

FERNANDA CAVALCANTI DE AZEVEDO

**ECOLOGIA DA ONÇA-PARDA: INTERAÇÕES DE UM PREDADOR DE
TOPO EM UM AGROECOSSISTEMA**

Tese apresentada à Universidade Federal de Viçosa, como parte das exigências do Programa de Pós-Graduação em Ecologia, para obtenção do título de *Doctor Scientiae*.

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APROVADA: 30 de novembro de 2017.

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(Orientador)



*There is a delight in the hardy life of open.
There are no words that can tell the hidden
spirit of the wilderness that can reveal its
mystery, its melancholy, and its charm.
The nation behaves well if it treats the natural
resources as assets which it must turn over to
the next generation increased and not
impaired in value.
Conservation means development as much as
it does protection.*

Theodore Roosevelt

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RESUMO

AZEVEDO, Fernanda Cavalcanti, D.Sc., Universidade Federal de Viçosa, novembro de 2017. **Ecologia da onça-parda: interações de um predador de topo em um agroecossistema.** Orientador: Fernando Cesar Cascelli Azevedo.

O padrão de atividade, o hábito alimentar e a organização espacial da onça-parda (*Puma concolor*) foram estudados em um agroecossistema em rápido desenvolvimento no sudeste brasileiro, utilizando uma combinação entre os métodos de armadilhas fotográficas e rádio telemetria por Sistema de Posicionamento Global (GPS). O estudo foi conduzido entre os anos de 2009 e 2017, no Triângulo Mineiro, município de Araguari, em uma região de ecótono entre os Biomas Cerrado e Mata Atlântica. De forma geral as onças-pardas apresentaram padrão de atividade predominantemente noturno e alta sobreposição temporal com as presas mais consumidas. Especificamente, machos tiveram comportamento noturno mais pronunciado do que fêmeas, que mostraram-se catemerais (isto é, usam o dia e a noite nas mesmas proporções) e consumiram mais presas de hábitos diurnos, como coatis (*Nasua nasua*) e teiús (*Salvator merianae*). Animais domésticos (cães e gado bovino) e pessoas transitam nas mesmas trilhas que onças-pardas, entretanto, a sobreposição temporal entre humanos, animais domésticos e este felino não foram expressivos. Onças-pardas alimentaram-se de uma grande variedade de presas (n = 20 espécies) na área de estudo. Porém, apresentaram comportamento especialista em relação à dieta, dependendo principalmente de presas silvestres, as quais foram mais consumidas tanto em termos de frequência de ocorrência quanto biomassa ingerida. Capivaras (*Hydrochaeris hydrochaeris*) e tatus-peba (*Euphractus sexcinctus*) foram selecionados, enquanto animais domésticos foram evitados, apesar de sua alta disponibilidade. Em relação à seleção de ambientes para caçar, onças-pardas mostraram preferência por ambientes de florestas e pasto sujo, provavelmente por oferecerem maior proteção em termos de cobertura vegetal e maiores oportunidades para emboscar presas. Onças-pardas caçaram a cada 3.54 ± 1.62 dias, sendo que fêmeas apresentaram tempo de manipulação das presas mais curto que machos, refletindo maior consumo de presas de pequeno porte por este sexo. Este resultado também destaca a capacidade de detecção de presas menores que 15 kg por meio do monitoramento de grandes carnívoros via rádio telemetria GPS e a checagem frequente de aglomerados de localizações. Onças-pardas apresentaram tamanho de área de vida média de 209.4 ± 46.5 km². Como esperado,

machos ocuparam áreas de vida mais extensas e percorreram maiores distâncias que fêmeas, corroborando um comportamento territorial mais pronunciado através de baixa sobreposição intrasexual. Onças-pardas também apresentaram forte associação com classes ambientais naturais (vegetação florestal), tanto em nível populacional quanto individual, destacando a importância dos fragmentos de vegetação remanescentes para a permanência deste predador de topo de cadeia em ambientes modificados pela ação humana. Os resultados aqui apresentados preenchem uma lacuna no conhecimento da ecologia da onça-parda em ambientes tropicais antropizados. Os dados demonstram que a permanência de um carnívoro de grande porte em paisagens modificadas está relacionada a: sua habilidade de ajustar seu padrão de atividade a diferentes fatores (incluindo antrópicos), e à oferta de uma base de presas silvestres e habitats de vegetação natural. Além disso, colaboram para desmistificar o alto impacto negativo atribuído a onças-pardas em áreas onde convive com espécies domésticas e o homem.

ABSTRACT

AZEVEDO, Fernanda Cavalcanti, D.Sc., Universidade Federal de Viçosa, November, 2017. **Puma Ecology: top predator interactions in an agro-ecosystem.** Advisor: Fernando Cesar Cascelli Azevedo.

Activity patterns, feeding habits and spatial organization of pumas (*Puma concolor*) were studied in an agro-ecosystem in Southeast Brazil, through camera trapping and radio-telemetry with GPS (Global Position System) technology. The study was carried from 2009 to 2017 in Minas Gerais state, Triângulo Mineiro region, Araguari municipality, an ecotone zone between Cerrado and Atlantic Forest biomes. Regarding activity patterns, in the study site pumas were mostly nocturnal and presented higher temporal overlapping with most consumed prey. Specifically, males showed mostly nocturnal behavior, while females were cathemeral (active at night and day hours in same proportions) and consumed more prey with diurnal activity such as coatis (*Nasua nasua*) and tegus (*Salvator merianae*). Domestic animals (dogs and cattle) and people use the same trails as pumas, however, temporal overlapping between humans, domestic animals and this felid are not expressive. Pumas feed on a wide variety of prey (n = 20 species) in the study site. But showed specialized behavior towards diet, relying mostly on wild prey, which were more consumed in terms of frequency of occurrence and biomass. Capybaras (*Hydrochaeris hydrochaeris*) and six-banded armadillos (*Euphractus sexcinctus*) were selected, while domestic animals were avoided despite their high availability in Araguari. Regarding habitat preference for killing prey, pumas showed a pronounced preference for forested habitats and pasture with shrubs, probably because they offer cover protection and opportunities to ambush prey. Pumas hunted every 3.54 ± 1.62 days, being that females presented shorter handling time of prey than males, reflecting higher consumption of small prey by this sex. This result also highlights the potential of detection of smaller prey than 15 kg through the monitoring of large-sized carnivores using GPS devices and the frequent verifying of clusters of locations. Mean home range size for pumas was 209.4 ± 46.5 km². As expected, males exhibited larger home ranges and traveled greater distances per day than females, showing a most pronounced territorial behavior, as also suggested by low intrasexual overlap. Pumas showed strong habitat association with natural features (forest vegetation) both at population and individual level, highlighting the importance of

fragments of natural vegetation for the permanence of this top-predator in human-modified landscapes. The presented results fill a gap on puma's ecology knowledge in tropical ecosystems. Data demonstrate that the permanence of a large carnivore in modified landscapes is related to its ability to adjust its activity pattern to different factors (including anthropic), and the availability of wild prey and natural vegetation habitats. In addition, they collaborate to demystify the high negative impact attributed to pumas in areas where they cohabit with domestic species and humans.

INTRODUÇÃO GERAL

Nas últimas décadas, o crescente interesse pela manutenção das espécies em paisagens modificadas levou ao delineamento de ações globais para a conservação da biodiversidade (Marinho-Filho & Machado 2006; Vié et al. 2009). Os efeitos da antropização podem variar de acordo com os atributos comportamentais e ecológicos das espécies afetadas e suas relações com as características físicas da paisagem (White et al. 2002; Lyra-Jorge et al. 2008). Entretanto, algumas espécies possuem atributos que as tornam particularmente mais sensíveis às mudanças no ambiente. Dentre elas, os carnívoros de grande porte estão entre as mais negativamente afetadas, devido às altas demandas energéticas, a necessidade de grandes territórios e às baixas densidades populacionais (Glittleman et al. 2001; Terborgh et al. 2001).

Inserida neste contexto de preservação *versus* antropização, a biodiversidade Neotropical é uma das mais ricas do planeta, motivo pelo qual diversas de suas eco-regiões são consideradas prioritárias para a conservação ou *Hotspots* mundiais (Mittermeier et al. 1999). Entre elas, o Cerrado, segundo maior bioma brasileiro, encontra-se sob alta pressão antrópica, sendo que menos de 20% de sua área encontra-se próximo do estado original (Myers et al. 2000). Como resultado da exploração rápida e desordenada um número relevante de espécies da fauna que habitam este bioma encontra-se atualmente listada como ameaçada de extinção (Machado et al. 2008).

A onça-parda (*Puma concolor*) é o segundo maior felino das Américas e o vertebrado terrestre com maior distribuição geográfica na região Neotropical (Sunkist & Sunkist 2009). Entretanto, devido às mudanças na paisagem ocasionadas pela perda e fragmentação de habitats e ao crescente conflito com populações humanas em expansão, a onça-parda atualmente ocorre em uma fração da sua área de distribuição e a

tendência das populações atuais é decrescente (Nielsen et al. 2015). No Brasil mesmo originalmente presente em todos os biomas (Oliveira 1994), algumas populações encontram-se bastante reduzidas ou mesmo localmente extintas (Azevedo et al. 2013). Os estudos com onças-pardas vivendo em vida livre no Brasil estão praticamente restritos a investigações sobre o comportamento alimentar através da coleta e análise de amostras fecais, sendo que grande parte destes trabalhos não está devidamente publicado. O levantamento de informações sobre a organização social, uso e seleção de habitats, padrões de atividade, movimentação e dispersão, comportamento reprodutivo, densidade e abundância foi realizado apenas de forma pontual, muitas vezes incidentalmente em projetos em que o foco era a onça-pintada (*Panthera onca*). A deficiência de dados sobre a onça-parda tem tornado insipiente as ações de conservação desta espécie e praticamente impossível a mediação de conflitos com humanos.

Os dados que compõem o trabalho aqui apresentado fazem parte de uma iniciativa do Programa de Conservação Mamíferos do Cerrado (PCMC) para levantar informações sobre a ecologia e a saúde das onças-pardas e compreender como esta espécie lida com as diferentes ameaças impostas à sua sobrevivência em uma região altamente impactada do Cerrado brasileiro. Entre 2009 e 2017, o Projeto Onça Parda do Triângulo Mineiro, por meio do monitoramento contínuo realizado utilizando armadilhas fotográficas, coleiras rádio-transmissoras GPS e coleta de indícios diretos e indiretos da presença da espécie, tem realizado o maior esforço para o estudo de onças-pardas no Brasil. A partir deste conjunto de dados, no primeiro capítulo desta tese analisamos o padrão de atividade da onça-parda e avaliamos a influência da atividade de suas principais presas e de fatores antrópicos sobre este comportamento. No segundo capítulo reunimos informações sobre o comportamento alimentar deste predador topo de cadeia vivendo em um agroecossistema, ao abordarmos aspectos chave da sua dieta

como, por exemplo, a composição, taxas e padrões de predação, além de verificarmos o uso e a seleção de presas. No terceiro e último capítulo examinamos a organização espacial da onça-parda em uma região em rápido desenvolvimento, estimando o tamanho e a sobreposição entre as áreas de vida e verificando como a onça-parda usa o habitat e se ocorre seleção do mesmo.

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CAPÍTULO I.

PUMA ACTIVITY PATTERN AND INTERACTIONS WITH PREY IN A HUMAN-DOMINATED LANDSCAPE AT SOUTHEAST BRAZIL

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Puma activity pattern and interactions with prey in a human-dominated landscape at Southeast Brazil

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Running heading: Puma activity patterns and interactions with prey

Abstract

Animal activity pattern corresponds to the individual diel cycle time and is an important attribute on species coexistence in ecological communities. However, activity patterns of most Neotropical species are still poorly understood. Based on an eight-year camera trapping survey conducted between 2009 and 2016, we evaluated puma's (*Puma concolor*) activity pattern in a human-dominated landscape in Southeast Brazil. Our objectives were to determine the activity pattern of pumas and to verify the influence of main prey species and anthropogenic factors on their behavior. We categorized activity pattern of all assessed species based on the proportion of independent records during night and day times. We tested for gender differences in activity patterns of pumas, and measured their overlap with most consumed prey, people and domestic dogs, using a coefficient of overlapping. Our results showed that in the study site pumas were mostly nocturnal. Specifically, males showed a mostly nocturnal behavior while females were active at night and day hours. Pumas exhibited a higher coefficient of overlap with prey species that were most often included in their diet, suggesting that pumas opportunistically prey upon species with similar activity patterns. Pumas adjusted their temporal activity patterns to both human and domestic animals' activities, keeping its nocturnal behavior when anthropogenic disturbances were present.

Keywords: agro ecosystems; Atlantic Forest; camera trapping; Cerrado; Felidae; habitat fragmentation;

Introduction

The activity pattern is an important attribute of a species behavior and corresponds to the individual biological rhythms. Species activity patterns are shaped by many different factors, from physiological adaptations to abiotic conditions (i.e., light, temperature and humidity) (Nielsen, 1984; Scheibe *et al.*, 1999), and by direct influence of species life history strategies (e.g. social organization, avoidance of competitors and predators) (Gittleman & Harvey, 1982). In addition, access to important resources, particularly prey, play a strong role in determining species daily cycle (Brown, Kotler & Bouskila, 2001; Di Bitetti *et al.*, 2010).

Some predators are known to locally adjust their foraging period to the behavior of their main prey, thus optimizing energy gain (Karanth & Sunquist, 2000). For instance, although jaguars (*Panthera onca*) are considered generalist predators and mostly nocturnal along different biomes, in habitats with high availability of diurnal prey, jaguars may show diurnal peaks (Crawshaw & Quigley, 1991; Foster *et al.*, 2013). The same behavior has been reported for African leopards (*Panthera pardus*), which are mostly nocturnal along savannah environments, but mainly diurnal in rainforests, as their main prey in this type of habitat (Jenny & Zuberbühler, 2005).

More recently, several studies have reported that high levels of human-driven disturbances and anthropogenic related activities (e.g., settlements, roadways, presence of domestic animals, and persecution) might influence carnivores activity patterns (Ngoprasert, Lynam & Gale, 2007; Henschel *et al.*, 2011). For instance, pumas (*Puma concolor*) and bobcats (*Lynx rufus*) may shift their activity patterns to avoid encounters with humans, leading to altered competitive interactions between the two species (Lewis *et al.*, 2015). Likewise, leopards may alter their temporal activity pattern in response to

high human pressure and to the presence of tigers within and outside protected areas (Carter *et al.*, 2015; Ngoprasert *et al.*, 2007).

Pumas are the Neotropical carnivore with the largest geographic distribution (Wilson & Mittermeier, 2009), occurring in almost all American countries, and recorded in a variety of landscapes, including human degraded habitats (Ripple *et al.*, 2014). As opportunistic hunters, pumas prey on a variety of species (Murphy & Ruth, 2010; Azevedo *et al.*, 2016). Their activity also vary considerably within and between study sites (Hornocker & Negri, 2010), being primarily nocturnal in the Belizean (Harmsen *et al.*, 2009, 2011) and Equatorial rainforests (Blake *et al.*, 2012), in the Venezuelan llanos (Scognamillo *et al.*, 2003) and at the Upper Paraná Atlantic Forest (Paviolo *et al.*, 2009). However, the species present cathemeral behavior, i.e., activity distributed approximately evenly throughout the 24h of the daily cycle (Van Schaik & Griffiths, 1996), in the Atlantic Forests of Argentina (Di Bitetti *et al.*, 2010), the subtropical dry forests of Mexico (Hernández-SaintMartín *et al.*, 2013), and the dry and rainforests of Bolivia (Gómez *et al.*, 2005; Romero-Muñoz *et al.*, 2010). Such variation in the activity behavior of pumas could be associated to their capacity to inhabit a variety of ecosystems along their wide geographical range. Pumas are described as territorial, and their mating system is strongly influenced by sexual selection (Logan & Sweanor, 2001, 2010). Male and female pumas may employ different approaches of social organization to maximize individual success (Logan & Sweanor 2001). Notwithstanding, no differences on daytime use among sexes have been reported (Romero-Muñoz *et al.*, 2010). Despite the influence of predator-prey interactions in shaping the activity pattern of pumas, anthropogenic disturbances may also play a role on the behavioral trait of the species.

Of the few studies that have investigated puma's activity pattern along South America, most were carried inside protected areas (Gómez *et al.*, 2005; Harmsen *et al.*,

2009; Di Bitetti *et al.*, 2010; Romero-Muñoz *et al.*, 2010; Blake *et al.*, 2012; Foster *et al.*, 2013). However, the current increasing interest on species maintenance along fragmented landscapes and agro-ecosystems has led to the design of global actions to biodiversity conservation (Marinho-Filho & Machado, 2006). Carnivores are recognized as key elements in ecosystems, potentially contributing to top-down regulations by structuring herbivore communities, though indirectly affecting herbivory patterns (Terborgh *et al.*, 2001). Some species also are predictors of environment dysfunctions, such as habitat fragmentation, climate changes, and other anthropogenic disturbances, as they depend on complex biotic and abiotic conditions to thrive (Ripple *et al.*, 2014). As a widespread apex predator, pumas are an excellent model to examine carnivores' ecology in non-protected areas, such as many along Brazilian savanna/Atlantic Forest, hotspots for biodiversity conservation (Myers *et al.*, 2000), and may contribute with vital information for future decisions on conservation and management.

The objectives of this study were to describe the activity pattern of pumas and to investigate factors that may influence the species behavior in a human-dominated landscape in Southeast Brazil. We focused on three main questions: (1) Is there a difference between male and female temporal activity patterns? (2) How does pumas' activity pattern overlap with those of their main prey species? (3) How does pumas' activity pattern overlap with those of people and domestic dogs (*Canis lupus familiaris*)? We hypothesized that there was no difference in activity pattern between male and female pumas. Furthermore, we hypothesized that the activity patterns demonstrated by pumas would reflect their main prey species activity in the study area. Specifically, we predicted that i.) both sexes would be active at the same time during a 24-hour period; ii.) there would be high activity pattern overlap between pumas and their main prey species; and iii.) there would be low activity pattern overlap between pumas and people/domestic dogs.

Materials and Methods

Study site

This research was conducted in private lands in Minas Gerais State, at Triângulo Mineiro region, municipality of Araguari, Brazil (18°46'S, 48°14'W and 18°21' S, 48°38'W; Fig. 1).

The study site comprehends an ecotone zone among Cerrado and Atlantic Forest biomes (Lopes *et al.*, 2012) with high richness of fauna and flora (Drummond *et al.*, 2005).

Currently, the area comprises a highly fragmented landscape represented by a matrix of multiple land use dominated by cattle ranches with exotic pasture (mainly *Urochloa* sp.), agriculture and human habitations. Under this scenario, different anthropic pressures, such as presence of people (by foot, vehicles and bicycles), domestic dogs and livestock inside natural patches are constant in the study site. Remaining natural vegetation is restricted to scattered patches of savannah and mesophytic seasonal forest (Oliveira-Filho & Ratter, 2002) which are mainly concentrated along the margins of Araguari and Paranaíba Rivers and their tributaries. Except for the Pau Furado State Park (2186 hectares), the study area is composed solely by private properties. The climate in region has two well marked seasons, one hot and wet from October to April and another cold and dry from May to September (Alvares *et al.*, 2013). Mean annual temperature and precipitation vary between 22–25°C and 1600–1800 mm, respectively (data available by CPTEC/INPE).

Data collection

This study is part of a long-term ecological research on pumas to underpin local conservation efforts in a non-protected area in Southeast Brazil. Camera trapping surveys were carried out to identify suitable sites for capturing pumas. Camera stations were almost continuously active between January 2009 and August 2016, with sampling effort ranging from six to twelve months per year. Cameras-trap were placed along the basin of Araguari

River at irregular intervals, ranging from 0.3 – 8.0 km ($\bar{X} = 1.9$ km) from each other. In total, 117 different camera stations were deployed ($\bar{X} = 26.42 \pm 7.44$ *SD* cameras per year) encompassing a sampled area of approximately 300 km². Each camera station consisted of one or two independent cameras (Tigrinus™, Santa Catarina, Brazil; Bushnell™, Kansas, USA). When in pairs, cameras were settled at both sides of trails 4–6 m apart and facing each other. Camera traps were set to take photos/videos with an interval of 30 seconds between records and were checked approximately every 20 days.

To investigate the activity patterns and temporal overlap between species we selected all camera trap records of pumas and their prey. Prey species were investigated through visits to GPS clusters of locations ($n = 70$) of six pumas (four males and two females) equipped with Global Position System collars (Lotek™ Fish & Wildlife Monitoring, Ontario, Canada/44400S and 4550S models; Sirtrack™ Wildlife Track Solutions, Hawkes Bay, New Zealand /G5C 375B Pinnacle GPS Iridium model) between February 2012 and November 2016. We defined GPS clusters of locations as any three or more puma locations within 50 m of each other elapsed over a minimum 12h period (Anderson & Lindzey, 2003). Once detected, each cluster was visited and visually searched on foot for possible prey remains (i.e., hair, skin, feather, bone fragment) in a diameter of 100 m radius. Some consumed prey species were not registered by camera traps or were recorded in low numbers, hence not allowing performing temporal overlap analysis.

All pumas were captured following standard protocols approved by the Instituto Chico Mendes de Conservação da Biodiversidade, Ministério do Meio Ambiente, Brazil (ICMBio SISBIO) under license numbers 18913-1 and 18913-4 (2009–2015), and by the Ethics Committees on Animal Use of Universidade Federal de Viçosa (process number 90/2014) and Universidade Federal de Goiás (process number 66/2014). To minimize the

risk of injury and holding time of animals during the capture procedures we equipped traps with VHF devices (Nortronic™), which were monitored at least every 2 hours by distance. In addition the traps were visually inspected every day in the morning before hottest hours.

Data analysis

For each camera trap record, we identified the species, date, time, and station.

Independence of records of the same species at the same or nearby camera trap station were obtained when taken at least 30 minutes apart, unless we were able to unambiguously identify that the same individual was photographed several times within this period (Linkie & Ridout, 2011). To reduce bias caused by possible repeated records of same individuals due to proximity of some camera trap stations, we only used the first record of stations placed ≤ 400 m apart (Ross *et al.*, 2013). Records of multiple individuals of social species, such as collared peccaries (*Pecari tajacu*), coatis (*Nasua nasua*) capybaras (*Hydrochoerus hydrochaeris*), livestock and domestic dogs, were considered as a single record of the species. We categorized the activity pattern of each species based on the proportion of independent records during hours of night (from 18:00 h to 5:59 h) and day (from 06:00 h to 17:59 h), following van Schaik & Griffiths (1996). Species were defined as diurnal (< 10% of records at night), nocturnal ($\geq 90\%$ of records at night), mostly diurnal (10–29% of records at night), mostly nocturnal (70–89% of records at night), or cathemeral (30–69% of records at night/day) (Gómez *et al.*, 2005). We used generalized linear models with Poisson distribution to test if the mean number of records of pumas differed between day and night hours. We used Poisson distribution because it is more suitable for count data. We tested male and female pumas separately to allow us to detect differences in activity patterns in relation to gender.

All analyses were performed in R v.2.6 (R Development Core Team 2014). The “overlap” R-package (Meredith & Ridout, 2016) was used to calculate the coefficient of overlapping (Δ) between species. For each sex, we carried overlap analysis between pumas and most important prey items. We also carried overlap analysis between pumas, people (on foot or riding horses/vehicles) and domestic dogs to verify if anthropogenic factors can influence species activity pattern. The coefficient of overlapping ranges from 0 (no overlap) to 1 (complete overlap) and is obtained taking the minimum of the density functions from the two cycles being compared at each time point. Coefficient of overlapping was calculated for: i) all puma records and their main prey species (wild and domestic prey); ii) males and females and their main prey species separately; and iii) all puma records and anthropogenic factors (people and domestic dogs). We used $\hat{\Delta}_1$ to estimate the coefficient of overlapping for small samples and $\hat{\Delta}_4$ for large samples (Ridout & Linkie, 2009; Meredith & Ridout, 2016). We calculated overlap index 95% confidence interval using smoothed bootstrap with 10000 resamples (Meredith & Ridout, 2016).

Results

Along eight years of camera trapping we obtained 2102 independent activity records of pumas ($n = 368$; 195 registers for males, 51 for females and 122 unidentified), prey species ($n = 1295$ records), domestic dogs ($n = 244$ records) and people ($n = 195$ records). Pumas were registered on 63 of the 117 camera stations and it was possible to individualize at least 20 animals (10 males and 10 females) (Fig. S1). Pumas were active mostly during nighttime (76.9% of records; Fig. 2a; Table S2) and, in general, activity declined after 04:00 h, reached the lowest percentages of activity around 12:00 h and did not resume before 16:00 h.

Pumas presented dissimilar activity patterns regarding sex (Fig. 2b). Mean number of male records during night hours was significantly higher than during day hours ($z = 8.23$, $df = 23$, $P = < 0.001$) (Fig. 3), showing they are mostly nocturnal (82.6% of male records occurred during night period). However, we found no significant difference between mean number of records of females at night and day hours ($z = 1.52$, $df = 23$, $P = 0.12$), indicating a cathemeral behavior for females. Males showed two main peaks of high activity, one after the beginning of night (around 20:00 h) and another around 04:00 h, before sunrise. Although females also had a peak of activity around 04:00 h, they also had activity peaks between 07:00 h and 16:00 h (when males were mostly inactive) and diminished considerably their activity when males increased activity around 18:00 h.

Most wild prey consumed by pumas at the study site were capybaras and giant anteaters (*Myrmecophaga tridactyla*), followed by tegu lizard (*Salvator merianae*), armadillos (*Euphractus sexcinctus* and *Dasyus novemcinctus*), brown-brocket deer (*Mazama gouazoubira*), and wild birds; pumas also preyed upon livestock, for instance cattle – *Bos taurus* and horses – *Equus caballus* (Table S1). Most prey species were active at the same time of pumas, with highest overlap of activity period observed for capybaras ($\hat{\Delta}_4 = 0.82$) and collared peccaries ($\hat{\Delta}_1 = 0.82$), followed by giant anteaters, nine-banded armadillos and tapitis ($\hat{\Delta}_4 = 0.78$; $\hat{\Delta}_1 = 0.75$ and $\hat{\Delta}_1 = 0.74$, respectively) (Table 1; Fig. S2). Lowest coefficients were observed for tegu lizard and coatis ($\hat{\Delta}_1 = 0.16$ and $\hat{\Delta}_1 = 0.25$, respectively; Table 1). Capybaras and giant anteaters were classified as mostly nocturnal, with peak of activity around 22:00 h and 19:00 h, respectively; whereas peccaries were classified as cathemeral, but also with peak of activity around 20:00 h (Table S2). When analyzed separately, male and female pumas presented differences on coefficient of overlapping toward prey species (Figs. 4 and 5). Highest activity peaks of two large-sized prey of male pumas (capybara and giant anteater) coincided markedly with the predator

activity peak, contrasting with coatis and tegu lizards, which had low overlapping and were never consumed by male pumas at our study site (Fig. 4). Female pumas overlapped less than males with prey in general, but also showed highest values of overlapping with cathemeral peccaries and nocturnal capybaras and anteaters, even though the three species were not among the most consumed items (Fig. 5). Though, coefficient of temporal overlapping for females and diurnal prey, such as coatis and tegu lizards, were higher than for males (Fig S3).

Pumas tended to avoid periods of high human (between 07:00 h and 17:00 h) and domestic dogs (between 05:00 h and 18:00 h) activity (Fig. 6). Considering temporal overlapping, pumas had low overlap of activity period with both humans ($\hat{\Delta}_4 = 0.398$) and domestic dogs ($\hat{\Delta}_4 = 0.480$), being the beginning of morning and nighttime periods with higher probability of encounters between these species.

Discussion

Due their elusive habits, behavioral knowledge from Neotropical wild felids is still scarce in the literature, especially for those living at anthropized landscapes. Filling part of this gap, our study showed that pumas inhabiting in such landscapes are mostly nocturnal.

Although puma activity patterns may vary across different sites (and also within sites), our results have corroborated studies from the Belizean (Harmsen *et al.*, 2009, 2011) and Equatorial rainforests (Blake *et al.*, 2012), the Venezuelan llanos (Scognamillo *et al.*, 2003), and other Brazilian biomes (Paviolo *et al.*, 2009; Foster *et al.*, 2013).

Our results demonstrated differences between male and female activity patterns, rejecting our first hypothesis and also what has been reported for pumas in other ecosystems (Romero-Muñoz *et al.*, 2010). Contrary to our first prediction, higher estimates of mean number of records at night for males, and the non-overlapping confidence interval

for that estimate with females, suggested that males are significantly more nocturnal, while females showed cathemeral behavior. In our region, the use of day hours by females may be explained as a strategy to diminish encounters with males and increase encounters with diurnal prey. It has also been reported that females avoid male-dominated travel routes because such encounters may result on infanticide events (Harmsen *et al.*, 2009). For instance, in New Mexico, males accounted for 53% of death causes of monitored females and their cubs (Logan & Sweanor, 2001). In this context, avoidance may be the best survival tactic for females, and this was reinforced when results of spatial overlapping revealed pumas rarely aggregated, and most male-female interactions were just associated with courtship (Logan & Sweanor, 2001).

Savanna ecosystems in subtropical regions are known for their species-rich wildlife occupying different niches in complex communities (Paglia *et al.*, 2012). Therefore, the great variety of available prey (Oliveira & Marquis, 2002) offers an array of food items that can be consumed at alternative periods of the day. Pumas have already been described as cathemeral predator, showing peaks of activity during the day, even when predominantly nocturnal (Gómez *et al.*, 2005; Di Bitetti *et al.*, 2010; Romero-Muñoz *et al.*, 2010; Hernández-SaintMartín *et al.*, 2013). The cathemeral behavior increases probability of encounters with a more diverse prey base (Scognamillo *et al.*, 2003). This might be beneficial for a generalist carnivore like the puma which consumes a broader variety of prey including diurnal and nocturnal species (Murphy & Ruth, 2010). Although our results reinforce the nocturnal habit of pumas, diurnal habits of females may be related to their more diversified and balanced diet in relation to males. While three main prey constitute the base of the diet of males, females prey on different items with more similar frequencies, having as main prey both diurnal (tegu lizard) and nocturnal (nine-banded armadillos) species.

Besides intraspecific interactions, several studies have related species activity patterns to food availability (Di Bitetti *et al.*, 2010; Harmsen *et al.*, 2011; Foster *et al.*, 2013; Ross *et al.*, 2013). Among carnivores, synchronized activity between predators and prey may represent an optimization of foraging time to maximize energetic gain (Brown *et al.*, 2001). In our study puma's activity period concurred with periods when most of their main prey species were active, probably to increase the chances of encounters with them, what confirms our second prediction. The capybara and giant anteater were the main prey consumed by pumas in general and, as expected, both species presented high activity overlap with pumas. Even when observed separately for males and females, these prey species figured between the most important in terms of overlapping. Although peccaries, which are usually reported as one of the main prey for pumas in other regions (Martins, Quadros & Mazzolli, 2008; Murphy & Ruth, 2010), were active at the same period, they seemed not to play an important role in the puma's diet at the study site. Peccaries live in alert groups and may show defense strategies and aggressive behavior towards predators (Taber *et al.*, 2011), making them less appealing due the risk of injury. Capybaras and other species of similar size can be potentially easier to take. Despite the differences in the consumption of food by males and females, the considerable activity overlap with prey species demonstrated in this study confirmed our second hypothesis that predators may adjust their activity to their main prey.

People, livestock, domestic dogs and pumas were often photographed on the same camera trap stations. Although remnants of natural vegetation (where camera traps were settled) are protected by the Brazilian environment law, they are legally used by people to get to Araguari River for fishing and recreational practices, but illegally for raising livestock and poaching. In general, people, dogs and cattle were more active during daylight hours, leading to low overlapping with pumas except at early hours of morning

and end of evening, which supported our third prediction. Regarding predation on livestock, our results showed low activity period overlapping of pumas with cattle and low frequency of this item on puma's diet, suggesting that pumas and cattle also are active on different periods of the day.

Our results reinforce that pumas are mostly nocturnal, but also suggest females may use periods of daylight to find alternative prey and avoid male encounters, despite anthropogenic pressures. Pumas are described as a plastic species, with the capacity of living in areas with some degree of perturbation (Murphy & Macdonald, 2010). The ability to adjust its activity pattern to different factors is certainly an important compensation mechanism for dealing with human disturbances along agro-ecosystems.

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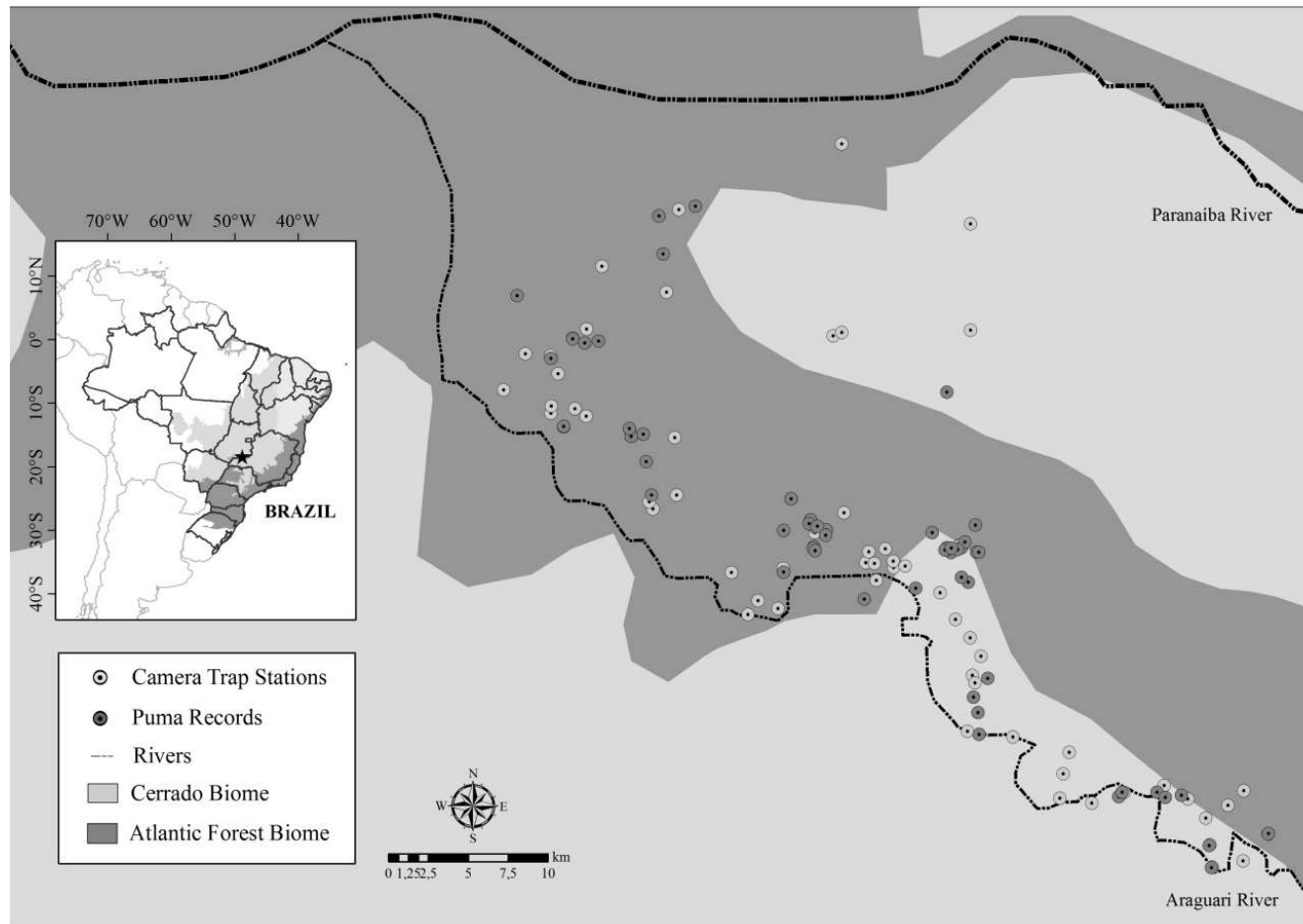


Figure 1 Location of study site with camera trap stations installed from 2009 to 2016 in Araguari, Minas Gerais, Brazil.

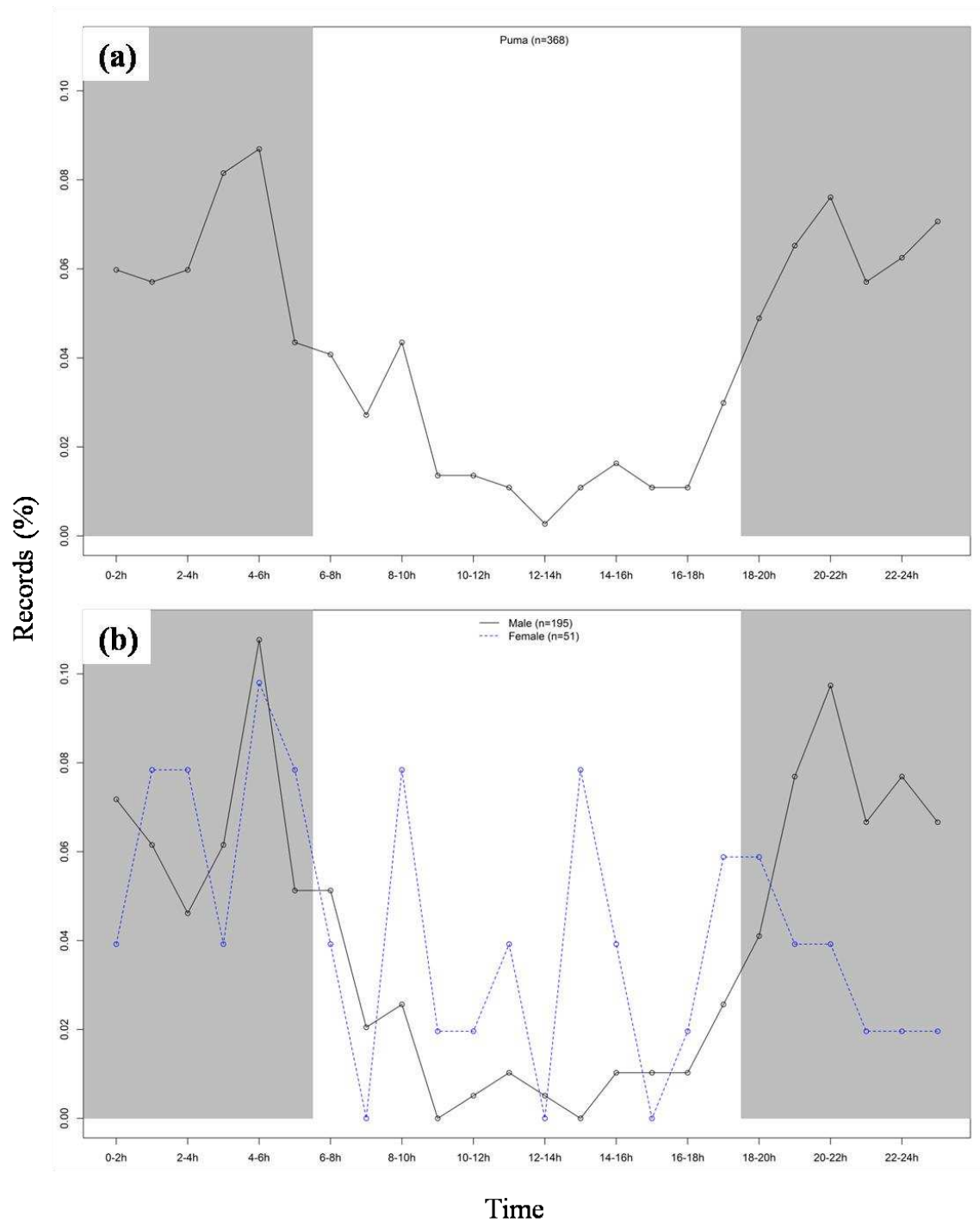


Figure 2 Activity pattern of pumas (*Puma concolor*) based on camera trap surveys (from 2009 to 2016) in Araguari, Minas Gerais, Brazil: (a) including all puma records; (b) presenting males and females separately. Grey background indicates night hours and white background day hours.

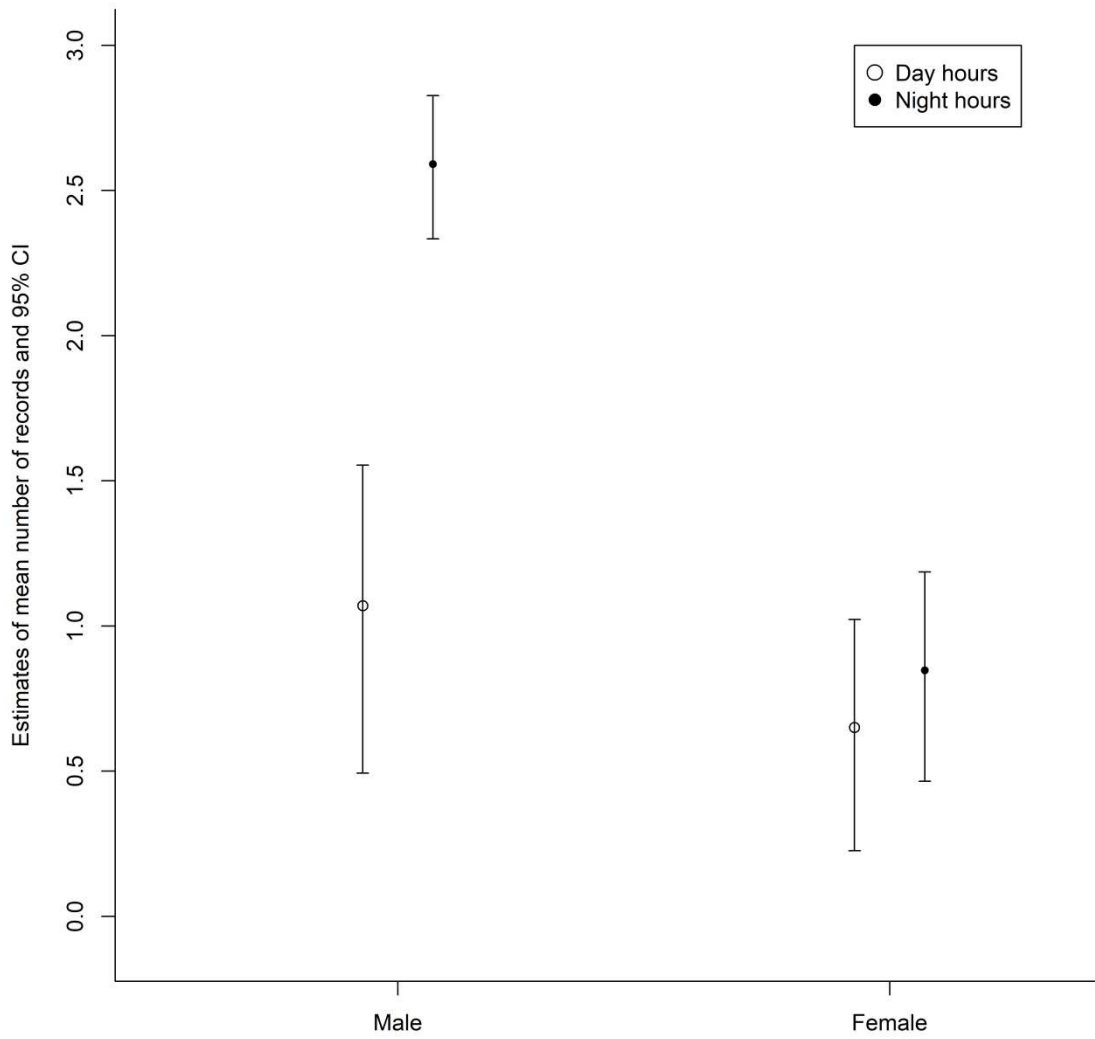


Figure 3 Estimates of mean records of male and female pumas (*Puma concolor*) during day and night hours with 95% confidence interval (CI) in Araguari, Minas Gerais, Brazil.

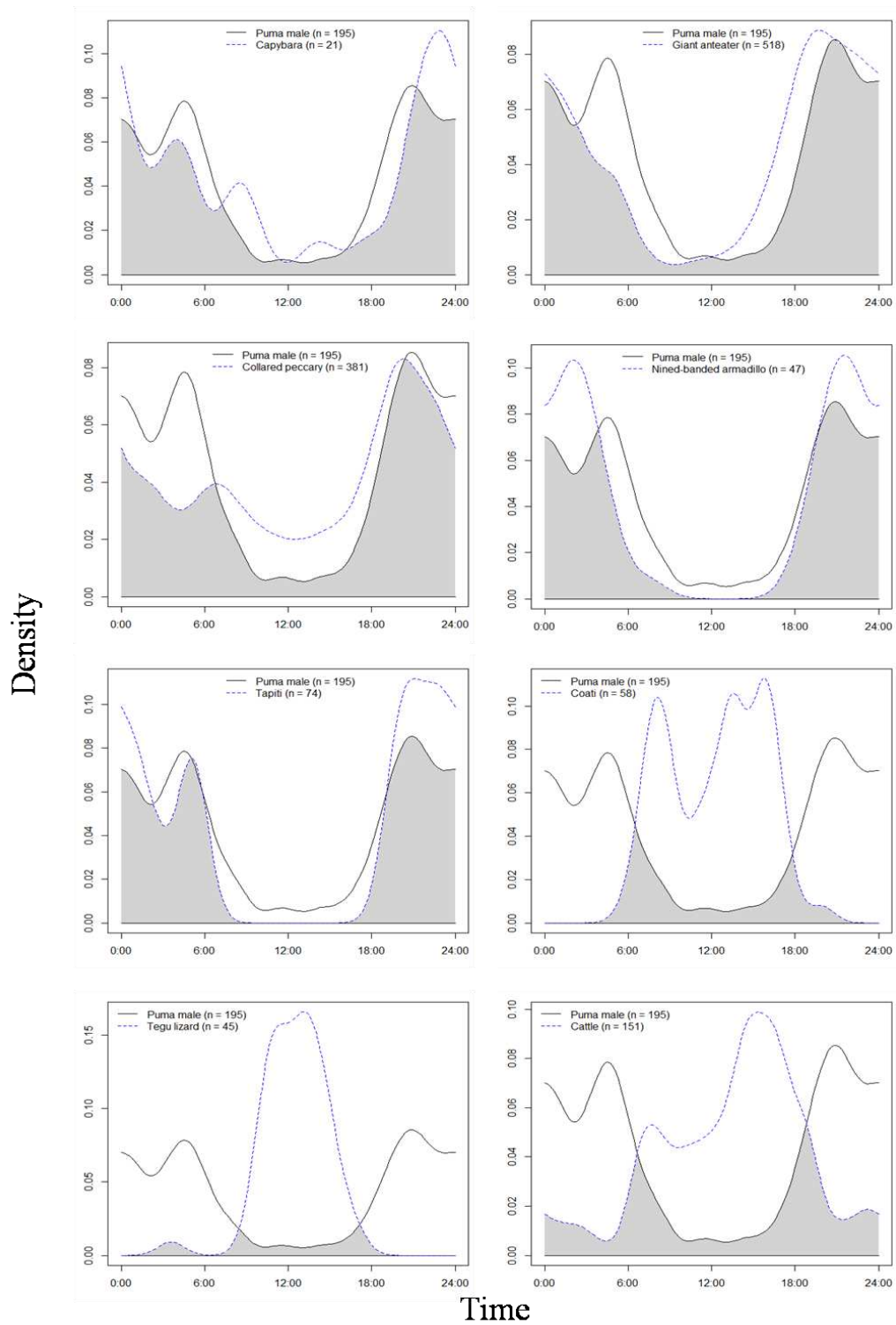


Figure 4 Density estimates of daily activity patterns for male pumas (*Puma concolor*) and main prey in Araguari, Minas Gerais, Brazil. Solid lines are kernel-density estimates for pumas, whereas dashed lines are prey species. Overlap coefficient is represented by the shaded area.

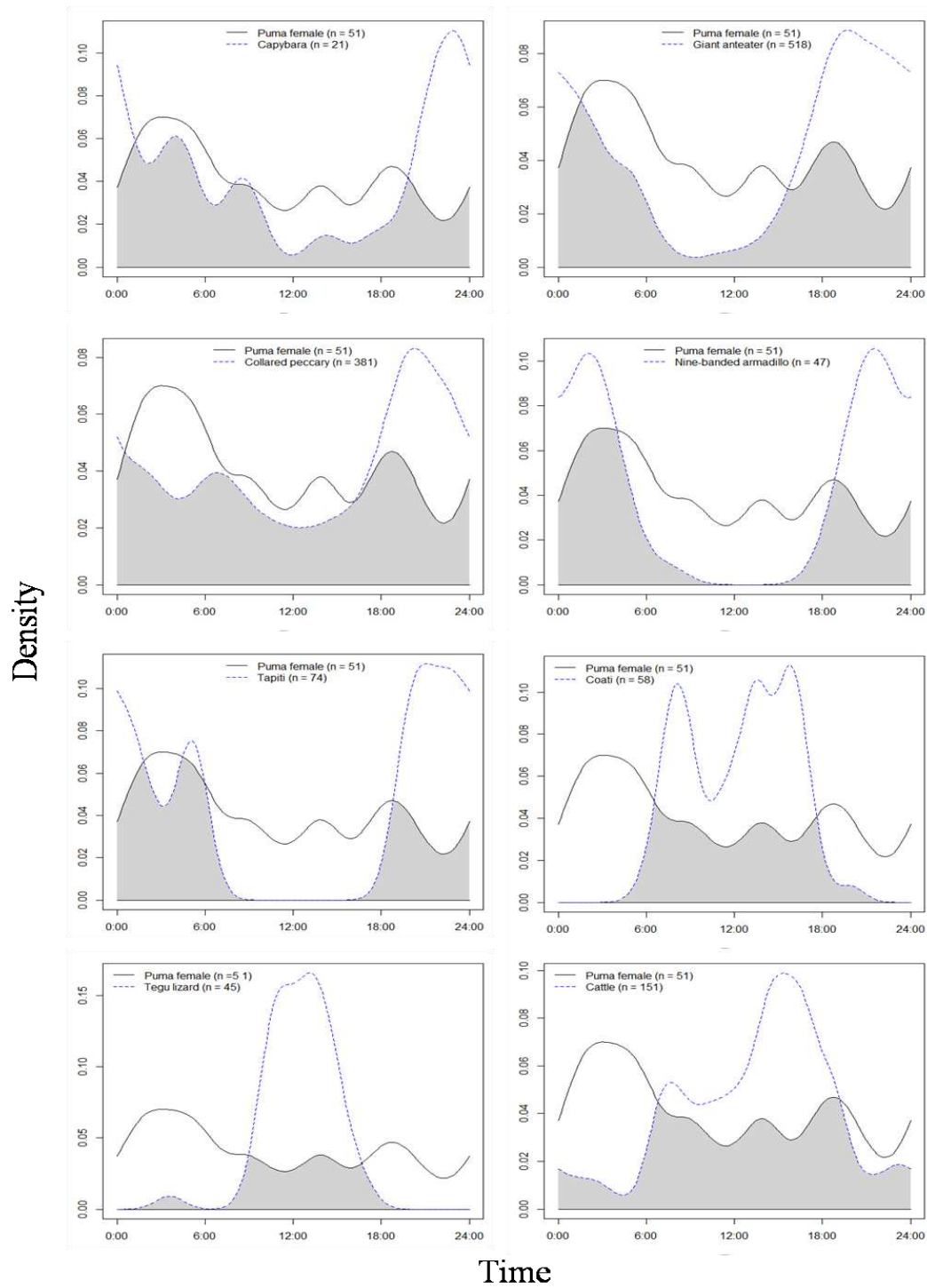


Figure 5 Density estimates of daily activity patterns for female pumas (*Puma concolor*) and main prey species in Araguari, Minas Gerais, Brazil. Solid lines are kernel-density estimates for pumas, whereas dashed lines are prey species. Overlap coefficient is represented by the shaded area.

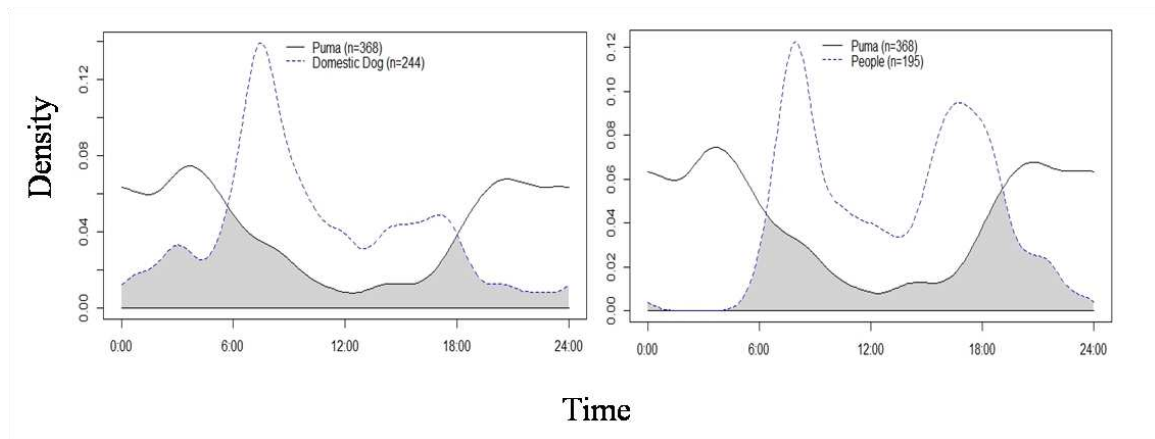


Figure 6 Density estimates of daily activity patterns for pumas (*Puma concolor*), domestic dogs (*Canis lupus familiaris*) and people in Araguari, Minas Gerais, Brazil. Solid lines are kernel-density estimates for pumas, whereas dashed lines are prey species. Overlap coefficient is represented by the shaded area.

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Table 1 Number of independent camera trap records (n), estimates coefficients of overlapping (Δ) of wild prey species with pumas (*Puma concolor*) and 95% confidence intervals (CI). Data are from camera trap survey from 2009 to 2016 in Araguari, Minas Gerais, Brazil.

Prey species	<i>Puma concolor</i>						
	N	Total (n = 368)		Male (n = 195)		Female (n = 51)	
		Estimate	CI	Estimate	CI	Estimate	CI
<i>Hydrochoerus hydrochaeris</i>	21	0.82	0.65 - 0.95	0.81	0.64 - 0.93	0.68	0.49 - 0.86
<i>Pecari tajacu</i>	381	0.82	0.76 - 0.88	0.79	0.73 - 0.86	0.74	0.63 - 0.85
<i>Myrmecophaga tridactyla</i>	518	0.78	0.72 - 0.84	0.82	0.76 - 0.88	0.64	0.52 - 0.75
<i>Dasypus novemcinctus</i>	47	0.75	0.66 - 0.84	0.79	0.69 - 0.88	0.57	0.43 - 0.7
<i>Sylvilagus brasiliensis</i>	74	0.74	0.65 - 0.82	0.82	0.72 - 0.90	0.57	0.44 - 0.68
<i>Nasua nasua</i>	58	0.25	0.19 - 0.33	0.19	0.12 - 0.27	0.42	0.29 - 0.56
<i>Salvator merianae</i>	45	0.16	0.09 - 0.23	0.11	0.05 - 0.18	0.31	0.18 - 0.44

Supplementary material

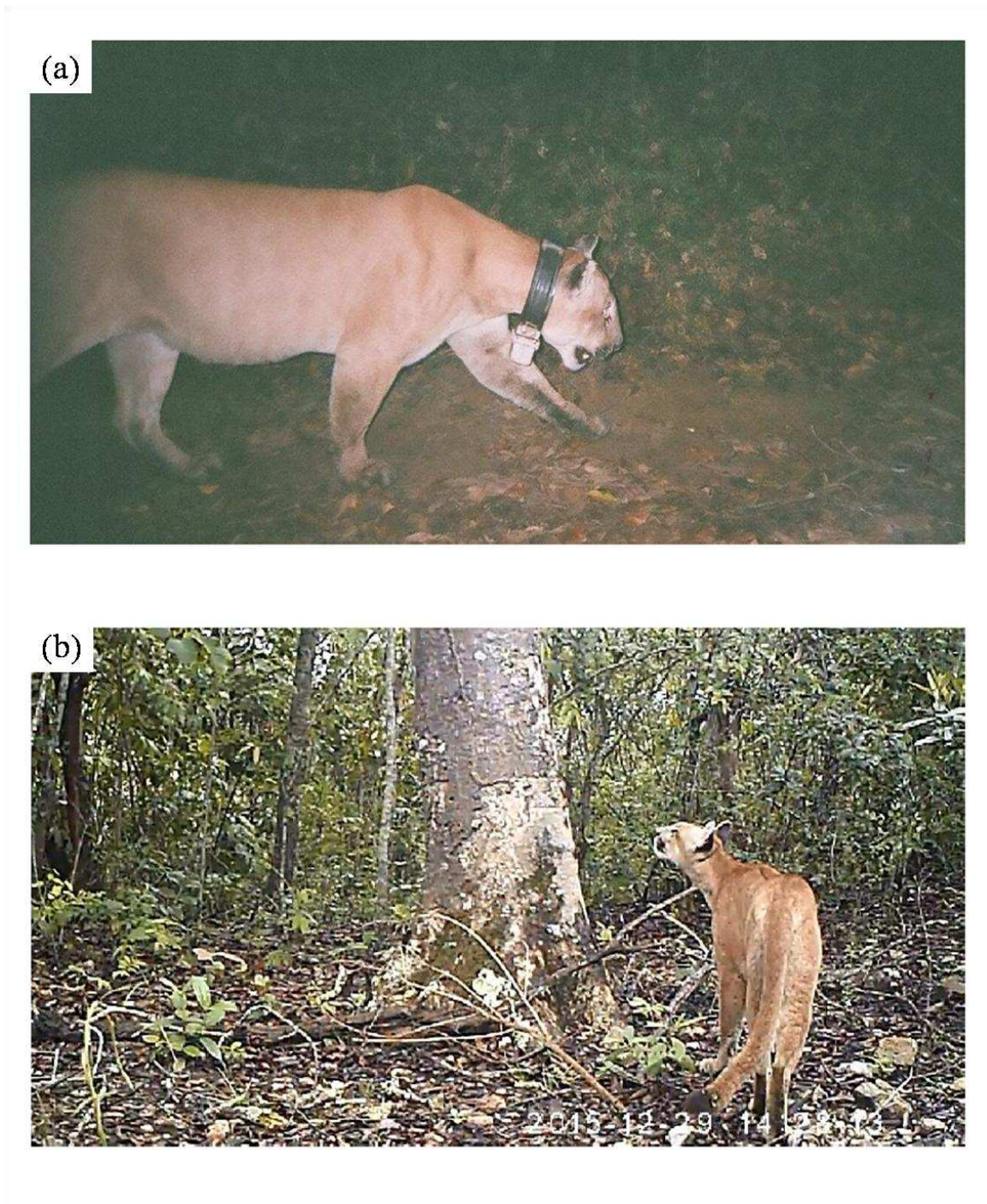


Figure S1 Pumas (*Puma concolor*) registered at Camera-traps survey from 2009 to 2016 in Araguari, Minas Gerais, Brazil. (a) collared male puma during nighttime, (b) female puma during daytime.

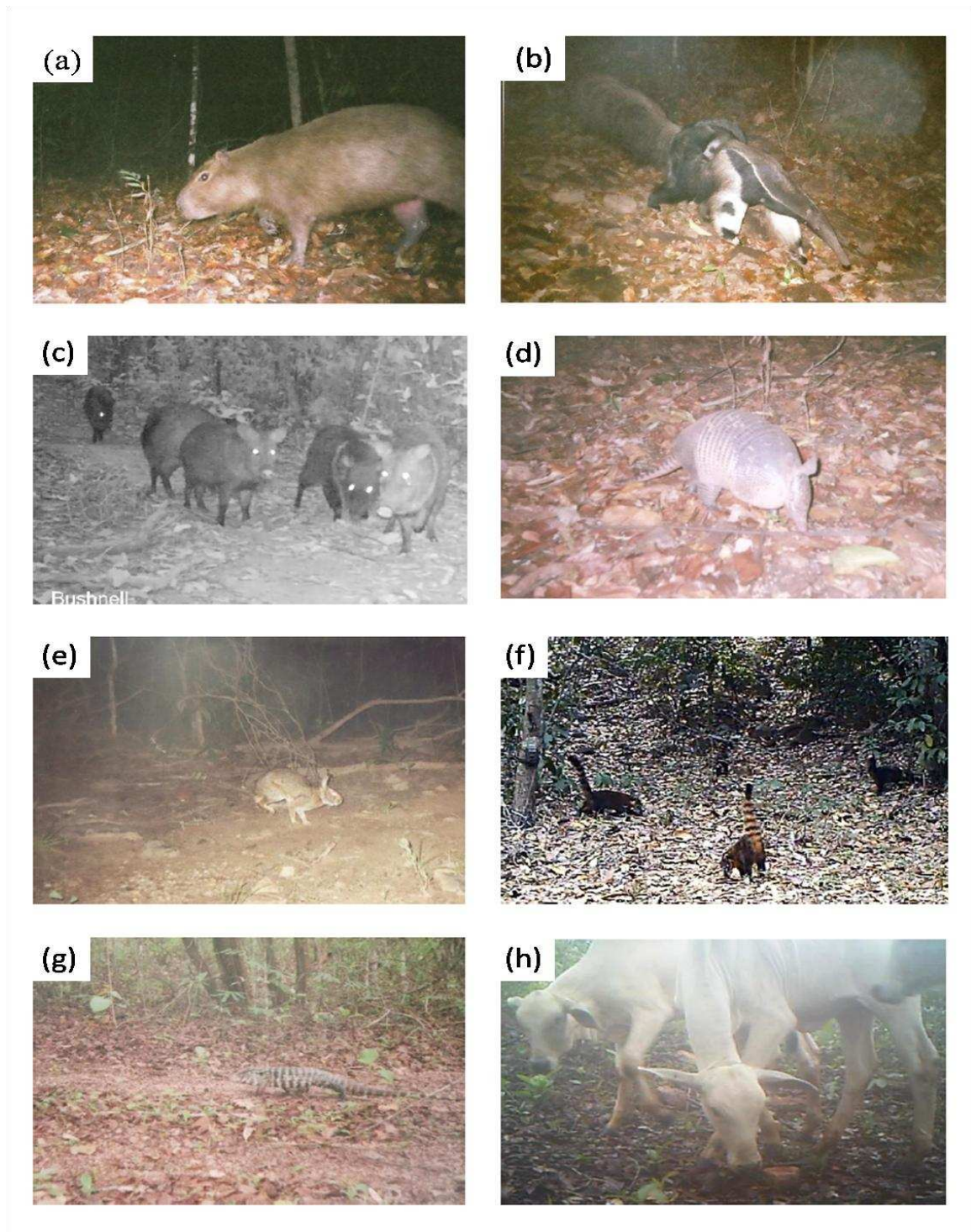


Figure S2 Prey species registered at Camera-traps from 2009 to 2016 in Araguari, Minas Gerais, Brazil. (a) capybara (*Hydrochoerus hydrochaeris*), (b) giant anteater (*Myrmecophaga tridactyla*), (c) collared peccary (*Pecari tajacu*), (d) nine-banded armadillo (*Dasyus novemcinctus*), (e) tapiti (*Sylvilagus brasiliensis*), (f) coati (*Nasua nasua*), (g) tegu lizard (*Salvator merianae*), and (h) cattle (*Bos Taurus*).

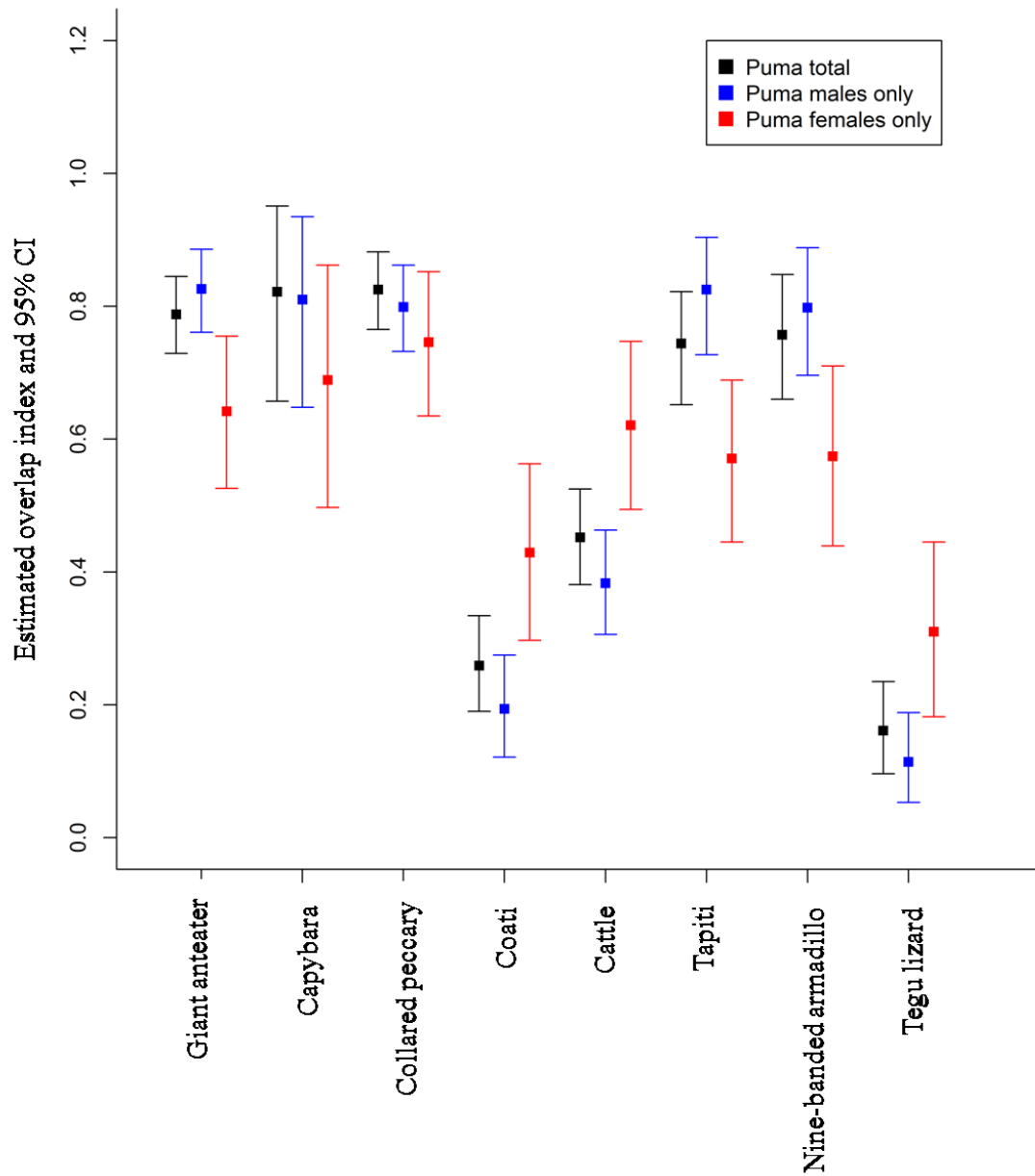


Figure S3 Estimate overlap index and 95% of confidence interval, CI, for all pumas (*Puma concolor*), for male pumas only, for female pumas only and wild prey species registered at Camera-traps from 2009 to 2016 in Araguari, Minas Gerais, Brazil.

Table S1 Prey species consumed by pumas (*Puma concolor*) in Araguari, Minas Gerais, Brazil. Species diet was assessed through visiting GPS clusters of location (n) of monitored pumas.

Species	<i>Puma concolor</i>		Male		Female	
	n	%	n	%	n	%
<i>Hydrochoerus hydrochaeris</i>	29	28.71	28	43.75	1	2.7
<i>Myrmecophaga tridactyla</i>	16	15.84	14	21.88	2	5.41
<i>Salvator merianae</i>	7	6.931	0	0	7	18.9
<i>Euphractus sexcinctus</i>	6	5.941	6	9.375	0	0
Mammals unidentified	6	5.941	0	0	6	16.2
<i>Mazama gouazoubira</i>	4	3.96	1	1.563	3	8.11
Wild birds unidentified	4	3.96	2	3.125	2	5.41
<i>Dasypus novemcinctus</i>	3	2.97	0	0	3	8.11
<i>Equus caballus</i>	3	2.97	3	4.688	0	0
<i>Gallus gallus</i>	3	2.97	1	1.563	2	5.41
<i>Lycalopex vetulus</i>	2	1.98	0	0	2	5.41
<i>Nasua nasua</i>	2	1.98	0	0	2	5.41
<i>Pecari tajacu</i>	2	1.98	1	1.563	1	2.7
<i>Sylvilagus brasiliensis</i>	2	1.98	0	0	2	5.41
<i>Cariama cristata</i>	2	1.98	0	0	2	5.41
<i>Felis catus</i>	2	1.98	2	3.125	0	0
<i>Bos taurus</i>	2	1.98	2	3.125	0	0
<i>Anas platyrhynchos</i>	2	1.98	2	3.125	0	0
<i>Crax fasciolata</i>	1	0.99	1	1.563	0	0
<i>Tigrisoma lineatum</i>	1	0.99	1	1.563	0	0
<i>Numida meleagris</i>	1	0.99	0	0	1	2.7
Dipsadidae unidentified	1	0.99	0	0	1	2.7
Total	101	100	64	100	37	100

Table S2 Activity patterns classification (based on % of camera trap records) of pumas (*Puma concolor*) and prey species in Araguari, Minas Gerais, Brazil.

Species	n	Day records %	Night records %	Classes
<i>Puma concolor</i>	368	23.1	76.9	MN
<i>Myrmecophaga tridactyla</i>	518	18.5	81.5	MN
<i>Pecari tajacu</i>	381	33.9	66.1	Ca
<i>Bos taurus</i>	151	77.5	22.5	MD
<i>Sylvilagus brasiliensis</i>	74	0	100	No
<i>Nasua nasua</i>	58	96.6	3.4	Di
<i>Dasypus novemcinctus</i>	47	4.3	95.7	No
<i>Salvator merianae</i>	45	97.8	2.2	Di
<i>Hydrochoerus hydrochaeris</i>	21	23.8	76.2	MN

Ca, Cathemeral; Di, Diurnal; MD, Mostly Diurnal; MN, Mostly Nocturnal; No, Nocturnal

CAPÍTULO II.

FORAGING ECOLOGY OF PUMAS IN A HUMAN-DOMINATED LANDSCAPE AT SOUTHEAST BRAZIL

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Foraging ecology of pumas in a human-dominated landscape at Southeast Brazil

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Running heading: Foraging ecology of pumas in a human-dominated landscape

Abstract

Carnivores perform important community-level functions, including the maintenance of prey densities and their associated habitats. Understanding carnivores' energy requirements are particularly important in human-disturbed landscapes once their populations are especially susceptible to anthropogenic effects. Here, we used GPS technology to investigate pumas *Puma concolor* feeding behavior between 2012 and 2017. Diet composition, niche breadth, prey selection, and patterns of predation were determined from clusters of locations, while prey availability was assessed through camera trapping surveys. Pumas living at a Brazilian agro-ecosystem of Southeastern Brazil did not consume prey according to their availability, nor according to habitat availability. Our results indicate that pumas selected capybara (*Hydrochaeris hydrochaeris*) and six-banded armadillo (*Euphractus sexcinctus*) over other more abundant prey, being forests and pasture with shrubs the preferred habitat classes. On average, pumas hunted every 3.54 ± 1.62 days, and wild prey species were the most consumed both in terms of frequency of occurrence and biomass. Probability of an encountering of a predation event increased in more than 50% after two nights at a GPS cluster, reaching a peak of 90% of probability of prey encountering after 80 hours at the GPS cluster. Niche breadth of pumas varied among sexes, as males killed proportionally more large-sized and less diverse prey than females. Factors affecting prey choice in pumas differ across its distributional range, and reflect part of the ability of this top predator to adapt to different ecosystems, even the modified ones. Pumas' foraging ecology is important for planning effective conservation and management actions, especially where pumas are locally vulnerable to extinction, as puma populations in southeastern Brazil.

Introduction

It is well established that predatory activities of large carnivores play an important role on the biodiversity and structural integrity of entire ecosystems [1]. Carnivores perform various important community-level functions, including the maintenance of prey densities and their associated habitats [2,3]. Therefore, knowing species dietary habits may provide a good picture of energy requirements in natural communities. This is particularly important when examining predator-prey dynamics in human-disturbed landscapes [4,1], since large carnivores' populations are especially susceptible to anthropogenic changes due to their low densities, vast space requirements, and high dependency on prey availability [5].

The lack of information on feeding ecology of animals may hamper the development of appropriate conservation and management measures for both species and ecosystems. Unfortunately, such deficiency is common for ecologically important, yet threatened, species throughout much of the developing world [6]. For example, large undisturbed Neotropical grasslands are currently rare along South America, specially at Brazil, because they have been extensively converted for agricultural purposes and heavily degraded due to livestock pressure [7,8]. Furthermore, there is scant information on the use and selection of food resources by predator species inhabiting these areas, including the puma (*Puma concolor*).

Pumas are a widespread top predator inhabiting a variety of ecosystems [9]. Throughout their range, pumas have a broad diet that includes small to large-sized mammals, birds, and reptiles [10]. On temperate regions, where medium to large-sized ungulates are common, most consumed prey's weight range from 20 to 80 kg [10], whereas along the tropics, where potential prey are smaller, diet encompasses mostly species from 7 to 30 kg [11]. Although wild prey compose most of puma's diet along its

range, consumption of domestic animals and exotic prey species are not rare (e.g., sheep, horse, cattle, domestic fowl, hares) [12–16]. The use of alternative prey species by pumas is apparently related to changes in prey availability, vulnerability and distribution [17].

Widely distributed through the Brazilian territory, pumas are found on an array of ecosystems, from Amazon Forest to Caatinga [18]. Although the species is listed as Least Concern along its distribution [19], pumas were recently classified as Vulnerable to extinction in Brazil, mainly due to habitat loss and fragmentation, and retaliation resulting from conflicts with livestock owners [20]. Studies on pumas feeding ecology are few in Brazil and, most are restricted to fecal analysis methods [21–24]. However, depending on environment conditions (e.g. terrain, litter, humidity), locating felid scats may be challenging, limiting thus sample sizes. More recently, the use of global position system (GPS) radio collars has been contributing to elucidate fundamental aspects of predation, through the assessment of clusters of locations to identify kills and other feeding ecology parameters [25].

Our study represents the first attempt to understand puma's foraging ecology at a Brazilian agro-ecosystem using a different approach to assess the specie's diet. We used GPS data from monitored pumas to find clusters of locations and investigate their feeding behavior, addressing key aspects such as prey composition, kill rates, prey selection, and predation patterns. We hypothesized that pumas consume more domestic prey in human-dominated landscapes. Specifically, we predicted that i) pumas are generalist predators and would consume prey according to prey availability; ii) more events of puma predation would be found in more representative habitats in terms of availability; and iii) males pumas would kill larger prey than females due dissimilar energetic demands.

Materials and Methods

Study site

The study was conducted on private ranches in the municipality of Araguari, at the Triângulo Mineiro region, Minas Gerais State, Brazil (18°46'S, 48°14'W and 18°21' S, 48°38'W; Fig. 1). The region encompasses an ecotone zone of Cerrado and Atlantic Forest biomes [26], both considered hotspots for conservation due their rich biodiversity and high human impact [27]. Over the past two centuries, natural vegetation in the region has been reduced to small/medium-sized fragments severely disturbed by indiscriminate timber, extensive ranching and fire events. Currently, the landscape comprises an agro-ecosystem matrix of multiple land uses dominated by cattle ranches (*Bos taurus*), mainly filled by exotic pasture (*Urochloa* spp.), and agriculture plantations. Pasture and agricultural activities occupy at least 60 % of the entire study site [28]. Based on a traditional grazing and herd management system, few properties have a strict control of domestic animals and reproductive season, or adopt preventive/mitigating measures to avoid predation by wild carnivores (F.C. Azevedo and F.G. Lemos, unpublished data). Large and medium-sized domestic ungulates (e.g., cattle, horses *Eqqus caballus*, swine *Sus scrofa*) are abundant, as well domestic fowl including chickens (*Gallus gallus*), guinea fowl (*Numida meleagris*), and ducks (*Anas* spp.). Remaining natural vegetation correspond to 40% of the study site and is restricted to scattered patches of mesophytic seasonal forest and savannah [28,29], concentrated along the margins of Araguari and Paranaíba rivers and their tributaries. Though the Brazilian environmental law obligates farmers to protect reminiscent vegetation within properties, most are not fenced, leaving cattle indirect contact with wildlife. Climate is classified as subtropical (Cwa) according to Köppen and has two well marked seasons, one hot and wet from October to April and another mild and dry from May to

September [30]. Mean annual temperature and precipitation vary between 22–25°C and 1600–1800 mm, respectively (data available by CPTEC/INPE).

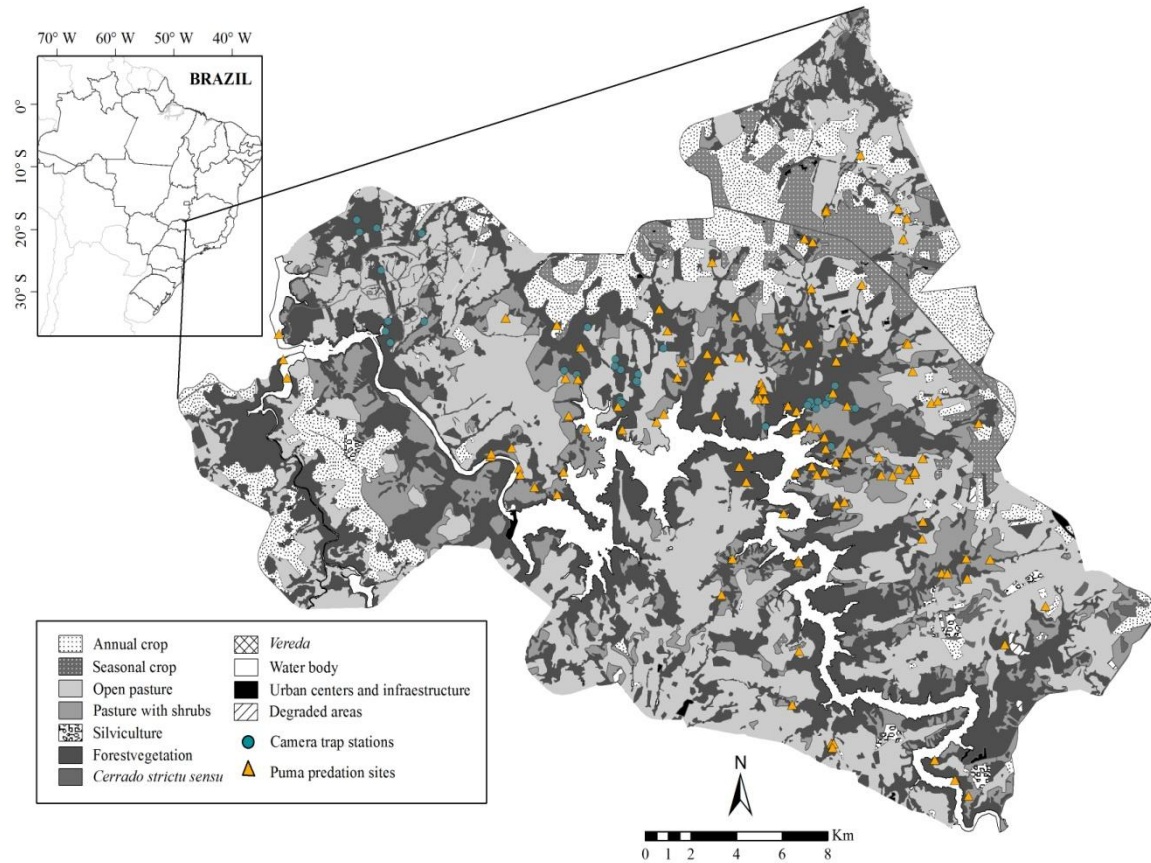


Fig 1. Map of the study site with camera-trap stations, puma (*Puma concolor*) predation sites and land cover classification in Araguari, Minas Gerais, Brazil, between 2012 and 2016.

Trapping and handling procedures

From February 2012 to April 2016, we captured and monitored six pumas (four males and two females) using soft-hold foot snares and immobilized them using a combination of tiletamine-zolazepam at 10mg/kg (Zoletil™, 100mg/ml, Virbac, São Paulo, Brazil) and xylazine at 0.7 mg/kg (Xilazin, 10% Syntec, São Paulo, Brazil), administered via projectile dart. Pumas were aged according to a combination of physical characteristics

such as dentition, pelage spotting progression, body mass [31], and reproductive status (e.g. females nursing or nulliparous). All pumas were adults (≥ 30 months old; [31]) and were fitted with drop-off GPS collars (two with Lotek™ Fish & Wildlife Monitoring, Ontario, Canada/ 4550S model; four with Sirtrack™ Wildlife Track Solutions, Hawkes Bay, New Zealand /G5C 375B Pinnacle Iridium model), programmed to record locations during 24 hours every five hours interval (Lotek™ models) or every two hours (Sirtrack™ models). All GPS collars had a standard Very High Frequency (VHF) transmitter, an activity sensor, and an on board memory to store location data until they were downloaded remotely either by distance or satellite transmission.

To minimize the risk of injury and holding time of animals we equipped snares with VHF devices (Nortronic™), which were monitored at least every 2 hours by distance. In addition the traps were visually inspected every day in the morning before hottest hours. All animals were captured following standard protocols approved by the Instituto Chico Mendes de Conservação da Biodiversidade, Ministério do Meio Ambiente, Brazil (ICMBio SISBIO) under license numbers 18913-1 and 18913-4 (2009–2015), and by the Ethics Committees on Animal Use of Universidade Federal de Viçosa (process number 90/2014) and Universidade Federal de Goiás (process number 66/2014).

Feeding site surveys

Prey composition and predation characteristics were investigated checking clusters of locations provided by GPS collars of the six monitored pumas. We defined GPS clusters of location by visually identifying any three or more locations within 50 m of each other obtained in a period of 24 hours and treating them as potential predation sites (adapted from [32]). Once detected, each cluster was visited and searched systematically on foot

for possible prey remains (i.e., hair, skin, feather, bone fragment) in a diameter of 100 m radius. Additionally, all puma locations in the vicinity of ranch facilities were checked, independent of the stated premises, since they could represent livestock predations. When evidences were insufficient to provide confident prey identification we recorded items as unidentified. Investigation of GPS clusters did not always allow for the detection of small prey items during site searching (i.e., either if prey was completely consumed or remains were carried by scavengers or due weather conditions). Here we located and identified prey items ranging from at least 1.5 kg to > 15 kg in size (e.g., marsupials and wild birds). Thus, prey items were then classified into three major groups: small-sized (<1.5 kg), medium-sized (1.5 – 15 kg), and large-sized (> 15kg) prey.

Prey composition and predation characteristics

Carcasses found at predation sites were identified to the smallest taxonomic group possible. The importance of each item was determined by its frequency of occurrence (FO) and consumed biomass. We usually visited predation sites after pumas had consumed their prey, which allowed for determination of FO. In turn, because we were unable to obtain biomass values, these were estimated based on approximate live weights of consumed prey species from current literature [33–35]. This approach assumes that all individuals of a given prey species are adult-sized. In addition, we calculated measures of niche breadth according to the standardized Levins index (1968), following the formula $B_A = [(1/\sum p_i^2) - 1] / n - 1$; where, B_A represents the Levin's measure of niche breadth, p the proportion of prey in each food category i , and n the number of categories. This index ranges from 0 to 1, with lower values indicating a specialized diet and higher values a generalist one.

In order to evaluate the influence of sample size on the results of GPS cluster of locations analysis, following [36], we firstly randomly selected five predation sites where prey was located. We then added to the results another five clusters and thus repeatedly. The cumulating frequency of occurrence of different prey items over successive random draws was then assessed to infer effect of sample size on final dietary results.

Predation characteristics as kill rates, kill interval and prey handling time (time spent consuming prey) were analyzed for five pumas continuously monitored for ≥ 4 weeks and with collar fix success rate of $> 45\%$ [37,38]. We define predation event as hours between the first and last location for each puma at the kill site, and used time interval between known consecutive predation events to estimate time interval between kills. Only intervals in which clusters were searched consecutively were used for the analysis. We used Pearson correlations to verify the relationship between time on kill and the estimated prey weight found at clusters. GPS clusters where prey species were not identified were not used in this analysis.

We used forward stepwise logistic regression analysis (binomial distribution of presence/absence of carcasses) to model the probability of a predation event at a GPS cluster. We used five explanatory variables: number of locations at clusters, total time at clusters (hours), number of nights at clusters (locations between 18:00 h of first day to 06:00 h of the next), number of nocturnal locations at clusters, and a combination of total time versus number of nights at clusters. We based model selection on strength of variable significance (Wald χ^2 , $P < 0.05$), testing the null hypothesis that longer time at clusters did not represent a higher probability of finding a puma predation event.

Prey availability and selection

We estimated the abundance of puma prey species across the study area using records from camera-trapping. The purpose of the remote camera survey was to identify suitable sites for capturing pumas as part of a broader monitoring program on pumas to underpin local conservation efforts in a non-protected area of Southeast Brazil. Each camera station consisted of one or two independent cameras (Tigrinus©, Santa Catarina, Brazil, and Bushnell©, Kansas, USA) placed at irregular intervals, covering an area of 60 km². Cameras were placed along trails, and when in pairs facing each other about 4 to 6 m apart with the trail in between. Camera stations were set to take photos/videos with interval of 30 seconds between records and were checked approximately every 20 days.

To assess prey species abundance we calculated an index for all puma prey that were captured on camera-trapping following [39]. For species abundance index we used the formula $N = \sum_{i=1}^n ((N_i / (S_i * T_i)) / n) * S$, where N is the species abundance throughout the study site; N_i equals the number of captures of any species at a specific camera location; S_i refers to the area covered by one camera station (15 x 15m); T_i represents the time period of monitoring of the specific camera; S refers to the area of the whole study site; and n is the amount of cameras in the study.

We defined prey selection as the killing of a prey species in greater proportion than expected given their availability [38]. Comparisons of observed counts of each prey item found in the GPS clusters with estimated prey abundance were used to assess selectivity in predation. We used chi-square log likelihood analysis to determine resource selection at puma's population level, testing the null hypothesis of non-selective predation, and Manly standardized resource selection index for constant resources to compare prey selection among different prey species available. We choose to use this selection index because it is not affected by the inclusion or exclusion of

resources that are rarely consumed [40]. The selection ratios w_i for each resource used were calculated as:

$$w_i = \frac{\text{resource proportion used } i}{\text{resource proportion available } i}$$

Then they were standardized as follows:

$$b_i = \frac{w_i}{\sum_{i=1}^H w_i}$$

Where H = number of species units, i = ranges from 1 to H, and b_i is the probability that for any selection event, a puma would choose prey species i over all other prey species (Manly et al. 2002). The outcome provides a direct comparison between selection ratios within each resource type (species). If $b_i = 1/H$, a prey was consumed in proportion to abundance in the study area, whereas $b_i > 1/H$ means that a prey was preferred and $b_i < 1/H$ indicates a prey was avoided among all other prey types.

Patterns of predation

In order to verify if locations of predations occurred in accordance to habitat availability, first we classified the landscape based on a set of images obtained from the RapidEye[®] Satellite Sensor (RapidEye AG, Berlin, Germany; 2015) using ArcGIS 10.2 in conjunction with Quantum GIS 9.2 software (ESRI[™] and QGIS[®], Open Source Geospatial Foundation Project; respectively). Images resolution was 5 meters in a scale of 1: 20,000 ha. Eleven categories were determined according to Brazil land use and coverage [41] and further subdivided in three major classes: Natural Areas encompassing habitat types such as *vereda*, *cerrado stricto sensu* and forest vegetation; Anthropic Areas encompassing seasonal crop, perennial crop, silviculture, open pasture, pasture with shrubs, degraded area, urban centers and infrastructure; and Hydrography including rivers, streams, and artificial dams. Under forest vegetation class we grouped

patches of deciduous and semi-deciduous forests, dry forests and *cerradões* [26]. Regarding the perennial crop class, coffee were the most representative, while corn, soybean and sorghum crops were for seasonal class. Open pasture class was characterized by pastures grazed by livestock, while pasture with shrubs was also exotic pastures but without use, already under some recovery successional stage (i.e., exotic grass permeated by herbs, shrubs and small pioneer species).

To investigate which was the most suitable habitat for hunting, we overlapped coordinates obtained from all GPS clusters of locations of prey killed to the map of land use and coverage, determining habitat selection by comparing the use of different habitats by pumas for hunting and the availability of those habitats in the study area ('second-order' habitat selection; [42]). Finally, we used Manly standardized resource selection index (as described previously) for constant resources to compare locations of prey killed among different habitat types to determine puma's patterns of predation, testing the null hypothesis of non-selective location of prey killed regarding habitat class. The selection ratios w_i for each resource used were calculated as:

$$w_i = \frac{\text{number of prey killed per habitat } i}{\text{habitat proportion available } i}$$

Then they were standardized as follows:

$$b_i = \frac{w_i}{\sum_{i=1}^H w_i}$$

Where H = number of habitats units, i = ranges from 1 to H, and b_i is the probability that for any kill, a puma would kill a prey in a habitat i over all habitats available [40].

The outcome provides a direct comparison between selection ratios within each resource type (habitat).

Results

Prey composition and predation characteristics

Pumas were monitored for periods ranging from 10 months to 16 months (mean \pm SD, 13 ± 2.48 months) resulting in 3767 ± 1780.3 acquired locations (Table 1). Success rate at obtaining GPS locations was 75% (ranging from 65% to 86%) of the total gathered amount. In total, we investigated 216 potential feeding sites of the 723 identified GPS cluster extracted from puma locations. Of these, we located prey remnant at more than 50% of clusters (120). We were not able to check 100 clusters (13.8%) due to inaccessible terrain or due to the land owners' non-consent to access ranches. The remaining clusters (407) were not visited prior to the start of these analyzes. Despite 56% of potential predation sites had not been visited, sample size was sufficient to describe puma diet at study site, as the proportion of different consumed prey species stabilized from the 50th cluster onwards (Fig 2).

Table 1. Monitoring parameters and predation characteristics for GPS-collared pumas (*Puma concolor*), between 2012 and 2016, in Araguari, Minas Gerais, Brazil. GPS, number of global positional system locations acquired; KN, number of kills found; KR, kill rates; TC, number of average total time at clusters; TB, time between clusters; BK, time between kills.

Puma ID	Range of Dates	Monitoring Period (days)	GPS	Visited Clusters	KN	KR	TC (hours)	TB (hours)	BK (hours)
M #171	Feb-Dec 2012	304	1159	6	5	0,83	-	-	-
M #470	May 2015-Apr 2016	334	3107	23	15	0,65	25	70	89
M #510	Aug 2015-Out 2016	486	3983	48	27	0,56	25	92	121
M #820	Apr 2016-May 2017	334	2489	40	28	0,70	23	85	100
F #710	May 2015-Out 2016	486	6259	38	16	0,42	18	37	-
F #230	April 2016-Jun2017	334	4531	61	29	0,48	10	29	31
			21528	216	120				

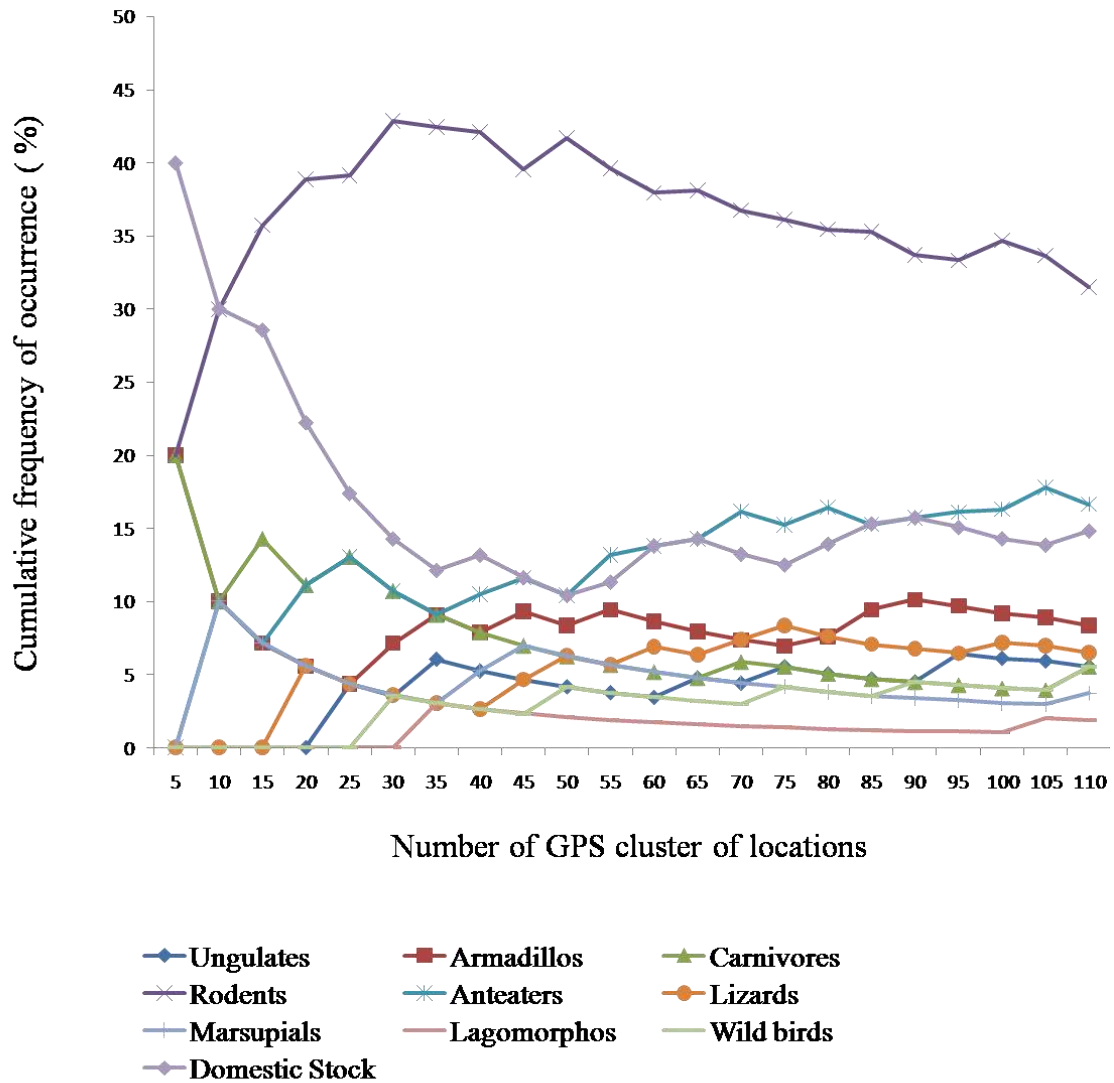


Fig 2. Effect of sample size on the frequency of occurrence of prey species in GPS-collared pumas (*Puma concolor*) clusters of locations, between 2012 and 2016, in Araguari, Minas Gerais, Brazil.

From the 120 clusters with prey remnants, we documented 120 prey items distributed in 20 identified species and 10 items unidentified. For the identified species, 14 constituted wild prey (n= 90; 70%), and six domestic stock (n = 10; 30%) and 10 items remained unidentified (Table 2). The majority of identified consumed prey items were capybaras (*Hydrochoerus hydrochaeris*, 28.3%) and giant anteaters

(*Myrmecophaga tridactyla*, 15%). Other mammals made up a further 20% of kills, represented by armadillos (*Euphractus sexcinctus* and *Dasyplus novemcinctus*, 7.5%), ungulates (*Mazama gouazoubira* and *Pecari tajacu*) and carnivores (*Lycalopex vetulus* and *Nasua nasua*) 5% both taxa, marsupials (*Didelphis albiventris*, 3.3%), and tapitis (*Sylvilagus brasiliensis*, 1.7%). Unidentified mammals represented 3.3% of the kills. Red-legged seriema (*Cariama cristata*), bared-faced curassow (*Crax fasciolata*), rufescent tiger-heron (*Tigrisoma lineatum*) and other wild birds together made up 9% of the kills, whereas tegu lizards (*Salvator merianae*) represented 5.8% of consumed prey. In turn, domestic prey kills were composed of domestic fowl (*Gallus gallus*, *Anas spp.*, and *Numida meleagris*, 9.1%), foals (*Equus caballus*, 2.5%), calves (*Bos taurus*, 1.7%), and cat (*Felis catus*, 1.7%) (Table 2).

Table 2. Distribution of prey found at kill sites, frequency of occurrence (FO) and biomass (BIO) of consumed items for GPS-collared pumas (*Puma concolor*), between 2012 and 2016, in Araguari, Minas Gerais, Brazil. Number of kills with percentage of kills presented in parentheses.

Prey Species	M# 171	M# 470	M# 510	M# 820	F# 710	F# 230	Total	Kills %	FO %	BIO % (kg)
Wild										
Capybara	2 (40)	10 (66,7)	8 (29,6)	13 (46,4)	1 (6,3)	0	34	28,3	30,9	53,8
Giant anteater	0	0	12 (44,4)	4 (14,3)	2 (12,5)	0	18	15	16,4	19,0
Tegu lizard	0	0	0	0	2 (12,5)	5 (17,2)	7	5,8	6,4	1,0
Six-banded armadillo	0	2 (13,3)	3 (11,1)	1 (3,6)	0	0	6	5	5,5	1,1
Common opossum	0	0	0	0	0	4 (13,8)	4	3,3	3,6	0,2
Brown-brocket deer	0	0	0	1 (3,6)	1 (6,3)	2 (6,9)	4	3,3	3,6	3,2
Coati	0	0	0	0	1 (6,3)	3 (10,3)	4	3,3	3,6	0,8
Nine-banded armadillo	0	0	0	0	3 (18,8)	0	3	2,5	2,7	0,4
Hoary-fox	0	0	0	0	2 (12,5)	0	2	1,7	1,8	0,3
Collared-peccary	0	0	1 (3,7)	0	1 (6,3)	0	2	1,7	1,8	1,8
Tapiti	0	0	0	0	1 (6,3)	1 (3,4)	2	1,7	1,8	0,1
Unidentified mammal	0	0	0	0	0	3 (10,3)	3	2,5	-	-
Red-legged seriema	0	0	0	1 (3,6)	0	3 (10,3)	4	3,3	3,6	0,3
Bare-faced curassow	0	1 (6,7)	0	0	0	0	1	0,8	0,9	0,1
Rufescent tiger-heron	0	0	0	1 (3,6)	0	0	1	0,8	0,9	0,0
Unidentified wild bird	0	2 (13,3)	0	0	0	3 (10,3)	5	4,2	-	-
Unidentified Dipsadidae	0	0	0	0	0	1 (3,4)	1	0,8	-	-
Domestic										
Fowl	0	0	0	4 (14,3)	2 (12,5)	2 (6,9)	8	6,7	7,3	0,7

Foal	1 (20)	0	2 (7,4)	0	0	0	3	2,5	2,7	10,6
Cat	0	0	1 (3,7)	1 (3,6)	0	0	2	1,7	1,8	0,3
Calf	2 (40)	0	0	0	0	0	2	1,7	1,8	6,3
Duck	0	0	0	2 (7,1)	0	0	2	1,7	1,8	0,3
Guinea fowl	0	0	0	0	0	1 (3,4)	1	0,8	0,9	0,1
Unidentified	0	0	0	0	0	1 (3,4)	1	0,8	-	-
Total	5	15	27	28	16	29	120	100	100	100

M, male pumas; F, female pumas.

Capybara, *Hydrochoerus hydrochaeris*; giant anteater, *Myrmecophaga tridactyla*; tegu lizard, *Salvator merianae*; six-banded armadillo, *Euphractus sexcinctus*; common opossum, *Didelphis albiventris*; brown-brocket deer, *Mazama gouazoubira*; nine-banded armadillo, *Dasypus novemcinctus*; hoary-fox, *Lycalopex vetulus*; coati, *Nasua nasua*; collared-peccary, *Pecari tajacu*; tapiti, *Sylvilagus brasiliensis*; red-legged seriema, *Cariama cristata*; bare-faced curassow, *Crax fasciolata*; Rufescent tiger-heron, *Trigisoma lineatum*; fowl *Gallus gallus*; cat *Felis catus*; calf *Bos taurus*; duck *Anas spp.*; guinea fowl, *Numida meleagris*

Male and female pumas' diet composition overlapped but differed in terms of niche breadth and species selected. Among wild prey species, males consumed only three items while females consumed seven prey exclusively. Capybara, giant anteater, brown brocket-deer and wild birds were consumed by both males and females. However, males consumed capybara and giant anteater in a larger proportion (44% and 21.3%, respectively) than females (2% and 4%, respectively). Six-banded armadillo was predated only by male pumas (8% of their prey). Among prey consumed only by females, tegu lizard was the most ingested (16.3%), followed by common opossum and coati (equally corresponded to 9.3% of the diet). Other items were consumed in similar proportions (Table 2). Regarding consumed biomass of wild prey, capybara was the most important prey species (53.8%), followed by giant anteater (19%), brown-brocket deer (3.1 %) and peccary (1.7%). Among livestock species, foal and calf, comprised 10.5% and 6.3% of total consumed biomass, respectively (Table 2).

Pumas standardized niche breadth was 0.31, and two species were frequently consumed (capybara and giant anteater). When analyzed separately, males showed a narrower niche breadth (0.22) relative to females (0.73). Mean weight of vertebrate prey (MWVP) for pumas was 6.3 kg (range 0.825 to 170 kg). When domestic stock was excluded from analysis, the MWVP was slightly reduced to 5.1 kg (range 0.825 to 45 kg), with no alteration of niche breadth value.

Number of kills registered by individual pumas ranged from 5 to 29 kills. The estimated mean kill rate on all prey species for all pumas was 0.61 ± 0.15 (mean \pm SD) prey/cluster (n = 5). When analyzed separately, the estimated mean kill rate for males was 1.48 ± 0.23 prey/cluster (n = 3), whereas for females was 0.45 ± 0.03 prey/cluster (n = 2; Table 2). On average, pumas hunted every 3.54 ± 1.62 days, ranging from 1 to 5 days. When analyzed separately, estimated mean interval between kills for males were

4.29 ± 0.66 days (n = 3) and for female 1.29 ± 1 day (n = 1). Average handling time of prey for all pumas was 20 ± 6 hours (n = 6), and for males and females was 24 ± 1 hours (n = 3) and 14 ± 6 hours (n = 2), respectively. The length of time pumas stayed at a kill site was significantly correlated with prey weight ($r = 0.517$, $n = 99$, $P = 0.001$; Fig 3). Average time pumas spent on a kill was 34.3 ± 30.9 hours (n = 6), for which average prey weight was 24.8 ± 21.1 kg (n = 120).

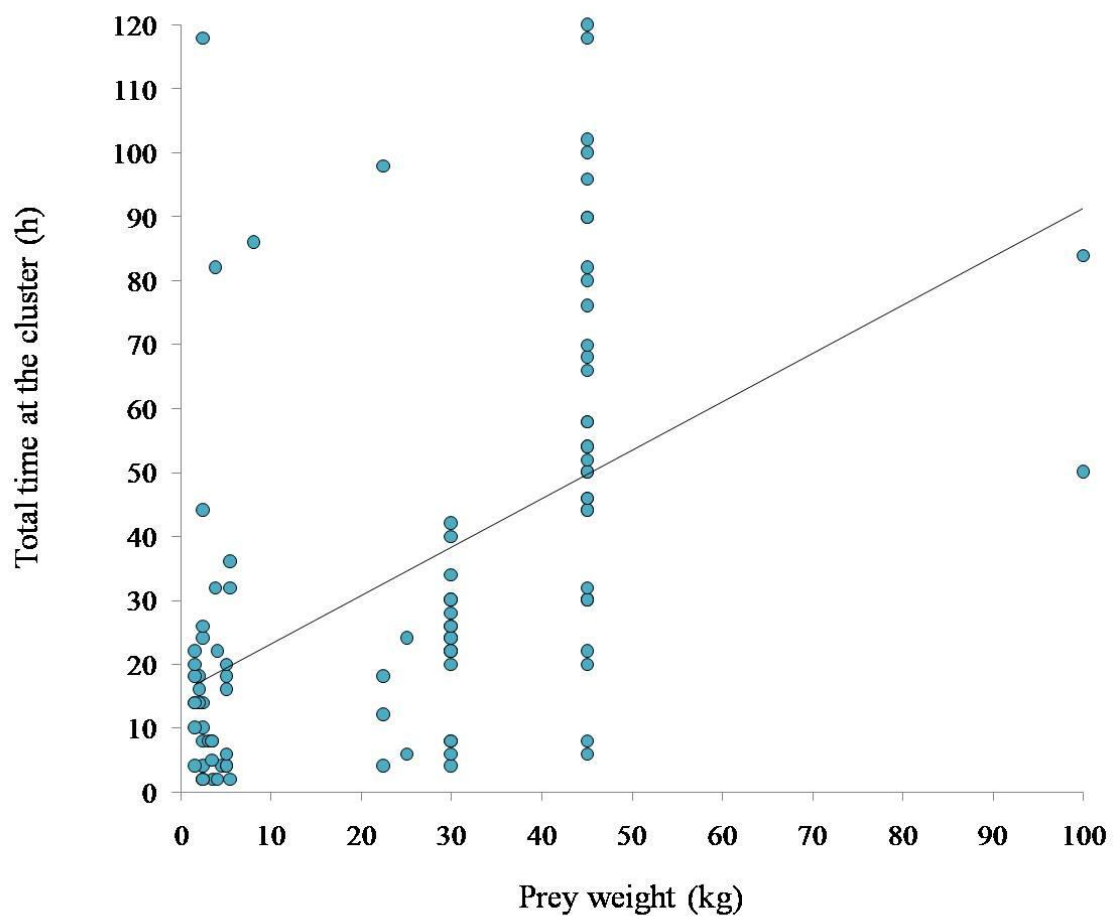


Fig3. Length of time (hours) spent at GPS clusters of locations in relation to prey weight for GPS-collared pumas (*Puma concolor*), between 2012 and 2016, in Araguari, Brazil. Mean time on kill and mean prey weight was 34.3 ± 30.9 hours and 24.8 ± 21.1 kg, respectively ($r = 0.517$, $n = 99$, $P = 0.001$).

Logistic regression analysis suggested that time and number of nights spent at GPS cluster best predicted a puma predation event ($\chi^2 = 6.90$, $P = 0.009$ and $\chi^2 = 4.11$, $P = 0.042$, respectively; Fig 4 and 5). Probability of encounter a predation event increased in more than 50% after two nights at a cluster, reaching its peak after 80 hours (90% of probability for encountering a prey).

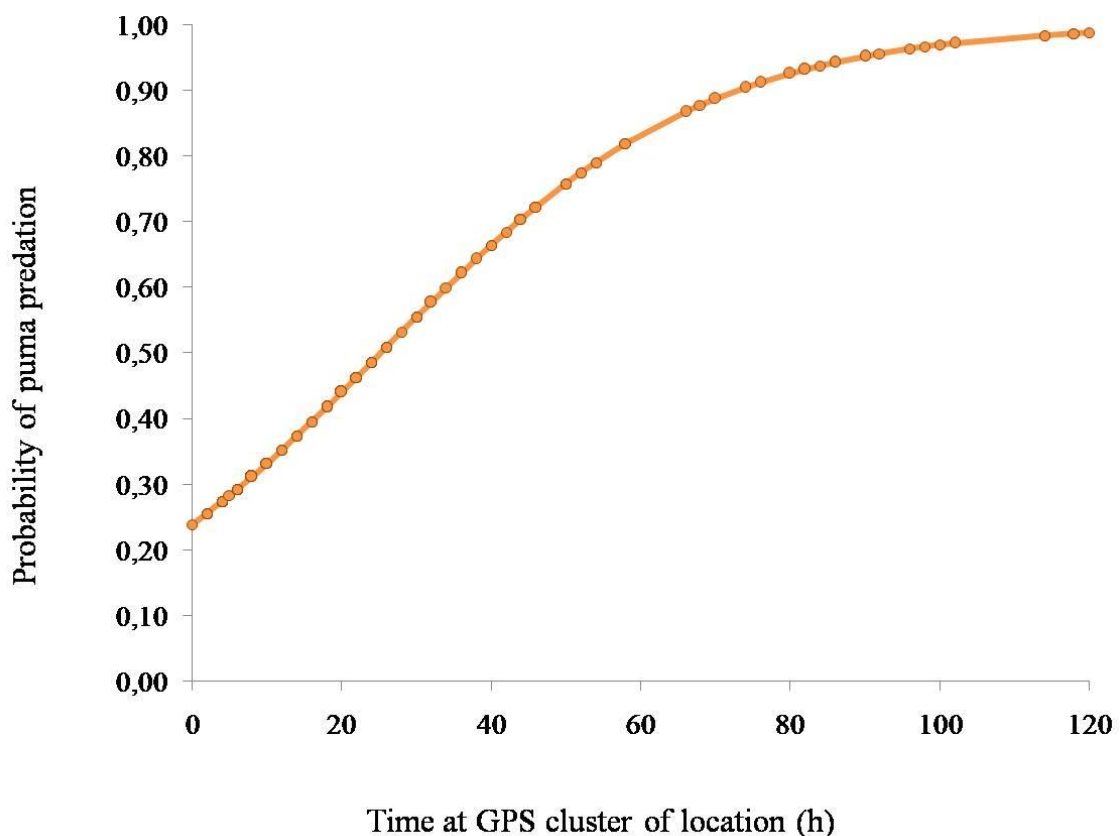


Fig 4. Probability of encounter puma (*Puma concolor*) predation in relation to time at GPS cluster of location from 193 observations, between 2012 and 2017, in Araguari, Minas Gerais, Brazil; where $P = \exp^u / (1 + \exp^u)$. Solid line represents puma predation data at GPS clusters, where $u = -1.161 + 0.046$ (time on cluster), $SE\beta_0 = 0.563$, and $SE\beta_1 = 0.017$; goodness-of-fit test suggested data fit the logistic model ($\chi^2 = 6.909$, $P = 0.009$).

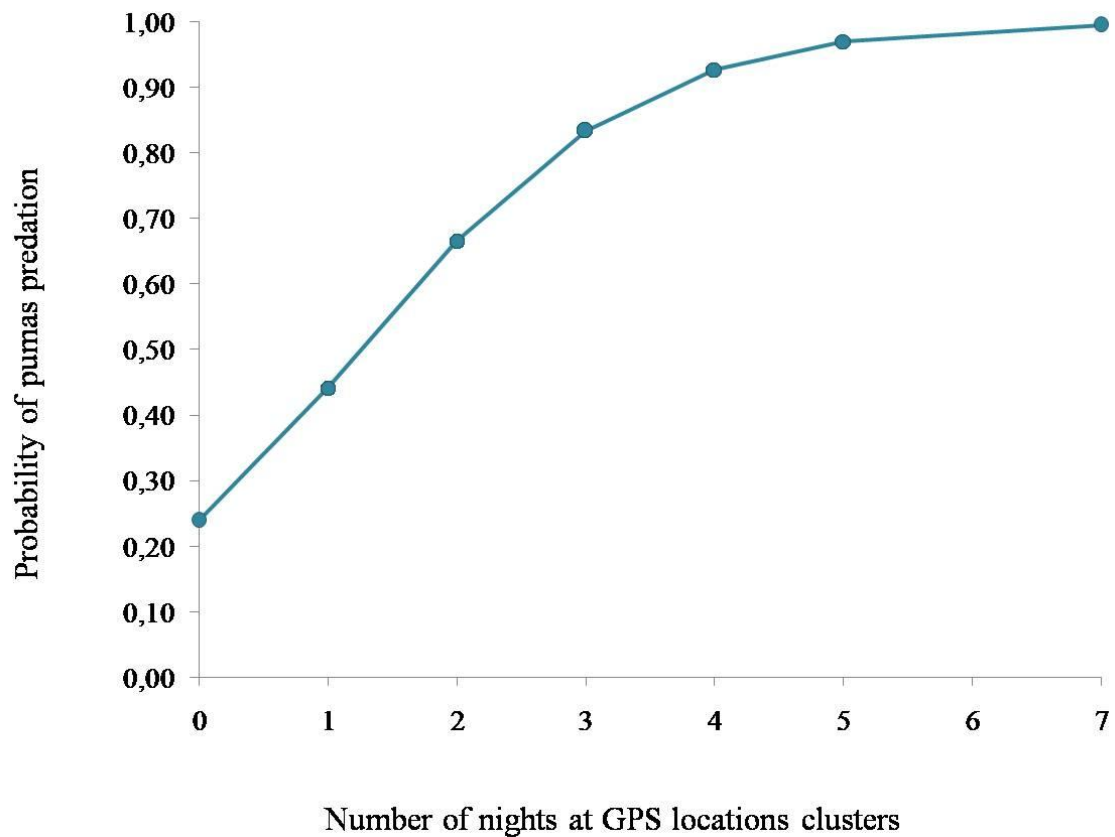


Fig 5. Probability of encounter puma (*Puma concolor*) predation in relation to number of nights at GPS cluster of location from 193 observations, between 2012 and 2017, in Araguari, Minas Gerais, Brazil; where $P = \exp^u / (1 + \exp^u)$. Solid line represents puma predation data at GPS clusters, where $u = -1.161 + 0.924$ (time on cluster), $SE\beta_0 = 0.563$, and $SE\beta_1 = 0.455$; goodness-of-fit test suggested data fit the logistic model ($\chi^2 = 4.116$, $P = 0.042$).

Prey availability and selection

Based on records from camera-traps, we were able to estimate abundance and density of twelve wild prey and two domestic species (Table 3). Pumas did select prey species in the study area ($\chi^2 = 113.97$; d.f. = 13; $P < 0.001$). Capybara and six-banded armadillo were selected in higher proportion than expected, being these armadillos the preferred food item for pumas (Fig 6).

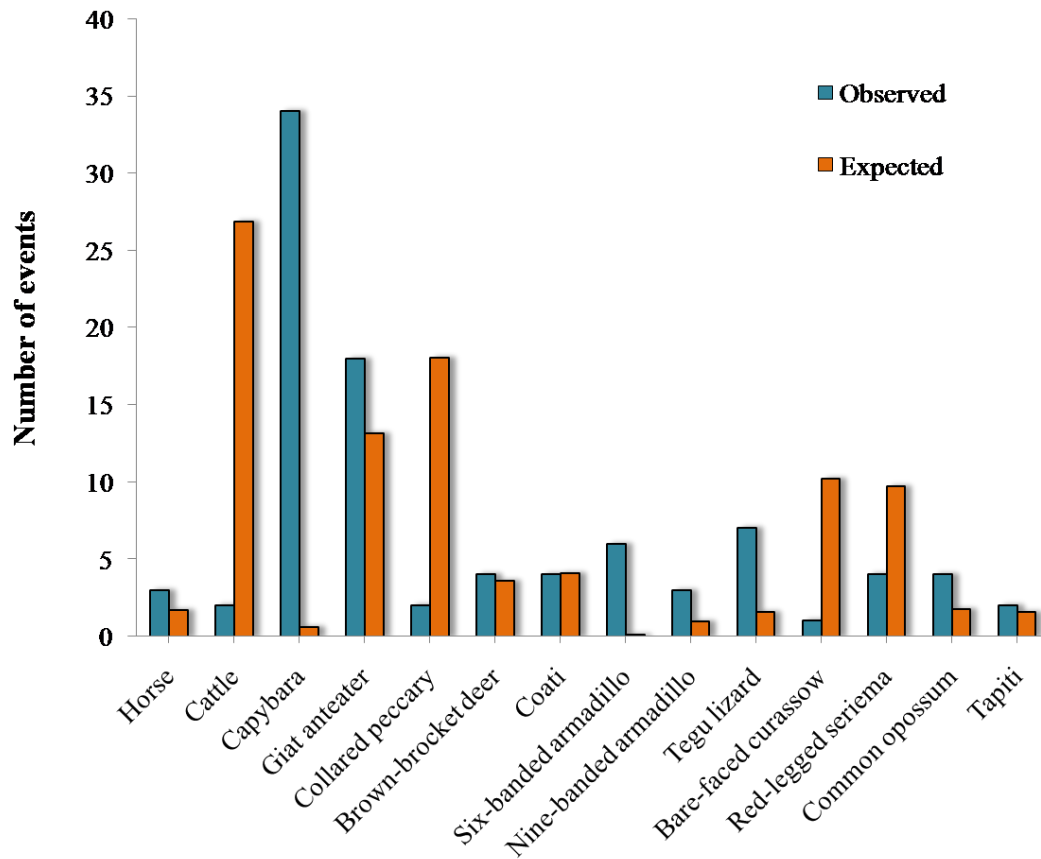


Fig 6. Wild and domestic prey species consumed by GPS-collared pumas (*Puma concolor*), between 2014 and 2016, in Araguari, Minas Gerais, Brazil. Blue columns indicated number of events of predation, whereas orange columns indicated expected number of prey to be consumed based on their availability in the area covered by cameras-traps.

Table 3. Estimation of abundance (individuals), density (individuals/km²), prey use and selection of wild and domestic prey species consumed by GPS-collared pumas (*Puma concolor*), between 2014 and 2016, in Araguari, Minas Gerais, Brazil.

Species	Abundance (proportion available)	Density (Km ²)	Number of animals used	Population (proportion available)	Selection Index (w)	Standardized Index	Status
Capybara	0.72	0.01	34	0.36	54.41	0.39	selected
Giant anteater	14.68	0.24	18	0.19	1.37	0.01	avoided
Tegu lizard	1.83	0.03	7	0.07	4.36	0.0315	avoided
Six-banded armadillo	0.06	0	6	0.06	67.21	0.485	selected
Common opossum	2.01	0.03	4	0.04	2.24	0.0162	avoided
Brown-brocket deer	4.01	0.07	4	0.04	1.12	0.0081	avoided
Coati	4.64	0.08	4	0.04	0.974	0.007	avoided
Nine-banded armadillo	1.08	0.02	3	0.03	3.06	0.02	avoided
Collared-peccary	20.25	0.34	2	0.02	0.11	0.0008	avoided
Tapiti	1.77	0.03	2	0.02	1.24	0.009	avoided
Red-legged seriema	10.93	0.18	4	0.04	0.41	0.003	avoided
Bare-faced curassow	11.44	0.19	1	0.01	0.098	0.0007	avoided
Horse	1.85	0.03	3	0.03	1.77	0.0128	avoided
Cattle	30.11	0.5	2	0.02	0.074	0.0005	avoided

Giant anteater, *Myrmecophaga tridactyla*; capybara, *Hydrochoerus hydrochaeris*; brown-brocket deer, *Mazama gouazoubira*; collared peccary, *Pecari tajacu*; red-legged seriema, *Cariama cristata*; bare-faced curassow, *Crax fasciolata*; tegu lizard, *Salvator merianae*; nine-banded armadillo, *Dasyus novemcinctus*; six-banded armadillo, *Euphractus sexcinctus*; common opossum, *Didelphis albiventris*; tapiti, *Sylvilagus brasiliensis*; coati, *Nasua nasua*.

Predation patterns

Human altered landscapes comprised almost 60% of the study area (perennial/seasonal crops, silviculture, open pasture, pasture with shrubs, urban centers and structure, and degraded areas). Predation did not occur according to the availability of habitats types ($\chi^2 = 119.879$; d.f. = 11; $P < 0.001$). Although forest represented only 31.9 % of available habitat in the study site, more kills than expected occurred in this class of habitat, which represented the most used habitat by pumas in terms of killing prey. Likewise, although pasture with shrubs represented only 9.1% of the study area, pumas also killed more prey within this type of habitat than expected based on its availability. Other types of habitats were avoided in terms of sites for killing prey by pumas (Table 4).

Table 4. Number of prey killed by pumas (*Puma concolor*) according to habitat classes. Selection index (w) indicates types of habitats where pumas preferred or avoided killing prey, between 2014 and 2016, in Araguari, Minas Gerais, Brazil. ha, hectare.

Habitat type	Area (ha)	Number of prey killed	Sample proportion used	Selection Index (w)	Standardized Index	Status
Open pasture	35,730.77	11	0.095	0.249	0.055	avoided
Forest Vegetation	30,024.65	84	0.724	2.270	0.498	selected
Perennial crop	8,737.74	0	0.00	0.00	0.00	avoided
Pasture with shrubs	8,571.14	18	0.155	1.740	0.374	selected
Water bodies	7,237.83	3	0.026	0.336	0.074	avoided
Seasonal crop	2,670.38	0	0.00	0.00	0.00	avoided
<i>Cerrado stricto sensu</i>	396.38	0	0.00	0.00	0.00	avoided
Silviculture	355.21	0	0.00	0.00	0.00	avoided
Urban centers	155.7	0	0.00	0.00	0.00	avoided
Roads	142.8	0	0.00	0.00	0.00	avoided
Degraded areas	94.94	0	0.00	0.00	0.00	avoided
<i>Vereda</i>	12.81	0	0.00	0.00	0.00	avoided
Total	94,130.35	116				

Discussion

Analysis on predation patterns from GPS clusters of location have been broadly used to study pumas diets in North America [37,43–48]. However, most studies focused on the interaction between pumas and large-sized prey species (e.g., ungulates). Besides being the first study to monitor pumas on a Brazilian ecosystem through GPS collars, our work showed that this methodology may also allow to locate a range of smaller items preyed by a top predator even in a Neotropical grassland environment.

Despite the fact that human-dominated landscapes comprised almost 60% of the study area and domestic animals are dispersed in all classes of habitats, pumas consumed more wildlife than domestic prey species, contradicting our first hypothesis. Farming activities increased deforestation in the Brazilian Cerrado, replacing natural areas with extensive pastures and agriculture fields. Habitats loss of tropical forests has many consequences, in particular the effects of deforestation on wildlife [49]. Predation on domestic livestock by large carnivores may be higher when the availability and/or the diversity of wild prey species are low [50,51]. This scenario could be applied to our study area, once the landscape has been severely modified by human actions. Under such circumstances, we expected that livestock predation by pumas could be established as a common pattern. Predation on domestic species comprised less than 15% of pumas' diet in Araguari, and when it happened it was more frequent on small-sized (e.g. domestic fowl) than on large livestock (e.g. cattle). Although frequency of livestock predation was low, it was concentrated on calves, what resembles the reported for other studies on pumas and confirms most predations occur upon this age class [13,50,52].

Despite the high potential encounters between pumas and domestic animals in the study area, pumas strongly selected wild prey. Although, we did not evaluate puma's population density over time, our results suggest that agro-ecosystems (i.e., rural

landscapes permeated by remaining natural vegetation that still support a representative base of wild prey interacting), may offer a survival possibility for pumas. Besides the regional peculiarities of a large and multiverse country as Brazil, municipalities with similar characteristics of the studied site are not uncommon throughout puma's distribution on the Brazilian territory. Direct public policies that contemplate actions of restoration and connectivity of fragmented landscape (e.g., better protection of legal reserve areas), restraint of illegal wildlife hunting (especially for synergetic/prey species), and the dissemination of livestock management techniques to avoid predation attempts might be effective actions for puma conservation in Brazil.

Pumas did not consume prey according to their availability in the study area, nor according to habitat availability, contradicting our first two predictions. Our results indicate that the array of wildlife consumed by pumas was relatively rich (n = 14 species) in an area with several habitat types modified by anthropogenic activities. Similar variety has been recorded in other South American studies [38,50,53] and along protected and non-protected areas within Brazilian ecosystems [21,22,54]. However, dietary breadth was relatively narrow and suggestive of feeding specialization, reinforcing the selective behavior of the species towards some types of prey, despite their availability at the study site.

We observed a pronounced selection by pumas towards capybaras and six-banded armadillos. Although not relatively abundant in the study area, capybaras are group-living species and the costs of predation towards this large rodent may be low due to their minimal potential risk of injury [55]. Furthermore, capybaras are closely related to water and our study site is crossed by two large rivers, several streams and artificial dams, providing a favorable habitat for them. Six-banded armadillos were not relatively abundant in the study area as well, but their preference by pumas may be

associated to their nocturnal behavior and minimal potential risk of injury. However, obtaining accurate estimates of animal density from camera trap surveys remains a constant challenge [56]. Although registered through other methods (e.g. tracking, visualization, predation clusters), capybaras and six-banded armadillos weren't recorded frequently by camera traps, probably because camera stations weren't set along most used habitats by the species. Results highlight the importance of factors associated with predator-prey interactions, such as predator hunting behavior and capture success, on prey vulnerability to predation [2,56]. In contrast, the disparity of observed avoidance for most abundant wild prey (e.g., peccaries and giant anteaters) may be associated with high injury risk or escape ability of animals. Peccaries, live in alert groups that show defense strategies and aggressive behavior towards predators, making the species hard to consumed by pumas as primary prey when other options are available [57].

Regarding habitat preference for killing, pumas showed preference for forested habitats and pastures with shrubs. Felids in general stalk their prey. Habitats providing cover to keep pumas concealed prior to a chase would be selected and would probably be the best environments for the ambush hunting strategy [58] as was the case for pastures with shrubs and forests. Moreover, habitats with some degree of vegetation cover that provide escape opportunities, may offer protection for both prey and predator. Carnivores' foraging decisions are driven by natural selection to optimize nutrient intake at the minimum energy expenditure and at the least risk to predator [59]. A wide range of ecological constraints regulates such decisions, however. As long as individuals can overcome these constraints and increase their chances of survival by hunting more efficiently, natural selection will favors optimally foraging predators[60]. Pumas at Triângulo Mineiro region seem to be balancing this by selecting suitable prey and particular habitats where to hunt. Their preferred vegetation types varied from

intermediate to high cover levels, where wildlife was more abundant. Hence, our results are helpful for planning puma's conservation strategies along disturbed landscapes. Based on its generalist feeding behavior and certain tolerance to habitat modification, pumas have been widely considered as a species of least concern with little need for dedicated conservation actions [19]. Our results indicate that pumas show some degree of specialization, at least regarding their choice for preferred prey and hunting habitats at an anthropized landscape. On a larger scale, such specialization may represent important differences on population densities and resilience to threats.

In our study, pumas fed on a wide variety of prey, however males and females selected different species and presented differences on predation patterns. Males killed proportionally more large-sized and less diverse prey, showing narrower dietary breadth than females. Pumas demonstrate a marked sexual dimorphism [61,62], thus larger body mass of males probably demands them to invest more energy on capturing larger prey than females. Females killed more frequently small and medium-sized items from other prey species, suggesting this group may avoid risks associated with killing larger, stronger prey [48]. Furthermore, this behavior could lead to higher opportunities of encountering with a broad array of diurnal species, tegus and birds. Cathemeral pattern of activity showed by females might be an adaptation for preying on different items from males.

Mean predation rate (3.54 days between kills) was lower than previously reported by other studies (ranges of 5.4–15.2 days) [32,37,63]. Lower predation rate presented by pumas may be associated with the difference between sizes of consumed prey along puma's range. Most studies have been conducted in North America, where pumas commonly consume large prey (e.g., elk *Cervus canadensis*, moose *Alces alces*,

and bighorn sheep *Ovis canadensis*), and the amount of meat that may be consumed is higher than in tropical ecosystems, leading to higher intervals between killings.

We found that time spent at the prey sites correlated positively with prey weight. Moreover, adult females presented shorter handling times at kill sites than males. As expected, pumas handle larger prey for longer periods of time. This is consistent with our findings related to different prey size consumed by sexes. Females relied upon small to medium prey spending less time on kills. We also demonstrated that GPS clusters technique can be expanded beyond its application to detect large-sized mammals (ungulates; [32]) and be used to identify other prey less than 15 kg consumed by pumas, when wearing collars programmed with a 2-5 hour fix rate.

Similarly to what has been reported for North American puma populations [32], time spent at cluster and number of nights at a cluster were two predictor variables that best explain the probability of finding [a puma predation event at our study site. The technique of verifying GPS cluster of locations offers a substantial improvement on the efficiency of evaluating kill rates and predation characteristics parameters, allowing more detailed monitoring of carnivores' feeding habits over long periods. Where models can be employed for parameter estimation, cluster evaluation may greatly reduce cost and effort associated with monitoring over the duration necessary to generate adequate kill rate estimates. Nonetheless, field visitation is especially crucial in multi-prey systems.

Factors affecting prey choice by pumas differ across its distributional range, and need to be understood once they reflect part of the ability of this top predator to adapt to different ecosystems, even those modified [55]. Understanding the role of pumas on the food web along anthropized landscapes is important for effective conservation and management planning. Such effort should be undertaken especially where this species is

locally threatened or vulnerable to extinction, as is the case of puma populations in southeastern Brazil.

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CAPÍTULO III.

THE IMPORTANCE OF FORESTS FOR A TOP PREDATOR: SPATIAL ECOLOGY AND HABITAT SELECTION BY PUMAS IN A HUMAN-DOMINATED SAVANNA ECOSYSTEM

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The importance of forests for a top predator: spatial ecology and habitat selection by pumas in a human-dominated savanna ecosystem

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Running heading: Spatial ecology of pumas in a human-dominated landscape

Abstract

Understanding species requirements is critical to the design of global actions focused on the conservation of biodiversity, especially to guarantee viable carnivore populations along human-dominated landscapes. We evaluate large carnivore adaptability to a disturbed landscape by studying pumas in a rapidly developing region at Southeast Brazil. Seven pumas were monitored via Global Positional System and had their spatial organization analyzed, through the new Autocorrelated Kernel Density Estimator using Continuous Time Movement Models, besides habitat selection evaluated. Pumas mean home-range size was $209.4 \pm 46.5 \text{ km}^2$. As expected, males exhibited larger home ranges and traveled greater distances per day than females, showing a most pronounced territorial behavior through low intrasexual overlap. Our study also confirmed puma's strong habitat association with natural features (forest vegetation) both at population and individual level. Pumas also selected positively for pasture with shrubs, a type of anthropized habitat that also offers cover and prey. When anthropized habitats were used, it was used during night hours. Our results fill a gap in puma's ecology knowledge in anthropized tropical environments and highlight the importance of natural habitat patches to this predator along human-modified areas, reinforcing the species demand for vast areas to thrive. In areas where conservation goals include the maintenance or increase of large predator populations, identifying the limits imposed by anthropogenic landscape change, and ensuring that these are not exceeded, is of high importance for conservation initiatives.

Keywords: Continuous movement models; Autocorrelated Kernel Density Estimator; habitat loss; home range overlap; land use; *Puma concolor*

Introduction

Habitat loss and fragmentation are two of the main threats to terrestrial vertebrates' survival worldwide (Baillie et al., 2004). Large carnivores are the species most negatively affected by human-driven disturbances and anthropogenic related activities (Cardillo et al., 2005). High energetic demands, vast spatial requirements, natural low densities, and ultimately the increase on negative interactions with humans, make large carnivores quite vulnerable (Glitteman et al., 2001). Habitat fragmentation may occur at different scales, potentially creating patches of low-quality habitat within individuals' home ranges (Moilanen and Hanski, 2006) or disrupting landscape-level connectivity, which is essential for sustaining fragmented subpopulations (Crooks and Sanjayan, 2006).

Large, continuous and pristine protected areas are uncommon in the modern scenario, even in remote parts of the planet. Therefore, understanding species requirements and designing global actions related to the conservation of biodiversity is critical to the permanence of viable carnivore populations in human-dominated environments (Carroll et al., 2001; Marinho-Filho and Machado, 2006). The persistence of large carnivores along changing landscapes depends on the functional connectivity and suitability of fragments and land management worldwide (Crooks and Sanjayan, 2006). Though, understanding how carnivores use and move along their landscapes may be vital to effective conservation decision making for this group.

Recent studies suggested that animals develop cognitive maps of the environment in which they inhabit, with the exact location of different important resources and exact path through the landscape to obtain them (Powell, 2012; Spencer, 2012). Carnivores are also able to select habitats at various spatial scales, establishing areas of use in the landscape and micro-sites within habitats (Millsbaugh and Marzluff,

2001). Size, shape and intensity of use within carnivore home ranges are often negatively correlated with abundance and spatial distribution of resource or habitat quality. However, these parameters may vary across species and habitats (Mitchell and Powell, 2004).

Considered a solitary and polygamous felid (Sunkuist and Sunquist, 2009), spatial organization and territory establishment in puma (*Puma concolor*) populations seem to be strongly influenced by social system and availability of key resources (Knopff et al., 2014; Logan and Sweanor, 2001; Machado et al., 2017). While females hold smaller home ranges that provide the necessary resources to sustain themselves and their kittens, males exhibit larger home ranges, with low or no overlap with other males, that provide access to numerous females for mating opportunities (Elbroch et al., 2015; Logan and Sweanor, 2001). In addition, previous work suggests that pumas have a moderate ability to accommodate anthropogenic disturbances within their home ranges through diurnal adjustments in activity and habitat selection (Knopff et al., 2014; Vickers et al., 2015). Pumas may shift their activity patterns to avoid human disturbance/encounters (Lewis et al., 2015), as well as the habitat use and selection may vary accordingly to day time (Dickson et al., 2005; Onorato et al., 2011).

Although pumas' spatial ecology are well studied in North America, scant information is known for Neotropical ecosystems (Laundré and Hernández, 2010), especially those highly altered by human activities, such as the Cerrado and the Atlantic Forest. Available data is limited to punctual studies (Barros et al., 2011), most from conserved areas of Brazilian grasslands (Silveira and Marinho-Filho, 2004; Vynne et al., 2011). In this work, we used patterns of home-range size and habitat selection to evaluate puma adaptability to a human-drive disturbed landscape at Southeast Brazil. Based on large carnivore's spatial ecology, we expected that pumas living on

fragmented landscapes would exhibit larger home range size than conspecifics living in more conserved habitats. Further, we hypothesized male's home range would be larger than female home range, overlap would be low and movement rates would be higher. Several studies have suggested that pumas are highly capable of persisting in human-altered landscapes, adjusting habit use accordingly (Beier et al., 2010). In general, natural habitats offer shelter and prey (Onorato et al., 2011). Therefore our third hypothesis was that pumas select native over human-modified habitats. We also predicted that, when using anthropogenic features, pumas would be found more frequently at night hours, when travel is more secure due to the cover of darkness.

Materials and methods

Study site

The study area covered approximately 940 km² of ranchlands situated in an ecotone zone of the Cerrado/Atlantic Forest biomes, in the West of Minas Gerais state, Brazil (18°46'S, 48°14'W and 18°21' S, 48°38'W; Fig. 1). The landscape comprised a matrix of multiple-use dominated by cattle ranches filled with exotic pasture (mainly *Urochloa* sp.), agriculture (mainly corn, coffee and soy beans), and human settlements in the form of houses and corrals, all crossed by paved and dirt roads. The two main rivers at the study site, Araguari and Paranaíba, were dammed for electrical purposes. Urban zone borders of the main cities (Araguari and Uberlândia) and counties in the region were no more than 30km from the center of the study area. Remaining natural habitats (less than 40% of the original vegetation, according to (Silveira, 2017) were composed of secondary savanna and mesophytic seasonal forests (Oliveira-Filho and Ratter, 2002) that stretches along farm ranches, and were restricted to patches that varied in size, shape, complexity

and isolation, not exceeding 2.000 ha. Remaining natural fragments, although legally protected by environmental law, were intensively used for livestocking, wood extraction, and recreational purposes (e.g., fishing, hiking, biking, motorcycling and illegal hunting).

The climate in Triângulo Mineiro region is classified as subtropical (Cwa) according to Köppen and has two well marked seasons, one hot and wet from October to April and another dry and cold from May to September (Alvares et al., 2013). Mean annual temperature and precipitation vary between 22–25°C and 1600–1800 mm, respectively (data available by CPTEC/INPE).

Habitat assessment

To determine the availability of different habitat types within the study site we classified the landscape based on a set of images obtained from the RapidEye[®] Satellite Sensor (RapidEye AG, Berlin, Germany; 2015) using ArcGIS 10.2 in conjunction with Quantum GIS 9.2 software (ESRI[®] and QGIS, Open Source Geospatial Foundation Project; respectively). The images resolution was 5 meters in a scale of 1: 20,000 ha. Eleven categories were determined according to Brazil land use and coverage (IBGE, 2013) and further subdivided in three major classes: Natural Areas encompassing *vereda*, *cerrado stricto sensu* and forest vegetation habitat types; Anthropic Areas encompassing seasonal crop, perennial crop, silviculture, open pasture, pasture with shrubs, degraded area, and urban centers and infrastructure; and Hydrography including rivers, streams, and artificial dams (Table 1, Fig. 1). Regarding natural areas class, forest vegetation classes encompasses forest formations of deciduous and semi deciduous forests, dry forests and *cerradões* (Lopes et al., 2012). The *vereda* class represents the hydromorphic phytophysiology composed by a mix of palm trees (e.g., *Maurithia flexuosa*), shrubs and herbs along water bodies. The *cerrado stricto sensu* phytophysiology is composed

by native grass punctuated with short trees and shrubs distant from each other. For anthropic areas, perennial and seasonal crop classes included the most representative plantations of each class, such as coffee (perennial), corn, soybean (annual) and others of minor importance. Open pasture comprised areas where exotic grass was planted and had been grazed by livestock, while pasture with shrubs is composed by areas of exotic grass without management (i.e., tall grass permeated by naturally recovering shrubs and small trees). The resulted land cover map was overlaid to pumas' locations for habitat use and selection analysis (Fig.2).

Capture, handling and GPS telemetry data

Pumas were captured using soft- hold foot snares and immobilized with a combination of tiletamine-zolazepam at 10 mg/kg (Zoletil®, 100 mg, Virbac, São Paulo, Brazil) and xylazine at 0.7 mg/kg (Xilazin, 10%, Syntec, São Paulo, Brazil) administered via projectile dart fired from a CO2 rifle. Once immobilized, animals were examined for body mass/condition, sex, age, and reproductive status (when possible). We classified pumas as adults (≥ 30 months old) and subadults (≥ 12 –30 months) based on physical characteristics such as presence of milk teeth, tooth eruption and wastage, and pelage spotting progression (Shaw et al., 2007). Subsequently, animals adults were fitted with a Global Position System (GPS) radio-collar (Lotek® Fish & Wildlife Monitoring, Canada / 44400S and 4550S models; Sirtrack® Wildlife Track Solutions, New Zealand /G5C 375B Pinnacle GPS Iridium model) and released at the same place of the capture, once totally recovered from immobilization. All GPS collars had a standard Very High Frequency (VHF) transmitter and a memory to store location data until they were downloaded remotely by distance (Lotek®) or satellite transmissions (Sirtrack®). Data stored in the collar included date, time, location, and activity, besides accuracy of GPS

transmissions. Collars were scheduled to take locations daily, with intervals of five (Lotek[®] models, used from 2009 to 2012) and two hours (Sirtrack[®] models, used from 2015 to 2017).

All pumas were captured following standard protocols approved by the Instituto Chico Mendes de Conservação da Biodiversidade/ Ministério do Meio Ambiente, Brazil (ICMBio SISBIO) under license numbers 18913-1 and 18913-4 (2009–2015), and by the Ethics Committees on Animal Use of Universidade Federal de Viçosa (process number 90/2014) and Universidade Federal de Goiás (process number 66/2014). To minimize the risk of injury we equipped traps with VHF devices, monitored at least every 2 hours by distance. In addition, the snares were visually inspected every day in the morning before the hot hours.

Home range and overlap analysis

We estimated home range sizes and overlap, home range crossing time, and distance traveled by pumas using R 3.3.1, package *ctmm* 0.3.4 (Continuous-Time Movement Modeling; Calabrese et al., 2016; Fleming et al., 2015; R Development Core Team, 2011). Ninety-five per cent home ranges were estimated through the Autocorrelated Kernel Density Estimator (AKDE), following Fleming et al. (2015). The AKDE is a new approach that estimates home range considering the dependency between locations in space and time. This new estimator progress in three steps that include, firstly, a exploratory visual diagnostic to verify home range stability and to infer about range-resident individuals (function *variogram*); secondly, the selection between the candidate models (Brownian Motion BM, Integrated Orstein-Uhlenbek IOU, and Orstein-Uhlenbek Foraging OUF processes) via maximum likelihood based on Akaike Information Criterion corrected for small finite sample size (*ctmm.fit* and *ctmm.select* functions,

respectively); and finally, the estimation of the AKDE home range contours with the 95% confidence intervals (CI). In addition, we examined the overlap among pumas home range using the *ctmm.overlap* function, which measures the similarity between known distributions and the static interaction between two individuals sharing the same area. The result is a number between 0 and 1 that can be interpreted as the % of intersection area.

Habitat use and selection analysis

Second and third order habitat selection were investigated using habitat classifications determined by categories of vegetation cover and puma locations. The second order selection concerns the habitat composition within home ranges of individuals; whereas third order selection identifies the selection of habitats by an individual within its home range (Johnson, 1980). First, we performed a χ^2 goodness-of-fit test to check if pumas used their home ranges randomly. We also used Manly standardized resource selection index for constant resources to compare locations of pumas among different habitat types to determine puma's habitat selection within their home ranges. We chose to use this selection index because it is not affected by the inclusion or exclusion of resources that are rarely consumed (Manly et al., 2002). After, we performed *Bonferroni Z*-statistic tests adjustment to calculate 95% confidence intervals. We considered two categories to be significantly different from each other when their confidence intervals did not overlap. All analysis were performed at the software Ecological Methodology (Krebs, 2002). The selection ratios w_i for each habitat used were calculated as:

$$w_i = \frac{\text{number of puma locations per habitat } i}{\text{habitat proportion available } i}$$

Index value indicates habitat avoidance when <1 , use according to availability when $= 1$, and indicates habitat selection when >1 . The outcome provides a direct comparison between selection rations within each resource type (habitat).

In order to verify whether habitat use was influenced by different temporal scale, we overlapped separately the locations from GPS-collared pumas obtained during hours of night (from 18:00 h to 5:59 h) and day (from 06:00 h to 17:59 h; (van Schaik and Griffiths, 1996) to the map of land use and cover. Performing the Manly standardized resource selection index for constant resources and the *Bonferroni Z*-statistic tests adjustment to calculate 95% confidence intervals (as described previously), we compare locations obtained during the day and night hours among different habitat types, testing the null hypothesis of non-selective location regarding habitat class.

Results

In total, we captured 12 pumas (seven males and five females) from 2009 to 2016, from which nine adult individuals were radio collared. We estimated home ranges, overlap, home range crossing time, and distance traveled for seven pumas (5 males and 2 females). Two adult pumas presented technical problems on the collar communication and did not provide data and were excluded from analysis. Mean monitoring period of individuals was 403 ± 84 (\pm SD) days, what accounted for 23.630 GPS position records for home range analysis (Table 2). The success rate at obtaining GPS locations was 75% (ranging from 65% to 86%) of the total gathered amount. All seven individuals were determined as range residents after variogram inspection (Fig.3), indicating that dataset of each individual was sufficiently reliable to describe home range sizes. The AKDE were obtained with model OUF performing best for all pumas.

Home range and overlap

Home range estimates (AKDE 95%) for males ranged from 196 km² (95% CI: 188.8-203.3) to 272.2 km² (95% CI: 228.4-319.8). For the two females, ranges were 134.8 km²

(95% CI: 104.1-169.3) and 183 km² (95% CI: 142.3-228.5; Table 2; Fig. 4). Male pumas on average took longer to cross their home ranges (2.4 ± 0.8 days) and traveled greater distances per day (14.5 ± 3.2 km/day) than females (7.0 ± 0.6 hours and 12.2 ± 1.9 km/day, respectively). Regarding overlap analysis, we considered only five individuals (three adult males and two adult females), which were simultaneously monitored between 2015 and 2017. Home range overlap index using 95% AKDE estimates (static interaction) was 0.61 ± 0.29 for male–female dyads; 0.27 ± 0.28 for male–male dyads; and 0.69 for female–female dyads (Fig.5).

Habitat use and selection

The habitat use and selection by adult pumas differed from what was expected based on habitat availability ($\chi^2 = 25369.62$, d.f. = 6, $P = 0.000$). In relation to available natural habitats, pumas selected forest vegetation more than expected, whereas *cerrado stricto sensu* and *vereda* was used less than available. Anthropized habitats (seasonal and perennial crop, open pasture and pasture with shrub) comprise together 59.2% of available habitats within the study site. Pasture with shrub was selected more than expected based on its availability (9.1%). However, despite open pasture represents 38.2% of the available class of habitat, it was used less than available. Males and females used and selected the same habitats within the study site ($\chi^2 = 10304.54$, d.f. = 6, $P = 0.000$; and $\chi^2 = 15830.67$, d.f. = 6, $P = 0.000$, respectively; Table 3).

Pumas also exhibited habitat preferences at the third-order level (Table 4). Individually pumas selected the same habitat types that were used more frequently than expected by all pumas, with the exception of M#470, that differently from other individuals, also selected water bodies besides the forest vegetation and the pasture with shrubs. These analyses indicated that pumas at the study site exhibit a consistent

preference for the forest vegetation and pasture with shrub, and avoid seasonal and perennial crop, open pasture and *cerrado stricto sensu*. Habitats such as *vereda*, silviculture, roads, urban centers, infrastructure and degraded areas were encompassed by puma's home range, however they did not presented more than 5 GPS locations per class of habitat.

The habitat use and selection by adult pumas during the day and night periods differed from what was expected based on availability ($\chi^2= 12456.101$, d.f. = 5, P = 0.000; and $\chi^2= 13209.193$, d.f. = 6, P = 0.000, respectively). Pumas used natural areas, represented by forest vegetation, more during the day than during the night, and anthropized areas (open pasture and pasture with shrubs) more during the nighttimes. Use of the remaining land-cover classes was independent of the time period (Fig. 6).

Discussion

This is the first study to evaluate the use of an anthropized Neotropical landscape with the recent developed Autocorrelated Kernel Density Estimator. In addition, based on the spatial organization of the first pumas monitored through GPS technology in Brazil with such a largest sample of locations, our work highlights the importance of natural habitat patches to these predators along human-modified areas, and reinforces the species demand for vast areas to thrive. We believe that our home ranges estimates reliably reflect pumas' behavior, once all individuals showed range stability and were considered residents at the study site. Furthermore, as expected for an accurate estimation of animals' home range, all individuals presented an expected minimum number of GPS locations, continuously monitoring period, and satisfactory success rate of obtained GPS locations (Fieberg and Börger, 2012; Hebblewhite and Haydon, 2010).

In general, pumas' home range estimates at our study site ranged from 183 to 272 km², and were within the reported range for the species along its distribution (from 33 to 775 km², (Gonzalez-Borrajo et al., 2017). However, information on puma's spatial organization from tropical environments is restricted to punctual studies, making difficult to establish comparisons. The main previous spatial information for pumas in Brazil was based on three males and two females monitored with VHF devices more than a decade ago at Emas National Park (ENP, Central Brazil) and surroundings (Silveira and Marinho-Filho, 2004). Mean home range size (estimated through 95% Harmonic Mean) was 120 and 64 km² for males and females, respectively. The only previous available information on pumas using GPS technology was from one male monitored in Brazil at Serra do Brigadeiro State Park, Southeast Brazil, which exhibited a 610 km² home range (N = 328 GPS locations, 11 months monitored; Paula et al., 2015).

Home ranges and movement distances are predicted to vary with habitat quality, and in general to increase across poor-quality landscapes (Fahrig, 2007). Large felids (e.g. pumas and jaguars *Panthera onca*) inhabiting disturbed areas have been reported to demand large home ranges to increase their averaged distance traveled (Dickson and Beier, 2002; Morato et al., 2016). This behavior may be associated to the tendency to increase foraging area, in order to meet daily survival needs (Gehrt et al., 2009). Despite differences with previous studies on sample size and range estimators, our results suggest pumas inhabiting less productive habitats, as the human-disturbed landscape at our study site, demand larger home ranges than their conspecifics living in protected areas, such as ENP. Larger home ranges on non-protected, fragmented landscapes are related to the lower productivity of agro-ecosystems in subtropical forests, which are

constantly negatively affected by anthropogenic factors (i.e., deforestation, illegal hunting, criminal fire; Gutierrez-Gonzales et al. 2012).

As we expected, males' home ranges were larger and distance traveled per day longer than females', corroborating the reported for pumas by previous studies (Logan and Sweanor, 2001; Machado et al., 2017). Sex is an important intrinsic factor that shapes the spatial ecology of solitary carnivores (Elbroch and Quigley, 2017; Logan and Sweanor, 2010). While females' movement and behavior are modulated mainly by the availability of food and offspring care, male's arrangements are determined by optimizing reproductive opportunities, implying on high territoriality and patrolling domain (Sunquist and Sunquist, 1989). Intersexual differences were supported by movement parameters, which suggest males traveled farther and faster than females, which moved more tortuously (represented by lower velocity autocorrelation timescale). Sex was the primary driver to explain spatial variation on home range overlap at the study site. Males overlapped significantly with females, as predicted for territorial carnivores (Logan and Sweanor, 2001; Macdonald and Loveridge, 2010). Females also showed high intra sexual overlap, contrasting with male-male dyads, which had the lowest degrees of overlapping

Regarding habitat use and selection, our third hypothesis was partially confirmed as male and female puma's selected native vegetation among all classes of habitats, despite its lower availability in the study site. However, pumas also selected pasture with shrubs, an anthropic habitat. Forested habitats provide a variety of critical attributes to puma survival, offering den sites, rest sites, and hunt opportunities once the species is favored by cover structures to stalking and ambush prey (De Angelo et al., 2011; Dickson and Beier, 2002; Husseman et al., 2003; Onorato et al., 2011). Densely vegetated non-forest habitats may also provide sufficient cover for predators (Balme et

al., 2007). These could include pasture with shrubs and tall grass bordering native vegetation/forest which, besides providing cover security, are also used by prey species that in a mix of open and close canopy habitats (e.g., brown-brocket deer *Mazama gouazoubira*, capybara *Hydrochaeris hydrochaeris*, red-legged bird *Cariama cristata*). In fact, it has been suggested that puma may also use modified environments, such as sugarcane plantations, to increase hunting opportunities (Magioli et al., 2014; Miotto et al., 2012). However, the use of agricultural matrices as an alternative for complementary resources is associated with the existence of forested habitat adjacent, functioning as source area for both prey and predators (Magioli et al., 2016, 2014). Our results for *vereda* and *cerrado strictu sensu* were unexpected (because they also represented natural vegetation classes). Pumas are traditionally associated with these types of habitats, but both second and third order selection analysis showed avoidance. To our concern, this result may reflect the relatively low occurrence of these classes of habitats in the study site, more than an indication of true avoidance.

As we predicted, pumas selected anthropized areas (open pasture and pasture with shrubs) more frequently during the nocturnal period than the diurnal. We attribute the higher use of open habitats at night hours to optimization of predation opportunities and facilitation of movement across the landscape. These are activities that predators commonly carry out during darkness, besides diminishing the risks of encounters with humans. It was already reported that pumas living close to urban areas or in rural areas may avoid human disturbances during the day and find temporal refuge from human activities at night (Dickson et al., 2005; Knopff et al., 2014; Lewis et al., 2015; Onorato et al., 2011).

Our results highlight that in a landscape dominated by a matrix of open, agricultural habitats, pumas exhibit large home ranges and heavily select natural

habitats, whose availability is lower than anthropized habitats. Our findings emphasize the importance of natural areas (in this case forests vegetation) for pumas living in agro-ecosystems. They also illustrate the need to protect and restore forest/natural vegetation within private areas along puma's range (e.g. legal reserves and environmental protection areas, as predicted by law at some countries as Brazil) in order to guarantee this top-predator conservation. Not surprisingly, anthropized open areas were avoided despite their availability and, therefore, do not represent suitable habitat for pumas (Vickers et al., 2015). In areas where conservation goals include the maintenance or increase of large predator populations, identifying the limits imposed by anthropogenic landscape change, and ensuring that these are not exceeded, is vital for conservation initiatives. Our approach provides novel and modern information on the spatial ecology of pumas and how this top-predator uses a mosaic landscape. It also fills a gap on puma knowledge from tropical environments, contributing to the long-term conservation and management of large carnivores in human-dominated landscapes.

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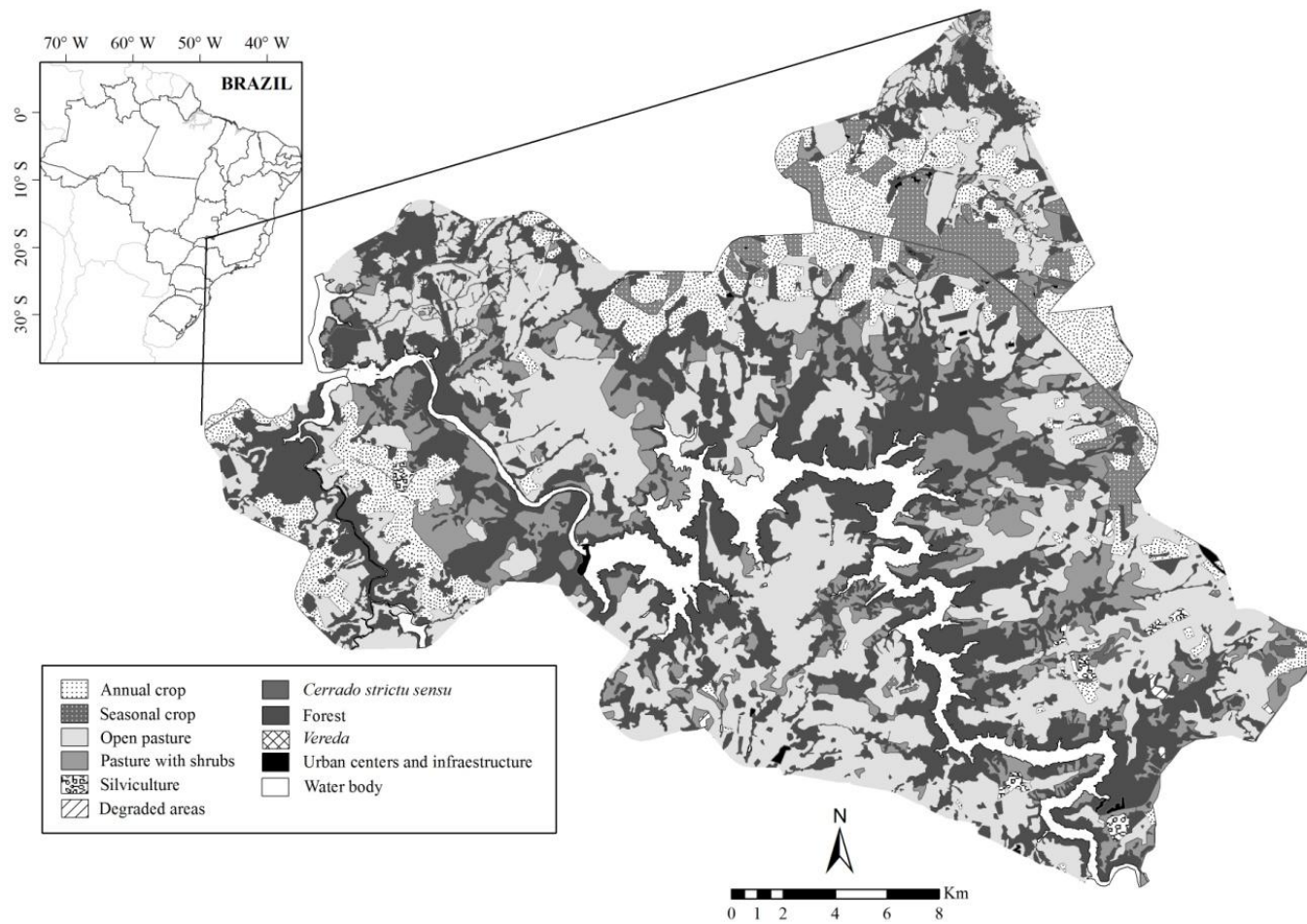


Fig. 1. Map of the study site in Araguari, Minas Gerais state, Brazil, depicting land cover classification.

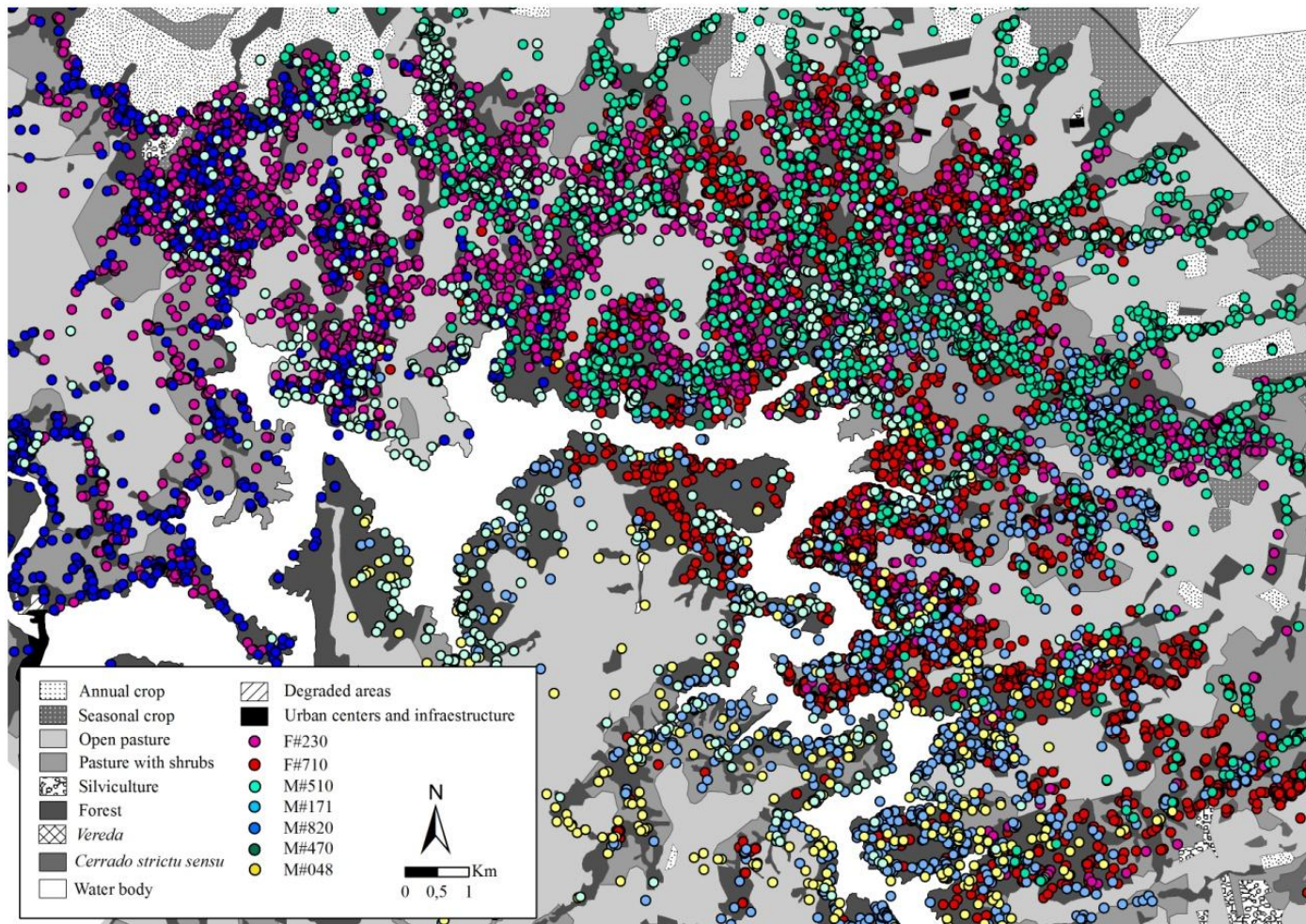


Fig. 2. Example of GPS-collared puma (*Puma concolor*) locations regarding the habitat class in Araguari, Minas Gerais, Brazil.

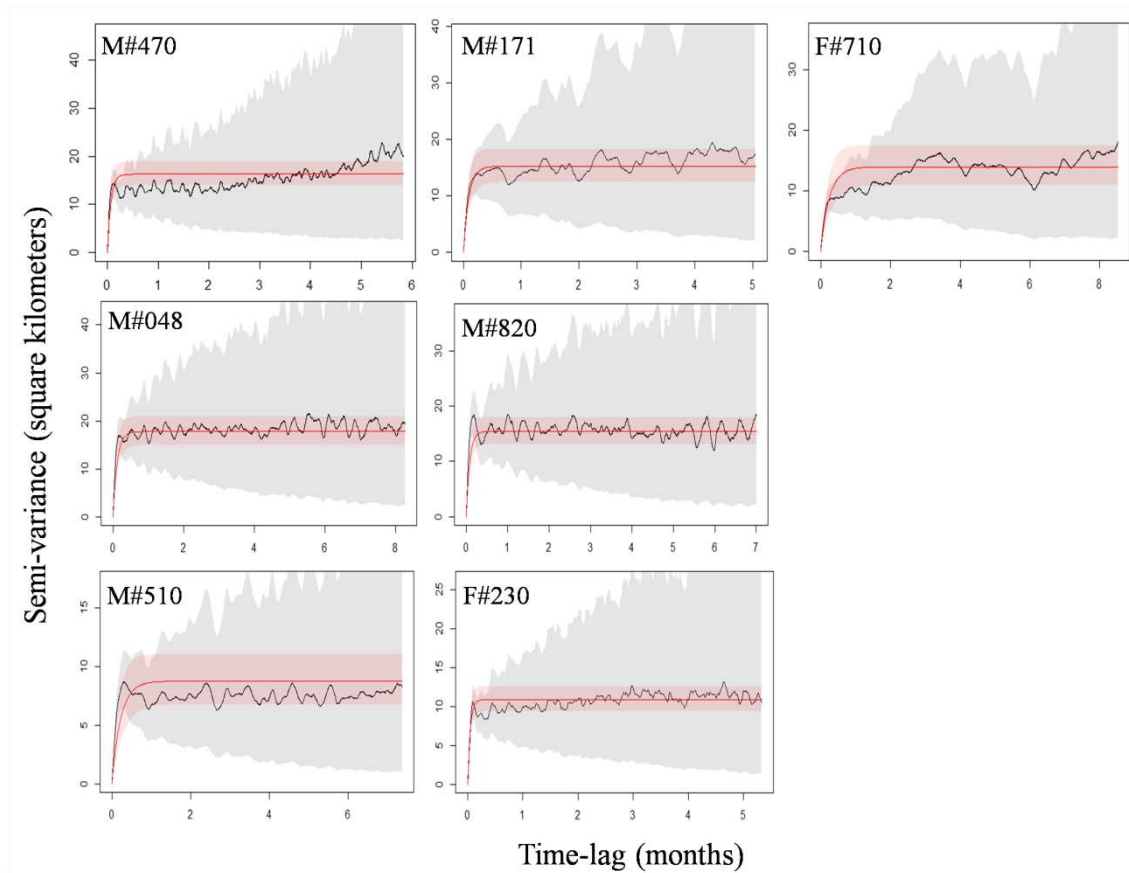


Fig. 3. Illustration of the variogram (semi-variance versus time-lag in months) including confidence interval (CI) of the estimates (red line and red shade) of seven resident GPS-collared pumas (*Puma concolor*), in Araguari, Minas Gerais, Brazil. M = male and F = female.

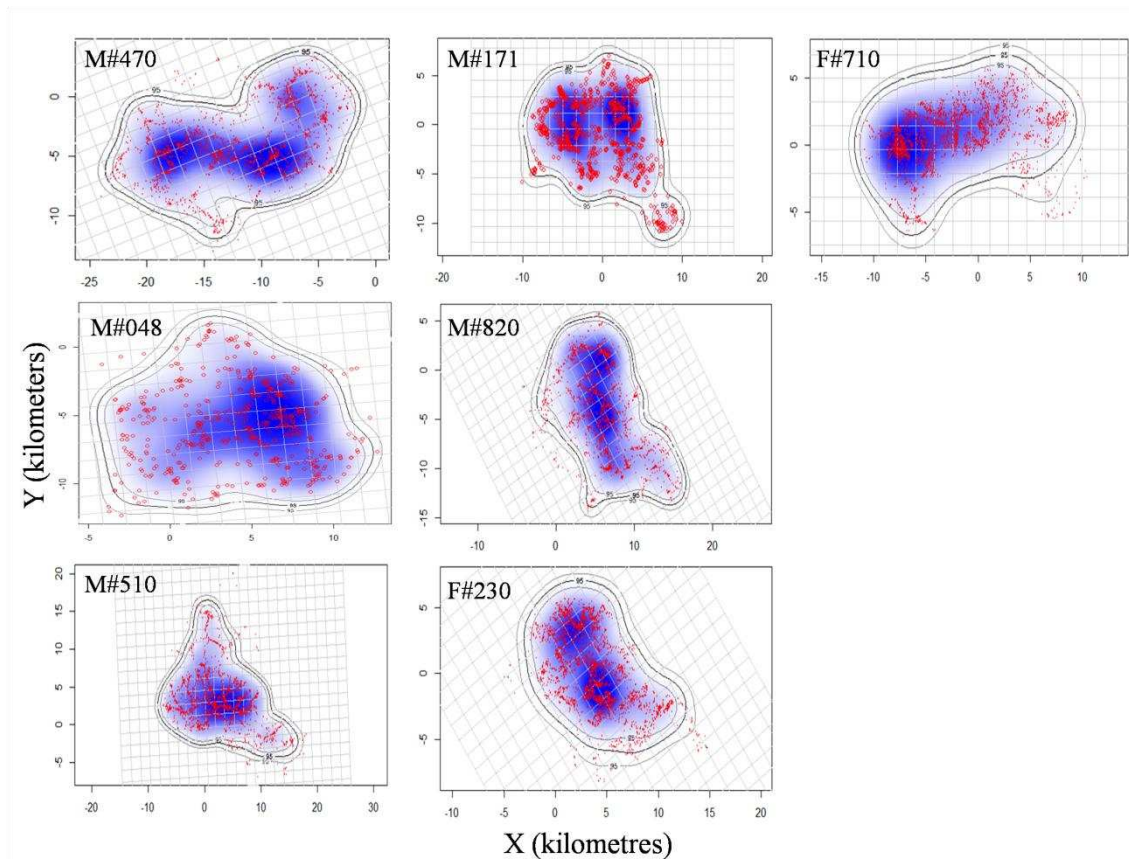


Fig. 4. Illustration of the 95% Autocorrelated Kernel Density Estimator (AKDE) home ranges (x and y kilometers) of seven resident GPS-collared pumas (*Puma concolor*), in Araguari, Minas Gerais, Brazil. The 95% AKDE home ranges in bold outline, including confidence interval of the estimates (gray outlines). M = male and F = female.

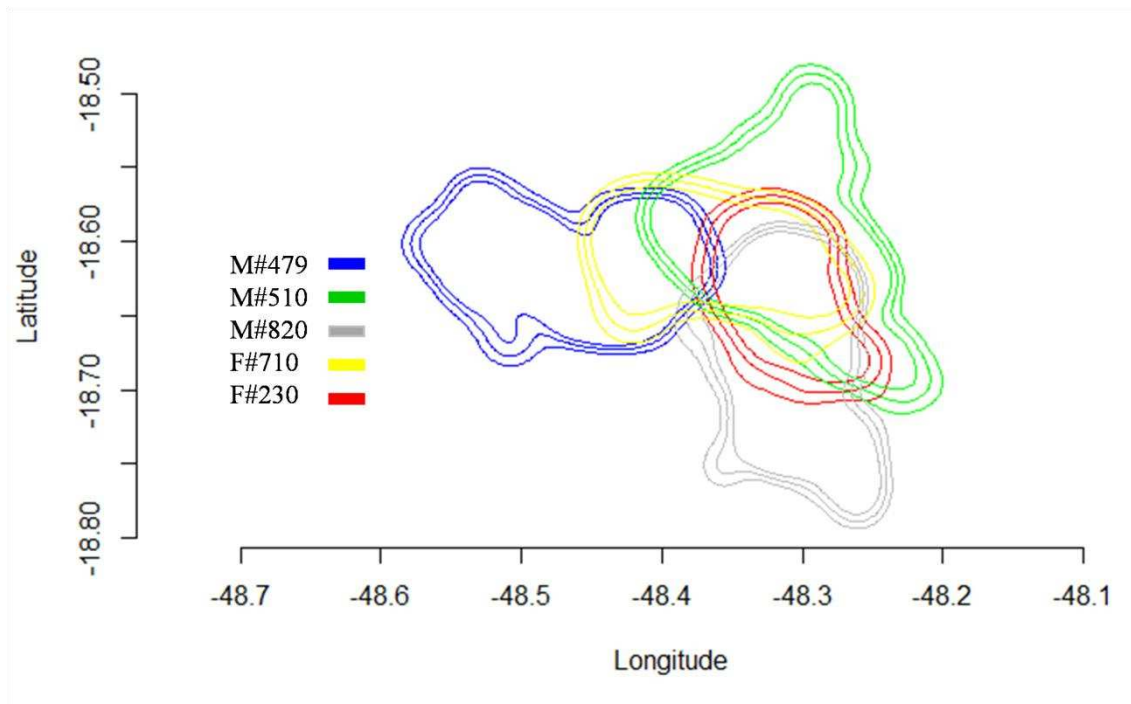


Fig. 5. Overlap between the 95% Autocorrelated Kernel Density Estimator (AKDE) home ranges of five residents of GPS-collared pumas (*Puma concolor*), in Araguari, Minas Gerais, Brazil.

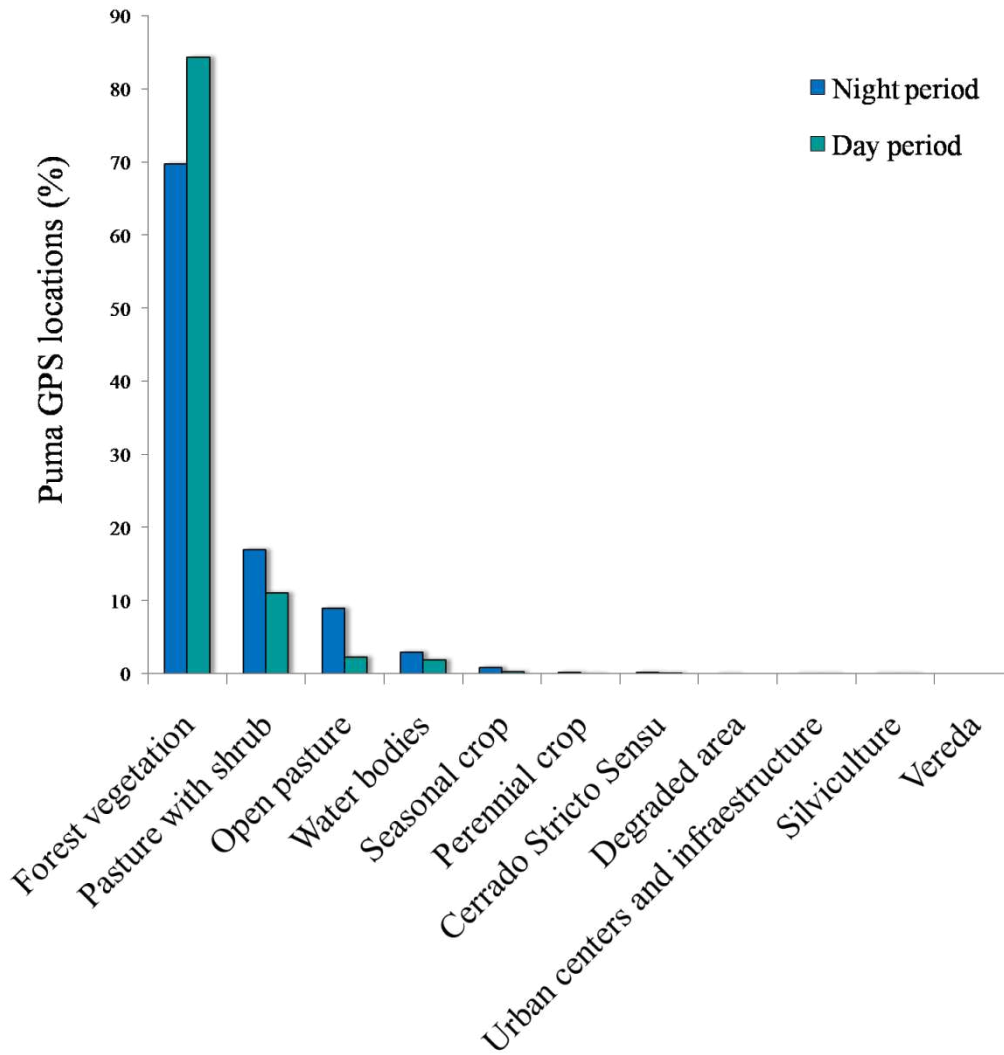


Fig. 6. Habitats used during different activity periods by GPS-collared pumas (*Puma concolor*), in Araguari, Minas Gerais, Brazil.

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Table 1. Habitat classification within conjoint home ranges of GPS collared pumas (*Puma concolor*) in Araguari, Minas Gerais, Brazil.

Land Cover Classification				
Class	Subclass	Habitat Class	Area (ha)	% Class
Natural Areas	Hydromorphic Vegetation	<i>Vereda</i>	12.81	0.01
	Shrub Vegetation	<i>Cerrado strictu sensu</i>	396.38	0.42
	Forest Vegetation	Forest vegetation	30024.65	31.90
Anthropized Areas	Agricultural Areas	Seasonal crop	8737.74	9.28
		Perennial crop	2670.38	2.84
		Silviculture	355.21	0.38
		Open pasture	35730.77	37.96
		Pasture with shrubs	8571.14	9.11
	Non Agricultural Areas	Urban centers and infrastructure	155.70	0.17
		Roads	142.80	0.15
		Degraded area	94.94	0.10
Hydrography	Hydrography	Water bodies	7237.83	7.69
			94130.35	100

Table 2. Movement parameters and home range sizes with 95% confidence intervals (CI) using 95% Autocorrelated Kernel Density Estimation (AKDE) for GPS-collared pumas (*Puma concolor*) in Araguari, Minas Gerais, Brazil, between 2009 and 2017.

ID	Status*	GPS locations	Monitoring period (days)	AKDE 95% (CI) (km²)	Velocity timescale	HR crossing time	Average distance traveled (km/day)
M #470	Resident	3,101	354	214.4 (184.6 - 250.5)	1.2 (h)	1.9 (day)	17.9
M #048	Resident	574	304	196.0 (188.8 - 203.3)	2.0 (h)	1.3 (day)	9.6
M #510	Resident	3,983	354	272.2 (228.4 - 319.8)	1.1 (h)	3.5 (day)	14.8
M #171	Resident	1,159	304	231.0 (188.7 - 277.4)	1.4 (h)	2.8 (day)	13.4
M #820	Resident	3,134	354	219.5 (186.6 - 255.0)	1.1 (h)	2.5 (day)	16.6
F #230	Resident	5,405	365	134.8(104.1 - 169.3)	32.3 (m)	6.6 (h)	10.9
F #710	Resident	6,274	354	183.0(142.3 - 228.5)	29.5 (m)	7.4 (h)	13.5

Best model fits for estimate home range of all individuals was OUF (Omstein-UhlenbeckForanging) process (following Fleming *et al.* 2014).

*Status of resident or non-resident animal was determined after variogram inspection.

Table 3. Combined second order selection results regarding proportion of available and used habitats, number of GPS locations, and habitat selection index (w) using

Bonferroni 95% confidence interval (CI) for GPS-collared pumas (*Puma concolor*) in Araguari, Minas Gerais, Brazil.

Habitat Class	Prop. of available area	No. of observed GPS locations	Prop. used habitat	Selection Index (w)	95% CI	Status
All Pumas						
Seasonal crop	0.0938	146	0.0063	0.0670	0.0521 - 0.0818	Avoid
Perennial crop	0.0289	33	0.0014	0.0491	0.0261 - 0.0720	Avoid
Open pasture	0.3820	1498	0.0645	0.1687	0.1573 - 0.1800	Avoid
Pasture with shrub	0.0918	3423	0.1473	1.6045	1.5364 - 1.6727	Select
Water bodies	0.0778	595	0.0256	0.3290	0.2931 - 0.3648	Avoid
Cerrado <i>strictu sensu</i>	0.0040	31	0.0013	0.3342	0.1728 - 0.4956	Avoid
Forest vegetation	0.3214	17509	0.7536	2.3449	2.3213 - 2.3686	Select
Male Pumas						
Seasonal crop	0.0938	108	0.0093	0.0996	0.0740 - 0.1253	Avoid
Perennial crop	0.0289	27	0.0023	0.0807	0.0390 - 0.1225	Avoid
Open pasture	0.3822	1013	0.0877	0.2294	0.2109 - 0.2479	Avoid
Pasture with shrub	0.0918	1585	0.1372	1.4941	1.4003 - 1.5879	Select
Water bodies	0.0778	539	0.0467	0.5993	0.5315 - 0.6671	Avoid
Cerrado <i>strictu sensu</i>	0.0040	15	0.0013	0.3252	0.0994 - 0.5510	Avoid
Forest vegetation	0.3214	8267	0.7155	2.2265	2.1914 - 2.2617	Select
Female Pumas						
Seasonal crop	0.0938	38	0.0033	0.0347	0.0196 - 0.0498	Avoid
Perennial crop	0.0289	6	0.0005	0.0177	0.0000 - 0.0372	Avoid
Open pasture	0.3822	485	0.0415	0.1086	0.0956 - 0.1216	Avoid
Pasture with shrub	0.0918	1838	0.1573	1.7137	1.6150 - 1.8125	Select
Water bodies	0.0778	56	0.0048	0.0616	0.0395 - 0.0837	Avoid
Cerrado <i>strictu sensu</i>	0.0040	16	0.0014	0.3431	0.1125 - 0.5738	Avoid
Forest vegetation	0.3214	9242	0.7912	2.4621	2.4306 - 2.4935	Select

Index value (\pm confidence interval) indicates habitat avoidance when <1 , use according to availability when $= 1$, and indicates habitat selection when >1 , with significant positive and negative selections ($P < 0.05$) marked in bold type. Only classes of habitat with more than five GPS locations were used on the analysis. Prop. = proportion.

Table 4. Combined third order selection results regarding proportion of available and used habitats, number of GPS locations, and habitat selection index (w) using *Bonferroni* 95% confidence interval (CI) for GPS-collared pumas (*Puma concolor*) in Araguari, Minas Gerais, Brazil.

Animal ID	Habitat Class	Prop. of available area	No. of observed GPS locations	Prop. used habitat	Selection Index (w) with 95% CI	Status
M #470	Seasonal crop	0.0970	26	0.0092	0.0946(0.0470 - 0.1421)	Avoid
	Open pasture	0.3960	185	0.0653	0.1648(0.1347 - 0.1950)	Avoid
	Pasture with shrub	0.0950	414	0.1461	1.5377(1.3578 - 1.7176)	Prefer
	Water bodies	0.0800	369	0.1302	1.6276(1.4240 - 1.8311)	Prefer
	Forest vegetation	0.3320	1840	0.6493	1.9556(1.8860 - 2.0252)	Prefer
M #048	Open pasture	0.4380	101	0.1763	0.4024(0.3116 - 0.4932)	Avoid
	Pasture with shrub	0.1050	76	0.1326	1.2632(0.9261 - 1.6003)	Prefer
	Water bodies	0.0890	23	0.0401	0.4510(0.2208 - 0.6812)	Avoid
	Forest vegetation	0.3680	373	0.6510	1.7689(1.6337 - 1.9041)	Prefer
M #510	Seasonal crop	0.0938	76	0.0192	0.2050(0.1423 - 0.2676)	Avoid
	Perennial crop	0.0289	26	0.0066	0.2273(0.1078 - 0.3469)	Avoid
	Open pasture	0.3822	420	0.1063	0.2780(0.2435 - 0.3125)	Avoid
	Pasture with shrub	0.0918	497	0.1258	1.3697(1.2151 - 1.5242)	Prefer
	Water bodies	0.0778	10	0.0025	0.0325(0.0049 - 0.0601)	Avoid
	Cerrado <i>strictu sensu</i>	0.0040	15	0.0038	0.9508(0.2915 - 1.6100)	Avoid
	Forest vegetation	0.3214	2908	0.7358	2.2898(2.2310 - 2.3485)	Prefer
M #171	Seasonal crop	0.0970	5	0.0043	0.0444(0.0000 - 0.0954)	Avoid
	Open pasture	0.3960	101	0.0869	0.2195(0.1657 - 0.2733)	Avoid

	Pasture with shrub	0.0950	170	0.1463	1.5400(1.2589 - 1.8211)	Prefer
	Water	0.0800	36	0.0310	0.3873(0.223 - 0.5509)	Avoid
	Forest vegetation	0.3320	850	0.7315	2.2033(2.1024 - 2.3042)	Prefer
M #820	Open pasture	0.4380	206	0.0680	0.1552(0.1291 - 0.1812)	Avoid
	Pasture with shrub	0.1050	428	0.1412	1.3448(1.1943 - 1.4953)	Prefer
	Water bodies	0.0890	101	0.0333	0.3744(0.282 - 0.4659)	Avoid
	Forest vegetation	0.3680	2296	0.7575	2.0584(2.0056 - 2.1113)	Prefer
F #230	Open pasture	0.4360	111	0.0205	0.0471(0.0357 - 0.0585)	Avoid
	Pasture with shrub	0.1050	969	0.1792	1.7065(1.5785 - 1.8344)	Prefer
	Water bodies	0.0880	51	0.0094	0.1072(0.0687 - 0.1456)	Avoid
	<i>Cerrado strictu sensu</i>	0.0050	16	0.0030	0.5917(0.2112 - 0.9722)	Avoid
	Forest vegetation	0.3660	261	0.7879	2.1528(2.1136 - 2.1919)	Prefer
F #710	Seasonal crop	0.0940	38	0.0061	0.0644(0.0369 - 0.0919)	Avoid
	Perennial crop	0.0290	6	0.0010	0.0330(0.0000 - 0.0685)	Avoid
	Open pasture	0.3840	374	0.0596	0.1553(0.1347 - 0.1758)	Avoid
	Pasture with shrub	0.0920	869	0.1385	1.5058(1.3807 - 1.6309)	Prefer
	Water bodies	0.0780	5	0.0008	0.0102(0.0000 - 0.0223)	Avoid
	Forest vegetation	0.3230	4981	0.7940	2.4583(2.4166 - 2.5000)	Prefer

Index value (\pm confidence interval) indicates habitat avoidance when <1 , use according to availability when $= 1$, and indicates habitat selection when >1 , with significant positive and negative selections ($P < 0.05$) marked in bold type. Only classes of habitat with more than five GPS locations were used on the analysis. Prop. = proportion.

ANEXO I

Imagens ilustrando aspectos da tese





	SAB	DON	SEB	TER	QUA	QUI	SEX
QUIABA	CAIO MOZART BIA	CAIO MOZART BIA	CAIO MOZART HAROLDO	CAIO MOZART HAROLDO	CAIO MOZART HAROLDO	CAIO MOZART HAROLDO	REUNIDO
MARCOS	ABRE	ISIS	ISIS	ISIS	ISIS	ISIS	MATHEUS
GALENO	HAROLDO MATHEUS ISIS	HAROLDO MATHEUS	BAGUAL ABRE BIA MATHEUS FRED FEA	BAGUAL ABRE BIA MATHEUS FRED FEA	BAGUAL ABRE BIA MATHEUS FRED FEA	BAGUAL ABRE BIA MATHEUS FRED FEA	FECHA

"É muito fácil confiar em quem tem abobota, confiança em si mesmo!" (Dagueres)







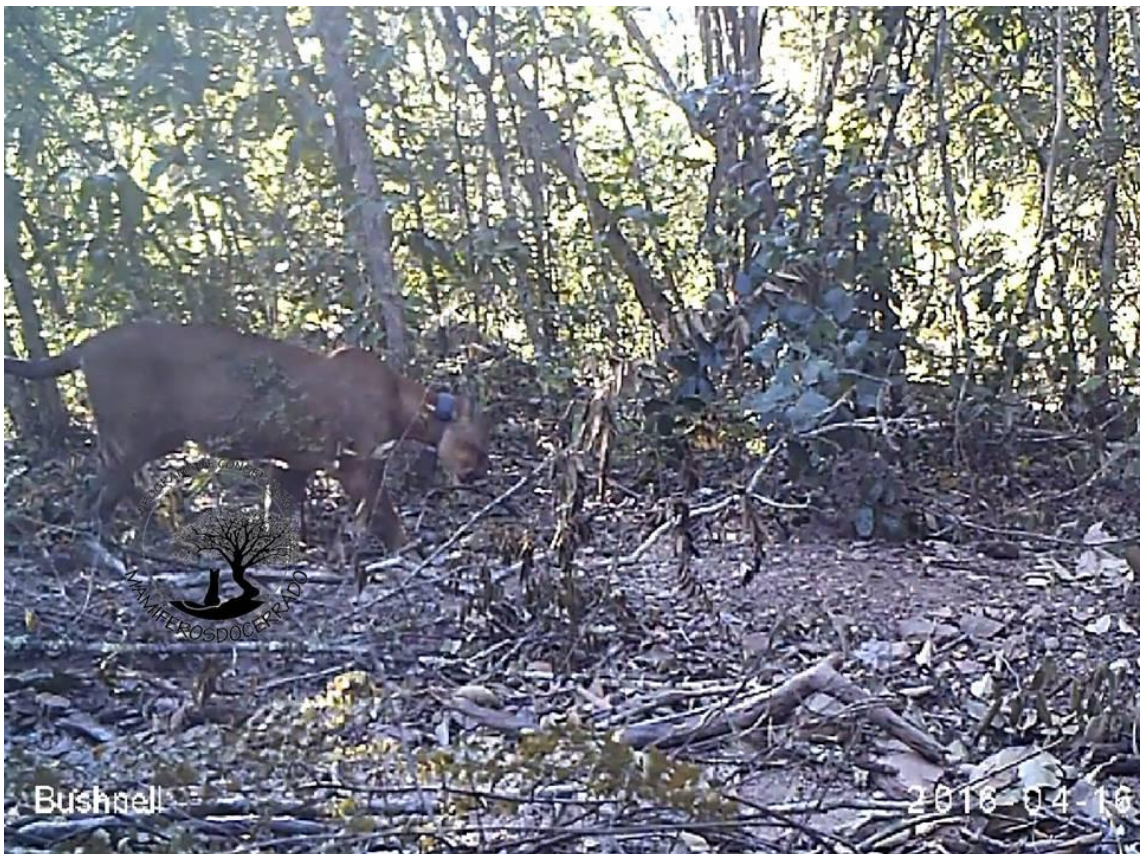
















ANEXO II

Licenças



Ministério do Meio Ambiente - MMA

Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis - IBAMA

Instituto Chico Mendes de Conservação da Biodiversidade - ICMBio

Sistema de Autorização e Informação em Biodiversidade - SISBIO

Autorização para atividades com finalidade científica

Número: 18913-1	Data da Emissão: 17/03/2009 15:28	Data de Validade: 17/03/2010
Dados do titular		
Registro no Ibama: 1827988	Nome: Frederico Gemésio Lemos	CPF: 014.293.776-23
Título do Projeto: MONITORAMENTO DE ONÇAS- PARDAS (PUMA CONCOLOR) E FELINOS SIMPÁTRICOS NA ÁREA DE INFLUÊNCIA DO COMPLEXO ENERGÉTICO AMADOR AGUIAR, MINAS GERAIS, BRASIL		
Nome da Instituição : Instituto para Conservação dos Carnívoros Neotropicais		CNPJ: 01.727.994/0001-05

Observações, ressalvas e condicionantes

1	As atividades de campo exercidas por pessoa natural ou jurídica estrangeira, em todo o território nacional, que impliquem o deslocamento de recursos humanos e materiais, tendo por objeto coletar dados, materiais, espécimes biológicos e minerais, peças integrantes da cultura nativa e cultura popular, presente e passa da, obtidos por meio de recursos e técnicas que se destinem ao estudo, à difusão ou à pesquisa, estão sujeitas a autorização do Ministério de Ciência e Tecnologia.
2	Esta autorização não exige o titular e a sua equipe da necessidade de obter as anuências previstas em outros instrumentos legais, bem como do consentimento do responsável pela área, pública ou privada, onde será realizada a atividade.
3	Esta autorização não poderá ser utilizada para fins comerciais, industriais, esportivos ou para realização de atividades inerentes ao processo de licenciamento ambiental de empreendimentos. O material biológico coletado deverá ser utilizado para atividades científicas ou didáticas no âmbito do ensino superior.
4	A autorização para envio ao exterior de material biológico não consignado deverá ser requerida por meio do endereço eletrônico www.ibama.gov.br (Serviços on-line - Licença para importação ou exportação de flora e fauna - CITES e não CITES). Em caso de material consignado, consulte www.ibama.gov.br/sisbio - menu Exportação.
5	O titular de licença ou autorização e os membros da sua equipe deverão optar por métodos de coleta e instrumentos de captura direcionados, sempre que possível, ao grupo taxonômico de interesse, evitando a morte ou dano significativo a outros grupos; e empregar esforço de coleta ou captura que não comprometa a viabilidade de populações do grupo taxonômico de interesse em condição in situ.
6	Este documento não dispensa o cumprimento da legislação que dispõe sobre acesso a componente do patrimônio genético existente no território nacional, na plataforma continental e na zona econômica exclusiva, ou ao conhecimento tradicional associado ao patrimônio genético, para fins de pesquisa científica, bioprospecção e desenvolvimento tecnológico.
7	Em caso de pesquisa em Unidade de Conservação Federal, o pesquisador titular deverá contactar a administração dessa unidade a fim de CONFIRMAR AS DATAS das expedições, as condições para realização das coletas e de uso da infra-estrutura da unidade.
8	As atividades contempladas nesta autorização abrangem espécies brasileiras constantes de listas oficiais (de abrangência nacional, estadual ou municipal) de espécies ameaçadas de extinção, sobreexplotadas ou ameaçadas de sobreexplotação.

Outras ressalvas

1	No caso da utilização de animais vivos como isca, esses deverão ser domésticos, possuir procedência, estarem saudáveis e receber tratamento adequado durante a sua manutenção.
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Equipe

#	Nome	Função	CPF	Doc. Identidade	Nacionalidade
1	Fernanda Cavalcanti Azevedo	Coordenadora e bióloga de campo	032.310.099-60	6262453/1 ssp-PR	Brasileira
2	Hugo Cardoso de Moura Costa	Biólogo de campo	069.416.176-40	13084336 ssp-MG	Brasileira
3	RONALDO GONCALVES MORATO	Médico Veterinário / Reprodução	074.413.198-70	15931144 SSP-SP	Brasileira
4	Joares Adenilson May Júnior	Médico Veterinário	910.011.889-34	2539609 ssp-SC	Brasileira
5	ROGERIO CUNHA DE PAULA	Biólogo / Análise da ecologia espacial	166.165.498-36	201852718 SSP-SP	Brasileira

Locais onde as atividades de campo serão executadas

#	Município	UF	Descrição do local	Tipo
1	ARAGUARI	MG	Área de Influência do Complexo Energético Amador Aguiar	Fora de UC

Atividades X Táxons

#	Atividade	Táxons
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Este documento (Autorização para atividades com finalidade científica) foi expedido com base na Instrução Normativa Ibama nº154/2007. Através do código de autenticação abaixo, qualquer cidadão poderá verificar a autenticidade ou regularidade deste documento, por meio da página do Ibama/Sisbio na internet (www.ibama.gov.br/sisbio).

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Ministério do Meio Ambiente - MMA
 Instituto Chico Mendes de Conservação da Biodiversidade - ICMBio
 Sistema de Autorização e Informação em Biodiversidade - SISBIO

Autorização para atividades com finalidade científica

Número: 18913-3	Data da Emissão: 24/03/2011 16:50
Dados do titular	
Nome: Frederico Gemesio Lemos	CPF: 014.293.776-23
Título do Projeto: MONITORAMENTO DE ONÇAS- PARDA (PUMA CONCOLOR) E FELINOS SIMPÁTRICOS NA ÁREA DE INFLUÊNCIA DO COMPLEXO ENERGÉTICO AMADOR AGUIAR, MINAS GERAIS, BRASIL	
Nome da Instituição : Consórcio Capim Branco Energia	CNPJ: 04.569.007/0001-80

Cronograma de atividades

#	Descrição da atividade	Início (mês/ano)	Fim (mês/ano)
1	Monitoramento de câmeras	03/2011	12/2012
2	Monitoramento de animais com rádio-colar	03/2011	12/2012
3	Avaliação de conflitos na região	03/2011	12/2012
4	Determinação da dieta de onças-parda	03/2011	12/2012

De acordo com o art. 33 da IN 154/2009, esta autorização tem prazo de validade equivalente ao previsto no cronograma de atividades do projeto.

Observações e ressalvas

1	As atividades de campo exercidas por pessoa natural ou jurídica estrangeira, em todo o território nacional, que impliquem o deslocamento de recursos humanos e materiais, tendo por objeto coletar dados, materiais, espécimes biológicos e minerais, peças integrantes da cultura nativa e cultura popular, presente e passa da, obtidos por meio de recursos e técnicas que se destinem ao estudo, à difusão ou à pesquisa, estão sujeitas a autorização do Ministério de Ciência e Tecnologia.
2	Esta autorização NÃO exime o pesquisador titular e os membros de sua equipe da necessidade de obter as anuências previstas em outros instrumentos legais, bem como do consentimento do responsável pela área, pública ou privada, onde será realizada a atividade, inclusive do órgão gestor da unidade de conservação estadual, distrital ou municipal, ou do proprietário, arrendatário, posseiro ou morador de área dentro dos limites de unidade de conservação federal cujo processo de regularização fundiária encontra-se em curso.
3	Este documento somente poderá ser utilizado para os fins previstos na Instrução Normativa IBAMA nº 154/2007 ou na Instrução Normativa ICMBio nº 10/2010, no que especifica esta Autorização, não podendo ser utilizado para fins comerciais, industriais ou esportivos. O material biológico coletado deverá ser utilizado para atividades científicas ou didáticas no âmbito do ensino superior.
4	A autorização para envio ao exterior de material biológico não consignado deverá ser requerida por meio do endereço eletrônico www.ibama.gov.br (Serviços on-line - Licença para importação ou exportação de flora e fauna - CITES e não CITES). Em caso de material consignado, consulte www.icmbio.gov.br/sisbio - menu Exportação.
5	O titular de licença ou autorização e os membros da sua equipe deverão optar por métodos de coleta e instrumentos de captura direcionados, sempre que possível, ao grupo taxonômico de interesse, evitando a morte ou dano significativo a outros grupos, e empregar esforço de coleta ou captura que não comprometa a viabilidade de populações do grupo taxonômico de interesse em condição in situ.
6	Este documento não dispensa o cumprimento da legislação que dispõe sobre acesso a componente do patrimônio genético existente no território nacional, na plataforma continental e na zona econômica exclusiva, ou ao conhecimento tradicional associado ao patrimônio genético, para fins de pesquisa científica, bioprospeção e desenvolvimento tecnológico.
7	Em caso de pesquisa em UNIDADE DE CONSERVAÇÃO, o pesquisador titular desta autorização deverá contactar a administração da unidade a fim de CONFIRMAR AS DATAS das expedições, as condições para realização das coletas e de uso da infra-estrutura da unidade.
8	As atividades contempladas nesta autorização abrangem espécies brasileiras constante de listas oficiais (de abrangência nacional, estadual ou municipal) de espécies ameaçadas de extinção, sobreexploradas ou ameaçadas de sobreexploração.

Outras ressalvas

1	No caso da utilização de animais vivos como isca, esses deverão ser domésticos, possuir procedência, estarem saudáveis e receber tratamento adequado durante a sua manutenção.
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Equipe

#	Nome	Função	CPF	Doc. Identidade	Nacionalidade
1	Fernanda Cavalcanti Azevedo	Coordenadora e bióloga de campo	032.310.099-60	6262453/1 SSP-PR	Brasileira
2	RONALDO GONCALVES MORATO	Médico Veterinário / Reprodução	074.413.198-70	15931144 SSP-SP	Brasileira
3	ROGERIO CUNHA DE PAULA	Biólogo / Análise da ecologia espacial	166.165.498-36	201852718 SSP-SP	Brasileira
4	Simone Mendes da Silva	Colaboradora	030.493.446-10	M9 140 734 SSP/MG-MG	Brasileira
5	Adriano Gambarini	Fotógrafo	153.635.128-82	17677156 ssp/sp-SP	Brasileira
6	Ricardo Corassa Arrais	Coordenador Veterinário	311.495.088-41	284103603 ssp-SP	Brasileira

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Autorização para atividades com finalidade científica

Número: 18913-4	Data da Emissão: 22/07/2014 10:07	Data para Revalidação*: 21/08/2015
* De acordo com o art. 33 da IN 154/2009, esta autorização tem prazo de validade equivalente ao previsto no cronograma de atividades do projeto, mas deverá ser revalidada anualmente mediante a apresentação do relatório de atividades a ser enviado por meio do Sisbio no prazo de até 30 dias a contar da data do aniversário de sua emissão.		

Dados do titular

Nome: Frederico Gemesio Lemos	CPF: 014.293.776-23
Título do Projeto: Ecologia e conservação de felinos ameaçados de extinção no Triângulo Mineiro e no sudeste de Goiás	
Nome da Instituição : UNIVERSIDADE FEDERAL DE GOIAS	CNPJ: 01.567.601/0001-43

Cronograma de atividades

#	Descrição da atividade	Início (mês/ano)	Fim (mês/ano)
1	Monitoramento de câmeras	03/2011	12/2012
2	Determinação da dieta de onças-parda	03/2011	12/2012
3	Avaliação de conflitos na região	03/2011	12/2012
4	Monitoramento de animais com rádio-colar	03/2011	12/2012
5	Monitoramento através de armadilhas fotográficas	09/2014	12/2016
6	Avaliação dos conflitos com animais domésticos nas regiões de estudo	10/2014	12/2014
7	Captura, marcação e coleta de amostras biológicas das espécie alvo	10/2014	06/2015
8	Monitoramento dos animais com rádio-colar	10/2014	12/2016
9	Determinação da dieta das espécie foco	10/2014	12/2016

Observações e ressalvas

1	As atividades de campo exercidas por pessoa natural ou jurídica estrangeira, em todo o território nacional, que impliquem o deslocamento de recursos humanos e materiais, tendo por objeto coletar dados, materiais, espécimes biológicos e minerais, peças integrantes da cultura nativa e cultura popular, presente e passada, obtidos por meio de recursos e técnicas que se destinem ao estudo, à difusão ou à pesquisa, estão sujeitas a autorização do Ministério de Ciência e Tecnologia.
2	Esta autorização NÃO exige o pesquisador titular e os membros de sua equipe da necessidade de obter as anuências previstas em outros instrumentos legais, bem como do consentimento do responsável pela área, pública ou privada, onde será realizada a atividade, inclusive do órgão gestor de terra indígena (FUNAI), da unidade de conservação estadual, distrital ou municipal, ou do proprietário, arrendatário, posseiro ou morador de área dentro dos limites de unidade de conservação federal cujo processo de regularização fundiária encontra-se em curso.
3	Este documento somente poderá ser utilizado para os fins previstos na Instrução Normativa IBAMA n° 154/2007 ou na Instrução Normativa ICMBio n° 10/2010, no que especifica esta Autorização, não podendo ser utilizado para fins comerciais, industriais ou esportivos. O material biológico coletado deverá ser utilizado para atividades científicas ou didáticas no âmbito do ensino superior.
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6	O titular de autorização ou de licença permanente, assim como os membros de sua equipe, quando da violação da legislação vigente, ou quando da inadequação, omissão ou falsa descrição de informações relevantes que subsidiaram a expedição do ato, poderá, mediante decisão motivada, ter a autorização ou licença suspensa ou revogada pelo ICMBio e o material biológico coletado apreendido nos termos da legislação brasileira em vigor.
7	Este documento não dispensa o cumprimento da legislação que dispõe sobre acesso a componente do patrimônio genético existente no território nacional, na plataforma continental e na zona econômica exclusiva, ou ao conhecimento tradicional associado ao patrimônio genético, para fins de pesquisa científica, bioprospecção e desenvolvimento tecnológico. Veja maiores informações em www.mma.gov.br/cgen .
8	Em caso de pesquisa em UNIDADE DE CONSERVAÇÃO, o pesquisador titular desta autorização deverá contactar a administração da unidade a fim de CONFIRMAR AS DATAS das expedições, as condições para realização das coletas e de uso da infra-estrutura da unidade.
9	As atividades contempladas nesta autorização abrangem espécies brasileiras constante de listas oficiais (de abrangência nacional, estadual ou municipal) de espécies ameaçadas de extinção, sobreexplotadas ou ameaçadas de sobreexplotação.

Equipe

#	Nome	Função	CPF	Doc. Identidade	Nacionalidade
1	Ricardo Corassa Arrais	Coordenador Veterinário	311.495.088-41	284103603 ssp-SP	Brasileira
2	Ísis Zanini das Candeias	Pesquisadora Colaboradora/Veterinária	330.774.618-97	43959621x ssp-SP	Brasileira

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Código de autenticação: 85974844



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CERTIFICADO

A Comissão de Ética no Uso de Animais - CEUA/UFV certifica que o processo nº 90/2014, intitulado “A ecologia da onça-parda *Puma concolor* no Triângulo Mineiro”, coordenado pelo professor Fernando César Cascelli Azevedo do Departamento de Biologia Geral, está de acordo com a Legislação vigente (Lei Nº 11.794, de 08 de outubro de 2008), as Resoluções Normativas editadas pelo CONCEA/MCTI, a DBCA (Diretriz Brasileira de Prática para o Cuidado e a Utilização de Animais para Fins Científicos e Didáticos) e as Diretrizes da Prática de Eutanásia preconizadas pelo CONCEA/MCTI, portanto sendo aprovado por esta Comissão em 04/12/2014, com validade de 12 meses.

CERTIFICATE

The Ethic Committee in Animal Use/UFV certify that the process number 90/2014, named “The ecology da onça-parda *Puma concolor* at Triângulo Mineiro region”, is in agreement with the actual Brazilian legislation (Lei Nº 11.794, 2008), Normative Resolutions edited by CONCEA/MCTI, the DBCA (Brazilian Practice Guideline for the Care and Use of Animals for Scientific Purposes and Teaching) and the Guidelines of Practice the Euthanasia recommended by CONCEA/MCTI therefore being approved by the Committee on December 04, 2014 valid for 12 months.



Prof. Atima Clemente Alves Zuamon

Presidente

Comissão de Ética no Uso de Animais – CEUA/UFV



MINISTÉRIO DA EDUCAÇÃO
UNIVERSIDADE FEDERAL DE GOIÁS
PRÓ-REITORIA DE PESQUISA E INOVAÇÃO
COMISSÃO DE ÉTICA NO USO DE ANIMAIS/CEUA



Goiânia, 20 de outubro de 2014.

**PARECER CONSUBSTANCIADO REFERENTE AO ATENDIMENTO DE
PENDÊNCIA DO PROTOCOLO N°. 66/14**

I. IDENTIFICAÇÃO:

1. **Título do projeto:** “Projeto Onça-parda do Triângulo Mineiro: Monitoramento de espécies de felinos ameaçadas de extinção no município de Araguari, Minas Gerais, Brasil”.
2. **Pesquisador Responsável:** Frederico Gemesio Lemos, UFG - Catalão
3. **Unidade/Órgão do pesquisador:** UFG – Catalão
4. **Pesquisadores Participantes:** Fernanda Cavalcanti de Azevedo –UFV – Viçosa
Ricardo Corassa Arrais, USP; Mozart Caetano de Freitas Jr. , sem vínculo
5. **Unidade onde será realizado:** Pesquisa de campo no município de Araguari, Minas Gerais, Brasil.
6. **Data de apresentação do protocolo a CEUA:** 18/08/14
7. **Data de Atendimento das Pendências:** 16/09/14

II - Parecer da CEUA:

Informamos que a *Comissão de Ética no Uso de Animais/CEUA* da Universidade Federal de Goiás, após análise das adequações solicitadas, **Aprovou** o projeto acima referido e o mesmo foi considerado em acordo com os princípios éticos vigentes.

Reiteramos a importância deste Parecer Consubstanciado e lembramos que o(a) pesquisador(a) responsável deverá encaminhar à CEUA-PRPI-UFG o Relatório Final baseado na conclusão do estudo e na incidência de publicações decorrentes deste, de acordo com o disposto na Lei n°. 11.794 de 08/10/2008 e Resolução Normativa n°. 01, de 09/07/2010 do Conselho Nacional de Controle de Experimentação Animal-CONCEA. O prazo para entrega do Relatório é de até 30 dias após o encerramento da pesquisa, prevista para conclusão em **30/04/2016**.

III - Data da reunião: 20/10/2014

Assinado de forma digital por
RENATA MAZARO:12343522812
Dados: 2014.11.03 12:47:59
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Dra. Renata Mazaro e Costa
Coordenadora da CEUA/PRPI/UFG

Comissão de Ética no Uso de Animais/CEUA
Pró-Reitoria de Pesquisa e Inovação/PRPI-UFG, Caixa Postal: 131, Prédio da Reitoria, Piso 1, Campus Samambaia (Campus II) -
CEP:74001-970, Goiânia – Goiás, Fone: (55-62) 3521-1876.
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