Universidade de Aveiro Departamento de Biologia
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GRASIELA EDITH DE OLIVEIRA PORFIRIO

Ecologia e Conservação de felinos no Pantanal do Brasil

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Tese apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Doutor em Biologia, ramo Ecologia, Biodiversidade e Gestão de Ecossistemas, realizada sob a orientação científica do Doutor Carlos Manuel Martins Santos Fonseca, Professor Auxiliar com agregação do Departamento de Biologia da Universidade de Aveiro e co-orientação do Doutor Pedro Sarmento, Técnico Superior do Instituto da Conservação da Natureza e das Florestas.

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Aos meus pais por todo o amor, zelo, dedicação, apoio, e incentivo;

E a todos aqueles dedicam suas vidas para proteger e entender a natureza.

o júri

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palavras-chave Felinos, conservação, Serra do Amolar, Pantanal

resumo

A rápida conversão dos habitats e a degradação ambiental têm atingido números alarmantes no Pantanal colocando em risco toda a sua biodiversidade. Soma-se a esse cenário o fato do bioma contar com poucas unidades de conservação, que juntas não ultrapassam 10% do território. Os felinos, como predadores, desempenham um papel vital para o bom funcionamento dos ecossistemas, entretanto são espécies que necessitam de grandes áreas, possuem baixas densidades populacionas e, geralmente são demasiadamente sensíveis à perturbação ambiental. No Pantanal, assim como em outros locais, esses animais ainda são alvos da caça predatória em resposta aos prejuízos causados pela predação dos rebanhos ou criações. A Serra do Amolar é considerada uma área de extrema importância e de alta prioridade para a conservação dentro do bioma. Nessa região estão presentes quatro espécies de felinos: a onça-pintada (*Panthera onca*), a onça-parda (*Puma concolor*), a jaguatirica (*Leopardus pardalis*), e o jaguarundi (*Puma yagouaroundi*). Porém, pouco se sabe sobre a ecologia dessas espécies nessa região tão afetada pelas inundações e secas características do Pantanal, e sobre a interação entre as comunidades que vivem no entorno das áreas protegidas e esses animais. O objetivo geral desse estudo foi aumentar o conhecimento sobre os felinos e entender como as pessoas interagem com os mesmos, a fim de contribuir para a conservação na Serra do Amolar. Foram realizadas campanhas de armadilhagem fotográfica em duas áreas do Amolar abrangendo cerca de 83.000 hectares, a fim de identificar as espécies de mamíferos que ocorrem na região, e que podem ser potenciais presas dos felinos, e estudar a relação espaço-temporal entre eles e suas potenciais presas. Realizamos inquéritos em três escolas ribeirinhas para avaliar o conhecimento e as percepções de alunos do ensino fundamental com relação às quatro espécies focais; e inquéritos com a população adulta para avaliar as percepções e atitudes com relação à onça-pintada. Registramos 33 espécies de mamíferos em ambas as áreas de estudo. Observamos que os grandes felinos são catemerais refletindo a atividade temporal com presas de grande porte, enquanto a jaguatirica, de hábitos noturnos, sobrepoe sua atividade às presas menores. A ocupação da onça-pintada é influenciada pela abundância de presas, enquanto que a da onça-parda é influenciada pela densidade das manchas em áreas de mata seca fechada. Onças-pintadas e pardas podem ser potenciais competidores em escala temporal e espacial, enquanto as jaguatiricas tendem a usar recursos de maneira diferenciada. Adultos e crianças tendem a ter percepções negativas quanto aos felinos, que estão relacionadas ao medo de ataques. Além de aumentar o conhecimento científico a cerca das espécies e investir na proteção das áreas, são necessárias ações de educação ambiental a fim de minimizar a relação de medo e conscientizar a comunidade ribeirinha sobre a importância dessas espécies para a manutenção da biodiversidade pantaneira.

keywords Felids, conservation, Serra do Amolar, Pantanal

abstract

Habitat conversion and environmental degradation have reached alarming levels in the Pantanal, endangering all its biodiversity. This scenario is complicated by the fact that the biome relies on only a few protected areas, which combined do not exceed 10% of the territory. Felids, as predators, play a vital role in the maintenance of this ecosystem, but require large areas, have low population densities and, typically, are very sensitive to environmental disturbances. Amolar Mountain Ridge is considered an area of extreme importance and high priority for conservation within the biome. There are four species of felids in this region: the jaguar (*Panthera onca*), the puma *(Puma concolor*), the ocelot *(Leopardus pardalis*), and jaguarundi (*Puma yagouaroundi*). However, little is known about the ecology of these species in this region or the magnitude of interaction between the communities living around the protected areas and the animals. The goal of this study was to increase our knowledge about these felids and understand how people interact with them in order to contribute to their conservation in the network of parks within Amolar. Camera trapping surveys were carried out in two areas of the network, covering approximately 83,000 hectares, in order to identify the species of mammals occurring in the region, those that may be potential prey for the felids, and to obtain basic ecological data about both felids and prey. In addition, we conducted surveys in three riverside schools in order to assess the knowledge, perceptions and attitudes of schoolchildren regarding the four focal felids, and surveys among the adult population to assess their perceptions and attitudes towards the jaguar. We recorded a total of 33 species of mammals from both study areas. The large cats were cathemeral, reflecting the temporal activity of larger prey, whereas the ocelot was nocturnal, mirroring the activity of smaller prey. Jaguar occupancy was influenced by prey abundance, while puma occupancy was influenced by patch density in drier dense forest. Jaguars and pumas may be competitors over temporal and spatial scales, while no resource overlap was found for ocelots. Overall, both adults and children tended to have negative perceptions about the cats, which were related to the fear of being attacked. To increase awareness about the species and to maximize the effectiveness of protective measures in the network of reserves, it is recommended to develop and implement an Environmental Educational Program in the medium- to long-term in order to minimize the fear of these felids and to counsel locals on the role of felids in the maintenance of the Pantanal's biodiversity.

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"Que a importância de uma coisa há que ser medida pelo encantamento que a coisa produza em nós." Manoel de Barros

CHAPTER 1

GENERAL INTRODUCTION AND OBJECTIVES

PANTANAL BIOME: CHARACTERISTICS, BIODIVERSITY, HUMAN OCCUPATION AND CONSERVATION STATUS

The Pantanal biome is considered the largest floodplain in the world, with an area of about 160,000 km^2, covering territories from three South American countries: Brazil with approximately 140,000 km^2, Bolivia with 15,000 km^2, and Paraguay with the smallest area corresponding to 5,000 km^2 (Junk *et al*., 2006). The Brazilian portion is located in the Upper Paraguay River Basin in the states of Mato Grosso and Mato Grosso do Sul, between latitudes 15° 30' and 22° 30' South, and longitude 54° 45' and 58° 30' West (Silva and Abdon, 1998).

The biome is formed by a complex mosaic of habitats (Figure 1.1), which are greatly influenced by the seasonal flooding (Alho and Sabino, 2011) that occurs due to riverbank breaches arising from local rainfall (Junk *et al*., 2006). Due to the slight declivity of the terrain, water is retained in the system, taking about three to four months to cross the entire territory (Alvarenga *et al*., 1984). The rainy season occurs from October to April, while the dry season takes place from May to September (Junk *et al*., 2006). These characteristics contribute to the transformation of the Pantanal into a seasonal wetland (Alho, 2008) which, according to the flooding regime, soil type and vegetation, can be divided into 11 sub-regions: Cáceres, Poconé, Barão de Melgaço, Paraguai, Paiaguás, Nhecolândia, Abobral, Aquidauana, Miranda, Nabileque e Porto Murtinho (Silva e Abdon, 1998) (Figure 1.2).

The influence of neighboring biomes, such as the Cerrado, Amazon Forest and Chaco, also contributes to the diversity of environmental conditions found in the Pantanal (MMA, 2006), presenting different feeding and reproductive niches, as well as offering several essential ecosystem services (Alho, 2005). Such complexity is reflected in the Pantanal's biodiversity with at least 170 species of mammal inhabit the biome (Alho *et al*., 2011), 463 species of birds (Tubelis and Tomas, 2003), 263 species of fishes (Britski *et al*., 1999), 40 species of amphibians and 177 species of reptiles (Médri e Mourão, 2004), together with more than 2,000 species of plants (Junk *et al*., 2006) that have been recorded there. Although only a small number of endemic species have been described for the Pantanal (Junk *et al*., 2006), it is a refuge for several threatened or endangered species (Harris *et al*., 2005). Since seasonal floods cover most of its area, approximately 85% of the Pantanal is still covered by native vegetation, making it an important area for conservation (MMA, 2007; Cavalcanti *et al*., 2012).

Given its attributes and conservation value, the Pantanal was proclaimed by the Brazilian Constitution as a 'National Heritage' in 1988. UNESCO made it a Ramsar Site in 1993 and a World Biosphere Reserve in 2000. In the same year, UNESCO also granted the Natural World Heritage Certificate to the Pantanal (Junk *et al*., 2006). However, despite its great diversity and environmental importance, about 95% of the land in the Pantanal is privately owned (Crawshaw and Quigley, 1991; Seidl *et al*., 2001), and less than 5% of the Brazilian Pantanal is protected under conservation units (Crawshaw and Quigley, 1991).

Extensive cattle ranching has been the dominant economic activity and land use in the region for more than two centuries (Seidl *et al*., 2001). Until recently, this had little impact, but the traditional model has been changing due to the use of new technologies that promote deforestation and environmental and hydrological degradation (Harris *et al*., 2005; Desbiez *et al*., 2010). Additionally, the expansion of agriculture, especially monocultures of soybean and sugarcane, in the plateau surrounding the Pantanal, contributes to habitat conversion, erosion, soil compaction, pollution and contamination of water with heavy metals (Alho and Sabino, 2011), as well as ever-increasing threats of forest fires, overfishing, hunting, mining and unregulated tourism (Alho, 2008). Therefore, the Pantanal is threatened by recent development trends (Harris *et al*., 2005; Alho and Sabino, 2011) and an agenda for sustainability is urgently needed in order to guarantee the conservation of this biome (Alho and Sabino, 2011).

Figure 1.1: Some of the habitat types found in the Pantanal Biome. A) Riparian Forest; B) “Cordilheiras” (Local name given to a stripe of vegetation) and permanently flooded fields; C) Mountains with flooded fields; D) “Salinas” (alkaline lakes) with vegetation influenced by Chaco; E) Cerradão (Forest typical from the Cerrado); F) Semidecidual forest in the dry season. Picture C courtesy of Markus Mauthe. The rest of figures by Grasiela Porfirio.

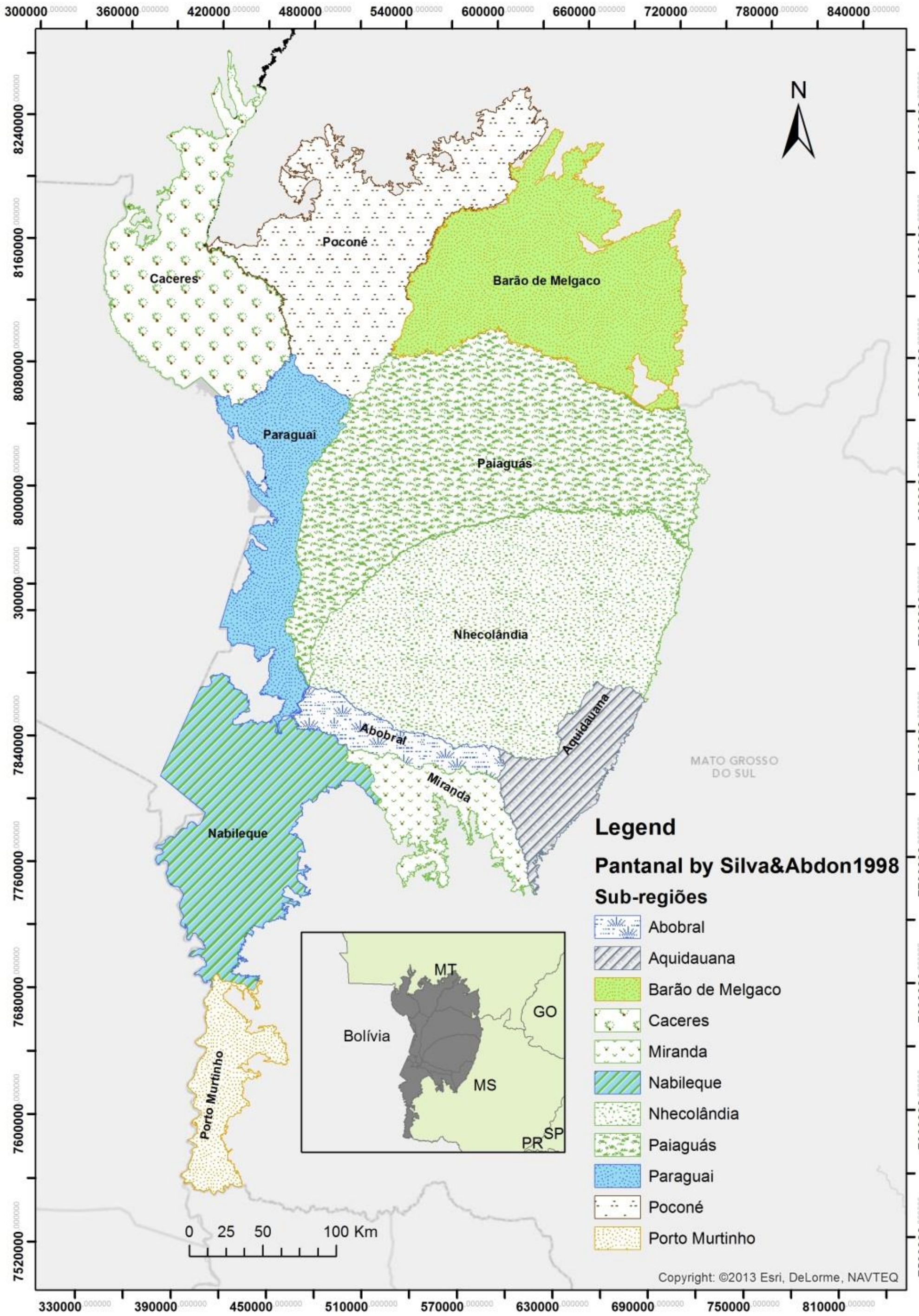

Figure 1.2: Pantanal delimitation in Brazilian territory and its sub-regions according to Silva and Abdon (1998).

AMOLAR MOUNTAIN RIDGE: A PRIORITY AREA FOR CONSERVATION IN THE PANTANAL

Although the Pantanal is known globally as a large floodplain, there are some natural elevated areas, such as the Urucum Massif and Amolar Mountain Ridge. The Amolar Mountain Ridge is located in the sub-region of Paraguai (Figure 1.2), about 180 km north of Corumbá, and extends northwest for about 40 km along the border with Bolivia to the border with the state of Mato Grosso, Brazil (IHP, unpublished data). This Precambrian formation constitutes an abrupt ecotone with the seasonally-flooded plains of the Pantanal (Junk *et al*., 2006), acting as a geological impediment to water flow and playing an important role in the complex ecological network that integrates rivers, plains and biological communities (Collischonn *et al*., 2005). Due to its uniqueness, the Environment Ministry of Brazil considers the Amolar Mountain Ridge and its surroundings as an important area, endowing it with a high priority for biodiversity conservation (MMA, 2007).

Being located in a remote place, surrounded by an area that is permanently flooded, on the Brazilian side, the Amolar Mountain Ridge (AMR) can only be accessed by boat or plane. These characteristics make livestock-ranching difficult. However, these attributes do not hinder exploitation of the area for other purposes. Currently, there are about 70 families living in the AMR and its surrounding area (IHP, unpublished data), who subsist on fishing-related activities (professional or recreational) and maintain a riverside lifestyle. These communities depend on the river and forests for the collection and sale of live bait, and for fish, agriculture, the extraction of firewood, honey, natural remedies, etc. Nevertheless, due to lack of state involvement in environmental protection and provision of public services to these communities, AMR is increasingly threatened by humans activities; mainly overfishing, unregulated tourism, hunting, deforestation, logging, degradation of river headwaters and large wildfires that decimate thousands of hectares in a short period of time, especially during the dry season (IHP, unpublished data).

In an attempt to protect this environment of great scenic beauty and its biodiversity, some landowners have joined forces to create an informal mosaic of conservation units called the "Network for Protection and Conservation of Amolar Moutain Ridge" (Figure

1.3), which legally protects over 200,000 hectares of Pantanal biome (Bertassoni *et al.*, 2012a), representing 7% of the area of private reserves in Brazil (IHP, unpublished data).

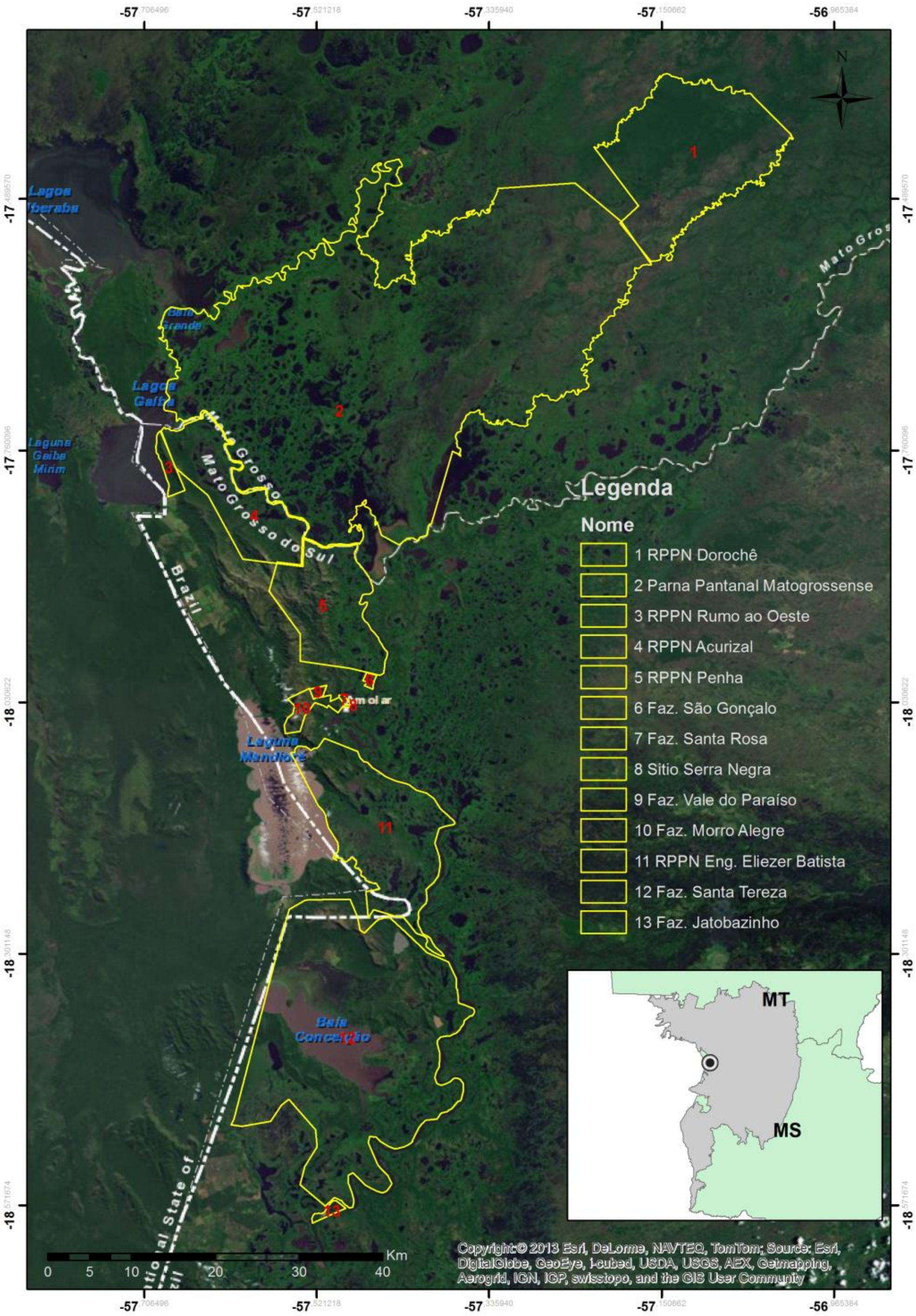

Figure 1.3: Network for Protection and Conservation of Amolar Mountain Ridge (in yellow), Brazilian Pantanal, Mato Grosso and Mato Grosso do Sul States.

FELID SPECIES IN THE PANTANAL AND AT AMOLAR MOUNTAIN RIDGE

Current data support that nine species of felids occur in Brazil due to molecular analyzes that revealed recently a distinct species from *Leopardus* genus – *Leopardus guttulus* (Trigo *et al*., 2013). From this total, eight species are found in the Brazilian Pantanal (Alho *et al*., 2011). There are five species of the genus *Leopardus*, two of the genus *Puma*, and one of the genus *Panthera* (Table 1.1). Most of the available information on these felids concerns ecological and biological aspects of the jaguar (*Panthera onca*) and its relationship with humans (Quigley and Crawshaw, 1992; Zimmermann *et al*., 2005; Soisalo and Cavalcanti, 2006; Azevedo and Murray 2007a, 2007b; Cavalcanti and Gese, 2010; Foster *et al*., 2013), and basic data on the ocelot (*Leopardus pardalis*) (Trolle and Kéry, 2003 and 2005). Apart from unpublished theses (for example, Silveira, 2004), new records (Godoi *et al*., 2010) or general species surveys (Schaller, 1983; Alho, 1987; Alho *et al*., 2011), there is little information available concerning pumas (*Puma concolor*), and the other small cats in the Pantanal.

Table 1.1: Felid species occurring in the Pantanal according to Alho *et al*. (2011), their common names and levels of threat according to the Livro Vermelho da Fauna Brasileira Ameaçada de Extinção [Red Book of the Brazilian Fauna under threatened] (MMA, 2008) and the International Union for Conservation of Nature (IUCN, 2013).

Species	Common name	MMA	IUCN
Leopardus colocolo (Molina, 1782)	Pampas cat	Vu	Nt
Leopardus geoffroyi (d'Orbigny and Gervais, 1844)	Geoffroy's cat	-	Nt
Leopardus pardalis (Linnaeus, 1758)	Ocelot	Vu	-
Leopardus tigrinus (Schreber, 1775)	Oncilla	Vu	Vu
Leopardus wiedii (Schinz, 1821)	Margay	Vu	Nt
Panthera onca (Linnaeus, 1758)	Jaguar	Vu	Nt
Puma concolor (Linnaeus, 1771)	Puma	Vu	-
Puma yagouaroundi (E. Geoffroy, 1803)	Jaguarundi	Vu	-

Vu = vulnerable, Nt = Near threatened

Of the eight species recorded in the Pantanal by Alho *et al.* (2011), four (jaguar, puma, ocelot and jaguarundi) are found at AMR (Figure 1.4), especially at Engenheiro Eliezer Batista Private Natural Heritage and Santa Tereza Ranch (both included in the AMR protected network). However, there is little information about them (Schaller *et al*., 1983; Bertassoni *et al*., 2012b). The jaguar is the best-known species in the region due to the studies of Schaller and Vasconcelos (1978) and Schaller and Crawshaw (1980). Apart from species inventories (Schaller, 1983; Bertassoni *et al*., 2012b; Porfirio *et al.* submitted) there is virtually no information on the population status, habitat use and interspecific interactions among these species.

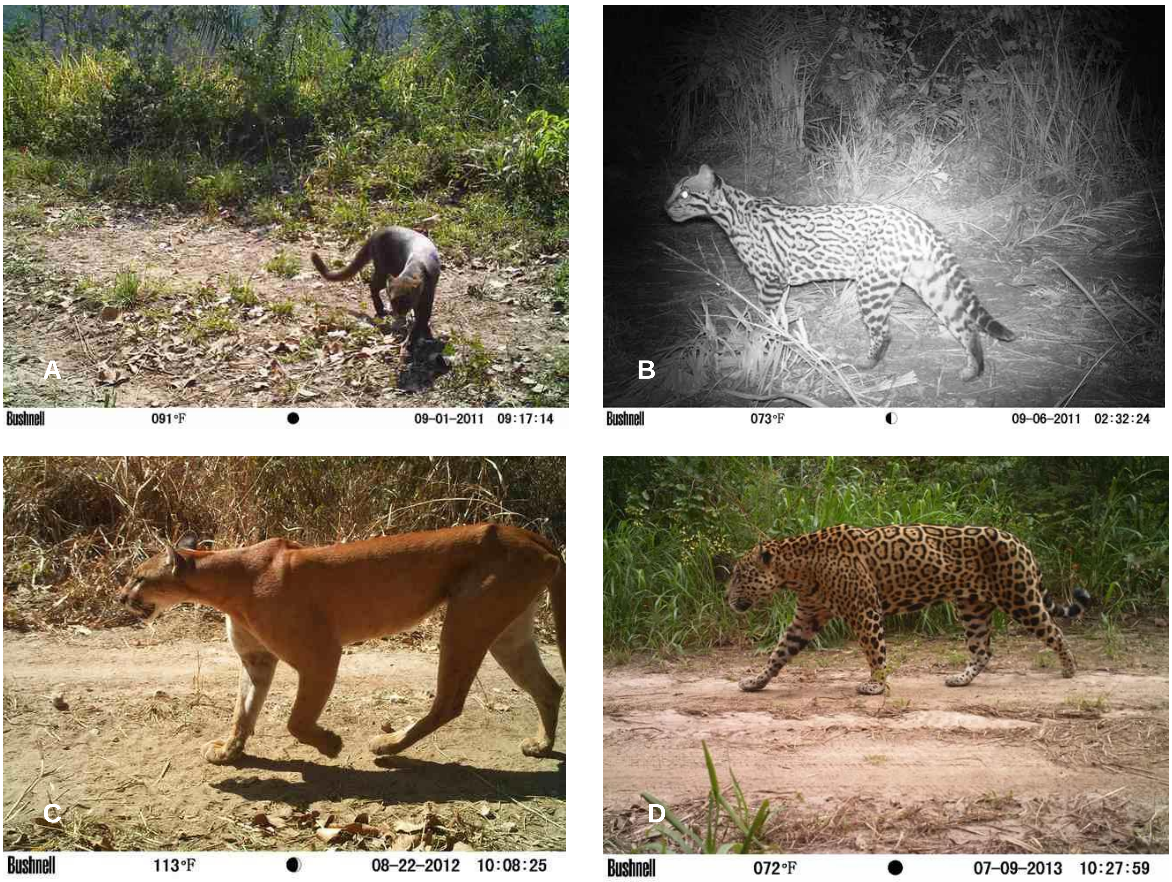

Figure 1.4: Felids species found at Amolar Mountain Ridge, Brazilian Pantanal. A) *Puma yagouaroundi* (jaguarundi), B) *Leopardus pardalis* (ocelot), C) *Puma concolor* (puma), D) *Panthera onca* (jaguar).

THESIS OBJECTIVES

Given the context outlined above, the general objective of this thesis was to increase knowledge about the feline species that inhabit the AMR region and understand the relationship between the felids and the riverside communities, thereby, contributing to their conservation. The specific objectives were:

- To provide a list of mammal species that inhabit the AMR and that could play an important role as potential prey for felids;
- To obtain basic ecological data on the presence of felids (occupancy rates, habitat use, intra and inter-specific interactions);
- To investigate people's knowledge, perceptions and attitudes towards focal felid species in order to develop an environmental education program in riverside schools to raise awareness of their natural role in the biome;
- To establish a medium to long term protocol of felids' monitoring covering the whole network of protected areas in order to propose future conservation measures.

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"Poderoso para mim não é aquele que descobre ouro. Para mim poderoso é aquele que descobre as insignificâncias (do mundo e as nossas)." Manoel de Barros

CHAPTER 2

Medium to large size mammals of Southern Serra do Amolar, Mato Grosso do Sul, Brazilian Pantanal

Porfirio, G., Sarmento, P., Xavier-Filho, N.L., Cruz, J., Fonseca, C. Medium to large size mammals of Serra do Amolar, Brazilian Pantanal. Manuscript submitted to *Checklist Journal* (ID SL092-13)

ABSTRACT

Serra do Amolar (Amolar Mountain Ridge) is considered a Priority Area for biodiversity conservation in the Pantanal biome according to the Environmental Ministry of Brazil. Despite this fact, it is a littlestudied area, lacking basic information such as species inventories. In this study we provide a list of medium- to large-sized mammals which inhabit the southern Serra do Amolar. We carried out a survey at Engenheiro Eliezer Batista Private Natural Heritage Reserve and Santa Tereza ranch from March 2009 to May 2013.We used non-invasive methods to provide a list of 33 mammal species from 18 families, including Endangered species such as the giant otter (*Pteronura brasiliensis*), Vulnerable species such as the lowland tapir (*Tapirus terrestris*), and Near Threatened species such as the jaguar (*Panthera onca*), highlighting the importance of this area for mammal conservation at a regional perspective.

Keywords: inventories, mammals, camera trapping, Pantanal

INTRODUCTION

The Pantanal is one of the largest continuous wetlands of the world and it covers around 210,000 km^2 (Mittermeier *et al*. 2002) in Brazil, Bolivia and Paraguay. This biome is known for its unique abundance of wildlife (Trolle 2003) which results from seasonal changes in feeding and reproductive niches (Alho 2008; Alho *et al.* 2011). Despite this fact, the mammalian fauna of the Pantanal is still poorly known (Rodrigues *et al*. 2002; Desbiez *et al*. 2010), whereas the threats to the biome are increasing, mainly due to changes in cattle production in the floodplains particularly by the use of more nutritious pasture, and agriculture on the plateau, both leading to an increase in deforestation and loss of natural habitat (Desbiez *et al.* 2009a; Desbiez *et al*. 2009b; Alho and Sabino 2011). Since the early 1970s, ranchers have been clearing land, mainly through the use of fire, and planting pastures of exotic grasses to improve the carrying capacity for livestock (Desbiez *et al*. 2011). Approximately 17% of the Pantanal has been deforested through the use of fire (Alho 2008) and private ranches, whose main economic activity is beef production, occupy approximately 95% of the Brazilian Pantanal (Harris *et al*. 2005). Other threats are caused by non-sustainable practices of socio-economic development, such as illegal fishing and hunting, unplanned tourism, and pollution by pesticides, leading to a progressive deterioration of natural habitats (Alho 2008; Alho and Sabino 2011).

Within the vulnerability scenario of the Pantanal (Harris *et al.* 2005; Alho and Sabino 2011), species surveys and inventories provide the essential baseline data for monitoring impacts on wildlife, caused by factors such as habitat conversion and climate change, and for determining conservation priorities (Tobler *et al.* 2008). In this context, knowledge of the biodiversity of the region is critical since it is the basis for improving integrated management of the entire biome.

Regarding mammal biodiversity, several inventories conducted since the 1980s identified a total of 174 species in the Brazilian Pantanal (Schaller 1983; Alho *et al*. 1987; Rodrigues *et al*. 2002; Trolle 2003; Alho 2008; Alho *et al.* 2011). In a recent update, Carmignotto *et al.* (2012) asserted that 79 species of mammals are shared between Cerrado, Caatinga, Amazonian and Atlantic rain forest. Endemism regarding the entire fauna and flora is virtually absent in the Pantanal (Harris *et al*. 2005; Junk *et al.* 2006).

Although mammal occurrence and distribution in the Pantanal is considered poorly documented (Rodrigues *et al*. 2002; Trolle 2003; Junk *et al.* 2006; Desbiez *et al.* 2010), there is a consensus that this biome serves as a refuge for the largest population of several threatened and endangered species, such as the marsh deer *Blastocerus dichotomus* (Illiger, 1815), the giant otter *Pteronura brasiliensis* (Gmelin, 1788), the giant anteater *Myrmecophaga tridactyla* Linnaeus, 1758, the jaguar *Panthera onca* (Linnaeus, 1758), the giant armadillo *Priodontes maximus* (Kerr, 1792), and many others as pointed out by Harris *et al.* (2005) on its appraisal on Pantanal diversity. Considering this point, increasing knowledge on the distribution of mammals and their conservation *status* in the Pantanal, can contribute to the improvement of conservation strategies for these species, since the biome is currently facing changes in its landscape (Desbiez *et al*. 2009a; Desbiez *et al.* 2010). Thus, the goal of this study is to provide a list of medium- and large-sized mammals found in southern Serra do Amolar, situated in the Pantanal of Brazil, and to assess capture rates based on camera trapping surveys.

MATERIALS AND METHODS

Study site

The study was carried out at Serra do Amolar region on Santa Tereza ranch (57° 30'10" W, 18° 18'38" S) and Engenheiro Eliezer Batista Private Natural Heritage Reserve (18°05'25" S, 57°28'24" W). Both properties are situated in the state of Mato Grosso do Sul, at approximately 180 km north of Corumbá, in the Upper Paraguay Basin, limited to the west by the Bolivian border, and to the east by the Pantanal floodplains (Figure 2.1). Although considered one of the largest floodplains of the world, Pantanal has mountainous areas such as Urucum Massif and Amolar (Silva *et al.* 2000). The highest point is the Amolar peak at an altitude of 1000 m. This Precambrian massif establishes an abrupt ecotone with the seasonally flooded plains of the Brazilian Pantanal (Junk *et al.* 2006), working as a geological control of the water drainage. The climate of the Upper Paraguay Basin (APB) is considered seasonal and as tropical savannah (AW) according to the Köppen classification (Cadavid-Garcia 1984), with hot and humid climate in the summer, and dry and cold climate during the winter, with an annual average precipitation of 1,300 mm (PCBAP 1997). The predominant vegetation of the Serra do Amolar region is composed by gallery forest and riparian forest along watercourses and the Paraguai River, dry and humid savannahs, seasonal deciduous forest and seasonal semi-deciduous forest, and rocky fields in minority (approximately 1%) (Sá Arruda *et al.* 2012; Carmignotto *et al*. 2012).

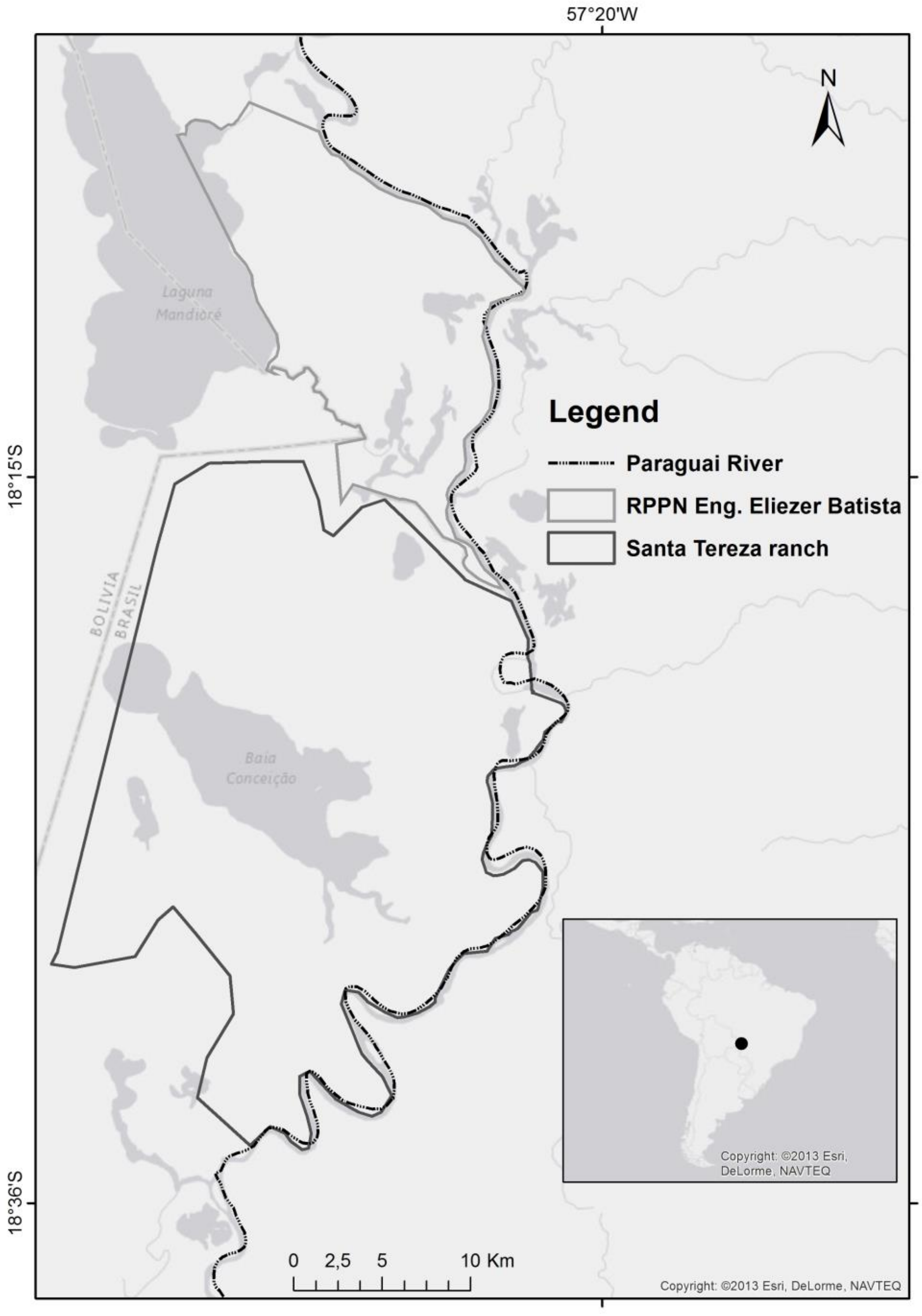

Figure 2.1: Map of the study site located at the Engenheiro Eliezer Batista Private Natural Heritage Reserve, and the Santa Tereza ranch, Pantanal of Brazil.

The first area surveyed was Engenheiro Eliezer Batista Private Natural Heritage Reserve (EEB), covering a total area of 20,268 ha. The EEB protected area was created in 2008 by private initiative in order to enhance the conservation efforts of the Pantanal Matogrossense National Park. The EEB protected area is shaped by mountains, swamps and seasonally flooded grasslands. The possible flood area is comprised by water bodies that represent 58% of the EEB PNHR. A Private Natural Heritage Reserve is a category of protected area established by the Brazilian Federal Decree N^{o}. 98914 of 1990, and updated by Decree N^{o}. 1992 of 1996, where citizens voluntarily engage in the process of effective protection of Brazilian representative ecosystems.

Santa Tereza ranch, the second place surveyed, is in a contiguous area with EEB, and covers 63,000 ha, where only 3% is used for cattle ranching. No other economic activity is carried out on the ranch. The forest remnants occupy an area surrounding the Baía Vermelha, one of the largest lakes of the Paraguay River basin (Calheiros and Ferreira 1997).

Four traditional communities: Castelo, Paraguai Mirim, Amolar and Barra do São Lourenço, with approximately 400 people, are settled in the neighborhood of the study site, and their main economic activities are associated with fishing and small scale cattle production. Subsistence hunting is reported by some locals, and is directed at species such as capybaras *Hydrochoeris hydrochaeris* (Linnaeus, 1766), caimans *Caiman yacare* (Daudin, 1802), and peccaries *Pecari tajacu* (Linnaeus, 1758).

Data collection

The study was carried out in seven phases: (I) from March 2009 to February 2010; (II) in March 2011; (III) from August to October 2011; (IV) from November 2011 to January 2012; (V) from February to May 2012; (VI) from August to September 2012; and (VII) from November 2012 to May 2013. We used a range of non-invasive methodologies to conduct the surveys, including camera trapping, track census, and direct observations (Silveira *et al*. 2003; Trolle 2003; Lyra-Jorge *et al*. 2008). Camera trapping was the main method employed and, the other methods were used to complement the species list.

Paths, dirt roads, sand banks and watercourse margins were followed along phases I and II, in order to record the presence of mammals based on track census and direct observations, this last especially for arboreal species, at Engenheiro Eliezer Batista Protected Area. Tracks were identified based on Lima-Borges and Tomas (2004). In the other phases, several camera trapping surveys were carried out at Engenheiro Eliezer Batista Protected Area and Santa Tereza ranch (Table 2.1). The cameras were installed in different habitats, such as gallery forests, savannahs, and deciduous and semi deciduous forests. All cameras were programmed to operate continuously (24 h/day) and to take pictures at an interval of 30 seconds for the digital models (Bushnell Trophy Cam and Panthera Camera Trap V4), and of five minutes for the analogical equipment (Tigrinus Conventional 6C). The geographic coordinates of camera traps, photographic captures, presence signs, and observations were recorded using a GPS navigator.

Table 2.1: Data of camera trapping campaigns carried out in Engenheiro Eliezer Batista Private Natural Heritage Reserve, and Santa Tereza ranch from August 2011 to May 2013.

Study phase	N of camera traps	Average distance between cameras (m)	Survey days	Sampling effort (camera-days)
III	23	500	62	1,426
IV	12	1,500	58	696
V	20	1,500	95	1,900
VI	14	500	30	420
VII	42	2,000	166	6,972
Total	110	-	411	11,414

Camera trapping sampling effort was determined by multiplying the number of camera traps by the number of sampling days (1d=24 hours) as seen in Srbek-Araujo and Chiarello (2005). Food scraps and cat urine were used to attract the animals. Camera trap records were identified according to Lima-Borges and Tomas (2004) and by drawings in Eisenberg and Redford (1999). Nomenclature followed Wilson and Reeder (2005).

To estimate the relative abundance of the terrestrial mammals, we used the Relative Abundance Index (RAI) (Carbone *et al.* 2001), which is calculated using the number of independent pictures from each species divided by the sampling effort. We used an interval of 24 h between pictures of the same species to guarantee the independence between them (Tobler *et al.* 2008). A species accumulation curve was obtained through randomizations (with 1000 runs) of different size samples, using the software R version 2.15.3. We treated each survey day as a sample, following Tobler *et al.* (2008).

RESULTS

With a total sampling effort for track census and direct observations equivalent to 378,5 km over 45 field days, and a camera trapping sampling effort of 11,414 camera-days (Table 2.1), we recorded 33 species from 18 families (Table 2.2 and Figure 2.2a and 2.2b). Carnivora was the richest mammalian order in our inventory (Table 2.2).

During the surveys we found four primate species (Figure 2.3), and all the species identified by tracks had a camera trapping record (Table 2.2). The agouti *Dasyprocta azarae* Lichtenstein, 1823, crab-eating fox *Cerdocyon thous* (Linnaeus, 1766) , and gray brocket deer *Mazama gouazoubira* (Fischer, 1814) were the most recorded species by the camera traps, while the six banded armadillo *Euphractus sexcinctus* (Linnaeus, 1758), the giant armadillo, the southern tamandua *Tamandua tetradactyla* (Linnaeus, 1758), the white-lipped peccary *Tayassu pecari* (Link, 1795) and the marsh deer *Blastocerus dichotomus* (Illiger, 1815) were the least recorded, and therefore showed the lowest RAIs (Figure 2.4). The species accumulation curve obtained considering the camera trapping records showed an asymptotic tendency (Figure 2.5).

Figure 2.2a: Mammal species detected at southern Amolar mountain ridge (Engenheiro Eliezer Batista Private Natural Heritage Reserve and Santa Tereza ranch) through camera trapping surveys carried out from August 2011 to May 2013. A. *Pecari tajacu*; B. *Leopardus pardalis*; C. *Dasyprocta azarae*; D. *Hydrochoeris hydrochaeris*; E. *Panthera onca*; F. *Myrmecophaga tridactyla*; G. *Nasua nasua*; H. *Mazama gouazoubira*; I. *Puma yagouaroundi*; J. *Cerdocyon thous*; L. *Puma concolor*; M. *Tolypeutes matacus*; N. *Tapirus terrestris*; O. *Tamandua tetradactyla*; P. *Sylivilagus brasiliensis*.

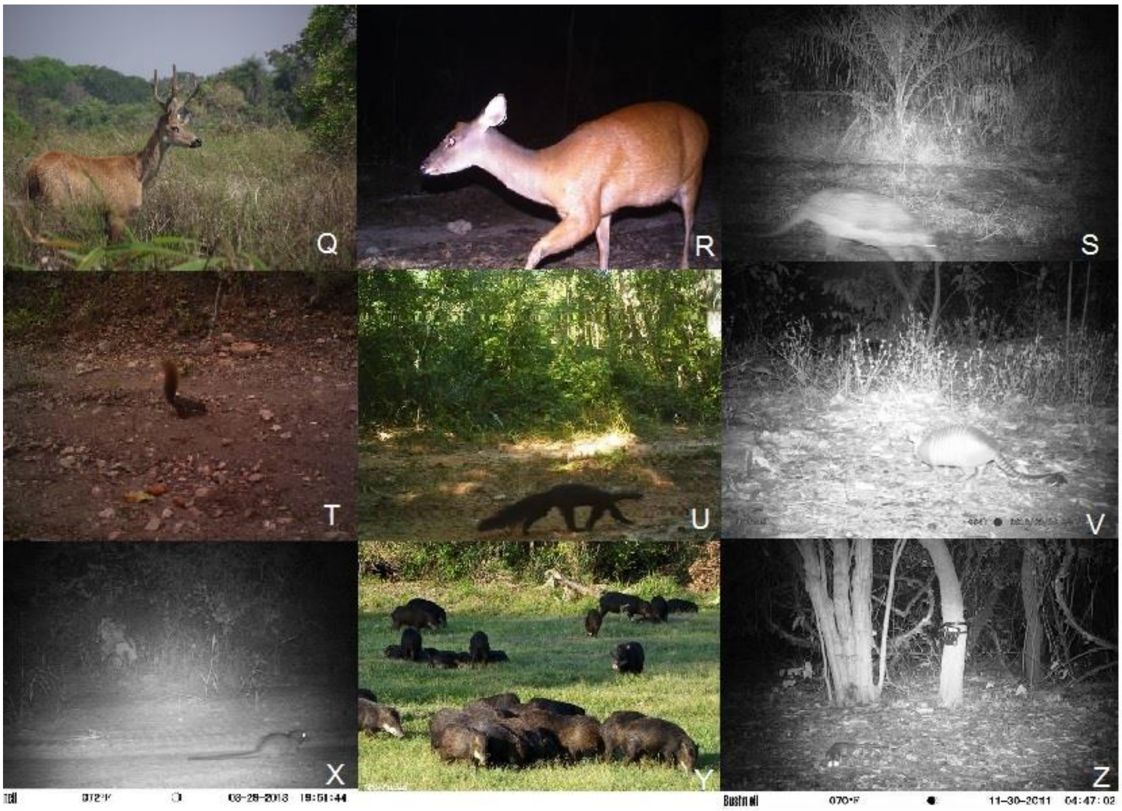

Figure 2.2b: Mammal species detected at southern Amolar mountain ridge through camera trapping surveys and direct observations carried out from August 2011 to May 2013. Q. *Blastocerus dichotomus;* R. *Mazama americana;* S. *Priodontes maximus;* T. *Urosciurus spadiceus;* U. *Eira barbara;* V. *Dasypus novemcinctus;* X. *Thrichomys pachyurus*; Y. *Tayassu pecari* picture by Fabio Paschoal*; Z. Philander opossum.*

Table 2.2: List of species, common name, habitat type, conservation status according to IUCN Red List (2013), and type of record of mammals identified in Engenheiro Eliezer Batista Private Natural Heritage Reserve and Santa Tereza ranch. GF= Gallery Forest, RF= Riparian Forest, DS= Dry Savannah, HS= Humid Savannah, SDF= Seasonal Deciduous Forest, SSF= Seasonal Semi-deciduous Forest, RF= Rocky Field, R=River, T= Tracks, CT= Camera trap, DO= Direct Observation, B= Burrow, LC= Least Concern, DD= Data Deficient, V= Vulnerable, NT = Near Threatened, E=Endangered.

Taxon and Scientific name	Common name	Habitat type	Degree of threat	Type of record
Cervidae				
Mazama gouazoubira (Fischer, 1814)	Gray brocket deer	GF, RF, SDF, SSF	LC	T/CT
Mazama americana (Erxleben, 1777)	Red brocket deer	GF, RF, SDF, SSF	DD	CT/DO/T
Blastocerus dichotomus (Illiger, 1815)	Marsh deer	HS	V	T/CT/DO
Tayassuidae				
Pecari tajacu (Linnaeus, 1758)	Collared peccary	GF, DS, SSF	LC	CT/T
Tayassu pecari (Link, 1795)	White-lipped peccary	SSF, GF	V	CT/T
Didelphidae				
Philander opossum (Linnaeus, 1758)	Gray four-eyed opossum	RF, SSF	LC	CT
Canidae				
Cerdocyon thous (Linnaeus, 1758)	Crab-eating fox	GF, DS, SDF, SSF	LC	T/CT/DO
Felidae				
Leopardus pardalis (Linnaeus, 1758)	Ocelot	GF, RF, DS, HS, SDF, SSF	LC	T/CT

Puma yagouaroundi (É. Geoffroy, 1803)	Jaguarundi	SSF	LC	T/CT
Puma concolor (Linnaeus, 1771)	Puma	SDF, SSF	LC	T/CT
Panthera onca (Linnaeus, 1758)	Jaguar	RF, GF, HS, SSF	NT	T/CT/DO
Mustelidae				
Eira barbara (Linnaeus, 1758)	Tayra	SDF, SSF	LC	CT/DO
Lontra longicaudis (Olfers, 1818)	Neotropical otter	RF, R	DD	DO
Pteronura brasiliensis (Gmelin, 1788)	Giant otter	RF, R	E	DO
Procyonidae				
Nasua nasua (Linnaeus, 1766)	South America Coati	DS, SDF, SSF	LC	T/CT
Procyon cancrivorus (C.[Baron] Cuvier, 1798	Crab-eating raccoon	SSF	LC	CT
Sciuridae				
Urosciurus spadiceus Olfers, 1818	Southern Amazon Squirrel	SDF, SSF	LC	DO/CT
Dasyprocta azarae Lichtenstein, 1823	Azara’s agouti	RF, SSF	DD	T/CT/DO
Caviidae				
Hydrochoeris hydrochaeris (Linnaeus, 1766)	Capybara	GF, RF, HS	LC	T/CT/DO
Echimyidae				
Thrichomys pachyurus (Wagner, 1845)	Sauía	SDR, RF	LC	DO/CT
Tapiridae				

Tapirus terrestris Linnaeus, 1758	Lowland tapir	GF, RF, DS, SDF, SSF	V	T/CT
Cebidae				
Cebus apella (Linnaeus, 1758)	Brown capuchin	GF, SSF	LC	DO/CT
Mico melanura (É. Geoffroy, 1812)	Silvery marmoset	SDF, SSF	LC	DO
Aotidae				
Aotus azarae (Humboldt, 1811)	Azara´s night monkey	SDF, SSF	LC	DO
Atelidae				
Alouatta caraya (Humboldt, 1812)	Black howler monkey	RF, SDF, SSF	LC	DO/CT
Pitheciidae				
Callicebus pallescens (Thomas, 1907)	Chacoan Titi monkey	SDF, SSF	LC	DO
Dasypodidae				
Dasypus novemncictus Linnaeus, 1758	Nine banded armadillo	GF, SSF	LC	CT
Priodontes maximus (Kerr, 1792)	Giant armadillo	SSF	V	T/B/CT
Euphractus sexcinctus (Linnaeus, 1758)	Six banded armadillo	DS, SSF	LC	CT
Tolypeutes matacus (Desmarest, 1804)	Southern Three banded armadillo	SSF	NT	CT
Myrmecophagidae				
Myrmecophaga tridactyla Linnaeus, 1758	Giant anteater	DS, HS, SSF	V	CT
Tamandua tetradactyla (Linnaeus, 1758)	Southern tamandua	SSF	LC	CT

Leporidae				
Sylvilagus brasiliensis (Linnaeus, 1758)	Tapeti	SDF, SSF	LC	CT

Figure 2.3: Primates observed at southern Serra do Amolar, Pantanal of Brazil. a) *Callicebus pallescens* picture by Erison Monteiro; b) *Aotus azarae* picture by Claudenice Faxina; c) *Allouata caraya*; d) *Cebus apella*.

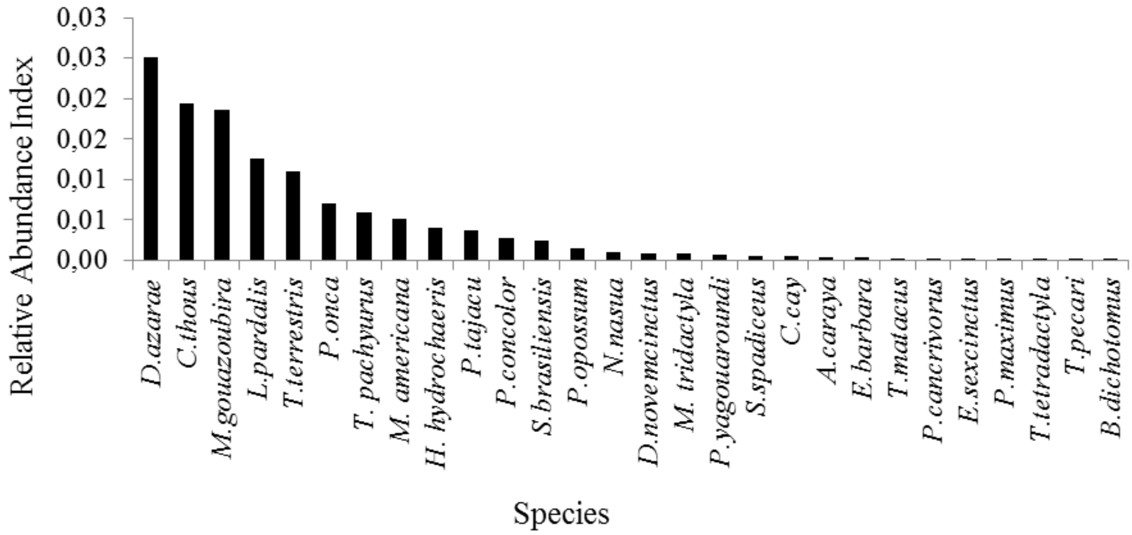

Figure 2.4: Index of Relative Abundance (RAI) obtained by the number of records of each mammal species registered by camera trapping at the Engenheiro Eliezer Batista Private Natural Heritage Reserve and the Santa Tereza Ranch and the sampling effort carried out from August 2011 to May 2013.

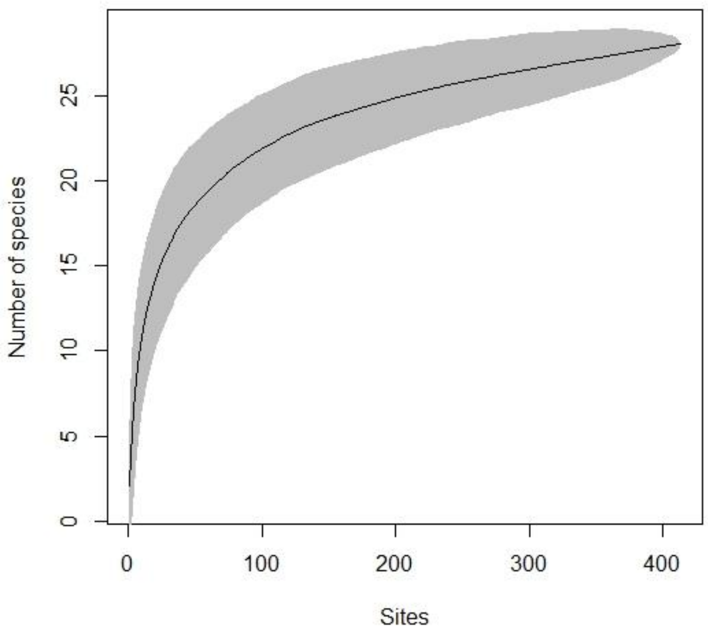

Figure 2.5: Species accumulation curve obtained through randomizations (with 1000 runs) considering the camera trapping surveys carried out at the Engenheiro Eliezer Batista Private Natural Heritage Reserve and the Santa Tereza ranch from August 2011 to May 2013.

DISCUSSION

One of the first inventories in Pantanal that includes a broad multi-taxa sampling effort was conducted by Schaller (1983) on the Acurizal Ranch, identifying 64 species, of which 43 were non-flying mammals. In the Nhecolândia sub-region of the Pantanal, Alho *et al.* (1987) identified 33 mammal species, excluding bats, while Desbiez *et al.* (2010) observed 25 medium-to large-sized mammal species in the same area as Alho *et al.* (1987) through direct observations, evidence from tracks or fresh burrows. In the southeastern part of the Pantanal, Trolle (2003) recorded 30 species of medium- to large-sized mammals, while Rodrigues *et al.* (2002) recorded 93 species for the entire floodplain. The PCBAP (Plano de Conservação da Bacia do Alto Paraguai – Conservation Plan for the Upper Paraguay River Basin - Brasil 1997) also provides one of the most complete lists that have been published for the mammals that inhabit the region, listing 75 species, and being used as a reference for the Pantanal region (Rodrigues *et al*. 2002). Until recently, it was believed that 132 mammal species occurred in the Pantanal (Alho 2008). Nevertheless, in a recent update, Alho *et al.* (2011) cites 170 mammal species in the Brazilian Pantanal.

In this study, we recorded 33 species out of the 43 non-flying mammal species believed to inhabit the region of the study area according to Schaller (1983). In particular, we recorded ones similar to those observed by this author on Acurizal Ranch, located 30 km north of our study area, in the northern side of Amolar Mountain Ridge. Although we used multiple methods in our inventory, we did not register some species observed by Schaller (1983), such as the maned wolf *Chrysocyon brachyurus* (Illiger, 1815), and some arboreal species such as the prehensile-tailed porcupine *Coendou prehensilis* (Linnaeus, 1758). His study was carried out at the end of 1970s and, by that time, these species were already considered extremely rare or difficult to detect (Schaller 1983).

The differences concerning RAIs seem to reflect the behavior and abundance of the terrestrial species. Clearly, the placement of the camera traps near the ground, and the level of sensitivity of the sensor biased our results in favor of medium- to large-sized ground-dwelling mammals, especially those species that frequently use roads, where camera traps are preferentially installed (Harmsen *et al*. 2010). That said, with this method, we did capture some small mammal species such as *Thrichomys pachyurus* (Wagner, 1845) and *Philander opossum* (Linnaeus, 1758) that presents two spots over the eyes, prehensile tail, with less than 20% of the basal portion covered with fur, which the rest is nude, black in 2/3 basal portion and discolored in 1/3 distal portion as described in Rossi and Bianconi (2011) (Figure 3). Since different species have different probabilities of being detected by camera traps due to distinct behavioral traits, it is important to emphasize that this index is an estimation of species abundance relative to the abundance of all other species identified by the method, and cannot be used as a population size estimator (Walker *et al*. 2000; Eduardo and Passamani 2009). The dense vegetation and the flooded fields restricted our movement while surveying the area and, due to these difficulties, we used these results only as a rough estimate. We agree with Sberk-Araujo and Chiarello (2005) in that camera traps are relatively practical and non-intrusive method, especially for surveying nocturnal, rare and cryptic mammals. Although some expected species were not recorded by the camera traps, our species accumulation curve showed an asymptotic tendency, demonstrating that we recorded a high diversity of medium-to large sized ground-dwelling mammals that nearly reports all species expected for the area, probably leaving outside those that might be extinct in the area, occur un low population densities or that current methodology failed in their capture (Voss and Emmons 1996).

Several threatened species inhabit EEB PHNR and Santa Tereza ranch. Among them, we recorded Endangered species such as the giant otter, which according to Schaller (1983) was considered virtually exterminated in the area due to intensive hunting; Vulnerable species such as the lowland tapir, the marsh deer, and the giant armadillo, with the first camera trapping record reported for Serra do Amolar at Engenheiro Eliezer Batista Protected Area in 2012 (Porfirio *et al*. 2012), and Near Threatened species such as the jaguar. In Brazil, the persecution of this last species, as well as any other wildlife species, is illegal, but there are still cases of jaguar shooting that are carried out in an attempt to minimize the damages caused to livestock predation (Marchini and Macdonald 2012). Human occupancy around the reserve is composed primarily of traditional communities that focus their subsistence on fishing activities, but there are also small cattle raising systems. Hence, a single event of cattle depredation by native predators is treated as a significant loss that can lead to the persecution of these animals. So, in this context, it is quite important to gather all possible data on jaguar presence and abundance in order to apply consistent measures that can minimize these losses.

The white-lipped peccary *Tayassu pecari* (Link, 1795), that is one of the most important prey of the jaguar (Taber *et al.* 1997; Weckel *et al.* 2006), and is a Vulnerable species (IUCN 2013), was recorded only once by camera trap in May 2013, although a medium herd (with approximately 20 individuals) was observed in November 2006 at Santa Tereza ranch (GP, personal observation). The white-lipped peccary is an abundant and widespread fruit-eating mammal in Neotropical rainforests (Bodmer 1990), that has a strong association with forested areas (Desbiez *et al*. 2009b). Although the main threats to the species are related to habitat loss and hunting pressure (Carrillo *et al*. 2002), we believe that the species may occur in low densities in the study site as it is the case in the floodplains, one of the predominant habitat types since, in another study area in central Pantanal, Desbiez *et al.* (2009a) found that white-lipped peccary densities were higher in forested landscapes when compared to the floodplain, where the species was rarely sighted.

The southern three banded armadillo *Tolypeutes matacus* (Desmarest, 1804), another Near Threatened species found in our inventory, was already recorded in the Serra do Amolar (Schaller 1983) and in the Pantanal of Nhecolândia (Alho *et al*. 1987). This species is distributed from southeastern Bolivia and Mato Grosso, Brazil, south through the Paraguayan Chaco to the Province of Buenos Aires in Argentina (Wetzell 1985). Considered an opportunistic insectivore (Bolkovic *et al*. 1995), this armadillo is probably facing a significant decline due to widespread habitat loss through much of its range, and because of exploitation as food (Abba and Superina 2010).

Considering the lack of information for this region, it is also important to highlight the detection of some species that exhibit a status of Data Deficient according to the IUCN Red List (2013): the river otter *Lontra longicaudis* (Olfers, 1818), the agouti *Dasyprocta azarae* Lichtenstein, 1823, and the red brocket deer *Mazama americana* (Erxleben, 1777). These species were reported in other inventories carried out in the Pantanal (Trolle 2003; Desbiez *et al.* 2010) and these records are essential for mammal conservation at a regional scale, since the presence or absence of a particular species is the basic information towards a better understanding of its ecological requirements.

We recorded four of the six primate species reported for the Pantanal according to Rodrigues *et al.* (2002) and Melo *et al.* (2009), and these species seem to exhibit fragmented distribution, except *Alouatta caraya* (Humboldt, 1812), which is commonly registered in extensive areas. For example, *Mico melanura* (É. Geoffroy, 1812), occurs only in small isolated and high areas such as Urucum Massif (Vivo, 1991), and there is a considerable lack of information of its *status* in the Pantanal floodplain (Rodrigues *et al*. 2002). The remaining primates seem to be associated with specific vegetation types. For example, Azara's night monkey *Aotus azarae* (Humboldt, 1811), seems to occur in transitional vegetation zones, and on ridges (Rodrigues *et al*. 2002; Cáceres *et al*. 2008). Although *Aotus azarae* has nocturnal habits (Fernandez-Duque and Erkert 2006), it was twice visualized during the day in the EEB PNHR. According to Schaller (1983), this species also occasionally calls in the daytime, and Fernandez-Duque and Erkert (2006) found that this species may be more active during the day if unfavorable lightning or temperature conditions prevail during the night. *Callicebus pallescens* (Thomas, 1907) was identified through direct observation and vocalization. According to Hershkovitz (1990), *C. pallescens* occur in the study site, but there is little information about primate species for the Pantanal, and Tomas *et al.* (2010) pointed out a controversy concerning the validity of this species for the genus *Callicebus* that occurs in the region.

Deers in the Pantanal are represented by four species: *Blastocerus dichotomus*, *Mazama americana*, *Mazama gouazoubira* and *Ozotoceros bezoarticus* (Linnaeus, 1758). The first is associated to the marsh and flooded areas, while the species from the genus *Mazama* can be found over the entire floodplain. *Ozotoceros bezoarticus,* which was not identified in this study site, inhabit mainly field areas (Rodrigues *et al*. 2002) and, since little of this vegetation type is found in the reserve, this could probably be the reason justifying the absence of the species in our inventory.

The richness of carnivores found in our study site followed a pattern close to that observed in other mammal studies carried out in the Pantanal (Trolle 2003; Desbiez *et al.* 2010). That said, we registered 50% of the carnivore species that occur in the Pantanal according to Alho *et al.* (2011). The presence of such high number of species suggests that the study area presents sufficient habitat integrity and abundant prey, the most important ecological requirements for carnivores (Pierce *et al.* 2000).

The importance of the EEB PNHR and Santa Tereza ranch for the conservation of biodiversity is based not only on the presence of endangered and threatened species, but also on the diversity of habitats as a result of the influence of neighboring biomes such as the Chaco, Amazon Forest and Cerrado. Additionally, the EEB PNHR and Santa Tereza ranch are located in a strategic geographical position, in the corridor composed by the

Pantanal Matogrossense National Park and four other Private Natural Heritage Reserves that together comprise the Network for Protection and Conservation of the Serra do Amolar ("Rede de Proteção e Conservação da Serra do Amolar"), a multi-organizational conservation framework for the Serra do Amolar that legally protects 209,000 hectares of Pantanal biome (Bertassoni *et al*. 2012). Furthermore, our study applies the recommendations of the Environment Ministry of Brazil (MMA 2007), which establishes, as a priority, biodiversity inventories for the Serra do Amolar region, since it is classified as an area of extremely high importance for conservation. The results obtained with this study reveal the need to concentrate conservation initiatives in this region, in public and private areas, since it plays an important role as a refuge for the mammal fauna in the western floodplains of the Pantanal.

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“Guarda num velho baú seus instrumentos de trabalho: 1 abridor de amanhecer, 1 prego que farfalha, 1 encolhedor de rios e 1 esticador de horizontes.” Manoel de Barros

CHAPTER 3

Activity patterns and temporal overlap among predators and their potential prey in the Brazilian Pantanal

Porfirio, G., Sarmento, P., Foster, V.C., Fonseca, C. Activity patterns and temporal interactions among predators and their potential prey in the Brazilian Pantanal. Submmited to *European Journal of Wildlife Research* (EJWR-D-14-00012).

ABSTRACT

Little is known about the activity patterns and temporal interactions between the mammalians found in the Pantanal, a seasonal marked floodplain known worldwide for its abundance of wildlife. In this study, we used remotely-triggered photographs and kernel density to describe activity patterns and to evaluate differences in times of movement or travel by jaguars (*Panthera onca*), pumas (*Puma concolor*), ocelots (*Leopardus pardalis*) and their potential prey in the western Brazilian Pantanal. We tested for seasonal differences in activity patterns, temporal avoidance, and assessed the patterns of temporal overlap between predators and prey. Only one species (*Dasyprocta azarae*) showed significant difference in the activity pattern between seasons. The times of movement or travel by jaguars and pumas strongly overlapped, but overlap of activity by the larger felines with ocelots was limited. Cats of all three species had high incidences of temporal overlap with some of their potential prey. Our results suggest that jaguars and pumas may be competitors, while ocelots may use differences in times as niche differentiation. Other factors besides temporal separation, such as habitat use or consumption of prey from distinct species or size may be driving the coexistence of larger felids in our study site.

Keywords: activity patterns, Brazil, *Leopardus pardalis*, Pantanal, *Panthera onca*, *Puma concolor*

INTRODUCTION

The understanding of activity patterns is a key issue in the study of animal behavior since it allows understanding species habitat use, ecological requirements (van Shaik and Griffith 1996; Gómez *et al*. 2005; Manfredi *et al.* 2011), and the mechanisms of species coexistence (Romero-Muñoz *et al.* 2010; Foster *et al.* 2013). Differences in the activity patterns observed in the wildlife may be influenced by several factors. Van Shaik and Griffith (1996) explained differences in daily activity patterns of rainforest mammals using species' relative by size, while other authors suggest that variations facilitate species coexistence by avoiding competition (Romero-Muñoz *et al.* 2010), may increase encounters with prey (Foster *et al*. 2013), or could be a strategy to avoid predation (Ross *et al.* 2013).

Jaguars (*Panthera onca*), pumas (*Puma concolor*) and ocelots (*Leopardus pardalis*), which are considered opportunistic predators (Iriarte *et al.* 1990, Taber *et al.* 1997, Di Bitetti *et al.* 2006, Silva-Pereira *et al.* 2011), coexist across much of their geographic range (Sunquist and Sunquist 2002). Since jaguars and pumas are similar in size, have similar diets (Nuñez *et al.* 2000, Foster *et al.* 2009), and occupy many of the same habitats, some level of segregation is expected in order to promote coexistence (Oliveira 2001, Harmsen *et al.* 2009). On the other hand, ocelots, which are smaller (Di Bitetti *et al.* 2010), prey on smaller and different prey (Emmons 1987), tending to avoid both larger felids due to the risk of predation (Emmons *et al.* 1989, Di Bitetti *et al.* 2006).

Previous studies on jaguars and pumas in sympatry have found similar activity patterns, which are mainly nocturnal or crepuscular (Nuñez *et al.* 2000; Harmsen *et al.* 2009; Maffei *et al.* 2004), although the patterns vary within and between study sites (Scognamillo *et al*. 2003; Harmsen *et al.* 2009; Romero-Muñoz *et al.* 2010; Foster *et al.* 2013). In contrast to the wider activity patterns of jaguars and pumas, ocelots are almost strictly nocturnal (Maffei *et al*. 2002, Di Bitteti *et al.* 2006; Kolowski and Alonso 2010). This difference in activity may reflect uses of most favorableperiod since the bulk of ocelots' small prey are nocturnal (Emmons 1987), or may be a response to interference competition (Palomares and Caro 1999).

Jaguars, pumas and ocelots may mirror their activity patterns with the ones of their potential prey to increase the probability of encounters, thereby reducing energy expended to capture prey (Emmons 1987, Mendes Pontes and Chivers 2007, Harmsen *et al.* 2011, Foster *et al.* 2013). Such behavior is explained by Optimal Foraging Theory, which states that predators should forage according to the energy costs involved in seeking and manipulating prey, which should not be greater than the energy benefits obtained (MacArthur and Pianka 1966). In response, prey may alter their foraging times to avoid predators (Harmsen *et al.* 2011, Ross *et al.* 2013), which may be explained under the concept of risk allocation hypothesis (Lima and Bednekoff 1999). This hypothesis suggest temporal changes under the risk of predation, in which animals may exhibit antipredator efforts in response to high-risk situations, and feeding efforts at low risk-situations (Lima and Bednekoff 1999). Several studies recently concerned about predator-prey temporal interactions in some level (Romero-Muñoz *et al*. 2010, Linkie and Ridout, 2011, Foster *et al.* 2013, Ross *et al.* 2013), and in this study we provide information for the Brazilian Pantanal. This biome is a highly dynamics environment with seasonally flooded areas (Junk *et al.* 2006) that presents a good opportunity for the study of the effects of seasonality in the activity patterns, and possible relationships between predators and their potential prey.

In this paper we investigated the activity patterns of jaguars, pumas, ocelots and their potential prey using photographs taken by remotely-triggered cameras set during the wet and dry seasons. We designed our research to answer the following questions: (1) Do the activity patterns of mammals differ between the wet and dry seasons? (2) Do jaguars, pumas and ocelots exhibit temporal avoidance? And (3) Does predators overlap their activity patterns with any of their known potential prey occurring in the area?

MATERIAL AND METHODS

Study Area

Study was carried out in two sites at Amolar Mountain Ridge: Santa Tereza ranch and Engenheiro Eliezer Batista Private Protected Area. Both study sites are nearly 830 km^2. Amolar Mountain Ridge is locates in the Upper Paraguay River Basin, in the western Brazilian Pantanal, close to the border with Bolivia. It is a Precambrian massif that establishes an abrupt ecotone with the seasonally flooded plains of the Brazilian Pantanal

(Junk *et al.* 2006), functioning as a geological control of the water drainage and a refuge for several species of mammals. The Environment Ministry of Brazil considers it a priority area for biodiversity conservation in the Pantanal (Ministério do Meio Ambiente 2007). The study site undergoes drastic environmental perturbations each year, with inundation and desiccation phases as a result of its topography and levels of precipitation. The climate of the Upper Paraguay Basin is seasonal and, according to the Köppen classification is tropical savannah (AW) with hot and humid weather in the summer and dry and cold weather during the winter (Cadavid-Garcia 1984). Average annual precipitation is 1,300 mm (PCBAP 1997). The rainy season is October-April, while the dry season is May-September (Junk *et al.* 2006). Main vegetation types in both sites includes pioneer herbaceous formations (50%), which can be reached by the flood periods, seasonal semideciduos alluvial forest (11%), seasonal deciduous submontane forest (19%), besides permanent river and lakes that comprise approximately 20% of both areas (IHP, non-published data).

Data collection

We conducted six camera surveys between November 2011 and September 2013 (Table 3.1). During the 1st, 4th and 6th surveys, we spaced cameras 500 m apart, while in the remaining surveys we spaced them approximately 1.5-2.0 km apart. Each station had one camera placed 40-50 cm above the ground along dirt roads, river margins and in the forest (Figure 3.1). We used Bushnell Trophy Cam (Bushnell®, Kansas, USA) and Panthera V3 (Panthera, New York, USA) digital cameras, and Tigrinus Conventional 6C (Tigrinus®, Santa Catarina, Brazil) analogical camera. Cameras operated 24 hours/day, with 30-second intervals between pictures for the digital cameras and five minute intervals for the analog cameras. Camera triggering time was set in 0.5 seconds. We checked stations at 15-30 day intervals to change batteries or film or to download pictures. Malfunctioning cameras were replaced and card with 8 GB were used to avoid loss of records.

Table 3.1: Data from camera trapping campaigns carried out in Engenheiro Eliezer Batista Private Natural Heritage Reserve and Santa Tereza ranch, both located at Amolar Mountain Ridge (western Brazilian Pantanal), from August 2011 to September 2013.

Survey ID	Period of surveys	N^{o}. of camera traps	Average distance between cameras (m)	Survey days	Sampling effort (camera-days)
I	Aug – Sep 2011	23	500	62	1,426
II	Nov 2011- Jan 2012	12	1,500	58	696
III	Fev-May 2012	20	1,500	95	1,900
IV	Aug-Sep 2012	14	500	30	420
V	Nov 2012-May 2013	41	2,000	169	6,929
VI	Apr-Sep 2013	9	500	148	1,332
Total	-	119	-	562	12,703

Statistical analysis

We categorized photos by rainy (October-April) or dry season (May-September). To avoid autocorrelation, for each species we only used photos taken at least one hour apart, unless it was possible to distinguish individuals in which case each photo was considered independent (Linkie and Ridout 2011; Romero-Muñoz *et al.* 2010; Foster *et al.* 2013), and to reduce bias caused by repeated records of the same animal due to the proximity of some cameras, we used just the first record per hour per camera site as a detection event for each 24-h period, and the remaining records were eliminated from the analysis (Ross *et al.* 2013). We classified observations as diurnal (if activity was predominantly between 1 hour after sunrise and 1 hour before sunset), nocturnal (if activity was predominantly between 1 hour after sunset and 1 hour before sunrise), and crepuscular (if activity occurred up to 1 hour before and after sunrise and sunset).

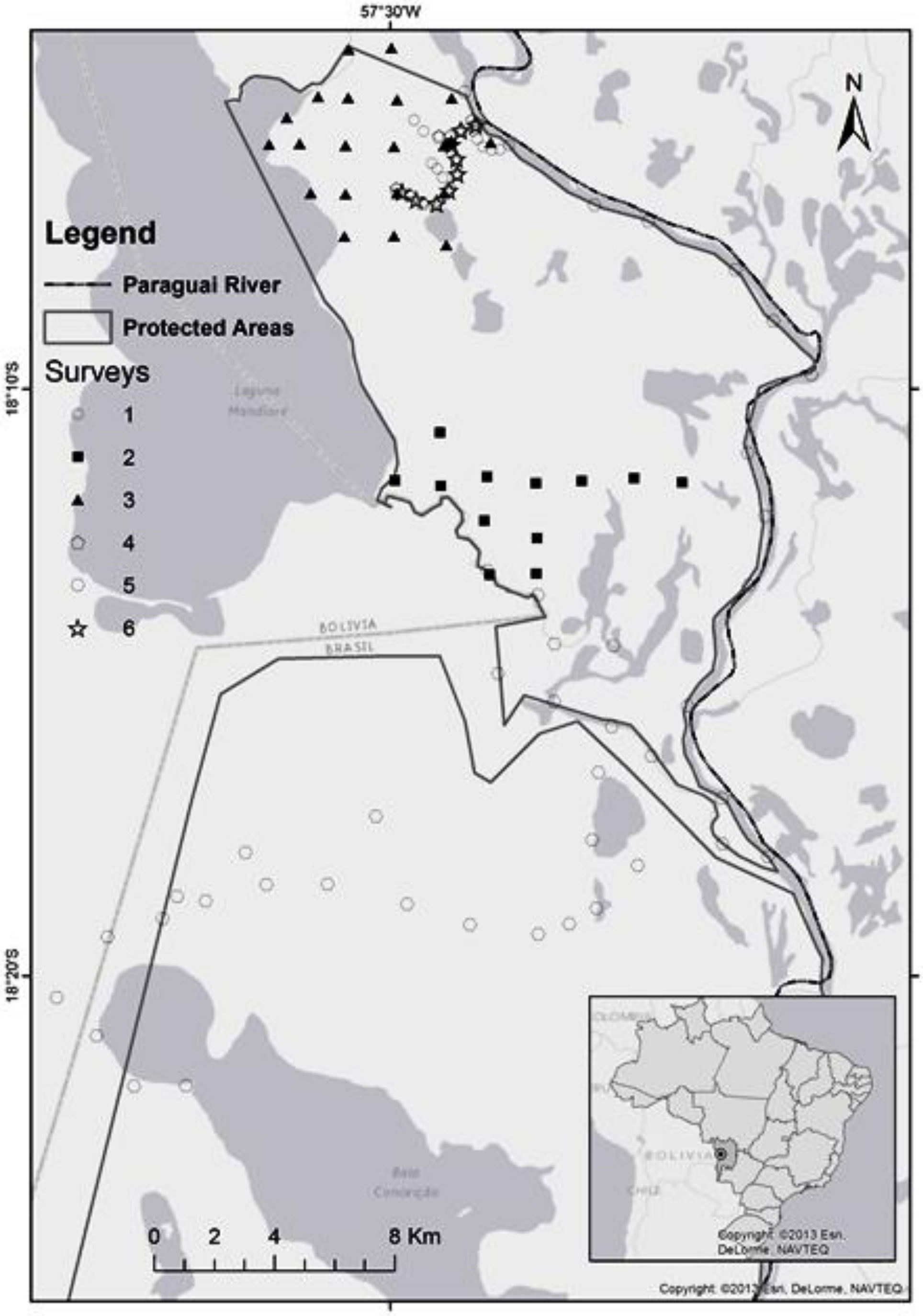

Figure 3.1: Study site with camera trapping distribution in the western Brazilian Pantanal.

We obtained times of sunrise and sunset from Moonrise 3.5 (Sidell 2002), and converted the time of each photo to solar time following Foster *et al.* (2013). Moonrise 3.5 considers dates and geographic positions, thus correcting changes during winter and summer times in order to make data comparable since deals with solar time that compensates for local time and daylight savings. Following Gómez *et al.* (2005) and

Romero-Muñoz *et al*. (2010) we classified species as diurnal (< 15% of the observations were at night), nocturnal (> 85% of the observations at night), mostly diurnal (15-35% of the observations at night), mostly nocturnal (65-85% of the observations at night), crepuscular (50% of the observations during the crepuscular period), and the rest were classified as cathemeral (species that were active both day and night).

We analyzed data only for species that had > 20 independent photographs (Gómez *et al.* 2005). We used the two-step approach developed by Ridout and Linkie (2009) firstly to estimate the activity pattern of each species using kernel density and, next, to measure the overlap between two estimated distributions using a coefficient of overlapping (Δ), which varies from 0 (no overlap), to 1 (complete overlap) (Ridout and Linkie 2009; Linkie and Ridout 2011). A bandwidth smoothing factor of 0.02 was used in the analyses (Ridout and Linkie 2009). Kernel density treats pictures as random samples from an underlying continuous distribution instead of grouping them into discrete time categories (Foster *et al*. 2013). Of the several methods described by these authors for calculating this coefficient, we used the estimator $\Delta_{1,}$ which is recommended for small sample sizes (Linkie and Ridout 2011).

We used R 2.13.0 (R Development Core Team 2011) and an adaptation of scripts developed by Linkie and Ridout (2011; http://kent.ac.uk/ims/personal/msr/overlap.html) for statistical analyses. A confidence interval was calculated for Δ as a percentile of intervals from 500 bootstrap samples (Linkie and Ridout 2011; Foster *et al*. 2013). We used Watson's two-sample test of homogeneity used for circular data (Jammalamadaka and SenGupta 2001), for which the solar time was converted to radians (varying from 0 to 2π). This test gives a result based on a critical value. If U^2 is greater than the critical value, then the null hypothesis is rejected and the two samples are deemed to differ significantly. When the test statistic U^2 is less than the critical value, the null hypothesis cannot be dismissed. Scripts are available at http://artax.karlin.mff.cuni.cz/r-help/library/CircStats/html/watson.two.html.

We analyzed photos for the most important prey species for jaguars and pumas according to Romero-Muñoz *et al.* (2010), Linkie and Ridout (2011) and Foster *et al.* (2013) in the Brazilian Pantanal (Table 3.2). Little is known of the diet of ocelots in the Pantanal (Bianchi 2009) but, since small mammals comprise the bulk of these felids' diets elsewhere (Emmons 1987; Bianchi 2009; Silva-Pereira *et al*. 2011), we analyzed photos of

Azara's agouti (*Dasyprocta azarae*), Brazilian rabbit (*Sylvilagus brasiliensis*) and the Paraguayan punaré (*Thrichomys pachyurus*) as potential prey.

Table 3.2: Mammal species selected as potential prey for the jaguar and puma at Amolar Mountain Ridge based on previous literature.

Prey species	Jaguar[a]	Puma[b]
Cervidae		
Mazama americana	x	x
Mazama gouazoubira	x	x
Tapiridae		
Tapirus terrestris	x	
Tayassuidae		
Pecari tajacu	x	
Dasyproctidae		
Dasyprocta azarae		x
Caviidae		
Hydrochoeris hydrochaeris	x	x

[a] According to the studies of Schaller and Crawshaw, 1980; Crawshaw and Quigley, 2002; Azevedo and Murray, 2007; Cavalcanti and Gese, 2010.

[b] According to the studies of Schaller and Crawshaw, 1980; Emmons, 1987; Taber *et al*., 1997; Nuñez *et al*., 2000; Crawshaw and Quigley, 2002.

RESULTS

With a total effort of 12,703 camera-days, we obtained 1,988 independent photos of 28 mammal species, with > 20 photos each for 12 species (n=1,851; Figure 3.2; Table 3.3). The only species that presented a change in its activity patterns between the rainy and dry season was Azara's agouti, which was diurnal in the rainy season and diurnal with high crepuscular peaks during the dry season (U^2=0.2841, p<0.01) (Figure 3.3). Jaguars, pumas, collared peccaries (*Pecari tajacu*) and gray brocket deer (*Mazama gouazoubira*) displayed cathemeral activity patterns, while tapirs (*Tapirus terrestris*), Brazilian rabbits, and

Paraguayan punarés were nocturnal. Crab-eating-foxes (*Cerdocyon thous*) were mostly nocturnal, as were ocelots and red brocket deer (*Mazama americana*). Only capybaras (*Hydrochoeris hydrochaeris*) were diurnal.

Since we did not find significant differences in activity patterns between the rainy and dry seasons for any species except Azara's agouti, we used all 1,851 pictures to carry out the analyses of overlapping activity. Data from Azara's agouti were not used in further analysis. Activity distributions of jaguars and pumas overlapped extensively with no significant differences [Δ_1= 0.88 (0.70-0.88), U^2=0.0326, p>0.01]. In contrast, activity patterns of jaguars and ocelots [Δ_1=0.69 (0.55-0.74), U^2 = 0.8587, p<0.01] and of pumas and ocelots [Δ_1= 0.66 (0.56-0.70), U^2 = 0.4206, p<0.01] differed significantly (Figure 3.4).

Activity patterns of jaguars showed almost complete overlaped and no significant differences with gray brocket deer [Δ_1=0.92 (0.82-0.93), U^2=0.0394, p>0.01] collared peccaries [Δ_1=0.76 (0.62-0.81), U^2=0.1900, p>0.01] and capybaras [Δ_1=0.73 (0.59-0.81), U^2=0.1900, p>0.01] were observed (Table 4.4). Jaguar activity times coincided little with those of other potential prey, such as the red brocket deer, tapir and Azara's agouti, and patterns of activity differed significantly (Table 4.4).

Activity patterns of pumas also did not differ from those of gray brocket deer [Δ_1=0.86 (0.73-0.87), U^2=0.0409, p>0.01]. Overlap in activity patterns between pumas and capybaras [Δ_1=0.78 (0.57-0.79), U^2=0.1484, p>0.01], between pumas and collared peccaries [Δ_1=0.75 (0.57-0.82), U^2=0.1868, p>0.01] were approximately complete. Pumas had little coincidence of activity times with Azara's agoutis, red brocket deers and tapirs, and patterns of activity also differed significantly (Table 4.4).

The activity times of ocelot coincided extensively with those of Paraguayan punaré [Δ_1=0.82, (0.72-0.86), U^2=0.2452, p>0.01] and Brazilian rabbits [Δ_1=0.77, (0.62-0.84), U^2=0.2307, p>0.01], with no significant differences (Table 4.4).Coincidence in activity times was approximate to 0for ocelots and Azara's agoutis [Δ_1=0.31, (0.27-0.36), U^2=6.0166, p<0.01] (Table 4.4).

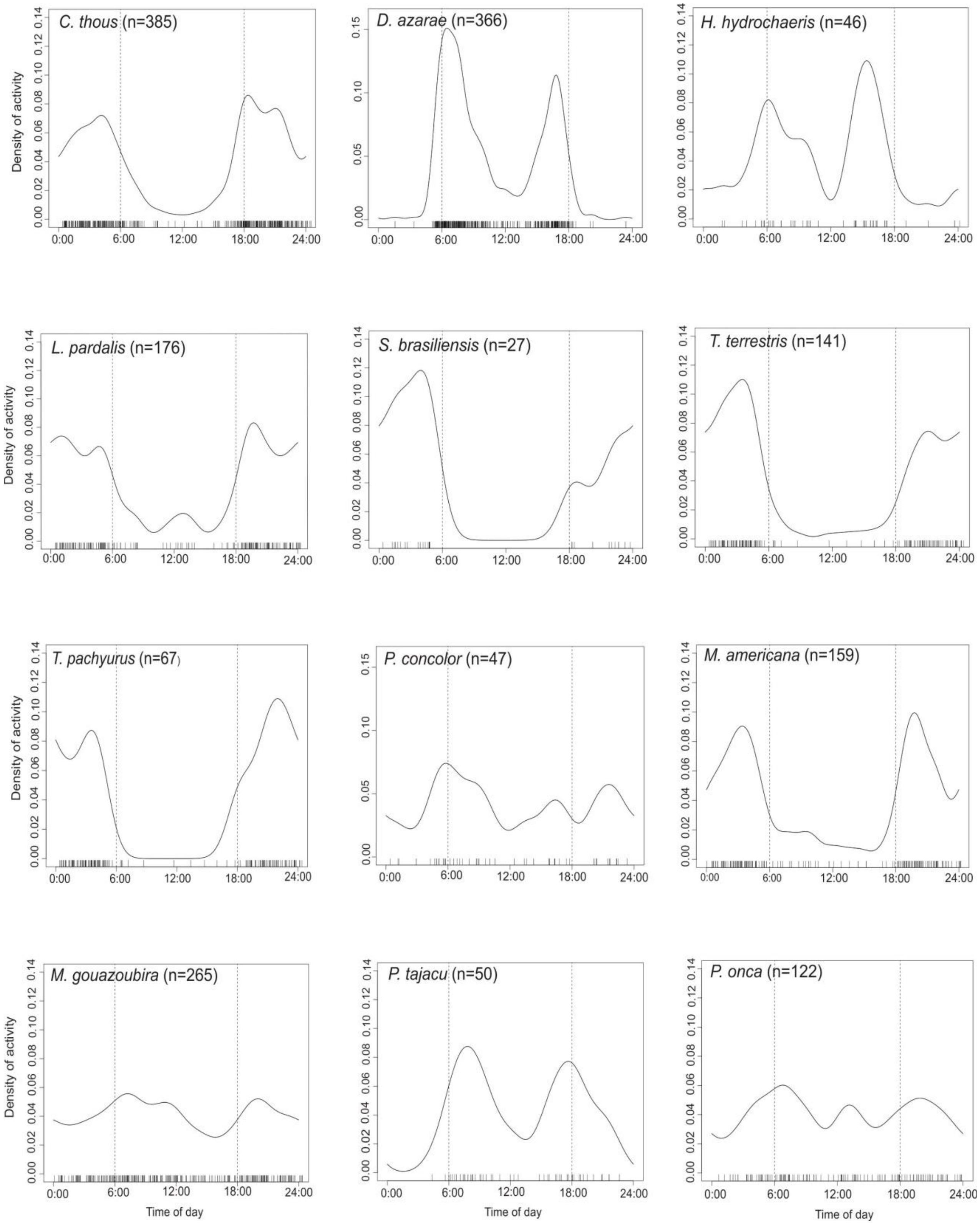

Figure 3.2: Kernel densities of a mammal assemblage in the western Brazilian Pantanal. Individual records are shown as short vertical lines above the x-axis. The grey dashed lines represent the approximate time of sunrise and sunset.

Table 3.3: Number of records (N), activity periods and classification of species registered using camera trapping data carried out for a mammalian assemblage in the western Brazilian Pantanal.

Taxon	N	Nocturnal (%)	Crepuscular (%)	Diurnal (%)	Classification
Carnivora					
Cerdocyon thous	385	67.5	24.0	8.5	Mostly nocturnal
Leopardus pardalis	176	74.5	13.5	12.0	Mostly nocturnal
Panthera onca	122	41.0	40.0	19.0	Cathemeral
Puma concolor	47	40.5	25.5	34.0	Cathemeral
Cetartiodactyla					
Mazama americana	159	77.0	13.0	10.0	Mostly nocturnal
Mazama gouazoubira	265	43.0	19.0	38.0	Cathemeral
Pecari tajacu	50	18.0	32.0	50.0	Cathemeral
Lagomorpha					
Sylvilagus brasiliensis	27	89.0	11.0	0	Nocturnal
Perissodactyla					
Tapirus terrestris	141	88.5	3.5	8.0	Nocturnal
Rodentia					
Dasyprocta azarae	366	2.0	44.0	54.0	Cathemeral
Hydrochoeris hydrochaeris	46	15.0	17.0	68.0	Diurnal
Thrichomys pachyurus	67	86.5	13.5	0	Nocturnal

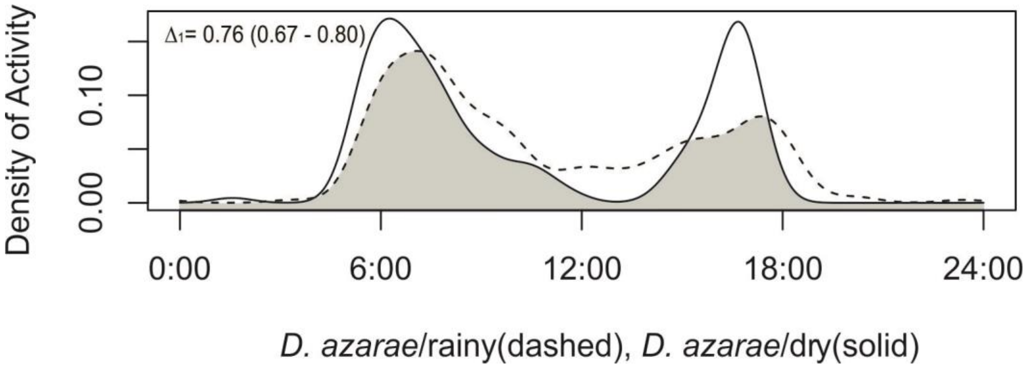

Figure 3.3: Coefficient of overlap of daily activity patterns between the Azara's agouti during the rainy and dry season in the western Brazilian Pantanal. Overlap is represented by the shaded area.

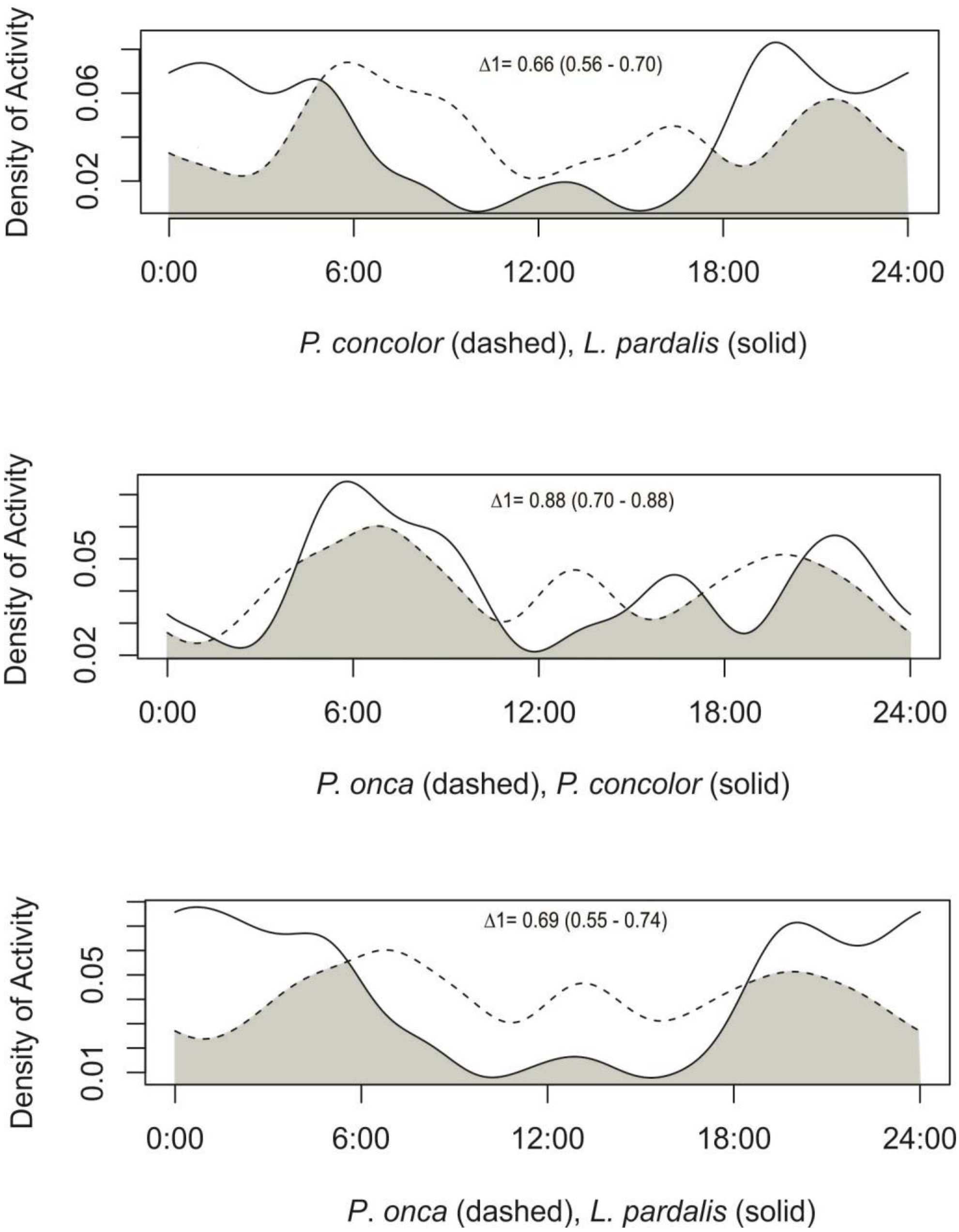

Figure 3.4: Coefficient of overlap of daily activity patterns between jaguar, puma and ocelot in the western Brazilian Pantanal. Overlap is represented by the shaded area.

Table 3.4: Coefficient of overlap (Δ_1) of daily activity patterns between ocelots, pumas, jaguars, and their potential mammalian prey species, and Watson's two sample test of homogeneity (U^2) at Amolar Mountain Ridge, Brazilian Pantanal (95% bootstrap confidence intervals are in parentheses).

Predator/prey	Coefficient of overlap	U^2
Ocelot/Azara's agouti	0.31 (0.27-0.36)	6.0166*
Ocelot/Paraguayan purané	0.82 (0.72-0.86)	0.2452
Ocelot/Brazilian rabbit	0.77 (0.62-0.84)	0.2307
Puma/Red brocket deer	0.62 (0.48-0.69)	0.4632*
Puma/Azara's agouti	0.62 (0.50-0.67)	0.4918*
Puma/Gray brocket deer	0.86 (0.73-0.87)	0.0409
Puma/Collared peccary	0.75 (0.57-0.82)	0.1868
Puma/Capybara	0.78 (0.57-0.79)	0.1484
Puma/Tapir	0.56 (0.44-0.62)	0.8723*
Jaguar/Azara's agouti	0.55 (0.48-0.61)	1.0902*
Jaguar/Red brocket deer	0.65 (0.54-0.74)	0.8760*
Jaguar/Gray brocket deer	0.92 (0.82-0.93)	0.0394
Jaguar/Tapir	0.57 (0.48-0.63)	1.5964*
Jaguar/Capybara	0.73 (0.59-0.81)	0.2006
Jaguar/Collared peccary	0.76 (0.62-0.81)	0.1900

*significant differences at $p<0.01$

DISCUSSION

Overall, the species we studied followed activity patterns previously reported in literature (Maffei *et al.* 2002, Gómez *et al.* 2005, Romero-Muñoz *et al.* 2010, and Foster *et al.* 2013). The mostly nocturnal activity pattern observed for crab-eating foxes has also been reported in Chaco-Chiquitano Transitional Forest of Bolivia (Maffei *et al.* 2002), in northeastern Argentina (Di Bitteti *et al*. 2009) and in southeastern Brazil (Vieira and Port 2007). Similarly, nocturnal habits for tapirs have been observed in the Chaco-Chiquitano ecotone of Bolivia (Maffei *et al.* 2002, Romero-Muñoz *et al.* 2010), and in the Amazon Forest (Gómez *et al.* 2005).Activity peaks during the day have been reported for the capybara in another area of the Pantanal (Foster *et al.* 2013), and in the Amazon Forest they are cathemeral (Gómez *et al*. 2005). Gray brocket deer, which was reported as diurnal in areas of Bolivia (Maffei *et al*. 2002, Romero-Muñoz *et al.* 2010), is cathemeral in our study site, while red brocket deer was cathemeral in the Amazon Forest (Gómez *et al.* 2005) as reported in our study. Nocturnal habits of Brazilian rabbit was also found in the Amazon Forest (Gómez *et al.* 2005) and in Bolivia (Maffei *et al.* 2002, Romero-Muñoz *et al*. 2010), and collared peccaries in Bolivia and in the Amazon Forest are reported as diurnal or mostly diurnal (Gómez *et al.* 2005, Romero-Muñoz *et al.* 2010), while in our study site they are cathemeral.

Azara's agoutis were the only animals that showed significant differences in seasonal activity patterns. Oliveira-Santos *et al.* (2013) described Azara's agoutis, in another area of the Pantanal, as being strictly diurnal with crepuscular peaks. Considering that this species presented low levels of temporal overlap with all three feline predators found in our study site (Table 4.4), this may reflect a strategy to reduce the risk of predation (Harmsen *et al.* 2011), since it sleeps inside warrens that are relatively inaccessible to these predators.

Of the feline species, jaguars exhibit cathemeral behavior, differently from the most diurnal pattern observed in other areas of the Pantanal by Crawshaw and Quigley (1991) and Foster *et al.* (2013), while ocelots were predominately nocturnal as reported for the Bosque Chiquitano of Bolivia (Maffei *et al*. 2002), Bolivian Amazon (Gómez *et al*. 2005), the Atlantic Forest of Argentina (Di Bitteti *et al.* 2006), and the Peruvian Amazon (Kolowski and Alonso 2010). As for the jaguar, the puma also proved to be cathemeral in our study site, mirroring observations by Gómez *et al.* (2005) in Bolivia.

According to the competitive exclusion principle, natural selection leads to different patterns of resource exploitation among competitors (Moll and Brown 2008), generating differing resource selection and use of space and time. One of the most important mechanisms for allowing niche-sharing species to coexist is the competition-colonization trade-off, which posits that species that are stronger competitors will be specialists, whereas species that are better colonizers are more likely to be generalists (Rodríguez *et al.* 2007). Three principal hypotheses have been proposed to explain the coexistence of the three cat species studied: 1) distinct use of habitats (Sollmann *et al.* 2012), 2) intake of different prey species (Nuñez *et al.* 2000; Scognamillo *et al.* 2003), and 3) different activity patterns (Monroy-Vilchis *et al.* 2009a; Romero-Muñoz *et al.* 2010). In our study we observed that jaguars and pumas share similar activity patterns, which in turn strongly overlap with some of their known potential prey species, while ocelots presents different activity patterns, having much of their time activity coinciding with some potential prey. In contrast, Romero-Muñoz *et al.* (2010) found in southern Bolivia that jaguars and pumas avoid each other temporally, presumably in order to reduce interference or resource competition, and neither follows the activity pattern of any particular prey species. However, it is likely that other factors such as habitat use (Sollmann *et al.* 2012) or consumption of distinct prey species of different sizes (Nuñez *et al.* 2000) permit the coexistence of jaguars and pumas in the Pantanal. In contrast, due to its smaller size, the activity pattern of the ocelot appears to have diverged in relation to the larger felids, possibly as a mechanism to promote their coexistence (Palomares *et al.* 1996), or even to track the activity of smaller prey (Emmons 1987).

Jaguars and pumas, as opportunistic predators, may feed on a large variety of prey, but they tend to consume mainly medium to large-sized prey (Emmons 1987, Taber *et al.* 1997, Nuñez *et al.* 2000, Monroy-Vilchis *et al.* 2009b). The main jaguar's and puma's mammalian prey in neotropics are both peccaries (*Tayassu pecari*, and *Pecari tajacu*), deers (*Mazama gouazoubira*, and *Mazama americana*), armadillos (*Dasypus novemcinctus*), capybaras (*Hydrochoeris hydrochaeris*) and medium-sized rodents (*Agouti paca*, and *Dasyprocta azarae*) (Emmons 1987, Taber *et al.* 1997, Nuñez *et al.* 2000, Scognamillo *et al.* 2003, Weckel *et al.* 2006, Foster *et al.* 2009). Several studies about some of these preys' activity patterns demonstrated differences according to study areas specifications, but both pecary species (Weckel *et al.* 2006, Romero-Muñoz *et al.* 2010, Harmsen *et al.* 2011), both deer species (Weckel *et al.* 2006, Romero-Muñoz *et al.* 2010, Harmsen *et al.* 2011) and Azara's agouti (Oliveira-Santos *et al.* 2013) tend to be diurnal. Capybaras area essentially diurnal or cathemeral (Crawshaw and Quigley 1991, Maffei *et al*. 2002, Foster *et al.* 2013), and armadillos, and pacas are nocturnal (Maffei *et al.* 2002, Weckel *et al*. 2006, Harmsen *et al*. 2011). Some studies suggested that the activity patterns of felids may be determined by those of their main prey (Emmons 1987, Mendes and Pontes Chivers 2007, Harmsen *et al.* 2011). In this sense, cathemeral behavior of both felids investigated presentes some advantages as they can forage at any time of the day because their known main potential prey in the study site are also cathemeral or diurnal. This is useful also considering that jaguars and pumas may consume same prey species (Nuñez *et al.* 2000). Consequently, since pumas are ecologically more plastic, they may respond to a possible competition by broadening their prey niche (Nuñez *et al*. 2000) or even by taking the same species as jaguars but targeting a different age class (Scognamillo *et al.* 2003). In contrast, red brocket deer, which is described as diurnal or cathemeral in other study sites (Gómez *et al*. 2005, Weckel *et al*. 2006, Harmsen *et al*. 2011), showed the lowest level of activity overlap with jaguars and pumas, being mostly nocturnal, suggesting an adaptation of its activity as an anti-predation strategy (Harmsen *et al.* 2011, Ross *et al*. 2013).

As smaller predators, ocelots are expected to exploit smaller prey (Davies *et al.* 2007; Bianchi 2009). In fact its activity overlaps extensively with that of two small mammals, Paraguayan punaré and the Brazilian rabbit. Ocelots may allocate hunting effort to other small species in the Brazilian Pantanal, such as opossums (*Philander opossum*), but the low number of records of this species in our dataset did not allow us to carry out more extensive analyses.

In conclusion, camera trapping can be considered an efficient tool to provide a general overview about mammals' activity patterns during the dry and wet season, and to analyze predators and known potential prey temporal overlap. Nevertheless, future studies addressing prey abundance, availability and consumption by these predators, as well as the spatial interactions among them, could shed further light upon the mechanisms involved in predator-prey interactions in our study site, aside from the temporal separation investigated here.

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"Pode o homem enriquecer a natureza em sua incompletude?" Manoel de Barros

CHAPTER 4

Occupancy and detectability patterns of felids at Amolar Mountain Ridge, Brazilian Pantanal

Manuscript in preparation

ABSTRACT

Conceptually, occupancy models have been used to estimate the proportion of sites or sampled areas occupied by a target species. Recently, this approach has been widely used in medium- to long-term monitoring programs, and to study others aspects such as niche partitioning between competitors. In this study, we investigated the factors affecting jaguar, puma and ocelot occupancy and detectability patterns using camera trapping and single season species occupancy models, accounting for imperfect detection. We predicted that jaguars and pumas, known to be competitors, would prefer different habitats in order to promote coexistence. This pattern was also expected for ocelots, which may be associated with niche partitioning (avoidance of larger felids) or may be associated with the availability of preferred prey. The major findings of this study were: 1) jaguar occupancy was influenced by prey abundance; 2) puma occupancy was influenced primarily by the density of patches and then by prey abundance, which may have contributed to potential competition with jaguars; 3) ocelot occupancy was influenced by pioneer herbaceous formations. Puma occupancy was not influenced by jaguar presence, while ocelots were not affected by the presence of either jaguars or pumas. Methodologically, this approach may be among the most appropriate tool to monitor felids in the medium- to long-term in our study site due to its effectiveness and low costs. This approach, in addition to investigations of feeding habits and prey occurrence, may increase our understanding of the interspecific interactions of felids at Amolar Mountain Ridge, thereby facilitating decision-making processes related to wildlife conservation.

Keywords: jaguar, puma, ocelot, Pantanal, Amolar Mountain Ridge, occupancy modeling.

INTRODUCTION

Amolar Mountain Ridge (AMR) is considered a high priority area for biodiversity conservation within the Pantanal biome (MMA, 2007). The region presents a high diversity of habitats as a result of the influence of neighboring biomes such as the Chaco, Amazon Forest and Cerrado, which explains the rich local biodiversity (Porfirio *et al*., submitted). A major part of AMR is currently protected by a set of Private Natural Heritage Reserves, ranches and a National Park, comprising a private initiative known as Rede de Proteção e Conservação da Serra do Amolar (Network for the Protection and Conservation of Amolar Mountain Ridge) that legally protects over 200,000 hectares of the region (Bertassoni *et al*., 2012). Since almost 95% of the Pantanal is comprised of private lands dedicated to cattle ranching (Seidl *et al*., 2001), this initiative represents a significant conservation effort within the Brazilian portion of the biome.

AMR also acts as a refuge for several endangered species of mammals such as giant river otters (*Pteronura brasiliensis*), tapirs (*Tapirus terrestris*) and giant armadillos (*Priodontes maximus*) (Porfirio *et al*., submitted). Felids recorded from the region include jaguar (*Panthera onca*), puma (*Puma concolor*), ocelot (*Leopardus pardalis*) and jaguarundi (*Puma yagouaroundi*). The jaguar is considered globally and nationally threatened (Near Threatened and Vulnerable *status*, respectively by IUCN, 2013 and MMA, 2008), while the other species are nationally threatened (Vulnerable *status* by MMA, 2008), with legal protection reinforcing the commitment of landowners to their conservation.

Jaguars, pumas and ocelots coexist in most of the Neotropics (Sunquist and Sunquist, 2002; Di Bitteti *et al*., 2010). As a result, some level of differentiation is expected in terms of their use of trophic, temporal and spatial resources in order to facilitate and promote coexistence (Schoener, 1974). Despite the great overlap in geographic ranges, similar size, morphology and diets (Nuñez *et al*., 2000; Harmsen *et al*., 2009), jaguars and pumas can coexist by using different habitats (Sollmann *et al*., 2012), consuming prey of different ages or sizes (Nuñez *et al*., 2000; Scognamillo *et al*., 2003), or by having different activity budgets (Monroy-Vilchis *et al*., 2009; Romero-Muñoz *et al*., 2010). Ocelots are smaller (Di Bitteti *et al*., 2010) and usually target smaller prey (Emmons, 1987). Although in some regions there can be some degree of overlap between ocelots, jaguars and pumas in terms of prey consumption (Sunquist and Sunquist, 2002), ocelots usually exhibit differing activity patterns to these larger felids, possibly as a mechanism to avoid predation (Emmons, 1989; Di Bitteti *et al*., 2006), and tend to target different prey resources to avoid competition (Emmons, 1987; Porfirio *et al*., submitted).

Jaguars, pumas and ocelots are key components of neotropical ecosystems exerting strong influences on the structuring of forest communities (Terborgh, 1990). As top predators they regulate the abundance and density of their prey, which otherwise would negatively impact vegetation diversity (Terborgh, 1988; Terborgh *et al*., 2006). Jaguars in particular are considered indicator species, and their presence usually reflects a healthy ecosystem, so obtaining data about their presence and ecological requirements may help in decision-making processes in terms of identifying areas that merit protection (Miller and Rabinowitz, 2002). Additionally, under the concept of umbrella species, jaguars can play an important role in the conservation of neotropical biodiversity (Linnel *et al*., 2000; Davis *et al*., 2011).

This study of feline species in AMR presents a valuable opportunity to understand interspecific relationships within an area that is little affected by the presence of livestock, which is almost impossible in other places of the Pantanal due to the dominance of this land use activity (Seidl *et al.*, 2001). Livestock presence can lead to changes in the natural habits of felids (Crawshaw, 2004; Palmeira *et al*., 2008). Furthermore, due to the low level of human disturbance, which can also affect species' habits (Di Bitteti *et al*., 2010; Sollmann *et al*., 2012), and to the dramatic environmental changes due to inundation and desiccation phases characteristic of the Pantanal, AMR is also an interesting place to assess patterns of spatial habitat use by these felids based on niche partitioning theory (Schoener, 1974).

In this context, occupancy and co-occurrence models have been widely used in wildlife monitoring and conservation programs in recent years (Jackson *et al*., 2005; O'Connell *et al*., 2006; Zeller *et al*., 2011; Long *et al*., 2011; Sollmann *et al*., 2012; Rich *et al*., 2013). Investigations concerning the effects of environmental covariates on species occurrence are fundamental to effective conservation (Karanth *et al*., 2009). Such methods have also been proven to be successful for testing assumptions of niche partitioning theory among species, clarifying aspects of species coexistence (Sollmann *et al*., 2012; Cruz *et al*., submitted).

In this study, we investigated the factors affecting jaguar, puma and ocelot occupancy and detectability patterns using camera trapping and single season species occupancy models, accounting for imperfect species detection (MacKenzie *et al*., 2002; MacKenzie *et al*., 2006). Since jaguars and pumas have similar activity patterns in our study site, and possibly share the same potential prey resources (Porfirio *et al*., submitted), we expected differences in spatial habitat use as a mechanism to promote their coexistence. Likewise, we also expected differences in occurrence regarding ocelots related to niche partitioning with other felids (Schoener, 1974) or even related to the availability of potential prey in such habitats (Nuñez *et al*., 2000).

MATERIAL AND METHODS

Study Site

The study was carried out at two sites of AMR: Santa Tereza ranch (57°30’10”W, 18°18’38”S) and Engenheiro Eliezer Batista Private Natural Heritage Reserve (57°28’24”W, 18°05’25”S). Both estates are of approximately 830 km^2. AMR is situated in the state of Mato Grosso do Sul, approximately 180 km north of Corumbá, in the Upper Paraguai Basin, close to the border with Bolivia and Mato Grosso state (Figure 4.1). The climate of the Upper Paraguay Basin (APB) is considered seasonal and as tropical savannah (AW) according to the Köppen classification, with hot and humid weather in the summer, and dry and cold weather during the winter, with annual average precipitation of 1,300 mm (PCBAP, 1997). The predominant vegetation found in the study site is composed of seasonal semi-deciduous alluvial forest, pioneer herbaceous formations, and seasonal sub-montane deciduous forest, together with dry and flooded savannas (Sá Arruda *et al*., 2012). To date, 33 mammal species have been identified at AMR, including four species of felids and potential prey such as capybaras (*Hydrochoeris hydrochaeris*), gray brocket deer (*Mazama gouazoubira*), red brocket deer (*Mazama americana*), collared peccary (*Pecari tajacu*) and Azara’s agouti (*Dasyprocta azarae*) (Porfirio *et al*., submitted).

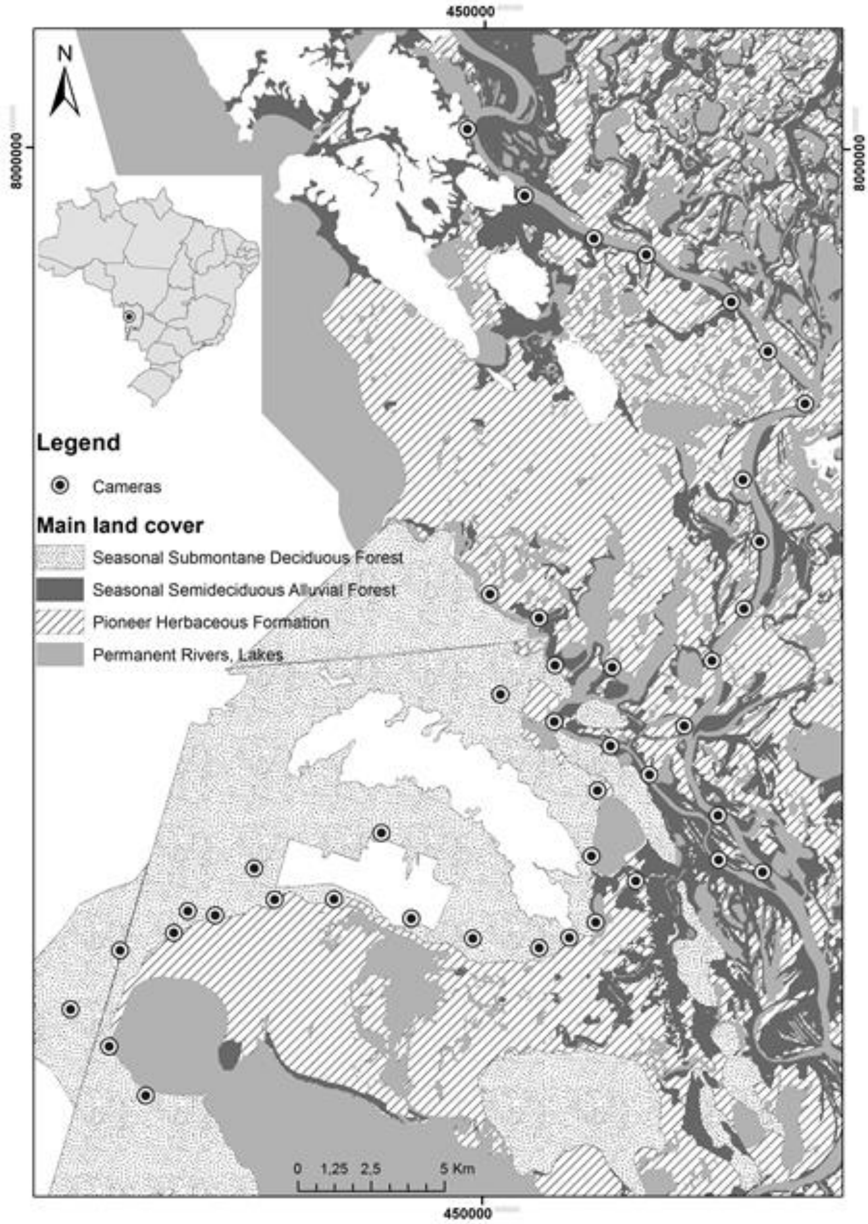


Figure 4.1: Study area and the location of the camera traps at Amolar Mountain Ridge installed in 2012-2013. Inset shows the general location of the study site in Brazil and of the Brazilian Pantanal.

Camera trapping

Felid presence was assessed between November 2012 and May 2013 using camera traps (Bushnell Trophy Cam, Kansas, USA; Panthera V3, New York, USA; Tigrinus Conventional 6C). Due to the low number of camera traps available, surveys were first carried out at Engenheiro Eliezer Batista (November 2012 – February 2013) and then at Santa Tereza Ranch (March 2013 – May 2013) (Figure 4.1), using 21 cameras per survey. Cameras were placed in trees, at 45-50 cm above ground, in bushes and along dirt roads, and were spaced approximately 2.0-2.5 km apart to ensure spatial independence (Sollmann *et al*., 2012). Cameras operated 24 hours/day for approximately 85 days per survey, with 30-second intervals between pictures for the digital cameras and five minute intervals for the analogic cameras. Stations, which consisted of one camera, were checked at 20-30 day intervals to change batteries and film and to download pictures.

Explanatory variables

To investigate factors affecting the patterns of occupancy (ψ) and detectability (*p*) of felids, we used four groups of explanatory variables: landscape structure, landscape cover, prey abundance and competitor abundance (Table 4.1). Landscape structure and landscape cover were estimated based on a 2000 meter buffer placed around the cameras. Landscape variables such as area and edge, aggregation and diversity were estimated using FRAGSTAT 4.0 software at an 8-m cell resolution (McGarigal *et al*., 2012), and ArcGIS 10.2 (ESRI). Continuous covariates were standardized to z-scores in order to carry out the analysis (Royle and Nichols, 2003). Covariate exploration was conducted in order to find outliers and to select those that were not correlated. To assess collinearity, we used a Spearman rank correlation coefficient script built into TINN-R software. The value of ± 0.5 was chosen to indicate high collinearity between covariates (Zuur *et al*., 2009), in which case one covariate was excluded from the analysis. Some covariates were log transformed in order to be used in the models.

Table 4.1: Description and summary of the explanatory variables used to examine the influence of landscape, prey abundance and competitor abundance on felid occupancy and detectability at AMR.

Variable (unit)	Code	Description	Transformation
Landscape Cover (%)		% of each land cover	
Seasonal Semi-deciduous Alluvial Forest	FESA		Logarithmic
Pioneer Herbaceous Formation	FPH		Logarithmic
Permanent Rivers and Lakes	RP		Logarithmic
Seasonal Sub-monante Deciduous Forest	FEDS		
Landscape structure			
Patch density	PD	Density of patches at landscape level	Logarithmic
Largest Patch Index (%)	LPI	The percentage of the landscape comprised by the largest patch (measures the dominance)	
Edge Density (m/ha)	ED	Length of edge structures per hectare	Logarithmic
Landscape Shape Index	LSI	Measures the perimeter-to-area ratio (a more complex shape will have a higher ratio than a less complex shape)	
Patch Richness	PR	Number of patches	
Shannon's Diversity Index	SHDI	Measure of relative patch diversity	
Shannon's Evenness index	SHEI	Measure of patch distribution and abundance	
Prey abundance	Prey	Sum of potential prey	

	abundance per each site given by induced abundance heterogeneity models *
Competitor Abundance	Consisted of the average number of independent jaguar and puma detections per site**

*Royle and Nichols, 2003; **Used only in ocelot and puma modeling.

An estimation of prey abundance for each site was calculated using induced abundance heterogeneity models (Royle and Nichols, 2003). This model allows the estimation of species abundance without the necessity of individual identification, based only on species presence or absence in each site. Occupancy estimation is used under the basic assumption that heterogeneity in detection can be modeled through time or site-specific covariates (Royle and Nichols, 2003; Mackenzie and Royle, 2005). However, variations in local abundance can result in variation in a species detection probability among sites that could be difficult to model (Royle, 2006). So, detection probability will have a tendency to increase with a species' local abundance. In study areas where species abundance varies between sites, this will cause substantial heterogeneity in the detection probability, particularly in gregarious mammals. This is the basis for the model developed by Royle and Nichols (2003), where exploration of the relationship between abundance, detection and occupancy can be used to estimate the first parameter. According to this model, the site-specific detection probability is expressed by:

$$p_i = 1 - (1 - r)^{N_i}$$

Where p_i is the probability of detecting at least one individual of the target species at site i, r is the individual detection probability, and N_i is the abundance at site i. These constitute the real parameters of the model. When local abundance is unknown, but is likely to be static during the sampling period, it can be modeled using a Poisson, zero-inflated Poisson or a negative binomial distribution (Wenger and Freeman, 2008). In our case, and considering the low number of zeros, we used a Poisson distribution with a mean λ, which represents the average number of individuals in each site. In this model, occupancy is calculated as a derived parameter using the formula:

$$\varphi = \Pr(N > 0) = 1 - r^{-\lambda}$$

We ran analyses with the package 'unmarked' (Fiske and Chandler, 2011) of the software R (R Development Core Team, 2012) using the function occRN. This model has three assumptions: I) animal detections need to be independent, II) the number of animals at each site (N) needs to be constant during the survey, III) detectability of each animal needs to be constant throughout the survey. We met these assumptions by widely spacing the cameras, by reducing the time that cameras were in the field (~85 days) (Sarmento *et al*., 2010), and by creating 17 sampling occasions of 5 consecutive days making the heterogeneity in detection more evident. Capture histories were constructed using binary code for presence (1) and absence (0). Prey abundance at each site was estimated using an empirical Bayes method and posterior lambda distributions by employing the function ranef in the 'unmarked' R statistical package. This method returns an object storing the posterior distribution of the latent variable at each site (Royle and Dorazio, 2008).

Competitor abundance variables consisted of the average number of jaguar and puma independent detections per site (more than 24 hours apart) for each trapping occasion. Jaguar and puma abundance were used for the ocelot models, and jaguar abundance was used for the puma models.

Single-species detectability and occupancy models

We estimated jaguar, puma and ocelot occupancy (ψ) and detectability (*p*) using a maximum likelihood framework from our detection/non-detection data (MacKenzie *et al.*, 2002; MacKenzie *et al*., 2006). The detection histories (h_i) of the targeted species were constructed for each camera trap location over a 15-day sampling period. Conceptually, occupancy models have been used to estimate the proportion of sites or sampled areas occupied by a target species (MacKenzie *et al*., 2002). Such models account for the probability that a species is present (confirmed presence), and that a species is not detected (complete absence or undetected during the surveys) (MacKenzie *et al*., 2006). By using detection (1) and non-detection (0) data collected across multiple sites and recorded as a detection history (h_i), it is possible to estimate detection probabilities (*p*) and the proportion of sites occupied by a target species (ψ) (MacKenzie *et al.*, 2006). A probability of observing a particular detection history is translated into the following equation:

$$Pr(h_i=0101)= \psi(1-p_1)p_2(1-p_3)p_4,$$

which means that a site was occupied by a species that was not detected on the first and third occasions, but was on the second and fourth (MacKenzie *et al.*, 2006). However, in real terms, it is expected that there will be some influence of site characteristics (such as habitat type, patch size and density or abundance of prey) on occupancy, as well as variation in *p* due to, for example, weather conditions (MacKenzie *et al.*, 2002). Thus, covariate effects can be introduced into the model to predict species occupancy and detectability patterns (MacKenzie *et al.*, 2002; Long *et al.*, 2011), thereby accounting for imperfect detectability (Wintle *et al.*, 2005; MacKenzie *et al.*, 2006).

We ran analyses in R 2.15.3 version (R Core Development Team, 2013) using the package 'unmarked' (Fiske and Chandler, 2011) in order to carry out single-season, single-species models including covariate effects (Long *et al.*, 2011). The data was analyzed following a 2-step approach (Sarmento *et al.*, 2010; Long *et al.*, 2011), first calculating the effects of covariates on detection probabilities, keeping occupancy constant (i.e. ψ [.] p[covariates]), and then using the best-fitting model for detection probabilities to create models integrating covariates to explain patterns of occupancy. To model detection, we used the covariates that were most likely to affect movement (habitat variables, prey abundance and felid abundance to model *p* for pumas and ocelots) (Negrões *et al.*, 2010). To model occupancy, we used the entire set of variables, with the exceptions highlighted above for competition. First, we constructed the saturated model, and then using the dredge function of the MuMin package (Bartón, 2013), we ran the entire set of possible models, which were ordered by AIC (Akaike Information Criteria). Models with Δ AIC values ≤ 2 from the most parsimonious model were considered robustly supported, and the variables used were then considered determinant in species occurrence patterns based on Akaike's weight for each one (Sarmento *et al.*, 2010). Except if a single model had a $\omega_i > 0.90$, other models were also considered when making inferences about the data using a model averaging technique (Anderson and Burnham, 2002). A 90% confidence model set was created by summing all ω_i up to 0.90. A likelihood ratio (LR) test were used to find significant differences among the models based on deviance (-2logL) between pairs of models and the critical value of the χ^2 distribution. Selected models allowed the average estimates of occupancy and detectability to be calculated for each site, giving a final average estimate for the season. For each model, we estimated overdispersion using the observed chi-square goodness-of-fit (GOF) statistic, and by calculating the $\hat{c}$ parameter (Mackenzie and Royle, 2005), for which values should be close to 1 if there is no overdispersion.

RESULTS

With an effort of 3,486 camera-days, we recorded 137 independent detections of jaguars (n=52), pumas (n=20) and ocelots (n=65). Induced abundance heterogeneity models were run on five potential prey species for felids: tapir, gray brocket deer, red brocket deer, capybara and azara's agouti (Table 4.2). Tapir had the highest average abundance per site (λ=0.57±0.13), followed by azara's agouti (λ=0.54±0.12), red brocket deer (λ=0.46±0.19), gray brocket deer (λ=0.42±0.11), and capybara (λ=0.20±0.08) (Figure 4.2).

JAGUAR

Jaguars were detected at 21 sites, which corresponded to a naïve site occupancy of 0.50. We obtained three models with a Δ AIC $\leq$ 2 and with a cumulative AIC weight of 0.95 (Table 4.3). Since the LR test did not reveal significant differences between them (χ^2 = 5.579, p> 0.133 between model Jg1 and Jg2; χ^2 = 0.332, p> 0.564 between model Jg2 and Jg3; χ^2 = 5.911, p> 0.205 between model Jg1 and Jg3), we used all of them to predict average jaguar occupancy and detectability. Two covariates had a significant positive effect on detection, pioneer herbaceous formation (LogFPH) and prey abundance, both having positive β coefficients with a SE that did not overlap zero (Table 4.4). Permanent rivers and lakes (LogRP) had a significant negative influence on detection probability, while LogFPH and prey abundance had positive influences on jaguar detectability (Table 4.4, Figure 4.3). The most significant covariate predicting occupancy was prey abundance, which appeared in the three models and had a sum of AIC weights of 0.954 (Table 4.5;

Figure 4.4). LogFPH had a significant negative effect on jaguar occupancy, whereas LogRP and LogPD had significant positive effects (Table 4.4). The average probability of detecting jaguar at a given site was equivalent to 0.19 (mean ±SE: 0.19±0.062), and the most robust models estimated that 0.78 of the surveyed area was occupied by jaguars (mean ±SE: 0.78±0.18) (Figure 4.5).

PUMA

Pumas were detected at 5 sites, which corresponded to a naïve site occupancy of 0.11. Three models with a Δ AIC ≤ 2 and with a cumulative weight of 0.93 were obtained for pumas (Table 4.3). Since the LR test did not reveal significant differences between the first two models ($\chi^2 = 0.407$, p> 0.523) and it was not possible to apply the test for the third since the degrees of freedom were 0, the three were chosen to predict puma occupancy and detectability (Table 4.3). The detection probability was only influenced by prey abundance, for which β coefficients were positive and SEs did not overlap zero (Table 4.4, Figure 4.3). Occupancy was mostly influenced by LogPD (Table 4.5), which was present in the top two ranking models and had a positive and significant influence (Table 4.4). Prey abundance was also an important variable for modeling occupancy and had a positive significant effect (Tables 4.4 and 4.5; Figure 4.4). The variable LogFPH was the least important variable. Occupancy by pumas was not influenced by jaguar abundance (models with Δ AIC ≤ 2, and SEs higher than β coefficients). Models predicted that 0.35 of the surveyed area was occupied by puma (mean ±SE: 0.35±0.21) (Figure 4.5), while the average probability of detecting puma at a given site was 0.10 (mean ±SE: 0.10±0.04).

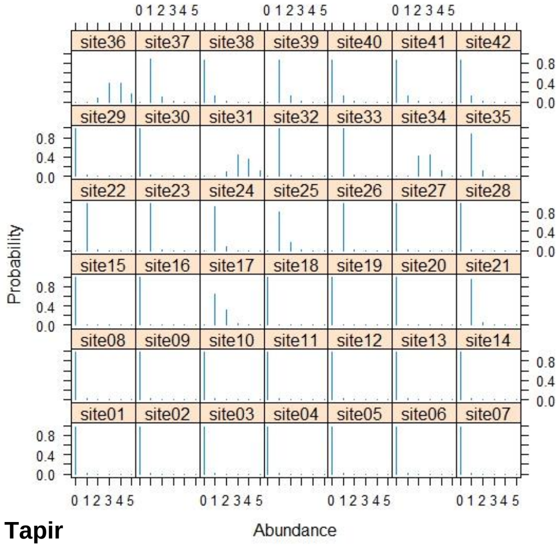
OCELOT

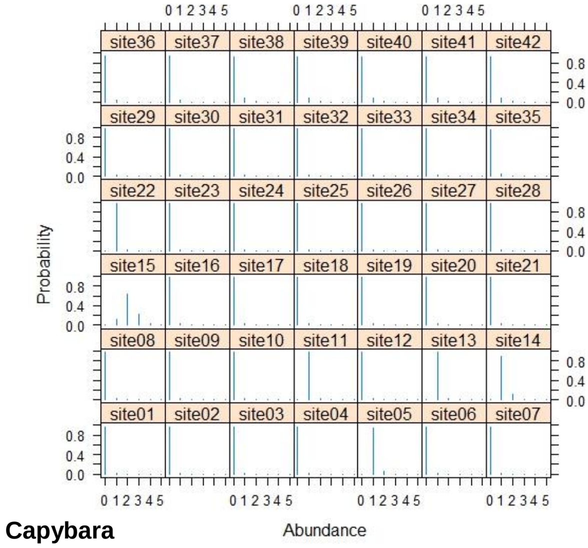
Ocelots were detected at 20 sites, which corresponded to a naïve site occupancy of 0.47. Three models were obtained for ocelot with a Δ AIC ≤ 2 and with a cumulative weight of 0.93 (Table 4.3). The LR test did not reveal significant differences between these three models ($\chi^2 = 0.308$, p> 0.079 between model 1 and 2; $\chi^2 = 0.309$, p> 0.078 between model 1 and 3; and between model 2 and 3 it was not possible to apply the test since the degrees of freedom were 0) and so all three were chosen to predict ocelot occupancy and detectability. Ocelot detectability was negatively influenced by permanent rivers and lakes (LogRP) (Table 4.4, Figure 4.3). Although FEDS (Seasonal Sub-montane Deciduous

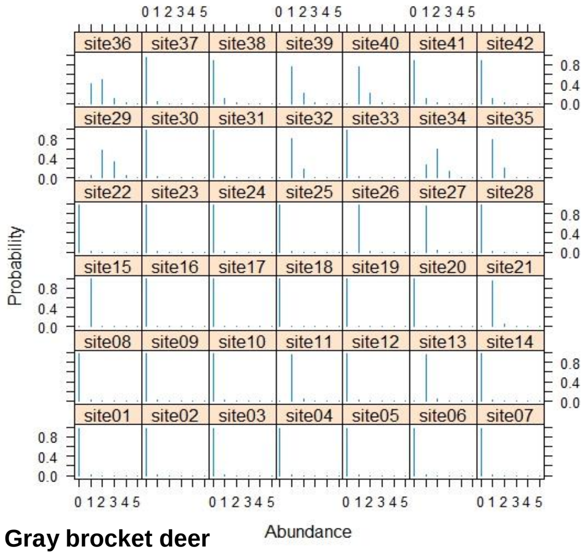
Forest) appeared in top position in the covariate ranking, its SEs were all higher than the estimated β coefficients (see Table 4.4). Therefore, the best covariate to explain ocelot occupancy was defined by pioneer herbaceous formations (LogFPH), which had a significant positive effect (Tables 4.4 and 4.5; Figure 4.4). Ocelot occupancy was not influenced by jaguars and pumas (models with Δ AIC ≤ 2, and SEs higher than β coefficients). Models predicted that 0.55 of the surveyed area was occupied by ocelot (mean ±SE: 0.55±0.16) (Figure 4.5), while the average probability of detecting ocelots at a given site was 0.32 (mean ±SE: 0.32±0.10).

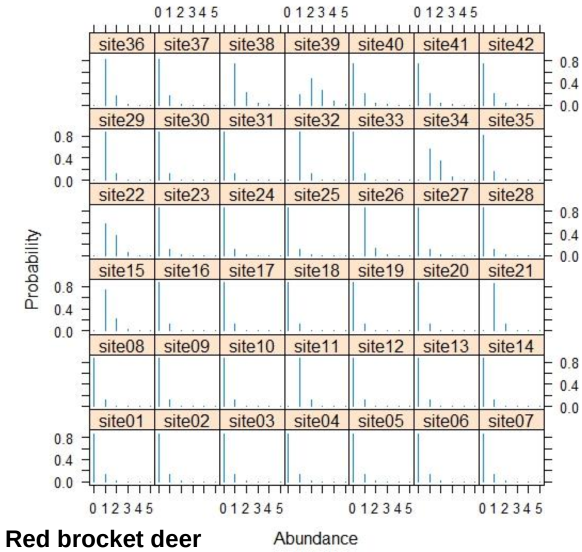
Table 4.2: Induced abundance heterogeneity models used to estimate prey abundance for each surveyed site and the respective number of parameters estimated, AIC, delta AIC, AIC weight and cumulative weight.

Species	models	n pars	AIC	Δ AIC	AICw	$Cumul_w$
Azara's agouti Ag1	λ (.) *r*(.)	2	307.79	0.00	0.999	1.00
Red brocket deer Rb1	λ (.) *r*(.)	2	290.66	0.00	0.991	0.99
Tapir Tp1	λ (.) *r*(.)	2	290.66	0.00	0.991	0.99
Gray brocket deer Gb2	λ (.) *r*(.)	2	251.92	0.00	0.994	0.99
Capybara Cap1	λ (.) *r*(.)	2	123.02	0.00	0.997	1.00









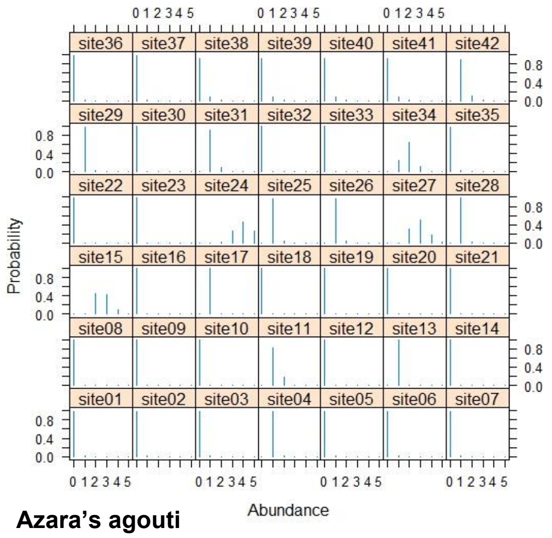


Figure 4.2: Posterior distributions of estimated abundance of prey per site at Amolar Mountain Ridge (2012-2013) based on induced abundance heterogeneity models (Royle and Nichols, 2003).

Table 4.3: Comparative list of the most robust models exploring the covariates for occupancy of jaguar, puma and ocelot at AMR.

Species	Model	n Pars	AIC	ΔAIC	AIC_w	$Cumul_w$	$\hat{c}$
Jaguar							
Jg_1	Ψ (Prey) *p*(LogFPH+LogRP+Prey)	6	176.80	0.00	0.441	0.44	1.27
Jg_2	*Ψ*(LogFPH+LogRP+LogPD+Prey) *p*(LogFPH+LogRP+Prey)	9	177.22	0.42	0.358	0.80	1.02
Jg_3	*Ψ*(LogFESA+LogFPH+LogRP+LogPD+Prey) *p*(LogFPH+LogRP+Prey)	10	178.89	2.09	0.155	0.95	1.02
Puma							
Pm_1	*Ψ*(LogPD) *p*(Prey)	4	57.48	0.00	0.546	0.55	1.00
Pm_2	*Ψ*(LogPD+Prey) *p*(Prey)	5	59.07	1.59	0.246	0.79	1.37
Pm3	*Ψ*(LogFPH) *p*(Prey)	4	60.17	2.70	0.142	0.93	1.28
Ocelot							
Oc_1	*Ψ*(FEDS+LogFPH+PR) *p*(LogRP)	6	199.12	0.00	0.432	0.43	1.00
Oc_2	*Ψ*(FEDS+LogPD) *p*(LogRP)	5	200.20	1.08	0.252	0.68	0.96
Oc_3	*Ψ*(FEDS+LogFPH) *p*(LogRP)	5	200.22	1.10	0.249	0.93	1.00

Table 4.4: Estimates of beta coefficients and standard error (SE) for covariates contained in the best models for felid occupancy at AMR.

Species	***Ψ***								***p***			
	Intercept	LogFPH	LogRP	LogPD	Prey	LogFESA	FEDS	PR	Intercept	Prey	LogRP	LogFPH
Jaguar												
Jg_1	1.65(0.83)				2.10(1.16)				-156 (0.28)	0.36(0.24)	-0.58(0.27)	1.00(0.30)
Jg_2	5.79(3.53)	-4.46(3.18)	3.39(2.99)	2.30(1.98)	3.33(2.11)				-1.73 (0.24)	0.50(0.21)	-0.69(0.25)	1.18(0.28)
Jg_3	5.63(3.32)	-4.31(2.79)	2.29(3.20)	2.58(2.02)	3.61(2.16)	1.53(2.68)			-1.72 (0.23)	0.49(0.21)	-0.68(0.25)	1.17(0.28)
Puma												
Pm_1	-3.31(2.38)			6.68(4.55)					-2.90 (0.64)	1.32(0.37)		
Pm_2	-5.04(1.37)			7.09(4.63)	0.78(1.09)				-2.51 (0.89)	1.13(0.48)		
Pm_3	0.68(1.37)	2.5 (2.05)							-3.46 (0.70)	1.53(0.38)		
Ocelot												
Oc_1	4.28(5.01)	0.89(0.68)					16.70(19.95)	-0.73(0.45)	-19.2(6.94)		-119.3(44.55)	
Oc_2	2.93(4.49)			0.46(0.39)			11.43(17.99)		-18.6(7.58)		-115.8(48.57)	
Oc_3	4.69(4.90)	0.66(0.60)					18.38(19.51)		-18.9(7.04)		-117.8(45.16)	

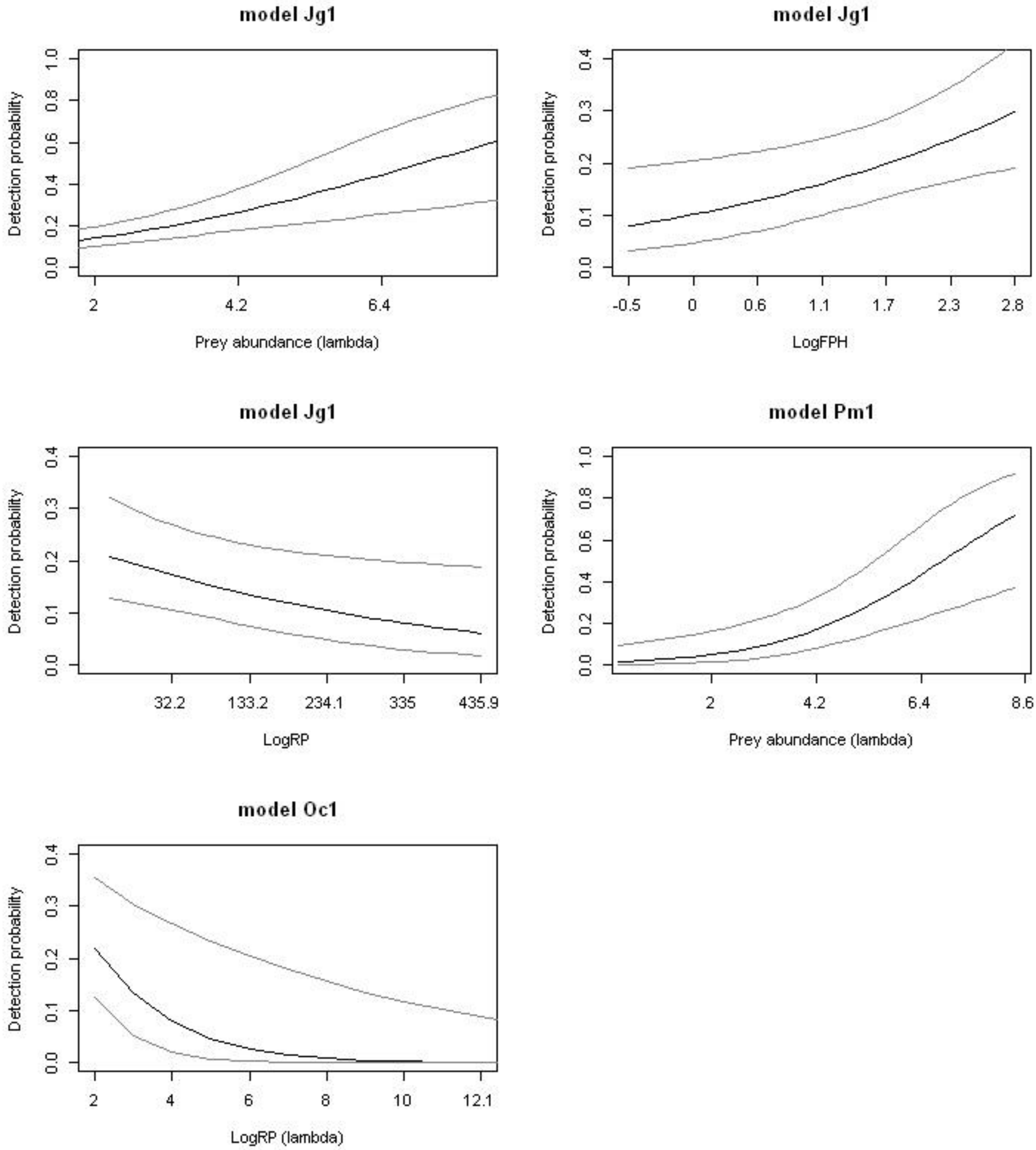


Figure 4.3: Estimated probabilities of felid detection as a function of the covariates of first selected models based on Δ AIC. Jg1 (Jaguar); Pm1 (Puma); Oc1 (Ocelot).

Table 4.5: Sum of AIC weights and covariate ranking based on weight for all candidate models for felid occupancy at AMR.

Species	Covariate	Sum AIC weights
Jaguar	Prey	0.954
	LogFPH	0.513
	LogRP	0.513
	LogPD	0.513
	LogFESA	0.155
Puma	LogPD	0.792
	Prey	0.246
	LogFPH	0.142
Ocelot	FEDS	0.933
	LogFPH	0.748
	PR	0.499
	LogPD	0.252

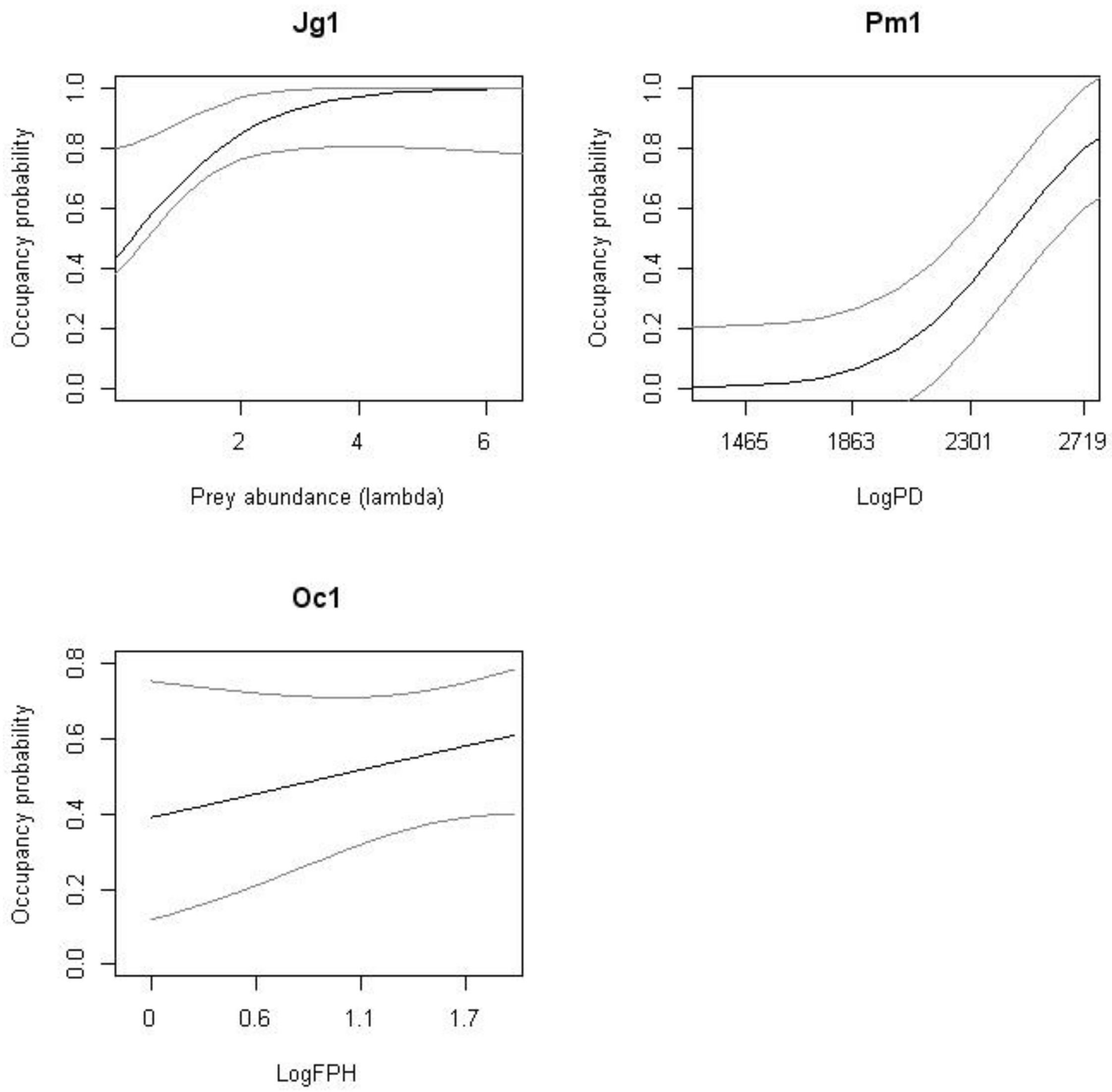


Figure 4.4: Estimated probabilities of felid occupancy as a function of the covariates of first selected models based on Δ AIC. Jg1 (Jaguar); Pm1 (Puma); Oc1 (Ocelot).

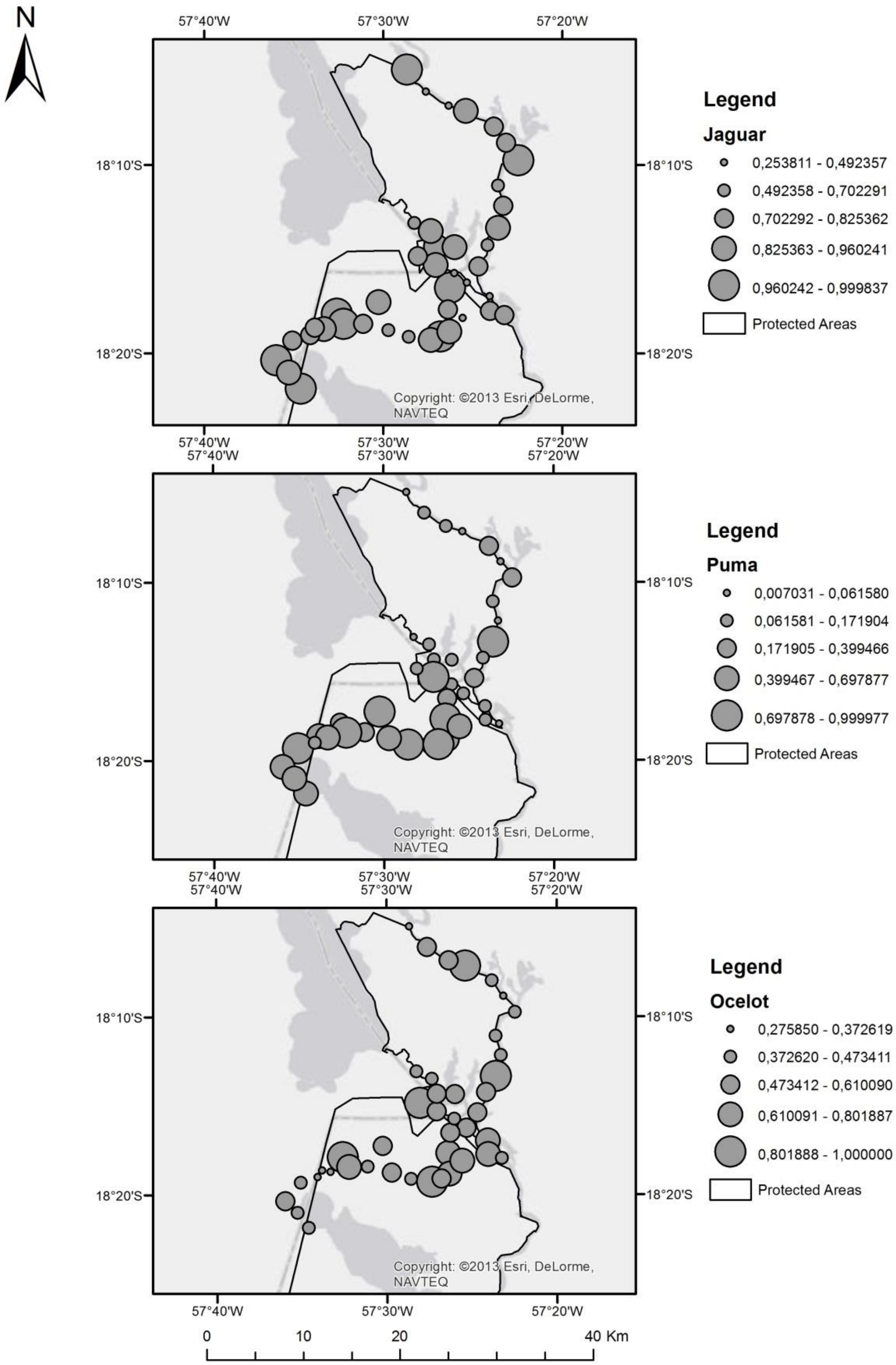


Figure 4.5: Felid occupancy estimation per site at Amolar Mountain Ridge between 2012-2013.

DISCUSSION

Traditionally, coexistence between sympatric species with similar habits is explained by niche partitioning theory (Schoener, 1974; Gordon, 2000). For carnivores, such approaches have focused on how species share resources in terms of diet (Taber *et al*., 1997; Nuñez *et al*., 2000; Gatti *et al*., 2006), time (Di Bitteti *et al*., 2009; Foster *et al*., 2013) and space (Palomares *et al*., 1996; Sollmann *et al*., 2012), or even considering at least two of these dimensions (Scognamillo *et al*., 2003; Jácomo *et al*., 2004; Vieira and Port, 2007). Investigating spatial scale, overall, we found that jaguars, pumas and ocelots responded differently to covariates influencing occupancy patterns (Long *et al*., 2011), which may contribute to their coexistence (Sollmann *et al*., 2012).

Although occasionally they were detected in the same sites, we found some evidence of habitat use segregation among felid species, which was apparent in the differences for occupancy estimates for each species. Such behavior may be revealed by incorporating imperfect detection probability parameters (detection probability < 1) into occupancy models (Royle and Nichols, 2005). This is a fundamental concern in occupancy estimates, since detectability may vary both spatially and temporally (Mackenzie *et al*., 2002; Royle and Nichols, 2005). Therefore, inferences that do not deal with imperfect detection may be biased since condition is seldom encountered in field sampling of animal populations (Royle and Nichols, 2005).

Jaguar occurrence was primarily positively influenced by prey abundance and, secondarily, by permanent rivers and lakes and patch density, while it was negatively influenced by pioneer herbaceous formation. In fact, jaguars are generally described as opportunistic predators (Rabinowitz and Notthingham, 1986; Aranda and Sanchez-Cordero, 1996), using prey relative to its abundance (Weckel *et al.*, 2006). Prey abundance exerts a strong influence on jaguar occupancy in our study area, reinforcing the idea that prey availability is one of the main factors affecting the ecological behavior of felids, even influencing the patterns of coexistence (Nuñez *et al*., 2000; Ramalho, 2006). The jaguar's preference for dense habitats close to water has been documented before (Emmons, 1987), including in the Pantanal (Crawshaw and Quigley, 1991).

In contrast, puma occupancy was mostly influenced by the density of patches and, secondarily, by prey abundance and pioneer herbaceous formation. Historically, pumas are reported to prefer forested areas or open and dry habitats (Franklin *et al*., 1999; Nuñez *et* *al*., 2000; Romero-Muñoz *et al*., 2010). Dense vegetative cover may be preferred since it offers a variety of resources that favor felid survival, such as camouflage to ambush prey, refuge and protection for cubs (Monroy-Vilchis *et al*., 2009). In our study site, the preferences observed may also be associated with prey availability in the dense dry forested areas (found mainly at Santa Tereza ranch), since prey abundance was the second-most important covariate driving puma occupancy. This effect may increase potential competition with jaguars, which are described as a dominant competitor over puma in the Pantanal (Crawshaw and Quigley, 1991). This dominance may be the reason why pumas seem to be rare in places where jaguars are abundant (Azevedo and Murray, 2007). In fact, we expected some level of segregation in habitat use by these felids, since they significantly overlapped at the temporal scale, and demonstrated high levels of activity overlap with the same potential prey species (Porfirio *et al*., submitted). However, due to our low capture rates for pumas, especially at Engenheiro Eliezer Batista site for which more than 58% of its area is permanently flooded (Porfirio *et al*., submitted), and the puma's preference for drier habitats (Nuñez *et al*., 2000), our data suggest that puma abundance and density are low at AMR, so that jaguar abundance apparently does not influence puma occupancy in our study area. Nevertheless, pumas merit further investigation due to the low detection probabilities observed (0.10±0.04). According to O'Connell *et al*. (2006), when detection probabilities fall below 0.15, the occupancy models produced may not be appropriate for use. In such cases, these authors suggest some additional effort in order to increase detection rates; for example, by reallocating sampling effort, extending periods of surveys, or even changing the methodologies used in order to provide more precise assessment of site occupancy.

Ocelot occupancy, in turn, was influenced primarily by pioneer herbaceous formation, which is comprised of shrubs and native pastures mixed with flooded and dry habitat, and secondly by patch richness. Although ocelots may occur in different habitats, such as tropical-dry and humid forests, riverbanks and swampy savannas (Murray and Gardner, 1997), they are documented as preferring closed habitats and dense thorny shrubs (Murray and Gardner, 1997; Haines *et al*., 2006; Di Bitteti *et al*., 2006), which is corroborated by our findings. Nevertheless, more investigation is needed concerning the other factors affecting ocelot occurrence, such as diet and prey availability, to clarify the habitat preferences observed. This would help to explain whether the ocelot's preference for such habitats is linked to adjustments in the use of resources as a means to reduce competition with larger felids (Palomares and Caro, 1999), thereby promoting their coexistence (Gordon, 2000), or whether it is associated with the availability of food resources in such habitats, i.e. independently of the occurrence of other felids. It is well known that prey abundance exerts an effect on felid occurrence (Pierce et al., 2000; Ramalho, 2006), influencing among other factors their density and survival rates (Fuller and Sievert, 2001). Additionally, co-occurrence studies of felids at AMR could also help to clarify interspecific interactions (Di Bitteti *et al*., 2010; Sollmann *et al*., 2012). Nevertheless, the differences in the use of habitat in the spatial and temporal scales by ocelots compared to the other felids in our study site is clear (this study and Porfirio *et al*., submitted, respectively), which may be one of the factors promoting felid coexistence at AMR.

Seasonal fluctuations in water levels due to flooding and dry periods change habitat availability for the felids and their potential prey, possibly exerting a strong influence on the patterns of detectability and occupancy (O'Connell *et al*., 2006), and ultimately affecting interspecific interactions. However, only medium- to long-term monitoring will allow us to understand the felids' responses to such changes in the Pantanal (Junk *et al*., 2006).

We assert that the method used here to investigate factors affecting felid occupancy and detectability has a strong potential to be amongst the best tools to monitor the felid population at AMR in the medium- to long-term, as previously discussed by Sarmento *et al.* (2010). The method can be easily implemented (with due regard to model assumptions), and it is less expensive than traditionally-employed methodologies to estimate abundance (MacKenzie *et al*., 2002; Gu *et al*., 2004). Furthermore, it provides useful information for management (MacKenzie *et al*., 2002), especially when compared to mark-capture-recapture data, which essentially would require the use of at least two cameras per site in order to ensure perfect individual identification (Negrões *et al*., 2012), and would not have been feasible in our study area due to the size of the area and limited resources. Additionally, the data obtained can be used to infer activity patterns (Foster *et al*., 2013), behavior (Harmsen *et al*., 2010) and prey abundance and density (Royle and Nichols, 2003) that, when combined with future studies addressing felid feeding behavior, will help to clarify our understanding about the ecology of these species at AMR. This kind of monitoring and knowledge, especially for intangible areas, is essential for making management decisions for natural threats (such as forest fires), or for human-derived threats such as habitat loss due to deforestation and retaliatory/subsistence hunting, all of which can exert critical impacts on felids and their prey populations.

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“Por viver muitos anos dentro do mato moda ave, o menino pegou um olhar de pássaro – contraiu visão fontana. Por forma que ele enxergava as coisas por igual, como os pássaros enxergam." Manoel de Barros



CHAPTER 5

Knowledge and perceptions of schoolchildren about jaguars, pumas and smaller cats around a mosaic of protected areas in the Brazilian Pantanal

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ABSTRACT

Surveys to assess environmental knowledge are elementary tools to ensure successful environmental education. Felids are considered key components of the environment, acting as flagships for conservation. Nevertheless, they are threatened by loss of habitat, prey reductions and poaching. In the mosaic of protected areas in the Brazilian Pantanal, where several Environmental Education activities are supported, felines are a priority conservation target. We present the results of surveys to investigate schoolchildren's knowledge and perceptions about felids. Our results show that larger species are better known than smaller ones, and that negative perceptions are a concern, demonstrating priorities for environmental education.

Keywords: knowledge, perceptions, environmental education, felids, Pantanal

INTRODUCTION

Felids constitute one of the most recognizable groups of predator species. Eight species occur in Brazil (Cheida *et al*, 2011) and all of them are found in the Brazilian Pantanal (Alho *et al*., 2011); known worldwide as the largest freshwater wetland in the world (Seidl *et al*., 2001) and for its unique abundance of wildlife and pristine conservation status (Trolle, 2003). The Brazilian Pantanal harbors jaguars (*Panthera onca*) and pumas (*Puma concolor*), which are the largest predators in the Neotropics (Campos Neto *et al*., 2011), ocelots (*Leopardus pardalis*), which are the largest of the world's small spotted cats (Kolowski and Alonso, 2010), and small species such as pampas cat (*Leopardus colocolo*), Geoffroy's cat (*Leopardus geoffroyi*), oncillas (*Leopardus tigrinus*), margays (*Leopardus wiedii*) and jaguarundis (*Puma yagouaroundi*).

As in other areas, these species have been severely threatened by recent unsustainable practices of development that have led to a reduction in natural habitat due to agriculture and livestock expansion, consequently causing a decrease in the supply of natural prey (Nowell and Jackson, 1996) and diseases (Weber and Rabinowitz, 1996; Furtado *et al*., 2013). Poaching, often due to retaliation for losses caused by livestock predation, is another significant threat (Zimmermann *et al*., 2005; Altrichter *et al*., 2006). However, felids play an important role as top predators, maintaining ecosystems by controlling and balancing prey populations and thereby reducing the pressure on plant resources (Pitman *et al*., 2002). Despite their ecological importance, these species will only survive if humans choose to protect them (Stokes, 2007).

Concerned about biodiversity conservation, a group of landowners from Amolar Mountain Ridge, an area considered by the Environment Ministry of Brazil as extremely important for biodiversity conservation within the Pantanal biome (MMA, 2007), decided to join forces in 2010 to create a mosaic of protected areas covering 2,720 km^2 (Bertassoni *et al*., 2012). Several activities were established in order to contribute to the conservation of this important portion of the biome, including Environmental Education, which is carried out in the only three schools located around the mosaic. Since 2012, several surveys were carried out in these schools to assess knowledge and various aspects of the schoolchildren's relationships with the environment, including those with the felids that inhabit the mosaic. These felids are considered indicator and umbrella species for conserving the biome, flagships for conservation support and important tourist attractions (Loveridge *et al*., 2010). Information obtained from such surveys has proven useful elsewhere to identifying priorities for environmental education actions (Padua *et al*., 2006; Ferrie *et al*., 2011).

Generally, the felids of the Pantanal are negatively perceived by ranchers (especially jaguars, but also pumas), who link these animals to the damage caused due to livestock depredation (Zimmermann *et al*., 2005; Santos *et al*., 2008; Marchini and Macdonald, 2012). Santos *et al.* (2008) investigated the perceptions of children about the jaguar in the Pantanal using drawings, and these authors also observed a high incidence of negative feelings amongst children regarding this species. Nevertheless, little is known about the opinions of other local inhabitants of the Pantanal, e.g. riverside people, regarding the felid species in their vicinity, including the smaller species. Considering that children undergo rapid development (Carvalho, 2001; Damerell *et al*., 2013), and the importance of this age class for spreading conservation concepts to their families and friends (Damerell *et al*., 2013), it is imperative to assess current knowledge and perceptions amongst them in order to direct awareness through targeted education and the development of conservation strategies (Santos *et al*., 2008; Thornton and Quinn, 2009; Ferrie *et al*., 2011; Akengin and Aydemir, 2012). In this study, we present information regarding current knowledge and perceptions of schoolchildren living in the surroundings of Amolar Moutain Ridge about four felid species found in the region; namely jaguar, puma, ocelot and jaguarundi. We designed our research to answer the following questions: 1) Do the students recognize the four felids species that inhabit the region? and 2) What are the perceptions of students about the focus felids? We also tested the hypothesis that the larger felids were better known than smaller ones.

METHODS

The study was carried out in June and July of 2012 in three riverside schools located along the Paraguai River in the surroundings of Amolar Mountain Ridge, where the mosaic of protected areas is located (Figure 5.1). Schools are located in three different riverside communities, where activities related to tourist fishing, professional fishing and cattle ranching are the main sources of income. Since these communities are only accessible by boat and are located at least 100 km from the nearest city (Corumbá), they lack regular basic public services such as medical care and public transportation.

Jatobazinho School is maintained by a non-profit organization and has approximately 40 students, all of whom live in the school and go home for holidays and vacations. Paraguai Mirim School (PM) holds around 65 students, while Barra do São Lourenço School (BSL) has 25 students (Figure 5.1). PM and BSL are maintained by the City Hall of Corumbá and the students travel to and from their homes every day by means of a public school boat. All three schools only offer Elementary level education (i.e. from 1^{st} to 9^{th} year).

We used semi-structured questionnaires involving both open and closed questions to assess knowledge and perceptions regarding the focal species (Torkar, Mohar, Gregorc, Nekrep, and Adamič, 2010; Liu, McShea, Garshelis, Zhu, Wang, and Shao, 2011). Questions were accompanied by pictures of the feline species in their natural habitat (Appendix A). Additionally, we gathered information about the students, such as name, gender, educational year and age.

We let each student answer the questionnaire individually in the classroom, without the influence of colleagues or their teachers. On some occasions, we had to read the questions to those students who had reading difficulties. Information about attacks by felids on people or livestock was informally collected after the classroom activities. All questionnaires and their responses were recorded on a data sheet and entered into a database (Microsoft Excel 2008). Later, the information was translated from Portuguese to English. Responses were then converted to percentages following Ferrie *et al.* (2011).

A Chi-square test was used to analyze the question concerning perceptions of the felids in order to verify significant differences in the responses attributed to each species. A two-sample T test was used to test the hypothesis that larger species were better known (or correctly identified) than the smaller ones. Responses were assigned a score that ranged from 1 (correct identification) to 0 (blank answers and incorrect identification) for each felid species. Then, we summed the scores for larger and smaller felids separately. The final score for each student was calculated as the sum of scores for the two responses given to the larger and the smaller felids, respectively, i.e. ranging from 0 to 2. We performed the test using PAST software version 2.17 (Hammer *et al*., 2001).

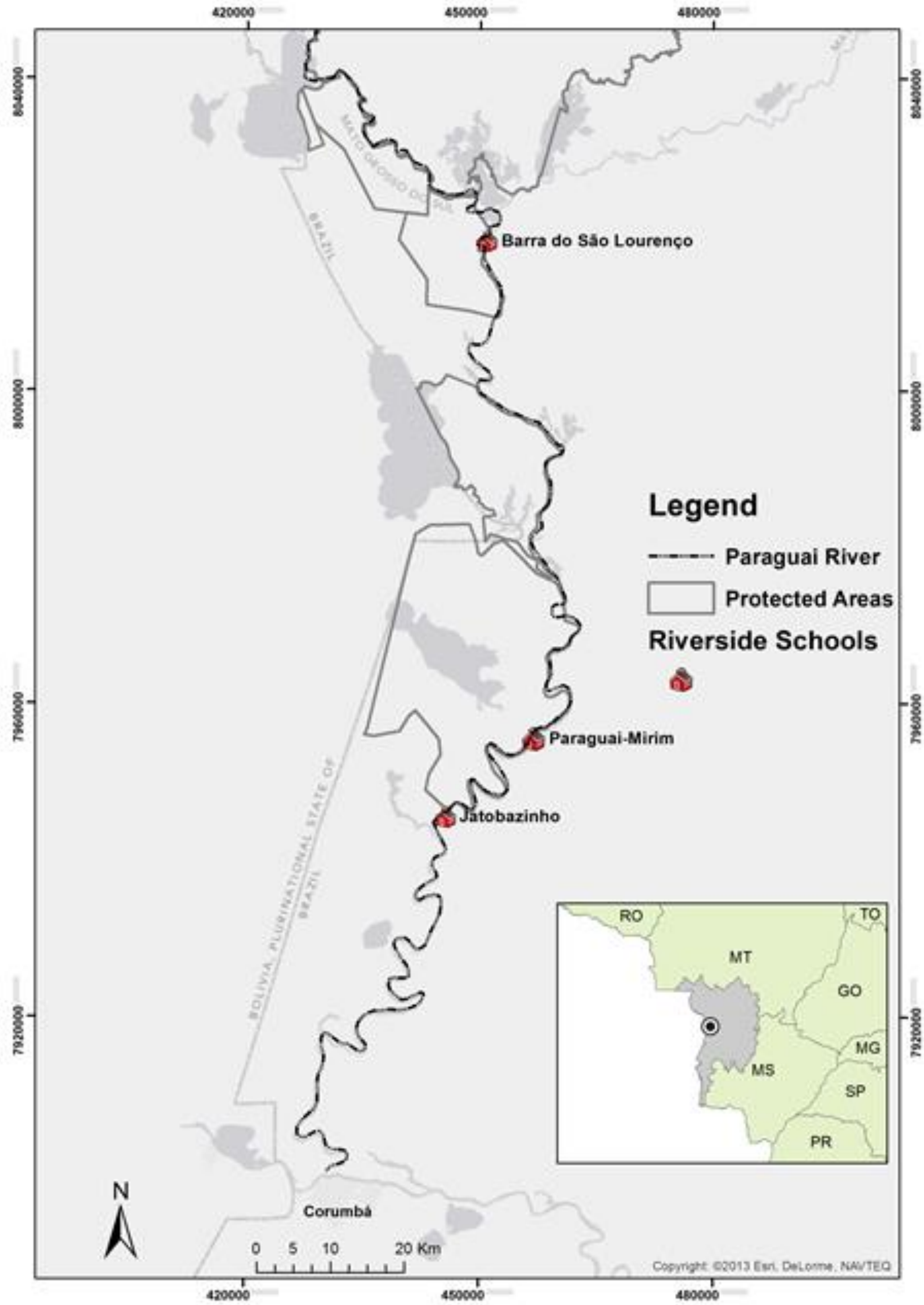

Figure 5.1: Study site with surveyed schools along the Paraguai River and Amolar Mountain Ridge Protected Areas, Western Brazilian Pantanal.

RESULTS

The study was carried out with 115 students. There was no sex-bias among respondents; 49.5% were girls and 50.5% were boys. Their average age was 10.94 years old (SD=3.30, Min=6, Max=21). Elementary School in Brazil lasts nine years (Law nº 10.172/2001) and around 40% of the students were undergoing their fourth or fifth year.

Regarding students' knowledge of species, we observed that 100% of the students recognized jaguars, but only 80% named the species correctly. This pattern of recognizing a species but not being able to name it correctly was also observed for the other species. Around 85% of the students recognized pumas, but only 62% named it correctly; pumas were also named as lion and jaguarundi by the students. Ocelots were recognized by almost 92% of the students, but were named correctly by only 70%. Ocelots were most frequently misidentified as jaguar cubs. The species least recognized was the jaguarundi (56%), with only 33% correctly naming it. Our hypothesis that the larger felids would be more frequently identified correctly could not be discounted (t=3.91; p<0.01) (Figure 5.2).

Students' perceptions differed significantly between the species (χ^2= 41.828, DF=12, p<0.001) (Figure 5.3). We found that "beautiful" and "dangerous" were the predominant words used to describe the large felids (jaguar and puma). Around 52% of the students stated that the ocelot was a "beautiful" cat, while approximately 25% had the same perception of the jaguarundi. The jaguarundi was also perceived as "dangerous" (19%), but a significant proportion of the students (20%) did not answer this question for the jaguarundi.

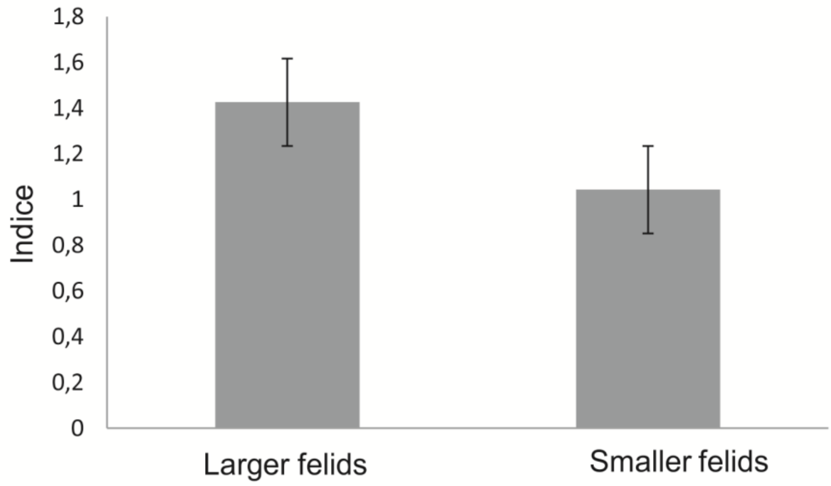

Figure 5.2: Result of the two-sample T test showing that larger felids were better known by schoolchildren of the Pantanal than the smaller felids species (t=3.91; p<0.01).

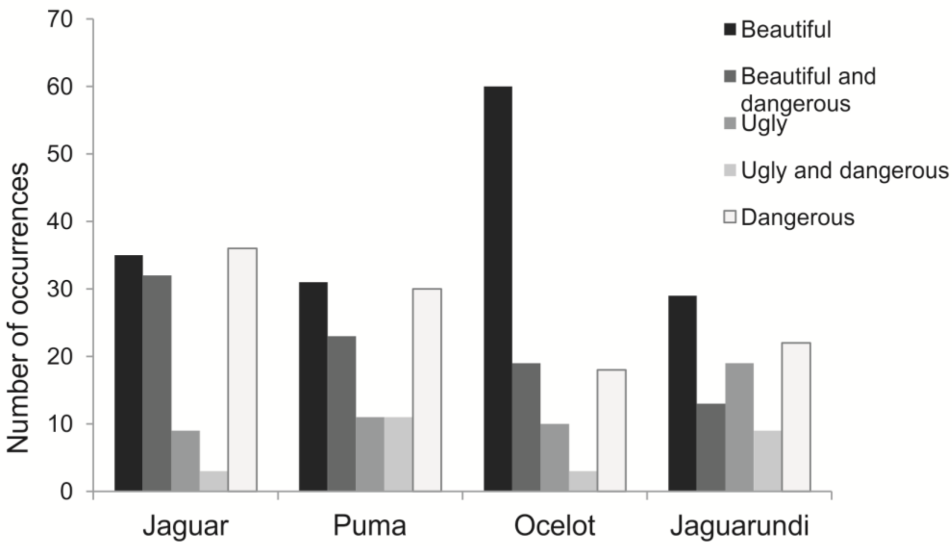

Figure 5.3: Summary of the responses of 115 students regarding their perceptions about four felids found in the surroundings of Amolar Mountain Ridge, Western Brazilian Pantanal.

DISCUSSION

Felids are ecologically, culturally and economically important, but these positive values are sometimes in stark contrast to the relationship between felids and people in areas where they coexist (Loveridge *et al.*, 2010). In this study, we observed that larger felids (jaguars and pumas) were the species most correctly identified or better known by the students when compared with the smaller ones (ocelots and jaguarundis). Several factors may be influencing the students' knowledge and perceptions, such as density and encounter probability with the felid species (Astete *et al.*, 2008; Maffei *et al.*, 2007), species' habits (Kolowski and Alonso, 2010), tolerance of felids to human disturbance (Campos-Neto *et al.*, 2011), and level of conflict between humans and felids (Zimmermann *et al.*, 2005; Marchini *et al.*, 2011).

All these factors are clearly applicable to the jaguar. The Brazilian Pantanal is a major stronghold for jaguars in the Americas (Zimmermann *et al.*, 2005), and this species is widely represented in the culture of the local pantaneiros (riverside people, cowboys, etc.) (Marchini and Macdonald, 2012). Thus, it is not surprising that the jaguar was among the best known species in our study site. Extensive cattle-ranching has been the dominant economic activity and the predominant land use in the Pantanal over the past two centuries (Seidl *et al.*, 2001). Consequently, one of the main threats to this species is human persecution due to livestock depredation (Cavalcanti and Gese, 2010), which poses a serious challenge for the conservation of this species (Cavalcanti *et al.*, 2010). The capture and killing of a jaguar as a retaliatory response due to livestock losses is considered an act of bravery among the pantaneiros (Banducci, 2007) (although it is legally prohibited) and, from a very young age, children hear stories about this practice, which can contribute to negative perceptions towards the species. However, in the 1990s, ecotourism emerged as an income source and began to be carried out in some cattle ranching and protected areas and along rivers. Since then, the positive image of the jaguar has increased and it has been strongly associated with pictures, crafts, outdoor trips, magazines, newspapers, songs, etc. As a consequence, jaguars have begun to have a more favorable profile due to the promotion of tourism and growing employment.

Puma, the second largest species, is one of the most tolerant species to human presence and habitat conversion (Campos Neto *et al.*, 2011). In Brazil, pumas are constantly in the media for invading backyards of houses, schools, roads, etc. Most of the time, these animals are evading anthropogenic threats such as forest fires, deforestation or traffic, or are searching for domestic prey, which causes conflict with humans. Nevertheless, only around 60% of the students correctly identified pumas. The lack of knowledge regarding this species in our study site may be related to the low density of the species along the Paraguai River where schools and local communities are located, since pumas are better adapted to drier ecosystems (Romero-Muñoz *et al.*, 2010).

Ocelots had a high incidence of correct identification in our study site. Although ocelots are smaller, harder to see and predominantly nocturnal (Kolowski and Alonso, 2010; Harmsen *et al.*, 2011), they are well-known due to chicken depredation (Marchini *et al.*, 2011), which is a problem in some communities. In fact, we heard about this conflict in our study site which, according to the students, is quite common and generates persecution of the species. The jaguarundi was the least known species and, consequently, the species with the biggest percentage of blank answers regarding perceptions towards it, demonstrating that this species is not well-known by the local people. Jaguarundi are smaller than ocelots but, due to their diurnal habits, are considered one of the most easily-sighted felines; leading to a false impression of being common (Maffei *et al.*, 2007), though it is a poorly known species even by researchers (Oliveira, 1998; Grigione *et al.*, 2007) and one that occurs in low densities at Amolar Mountain Ridge (Porfirio *et al*., in prep.).

Overall, the perceptions regarding larger felid species were balanced between positive and negative feelings (Figure 5.3). This differs from the observations of Santos *et al.* (2008) in another area of the Pantanal that found high incidences of negative interactions in a study that just considered the jaguar. Perceptions in our study area about the smaller species, especially ocelots, were mostly positive, as was also reported by Lucherini and Merino (2008) in the High Andes of Argentina where schoolchildren were more tolerant of small felid species, especially when compared to pumas, the largest felid of their study site.

Concerning jaguars, the negative perceptions are likely to be motivated by the survival instinct and self-defense behavior that parents have taught their children in these regions, since in some areas the risks of attacks are real (Campos-Neto *et al.*, 2011). Following completion of the questionnaires, the students related several stories that had been told to them by their parents involving fishermen's encounters with jaguar, livestock attacks and people's general fear of the species. Overall, although also perceived as beautiful (a positive feeling), students seemed to view jaguars as a potential threat that pose a constant risk to humans, demonstrating that this interaction in the Pantanal needs to better understood. Pumas were also frequently perceived as dangerous, but this species was also associated with contrasting positive feelings (beautiful). Children perceived ocelots as beautiful; although, from an early age, they learn that this species represents economic damage through chicken depredation.

Our results suggest that environmental education actions need to be concentrated on information to minimize negative feelings and reinforce positive values, and on demystifying the idea that felids represent a constant threat or only cause damage. Efforts should also focus on increasing the knowledge amongst inhabitants about these species, and most importantly their role in the environment (Zinn *et al.*, 2000; Santos *et al.*, 2008; Lucherini and Merino, 2008; Ferrie *et al.*, 2011; Akengin and Aydemir, 2012). In the medium- to long-term, such actions will contribute to the conservation of these species and the entire mosaic, since the involvement of local people in the protection of felids is considered a key element in conservation strategies (Ferrie *et al.*, 2011). Children represent a priority target group for such programs. Considering that they are still undergoing cognitive development, it is assumed that children can internalize environmental awareness much more successfully than adults, whose repertoire of habits and behaviors are more crystallized and difficult to reorient, and so environmental education programs are more likely to translate into changed behaviors in children (Carvalho, 2001).

To the best of our knowledge, this is the first study focusing on the knowledge, perceptions and attitudes regarding these four felids species among Elementary School students in the Brazilian Pantanal as part of a long-term environmental educational program. Although the knowledge and perceptions of schoolchildren towards these species are not the only conservation concerns, given the other significant threats faced by these felids and their environments, both are fundamental elements that should not be neglected in conservation strategies. Since felids are considered umbrella species, i.e. their protection indirectly protects many other species and habitats (Loveridge *et al.*, 2010), their conservation is crucial to maintaining the biodiversity of the Pantanal.

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Appendix A

Nome: ____ Fem ____ Masc _____

Série: __________________ Idade: ____ Região em que mora: __________________

Você sabe quem sou eu? Sim Não

Qual é o meu nome? _____________________

Eu sou: bonita ◯

feia ◯

perigosa ◯

bonita e perigosa ◯

feia e perigosa ◯

Você sabe quem sou eu? Sim Não

Qual é o meu nome? _____________________

Eu sou: bonita ◯

feia ◯

perigosa ◯

bonita e perigosa ◯

feia e perigosa ◯

Você sabe quem sou eu? Sim Não

Qual é o meu nome? _____________________

Eu sou: bonita ◯

feia ◯

perigosa ◯

bonita e perigosa ◯

feia e perigosa ◯

Você sabe quem sou eu? Sim Não

Qual é o meu nome? _____________________

Eu sou: bonita ◯

feia ◯

perigosa ◯

bonita e perigosa ◯

feia e perigosa ◯

"Sou hoje um caçador de achadouros da infância. Vou meio dementado e enxada às costas cavar no meu quintal vestígios dos meninos que fomos." Manoel de Barros


CHAPTER 6

How are jaguars perceived by local communities along the Paraguai River in the Brazilian Pantanal?

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ABSTRACT

Rapid habitat conversion, hunting as a retaliatory response to livestock depredation and potentially lack of knowledge regarding the species' ecological role are the main factors influencing jaguar conservation in the Pantanal. Investigation of people's perceptions and attitudes towards a species is an important element of conservation initiatives, but most information concerning human perceptions about jaguars in the Pantanal comes from the conflict with ranchers, who typically perceive this species negatively due to economic losses. No information is available concerning other inhabitants' perceptions of the jaguar, particularly along riversides where the main activity is professional and recreational fishing. We used semi-structured questionnaires to interview 50 riverside inhabitants on how they perceive the jaguar and to investigate the influence of education and age on such perceptions compared to locals from rural properties in the Pantanal and other Brazilian biomes. "Dangerous" was the predominant perception. We found that the negative perceptions about jaguars related to people's safety and not to economic losses from livestock depredation. We highlight environmental education programs, ecotourism and better strategies to reduce livestock losses as useful tools for minimizing the perception that jaguars are dangerous in all situations.

Keywords: perceptions, attitudes, jaguars, Pantanal

INTRODUCTION

Covering 200 000 km^2, the Brazilian Pantanal is a major stronghold for jaguarsin the Americas (Zimmermann *et al*., 2005) and, currently, the species is heterogeneously distributed through 63% of this biome (Cavalcanti *et al*., 2012). However, in this area, most of the jaguar population lives outside protected areas as 95% of the Pantanal consists of private lands (Crawshaw & Quigley, 1991; Seidl *et al*., 2001), where the main economic activity is extensive cattle ranching (Seidl *et al*., 2001; Cavalcanti & Gese, 2010). Jaguars have coexisted with humans and their livestock for nearly 200 years in the Pantanal (Crawshaw & Quigley, 1991; Cavalcanti & Gese, 2010) and livestock predation is considered one of the main causes of people's intolerance towards this species (Zimmermann *et al*., 2005; Cavalcanti *et al*., 2012).

Although the jaguar has been well studied in the Pantanal (Schaller & Crawshaw, 1980; Crawshaw & Quigley, 1991; Crawshaw & Quigley, 2002; Dalponte, 2002; Soisalo & Cavalcanti, 2006, Azevedo & Murray, 2007; Cavalcanti & Gese, 2010; Cavalcanti *et al*., 2012), little information has been accumulated concerning people's perceptions and attitudes towards this felid. When available, this information mostly involves the conflict relationship between ranchers and jaguars due to livestock depredation (Zimmermann *et al*., 2005; Santos *et al*., 2008; Marchini & Macdonald, 2012). No information exists on the relationship between the jaguar and traditional communities that live along the main rivers of the Pantanal (Paraguai, Taquari and Cuiabá), and that subsist mainly on fishing.

Large predators are negatively perceived because people fear being attacked or having livestock predated, which may represent an important component in the conflict due to the social economic context, and due to the lack of knowledge regarding their ecological role (Campbell & Alvarado, 2011; Soto-Shoender & Main, 2013). In this study, we evaluate perceptions of the jaguar among adults in riverside communities along the Paraguai River, from Corumbá to Pantanal Matogrossense National Park. According to Cavalcanti *et al*. (2010), better informed people tend to fear the jaguar less. Therefore, we sought to answer the following questions: (I) is the perception of the jaguar related to the level of education and age of the local people?, and (II) are the perceptions of local riverside people different from those of rural properties where the main activity is cattle ranching, or from inhabitants of other Brazilian biomes?

STUDY AREA

The study was carried out from April to June 2011, along approximately 400 km of the Paraguai River, from Corumbá to Pantanal Matogrossense National Park. This chosen area encompasses the only federally-protected area within the Pantanal biome and is close to the Amolar Mountain Ridge (a poorly-known area, but considered as extremely important for biodiversity conservation (MMA, 2007)).

Paraguai River is the main drainage channel of the Pantanal (Calheiros & Ferreira, 1997), flowing 2621 km north to south, of which 1693 km is located in Brazil (Innocencio, 1977). The predominant vegetation along the river is gallery forest, which in the most elevated areas is not influenced by the seasonal floods that occur in the Pantanal (Pott, 1982), and flooded fields composed of native grasses (da Silva *et al*., 2000). The climate is warm, with a dry winter season (Köppen's *Aw* seasonal regime - tropical wet and dry or savanna climate) (Cadavid-Garcia, 1984). The amount of rain varies from 800 to 1400 mm/year, of which almost 80% falls between November and March (da Silva *et al*., 2000).

The main economic activities along the Paraguai River are recreational and professional fishing (Franco *et al*., 2013). Cattle-ranching is limited due to seasonal flooding and the small size of riverside properties. Although low in density, several communities occupy the river margins, of which Castelo, Paraguai Mirim, Amolar and Barra do São Lourenço are the most populated. Together, these communities comprise approximately 70 extended families, distributed along approximately 400 km of the Paraguai River (Instituto Homem Pantaneiro, unpublished data).

METHODS

We interviewed riverside community adults using a semi-structured questionnaire accompanied by a jaguar picture (Marker *et al*., 2003; Conforti & Azevedo, 2003; Santos *et al*., 2008). We travelled by boat, stopping at residences located along the riverbanks and, randomly, at residences located in Castelo, Paraguai Mirim, Amolar and Barra do São Lourenço (Figure 6.1). On some occasions we interviewed more than one person from the same family, but those interviews were done at the same time and the interviewees were separated from each other to avoid any bias. The questionnaire comprised open and closed questions to gather information about the interviewee and their perceptions of jaguars, following Santos *et al*. (2008).

To profile the interviewees, we asked for their age, gender, birthplace, time living in the region, profession and level of education. To determine perceptions of the jaguar, we asked three questions: (a) *"Have you ever seen a jaguar?"*, (b) *"Where did you see a jaguar?"*, and (c) *"What do you think of the jaguar?"*. The first question allowed us to evaluate how recognizable the species is. Responses to the third question (c) established perceptions of the jaguar, with respondents given the possibility of answering "dangerous" (*i.e*. a threat to human life), "beautiful" or both (*i.e*. beautiful and dangerous), which was interpreted as a neutral response (Santos *et al*., 2008).

Another two questions were posed concerning the 'values' that people attribute to the jaguar: (a) "*Do you think the jaguar should be eliminated from nature?"*, and (b) *"Why?"*, so that interviewees could justify either elimination or protection of jaguars (Santos *et al*., 2008). Responses to these two questions revealed the values associated with jaguars, which were categorized (as for Santos *et al*., 2008) as: (1) anthropocentric; demonstrating a desire to conserve the jaguar for future generations or believing that the species should be allowed to persist if it does not pose risks to humans, (2) religious; viewing the jaguar as a religious icon, (3) economic; related to economic losses from livestock predation, (4) moral; since jaguars are protected by Brazilian law, or (5) ecological; recognizing the ecological role of the species. Additionally, during interviews, we collected information about the occurrence of jaguar attacks on humans in the region.

Analyses were conducted using R software, version 2.15.3 (R Core Development Team, 2009). To test the effect of educational level and age of interviewees, we performed a General Linear Mixed Model (GLMM) function. Perceptions were inferred as positive when the respondent answered "no" to the question "*Do you think the jaguar should be eliminated from nature*?" (attributed the value 1), and negative when the answer was yes (attributed the value 0). Educational level was converted into a numeric variable, from 1 to 6, corresponding to: 1- illiterate; 2- incomplete Fundamental School (i.e. Elementary School); 3- complete Fundamental School; 4- complete Medium School (i.e. High School); 5- incomplete undergraduate (Tertiary education); 6- complete undergraduate (Tertiary education). The Akaike Information Criterion (AIC, Akaike, 1974) was used to evaluate the best model. A Chi-square test was used to compare the perceptions ("beautiful", "dangerous", "beautiful and dangerous") and the values attributed to the jaguar among riverside locals. This data was also compared to that of inhabitants of rural properties and other Brazilian biomes, such as the Amazon forest, Cerrado, Caatinga and Atlantic Forest, using data from Santos *et al*. (2008).

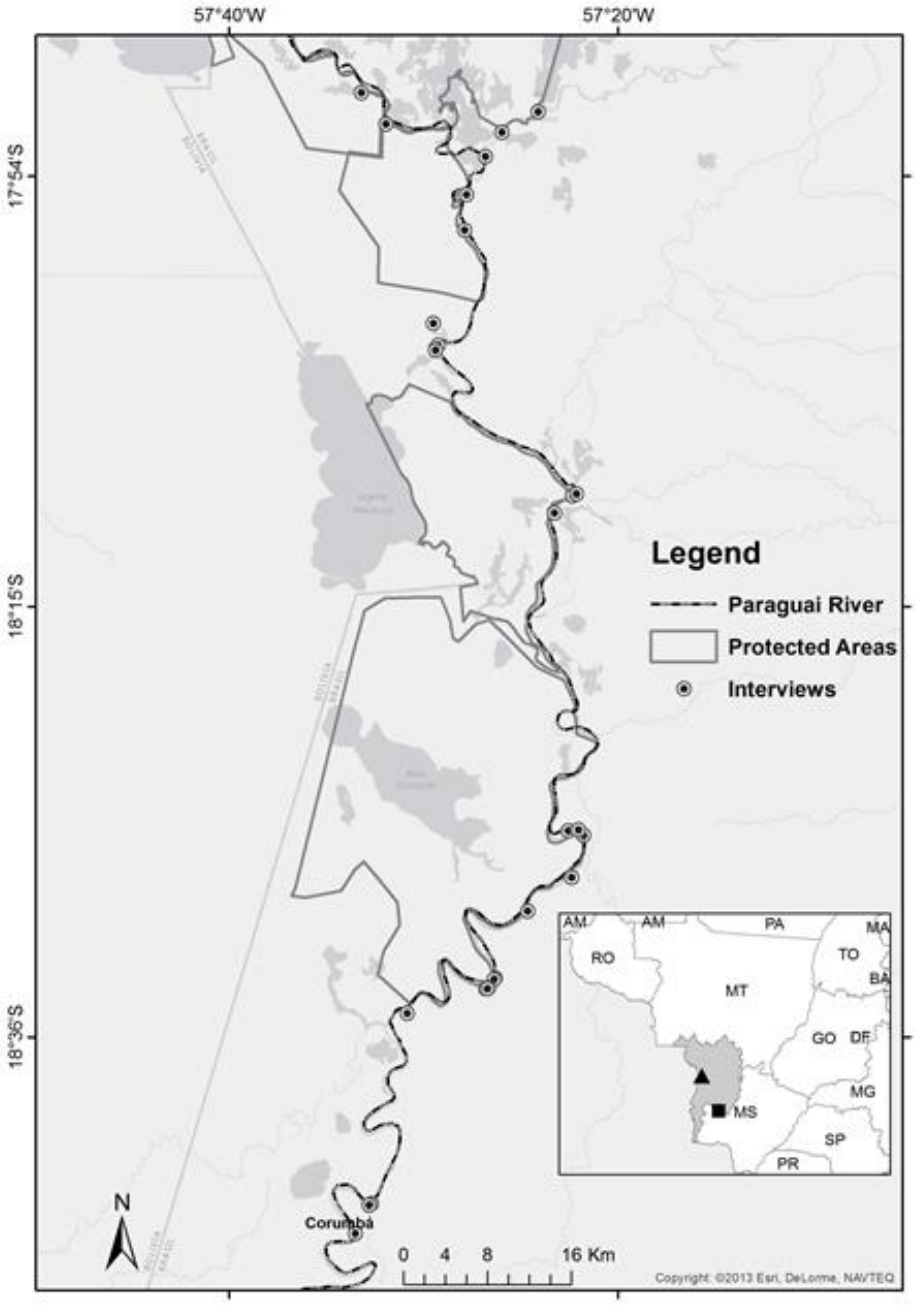

Figure 6.1: Study site and interviewed communities along the Paraguai River in 2011 (▲), and study site of Santos *et al*., (2008) in the Miranda sub-region of the Pantanal biome (■).

RESULTS

We carried out 50 interviews with locals along the Paraguai River, of which 78% were men (n=39) and 22% were women (n=11). Fifty-eight percent of the interviewees ranged from 20 to 59 years old, and 32% were 60 years or older. Only 10% of the interviewees were aged 15 to 19 years. Most of the riverside inhabitants were born in cities within the Pantanal (84% in Corumbá, Poconé, Miranda or Barão do Melgaço), and 14% had been born along the Paraguai River. Only one foreigner (from Germany) had been living in the region for more than 20 years.

Illiteracy was the most frequent level of education identified (40%), followed by incomplete Fundamental School (36%). Only 10% of the interviewees had completed Fundamental School and even fewer had completed Medium School (8%). One interviewee had graduated tertiary education, while another was still undergoing undergraduate education.

Subsistence agriculture combined with small-scale cattle ranching were the main professions of the interviewees (24%), followed by professional fishing, cattle ranching alone, housekeeping, property management, cowboy, subsistence agriculture alone, live bait collection or boat captain. All of the interviewees confirmed using fishing resources from the river as a complementary food source.

All interviewees recognized the jaguar, and 92% stated that they had seen one in its natural environment. The remainder recognized jaguars from photos, skins or tracks. "Dangerous" accounted for 48% of the responses to the question on perceptions, followed by "combination of both" (dangerous and beautiful) (28%). "Beautiful" was the least cited perception of the jaguar. Perceptions differed significantly between riverside people, locals that live on cattle ranches in the Pantanal and inhabitants of other Brazilian biomes (Chi^2= 102.349, df=10, p<0.001), with a higher proportion of riverside locals perceiving the jaguar as dangerous (Figure 6.2).

Age and educational level seems to influence perceptions of the jaguar along the Paraguai River. Based on the GLMM analysis, the best explanatory model was age+school (ΔAICc <2; AICc weight = 0.765) (Table 6.1), with β coefficients of -0.009 (SE= 0.004) for age and 0.112 (SE = 0.024) for school. Older people tended to have negative perceptions about the jaguar (p< 0.01), while those with a higher level of education tended to have more positive perceptions of the species (p< 0.05).

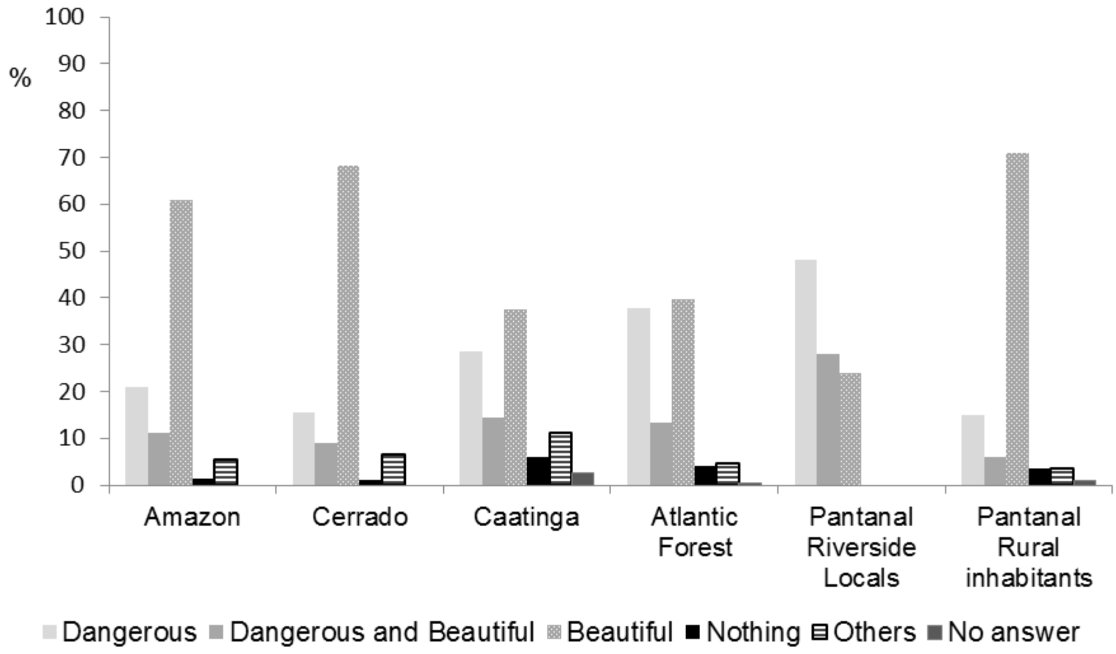

Figure 6.2: Perceptions of the jaguar as stated by riverside locals (n=50) during interviews carried out in 2011 along Paraguai River (this study), and by locals from rural properties in the Miranda sub-region of the Pantanal (n=200), and other Brazilian biomes (n=200) (data from Santos *et al*., 2008 for both latter groups), expressed in percent.

Although responses indicated that the jaguar is perceived as a dangerous animal that can kill a person or cause damage to livestock, 66% felt that the jaguar should not be eliminated from nature. The values associated with the jaguar by riverside inhabitants differed significantly from those of locals from ranches and from other Brazilian biomes (Santos *et al*., 2008) (Chi^2= 201.145, df=20, p<0.001) (Figure 6.3). The predominant reasoning for this was anthropocentric (i.e. protection for future generations), followed by economic and ecological considerations. Three cases of non-fatal jaguar attacks on people were reported by the interviewees in the last ten years in the region of the Paraguai River.

Table 6.1: Models explaining factors influencing adult perceptions of the jaguar with its respective β coefficients (Age and School) along the Paraguai River (Brazilian Pantanal) in 2011. Models are ordered by rank according to the ΔAIC and weightings (wAIC).

Model	Intercept	Age	School	Df	Loglike	AICc	ΔAICc	wAICc
Age+School	0.805	-0.0094	0.118	4	-27.366	63.6	0.00	0.765
Age	1.111	-0.009	-	3	-30.125	66.8	3.15	0.158
School	0.4216	-	0.1146	3	-31.077	68.7	5.06	0.061
Null	0.660	-	-	2	-33.589	71.4	7.81	0.015

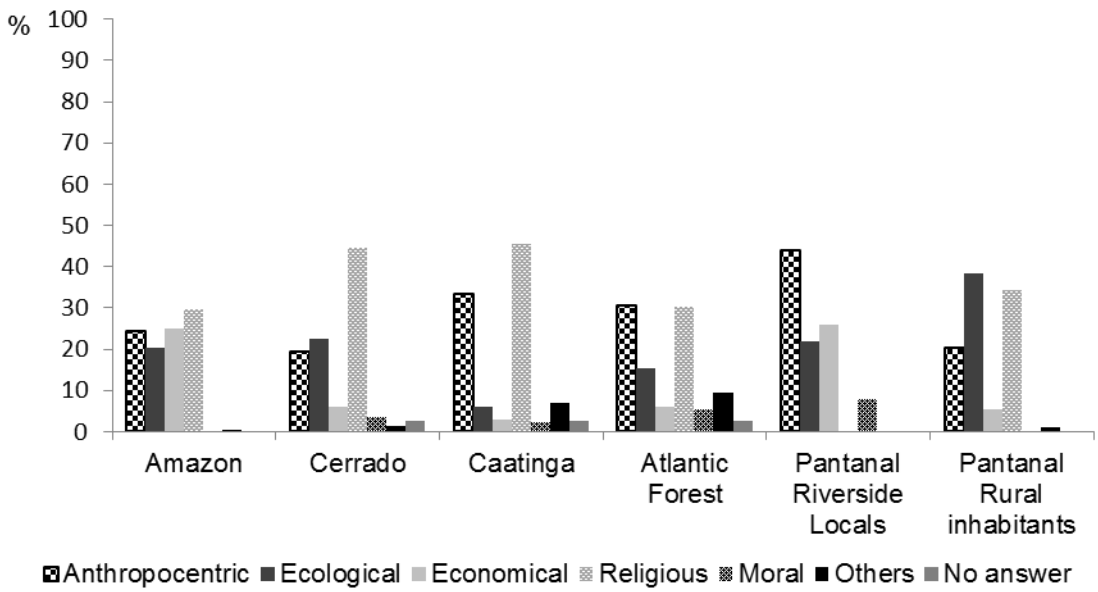

Figure 6.3: Values attributed to the jaguar by riverside locals interviewed in 2011 along Paraguai River (n=50) (this study), and by locals from rural properties in the Miranda sub-region of the Pantanal (n=200), and other Brazilian biomes (n=200) (data from Santos *et al*., 2008 for both latter groups), expressed in percent.

DISCUSSION

The conflict between ranchers and jaguars in the Pantanal is well documented and is typically associated with livestock depredation (Zimmermann *et al*., 2005; Silveira *et al*., 2008; Cavalcanti & Gese, 2010; Marchini & Macdonald, 2012), as occurs elsewhere where domestic livestock coexist with carnivores (Mizutami, 1999; Butler, 2000; Patterson *et al*., 2004; Rigg *et al*., 2011). However, this association is not relevant to riverside communities where the main activity is not cattle ranching. Due to their dependency on river and forest resources such as fish, bait, water, firewood and natural medicines, riverside people are in direct contact with jaguars, which prefer forest habitats in close proximity to water (Crawshaw & Quigley, 1991). Thus, it is not surprising that 92% of the interviewed people had seen a jaguar in its natural habitat. Of the 200 people in the Pantanal interviewed by Santos *et al*. (2008), 78% stated that they had seen a jaguar in its natural environment.

We noted from our interviews that although people view the jaguar as a dangerous animal and highlighted the risks to humans, they do not think that the species should be eliminated. We link this to the high incidence of anthropocentric values attributed to the jaguar (riverside communities want future generations to know the species and enjoy its beauty, though they are afraid of the risks it currently poses to them). The negative perceptions of riverside communities are related to concern for people's safety, whereas for ranchers and locals from rural properties it is predominantly related to the economic damage that the species can cause (although both these latter groups also expressed a desire to protect the jaguar, Zimmermann *et al*., 2005; Santos *et al*., 2008).

Interviewees highlighted their increased vulnerability to attacks during the wet season, when residences are surrounded by water, forcing inhabitants to move to higher areas that are also favored by jaguars. This has occurred almost every year since the extensive flood of 1974, which completely changed the environment and socio-economic context of the region as riverside inhabitants could no longer work in nearby flooded cattle ranches (Franco *et al*., 2013). Extensive flooding is the major ecological driver in the Pantanal and for most terrestrial mammals, including the jaguar, flooding drastically reduces the area available for foraging (Crawshaw & Quigley, 1991) making predatory attacks on livestock more frequent when wild prey is not available, as informally reported during our interviews. Therefore, although cattle ranching is not a crucial activity, losses caused by livestock predation still shape perceptions. Similarly, news of jaguar attacks on humans spread quickly among the locals, possibly increasing the fear and negative perceptions of the jaguar. Three cases of non-fatal jaguar attacks were reported by the interviewees, two (one fatal) were cited by Campos Neto *et al.* (2011), and other two were reported between 2013 and 2014 (G. Porfirio, pers. obs.).

Although jaguars are potentially dangerous to people (Marchini & Macdonald, 2012), according to Cavalcanti *et al*. (2010) fear of this species varies depending on knowledge of the species. As highlighted by Santos *et al*. (2008), several studies have proposed environmental education as a tool for mitigating conflict between humans and wildlife. Some educational material on coexistence between predators and domestic animals is already available (e.g. Marchini & Luciano, 2008; Marchini *et al*., 2011). The use of this kind of material, especially in schools located along the Paraguai River, should be promoted, especially since environmental awareness seems to be more easily attained and translated into behavior in young students (Carvalho, 2001; Lucherini & Merino, 2008). Furthermore, the regular presence of parents at environmental education events in schools could also contribute to their awareness in the medium- to long-term, thereby helping to foster a basic healthy coexistence with jaguars (Damerell *et al*., 2013). Since it has been suggested that there is a link between knowledge and positive attitudes towards animals (Torkar *et al*., 2010; Cavalcanti *et al*., 2010), changes in attitudes could be achieved and attenuated, independently of the age or educational level of these groups. This could be the most efficient and cost-effective way to work with the adults along the Paraguai River, since communities and houses are located far from each other, hindering logistic access. Nevertheless, there are other strategies, such as ecotourism and the employment of better management actions to minimize livestock predation (Marchini *et al*., 2011), to help protect the species (Loveridge *et al*., 2010) and shape more positive perceptions of jaguars.

We believe that the feeling that the jaguar needs to be protected along Paraguai River is derived from changes in tourism. Even though the main tourism-related activity in the region is recreational fishing (and not ecotourism), there are several cases where people have spent more than one hour observing a jaguar on the banks of the rivers (*e.g*. at Porto Joffre; G. Porfirio pers. obs.). Nevertheless, jaguar observation needs to be regulated in the Pantanal to limit risks, both to people and jaguars. Currently, only Mato Grosso state has a specific law to deal with jaguar observation by tourists, which mainly prohibits jaguar baiting (Consema Resolution 85/2011).

Since the Pantanal is currently facing landscape changes, especially due to habitat conversion (Desbiez *et al*., 2010), and human activity is the main threat to jaguars (Cavalcanti *et al*., 2012), understanding how people perceive this species and how they coexist and interact with it and the general environment is an essential tool to ensuring the persistence of jaguars along the Paraguai River, as well as in the wider Pantanal biome.

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"Natureza é uma força que inunda como os desertos." Manoel de Barros

CHAPTER 7

GENERAL DISCUSSION AND CONLUSIONS

SCIENTIFIC MONITORING AT AMOLAR MOUNTAIN RIDGE

Although considered an essential area for conserving the Pantanal's biodiversity (MMA, 2007), scientific studies at Amolar Mountain Ridge (AMR) are scarce. Most of the available information began to be published from the late 1970s and the region remains poorly known. The first documented studies were carried out at Acurizal Ranch (at that time, the protected area had not yet been established), which investigated jaguar predation on capybara (Schaller and Vasconcelos, 1978) and the movement patterns of jaguars in the swampy plain (Schaller and Crawshaw, 1980). These were amongst the first studies involving free-ranging jaguars in their natural environment.

In 1983, the first mammal inventory for the northern region of AMR was published (Schaller, 1983) and, recently, another mammal inventory has been submitted for publication (Porfirio *et al*., submitted). Since the early studies, technology has advanced greatly and methods for recording and studying species have improved. For example, camera trapping has been widely used in recent years, not only for species surveys (Trolle, 2003; Trolle and Kéry, 2005; Tobler *et al*., 2008), but also to investigate several ecological aspects such as species' abundance, density, interactions, behaviour, occupancy and activity patterns; especially those of terrestrial mammals (Trolle and Kéry, 2003; Soisalo and Cavalcanti, 2006; Negrões *et al*., 2010; Harmsen *et al*., 2010; Sarmento *et al*., 2010; Foster *et al*., 2013) as employed in the present study.

Through camera trapping at AMR, the first photographic record of the giant armadillo (*Priodontes maximus*) (IUCN status: Vulnerable) was obtained, which was believed to be extinct at AMR (Porfirio *et al*., 2012), and of the rare Southern three-banded armadillo (*Tolypeutes matacus*) (Porfirio, unpublished data) (IUCN status: Near-Threatened), demonstrating the relevance of this non-intrusive method for conservation initiatives (IUCN, 2013).

Studies concerning groups other than mammals have also been carried out in the AMR; for example, Prance and Schaller (1982) investigated the vegetation of the region, Campos *et al.* (1995) studied the dwarf caiman (*Paleosuchus palpebrosus*), and Morais *et al*. (2010) and Strussmann *et al.* (2011) researched the parasites in dwarf caiman and amphibians. Similarly, significant advancements in the knowledge of the biodiversity of AMR were made with the publication of "Descobrindo o paraíso" ("Discovering the paradise") (Rabelo *et al*., 2012), dedicated mostly to invertebrate surveys, the description of a new species of Hemiptera (Gil-Santana, 2012), and the recording of 10 species of spiders (though not scientifically described) (Raizer *et al*., 2012).

Although the biology and ecology of the species that inhabit AMR remains greatly unknown, previous and current efforts will certainly help to increase conservation measures. Arising from the results already obtained, better strategies for the protection and conservation of this unique location can be defined; for example, by indicating important but restricted areas within the reserves or recommending the acquisition of areas of strategic interest in order to enlarge the corridor of protection. Such strategies would particularly benefit the felid species, which have large home range sizes, are difficult to study and need large areas of good quality habitat and abundant prey (Silver *et al*., 2004; Swank and Terr, 1989; Inskip and Zimmermann, 2009). In this context, institutional partnerships and collaboration are critical to the continuity of scientific monitoring and for the conservation of the protected areas in order to continue filling gaps in our knowledge of the region's biodiversity and to assist in the decision-making process.

THE CONSERVATION STATUS OF FELIDS AT AMOLAR MOUNTAIN RIDGE

Locally, the main factors affecting the biodiversity at AMR, including the felid species, are overfishing, unregulated tourist activities, poaching, retaliatory hunting, deforestation, logging and forest fires around the protected areas (Moreira, 2011; Bertassoni *et al*., 2012). Furthermore, it has been observed that human perceptions and attitudes towards the felids are also issues of concern regarding their conservation (Chapter 5 and 6 of this thesis). From our research, we observed that age and educational level were influential on adult perceptions of the jaguar. The negative perceptions seem to develop early in childhood since, even though they do not know the felid species in their area well, children seem to perceive them as a constant threat. Adults' negative perceptions of the jaguar were mostly transmitted by individuals that do not tolerate the species or that do not know it well (Chapter 6 of this thesis).

Although adult perceptions of other felids beside jaguars have not been investigated in this study, these perceptions are probably also negative. Therefore, we feel that research on the factors that influence the way people view and coexist with the felids in the AMR are as relevant to their conservation as studies of their ecological requirements. Both types of studies can contribute significantly to developing a long-term environmental education program that will raise the awareness of local communities to the importance of felids in their environment and to minimize fear. Likewise, in the case of jaguars, it will be important to urgently regulate observations by recreational fishermen for touristic purposes to prevent accidents, in particular by prohibiting the use of bait to attract them, which would only serve to augment the negative views of the species due to the increasing potential risk of attacks, besides promoting changes in their natural behavior.

The records of jaguar baiting in our study site supported a recommendation by the Federal Public Ministry of Brazil to the Environment and Tourism Secretaries of Corumbá in December 2013, in order to implement an awareness campaign for tourists regarding the risks involving in baiting not only jaguars, but also other wild and endangered species such as the giant otters and macaws (Psittacidae). A municipal environment decree is currently being drafted by the mayor of Corumbá, forbidding the practice of baiting of wild animals and regulating the observation of wildlife by tourists. The sanctioning of this law will represent an advance for jaguar and other endangered species conservation, since Corumbá covers 65,000 km^2 of Pantanal, corresponding to almost half of its Brazilian portion (Junk *et al*., 2006).

NETWORK FOR THE PROTECTION AND CONSERVATION OF AMOLAR MOUNTAIN RIDGE AND THE CONSERVATION OF ITS FELIDS

One of the specific objectives of this thesis was to investigate the ecological aspects of the felid assemblage in AMR and the interactions with their potential prey, as well as to evaluate the relationship between humans and felids in the region in order to contribute to planning better strategies for regional conservation.

Arising from a growing understanding that scientific research provides important insights for conservation, the management of the network of protected areas at AMR encourages and prioritizes these studies by means of a specific objective-setting process, which is increasingly becoming more robust since its creation in 2007 (IHP, unpublished data). Felids can be used as great 'ambassadors' in the conservation process since they can act as flagship and umbrella species to promote and ensure conservation as they are particularly charismatic animals (Linnell *et al*., 2000). In addition, they can act as indicator species for the success of conservation programs in the network (Miller and Rabinowitz, 2002; Loveridge *et al*., 2010), facilitating evaluation of current and future actions. For example, an improved understanding of the ecological requirements of the felids and their prey will be useful for indicating additional interesting areas that can be included in the network, thereby enlarging its conservation coverage and effectiveness. Much of this understanding will be achieved using medium- to long-term felid monitoring through occupancy and co-occurrence models (Chapter 4). This kind of monitoring indicates more than just the proportion of sites occupied by a species, since it facilitates understanding of habitat preferences, abundance estimates and patterns of species interactions and coexistence (Mackenzie *et al*., 2002; Royle and Nichols, 2003; Sollmann *et al*., 2012). Furthermore, the current configuration of the protected network will help us to understand in the medium term some relevant aspects about the felids in the AMR, since it allows us to study species' behaviors in relation to flood and drought periods (that could possibly change occupancy patterns, prey availability and, consequently, the interactions among species), and in permanent flooded and dry habitats. Of particular value is the possibility to study species interactions without the confounding factor of livestock presence (which is not possible in other areas of the Pantanal). Currently, most of the available information about felids in the Pantanal, especially the jaguar, comes from places where livestock are present (for example, Azevedo and Murray, 2007a, 2007b and Soisalo and Cavalcanti, 2006).

In this context and given that the Pantanal is facing the threat of increased habitat conversion (Harris *et al*., 2005; Desbiez *et al*., 2010), the regional conservation of the AMR's felines and, indeed, their self-sustainability in the region relies heavily on this protected network. Nevertheless, important points must be taken into consideration to ensure the success of any potential integrated management proposal:

1. Ongoing research is needed to continue filling the gaps in our knowledge about the felid species in the AMR and their interactions with their prey and habitat;
2. An environmental education program must be continuously developed, emphasizing the importance of these species to the environment and the value of achieving sustainable practices for the environment;

3. Better cattle management techniques (Hoogesteijn and Hoogesteijn, 2011) should be applied in order to minimize problems associated with predation in the vicinity of protected areas;
4. Tourist activities involving the observation of jaguars, and other endangered species must be regulated in Mato Grosso do Sul State. Currently there is a formal complaint in the Federal Public Ministry aiming to judicially regulate this issue, but only in Corumbá. Although it represents a significant effort due to the size of the county, an effort covering the biome would be better to ensure species' protection. Mato Grosso State already has a legal guideline for the observation of free-ranging jaguars and pumas (Resolução Consema – 85/11).
5. Alternative and sustainable income sources should be identified for the riverside communities in order to minimize the unplanned use of natural resources, which leads to habitat degradation affecting the felids (Cavalcanti *et al*., 2012);
6. Models of sustainable use of natural resources should be created for the protected network, including promotion of the importance of felids to it, as a potential source of sustainable income (e.g. through ecotourism);
7. The protected network should be strengthened by inviting new partners and supporters to become involved;
8. Consideration should be given to granting tax incentives to the protected network or paying for its environmental services to encourage other landowners to join the conservation effort and to help maintain it.

FUTURE PERSPECTIVES

Considering the current extent of the protected network (approximately 272,000 hectares), it will be necessary to expand our studies, especially towards the central and northern portion of AMR. Our methodological approach could be enhanced by the inclusion of, for example, the collection of biological samples such as blood or scats, and through GPS telemetry. The use of scat sampling and GPS telemetry in the region would be interesting due to the inherent difficulties in studying the larger cats in the swampy plain. Scat analysis would be particularly useful because it is a non-intrusive method that allows several types of information to be gathered, such as on diet, presence of pathogens, reproduction, use of habitat and density estimates (Kohn and Wayne, 1997; Wasser *et al*., 2004; Sollmann *et al*., 2013). Such approaches, in addition to camera trapping, would help to clarify the unresolved issues that remain concerning the felids at AMR, for example:

- The influence of water level variation (flood and drought) on the behaviour, diet, home range and activity of the predators and their potential prey;

- Abundance and density estimates, e.g. using two camera traps per station (Negrões *et al*., 2012); and comparison of this method with the one proposed by Royle and Nichols (2003).

- The feeding ecology of the predators (Porfirio, 2009);

- Reproductive season and genetics;

- The health and sanitary status of the predators and their prey;

- The potential pathogens circulating among humans, wild cats and domestic animals (Furtado *et al*., 2013);

- A better understanding of interactions between humans and wildlife;

- The real impact of predation on livestock, compared to anecdotal reports from locals, as well as the possible increase in livestock predation following flooding, since these findings have important implications for the conservation of the predators.

It is hoped that a substantial part of this information will be realised following the creation of CBPan (Centro de Pesquisa da Biodiversidade Pantaneira – Research Centre for the Biodiversity of the Pantanal); a proposal that emerged through a partnership between Instituto Homem Pantaneiro (IHP) and University of Aveiro (Portugal), that also includes several other partners such as the Universidade Federal de Mato Grosso do Sul (UFMS), Fundação Ecotrópica, ICMBio and Instituto Acaia Pantanal. CBPan aims to promote, develop and execute scientific research, as well as act as a reference for scientific training at undergraduate and postgraduate levels in the Pantanal biome, particularly at the AMR. It intends to target activities such as studies of the fauna and flora of the Pantanal, economic valuation of biodiversity, socio-environmental studies and alternative uses of natural resources, which will certainly help to better understand and increase the knowledge about the AMR's biodiversity.

CONCLUSIONS

Overall, this study provides a good overview about felid interactions in the temporal and spatial scales, potential prey occurrence, as well as information about the relationship between people and the wild cats. Camera trapping proved to be an efficient tool in monitoring considering the results obtained, the costs and the low level of environmental and species disturbance. The use of interviews and questionnaires proved informative. Nevertheless, this study can be considered preliminary, highlighting more questions that need to be explored, especially concerning the prey density and occupancy patterns that affect felid biology and ecology in terms of feeding habits, home range and health status, and factors affecting people's perceptions and attitudes towards them.

Considering the current context in terms of scientific information, legislation and socio-economic approaches, we propose a systematic monitoring program for the next five years covering AMR and its surroundings, which could support a post-doctoral researcher and other postgraduate and undergraduate level research, involving three basic approaches: felid biology, ecology and their conservation. Jaguars are by far the most studied cats in the Pantanal, being the target of several studies (Schaller and Crawshaw (1980), Crawshaw and Quigley (1991), Azevedo and Murray (2007), Soisalo and Cavalcanti (2006), and Cavalcanti and Gese (2010)). Nevertheless, the importance of medium-sized felids as mesopredators cannot be discounted (Di Bitetti *et al*., 2006). Thus, we will develop our methodology to cover relevant aspects of all felids that occur at AMR, especially adjusting camera trapping surveys to meet the requirements of smaller species. Also, importantly, this monitoring program needs to cover the drought and flood periods, in order to better reflect the Pantanal environment (Junk *et al*., 2006).

A program of environmental education in the schools located around AMR will be carried out twice a year with weekly activities, where children' parents will be invited to participate in at least one of the encounters. A scheduled activity with adult riverside communities will be carried out in intercalated months to monitor the occurrence of livestock predation in the surroundings of AMR. During this monitoring, we will use specific guidelines (Marchini *et al*., 2011; Hoogesteijn and Hoogesteijn, 2011) to provide information that may reduce livestock losses. We will also carry out monthly campaigns during the period of recreational fishing (February-October) in order to increase tourist awareness of faunal protection and observation (Table 7.1). Through this monitoring proposal, we hope to gradually increase the understanding about felids at AMR, contributing not only to their protection and conservation, but also to this vital area of the Pantanal biome.

Table 7.1: Schedule and actions proposed for the next five years (2014-2019) regarding felid monitoring at Amolar Mountain Ridge, Brazilian Pantanal.

Actions	J	F	M	A	M	J	J	A	S	O	N	D
Camera trapping surveys			x	x	x			x	x	x		
Scat collection for diet studies			x	x	x			x	x	x		
Capturing efforts for GPS telemetry and collection of biological samples										x	x	
Environmental Education Program at surrounding schools					x				x			
Awareness campaigns for tourist trade			x	x	x	x	x	x	x	x		
Monitoring in surrounding riverside communities regarding livestock predation	x		x		x		x		x		x	

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