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Original investigation

Activity patterns of ocelots and their potential prey in the Brazilian Pantanal

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ABSTRACT

Camera trapping has been widely used to study different aspects of animal ecology, increasing scientific knowledge and helping in conservation initiatives. Recently, some studies demonstrated the use of this technique to study temporal predator-prey interactions, most of which focused on large felids. In this study, we investigate the activity patterns of the ocelot (*Leopardus pardalis*)—a medium-sized neotropical cat—and its known potential prey in the Brazilian Pantanal using photographs taken by camera traps. We tested for seasonal differences in activity patterns, and assessed the patterns of temporal overlap between this felid and three known potential prey: the Brazilian rabbit (*Sylvilagus brasiliensis*), Azara's agouti (*Dasyprocta azarae*), and Paraguayan punaré (*Thrichomys pachyurus*). We estimated activity patterns using kernel density and measured the overlap between estimated paired distributions using a coefficient of overlap, hypothesizing that activity patterns would change between the rainy and dry season, and that overlap would be higher with rodents since they comprise the bulk of the ocelot's diet in the Pantanal and elsewhere. Azara's agouti and the Paraguayan punaré were the only species that presented significant changes in their activity patterns between seasons. Contrary to our hypothesis, there was low coincidence of activity patterns between ocelots and Azara's agouti for both seasons, but temporal overlap between ocelots and Paraguayan punarés was high with no significant difference, at least in the dry season. Overall, temporal overlap between ocelots and Brazilian rabbits was high, with no significant differences. In general, our results suggest that ocelots may tailor their activity to that of some of their potential prey to increase the probability of encounters. The results provide the first insight into temporal interactions involving ocelots and their potential prey in the Brazilian Pantanal.

Introduction

The ocelot is the largest of the world's small spotted cats (Kolowski and Alonso, 2010), with a geographic distribution ranging from the southern United States to North Argentina (Murray and Gardner, 1997). Ocelots prefer dense habitats to open areas (Haines et al., 2006; Haverson et al., 2004), are almost strictly nocturnal (Di Bitetti et al., 2006; Kolowski and Alonso, 2010; Maffei et al., 2002), and are opportunistic predators (Emmons, 1987), preying on a wide spectrum of prey such as small mammals, birds, lizards and snakes (Bianchi et al., 2013; Emmons, 1987), although they occasionally prey on larger animals (Bianchi et al., 2013; Villa Meza et al., 2002). Despite being listed as Vulnerable in Brazil and Least Concern globally (IUCN, 2016), the ocelot is considered abundant in the Brazilian Pantanal (Bianchi, 2009; Porfirio et al., 2014).

According to Optimal Foraging Theory, predators tend to minimize energy costs involved in seeking and manipulating prey, which should not be greater than the energy benefits obtained from those activities (MacArthur and Pianka, 1966). In terms of daily activity, ocelots must divide their time between several behaviors which include, amongst others, resting, hunting, and patrolling their territories, while avoiding potential dangerous encounters with jaguars and pumas (Di Bitetti et al., 2006; Emmons et al., 1989). Thus, an understanding of their daily activity patterns provides a behavioral and ecological metric that can be used as an indicator of energetic expenditure, foraging effort (Weckel et al., 2006) and predation risk (Rowcliffe et al., 2014).

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Recently, camera trapping has been used to study temporal predator-prey interactions using photographic capture data to quantify the activity patterns of predators and their potential prey (*e.g.* Foster et al., 2013; Hernández-Saintmartín et al., 2013; Linkie and Ridout, 2011; Monterroso et al., 2013, 2014; Romero-Muñoz et al., 2010). These studies are based on the assumption that predators may tailor their activity to that of their potential prey to increase the probability of encounters, thereby reducing the energy expended in capturing prey (Emmons, 1987; Foster et al., 2013; Harmsen et al., 2011). In response, it has also been reported that prey may alter their foraging times to avoid predators (Harmsen et al., 2011; Ross et al., 2013). Most such studies have focused on the interactions of larger felids (*e.g. Panthera onca*, *Puma concolor* and *Panthera tigris sumatrae*) with their potential prey (Foster et al., 2013; Hernández-Saintmartín et al., 2013; Linkie and Ridout, 2011; Romero-Muñoz et al., 2010), although there is also some information available for mesocarnivores (Monterroso et al., 2014). Nevertheless, information is still scarce concerning small-to medium-sized neotropical felids, such as the ocelot.

As for many other felids, ocelots are difficult to study in wild habitats due to their secretive habits, natural low densities and large territories (Trolle and Kéry, 2003). Thus, camera trapping has helped to substantially increase knowledge about this species which, over some of its distribution, is threatened mainly by fragmentation and habitat loss (IUCN, 2016). Here, using camera trapping, we study the effect of seasonality on the activity patterns and overlap in daily activity of ocelots and three of its known potential prey in the Brazilian Pantanal: the Brazilian rabbit (*Sylvilagus brasiliensis*) and the two rodents, Azara's agouti (*Dasyprocta azarae*) and the Paraguayan punaré (*Thrichomys pachyurus*) (Bianchi et al., 2013; Rocha-Mendes et al., 2010).

The Pantanal biome belongs to the category of temporary wetland (Junk et al., 2006), playing an important role in biodiversity due to its diversity of natural habitats, which offer several opportunities for feeding and reproductive niches (Alho, 2008). The annual wet and dry periods have a strong impact on distribution, community structure and population size of several animal species (Junk et al., 2006; Mamede and Alho, 2006). Thus, we designed our research to answer the following questions: (1) Do the activity patterns of ocelots and their potential prey differs between the rainy and dry seasons?; and (2) What are the patterns of overlap between the daily activities patterns of ocelots and potential prey? We hypothesized that activity patterns would change in response to seasonality and, since rodents comprise the bulk of ocelot prey in the Pantanal (Bianchi et al., 2013), we hypothesized that the overlap in activity would be higher with these prey compared to other non-rodent prey species.

Material and methods

Study area

The study was carried out at two adjacent sites at Amolar Mountain Ridge: Santa Tereza Ranch (18°18′38″ S, 57°30′10″ W) and Engenheiro Eliezer Batista Private Protected Area (18°05′25″ S, 57°28′24″ W) (Fig. 1). Both study sites are nearly 830 km^2 in area. Amolar Mountain Ridge is located 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 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). The rainy season is October–April, while the dry season is May–September (Junk et al., 2006). The main vegetation types at both sites includes dry and humid savannahs (50%), which can be submerged during the flood periods, gallery and riparian forest (5%), seasonal deciduous forest (10%), seasonal semi-deciduous forest (14%), rocky fields (1%), as well as permanent rivers and lakes that comprise approximately 20% of both areas.

Camera trapping

We conducted six camera-trapping surveys separated temporally between August 2011 and September 2013 (Table 1). A total of 119 cameras were spaced in an arrangement with a distance that varied between 500 and 2000 m, and total cameras used in each survey ranged from nine to 41 units. All surveys did not have the same duration (1–5 months) (Table 1). Each station had one camera placed 40–50 cm above the ground along dirt roads, river margins and in the forest. We used Bushnell Trophy Cam (Bushnell®, Kansas, USA) and Panthera V3 (Panthera, New York, USA) digital cameras. Cameras operated 24 h/day, with 30 s intervals between pictures. The camera triggering time was set at five seconds. We checked stations at 15–30 day intervals to change batteries and/or to download pictures. Malfunctioning cameras were replaced and 8 GB memory cards were used to ensure sufficient memory for all records.

Statistical analysis

We categorized photos by rainy (October–April) or dry season (May–September) following Junk et al. (2006). To avoid autocorrelation, we only used photos taken at least one hour apart for each species, unless it was possible to distinguish individuals, in which case each photo was considered independent (Foster et al., 2013; Linkie and Ridout, 2011; Romero-Muñoz et al., 2010). To reduce bias caused by repeated records of the same animal due to the proximity of some cameras (cameras placed 500 m apart), we only used 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 h after sunrise and 1 h before sunset), nocturnal (if activity was predominantly between 1 h after sunset and 1 h before sunrise), and crepuscular (if activity occurred up to 1 h before and after sunrise and sunset). 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 for changes during winter and summer times, in order to make data comparable since it accounts for 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 cathemeral (species that were active both day and night).

We used the approach developed by Ridout and Linkie (2009) to estimate the activity patterns of each species in each season using kernel density and, next, to measure the overlap between the 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) using R package *Overlap* (Meredith and Ridout, 2014). 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