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Density of ocelots in a semiarid environment in northeastern Brazil

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Abstract: Ocelots play a key role in ecological communities as mesopredators affecting the lower trophic level and other mesopredators. They show great variability in ecological traits across their distribution, but knowledge of this species is missing in several regions where it occurs. Here, we present the first study of ocelot in the Brazilian semiarid of Caatinga. Arid habitats might keep carnivore population density low and therefore vulnerable to environmental shocks and to human-induced changes, at risk of local extinction. To assess their population status, we used camera traps between September 2009 and January 2010. We estimated the density of ocelots using a spatially explicit capture-recapture method (SECR) to be 3.16 ± 0.46 individuals per 100 km^2. This is a low-density estimate for ocelots, which might reflect the harsh conditions of the arid habitat. A longer population study of the ocelot can answer if this low population density is enough for a long-term persistence of this species in this and other arid environments.

Keywords: *Arid environments, Brazil, Density, Ocelot, SECR.*

Densidade da jaguatirica em um ambiente semiárido no nordeste do Brasil

Resumo: Jaguatiricas possuem um papel fundamental em comunidades ecológicas como mesopredadores, afetando níveis tróficos inferiores e também outros mesopredadores. Esta espécie possui uma grande variabilidade em suas características ecológicas em toda a sua distribuição, no entanto, o conhecimento desta espécie possui lacunas em vários locais onde ela ocorre. Neste trabalho, nós apresentamos o primeiro estudo desta espécie no semiárido brasileiro da Caatinga. Ambientes áridos podem afetar negativamente as espécies carnívoras e, aliado a alterações antrópicas, esta espécie pode ser levada a extinção local se sua densidade populacional é baixa. Portanto, para verificar o nível populacional da jaguatirica em uma região protegida da Caatinga, instalamos armadilhas fotográficas, entre setembro de 2009 e janeiro de 2010. Com os dados obtidos, calculamos a densidade desta espécie através de métodos espacialmente explícitos (SECR). A densidade estimada da jaguatirica foi de 3.16 ± 0.46 indivíduos por 100 km^2. Esta estimativa é muito baixa para esta espécie, o que pode ser um reflexo das condições áridas deste ambiente. Um estudo populacional de maior duração pode ajudar a responder se esta baixa densidade é o suficiente para a persistência desta espécie a longo prazo tanto neste, quanto em outros ambientes áridos onde ela ocorre.

Palavras-chave: *Ambientes áridos, Brasil, Densidade, Jaguatirica, SECR.*

Introduction

The ocelot (*Leopardus pardalis*) occurs from southern Texas to north Argentina (Murray & Gardner 1997) in open environments, flood plains, dry coniferous forests, and rainforests (Emmons & Feer 1997). Besides the existence of many studies focused on this species through its distribution (de Villa Meza et al. 2002, Haines et al. 2005, Maffei & Noss 2008, Kolowski & Alonso 2010), very few have addressed this species in arid habitats (Laack 1991, González et al. 2003, Harveson et al. 2004, Maffei et al. 2005).

Ocelot densities vary across its distribution, ranging from 2.3 to 75.2 individuals per 100 km^2 (Table 1) and are thought to decrease with lower precipitation and increasing distance from the equator (Di Bitetti et al. 2008). This is because a lower precipitation may decrease productivity (Chesson et al. 2004) which in turn, might decrease carnivore prey densities (Herfindal et al. 2005, Pettorelli et al. 2009, Sandom et al. 2013), and higher latitudes often correlates with a lower precipitation (Prince & Goward 1995, Di Bitetti et al. 2008). However, arid environments might present different challenges to species in those regions.

The semiarid of the Caatinga, in northeastern Brazil (Figure 1), for instance, is a harsh environment where ocelots occurs (Oliveira & Cassaro 2005). This region has a high annual mean temperature (26º to 30º) and the lowest precipitation (300-1,000 mm/year) of Brazil (Prado 2008). Furthermore, this habitat is under heavily negative human induced changes like deforestation for ranches and plantations (Castelletti et al. 2004). However, there is almost no knowledge of ocelots' population status in the Caatinga.

Ocelots are ecologically important as mesopredators, not only affecting prey species, but potentially other carnivore species as well (de Oliveira & Pereira 2013), it is essential to conduct studies in this region where not only the ocelot, but also others species, faces a harsh environment that is being severely modified by human activities (Leal et al. 2008). Therefore, this study aims to contribute to the knowledge of ocelot populations in arid habitats by estimating its abundance and density in one of the few conservation units in the Caatinga (Leal et al. 2008).

Material and Methods

The study was conducted at the Serra da Capivara National Park (SCNP), in southern Piauí state (Figure 1), covering an area of 1,291 km^2 (FUMDHAM 1994). Local mean annual rainfall is approximately 644 mm with temperatures ranging from 12-45ºC and annual mean of 26ºC (Pellerin 1991). To make up for the lack of permanent natural water sources, the park's administration conducts artificial water hole management in which a water truck fills, periodically, artificial ponds distributed in the park.

We deployed 70 camera trap stations between September 1st 2009 and January 19th 2010 in roads and trails inside the park (Figure 1). We chose to install the stations in this way because several studies have demonstrated that big cats (Emmons 1988, Carbone & Christie 2001, Maffei et al. 2005) and ocelots (Trolle & Kéry 2005) have higher capture rates on roads and

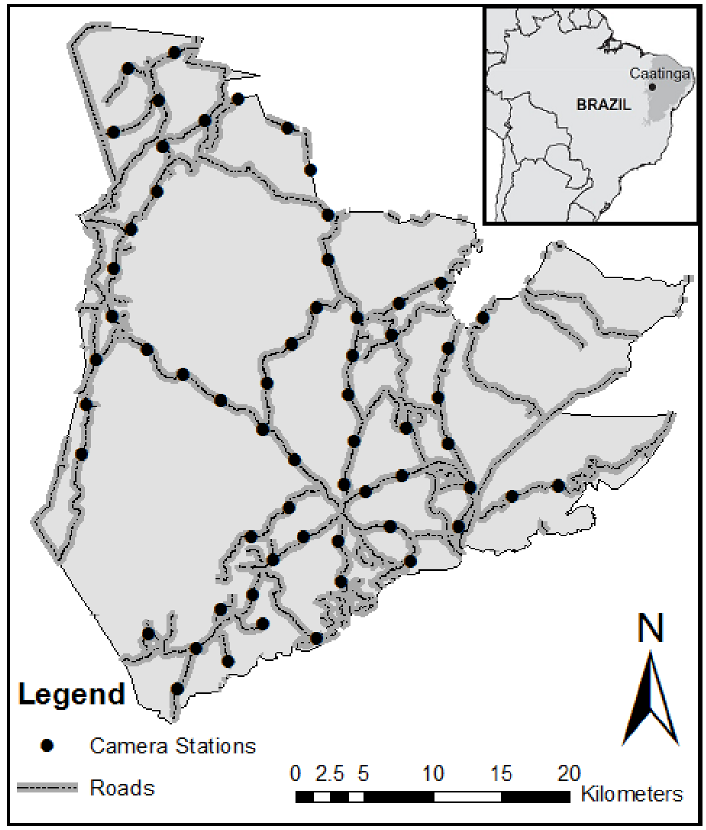

Figure 01. Map of Serra da Capivara National Park with camera locations.

Table 1. Ocelot density estimated in different studies and regions

Country	Habitat	Density (individuals/ 100 km^2)	Method[1]	Source
Peru	Amazon Forest	75,2	Non-spatial	Kolowski & Alonso (2010)
Brazil	Pantanal	56,4	Non-spatial	Trolle & Kery (2003)
Bolivia	Chaco dry forest	1.6-51.7	Spatially-explicit	Noss et al. (2012)
Peru	Amazon Forest	43,5	Non-spatial	Kolowski & Alonso (2010)
U. S. A.	Coastal grasslands	30	Non-spatial	Haines et al. (2006)
Belize	Tropical Rainforest	25,88	Non-spatial	Dillon & Kelly (2007)
Brazil	Atlantic Forest	21	Non-spatial	Fusco-Costa et al. (2010)
Argentina	Atlantic Forest	19,99	Non-spatial	Di Bitetti et al (2006)
Argentina	Atlantic Forest	13,36	Non-spatial	Di Bitetti et al (2006)
Argentina	Atlantic Forest	12,84	Non-spatial	Di Bitetti et al (2006)
Belize	Tropical Rainforest	12,61	Non-spatial	Dillon & Kelly (2008)
Argentina	Atlantic Forest	7,71	Non-spatial	Di Bitetti et al (2006)
Mexico	Sonora Desert	5,7	Non-spatial	González et al (2003)
Brazil	Caatinga	3,16	Spatially-explicit	This study
Brazil	Atlantic Forest	4	Non-spatial	Goulart et al. (2009)
Belize	Tropical Pine Forest	2.3-3.8	Non-spatial	Dillon & Kelly (2007)

[1] Density estimation method: Spatially-Explicity Capture-Recapture (SECR) or Non-spatial methods.

trails than on forested habitats. Additionally, the dense thorny vegetation and dramatic relief present in the park made it very difficult to install trap stations in other areas. Each station had two cameras (LeafRiver – Leaf River Outdoor Products, Taylorville, MS, US) facing each other in order to photograph both sides of the animal, which facilitates posterior individual identification. Cameras were set to operate continuously, with a 5-minute delay between consecutive photos. Each trap was spaced from the others by a mean distance of 2.9 ± 0.4 km (SD). Like other ocelot studies (Maffei et al. 2005, Di Bitetti et al. 2006, Maffei & Noss 2008), the present study was originally designed for jaguars (Silveira et al. 2009) and we opportunistically gathered important data on ocelots.

To estimate density we applied spatially explicit capture-recapture (SECR) Maximum-likelihood methods (Borchers & Efford 2008) implemented in software R 3.0.1 through the package "secr" (Efford 2011). These models estimates the density ($\hat{D}$), assuming the existence of a relation of the animal detection probability to the distance (d) from each animal home range center. This follows a two-parameters function, $g(d)$, with g_0 being the detection probability when $d = 0$, and a spatial scale σ, related to home range diameter (O'Brien & Kinnaird 2011). We considered six models with different effects on detection: (1) No variation in detection [g_0(.)σ(.)], (2) variation after the first capture [$g_0(b)$σ(.)], (3) variation with time [$g_0(T)$σ(.)], (4) differences between sexes [$g_0(sex)$σ(.)] (5) The conjoint effect of sex and time [$g_0(sex+T)$σ(.)] and (6) behavior and time [$g_0(b+T)$σ(.)]. We selected between models by using the Akaike Information Criterion adjusted for small samples (AICc).

Results

We registered 316 pictures of ocelots comprising 51 individuals. (Two researchers identified each picture independently). It is possible to identify sex easily in ocelot's pictures due the conspicuousness of the male's scrotum, and we found a sex ratio of 1.5:1 males to females (31 males and 20 females). We found 38 individuals (74.5%) at more than one station, 27 at more than two (52.9%) and 11 individuals (21.5%) had no recaptures (i.e. registered at only one photograph). There were also several pictures of juveniles and cubs; however, we did not include them in the analysis because we could not identify them individually. Model selection highlighted the difference between sexes on detection probability (Table 2), consistent with other studies that find ocelots are a territorial species with variation in home range and activity between sexes (Dillon & Kelly 2008). The highest-ranked model estimated 3.16 ± 0.46 ocelots/100 km^2.

Discussion

Ocelot density in our study area was at the lower end for this species in relation to other regions (Table 1), which could make this population especially prone to environmental changes – man made or not – and local extinction (Purvis et al. 2000). Several characteristics of this arid region could be affecting ocelot populations. The first environmental factor that might play a role keeping this ocelot population at lower levels is the low productivity. In some regions, low productivity can limit prey species (East 1984, McNaughton et al. 1989), which in turn may suppresses carnivore populations, because of the lower density of prey (Carbone & Gittleman 2002). This bottom-up effect, was hypothesized to be a main driver of ocelot density throughout its distribution (Di Bitetti et al. 2008). However, dry environments may affect ocelots adversely. Other studies on ocelots densities in arid regions estimated highly varying densities: 1.6 to 51.7 ocelots/100 km^2 in the Bolivian dry forests (Noss et al. 2012), 30 ocelots/100 km^2 in Texas (Haines et al. 2006) and 5.7 ocelots/100 km^2 .In Sonora, Mexico (González et al. 2003).

It is also interesting to note that the lowest density estimated for ocelots (2.3 individuals per 100 km^2) comes from a tropical pine forest in Belize (Dillon & Kelly 2007). These same authors, however, found a higher ocelot density in forests that were not pine-dominated (25 individuals per 100 km^2). Hence, vegetation structure may play an important role of this carnivore density across different regions. In our study, we estimated a low density in a region with a low productivity in an area with a dense vegetation structure, suggesting that in arid environments the productivity is a strong factor for ocelot density. However, we observed a high presence of rock cavies (*Kerodon rupestris*) during our survey. If this small rodent is an important part of ocelot's diet in this site, we do not believe low productivity is a main factor affecting ocelot density here. Unfortunately, the number of ocelot studies in arid regions are insufficient to verify a connection between productivity and density, as suggested by previously (Di Bitetti et al. 2008).

Several other factors may be relevant in arid landscapes. The interaction with other carnivore species can affect a species population (Palomares & Caro 1999, Caro & Stoner 2003, Dayan & Simberloff 2005, Donadio & Buskirk 2006). Ocelots co-occur with Jaguars and Pumas in the SCNP. These apex carnivores have a relatively high density in this park (Silveira et al. 2009) and they might negatively affect ocelot densities through intraguild killing (Ritchie & Johnson 2009).

Continuous monitoring of this species would help elucidate whether this low density is the natural state of ocelots in the Caatinga or whether the population is declining. Even if the density remains constant during different years, it is still a very low estimative and likely to be subject to local extinction with environmental changes or increase in human activities in the region. This study provides background for future research concerning ocelots in these and other arid habitats.

Table 2. Model selection results for different density models.

Model	AICc	ΔAICc	AIC weight
[g(sex)σ(.)]	1998,5	0	0,67
[g(sex + T)σ(.)]	2000,1	1,56	0,3
[g(b)σ(.)]	2005,7	7,24	0,01
[g(b + T)σ(.)]	2008,5	10,06	0
[g(.)σ(.)]	2012,1	13,64	0

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