Camera-trap study of ocelot and other secretive mammals in the northern Pantanal

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ABSTRACT
Reliable information on abundance of the ocelot (*Leopardus pardalis*) is scarce. We conducted the first camera-trap study in the northern part of the Pantanal wetlands of Brazil, one of the wildlife hotspots of South America. Using capture-recapture analysis, we estimated a density of 0.112 independent individuals per km^2 (SE 0.069). We list other mammals recorded with camera traps and show that camera-trap placement on roads or on trails has striking effects on camera-trapping rates.

MOTS CLÉS
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RÉSUMÉ
Étude par piège photographique d'ocelots et autres mammifères cachés dans le Pantanal nord. Bien que l'ocelot (*Leopardus pardalis*) soit relativement commun dans les plaines tropicales d'Amérique du Sud, peu de données sont disponibles sur l'abondance de ce félidé. Nous présentons ici les résultats de la première étude par piège photographique publiée pour la partie nord des zones humides du Pantanal au Brésil, l'un des sites les plus importants d'Amérique du sud pour la faune sauvage. En combinant l'utilisation de pièges photographiques avec des analyses de capture-recapture, nous avons estimé une densité d'ocelots de 0.11 individus indépendants par km^2 (SE 0.069). Nous donnons aussi une liste d'autres mammifères enregistrés par piège photographique. Finalement, nous montrons que le choix des emplacements des pièges, sur des routes ou sur des sentiers, a un effet marqué sur le taux de capture photographique.

INTRODUCTION

Reliable information on the abundances of the ocelot is surprisingly scarce (see Oliveira 1994; Nowel & Jackson 1996; Murray & Gardner 1997). Until recently, the very few published density estimates for ocelot from South America were based on radio-telemetry studies (Ludlow & Sunquist 1987; Emmons 1988). This method has a number of limitations for estimating population density (Karanth 1995, 1999).

Trolle & Kéry (2003) demonstrated that ocelots are individually identifiable from their body markings and estimated density using a capture-recapture method. This efficient, new method of combining camera-trapping with capture-recapture models has been used increasingly for a number of secretive mammalian species (Karanth 1995; Karanth & Nichols 1998; Carbone *et al.* 2001; Maffei *et al.* 2002, 2004; Noss *et al.* 2003, 2004; Trolle & Kéry 2003; Silver *et al.* 2004).

The principal aim of this study was to conduct a larger-scale investigation on ocelot density in the northern Pantanal and continue the development and evaluation of the camera-trap methodology.

Additionally, we present here data on other secretive mammals. Such information is of great importance in planning future studies and conservation measures in the Pantanal region.

Finally, we investigate how the placement of traps on roads or on trails influences camera-trapping rates.

Study Site

The study took place in the 106,000 ha private reserve Estância Ecológica SESC Pantanal situated between the Rio Cuiabá river and the tributary Rio São Lourenço in the Barão de Melgaço region, the north-eastern Pantanal, Mato Grosso, Brazil. A study area of approximately 54 km^2 was chosen in the north-eastern corner of the reserve between the field stations of Santa Maria by the Rio São Lourenço (16°42.655’S; 56°01.648’W) and São Luiz (16°41.201’S; 56°10.486’W). This particular area was chosen partly because the habitats were representative for the area and partly for logistical reasons.

A mosaic of closed and open as well as permanently dry and seasonally inundated habitat types was found in the study area , including gallery forest, semideciduous forest with the understorey dominated by acurí palms (*Scheelea phalerata*), Cerrado woodland, scrubland, and grassland. During the rainy season (usually a three-month period around December through February), large areas flood. However, by the end of the dry season, when this study took place (Oct-Dec 2002), no permanent water occurred in the study area, except for a number of artificial water holes. Typical of the Pantanal (Trolle 2003), which consists mainly of private cattle ranches, the study area has been affected considerably by various ranching-related activities. However, since the establishment of the reserve in 1998 these influences have been diminished and subsequently the natural succession has begun, giving a high coverage of grass, dense scrub, and thick forest undergrowth.

MATERIALS AND METHODS

Sampling

A standardized camera-trapping protocol appropriate for the ocelot was used (i.e. ensuring that at least one trapping station was present in each home range). The general framework of our study design followed Karanth & Nichols (1998) and Nichols & Karanth (2002). The study area was divided into four sub-areas. In each sub-area, 14 trapping stations were camera trapped for nine consecutive nights. Nine capture occasions were defined by the first to ninth day of trapping in each of the four subareas.

We covered the study area with a grid configuration, with trapping stations spaced approximately one km apart. We selected sites for the cameras that seemed promising, using animal signs as indicators. The trapping stations were placed mainly by dirt roads (car tracks) and animal trails. In total, 29 of the trapping stations were placed along roads and 27 on animal trails.

Fourteen passive infrared trail monitors were used (TrailMaster model TM550; Goodson &

Associates, Inc., Lenexa, Kansas) with adapted, automatic, weatherproof 35-mm Yashica or 32-mm Canon cameras with automatic flash (TrailMaster model TM35-1). In order to gain photographic records of both flanks of animals, each trap was equipped with two cameras. The traps were set up and programmed as described in Trolle (2003). Sardines in oil were applied as bait. The units were programmed to take photos between 1800 h–0500 h (approximately between sunset and sunrise). In the Pantanal, this avoids wasting the film within a few days on agoutis (*Dasyprocta*), birds, and sun-triggered photos (Trolle 2003).

DATA ANALYSIS

We used capture-recapture analysis to estimate population size for ocelots. The temporal pattern of sighting/non-sighting of individual ocelots contains information on the population size. Key to inference about population size is detection probability, i.e. the probability with which an ocelot present in the study area is photographed during one capture occasion. We assumed a closed population, i.e. that there were no numerical changes in the population during the study period, and used CAPTURE (Otis *et al.* 1978) to estimate population size.

Although the closure assumption appeared reasonable with a study duration of only 1.5 month, we tested this by the closure test in program CAPTURE and by a likelihood ratio test between a constrained and an unconstrained Cormack-Jolly-Seber model in program MARK (White & Burnham 1999). The latter procedure tests if a model assuming an open population fits significantly better than one where the population is assumed to be closed, i.e. where survival rate is constrained to be equal to 1. If it does not, this is taken as evidence that the closure assumption is tenable.

Program CAPTURE provides estimators for seven models that make different assumptions about sources of variation of detection probability: M_0, M_b, M_t, M_h, M_{th}, M_{bh} and M_{tb}. See Otis *et al.* (1978) and Karanth & Nichols (1998) for full details on these models. We used goodness-of-fit tests, between-model tests and the CAPTURE model-selection routine to select the appropriate model for population-size estimation.

We estimated density of ocelots in the study area by dividing the estimated population size by the estimated effective trapping area as described by Karanth & Nichols (1998). However, here we used both the full mean maximum distance moved (MMDM) and half the MMDM to define boundary strip width. MDM is the maximum distance between two trap locations for an animal trapped at more than one location. It is viewed as an approximation to home range diameter. The boundary strip is added to the core trapping-area perimeter (the minimum convex polygon defined by trap locations) to yield the total, effective trapping area from which the captured animals are likely to have been drawn from. A recent field test of density-estimation methods for small mammals has shown the full MMDM to be superior to the half MMDM method (Parmenter *et al.* 2003). However, determination of boundary-strip width is a thorny issue, so for better comparison among studies, we provide three density estimates pertaining to (1) the core area only, and adding a strip of (2) half and (3) the full MMDM. See Karanth & Nichols (1998) for formulae of estimators and their variances.

We used log-linear models to test if camera-trap rates were the same on roads and on trails. For each species with sufficient sample size, we used a Chisquare test to see if the numbers of captures on roads reflected expectations based on the number of trap-nights on roads (261) versus on trails (243). These analyses were conducted in the programme GenStat (Payne *et al.* 1993).

RESULTS

The 56 camera-trapping stations covered a minimum-convex polygon (MCP) area of 53.72 km^2. The total camera-trapping effort was 504 camera-trapping nights.

OCELOT DENSITY

Sixteen captures of ocelot were obtained, out of which 14 captures rendered photos of a quality that allowed individual recognition. Nine individual ocelots could be recognized, including six females and two males. There was no evidence for a violation of the closure assumption (test in CAPTURE: z = - 0.92, P = 0.18); test in MARK: $\chi_1{}^2$, P = 0.30). As selected by CAPTURE, we based estimation on the constant model M_0. Detection probability per occasion was estimated at 0.127 and, hence, over the entire study, at 0.706. Population size estimate was 12 (SE 3.351) with a 95% CI ranging from 10–26.

Only two animals were trapped at more than one trap station. Maximum distances moved were 0.6 and 5.1 km, respectively. This yielded a mean-maximum distance moved (MMDM) of 2.85 km (SE 2.25 km). Using half the MMDM to define the width of the boundary strip around the core minimum-convex polygon area defined by the trap locations yielded a density estimate of

TABLE 1. — Estimation of ocelot population size and density.
We use three different methods of obtaining the trapping area, MCP, half and full MMDM. This refers to the minimal convex polygon defined by the trap locations and to the area obtained by adding a boundary strip with width corresponding to half or the entire mean maximum distance moved between different captures of the same individual. The area is given in km^2 and density as the estimated number of independent ocelots per km^2.

Method	Area (km^2)	$\check{N}$ (*SE*)	$\check{D}$ (*SE*)
MCP (no boundary strip)	53.72	12 (3.35)	0.2234 (0.0624)
plus half MMDM	107.22	12 (3.35)	0.1119 (0.0685)
plus full MMDM	173.23	12 (3.35)	0.0693 (0.0624)

TABLE 2. — Species recorded by camera trapping.

Didelphis albiventris	White-eared opossum
Dasypus novemcinctus	Nine-banded long-nosed armadillo
Euphractus sexcinctus	Six-banded armadillo
Priodontes maximus	Giant armadillo
Myrmecophaga tridactyla	Giant anteater
Tamandua tetradactyla	Southern tamandua
Cebus apella	Brown capuchin monkey
Cerdocyon thous	Crab-eating fox
Chrysocyon brachyurus	Maned wolf
Nasua nasua South	American coati
Procyon cancrivorus	Crab-eating raccoon
Leopardus pardalis	Ocelot
Puma concolor	Puma
Tapirus terrestris	Brazilian tapir
Pecari tajacu	Collared peccary
Tayassu pecari	White-lipped peccary
Blastoceros dichotomus	Marsh deer
Mazama americana	Red brocket deer
Mazama gouazoubira	Brown brocket deer
Hydrochoeris hydrochaeris	Capybara
Cuniculus paca	Paca
Dasyprocta azarae	Azara's agouti
Thrichomys apereoides	Spiny rat
Sylvilagus brasiliensis	Brazilian forest rabbit

Note: When available, scientific names in this paper follow Voss *et al*. (2001) and common names Emmons & Feer (1997). Additional scientific and common names follow Eisenberg & Redford (1999).

ocelots in the study area of 0.112 (SE 0.069) animals per 5 km^2 (Table 1). The boundary-strip width chosen strongly affects the density estimate. Therefore, we also present density estimates that pertain to just the core MCP area (no boundary strip) and to an effective area with the full MMDM added.

Data on additional mammal species

A total of 24 large to medium-sized mammal species were recorded by the camera traps (Table 2), many of which are secretive and little known from the Pantanal. Worthwhile mentioning is also the fact that burrows and digging activity of *Priodontes maximus* were frequently found all over the study area.

Effect of trap location on or off roads on camera-trapping rates

About half of the trapping stations were placed on dirt roads (51.8%) and about half on animal trails (48.2%). Camera-trapping rates on roads were significantly different from those on trails (Table 3; log-linear model: χ_{11}^2, $P < 0.001$). For example, 96% of 202 captures of carnivores were on roads. In sharp contrast, only 26% of 46 captures of tapirs were on roads. Indeed, none of the species with sufficient sample size were caught in proportional numbers on roads and on trails (Table 4).

DISCUSSION

Biological considerations

The ocelot density found in our north-eastern Pantanal study site, 0.112 (SE 0.069) animals per km^2, was much lower than in the south-eastern Pantanal (0.564 (SE 0.201); Trolle & Kéry 2003). Longer-term studies are needed to confirm whether this large difference is permanent or maybe a result of ocelot population fluctuations (e.g., due to fluctuating prey availability). However, the results indicate that there

TABLE 3. — Camera-trapping rates (ctr) from two Pantanal sites.

	NE Pantanal (this study)		**SE Pantanal (Trolle 2003)**
Ctn	261/243		412
Trapping stations	29/27 (roads/trails)		33
Trapping hours	dusk-dawn		dusk-dawn
	ctr		ctr
	roads	trails	roads/cattle trails
Didelphis	–	0.41	–
Dasypus	0.77	1.23	2.91
Priodontes maximus	0.77	0.82	–
Myrmecophaga tridactyla	0.77	0.41	0.73
Cerdocyon thous	38.70	2.47	7.52
Chrysocyon brachyurus	3.83	–	–
Dusicyon vetulus	–	–	–
Procyon cancrivorus	22.22	0.41	8.50
Leopardus pardalis	5.75	0.41	6.80
Leopardus tigrinus	–	–	0.24
Leopardus wiedii	–	–	0.49
Panthera onca	–	–	0.24
Puma concolor	3.45	0.41	1.45
Tapirus terrestris	4.60	13.99	2.91
Cuniculus paca	–	1.65	–
Sylvilagus brasiliensis	0.77	1.65	–

TABLE 4. — Comparison of trapping rates on roads and on trails for selected species. For each species is given the number of captures (cap), the camera-trapping rates (ctr = number of captures per 100 trapping nights), the percentage of trapping stations that recorded the species (% trap stations), and, for each species, the chisquare test statistic and p-value for a test of association between observed and expected numbers of captures on and off-roads. The Null hypothesis assumes that species are captured on roads and on trails according to the proportion of trap-nights (261/243). All tests have one d.f.

	Overall			Traps on roads			Traps on trails			Test for association	
Trapping stations		56			29			27			
Camera-trapping nights		504			261			243		Chisquare	p-value
	cap	ctr	% trap stations	cap	ctr	% trap stations	cap	ctr	% trap stations		
P. maximus	4	0.79	7%	2	0.77	7%	2	0.82	7%	–	–
C. thous	107	21.2	50%	101	38.7	86%	6	2.47	11%	102.10	< 0.001
C. brachyurus	10	1.98	18%	10	3.83	34%	0	0	0%	13.86	< 0.001
P. cancrivorus	59	11.7	45%	58	22.2	83%	1	0.41	4%	71.65	< 0.001
L. pardalis	16	3.17	18%	15	5.75	31%	1	0.41	4%	14.70	< 0.001
P. concolor	10	1.98	18%	9	3.45	31%	1	0.41	4%	7.36	0.007
T. terrestris	46	9.13	39%	12	4.60	24%	34	14.0	56%	10.96	< 0.001

For *Priodontes maximus*, no test of association is shown for small sample size.

may be large differences in ocelot density from area to area in the Pantanal.

Tapirus terrestris, *Cerdocyon thous*, and *Procyon cancrivorus* all had comparatively high trapping rates, and are undoubtedly relatively abundant in the study area (Table 3; MT, pers. obs. from the Brazilian and Peruvian Amazon). *Priodontes maximus* seems much more common in the SESC area than in our study site in the south-eastern Pantanal (Trolle 2003). Finally, neither *Didelphis albiventris*, *Chrysocyon brachyurus*, nor *Sylvilagus brasiliensis* were found to occur in the southern study site (Trolle 2003).

METHODOLOGICAL CONSIDERATIONS

Determination of effective trapping area

Determination of strip width and its effect on density estimates needs further study. The suggestion of Karanth & Nichols (1998), to define strip width by an estimate of the radius of the home range (i.e. half the MMDM), is based on small mammals. It is unclear if this is appropriate for large territorial carnivores. In a recent study, adding a full MMDM strip width performed better at estimating density (Parmenter *et al.* 2003). Hence, we present three different estimates of density. Data to determine strip width may also come from outside a study, such as from a separate radio-telemetry study. Given the results by Parmenter *et al.* (2003) we would perhaps prefer to calculate density with the full MMDM boundary strip width added. See also the discussion in Noss *et al.* (2003).

Size of study area

Our density-estimation method breaks down when there are no animals captured at multiple locations. Both our ocelot data sets were small and just reached the minimal required sample size for computing an MMDM plus associated measure of imprecision (SE). Our small sample sizes are reflected in large confidence intervals. While these are undesirable, they still show one advantage of this method, *viz.* that imprecision in the component estimates of density is properly accounted for.

Obviously, trapping in a large area helps with regard to both of these issues. With increasing

core/boundary area ratio, the choice of strip width becomes less influential for density estimation. In addition, larger areas are likely to contain more animals, so that strip width can be estimated with greater precision.
Finally, we would recommend that sub-areas are camera trapped for longer than the nine days we used in this study. This will heighten the chance of recaptures, giving better estimations.

Effect of trap location on or off roads on camera-trapping rates
These results have significant methodological implications. There is a controversy among leading camera-trapping researchers over the use of camera-trapping rates to assess densities of secretive mammals that are *not* individually identifiable (Carbone *et al.* 2001, 2002; Jennelle *et al.* 2002). This debate is important, because camera trapping is likely to be used increasingly to provide data for conservation planning and assessment. Our results show that the placement of camera traps in relation to roads in a study area (something that will often vary between studies) is an essential covariate to take into consideration when trying to compare camera-trapping rates between studies and sites.

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