conserv.* 144, 1017-1024.
813 <https://doi.org/10.1016/j.biocon.2010.12.011>.

814 Tobler, M.W., Carrillo-Percestequi, S.E., Hartley, A.Z., Powell, G.V., 2013. High jaguar
815 densities and large population sizes in the core habitat of the southwestern Amazon. *Biol.*
816 *Conserv.* 159, 375-381. <https://doi.org/10.1016/j.biocon.2012.12.012>.

817 Tobler, M.W., Powell, G.V.N., 2013. Estimating jaguar densities with camera traps:
818 problems with current designs and recommendations for future studies. *Biol.*
819 *Conserv.* 159, 109-118. <https://doi.org/10.1016/j.biocon.2012.12.009>.

820 Tortato, M.A., Oliveira, T.G., 2005. Ecology of the oncilla (*Leopardus tigrinus*) at Serra
821 do Tabuleiro State Park, Southern Brazil. *Cat News*. 42, 28-30.

822 Trigo, T.C., Schneider, A., de Oliveira, T.G., Lehugeur, L.M., Silveira, L., Freitas,
823 T.R.O., Eizirik, E., 2013. Molecular data reveal complex hybridization and a cryptic
824 species of Neotropical wild cat. *Curr. Biol.* 23, 2528-2533. [10.1016/j.cub.2013.10.046](https://doi.org/10.1016/j.cub.2013.10.046).

825 Weston, M.A., Fitzsimons, J.A., Wescott, G., Miller, K.K., Ekanayake, K.B., Schneider,
826 T., 2014. Bark in the park: a review of domestic dogs in parks. *Environ. Manag.* 54, 373-
827 382. doi: 10.1007/s00267-014-0311-1.

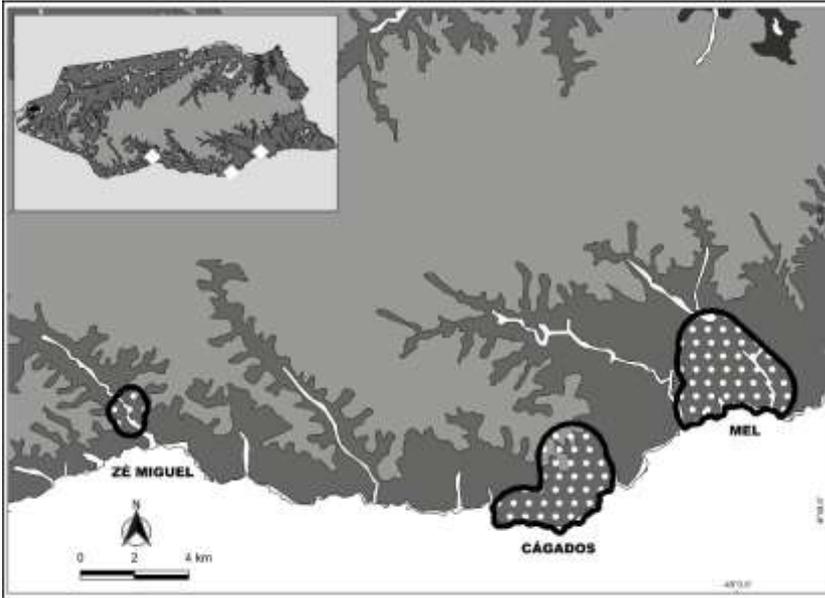
828 White, G. C., Burnham, K. P., Otis, D. L., Anderson, D. R., 1978. Users manual for
829 program CAPTURE.

830 WHO, 2005. National programs for the control of rabies in dogs. World Health
831 Organization, Geneva, Switzerland.
832 <https://www.who.int/rabies/animal/ExcerptTRS1031.pdf> (accessed 21 August, 2018).

833 Woodroffe, R., 1999. Managing disease threats to wild mammals. Anim. Conserv.
834 Forum. 2, 185-193. <https://doi.org/10.1111/j.1469-1795.1999.tb00064.x>

835 Young, J. K., Olson, K.A., Reading, R.P., Amgalanbaatar, S., Berger, J., 2011. Is wildlife
836 going to the dogs? Impacts of feral and free-roaming dogs on wildlife
837 populations. BioScience. 61 (2), 125-132. <https://doi.org/10.1525/bio.2011.61.2.7>.

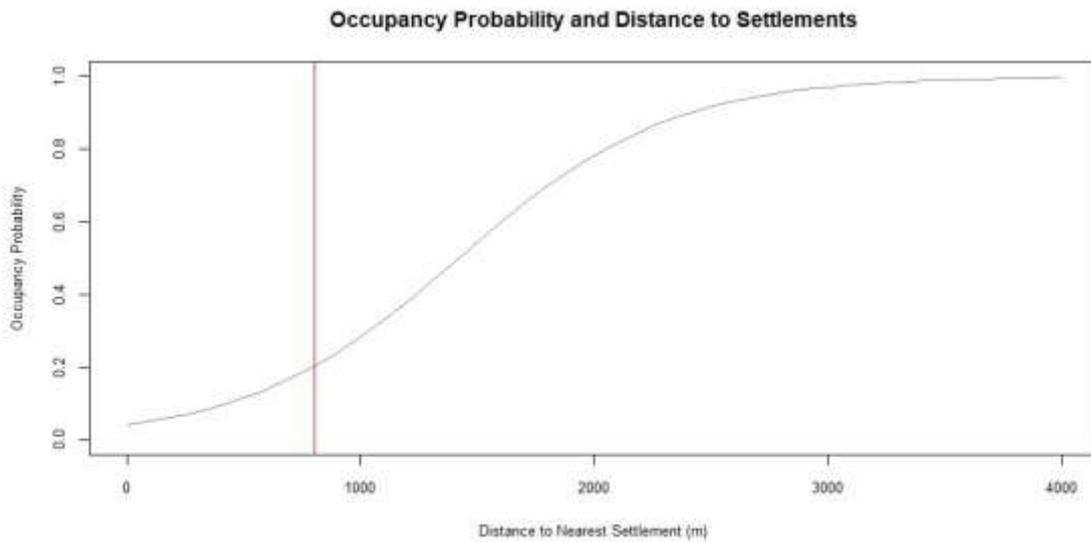
838



839

840 Figure S1. Camera trap sampling areas at the three sites, Mel, Cágados and Zé Miguel,
841 in Mirador State Park in the northern/MATOPIBA savannas of Brazil. The first two
842 sites provided density estimates, and the latter provided only relative abundance.

843



844

845 Figure S2. The occupancy probability and distance to households/settlements of
846 northern tiger cats in Mirador State Park shows that at distances less than 800 m, tiger
847 cat absence is 80%.

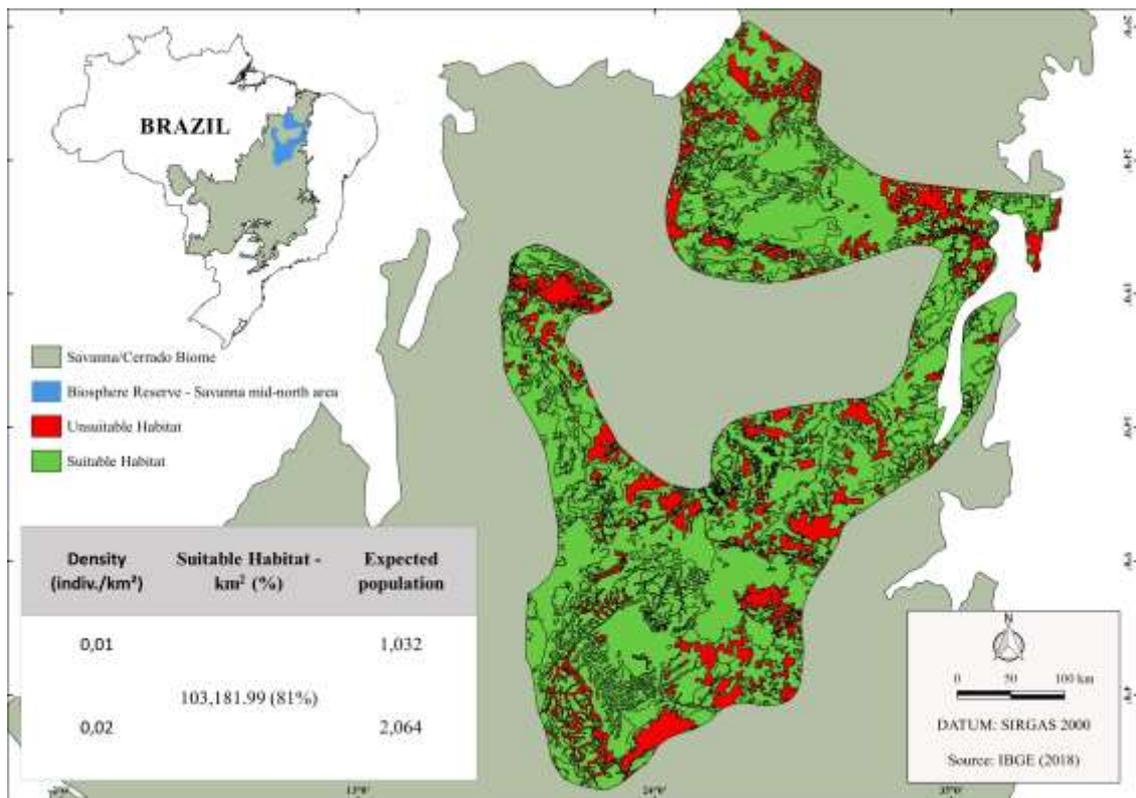
848

849

850 Table S3. Records of domestic dogs and distances travelled from the nearest households
 851 to the camera stations located in Mirador State Park, Brazil, the northern tiger cat's key
 852 worldwide conservation area.

Site	Relative abundance (photos/100 trap-days)	# individuals	Distance travelled by dogs	
			Mean maximum (km)	Mean minimum (km)
Mel	0.99	15	2.62 ± 1.07	1.9 ± 0.87
Cágados	3.44	7	10.93 ± 1.36	9.04 ± 0.30
MSP Mean			6.02 ± 4.01	4.87 ± 3.41

853



854 Figure S4. Expected population size of the northern tiger cat in suitable areas within the
855 MATOPIBA portion of the Cerrado Biosphere Reserve.

856

857 Table S5. Summary of parameter input values used in the baseline model for the
 858 *Leopardus tigrinus* population viability analysis.

Parameter	Baseline value
Number of populations	1
Initial population size (N / N _e / MATOPIBA-N _e)	287 / 57 / 600
Carrying capacity (N / N _e / MATOPIBA-N _e)	359 / 71 / 750
Inbreeding depression	6 LE
% of the effect of inbreeding due to recessive lethal alleles	50
Breeding System	Polygyny
Age of first reproduction (♀ / ♂)	2 / 2
Maximum age of reproduction	10
Annual % adult females reproducing (SD)	75% (10)
Number of litters per year	1
Average litter size	1.12
Density dependent reproduction?	No
Maximum litter size	2
Overall offspring sex ratio	50:50
% adult males in breeding pool	90
% mortality from age 0-1 (EV) (♀ / ♂)	42(7) / 42(7)
% mortality from age 1-2 (EV) (♀ / ♂)	22(5) / 37(5)
% annual mortality after age 2 (EV) (♀ / ♂)	13(2) / 13(2)
Catastrophe?	Disease outbreak
Annual frequency of occurrence	2.8%
Severity: reproduction (% of normal value)	0.95 / 0.80
Severity: survival (% of normal value)	0.85 / 0.60
Catastrophe	Habitat loss / fire
Annual frequency of occurrence	1.2%
Severity: reproduction (% of normal value)	0.95
Severity: survival (% of normal value)	0.50

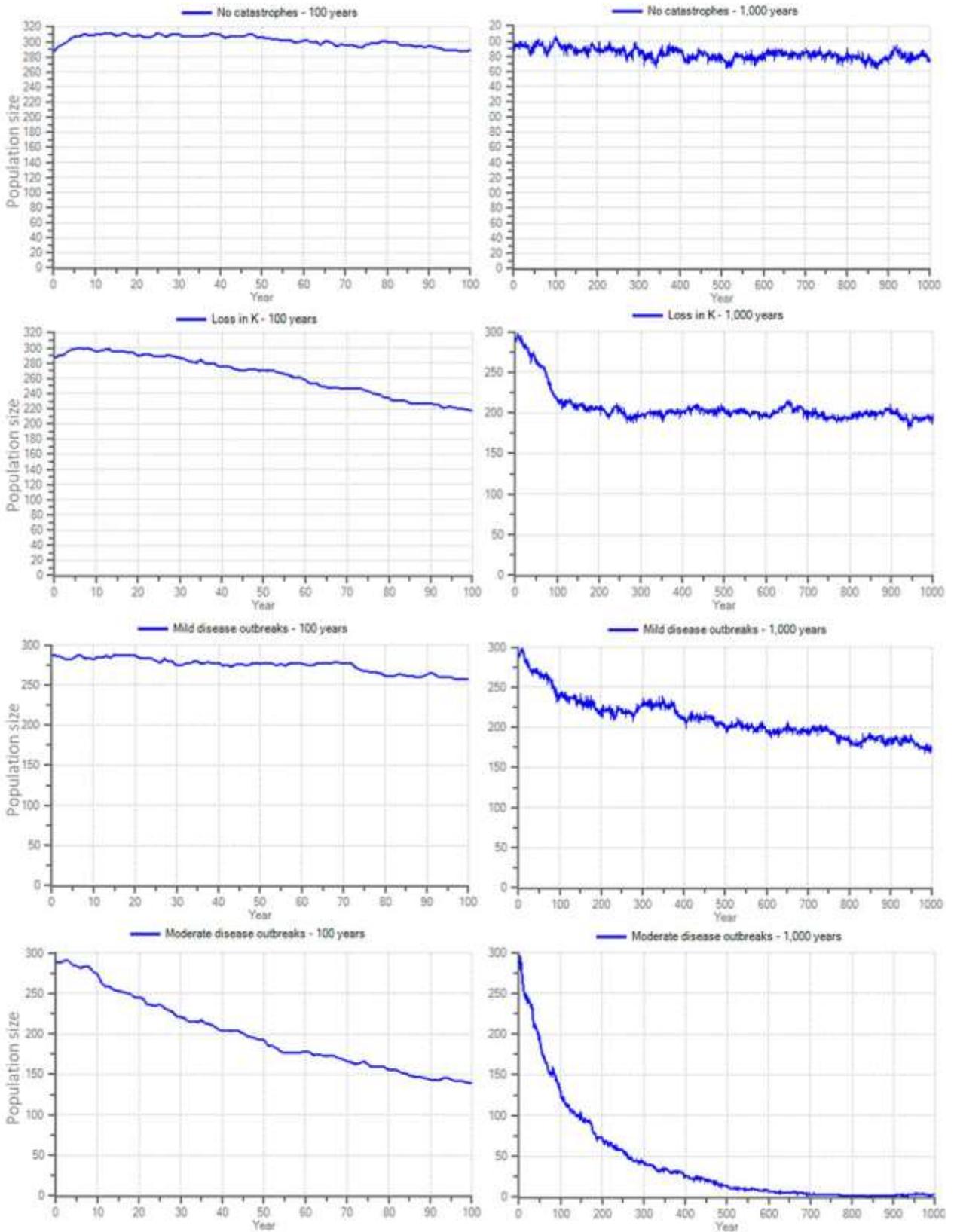
860 Table S6. Abundance models for northern tiger cats at the Mel site in Mirador State
 861 Park, Brazil, for six and 11 sampling occasions.

Models	Abundance	\pm SE	95% CI	Density (#/per km ²)	\pm SE	95% CI	AIC
11 occasions							
M ₀	6.5	0.8	6.0-8.5	0.14	0.018	0.13-0.19	65.815
M _t	6.2	0.5	6.0-7.4	0.14	0.01	0.13-0.16	59.853
M _h Chao	6.9	1.2	6.0-14.7	0.15	0.027	0.13-0.33	65.060
M _h Poisson	6.5	0.9	6.0-8.7	0.14	0.02	0.13-0.19	66.883
6 occasions							
M ₀	5.3	0.7	5.0-7.0	0.12	0.016	0.11-0.16	39.137
M _t	5.0	0.0	5.0-5.7	0.11	0.00	0.11-0.13	34.486
M _h Chao	7.3	4.2	5.0-21.9	0.16	0.093	0.11-0.49	39.433
M _h Poisson	5.3	0.7	5.0-5.7	0.13	0.016	0.11-0.17	41.137

862 Table S7. Expected population parameters and probability of extinction of the northern tiger cat in Mirador State Park in the case of isolation
 863 after 100 and 1,000 years, with 287 individuals and a carrying capacity (K) of 359.

Parameters	Scenarios						
	No catastrophes	Mild disease outbreak	Moderate disease outbreak	Mild disease + habitat loss	Moderate disease + habitat loss	Habitat loss	Loss in K (no catastrophes)
100 years (Mirador State Park)							
Initial population (K_{SECR})	287 (359) individuals						
Probability of extinction - %	0.0	0.0	0.0	0.95	0.97	0.94	0.0
Time to extinction* (years)	-	-	-	56	47	53	-
Stochastic population growth – r (standard deviation)	0.008 (0.076)	0.003 (0.081)	-0.008 (0.120)	-0.073 (0.253)	-0.089 (0.276)	-0.077 (0.261)	0.008 (0.076)
Number left in population (std. Dev.)	289 (60)	256 (76)	139 (104)	14 (11)	10 (2)	26 (27)	217 (37)
1000 years (Mirador State Park)							
Initial population (K_{SECR})	287 (359) individuals						
Probability of extinction - %	0.0	0.17	0.99	-	-	-	0.01
Time to extinction* (years)	-	627	342	-	-	-	359
Stochastic population growth – r (standard deviation)	0.007(0.076)	0.002 (0.084)	-0.011 (0.139)	-	-	-	0.007 (0.077)
Number left in population (std. Dev.)	273 (84)	208 (99)	193	-	-	-	192 (52)
1000 years (MATOPIBA)							
Initial population (K)	-	-	3000 (750)	-	-	-	-
Effective population - N_e	-	-	600	-	-	-	-
Probability of extinction - %	-	-	0.0	-	-	-	-
Time to extinction* (years)	-	-	-	-	-	-	-
Stochastic population growth – r (standard deviation)	-	-	0.013 (0.083)	-	-	-	-
Number left in population (std. Dev.)	-	-	655 (94)	-	-	-	-

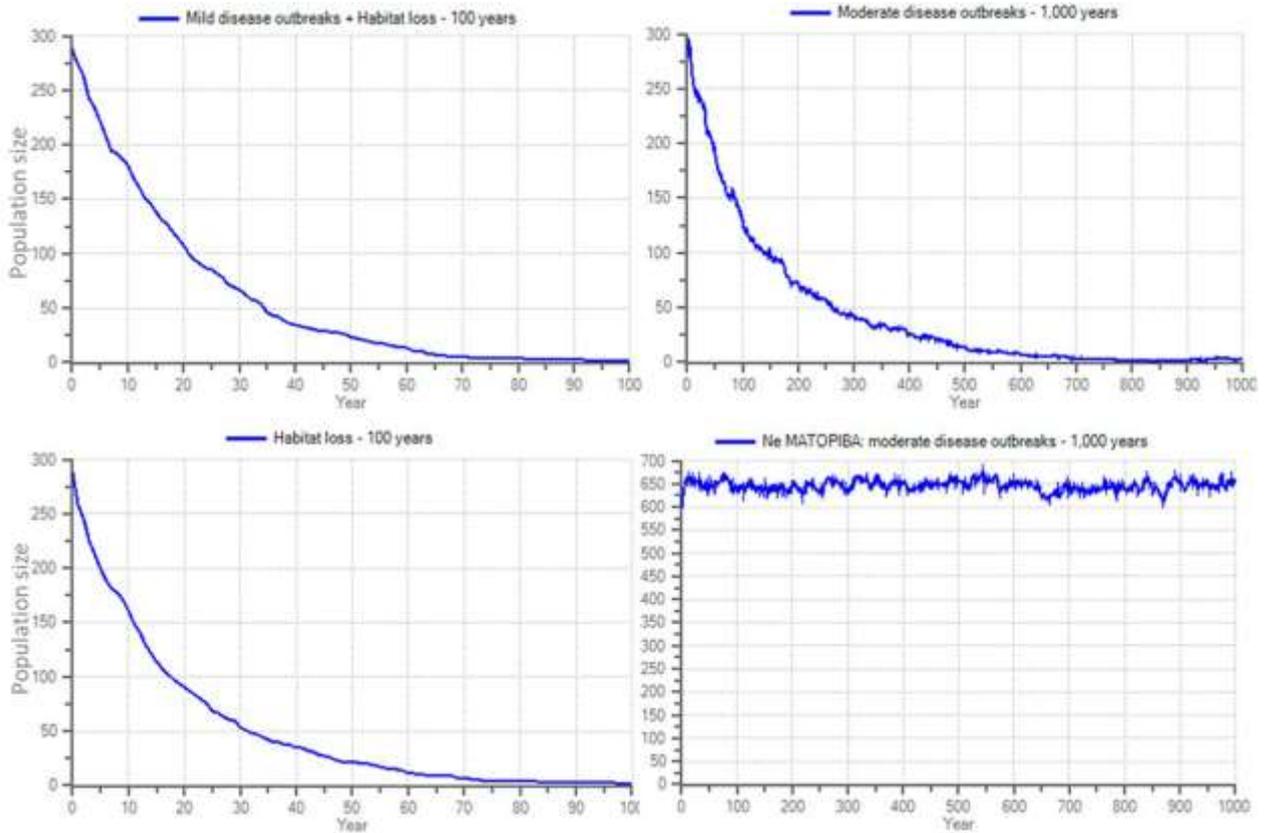
864



865

866

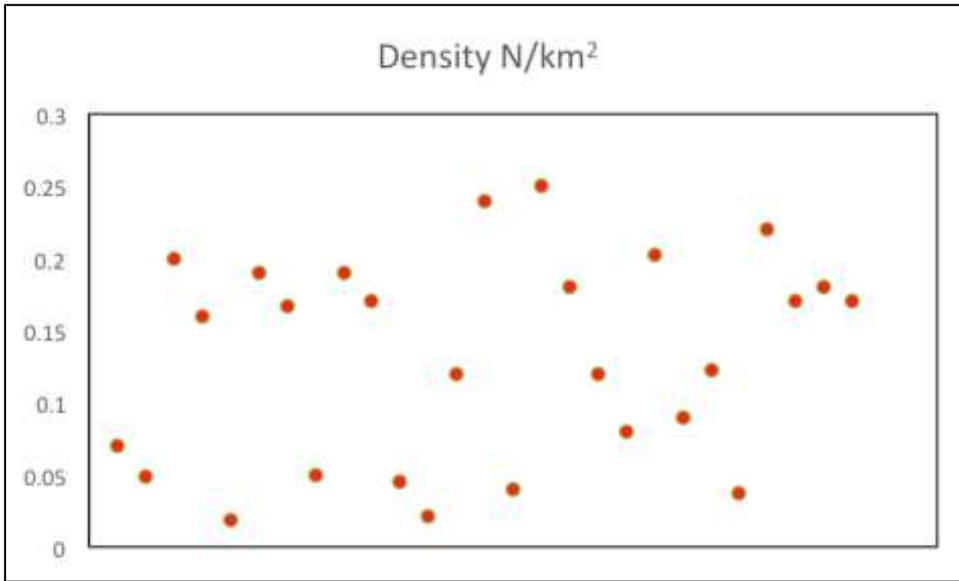
867



868 Figure S8. Population Viability Analysis estimates for Northern Tiger Cat in Mirador State
869 park and the MATOPIBA savannas.

870

871



872

873 Figure S9. Densities of small cats in tropical America: jaguarundis (*Herpailurus*
 874 *yagouaroundi*), margays (*Leopardus wiedii*), and northern (*Leopardus tigrinus*) and southern
 875 (*Leopardus guttulus*) tiger cats. These are all densities where ocelots are absent or rare. In most
 876 areas where ocelots are abundant, small cats' densities are smaller than the lower values
 877 presented here (Oliveira et al., 2018b).

878

879 Table S10. Carnivore abundances in Mirador State Park in the threatened
 880 northern/MATOPIBA savannas of Brazil, as determined after 5,030 camera-trapping days.

881

	Species	Individuals/100 trap-days
882	Northern tiger cat <i>Leopardus tigrinus</i>	1.014
	Pampas cat <i>Leopardus colocola</i>	0.119
	Ocelot <i>Leopardus pardalis</i>	0.020
883	Jaguarundi <i>Herpailurus yagouaroundi</i>	0.020
	Puma <i>Puma concolor</i>	0.239
884	Crab-eating fox <i>Cerdocyon thous</i>	5.527
	Hoary fox <i>Lycalopex vetulus</i>	0.636
885	Domestic dog <i>Canis lupus familiaris</i>	1.213
	Coati <i>Nasua nasua</i>	0.357
886	Hog-nosed skunk <i>Conepatus semistriatus</i>	0.755

887

888

CAPITULO II

Artigo estruturado de acordo com as normas da Revista de interesse para publicação
– Perspectives in Ecology and Conservation.

889 **Of small cats and dogs: Interspecific relationships of wild and domestic carnivores in the**
890 **northern savannas of Brazil**

891

892 **Abstract**

893 Among the several ecological forces that dictate the structure of carnivore
894 communities, interspecific relations could be considered relevant for the coexistence
895 of several species within an area. At Mirador State Park, a key conservation area in the
896 Brazilian Cerrado, the northern tiger cat (*Leopardus tigrinus*) and Pampas cat
897 (*Leopardus colocola*) share space with domestic dogs and humans. We therefore
898 addressed their influence as well as that of environmental variables on the spatio-
899 temporal exploitation mechanisms of both felid species, using Generalized Linear
900 (GLM) and Occupancy (OM) Models, as well as extrapolating their effects to our
901 sampled sites. We also analyzed activity patterns of both felids and of other carnivores.
902 Records were obtained between May 2018 and March 2019 with 30 camera traps
903 installed on two areas within the park, totaling 4,312 trap-nights. We obtained a
904 probability of habitat use of 0.012 and 0.99 for pampas cat and tiger cat, respectively.
905 Detectability of both species was directly affected by vegetation structure, while
906 habitat selection analyses showed that tiger cats avoided areas near human settlements
907 and with high intensity of use by domestic dogs. Conversely, pampas cat habitat
908 selection was mostly influenced by vegetation structure. Both felids and domestic dogs
909 showed a moderate degree of temporal overlap, while there was a significant temporal
910 segregation between both felids. The highest level of activity overlap was observed
911 between tiger cat and crab-eating fox (*Cerdocyon thous*). Crab-eating foxes were not
912 found to influence small felids' numbers or spatio-temporal ecologies. Domestic dogs
913 did potentially influenced tiger cats' numbers and spatial ecology. However, the
914 greatest menace of both canids on small cats is the potential of disease transmission.
915 Our results suggest anthropic threats could act with more intensity than environmental
916 factors in determining these species use of space, representing a risk for wildlife
917 conservation in the park.

918 **Keywords:** *Leopardus tigrinus*; *Leopardus colocola*; northern savanna; domestic
919 dogs; Occupancy models; temporal overlap

920

Highlights:

- 921 ➤ We assess the first interspecific relations among tiger cat, pampas cat and dogs.
- 922 ➤ We provide a refined habitat use analysis for both felid species.
- 923 ➤ Domestic dogs and human presence greatly influence habitat use of small felids.
- 924 ➤ High degree of temporal overlap between both felids and domestic dogs.
- 925 ➤ Anthropogenic variables represent a conservation issue for both felids.

926

1. Introduction.

927

928

929

930

931

932

933

934

935

936

937

938

939

940

941

Understanding interspecific relations in their most varied context is a central part of the fields of modern ecology and conservation biology. In the carnivore guild of a given community, interspecific interactions are a key process modulating species co-occurrence. Species interactions may provide much needed resilience for ecosystems to resist negative impacts both of anthropogenic and natural origin (Polis et al. 1989; Ritchie e Johnson, 2009; Di Bitetti et al. 2010; Ripple et al. 2014; Heim et al. 2019). In this context, intraguild predation and interspecific killing may be considered the most active ecological forces in the structuring of carnivoran communities in South America. Generally, larger carnivores influence behavioral and demographic aspects of smaller species in the same guild (de Oliveira and Pereira, 2014; Ripple et al. 2014). Expansion of human activities across the globe has altered these interactions in some carnivoran communities, particularly in areas where exotic carnivores have been introduced (Ferreira et al. 2018). Kays et al. (2015) have shown that domestic cats are rare where coyotes run free in North America. This brings interesting ecological perspectives in canids and felids interspecific relationships, also bridging out on wild-domestic carnivorans interactions.

942

943

944

945

946

947

948

949

950

951

952

953

954

955

956

Negative effects from exotic carnivore introductions are well documented, and 58% of all recent vertebrate extinctions were caused by exotic predators (Weston et al. 2014, Doherty et al. 2016, 2017). Within this group, domestic dogs (*Canis familiaris*) have lived near humans since they were domesticated ca. 15,000 years ago (Driscoll and Macdonald, 2010), reaching high densities and occupying several areas of different ecosystems (Ordeñana et al. 2010; Paschoal et al. 2018). Domestic dogs affect wildlife populations through direct predation, behavioral change, prey predation, and disease transmission (Doherty et al. 2016, 2017; Ellwanger and Chies, 2019). Cases of predation by domestic dogs range from an increase in predation pressure on small mammals and ungulates (Young et al. 2011) to the extreme case of a single dog causing a 55% decline in a kiwi (*Apteryx australis*) population (Taborsky, 1988). In the savannas of the Brazilian Cerrado, prior research suggest that domestic dogs are the main suspect of pathogen transmission and behavioral alterations in wild carnivores, even within protected areas (Curi et al. 2006; Lacerda et al. 2009, Lessa et al. 2016). Therefore, quantifying interactions between domestic dogs and wild carnivores in protected areas is key in order to guarantee long-term survival of several species.

957 In the Cerrado Biodiversity Hotspot, several protected areas are recognized not only by
958 their intrinsic value, but also by allowing important ecological processes to occur. Among these
959 areas, Mirador State Park (MSP) is home to several threatened species both globally and
960 nationally (Oliveira et al. 2014). The park has been recognized as a key area for the conservation
961 of small felids (< 15 kg), particularly the globally Vulnerable northern tiger cat – *Leopardus*
962 *tigrinus* (Schreber, 1775) and the Near Threatened pampas cat – *Leopardus colocola* (Molina,
963 1782) (Payan and de Oliveira, 2016; Lucherini et al. 2016; de Oliveira et al. 2020) (Fig.1). At
964 MSP, these two species are sympatric with other wild carnivores (e.g. puma – *Puma concolor*,
965 ocelot – *Leopardus pardalis*, jaguarundi – *Herpailurus yagouaroundi*, crab-eating fox –
966 *Cerdocyon thous* and hoary fox – *Lycalopex vetulus*) (Oliveira et al. 2014, 2020). Both tiger
967 cat (2.4 kg) and pampas cat (3.5 kg) have several natural history traits in common and also have
968 overlapping distribution in the Cerrado biome in Brazil, which make them potential
969 interspecific competitors (Oliveira et al. 2018, Queirolo et al. 2013, de Oliveira and Pereira
970 2014). Meanwhile, their spatial and temporal relations remain unknown. In order to address this
971 issue and canid-felid interspecific relationships, we combined occupancy and activity analyses
972 with the goal of answering the following questions: 1) How environmental and anthropogenic
973 factors influence space use of small felids in savannas? 2) Are there any interspecific
974 relationships modulating activity patterns for these species? 3) Do domestic dogs influence the
975 ecological niche of both felids? Do the larger domestic and wild canids exert a demographic
976 pressure on small cats? In order to answer these questions, we set up a camera trapping study
977 aiming on understanding the interspecific relationship of tiger cat and pampas cat and to assess
978 the potential role played by domestic dogs on their habitat usage and conservation needs. Our
979 results will also help us evaluate the role that MSP plays in the conservation of small felids on
980 the northern Cerrado savannas.

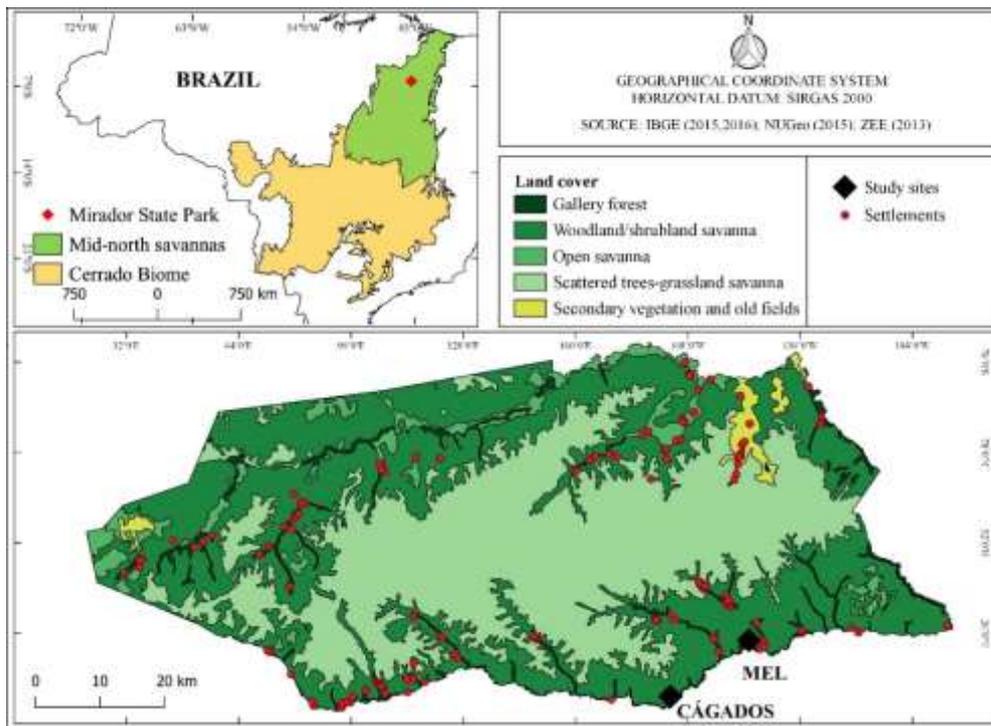


981 Fig. 1. Small threatened felids at Mirador State Park, northern tiger cat *Leopardus*
982 *tigrinus* and pampas cat *Leopardus colocola*.

983 2. Methods.

984 2.1 Study site.

985 Mirador State Park is a fully protected area located in the northern savannas of the
986 Cerrado biome, and with its 5,008 km² it is the second largest protected area in the entire biome
987 (Fig. 2). MSP vegetation includes several savanna formations varying from open savannas to
988 woodland savannas, tree cover ranges from 0 – 50% in most of the park. Tree cover is higher
989 in gallery forests, which occurs along the park's rivers (Rodrigues and Conceição, 2014). Two
990 sites within MSP were sampled: Mel and Cágados. Concerning vegetation structure, Mel has
991 slightly denser vegetation than Cágados. The amount of human settlements and the degree of
992 human activities is also higher at Mel. Brazilian environmental legislation prohibits extractive
993 activities, poaching and livestock raising in protected areas such as MSP. Nevertheless, there
994 are signs of these activities at our sampled sites as well as outside park limits (Oliveira et al.
995 2014).



997 Fig. 2. Location of Mirador State Park with the sampled sites, human settlements, and
 998 land cover.

999 2.2 Camera trapping

1000 The study was conducted between May, 2018 and March, 2019 with the use of camera
 1001 traps, the infrared Bushnell Trophy Cam HD (Bushnell Outdoor Products, Overland
 1002 Park/Kansas) and the white-flash ScoutGuard SG565 (Boly Inc., Santa Clara/California) and
 1003 Reconyx PC850 (Reconyx Inc. Holmen/Wisconsin). We established 30 sampling points, 12 at
 1004 Mel and 18 at Cágados, each of which consisted of a single camera trap. Camera trapping
 1005 followed a well-established and effective protocol for small neotropical felids (Oliveira et al.
 1006 2008, 2020). Camera spacing considered the radius of the smallest home ranges known for
 1007 small neotropical felids and varied from 0.5-1.0 km (Michalski et al. 2006; Oliveira et al. 2010;
 1008 Kasper et al. 2016). With this arrangement, all individuals within the sampling landscape had a
 1009 nonzero detection probability.

1010 2.3 Habitat use covariates

1011 We used the following six covariates associated with habitat quality and structure: 1)
 1012 tree cover (%), 2) elevation (m), 3) conditional habitat use by domestic dogs (conditional ψ), 4)

1013 distance to nearest human settlement (m), 5) distance to nearest water source (m), and 6)
1014 distance to nearest non-paved road (m) (Table S1).

1015 A 90,000 m² buffer was established around each sampling point. For each buffer, we
1016 estimated mean tree cover using data from the Global Forest Change Tree Cover Dataset
1017 (Hansen et al. 2013). On this dataset, trees are defined as vegetation taller than 5 m in height
1018 and are expressed as a percentage per 30x30 m pixel. We also estimated mean elevation above
1019 sea level for each buffer, using data from the United States Geological Survey (2019). All
1020 “distance to” covariates were measured from each camera trap: distance to non-paved roads
1021 and water sources were calculated using nearest neighbor analysis, while for human settlements,
1022 we averaged the distance to the three nearest settlements. All covariate values were extracted
1023 using QGIS ver. 3.4 (QGIS Development Team).

1024 Conditional habitat use by domestic dogs represents the probability of domestic dogs
1025 using each sampling unit independently. We obtained these values using single-season
1026 occupancy models in the software PRESENCE 10.7 (Hines, 2006; Mackenzie et al. 2006), with
1027 the same number of sampling occasions as the main analysis (23 occasions). Model selection
1028 was carried out using Akaike information criterion, with the best models being those with ΔAIC
1029 ≤ 2 (Burnham and Anderson, 2002). All covariate values were z-scored and tested for
1030 collinearity using Pearson correlation tests, we excluded highly correlated covariates ($|r| \geq 0.8$)
1031 (Long et al. 2011).

1032 **2.4 Data Analysis**

1033 Possible influences of anthropogenic and environmental variables on the spatial ecology
1034 of the two felid species were assessed using two types of hierarchical models: Generalized
1035 Linear Models (GLMs) and Occupancy Models (OMs). Combining these two techniques is
1036 highly recommended in order to reduce the probability of excluding covariates that could be
1037 important from an ecological point of view (Gorosito, 2018), especially in cases with low
1038 species detections (Michalski et al. 2015). The two methods use different data matrixes (OM –
1039 presence/absence matrix; GLM – number of independent records). Both of them were treated
1040 as proxies for habitat use. In order to evaluate activity patterns of both species, as well as
1041 possible influences of interspecific relations on such patterns, we analyzed temporal overlap
1042 between them (Ridout and Linkie, 2008; Meredith and Ridout, 2018). All analyses were
1043 performed in R ver. 3.6.0 (R Development Core Team 2019) using specific packages.

1044 **2.4.1 Occupancy models (OMs)**

1045 We acknowledge that the field sampling protocol violated the closure assumption, that
1046 is, we cannot guarantee that there were no changes in occupancy of the sampled sites. We
1047 therefore interpret occupancy probability as probability of habitat use (Mackenzie et al. 2006;
1048 Guillera-Arroita et al. 2010).

1049 Probability of use (ψ) and detection (p) were calculated using single season occupancy
1050 models (Mackenzie et al. 2002, 2006), with a binary detection history of 23 occasions, each
1051 composed of 13 days. We used a two-step approach for modeling purposes (Mackenzie et al.
1052 2006). On the first step, we estimated the influence of each covariate on the detection
1053 probability of each species (p), leaving ψ constant. On the second step, we fixed the covariates
1054 of the best ranked model from the first step and tested the influence of all covariates on ψ . This
1055 approach allows for higher precision in testing covariates individually or in groups (Marinho et
1056 al. 2017). We selected the best models based on AIC, with the best models being those with
1057 $\Delta\text{AIC} \leq 2$ (Burnham and Anderson, 2002). All models were constructed using the *unmarked*
1058 package (Fiske and Chandler, 2019).

1059 **2.4.2 Generalized linear models (GLMs)**

1060 GLMs were done separately for each species using a negative binomial distribution,
1061 which is the recommended distribution for over dispersed and/or zero inflated data (Sileshi,
1062 2008; Warton et al. 2016). We modeled the number of independent records at each sampling
1063 site as a function of the covariates, using the same model selection criterion as in the occupancy
1064 models ($\Delta\text{AIC} \leq 2$). GLM analyses were done using the *MASS* package (Ripley et al. 2019).

1065 **2.4.3 Temporal overlap of carnivores at MSP and canid-felid ratios**

1066 Besides exploring possible effects by domestic dogs on the activity patterns of tiger cat
1067 and pampas cat at MSP, we also assessed the potential effects of the crab-eating fox (*Cerdocyon*
1068 *thous*), the most abundant carnivore in the park and a potential competitor of the smaller felids.
1069 We built a matrix with independent records (those at least 1 hour apart, or less in the case of
1070 different individuals) for each species. We examined activity patterns and calculated overlap
1071 coefficients (Δ ; 0 – no overlap; 1 – complete overlap), for each species pair. We chose the Δ_1
1072 estimator as the species with the smallest sample had fewer than 75 records (Meredith and
1073 Ridout, 2018). In order to interpret Δ we followed the values proposed by Massara et al. (2018),
1074 $\Delta < 0.50$ as a low overlap value, $0.50 \geq \Delta \leq 0.60$ as moderate overlap, and $\Delta > 0.60$ indicating

1075 a strong degree of overlap. We estimated 95% confidence intervals as percentage intervals from
1076 10,000 bootstrap samples (Meredith and Ridout, 2018). We assessed significance using a
1077 Mardia-Watson-Wheeler test with a significance level of 0.05. We used the packages *Activity*
1078 (Rowcliffe, 2019), *Overlap* (Meredith and Ridout, 2018), and *Circular* (Lund et al, 2017) for
1079 the analyses.

1080 To shed light on the possible demographic influence of canids and felids, we identified
1081 individual tiger cat, fox and dog based on their characteristic spot patterns or color, body marks
1082 and features. Then, we compared their ratios. Pampas cat individuals could not be reliably
1083 identified because almost all were melanistic and lacked special features and marks to do so.

1084 **2.5 Predicting felid occurrence at MSP**

1085 In order to predict species occurrence at the sample sites, we used the β coefficients of the
1086 best occupancy models for each species. We divided the sampled areas with a 50x50 m grid, at
1087 each of which we extracted covariate values. For each area, we added a buffer equivalent to the
1088 mean maximum distance moved by northern tiger cat at MSP (2.4 ± 1.05 km). We used these
1089 buffers as base-maps for the predictors, which allowed us to avoid the disappearance of possible
1090 effects (Morris et al. 1987; Gorosito et al. 2018) and conditioned our predictions to effectively
1091 surveyed areas (Brozovic et al. 2018). Predictions maps were done using the packages *Lattice*
1092 (Sarkar, 2018) and *Raster* (Hijmans et al. 2019).

1093 **3. Results**

1094 **3.1 Occupancy Models (OMs):**

1095 After a survey effort of 4,312 trap-nights, we obtained 21 independent records of
1096 pampas cat and 41 of northern tiger cat, with a naïve occupancy of 23% and 50% respectively,
1097 and a spatial overlap of 16% (corresponding to five sampling points). Detection probabilities
1098 for both species were influenced by the same three covariates on the best ranking models (Table
1099 1). Among these covariates, tree cover had the greatest Akaike weight, resulting in detection
1100 probabilities of 0.16 (CI: 0.11-0.22) for northern tiger cat and 0.015 (CI: 0.002-0.094) for
1101 pampas cat. As expected, pampas cat was negatively affected by this covariate, suggesting they
1102 are more detectable on open areas. On the other hand, tiger cat was positively affected by tree
1103 cover, with higher predilection for areas with denser vegetation.

1104

1105 Table 1. Detectability and probability of habitat use models for Northern tiger cat and Pampas
 1106 cat in Mirador State Park. Only models with $\Delta AIC < 2$ are shown.

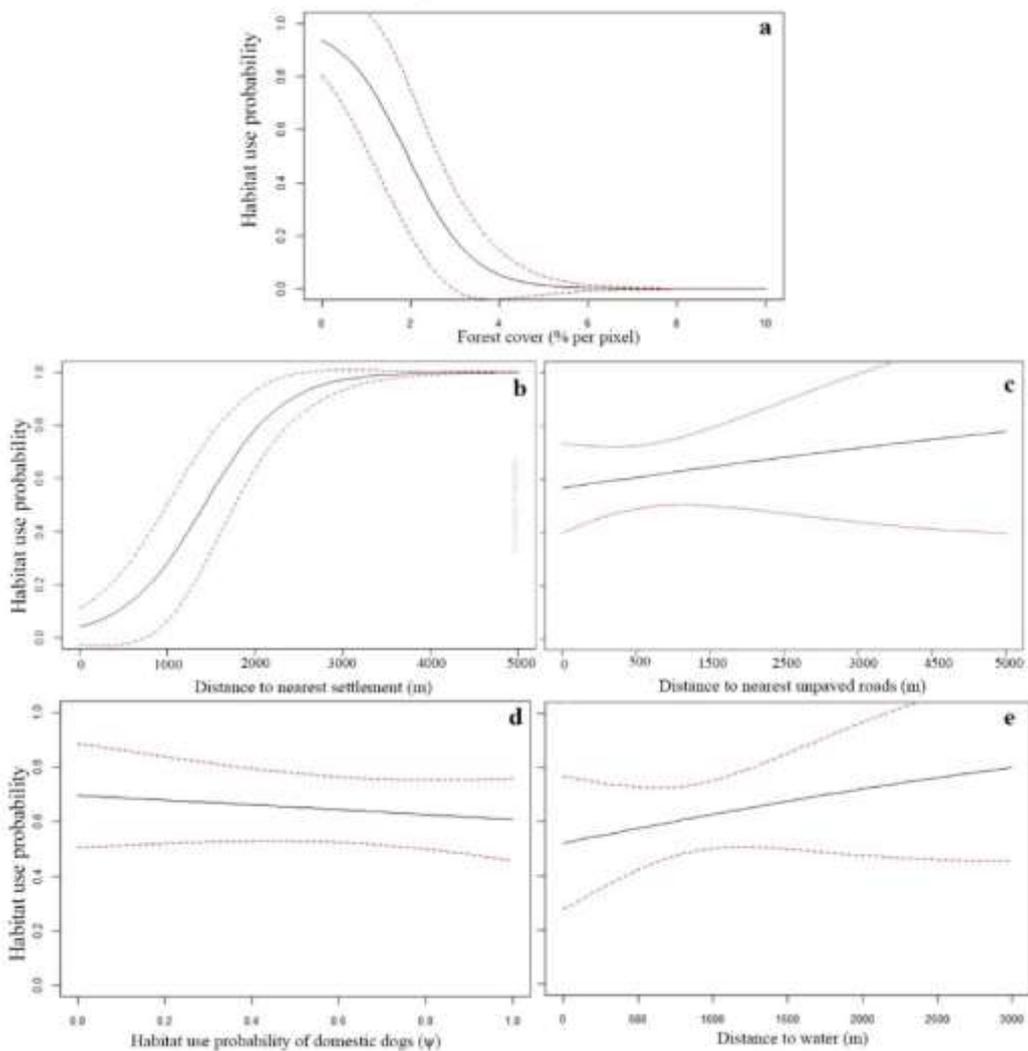
Best Models	nPar	AIC	ΔAIC	AICwt
Northern tiger detection models (step one)				
$\Psi(\text{constant}) p(\text{FC})$	3	246.49	0.00	0.127
$\Psi(\text{constant}) p(\text{DOG})$	3	247.05	0.56	0.096
$\Psi(\text{constant}) p(\text{null})$	2	247.26	0.77	0.086
$\Psi(\text{constant}) p(\text{FC}+\text{DOG})$	4	247.71	1.23	0.069
$\Psi(\text{constant}) p(\text{ELEV})$	3	247.89	1.40	0.063
$\Psi(\text{constant}) p(\text{FC}+\text{ELEV})$	4	247.97	1.48	0.060
$\Psi(\text{constant}) p(\text{DOG}+\text{ELEV})$	4	247.98	1.50	0.060
$\Psi(\text{constant}) p(\text{SET})$	3	248.22	1.73	0.053
$\Psi(\text{constant}) p(\text{FC}+\text{SET})$	4	248.25	1.76	0.052
Pampas cat detection models				
$\Psi(\text{constant}) p(\text{FC})$	3	119.30	0.00	0.399
$\Psi(\text{constant}) p(\text{FC}+\text{SET})$	4	119.81	0.51	0.310
$\Psi(\text{constant}) p(\text{FC}+\text{DOG})$	4	120.67	1.37	0.201
Northern tiger occupancy models (step two)				
$\Psi(\text{DOG}+\text{SET}+\text{WATER}) p(\text{FC})$	6	242.04	0.00	0.368
$\Psi(\text{UROAD}+\text{SET}) p(\text{FC})$	5	243.09	1.05	0.218
Pampas cat occupancy models				
$\Psi(\text{FC}) p(\text{FC})$	4	115.04	0.00	0.406

1107 **FC:** Tree cover; **DOG:** Conditional habitat use by domestic dogs; **ELEV:** Elevation; **SET:** Distance to nearest settlement;
 1108 **UROAD:** Distance to nearest paved road; **WATER:** Distance to nearest water source.

1109

1110 The best model for domestic dogs had constant detection probability and habitat use
 1111 influenced by forest cover ($\beta = 0.91 \text{ SE} \pm 0.65$, naïve occupancy = 0.50). The best models for
 1112 habitat use (ψ) were markedly different between both species. The best model for pampas cat
 1113 suggested low probability of habitat use ($\psi = 0.012$; 95% CI: 0.001-0.563) and a negative effect
 1114 by tree cover, suggesting this species likely exploits open areas at MSP with higher frequency
 1115 (Fig. 3a). For northern tiger cat there were two models with $\Delta AIC < 2$ (Table 1). The positive
 1116 influence of increasing distances to settlements, suggests this species avoids areas with human
 1117 presence (Fig. 3b). This felid also avoided areas near non-paved roads and areas with high
 1118 intensity of use by domestic dogs (Fig. 3c-d). The best models estimated a very high probability
 1119 of habitat use and a wide confidence interval ($\psi = 0.99-1.00$; 95% CI: 0.10-1.0). Unexpectedly,
 1120 distance to water sources had a positive effect on habitat use by northern tiger cat, suggesting
 1121 that the species does not exclusively use the water sources identified during the study (Fig. 3e).

1122 No other covariates were in the best models for detection or habitat use, and either had low
1123 explanatory power or did not converge (Table S2).



1124 Fig. 3. Habitat use probabilities for small felids at MSP in relation to different
1125 covariates. Dotted red lines represent standard errors.

1126 3.2 Generalized Linear Models (GLMs)

1127 Following the same pattern observed on the OMs, the GLMs also showed differences
1128 between both felid species. Tree cover was statistically significant for explaining pampas cat
1129 abundance, with a negative influence, which further suggests the species preference for open
1130 areas at MSP. For tiger cat all models had a similar Δ AIC with no significantly important
1131 covariates in explaining its abundance at our sampled sites (Table 2).

1132

1133

1134

1135

Table 2. GLM model results for both felids at MSP.

Model	Npar	AIC	Δ AIC	Dispersion
Northern tiger cat				
Null model (Intercept)	2	110.10	0.00	1.060
Forest cover	3	110.90	0.80	1.123
Distance to nearest settlement	3	111.62	1.52	1.112
Habitat use probability of dogs	3	111.73	1.63	1.110
Elevation	3	111.78	1.68	0.903
Distance to water	3	111.96	1.86	0.903
Distance to nearest unpaved roads	3	111.96	1.86	0.903
Pampas cat				
Forest cover ^a	2	64.012	0.00	1.391
Null model (Intercept)	3	70.365	6.35	1.351
Habitat use probability of dogs	3	70.549	6.53	1.260
Elevation	3	71.812	7.80	1.300
Distance to water	3	72.001	7.99	1.300
Distance to nearest unpaved roads	3	72.001	7.99	1.300
Distance to nearest settlement	3	72.309	8.30	1.300

1136

a: Statistically significant ($P = 0.028$)

1137

3.3 Predicting felid occurrence at MSP

1138

1139

1140

1141

1142

1143

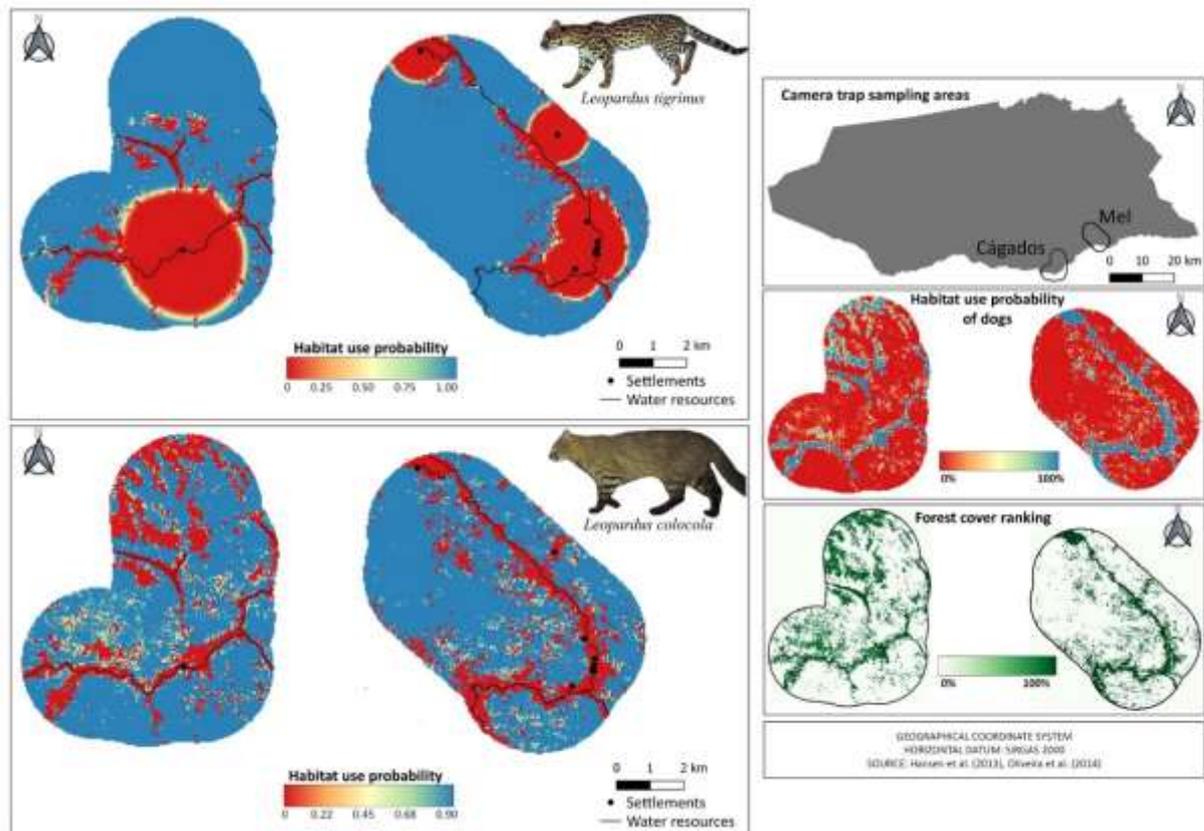
1144

1145

1146

1147

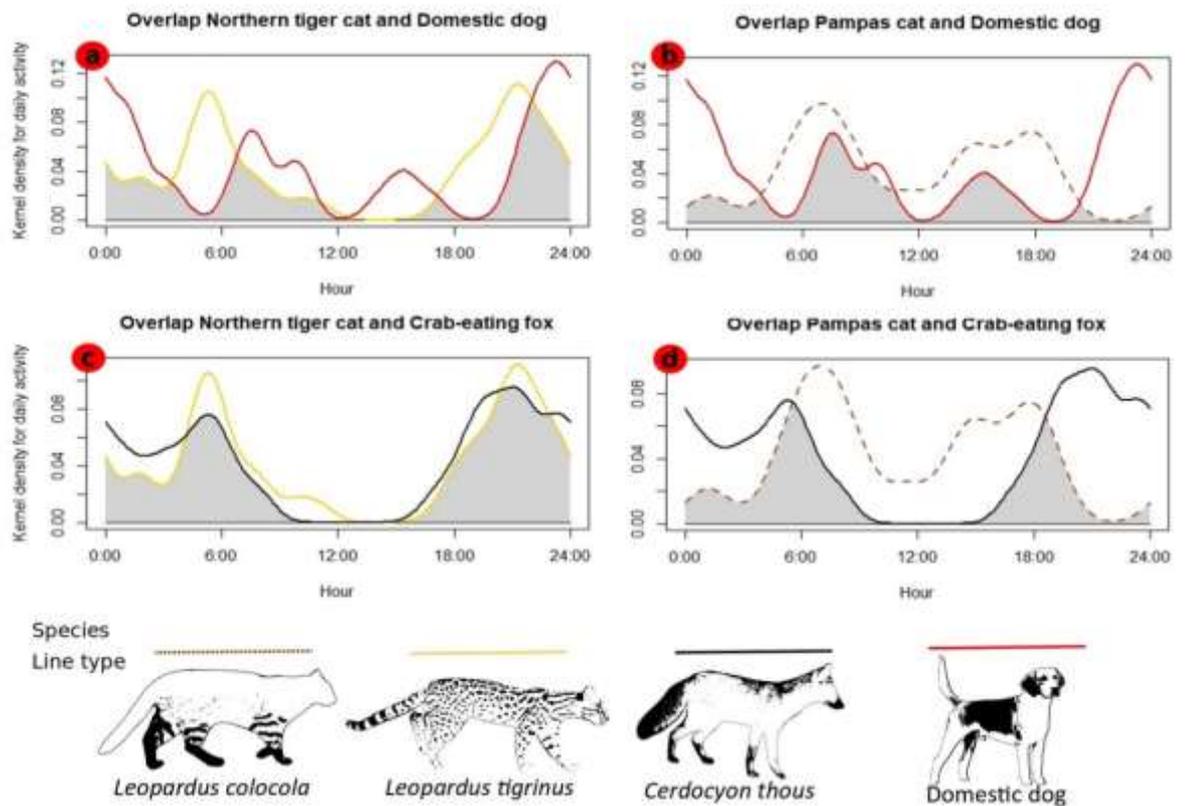
Due to the different values and signs of the coefficients, predictive maps showed interesting differences between both species. As expected, habitat use by pampas cat is smaller as tree cover increases, with the gallery forests showing very low probability of use ($\psi < 0.10$) (Fig. 4). Estimated predictions for tiger cat exhibited unusual patterns at the Cágados site, which could be due to hyper extrapolation of covariate coefficients or spatial autocorrelation between sampling points (Penjor et al. 2018). In general, anthropogenic covariates were extremely important for habitat use preferences of this species. Areas with high probability of use by domestic dogs were generally avoided by tiger cats. This pattern suggest that domestic dogs and human activities are directly limiting this species' capacity of exploiting different ecosystems at MSP (Fig. 4).



1149 Fig. 4. Predictive occupancy maps for *L. tigrinus* and *L. colocola* on the effectively
 1150 surveyed areas of MSP and maps for the main covariates.

1151 3.4 Temporal overlap between carnivores at MSP and canid : felid ratios

1152 Activity overlap between domestic dogs and wild carnivores differ for all species pairs.
 1153 There was a moderate degree of overlap between domestic dog and tiger cat ($\Delta_1 = 0.59$; 95%
 1154 CI: 0.44–0.75) (Fig. 5a); for pampas cat there was low overlap with domestic dogs ($\Delta_1 = 0.47$;
 1155 95% CI: 0.29 – 0.65); lastly, overlap between dog and crab-eating fox was high ($\Delta_1 = 0.61$ 95%
 1156 CI: 0.48 – 0.74). Temporal overlap between crab-eating fox and the two felids had inverse
 1157 results for both species: with tiger cat there was a high degree of overlap ($\Delta_1 = 0.82$; 95% CI:
 1158 0.72 – 0.92), while overlap with pampas cat was lower ($\Delta_1 = 0.47$; 95% CI: 0.30 – 0.64) (Fig.
 1159 5c-d). Temporal overlap between both felids was moderate ($\Delta_1 = 0.51$; 95% CI: 0.32 – 0.69)
 1160 and significantly different ($w = 14.271$; $df = 2$; $p < 0.001$). Among all other species pairs, only
 1161 pampas cat and crab-eating fox had significant differences ($w = 21.448$; $df = 2$; $p < 0.001$).



1162

1163 Fig. 5. Activity overlap plots of four carnivorous species (wild and domestic) from
 1164 MSP. Shaded areas correspond to temporal overlap between species pairs.

1165 At Mel, there were at least 12 individual foxes, 15 dogs and six tiger cats present,
 1166 whereas at Cágados there were 21 foxes, seven dogs and eight cats. This gives a ratio of 2 foxes:
 1167 1 cat and 2.7 foxes: 1 cat, respectively. For domestic dogs: tiger cats at Mel, ratio would be
 1168 2.5:1, whereas at Cágados it would be 0.9:1.

1169 4. Discussion

1170 4.1 Small felid habitat use at MSP

1171 The combination of methodologies for identifying habitat use patterns allowed us to
 1172 assess for the first time ever habitat preferences of threatened felids in the northern Cerrado.
 1173 Thoroughness is extremely important when addressing ecological processes through
 1174 correlations (Mackenzie et al. 2004). This is especially true for rare species, such as pampas,
 1175 where lack of detection may result in biased estimates of habitat use (Mackenzie and Royle,
 1176 2005; Linkie et al. 2007). In our case, accounting for imperfect detection through occupancy
 1177 models, and complementing this with the GLM, allowed us to avoid excluding ecologically
 1178 important variables (Gorosito et al. 2018). At MSP, the sole application of a GLM would

1179 arbitrarily exclude anthropic covariates that act directly on the behavior and survival of tiger
1180 cats as reported in other studies (Oliveira et al. 1996, 2014, 2020). On the other hand, the
1181 exclusive use of OMs for pampas cat would not provide robust inferences, as OMs require a
1182 high number of detections in order to effectively identify habitat use patterns (Gorosito et al.
1183 2018). Despite its importance, the lack of spatial independence between sampling points did
1184 not cause hamper to the analysis. This premise is often violated in studies with highly mobile
1185 species (Gould et al. 2019). Both felids have higher area requirements than what would be
1186 expected based on their body size (Oliveira et al, 2010; Payan and de Oliveira, 2016; Lucherini
1187 et al. 2016).

1188 Detection probability estimates for *L. tigrinus* were in line with what has been found
1189 previously in the semi-arid Caatinga biome and in the Sertão Veredas/Peruaçu National Parks
1190 conservation area mosaic (MSVP). Our detection probability estimates were equal to those of
1191 MSVP and slightly higher of those in the Caatinga (Marinho et al. 2017; Oliveira et al. 2018).
1192 The lowest detection probabilities are reported for the Boqueirão da Onça region, with a value
1193 of 0.08 (0.04-0.11) (Dias et al. 2019). We had the highest values ever reported for the species
1194 for the probability of habitat use. Both occupancy and detection tend to be positively correlated
1195 with abundance (Lopez and Pfister, 2001; Royle and Nichols. 2003). This seems to be the case
1196 at MSP, which has a population of tiger cats twice as high as that in other Brazilian northern
1197 savanna areas (Oliveira et al. 2020).

1198 In a similar fashion as Marinho et al. (2017) and Dias et al. (2019), probability of habitat
1199 use of tiger cats (interpreted as occupancy probability by both authors) was mainly influenced
1200 by anthropic covariates. In the Caatinga, tiger cats also avoided areas near human settlements,
1201 likely due to conflicts with domestic carnivores (Marinho et al. 2017). At MSP, predictive maps
1202 illustrated this as well, with areas within 800 m of human settlements having an 80% decline in
1203 probability of use by tiger cats. Although anthropic covariates were not present in the best
1204 models of pampas cats, the β coefficients showed that these covariates are of conservation
1205 interest at MSP. Direct predation by domestic dogs on pampas cat has been reported in the
1206 Brazilian Pampa (Lucherini et al. 2016) and just outside MSP there was a melanistic tiger cat
1207 killed by dogs (Oliveira 1996). Similarly in the Atlantic Forest, occupancy of southern tiger cat
1208 (*Leopardus guttulus*) and margay (*Leopardus wiedii*) declined as the number of domestic dog
1209 records increased (Cassano et al. 2014). It is known that domestic dogs can form packs and
1210 even attack larger carnivores (Lacerda et al. 2009; Oliveira 2011). At MSP, a significant portion

1211 of domestic dog records involved two or more individuals roaming together, thus representing
1212 a potential threat for the threatened felids.

1213 Domestic dogs generally avoid areas in which apex predators are present (Foster et al.
1214 2010). In the savannas of MSP, medium and large carnivores (i.e. jaguar (*Panthera onca*), puma
1215 and ocelot) are either absent or extremely rare (Oliveira, 1996, 2014, 2020). The lack of top
1216 down competitive pressure reflects on the high degree of spatial mobility of domestic dogs in
1217 MSP. During our study, 22 domestic dogs were identified, and they had a mean movement
1218 parameter of 6 km away from human settlements. These estimates suggest a spatial overlap of
1219 65% with the suitable habitat available for *L. tigrinus* in the park (de Oliveira et al. 2020). This
1220 inference is caused mainly by human activities, and it could result in increased competition and
1221 predation pressure in natural environments (Heim et al. 2019), which on the long term could
1222 result in the local extinction of both felids at MSP.

1223 From an ecological perspective, both pampas cat and tiger cat share similar
1224 environmental requirements in the savannas of the Brazilian Cerrado (Oliveira, 1994; Lucherini
1225 et al. 2016; Payan and de Oliveira, 2016). Resource exploitation strategies in relation to
1226 landscape characteristics and interspecific relations affect the spatial patterns of wild carnivores
1227 (Lyra-Jorge et al. 2009; de Oliveira and Pereira, 2014). Tree cover in particular, directly
1228 influenced pampas cat. This species is known to be associated with open habitats (Bagno et al.
1229 2004; Lucherini et al. 2016), even being regularly detected in open savannas and agrarian
1230 landscapes of Emas National Park (Bagno et al. 2004; Godoi et al. 2010; Giozza et al. 2017).
1231 We expected the opposite result for tiger cats at MSP, as this species tends to present high
1232 densities in closed or moderately open savannas within the park (Oliveira et al. 2020).
1233 Therefore, besides prioritizing areas with good vegetation conditions in the Cerrado, it is also
1234 important to understand the influence of the horizontal stratification typical of savanna habitats
1235 on both felids.

1236 Areas away from water sources showed high probability of habitat use by tiger cats.
1237 This, however, must be interpreted with caution since in arid and semi-arid environments water
1238 dictates abundance and survival of species (Wolff, 2001; de Oliveira and Diniz-Filho, 2010).
1239 Our result could be indicative of preference for smaller water sources that are not identifiable
1240 via satellite imagery (Marinho et al. 2018). Thus, we recommend future research prioritizing *in*
1241 *situ* search of water sources and analyzing the possible effects of seasonality.

1242 **4.2 Temporal overlap between carnivores at MSP, canid : felid ratios, and possible**
1243 **conservation effects**

1244 Interspecific relations between carnivores at temporal scales can create dynamics in
1245 carnivoran communities, directly influencing ecosystem functioning through changes in prey
1246 abundance and behavior (Roemer et al. 2009; Oliveira et al. 2011; Ripple et al. 2014; García-R
1247 et al. 2019). Small felid populations at MSP theoretically face little pressure from dominant
1248 wild carnivores (Maran et al. 1998; Oliveira et al. 2010).

1249 In the absence of top-down competitive pressure from larger predators, small felid
1250 activity patterns tend to be modulated by prey availability (Palomares and Caro, 1999; Pereira,
1251 2010; Gorini et al. 2011; Oliveira, 2011). Unsurprisingly tiger cats and pampas cats showed
1252 opposite patterns of diel activity, with the former being predominantly nocturnal and the latter
1253 mostly diurnal. In the Caatinga, activity patterns of northern tiger cats had a moderate overlap
1254 with small nocturnal mammals (Marinho et al. 2018), while its ecological equivalent from the
1255 Atlantic forest, the southern tiger cat (*L. guttulus*), was more diurnal in an area with larger felids
1256 (Oliveira et al. 2010, Massara et al. 2016). Prey base for pampas cat and tiger cat is similar,
1257 involving small mammals (< 100 g), birds, and squamates (Bagno et al. 2004; Oliveira, 2011).
1258 This high degree of dietary overlap along with similar body sizes increases the potential of
1259 competition, which results in segregation mechanisms. Besides temporal segregation between
1260 both species at MSP, there was a low degree of spatial overlap between them (ca. 16% of
1261 sampled points). Though these inferences are insightful, they are not enough to fully state that
1262 segregation between both species is exclusively to avoid competition. In order to disentangle
1263 this issue with greater precision, we would need to know the dietary composition of both cats,
1264 as well as their movement patterns related to habitat usage.

1265 Domestic dogs' activity patterns overlapped by more than 50% with those of tiger cat
1266 and their activity peaks did not differ significantly, which suggests dogs do not directly affect
1267 the diel activity of this felid. The same trend was observed for pampas cat. Nevertheless, this
1268 issue deserves attention, as domestic dogs are hosts of a variety of pathogens (Ellwanger and
1269 Chies, 2019). The degree of overlap between crab-eating fox and tiger cat (82%) and with
1270 pampas cat (47%) was even higher than the overlap with dogs.

1271 In North America, coyote numbers affected those of domestic cats (Kays et al. 2015).
1272 However, this premise does not seem to apply at all for the felid–canid groups, e.g. tiger cat X
1273 crab-eating foxes/dogs at MSP. Body size alone puts this 6 kg fox as a potential predator of

1274 tiger cat, as it falls in the range of carnivores that could potentially benefit from interspecific
1275 killing smaller competitors, like the 2.4 kg tiger cat. Considering the typically high densities
1276 reached by the tiger cats in MSP, especially at Cágados (de Oliveira et al. 2020), where fox
1277 abundance was higher, fox numbers seems, in fact, to be ecologically irrelevant for the
1278 threatened felid. This should relate to the highly adaptable and abundant crab-eating fox being
1279 a generalist omnivore, not a hypercarnivore as tiger cats are (Donadio and Buskirk 2006, de
1280 Oliveira and Pereira 2014). Although domestic dogs can kill smaller carnivores, and the fact
1281 that there was an isolated historic predation of dogs on a black tiger cat outside park limits
1282 (Oliveira 1996), dogs also do not seem to affect wild felid ecology. However, it could be argued
1283 that the higher densities of tiger cats found at Cágados than at Mel (de Oliveira et al. 2020),
1284 could be related to the fact that in the former area ratios are about 1:1, whereas at the latter there
1285 are 2.5 X more dogs than tiger cats.

1286 The scenario of high temporal overlap of dogs and foxes with both felids together with
1287 the high percentage of dogs and foxes with disease signs is favorable for disease transmission.
1288 Thus, it is more likely that crab-eating foxes and dogs represent a threat through potential
1289 disease transmission. At MSP, there are signs of dermatological pathologies on different
1290 individuals (Albuquerque et al. unpublished data). Furthermore, dogs can potentially act as
1291 spillover bridges, facilitating pathogen transfer between wildlife and humans and vice versa
1292 (Ellwanger and Chies, 2019), turning a conservation issue into a public health problem. A
1293 population viability analysis for tiger cats at MSP showed that a scenario with moderate disease
1294 outbreaks and habitat loss could cause the local extinction of the species within 100 years
1295 (Oliveira et al. 2020). This is suggestive that disease outbreaks could have major consequences
1296 for the two small felids. Therefore, conservation actions are urgently needed before reaching
1297 an inflexion point (Doherty et al. 2017).

1298 **Concluding remarks**

1299 Our results suggest that anthropogenic covariates could act with higher intensity than
1300 environmental factors on the spatio-temporal distribution of threatened felids. Results are also
1301 suggestive that in areas that domestic dogs are prevalent, they are an important variable to be
1302 considered in occupancy and conservation assessments. Therefore, in protected areas it is of
1303 paramount importance to reduce the movement of domestic dogs and to have domestic dogs of
1304 the surrounding areas vaccinated to avoid possible disease outbreaks into wild carnivorans
1305 populations.

1306 Different vegetation covers strongly influence habitat use, detectability, and segregation
1307 of tiger cats and pampas cats. A high-quality environment is also important for establishing
1308 conservation measures for these carnivores. In this sense, our results show that MSP fulfills the
1309 environmental needs of small felids, as long as anthropogenic threats are mitigated.
1310 Furthermore, quantifying interspecific interactions is crucial in order to fully understand the
1311 impacts of anthropogenic threats coming from free-roaming domestic animals. Thus, these
1312 factors should be integrated in future conservation assessments.

1313 Our results illustrate the need for conservation actions in the park, and for them to be
1314 efficient, we recommend cooperation between researches and park managers. This should
1315 ensure the long-term survival of pampas and tiger cats at one of their most important
1316 conservation areas in the Brazilian Cerrado.

1317

1318 **References**

1319 Bagno, M.A., Rodrigues, F.H.G., Villalobos, M.P., Dalponte, J.C., Brandão, R.A., Brito, B.,
1320 2004. Notes on the natural history and conservation status of pampas cat, *Oncifelis colocolo*, in
1321 the Brazilian Cerrado. *Mammalia* 68, 75–79. <https://doi.org/10.1515/mamm.2004.011>.

1322 Brian, A., Venables, B., Bates, D.M., Firth, D., Ripley, M.B., 2019. Package MASS.
1323 <http://www.stats.ox.ac.uk/pub/MASS4/> (accessed 21 December 2019).

1324 Brozovic, R., Abrams, J.F., Mohamed, A., Wong, S.T., Niedballa, J., Bhagwat, T., Sollmann,
1325 R., Mannan, S., Kissing, J., 2018. Effects of forest degradation on the moonrat *Echinorex*
1326 *gymnura* in Sabah, Malaysian Borneo. *Mamm. Biol.* 93, 135–143.
1327 <https://doi.org/10.1016/j.mambio.2018.10.003>.

1328 Burnham, K. P., Anderson, D. R. 2002. Model selection and multimodel inference: A practical
1329 information-theoretic approach. New York, NY: Springer-Verlag.

1330 Cassano, C.R., Barlow, J., Pardini, R., 2014. Forest loss or management intensification?
1331 Identifying causes of mammal decline in cacao agroforests. *Biol. Conserv.* 169, 14–22.
1332 <https://doi.org/10.1016/j.biocon.2013.10.006>.

1333 Conceição, G.M., Rodrigues, M. dos S., 2014. Diversidade florística das diferentes fisionomias
1334 de cerrado do Parque Estadual do Mirador, Maranhão, Brasil. *Brazilian Geogr. J.* 5, 139–156.

1335 Courtenay, O., Maffei, L., 2004. Crab-eating Fox *Cerdocyon thous*. In: Sillero-Zubiri, C.,
1336 Hoffmann, M. and Macdonald, D.W. (eds), *Canids: Foxes, Wolves, Jackals and Dogs. Status*
1337 *Survey and Conservation Action Plan*, pp. 32-38. IUCN / SSC Canid Specialist Group, IUCN,
1338 Gland, Switzerland and Cambridge, UK.

1339 Curi, N.H.A., Miranda, I., Talamoni, S.A., 2006. Serologic evidence of *Leishmania* infection
1340 in free-ranging wild and domestic canids around a Brazilian National Park. *Mem. Inst. Oswaldo*
1341 *Cruz* 101, 99–101. <https://doi.org/10.1590/S0074-02762006000100019>.

1342 de Oliveira, G., Diniz-Filho, J.A.F., 2010. Spatial patterns of terrestrial vertebrates richness in
1343 Brazilian semiarid, Northeastern Brazil: Selecting hypotheses and revealing constraints. *J. Arid*
1344 *Environ.* 74, 1418–1426. <https://doi.org/10.1016/j.jaridenv.2010.05.015>.

1345 de Oliveira, T. G., Pereira, J. A. 2014. Intraguild Predation and Interspecific Killing as
1346 Structuring Forces of Carnivoran Communities in South America. *J. of Mammalian Evol.* 4,
1347 427–436. <https://doi.org/10.1007/s10914-013-9251-4>.

1348 de Oliveira, T.G., Lima, B.C., Fox-Rosales, L.A., Pereira, R.S., Pontes-Araújo, E., de Sousa,
1349 A.L., 2020. A refined population and conservation assessment of the elusive and endangered
1350 northern tiger cat (*Leopardus tigrinus*) in its key worldwide conservation area in Brazil. *Glob.*
1351 *Ecol. Conserv.* <https://doi.org/10.1016/j.gecco.2020.e00927>.

1352 Di Bitetti, M. S., De Angelo, C. D., Di Blanco, Y. E., Paviolo, A. 2010. Niche partitioning and
1353 species coexistence in a Neotropical felid assemblage. *Acta Oecologica*. 4, 403–412.
1354 <https://doi.org/10.1016/j.actao.2010.04.001>.

1355 Dias, D.D.M., Massara, R.L., Campos, C.B. De, Henrique, F., Rodrigues, G., 2019. Human
1356 activities influence the occupancy probability of mammalian carnivores in the Brazilian
1357 Caatinga 1–13. <https://doi.org/10.1111/btp.12628>.

1358 Doherty, T.S., et al. 2017. The global impacts of domestic dogs on threatened vertebrates. *Biol.*
1359 *Conserv.* 210, 56–59. <https://doi.org/10.1016/j.biocon.2017.04.007>.

1360 Doherty, T.S., Glen, A.S., Nimmo, D.G., Ritchie, E.G., Dickman, C.R., 2016. Invasive
1361 predators and global biodiversity loss. *PNAS* 113, 11261–11265. [http://dx.doi.org/](http://dx.doi.org/10.1073/pnas.1602480113)
1362 [10.1073/pnas.1602480113](http://dx.doi.org/10.1073/pnas.1602480113).

1363 Donadio, E., Buskirk, S.W., 2006. Diet, morphology, and interspecific killing in carnivora. *Am.*
1364 *Nat.* 167, 524–536. <https://doi.org/10.1086/501033>.

1365 Driscoll, C.A., Macdonald, D.W., 2010. Top dogs: wolf domestication and wealth. *J. Biol.* 9,
1366 10, <http://dx.doi.org/10.1186/jbiol226>.

1367 Ellwanger, J.H., Chies, J.A.B., 2019. The triad “dogs, conservation and zoonotic diseases” –
1368 An old and still neglected problem in Brazil. *Perspect. Ecol. Conserv.* 17, 157–161.
1369 <https://doi.org/10.1016/j.pecon.2019.06.003>.

1370 Ferreira, A., Estadual, U., Cruz, D.S., Peres, C.A., 2018. Use of agroecosystem matrix habitats
1371 by mammalian carnivores (Carnivora): a global-scale analysis
1372 <https://doi.org/10.1111/mam.12137>.

- 1373 Fiske, I., Chandler, R., 2019. Overview of Unmarked: An R Package for the Analysis of Data
1374 from Unmarked Animals. R 1–5. <https://doi.org/10.1002/wics.10>.
- 1375 Foster, R.J., Harmsen, B.J., Valdes, B., Pomilla, C., Doncaster, C.P., 2010. Food habits of
1376 sympatric jaguars and pumas across a gradient of human disturbance. J. Zool. 280, 309–318.
1377 <https://doi.org/10.1111/j.1469-7998.2009.00663.x>.
- 1378 García-R, S., Botero-Cañola, S., Sánchez-Giraldo, C., Solari, S., 2019. Habitat use and activity
1379 patterns of *Leopardus pardalis* (Felidae) in the Northern Andes, Antioquia, Colombia.
1380 Biodiversity 20, 5–19. <https://doi.org/10.1080/14888386.2019.1590235>.
- 1381 Giozza, T.P., Jácomo, A.T.D.A., Silveira, L., Mundim, N., 2017. Riqueza e abundância relativa
1382 de mamíferos de médio e grande porte na região do Parque Nacional das Emas-GO. Rev. Bras.
1383 Zoociências 18, 71–87.
- 1384 Godoi, M.N., Teribel, R., Bianchi, R., Olifiers, N., Concone, H.V.B., Xavier Filho, N.L. 2010.
1385 New records of pampas cat for Mato Grosso do Sul state, Brazil. Cat News, 52, 28-29.
- 1386 Gorini, L., Linnell, J.D.C., May, R., Panzacchi, M., Boitani, L., Odden, M., Nilsen, E.B. 2011.
1387 Habitat heterogeneity and mammalian predator-prey interactions. Mammal. Rev. 42,55–77.
1388 <https://doi.org/10.1111/j.1365-2907.2011.00189.x>.
- 1389 Gorosito, I.L., Marziali Bermúdez, M., Busch, M., 2018. Advantages of combining generalized
1390 linear models and occupancy models to find indicators of habitat selection: Small mammals in
1391 agroecosystems as a case study. Ecol. Indic. 85, 1–10.
1392 <https://doi.org/10.1016/j.ecolind.2017.10.003>.
- 1393 Gould, M.J., Gould, W.R., Cain, J.W., Roemer, G.W., 2019. Validating the performance of
1394 occupancy models for estimating habitat use and predicting the distribution of highly-mobile

1395 species: A case study using the American black bear. *Biol. Conserv.* 234, 28–36.
1396 <https://doi.org/10.1016/j.biocon.2019.03.010>.

1397 Guillera-Aroita, G., Ridout, M.S., Morgan, B.J.T., 2010. Design of occupancy studies with
1398 imperfect detection. *Methods Ecol. Evol.* 1, 131–139. [https://doi.org/10.1111/j.2041-](https://doi.org/10.1111/j.2041-210x.2010.00017.x)
1399 [210x.2010.00017.x](https://doi.org/10.1111/j.2041-210x.2010.00017.x).

1400 Hansen, M.C.C., Potapov, P. V, Moore, R., Hancher, M., Turubanova, S.A. a, Tyukavina, A.,
1401 Thau, D., Stehman, S.V. V, Goetz, S.J.J., Loveland, T.R.R., Kommareddy, a, Egorov, A., Chini,
1402 L., Justice, C.O.O., Townshend, J.R.G.R.G., Patapov, P.V., Moore, R., Hancher, M.,
1403 Turubanova, S.A. a, Tyukavina, A., Thau, D., Stehman, S.V. V, Goetz, S.J.J., Loveland, T.R.R.,
1404 Kommareddy, A., Egorov, A., Chini, L., Justice, C.O.O., Townshend, J.R.G.R.G., 2013. High-
1405 Resolution Global Maps of. *Science.* 342, 850–854. <https://doi.org/10.1126/science.1244693>.

1406 Heim, N., et al. 2019. Carnivore community response to anthropogenic landscape change:
1407 species-specificity foils generalizations. *Landscape Ecol.* [https://doi.org/10.1007/s10980-019-](https://doi.org/10.1007/s10980-019-00882-z)
1408 [00882-z](https://doi.org/10.1007/s10980-019-00882-z).

1409 Hijmans, R.J., Etten, J. Van, Sumner, M., Cheng, J., Bevan, A., Bivand, R., Busetto, L., Canty,
1410 M., Forrest, D., Golicher, D., Gray, J., Greenberg, J.A., Karney, C., Mattiuzzi, M., Mosher, S.,
1411 Shortridge, A., Wueest, R., 2019. Package raster. <https://cran.r-project.org/package=raster>
1412 (accessed 03 october 2019).

1413 Hines, J.E. 2006. PRESENCE. Software to estimate patch occupancy and related parameters.
1414 United States Geological Survey/Patuxent Wildlife Research Center, Reston, USA.
1415 <https://www.mbr-pwrc.usgs.gov/software/presence.html> (accessed 10 July 2019).

1416 Kasper, C.B., Peters, F.B., Christoff, A.U., De Freitas, T.R.O., 2016. Trophic relationships of
1417 sympatric small carnivores in fragmented landscapes of southern Brazil: Niche overlap and

1418 potential for competition. *Mammalia* 80, 143–152. <https://doi.org/10.1515/mammalia-2014->
1419 [0126](https://doi.org/10.1515/mammalia-2014-0126).

1420 Kays, R., Costello, R., Forrester, T., Baker, M.C., Parsons, A.W., Kalies, E.L., Hess, G.,
1421 Millspaugh, J.J., McShea, W., 2015. Cats are Rare Where Coyotes Roam. *J. Mammal.* 96, 981–
1422 987. <https://doi.org/10.1093/jmammal/gyv100>.

1423 L. Massara, R., Paschoal, A.M. de O., L. Bailey, L., F. Doherty, P., Hirsch, A., G. Chiarello,
1424 A., 2018. Factors influencing ocelot occupancy in Brazilian Atlantic Forest reserves. *Biotropica*
1425 50, 125–134. <https://doi.org/10.1111/btp.12481>.

1426 Lacerda, A.C.R., Tomas, W.M., Marinho-Filho, J., 2009. Domestic dogs as an edge effect in
1427 the Brasília national park, Brazil: Interactions with native mammals. *Anim. Conserv.* 12, 477–
1428 487. <https://doi.org/10.1111/j.1469-1795.2009.00277.x>.

1429 Lessa, I., Corrêa Seabra Guimarães, T., de Godoy Bergallo, H., Cunha, A., M. Vieira, E., 2016.
1430 Domestic dogs in protected areas: a threat to Brazilian mammals? *Nat. e Conserv.* 14, 46–56.
1431 <https://doi.org/10.1016/j.ncon.2016.05.001>.

1432 Linkie, M., Dinata, Y., Nugroho, A., Haidir, I.A., 2007. Estimating occupancy of a data
1433 deficient mammalian species living in tropical rainforests: Sun bears in the Kerinci Seblat
1434 region, Sumatra. *Biol. Conserv.* 137, 20–27. <https://doi.org/10.1016/j.biocon.2007.01.016>.

1435 Long, R.A., Donovan, T.M., MacKay, P., Zielinski, W.J., Buzas, J.S., 2011. Predicting
1436 carnivore occurrence with noninvasive surveys and occupancy modeling. *Landsc. Ecol.* 26,
1437 327–340. <https://doi.org/10.1007/s10980-010-9547-1>.

1438 Lopez J.E., Pfister C.A., 2001. Local population dynamics in metapopulation models:
1439 implications for conservation. *Conserv. Biol.* 15, 1700 – 1709. [https://10.1046/j.1523-](https://10.1046/j.1523-1739.2001.00140.x)
1440 [1739.2001.00140.x](https://10.1046/j.1523-1739.2001.00140.x).

1441 Lucherini, M., Eizirik, E., de Oliveira, T., Pereira, J., Williams, R.S., 2016. *Leopardus*
1442 *colocolo*, Pampas Cat. IUCN Red List Threat. Species 8235.
1443 <http://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T15309A97204446.en>.

1444 Lund, U., Agostinelli, C., Arai, H., Gagliardi, A., Portugues, E.G., Giunchi, D., Irisson, J.-O.,
1445 Pocernich, M., Rotolo, F., 2017. Circular Statistics.
1446 <http://mirrors.ucr.ac.cr/CRAN/web/packages/circular/circular.pdf> (accessed 29 november
1447 2019).

1448 Lyra-Jorge, M.C., Ribeiro, M.C., Ciocheti, G., Tambosi, L.R., Pivello, V.R., 2010. Influence
1449 of multi-scale landscape structure on the occurrence of carnivorous mammals in a human-
1450 modified savanna, Brazil. *Eur. J. Wildl. Res.* 56, 359–368. [https://doi.org/10.1007/s10344-009-](https://doi.org/10.1007/s10344-009-0324-x)
1451 [0324-x](https://doi.org/10.1007/s10344-009-0324-x).

1452 MacKenzie, D.I., Bailey, L.L., 2004. Assessing the fit of site-occupancy models. *J. Agric. Biol.*
1453 *Environ. Stat.* 9, 300–318. <https://doi.org/10.1198/108571104X3361>.

1454 MacKenzie, D.I., Nichols, J.D., Lachman, G.B., Droege, S., Royle, J.A., Langtimm, C.A.,
1455 2002. Estimating site occupancy rates when detection probabilities are less than one. *Ecology*
1456 83, 2248–2255. [https://doi.org/https://doi.org/10.1890/0012-](https://doi.org/10.1890/0012-9658(2002)083[2248:ESORWD]2.0.CO;2)
1457 [9658\(2002\)083\[2248:ESORWD\]2.0.CO;2](https://doi.org/10.1890/0012-9658(2002)083[2248:ESORWD]2.0.CO;2).

1458 Mackenzie, D.I., Nichols, J.D., Royle, J.A., Pollock, K.H., Bailey, L.L., Hines, J.E., 2006.
1459 *Occupancy Estimation and Modeling: Inferring Patterns and Dynamics of Species Occurrence*,
1460 first ed. Elsevier, San Diego, CA.

1461 Mackenzie, D.I., Royle, J.A., 2005. Designing occupancy studies: General advice and
1462 allocating survey effort. *J. Appl. Ecol.* 42, 1105–1114. [https://doi.org/10.1111/j.1365-](https://doi.org/10.1111/j.1365-2664.2005.01098.x)
1463 [2664.2005.01098.x](https://doi.org/10.1111/j.1365-2664.2005.01098.x).

1464 Maran, T., Macdonald, D. W., Kruuk, H., Sidorovich, V., V.V. Rozhnov, 1998. The continuing
1465 decline of the European mink, *Mustela lutreola*: evidence for the intra-guild aggression
1466 hypothesis. *Symposia. Zool. Soc. London.* 71, 297–324.
1467 <https://doi.org/10.1017/CBO9780511721830.018>.

1468 Marinho, P.H., Bezerra, D., Antongiovanni, M., Fonseca, C.R., Venticinque, E.M., 2017.
1469 Estimating occupancy of the Vulnerable northern tiger cat *Leopardus tigrinus* in Caatinga
1470 drylands. *Mammal Res.* <https://doi.org/10.1007/s13364-017-0330-4>.

1471 Marinho, P.H., Bezerra, D., Antongiovanni, M., Fonseca, C.R., Venticinque, E.M., 2018.
1472 Activity patterns of the threatened northern tiger cat *Leopardus tigrinus* and its potential prey
1473 in a Brazilian dry tropical forest. *Mamm. Biol.* 89, 30–36.
1474 <https://doi.org/10.1016/j.mambio.2017.12.004>.

1475 Massara, R.L., Paschoal, A.M.O., Bailey, L.L., Doherty, P.F., Chiarello, A.G., 2016. Ecological
1476 interactions between ocelots and sympatric mesocarnivores in protected areas of the Atlantic
1477 Forest, southeastern Brazil. *J. Mammal.* 97, 1634–1644.
1478 <https://doi.org/10.1093/jmammal/gyw129>.

1479 Meredith, M., Ridout, M., 2018. Overview of the overlap package. *R Proj.* 1–9.
1480 <https://doi.org/10.1016/j.contraception.2006.09.005>.

1481 Michalski, F., Crawshaw, P.G., De Oliveira, T.G., Fabián, M.E., 2006. Notes on home range
1482 and habitat use of three small carnivore species in a disturbed vegetation mosaic of southeastern
1483 Brazil. *Mammalia* 70, 52–57. <https://doi.org/10.1515/MAMM.2006.004>.

1484 Michalski, L.J., Norris, D., De Oliveira, T.G., Michalski, F., 2015. Ecological relationships of
1485 meso-scale distribution in 25 neotropical vertebrate species. PLoS One 10.
1486 <https://doi.org/10.1371/journal.pone.0126114>.

1487 Morris, D.W., 1987. Ecological scales and habitat use. Ecology 68, 362–369. <http://dx>.
1488 doi.org/10.2307/1939267.

1489 Oliveira, M.J., 2018. Coocorrência espacial e temporal de mamíferos de médio e grande porte
1490 do Cerrado – competição interespecífica e predação. PhD thesis. Universidade Federal de Minas
1491 Gerais, Belo Horizonte, Brazil.

1492 Oliveira, T.G., 1996. A situação dos mamíferos brasileiros ameaçados de extinção do Parque
1493 Estadual de Mirador, Maranhão: problemas e perspectivas. Pesquisa em Foco, 4, 62-70.

1494 Oliveira, T.G., 2011. Ecologia e conservação de pequenos felinos no Brasil e suas implicações
1495 para o manejo. PhD thesis. Universidade Federal de Minas Gerais, Belo Horizonte, Brazil.

1496 Oliveira, T.G., 2014. Programa de Gestão Compartilhada do Parque Estadual do Mirador, Pró-
1497 Vida Brasil/SEMA (Secretaria de Estado do Meio Ambiente e Recursos Naturais).

1498 Oliveira, T.G., Kasper, C.B., Tortato, M.A., Marques, R.V., Mazim, F.D. Soares, J.B.G., 2008.
1499 Aspectos ecológicos de *Leopardus tigrinus* e outros felinos de pequeno-médio porte no Brasil,
1500 in: Oliveira, T.G. (Eds.), Plano de ação para a conservação de *Leopardus tigrinus* no Brasil.,
1501 Instituto Pró-Carnívoros/Fundo Nacional do Meio Ambiente, pp. 37-105.

1502 Oliveira, T.G., Pereira, J.A., 2014. Intraguild Predation and Interspecific Killing as Structuring
1503 Forces of Carnivoran Communities in South America. J. Mamm. Evol. 21, 427–436.
1504 <https://doi.org/10.1007/s10914-013-9251-4>.

1505 Oliveira, T.G., Tortato, M.A., Almeida, L.B., Beisiegel, B.D.M., 2013. Avaliação do risco de
1506 extinção do Gato-do-mato *Leopardus tigrinus* (Schreber, 1775) no Brasil. *Biodiversidade Bras.*
1507 3, 56–65.

1508 Oliveira, T.G., Tortato, M.A., Silveira, L., Kasper, C.B., Mazim, F.D., Lucherini, M., Jácomo,
1509 A.T., Soares, J.B.C., Marques, R.V., Sunquist, M.E., 2010. Ocelot ecology and its effect on the
1510 small-felid guild in the lowland Neotropics, in: Macdonald, D.W., Loveridge, A.J. (Eds.)
1511 *Biology and Conservation of Wild Felids*, Oxford University Press, Oxford, UK, pp. 563–574.

1512 Oliveira, T.G.de, 1994. *Neotropical cats: ecology and conservation*. EDUFMA, São Luís, MA,
1513 Brazil

1514 Ordeñana, M.A., Crooks, K.R., Boydston, E.E., Fisher, R.N., Lyren, L.M., Siudyla, S., Haas,
1515 C.D., Harris, S., Hathaway, S.A., Turschak, G.M., Miles, A.K., Van Vuren, D.H., 2010. Effects
1516 of urbanization on carnivore species distribution and richness. *J. Mammal.* 91, 1322–1331.
1517 <http://dx.doi.org/10.1644/09-MAMM-A-312.1>.

1518 Palomares, F., Caro, T.M., 1999. Interspecific Killing among Mammalian Carnivores. *Am. Nat.*
1519 153, 492–508. <https://doi.org/10.1086/303189>.

1520 Paschoal, A.M.O., Massara, R.L., Bailey, L.L., Doherty, P.F., Santos, P.M., Paglia, A.P.,
1521 Hirsch, A., Chiarello, A.G., 2018. Anthropogenic Disturbances Drive Domestic Dog Use of
1522 Atlantic Forest Protected Areas. *Trop. Conserv. Sci.* 11, 194008291878983.
1523 <https://doi.org/10.1177/1940082918789833>.

1524 Payan, E., de Oliveira, T.G., 2016. *Leopardus tigrinus*, Northern Tiger Cat. IUCN Red List
1525 Threat. Species 8235. [https://doi.org/10.2305/IUCN.UK.2016-](https://doi.org/10.2305/IUCN.UK.2016-2.RLTS.T54012637A50653881.en)
1526 [2.RLTS.T54012637A50653881.en](https://doi.org/10.2305/IUCN.UK.2016-2.RLTS.T54012637A50653881.en).

1527 Penjor, U., Macdonald, D.W., Wangchuk, S., Tandin, T., Tan, C.K.W., 2018. Identifying
1528 important conservation areas for the clouded leopard *Neofelis nebulosa* in a mountainous
1529 landscape: Inference from spatial modeling techniques. *Ecol. Evol.* 1–14.
1530 <https://doi.org/10.1002/ece3.3970>.

1531 Pereira, J.A., 2010. Activity pattern of Geoffroy's cats (*Leopardus geoffroyi*) during a period
1532 of food shortage. *J. Arid Environ.* 74, 1106–1109.
1533 <https://doi.org/10.1016/j.jaridenv.2010.03.017>.

1534 Polis, G.A., Myers, C.A., Holt, R.D, 1989. The ecology and evolution of intraguild predation:
1535 potential competitors that eat each other. *Ann. Rev. Ecol. Syst.* 20, 297-330.
1536 <https://doi.org/10.1146/annurev.es.20.110189.001501>.

1537 Queirolo et al. 2013. Avaliação do risco de extinção do Gato-palheiro *Leopardus colocolo*
1538 (Molina, 1782) no Brasil. *Biodiversidade Bras.* 3,

1539 Raíces, D., Bergallo, H., 2010. Diet and seed dispersion of the crab-eaten fox, *Cerdocyon thous*
1540 (Linnaeus, 1766) in Restinga de Jurubatiba National Park, Rio de Janeiro State, Brazil. *Neotrop.*
1541 *Biol. Conserv.* 5, 24–30. <https://doi.org/10.4013/nbc.2010.51.04>.

1542 Ridout, M.S., Linkie, M., 2008. Estimating overlap of daily activity patterns from camera trap
1543 data. *J. Agric. Biol. Environ. Stat.* 14, 322–337. <https://doi.org/10.1198/jabes.2009.08038>.

1544 Ripple, W.J. et al. 2014. Status and ecological effects of the world's largest carnivores. *Science.*
1545 343, 1241484. <https://doi.org/10.1126/science.1241484>.

1546 Ritchie, E.G., Johnson C.N, 2009. Predator interactions, mesopredator release and biodiversity
1547 conservation. *Ecol. Lett.* 12, 982–998. <https://doi.org/10.1111/j.1461-0248.2009.01347.x>.

1548 Roemer, G.W., Gompper, M.E., Van Valkenburgh, B., 2009. The Ecological Role of the
1549 Mammalian Mesocarnivore. *Bioscience* 59, 165–173. <https://doi.org/10.1525/bio.2009.59.2.9>.

1550 Rowcliffe, M., 2019. Animal Activity Statistics.
1551 <http://cran.irsn.fr/web/packages/activity/activity.pdf> (accessed 29 november 2019).

1552 Royle, J.A., Nichols, J.D., 2003. Estimating abundance from repeated presence-absence data or
1553 point counts. *Ecology*, 84, 777–790. [http://dx.doi.org/10.1890/0012-](http://dx.doi.org/10.1890/0012-9658(2003)084[0777:EAFRPA]2.0.CO;2)
1554 [9658\(2003\)084\[0777:EAFRPA\]2.0.CO;2](http://dx.doi.org/10.1890/0012-9658(2003)084[0777:EAFRPA]2.0.CO;2).

1555 Sarkar, D., 2018. Package lattice. <http://lattice.r-forge.r-project.org/> (accessed 03 october 2019).

1556 Sileshi, G., 2008. The excess-zero problem in soil animal count data and choice of appropriate
1557 models for statistical inference. *Pedobiologia (Jena)*. 52, 1–17.
1558 <https://doi.org/10.1016/j.pedobi.2007.11.003>.

1559 Taborsky, M., 1988. Kiwis and dog predation: observations at Waitangi state forest. *Notornis*
1560 35, 197–202.

1561 United States Geological Survey. 2019. Shuttle Radar Topography Mission (SRTM) 1 Arc-
1562 Second Global. <https://doi.org/10.5066/F7PR7TFT>.

1563 Warton, D.I., Lyons, M., Stoklosa, J., Ives, A.R., 2016. Three points to consider when choosing
1564 a LM or GLM test for count data. *Methods Ecol. Evol.* 7, 882–890.
1565 <https://doi.org/10.1111/2041-210X.12552>.

1566 Weston, M.A., Fitzsimons, J.A., Wescott, G., Miller, K.K., Ekanayake, K.B., Schneider, T.,
1567 2014. Bark in the park: A review of domestic dogs in parks. *Environ. Manage.* 54, 373–382.
1568 <https://doi.org/10.1007/s00267-014-0311-1>

1569 Wolff, F., 2001. Vertebrate ecology in caatinga: A. Distribution of wildlife in relation to water.
1570 B. Diet of pumas (*Puma concolor*) and relative abundance of felids. University of Missouri.

1571 Young, J.K., Olson, K.A., Reading, R.P., Amgalanbaatar, S., Berger, J., 2011. Is Wildlife Going
1572 to the Dogs? Impacts of Feral and Free-roaming Dogs on Wildlife Populations. *Bioscience* 61,
1573 125–132. <https://doi.org/10.1525/bio.2011.61.2.7>.

1574

1575 Supplementary material

1576 Table S1. Covariates employed in the analysis with their respective description, range, and
1577 mean

Covariates	Description	Range	Mean (SE)
Tree Cover (%)	Percent of trees > 5 m per pixel (30 x 30 m) in a 90,000 m ² buffer	0 - 32	4.64 (6.32)
Elevation (m)	Elevation above sea level obtained through Shuttle Radar Topography Mission (SRTM) - USGS (30 x 30 m) data) in a 90,000 m ² buffer	268 - 357	316 (20)
Habitat use probability of dogs (Ψ)	Habitat use probability for domestic dogs per camera trap obtained through the model (ψ [forest cover] p[constant])	0 - 1	0.58 (0.44)
Distance to settlements (m)	Euclidian distance to nearest 3 settlements from each camera trap	414 - 11,169	3,129 (2,410)
Distance to water sources (m)	Euclidian distance to nearest water source from each camera trap	21 - 2,603	1,186 (630)
Distance to unpaved roads (m)	Euclidian distance to nearest nonpaved road from each camera trap	0 - 2,461	765 (691)

1578

1579

1580 Table S2. β coefficients for each covariate from the single season occupancy models.

Covariates	Northern tiger-cat				Pampas cat			
	β	SE	P	z	β	SE	P	z
Occupancy modeling								
FC	0.301	0.529	0.570	0.568	-0.927	5.040	0.065	-1.840
ELEV	0.151	0.701	0.829	0.216	did not converge	did not converge	did not converge	did not converge
OCCDOG	-0.468	1.210	0.699	-0.387	-2.630	2.540	0.300	-1.037
SET	4.030	2.850	0.158	1.410	-0.504	1.520	0.740	-0.332
WATER	0.104	0.395	0.792	0.264	-20.750	49.800	0.677	-0.416
UROAD	0.166	0.627	0.792	0.264	did not converge	did not converge	did not converge	did not converge
Detection modeling								
FC	0.227	0.131	0.008 ^a	1.777	-2.970	1.358	0.002 ^a	-2.190
ELEV	-0.279	0.244	0.025 ^a	-1.140	0.325	0.586	0.058	0.554
OCCDOG	0.584	0.396	0.014 ^a	1.480	-0.425	0.859	0.062	-0.495
SET	0.183	0.175	0.029 ^a	1.050	0.674	0.395	0.008 ^a	1.710
WATER	-0.060	0.116	0.060	-0.523	0.220	0.283	0.438	0.775
UROAD	-0.096	0.183	0.060	-0.530	0.348	0.450	0.043 ^a	0.774
GLM								
FC	0.261	0.235	0.266	1.110	-2.743	1.249	0.028 ^a	-2.197
ELEV	-0.183	0.282	0.516	-0.649	-0.381	0.413	0.356	-0.923
OCCDOG	0.356	0.585	0.545	0.605	-1.068	0.814	0.190	-1.312
SET	0.184	0.271	0.496	0.680	-0.107	0.425	0.801	-0.252
WATER	-0.061	0.168	0.714	-0.366	-0.183	0.252	0.469	-0.725
UROAD	-0.098	0.267	0.714	-0.366	-0.290	0.401	0.469	-0.725

1581 * Statistically significant coefficient

1582