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Mosaics of Exotic Forest Plantations and Native Forests as Habitat of Pumas

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Abstract There is a general lack of information on the impact of forest plantations and presence of urban settlements on populations of resource-demanding species such as large felids. To partially address this problem, a project study was conducted to find out whether mosaics of forest plantations and native vegetation can function as adequate habitat for pumas *Puma concolor* in southern Brazil. The study was conducted within a 1,255 km^2 area, managed for planted stands of *Pinus* spp. and *Eucalyptus* spp. Individual identification of pumas was carried out using a combination of track-matching analysis (discriminant analysis) and camera-trapping. Both techniques recorded very similar number of individual pumas, either total (9 – 10 individuals) or resident (5 – 6 individuals). A new approach, developed during this study, was used to individualize pumas by their markings around the muzzle. Estimated density varied from 6.2 to 6.9 individuals per 100 km^2, ranking amongst the highest across the puma entire range, and a potential total population of up to 87 individuals in the study site. In spite of the availability of extensive areas without human disturbance, a radio-tracked female used a core home range that included forest plantations, an urbanized village, and a two-lane paved road with regular vehicular traffic. These high density of pumas and the specie's intensive use of modified landscapes are interpreted here as derived from conditions rarely found near human settlements: mutual tolerance by pumas and humans, and adequate habitat (regardless of plantations) largely due to inhibition of invasions and hunting. More widely, it suggests the potential of careful management in forestry operations to provide habitat conditions for resource-demanding species such as the puma. Furthermore, it highlights the importance of curbing invasions and hunting for the maintainance of healthy wildlife populations.

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Introduction

Forest plantations covered 187 million hectares in year 2000, with a current annual planting rate reaching 4.5 million hectares globally. South America accounts for 11% of the annual rate (Palmberg-Lerche and others 2002). In Brazil, the largest country in South America, forest plantations are believed to be expanding at a rate of 2.2 to 2.3 thousand square kilometers per year (Bacha and Barros 2004). Due to the large habitat requirements (food and space) of top carnivores (Mac Nab 1963; Eisenberg 1980; Robinson and Redford 1986), the identification of factors that define and limit carnivore distribution and abundance are a current topic in ecology (e.g. Beier 1995; Wiegand and others 1999; Carroll and others 2000; Riley and Malecki 2001; Comiskey and others 2002). Such knowledge is important in order to predict where target species are most likely to survive in the face of habitat disturbance, where conservation efforts should be focused, and which management implementations may be recommended to guarantee maintainance of carnivore populations.

Large felids are a particular group amongst the carnivores whose existence is generally believed to be incompatible with human activities. That notion steams from the fact that large cats can be a direct threat to human life (e.g. Beier 1991; Nyhus and Tilson 2004), or to livestock (e.g. Mazzolli and others 2002; Michalski and others 2006; Palmeira and Barrella 2007), and are, for these reasons, not generally tolerated near human settlements.

Regarding large cat tolerance to humans and habitat modification, in the other hand, there are examples of leopards living in high populated areas (Athreya and Belsare 2006), and pumas reaching suburban areas throughout their range. These are mostly records of their presence, with no detailed information on whether a specific land-occupation model provides conditions to maintain more than few individuals. Details of their ecology in this context are yet to be investigated. In fact, little is known of the responses of large cats to human interference and their survival chances in disturbed habitats (Nowell and Jackson 1996).

Investigating tolerance of large cats to changes in land-use such as to forest plantations is not simple, as it is difficult to isolate the predators' response to a single factor of disturbance near settlements. Settlements are often associated with other confounding effects that may also cause predator's population decline, such as reduction of prey-base due to hunting (Schaller 1983; Emmons 1987; Karanth and Sunquist 1992; Peres 1996; Cullen Jr and others 2000), direct persecution (e.g. Rabinowitz 1986; Norton and Henley 1987; Seidensticker and others 1990; Oli and others 1994; Mishra 1997; Franklin and others 1999; Mazzolli and others 2002), or general habitat impoverishment derived from unsustainable harvesting.

As a means to partially address this problem, I determined abundance of pumas in a modified environment and recorded home-range use near villages and and forest plantations. Differently than the often expected conditions of general habitat deterioration, however, hunting was not allowed and there was no livestock that could be a source of conflict. Thus, assessment of number of pumas and habitat conditions was virtually free from confounding effects derived from human removal of pumas or their prey.

This provided a useful insight into the ability of such commercial plantations to maintain large, resource demanding predators when management is in place.

The puma is a large territorial carnivore and as such make use of a large home range and is found at low densities. Home range of pumas in Brazil as estimated from radio-tracking were found to vary from 100 to 179 km^2 for females (n=4) (Sana and Crawshaw, pers. comm.) and from 130 to 220 km^2 for males (n=2) (Sana, pers. Comm.). Silveira (2004) found considerably larger home ranges. Considering those with more than 30 fixes and 100% Minimum Convex Polygon (MCP), he found a female to range over 479 km^2 (n=1) and male's occupying 287 to 763 km^2 (n=3). Density estimates for pumas based on camera-traps are available for South America (Kelly and others 2008), including Brazil (Trolle and others 2007), and have been found to vary from 0.67 to 6.8 pumas 100/km^2 (mean ± *SD*; 3.5 ± 2.5; n=4).

Pumas have recently made a come back in southern Brazil as a result of more restrictive environmental legislation and greater law enforcement, recolonizing areas in which they were previously absent or thought to be severely reduced in numbers (Mazzolli 2007). The study area also seemed to have experienced a recent increase in the number of pumas, and this is the immediate reason why this study was carried out.

Material and Methods

Study area

The study was conducted in a privately owned area in southern Brazil within the locality of Telêmaco Borba, State of Paraná at central coordinates (24°12' S, 50°33' W).

The total area encompassed 1,255 km^2, of which 513 km^2 (41%) was covered by native forests maintained mainly along watercourses and valleys, including small patches of native grassland and scrub. The remaining vegetation comprised planted stands of *Pinus* spp., *Eucalyptus* spp., and *Araucaria angustifolia*. Only planted forests were harvested, either for timber or cellulose extraction. Non-native stands were harvested at intervals of approximately seven years during which time there was a substantial growth of underbrush, and a clear-cut was carried out at the third interval (i.e. after 21 years).

Native vegetation was classified as "transitional" (IBGE 1992) because it consisted of a mosaic of different vegetation types. It harbored natural grasslands (steppe), coniferous forest (araucaria forest) also called mixed ombrofilous forest, and Atlantic rain forest also known as moist ombrofilous forest.

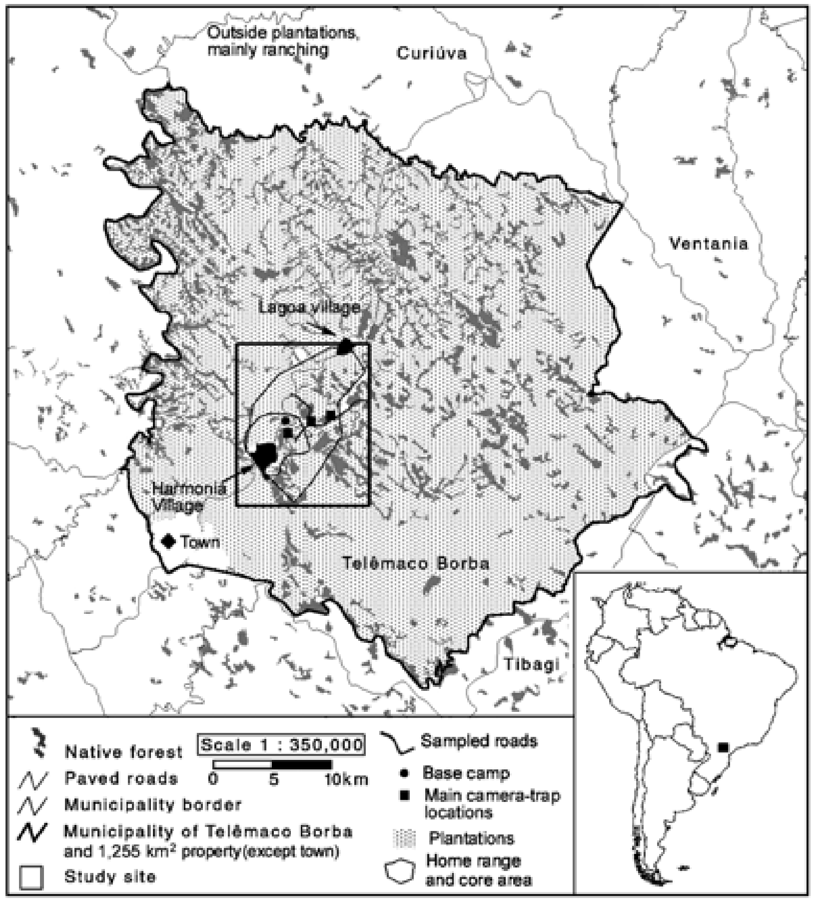


Figure 1. Figure representing the municipality of Telêmaco Borba and surroundings. The municipality, except the southwestern tip, is almost entirely owned by the forestry company. Note that the forestry area harbor far more native forest than the surrounding areas. The black retangle is the sampled site with 60% native vegetation, inside which lies the home range of the female mountain lion (larger contour) and the 90% kernel core area (smaller contour). The black squares are the general location of the camera-traps, which are 2 km from each other, and the gray lines are the roads surveyed for tracks, nearly 10 km in length. Background vegetation map was obtained from SOS Mata Atlântica. Central coordinates are 24° 12’S and 50° 33’ W.

Altitude varied from 700 to 960 m, with temperatures averaging approximately 18°C during summer (21st December to 21st March) and 14°C during winter (21st June to 21st September). A dry season sets during winter with precipitation falling to 71mm/month when periods of dry, clear weather last for several weeks (Fig. 2). Such dry seasons are characteristic of southern and south-eastern Brazilian mountains with drought increasing with both altitude and with distance from the coast (Safford 1999).

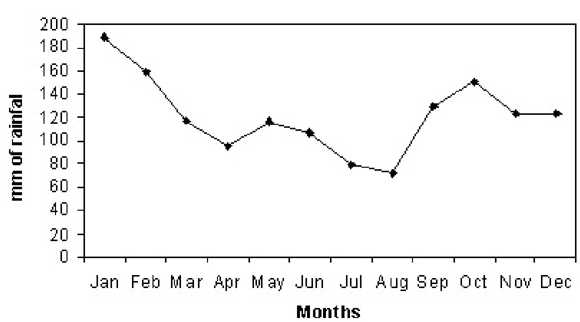


Figure 2. Average precipitation in the study area, data from 1946 to 1998 (source: Klabin).

Base camp for the current research was located within a wildlife captive breeding station, which had been set with the purpouse of maintaining native animals for future reintroduction, environmental education (visiting was allowed), and as a recovery centre for injured animals.

Study design

The main purpose of this study was to determine whether the study site was a suitable habitat for pumas. To be considered a suitable habitat, the area was expected to hold abundances of pumas similar to areas that had not been partially converted as the study site, and to harbor key prey species distributed at considerable numbers throughout the property. Although the puma population has not been monitored before the convertion to plantations for comparison of past and present status, it is reasonable to assume that low densities would indicate poor habitat quality for pumas, and high densities would indicate otherwise.

The current investigation was most intensively conducted in a 100 km^2 area known as ‘ecological park’, which possessed a higher than average proportion of native vegetation (60%) compared to other sites within the forestry property. Within that area, number of transient and resident pumas were estimated from camera-trapping and from track matching analysis.

The area sampled is considered small for a standard study on abundance of a large carnivore, particullarly if a generalization to the entire study area is desired. In fact, density seems to decrease with the area sampled for carnivores as a product of spatial heterogeneity in densities (Smallwood and Schonewald 1998) or due to the overlap with edges of many home ranges (Maffei and Noss 2008). To solve this problem two approaches that resulted in conservative density estimates were used, and are explained in detail in the camera-trapping section.

An attempt was made to extrapolate puma density found in the sampled area to the remaining of the property. To validate the inference that puma density would not vary with scaling densities to a larger area, the distribution and habitat preferences of the puma's most important prey in the study site was analysed. Investigation of the pumas's diet in the study site from the analysis of 119 scats indicated that seven major prey species account for 86 percent of total biomass consumed, including three ungulate species (peccaries and deer), two rodents (capybara and porcupine), one edentate (nine-banded armadillo) and one carnivore (coati) (Mazzolli 2000). It was assumed that abundance of puma throughout the entire property would not vary considerably from that found in the sampled area if distribution of these main prey species did not vary remarckably accross the property and if plantations were not avoided by them. This assumption was based on the fact that the distribution and abundance of predators is typically determined by that of their prey (e.g., Pierce and others 1999; Karanth and others 2004a, Kawanish and Sunquist 2004).

Distribution and frequency of prey.— The dataset on the distribution of puma's prey were collected by company employees, and consisted of sighting sheets of all animals observed during the course of their routine duties in the forest and elsewhere, covering the period between 1991 and 2000. It included information on location, parcel, habitat type (or forest cover) and the group size of the animals observed. The perfomance of this tasks show their commitment to the environmental trainning and additionally provided valuable information that may be used for area management.

For distribution analysis, number of sightings of prey species were compared amongst areas with different proportions of native vegetation (predominantly forest). To do that, the property was divided in four blocks. Block 1 contained 60-69% of natural vegetation, block 2 contained 50-59%, block 3 contained 40-49%, and block 4 contained 20-39% native vegetation.

All prey species rated very high in block 3 during a preliminary analysis, raising the concern that the number of observations in this block was due to employees reporting more frequently from there rather than a result of animal frequency. Consequently, this block was removed from the analysis to avoid bias in the results of the other blocks, except for porcupine. Because of the low sample size of observations for porcupine, the four original blocks were lumped into two by combining blocks 1 and 2, and blocks 3 and 4.

A χ^2 Goodness of Fit analysis was performed to test the association of prey animals with blocks and habitat (native vegetation, *Pinus* spp., *Eucalyptus* spp. and araucaria plantation). The statistics were always based on the same number of categories (n=4, thus $d.f$ =3), probability (α=0.10), and critical value (χ^2=6.25) for habitat type comparisons. During block comparisons χ^2 analyses were always based on three categories (n=3, thus df=2). If χ^2 resulted significant, preference or avoidance were then tested using individual confidence intervals involving Bonferroni z statistics, and constructed for each theoretical proportion of occurrence, using the formula below from Neu and others (1974):

$$\bar{p}i - z(1-\alpha/2k)\sqrt{\bar{p}i(1-\bar{p}i) \div n} \leq pi \leq \bar{p}i + z(1-\alpha/2k)\sqrt{\bar{p}i(1-\bar{p}i) \div n}$$

Critical values for Bonferroni statistics were the same for most analysis unless otherwise noted, with critical $Z_{(1-\alpha/(2*n))}$ value for forest cover ($Z_{0.9875}$=2.24) and for blocks ($Z_{0.983}$=2.12) (α=0.10).

Camera-trapping study design.— Data from camera-trapping was analysed in program CAPTURE (Otis and others 1978; Rextad and Burnham 1991) for the purpose of estimating the number of pumas ranging in the sampled area and to estimate density. Each month of the survey represented a capture occasion in which presence or absence of an individual was recorded. Although camera traps were set from June 1998 to March 2000, the author's absence from the study area after August 1999 followed unsupervised shifts in camera usage, thus occasions were considered only for the duration of 14 month (1,260 trap-nights) of the first year.

Three single-sided camera traps (Trailmaster, Model TM 1500, Goodson and Associates, Kansas, USA, online at www.trailmaster.com) were used to take photographs of pumas on roads rarely used by vehicles. Camera sites were often chosen based on *a priori* information on puma presence obtained from track identification, as a means to maximize capture and recapture rates. This is in accordance with the method, by which cameras should be placed in such a way to eliminate 'holes' – areas where animals may never encounter a camera – and thus increase capture probability (Karanth and others 2004b). The cameras were preliminarily shifted around seven different locations every month, and kept distant one to two kilometers from each other. During the course of the study, cameras were permanently set at three roads that yielded higher transit of pumas. Two of these roads were the same ones used for track-recording.

The small number of camera-traps and sampling roads hampered the calculation of the mean maximum distance moved between cameras (MMDM) the way it is most often proposed to estimate a buffer around the sampled area. Half of this distance (½ MMDM) is used to calculate a buffer radius around the sampled area. The area resulting from adding this buffer to the sampled area (effective area) is then used as a divisor for the population estimate with CAPTURE to obtain density (Karanth and Nichols 1998; Silver and others 2004; Kelly and others 2008). To address the lack of a calculated MMDM, two solutions were employed. The first solution was to borrow an estimated ½ MMDM obtained by Kelly and others (2008) for pumas. The second alternative was to measure the maximum distance that the radio-tracked female moved away from the border of the sampled area (Maximum Distance Moved from the Border, MDMB). Puma densities resulting from these two methods we quite similar. These methods are discussed below in more detail. The buffer was added to the polygon of the sampled area in ArcView (ESRI, Redlands, CA, USA).

The ½ MMDM borrowed was chosen from an area quite equivalent in size to the area sampled here, and which coincidently harbored the same estimated number of pumas and similar capture probabilities. The reason a ½ MMDM from a small area was chosen was because there is an indication that MMDM seems to increase with the size of the area sampled (R^2= 0.63; F=10.18; p<0.05, n=8) (data from Kelly and others 2008; Silver and others 2004). In fact, this borrowed ½ MMDM buffer produced an effective area only slightly larger than the home range of the radio-tracked female puma. This effective area size was unrealistically too small to account for the number of pumas recorded during this study, and would inflated the estimates of puma density. This lead to reason that perhaps the distances moved between cameras may indeed be biased in small areas, as cameras are not spread far enough to record true distances covered by pumas. Considering the current study, for instance, maximum distances recorded would normally not be larger than 2 km given the small sampled area and small number of camera traps employed, resulting in a very small bufer area.

The solution found by Kelly and others (2008) to go around the bias of small sampled areas was to multiply a correction factor to the densities of pumas found, based on the known differences in estimated density of jaguars (calculated with ½ MMDM) between small and large sampled areas. This correction factor reduce densities of pumas and compensate for the inflated number of individuals typically found when small areas are sampled, compensating small buffer areas. The bias caused by short maximum distance moved between cameras in small sampled areas has been acknowledged by other authors (Kawanish and Sunquist 2004; Soisalo and Cavalcanti 2006) which have addressed solutions differently. Soisalo and Cavalcanti (2006), for instance, demonstrated that maximum distances moved by jaguars tracked with GPS collars was indeed superior than the distances calculated using camera-traps.

It is reasonable to argue that the main idea behind the buffer is to account for the home ranges of border pumas that may not be well represented within the sampled area. Based on that, the alternative solution used to calculate buffer distance in this study was to measure the maximum distance that the radio-tracked female moved beyond the border (MDMB) of the sampled area. This was done by superimposing the polygon of the sampled area over the polygon of the home-range of the female puma in ArcView and measuring the maximum distance between borders. The resulting buffer was found to be within the range of one of the large sites surveyed for pumas by Kelly and others (2008), and looked more realistic when spatialized in perspective with the female's home range, and as an area that would encompass more than a single home range. The correction factor for small areas was not used in this case, as it would likely and erroneously attempt to compensate for the underestimated ½ MMDM buffers in small areas.

Camera-trapped pumas were identified individually by size, marks, shape, musculature, sex, and mostly from the shape of the black pattern around the muzzle (Fig. 4). The method of individual indentification of pumas by their body markings has been tested (Kelly and others 2008). It is considered here that validation procedures are not necessary for proofing once again that the method is adequate.

Track identification.— Initial search for tracks encompassed the entire study site, but concentrated on two interconnected, six kilometers long dust roads. These were secondary and infrequently used by people, and unlike most of the other roads, the soil was not hard-packed, providing optimal condition for track imprinting. Similarly to camera-trapping, these roads were chosen for optimization of 'capture' (and recapture) of the largest number of individuals in the shortest time interval.

Sampling was conducted at least twice a month over the entire length of the roads, from March 1998 to August 1999. Well-defined tracks were photographed using a camera fitted with either 35 mm or 300 mm lens, alongside a scale and identifying information. All tracks were photographed in shade to avoid distortion. Photographed tracks were then scanned at 150 dpi, and imported, retraced and scaled to natural size using *Adobe Freehand* (Adobe, San Jose, CA, USA). Tracks not as well-defined, that would not appear clearly in photographs, were traced onto acetate sheets in the field. When tracing, only the inner outline of deep tracks were recorded due to track spread in deeper soils (Fijelline and Mansfield 1989). After tracing, measurements slightly modified after Smallwood and Fitzhugh (1993) were taken from at least three paws of each track set (see Smallwood and Fitzhugh 1993 for definition of 'track' and 'track set') (Fig. 3). As with individual identification from body markings, identification by tracks is a standard sampling methodology that has been tested more than once (Smallwood and Fitzhugh 1993; Grigione and others 1999; Lewinson and others 2001).

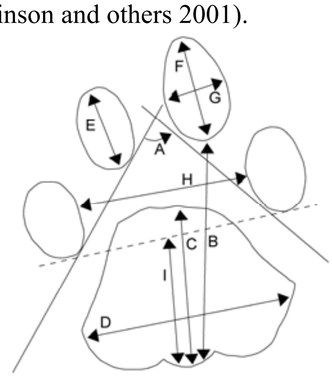


Figure 3. Schematic diagram of the measurements taken from mountain lion tracks. A, angle between toes (ABT); B, heel to lead toe length (HLTL); C, heel length (HL); D, heel width (HW); E, third toe lenght (TTL); F, lead toe lenght (LTL); G, lead toe width (LTW); H, outer toes spread (OTS); I, heel to outer toes (HOT).

Quantitative analysis was performed separately for each paw (e.g., right front, left rear) using stepwise multivariate discriminant analysis in SPSS (SPSS Inc., Chicago, Illinois, USA). Discriminating power may vary according to the paw chosen and for that reason individuals were discriminated on multiple paw analysis based on a decision matrix (Fitzhugh and Gorenzel 1985).

Unfortunately it was not possible to fit the data to the same capture-recapture analysis as done with camera-trap data. The number of consective recaptures of the same individuals were very low (most often two recaptures) and would not result reliable.

Capture and sedation.— Eight custom-designed live-traps were employed at different periods to capture pumas. The largest were those built of wooden poles wrapped with chain-link fence (n=4), and those built almost entirely of wood poles (n=2) averaging 5 x 5 x 2 meters in size. Moveable traps were smaller and made of iron, measuring 2 x 1 x 0.80 meters (n=2). One of the large traps had several ducks confined within a separate cage as bait, the remaining were baited with a single duck or chicken. Traps were checked every morning either by inspection or by assessing remotely with the aid of a receiver and 'trap-site transmitters' (Telonics, Mesa, Arizona, USA).

Captured pumas were sedated with a mixture of Zoletil at volumes of 50 mg/kg (0.6 to 1 ml), Rompun 0.5 ml, and Atropine 0.3 ml. Concentrations were Zoletil 50 mg/ml, Rompun 20mg/ml, and Atropine 1%. The pumas were weighed, measured, treated against parasites, and released at the capture site.

Radio-telemetry.— Radio-collar equipment, including transmitters MOD 315, receiver TR2, and antenna, were supplied by Telonics (Mesa, Arizona). Locations were plotted with a portable GPS model 12XL (Garmin, Olathe, KS, USA). Bearings were then input into LOAS software (Ecological Solutions, Sacramento, CA, USA) which generated the location coordinates.

Minimum convex polygon (Stickel 1954; Harvey and Barbour 1965; White and Garrot 1990) was utilized to estimate home range, and a kernel contour (Worton 1989) was produced to estimate core area. The polygon and core area contours were produced in Ranges V (Kenward and Hodder 1995), and exported to ArcView (ESRI, Redlands, CA, USA) where analysis of habitat utilization was performed.

Errors on the triangulation of radio-fixes were likely to be produced in the patchy native forest-exotic plantation environment, thus habitat use was evaluated on the basis of the proportion of each vegetation type and other features present within the female's 90% core area rather than on location fixes. Adittionaly to this alternative method to analyse habitat utilization, the researcher regularly approached the radio-collared puma by taking several fixes, enough to locate the patch of forest where the puma was present. Nine percent core area was used because it resulted as 25% of the female's home range, enoughly circumscribed to show that home range use was not random, i.e., the female remained more time in the core area than on the rest of her range.

An effort was made to keep a constant record of the female's movements and not lose contact for long. This avoided underestimation of home-range by not missing areas in which the puma might have been present and that would otherwise go unrecorded.

The forestry company's GIS department provided a digitized map of the study area, over which other GIS features were ovelayed for spatial analysis.

Results

Photographic recording and density estimate

General markings (Fig. 4a) and design patterns of the chin and muzzle (Fig. 4b) were found to be characteristic of each individual puma and were employed to recognize pumas from photographs.

A total of 1,260 trap-nights, over a period of 14 month using three camera-traps, resulted in a total of 39 photographs of pumas. Trap rate was one puma per 43 trap-nights or 2.3 pumas per 100 trap-nights, excluding consecutive recaptures (defined here as those recorded within a 24 hour period).

From the total number of photographs taken, 16 were considered unsuitable to include in density estimates. Unsuitable photos included those that were not lateral photographs, consecutive photos of the same animal during very short periods blurred photos, unidentified individuals, or those taken outside the study area. Thus, from the total of 39 photographs, only 23 were used in the density analysis. The female (af1) was the most often camera-recaptured individual (Fig. 4c).

Program CAPTURE appointed Model M(h) as having a higher value based on the capture-history of individuals (Table 1). This model allows variation in capture probability among individuals, but the probability of each individual being recaptured remains the same throughout the sampling period. Estimated population number was 13 (SE=3.5, CI=11 to 28, $\hat{p}$=0.13). The assumption of population closure was met (p= 0.35), hence the null hypothesis of closure was not rejected.

The resulting density of pumas varied little with the employment of the two different approaches used to draw the buffer area. Densities ranged from 0.062 to 0.069 individuals per km^2 (6.2 to 6.9 individual pumas per 100 km^2) (Table 2).

The entire plantation property is 1,255 km^2 in size. By extrapolating puma density to the whole area, numbers of pumas were estimated to range from 78 to 87, depending on the buffer method employed.

Tracking

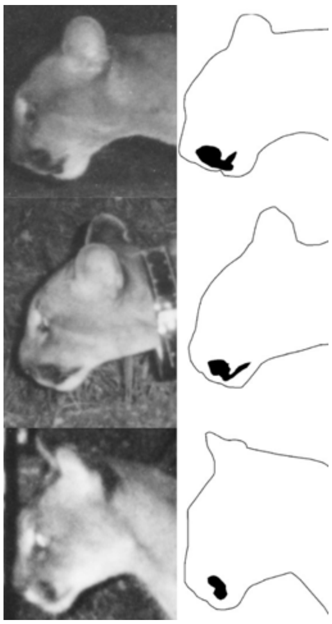
Track sets discrimated into 'groups' during multivariate analysis, each group considered to be an individual puma. The results from the track survey suggested the occurrence of nine adult and sub-adult pumas in the area, six of them were track-recaptured.

Discriminant analyses were performed to all four paws, resulting in four matrices (appendix 1), which in the end were concatenated in one final decision matrix resulting in nine groups. The primary criterion to consider a track set as belonging to a particular puma was that at least 75 % of the tracks from a set should fall within its own group within discriminant analysis. When this primary criterion was not met it meant that the track set shared characteristics with other track set(s). In this case, track sets were grouped (lumped) when they shared at least 25% of similarity with other track set.

a

Figure 4. **a** Markings that allowed for correct identification of mountain lions: black dot at the scrotum (left) and white slash on the chin (right); **b** The black area around the muzzle are unique to each individual; **c** Female mountain lion af1, over 15 years old (from teeth wear), live-trapped once during the study, and camera-trapped more than any other puma (nine times). Her collar allowed for her unmistakable recognition.

b



c

Fig. 4 continued

Table 1. Presence (1) or abscense (0) of individuals in each capture occasion, categorized in age and sex classes as adult males (AM), adult females (AF), subadult males (SM), subadult females (SF), and subadult of unknown sex (S). Each capture occasion correspond to a period of a month between June 1998 to August 1999.

Individual	Capture occasions													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
AM1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
AM2	0	0	0	1	0	1	1	0	1	0	0	0	0	1
AM3	0	0	0	1	0	0	0	0	0	0	0	0	0	0
AF1	1	1	0	0	0	1	0	0	0	1	1	1	0	0
AF2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
AF3	0	0	0	1	0	1	0	0	0	0	0	0	0	0
AF4	1	0	0	0	0	0	0	0	0	0	0	0	0	0
SM1	1	0	0	1	0	0	0	0	0	0	0	0	0	0
SM2	0	0	0	1	0	0	0	0	0	1	0	1	0	0
S3	0	0	0	0	0	0	0	0	0	0	0	1	0	0

Each capture occasion corresponds to a period of a month between June 1998 and August 1999

The percentage of variance explained by the two main discriminant functions during the four analysis was high, varying from 81.4 % to 100 %. The relative importance of each measurement varied according to the paw, but HLTL and HOT were amongst the most relevant measurements for both hind tracks, and OTS for the front tracks.

Evidence of the presence of family groups (female and offspring), like those obtained during camera-trapping, was also obtained from identification of recurring groups of animals over periods of more than three weeks. Two females were identified as being accompanied by three yearling/sub-adult offspring. At a later date, these offspring had either dispersed or became separated from their mothers, when a different female was recorded with a sub-adult offspring.

Trapping

Two pumas which happened to be mother and offspring (af1 and sm2) were captured during consecutive nights in one of the large traps, built with wooden poles and wrapped with chain-link fence, and measuring 5 x 4 x 2 m. The bait consisted of several ducks confined in the far end of the trap. The female had been previously recorded by her

Table 2. Results of puma density according with different methods to calculate buffer around sampled area.

Method	Buffer length	Correction factor	Estimated number of pumas	Estimated size of total area	Estimated puma density per km^2 (per 100 km^2)
½ MMDM[1]	2.04	0.414	5.38	86.36	0.062 (6.2)
MDMB[2]	4.5	none	13	188.32	0.069 (6.9)

[1] Half mean maximum distance moved between cameras

[2] Maximum distance moved from the border (of the sampled area) by the radio-tracked puma

conspicuous tracks, along with sets of tracks of her offspring.

The female weighed 20 kg and her larger male offspring 36 kg. On the basis of tooth wear characteristics (Gay and Best 1996), it was estimated that the female was over 15 years old (her teeth were all flat), while her offspring was judged to be over 15 months old. Both cats were radio-collared and released at the trapping site when fully recovered from sedation.

Radio-tracking and home range

The male offspring lost his collar within four days of capture, however, his tracks were frequently seen along with his mother's tracks during the study.

A total of 320 fixes were obtained while she was followed for 186 days. Attempts were made to locate the female at least once a day, resulting that radio signal was lost for no more than three consecutive days. In spite of the effort to maintain contact, the female was out of reception range for a total of 43 days.

The size of her home range based on a minimum convex polygon was 75.5 km^2, while the core area, utilized during 55% (103 days) of all tracking days, was 18.9 km^2 in size as estimated by the 90% kernel method (Fig. 1).

The core area (18.9 km^2) utilised by the female comprised 8.1 km^2 of natural forest and 8.9 km^2 eucalyptus and *Pinus* spp. plantations. The remainder of the core area included a dam (0.63 km^2), and the village of Harmonia (2.1 km^2). The core area was the most human-disturbed site within the female's home range and within the entire property, including such features as a dump for furniture and for other old wooden products, a paved road, a gas station and the factory's timber yard, which was constantly busy with trucks and tractor activity.

Nevertheless activity was detected very near such disturbances. On one occasion, the female was recorded resting during day-time in a small patch of *Pinus* spp. less than 40 m wide and 100 m long surrounded by the paved road at one side and the village houses at the other.

Other information also revealed the female's proximity to human disturbances. Of the total number of fixes obtained within the core area, 22 fixes (7%) were within 100 m of the paved road, and 15 of these were recorded during day time. Additionally, 51 fixes (16%) were recorded from forest patches located within the village boundary, 21 of which were during day time. The two-lane paved road within its core area was crossed 38 times during the seven month period of radio-tracking. On two occasions it was possible to record her behaviour during crossing attempts. The time spent to cross, almost nine hours in one situation, and seventeen hours in the other, revealed how carefull the female was while crossing.

Although this old female was successful at crossing roads without injury during all hers 15 years of life, not all pumas were that successful. A young adult male puma (weighting 46 kg) was hit and killed by a truck while crossing the paved road near the study site.

While pumas have been track-tracked for several kilometers on roads that crossed extensive forest plantations, and were frequently recorded crossing disturbed areas such as villages and plantations, radio-tracking data (obtained at patch level) indicated that pumas remained most of their time in native forests within the plantation site.

Distribution and habitat selection by prey

Total number of prey animals sighted were 2,252. Information on location was lacking in many instances from the database, wereas habitat type information was available more often.

It was found that most of the prey species do not avoid plantations or blocks with reduced proportion of natural forest cover. Rather, they often prefered plantations or blocks with lower natural forest cover (Table 3 and appendix 2). In spite of that, avoidance of native vegetation was not striking, though, except for deer, which displayed expected values for native vegetation almost four times (n=402) the observed occurrence (n=104). Deer showed a noteworthy preference for eucalyptus plantation, observed almost twice (n=304) as frequently as expected from the χ^2 distribution (n=153) for this habitat type.

Discussion

Individual identification of pumas

The small variation in observed numbers of pumas from both track-matching analysis and camera-trapping and the small *SE* of the abundance estimate in CAPTURE, are all indications of the precision of the techniques employed.

Successful recognition from photographs had been most often employed to study felids holding spotted and stripped coat as such patterns can be precisely identified from photographs. Pumas, however, hold a single color coat, in which identification is not always possible. CAPTURE estimates from camera-trap data, for instance, although

Table 3. Data for prey species are summarized below for habitat selection and distribution.

Species	Number sighted	Block χ^2 statistics (n)	Habitat χ^2 statistics (n)	Bonferroni fit (+ preference, – avoidance, = equal) per bock and per habitat type
Capybara	84	36 (23)	6 (28)	+ block 1, = block 2, - block 4, = native, + pinus, - eucalyptus, = araucaria
Coati	481	21 (126)	23 (307)	+ block 1, = block 2, - block 4, - native, + pinus, = eucalyptus, = araucaria
Collared peccary	541	32 (184)	28 (485)	+ block 1, - block 2, + block 4, - native, + pinus, - eucalyptus, = araucaria
Grey brocket deer	986	2 (446)	425 (986)	= all blocks, - native, + pinus, + eucalyptus, = araucaria
Nine-banded armadillo	108	12 (22)	9 (85)	+ block 1, = block 2, - block 4, - native, + pinus, = eucalyptus, = araucaria
Prehensile-tailed porcupine	36	0 (17)	2 (33)	= all blocks, = in all habitat types
White-lipped peccary	319	7 (118)	30 (284)	= block 1, = block 2, + block 4, - native, = pinus, = eucalyptus, +

providing a single estimate with associated error, requires an *a priori* indentification of individuals that should not be misleading.

It is acknowledged that individual identification of pumas may be subjective in many instances, but it is argued here that subjectivity have not impaired to conduct accurate identifications in puma studies so far. Kelly and others (2008) found that number of pumas varied consistently between three study sites regardless of the observer. In the current study particular markings enabled recognition, as did also the direct handling of two live-trapped pumas, including a female that was fitted with a radio collar.

Camera-trapping was a rather helpful technique to identify a non-trivial number of individuals given the small size of the study area. The use of single-sided cameras, though, did pose a problem, which required the removal of a couple of ambiguous photos, resulting in a possible underestimation of the count statistics. It is possible that ambiguous photographs would not be necessarily discarded if double-sided camera-traps were employed. Karanth and Nichols (1998) ground-breaking research on individual recognition of tigers recommended the use of double-sided camera-traps so that both sides of individuals may be recorded. Their article, which have popularized the use of the technique for density estimation of felids, was published during the time in which the current study was being conducted. Hence, the recommendation on use of double-cameras and density analysis was not as broadly available as it is today. While studies using single cameras have been published recently (e.g. Spalton 2006), several other publications have already employed the double-camera procedure for distinctly patterned felids (e.g. Wallace and others 2003; Maffei and others 2004; Soisalo and Cavalcanti 2006). The problem posed by the use of single-sided cameras would potentially reduce precision of estimates if individuals had not been almost exclusively photographed from a single side, for a simple reason. It is not possible to relate photographs from both sides of the same individual, taken at different occasions, to a single individual puma. During the analysis, only two photographs were discarded, on the basis that they might have been from an individual already identifyed from the other side. The relative precision of the results should not, however, be used as a reason to justify or encourage future density studies based on single-sided cameras.

Presence and behavior of pumas

Considerable amount of evidence was accumulated to support that this large scale forestry operation is an adequate habitat for pumas and their prey. Density of pumas (6.2 – 6.9 individuals per 100 km^2) as estimated by camera-trapping rated amongst the highest for pumas across their range (see Kelly and others 2008 for a short summary of densities), and the number of pumas recorded from tracks closely matched those recorded by camera-traps (9 - 10 individuals). Other supportive evidence were the presence of resident pumas (5 - 6 individuals), presence of family groups, offspring survival to adulthood, occurrence of prey throughout the property, and converted areas encompassed by a core home-range.

Large prey such as the peccaries did not show aversion to habitats with low forest coverage, and in fact results show that they were recorded in the block with lowest forest coverage (block 4) more frequently than expected. It is acknowledged, though, that this dataset should be analysed with certain caution. While recording species employees may have spent most of their time in plantations rather than in native habitats, and as a consequence may have inflated the number of individuals present in plantations as opposed to native habitats. This does not, however, apply to the analysis of blocks commented in the previous paragraph, as blocks are large areas several hundered square kilometers in size, with acctually no margin for errors of this type. Regardless of expected tendency to record species more often at plantations, the presence of important prey species of puma recorded during several occasions within plantations may at least be conservatively interpreted as tolerance to these converted habitats. Peccaries may nonetheless benefit from resting under thick scrub of secondary vegetation that eventually grows under pinus plantations, and other species such as deer browse the weeds found in the floor of eucalyptus plantations.

It is reasonable to assume that the entire 1,255 km^2 property held adequate habitat for pumas. Analysis of prey distribution and habitat preferences show that areas with plantations are not avoided, and prey is distributed in all habitat types and across different areas of the property. Furthermore, opportunistic records of pumas and prey confirmed their presence elsewhere in the property. Additional evidence are available to support that pumas may persist in connected habitats with reduced levels of forest coverage in southern Brazil (Mazzolli 2006).

There is no reason to suspect that pumas were wandering near human dwellings attracted exclusively by additional food supply provided by captive and domestic animals. Incidents of that nature were so sporadic that would be impossible for a single puma to subsist on it. The breeding centre is the number one suspect as an attraction for pumas, holding prey such as capybara and deer captive. Pumas attempts to prey on these captive animals resulted very unprofitable. Only two deer were killed and partially eaten during the extent of this study, and a maned wolf was killed but not eaten. There was evidence that pumas other than the radio-tracked female wandered into the relatively open grounds of the breeding centre, among other things leaving claw marks in a clearing 40 m distant from base camp.

Pumas also rarely provoked incidents in the villages. At the 'Lagoa' village (at the northern tip of the female's home range) a dog was attacked by a sub-adult puma that ended up killed with a club. This puma, unlike others that had been examined (two captured and one road kill) and those photographed, showed atypical body conditions and was very ill and underweight (Mazzolli 2009).

Pumas were also found in adjacent properties with commercial forestry and ranching activities, even though these areas they were small and largely unforested when compared with the forestry area (see Fig. 1). The forestry operation area thus held a superior forest coverage than the surrounding areas.

Presence of species that have little tolerance to modified habitats (Chiarello 2000), such as the white-lipped peccary and giant anteater also indicated good habitat condition in the study area. The presence of these species is a remarckable finding considering that, in the neighbouring southern states holding similar habitat types, the once widespread white-lipped peccary is currently found in only four distinct and circunscribed locations, and the giant anteater has been wiped out from those states (Mäher and Schneider 2003, Mazzolli 2005). Given its large home range and specialized food requirements, the giant anteater has been considered, along with top carnivores, 'sensitive indicators of the amount of disturbances inflicted in a habitat' (Eisenberg 1980).

The absence of cattle ranching in forestry operations and the environmental guidelines of the company running the forestry operations were surely decisive to maintain a high level of tolerance of employees toward the presence of pumas. Under that scenario, pumas were not persecuted even when approaching the main villages. In fact, they were frequently seen by security guards crossing one of the main villages during the night. Although such tolerance toward wild felids is not usual, the case presented here may be an incentive for others to adopt a similar friendly attitude. Felids, in the other hand, may adapt to human presence even after disturbance. For instance, Schaller (1972) recorded that one of his African lions learned to avoid his car after being tagged, and "*required a year of frequent contacts with this animal before he accepted the car as indifferently as he had done prior to tagging*". Franklin and others (1999) argued that with decreased hunting pressure and harassment by horsemen and their dogs in the Torres del Paine National Park in Chile, "*remarkable shifts in behaviour occurred in this puma population which have habituated to people and are being observed more often by park visitors*". Similarly, one female leopard at Londolozi Game Reserve in South Africa "*permitted visitors to approach closely, even when she is nursing cubs*" (Norton 1984). While interactions such as that are expected to happen in reserves where animals may habituate with visitors, regardless if it as private or public reserve, it is noteworthy that pumas have adapted to live near people under intensive commercial forestry systems (logging was carried on at a 24 hour basis), even if at peculiar conditions of protection.

Management in private lands

Private lands are also an important habitat component for pumas in Florida (Belden and others 1988; Maehr 1990). Other examples include the Pantanal in Brazil, 95% of which is privately owned (Quigley and Crawshaw 1992). Private lands, however, are infrequently managed to maintain wildlife because of conflicts involving wild animal populations and commercial agro-forestry operations (that vary in intensity according to geographical location and species involved). Nonetheless, there is a world-wide trend to implement sustainable managed productive systems which are not completely harmful to wildlife survival, including forestry, wildlife management, and eco-tourism (Child 1995; Taylor and Dunstone 1996; Evans 1999). The role of these managed areas is best described as complementary to the existing network of protected reserves (Frankel 1983). Of all managed systems, environmentally-friendly forestry has gained momentum as the demand of consumer markets for wood supplied from ”green” sources have been established in the form of "buyers group". This consumer market has been encouraged by the WWF's Global Forest and Trade Network programme (WWF 1996, ECE/FAO 2000), among others.

Forest plantations, however, are not benefical habitats in all situations, resulting that this study should not be used to endorse indiscriminated plantation of exotic forests. In southern Brazil, there are examples of plantations that are dramatically changing the landscapes of areas dominated by relicts of native grasslands and are incorrectly managed. Plantation expansion, mainly of exotic *Pinus ellioti* and *P. taeda*, are taking place without environmental permits, or permits have been issued without the Study and Report of Environmental Impact (EIA/RIMA) as required (Pillar and others 2006). Lack of environmental enforcement is partially due to the fact that plantations of *Pinus* spp. have come out of the large areas owned by companies and have spread out among numerous stakeholders. This increases the number of initiatives and also the complexity in monitoring the rapid increase in forest plantations. In such case, zonation of forest plantations should be used in synergy with forest certification to ensure reduction in grassland conversion.

To solve this situation, forest certification protocols should more rapidly be incorporated into the entire production and purchase chain, ensuring that large certified pulp and paper companies are also purchasing certified wood from suppliers.

Although it is desirable that this article, among other things, raise manager’s and decision maker’s goals regarding pacific coexistence of wildlife with humans, it is acknowledged that conditions found in urbanized areas and villages outside large private operations are expected to be more problematic to deal with. Pumas have wandered into suburban areas throughout their range, but that does not directly mean that the habitat in those places are adequate to maintain a population. Pumas are known to use suburban areas as corridors that connect different portions of their range or happen to reach these areas by chance while dispersing (Beier 1995). The situation presented here is peculiar, and very dissimilar to the ones normally found in suburbane zones. To start with, both villages encompassed by the property were built by the company exclusively for occupation by company employees. This situation gives the company more control to easily use a top down approach to spread its policies regarding environmental procedures and decision regarding expansion of the villages. It is more difficult to reach consensus in public towns and villages given the multiple and often antagonic interests of different sectors of the society, and particularly in those cases where land disputes develop. Forestry operations, depending on the situation, may also have to deal with land claims, harvesters and hunters from neighboring communities.

Public towns may have dynamic growth unlike the ones found in this study. There may have, for example, formal or informal interests to expand the network of paved roads or houses into forest refuges, a situation that will inevitably bring negative consequences to wildlife populations. In the study area, in the other hand, there was a concern that native forests remained untouched. Logging was thus conducted exclusively on plantations. Building of new roads or expansion of villages was not considered, instead, the company had plans to move employees to the neighbouring town.

At a time when natural habitats are shrinking as we speak, never the participation of stakeholders to preserve additional habitats to the existing network of protected areas were so necessary. The lesson learned is that forest plantations, and possibly other types of forest management procedures, may be invaluable allies in the conservation of resource demanding species such as the puma. Furthermore, it highlights that reduction of unsustainable harvesting and hunting, desestimulted by the continuous presence of employees throughout the property, may have very positive results to wildlife despite habitat modification. Many protected areas suffer from habitat impoverisment exactly because there is not enough people managing them, and perhaps could benefit from having sustainable management stimulated on their surroundings.

The results from this study will hopefully inspire managers and decision makers to realize that quite audacious conservation goals may be reached in commercial forestry systems. They may be used as a convincing argument to seek ambitious conservation goals in cooperation with stakeholders.

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Appendix 1

Tables with classification results from discrimant analysis of puma tracks for each paw (right front, left front, right hind, left hind). Groups in rows and predicted groups in columns. Track sets that rated above 75% were assigned to their own group. The remaining track sets were lumped to other groups according with predicted values in columns.

Groups	Predicted groups									
	3	4	9	12	14	19	27	28	29	31	*N*
Right front											
3	71,43	0	0	28,57	0	0	0	0	0	0	7
4	0	90	0	0	0	0	10	0	0	0	10
9	10	0	80	10	0	0	0	0	0	0	10
12	0	0	0	100	0	0	0	0	0	0	4
14	0	0	0	0	80	0	20	0	0	0	5
19	0	0	0	0	20	60	0	0	20	0	5
27	0	0	0	0	0	33,33	66,67	0	0	0	3
28	0	0	0	0	0	20	0	80	0	0	5
29	0	0	0	0	25	0	0	25	50	0	4
31	0	0	16,67	0	16,67	0	0	16,67	0	50	6

Groups	Predicted groups								
	3	4	5	9	12	13	28	29	*N*
Left front									
3	100	0	0	0	0	0	0	0	8
4	0	92,31	0	0	7,69	0	0	0	13
5	0	0	100	0	0	0	0	0	4
9	0	0	0	50	25	25	0	0	4
12	0	0	0	0	77,78	22,22	0	0	9
13	0	0	0	33,33	0	66,67	0	0	3
28	0	0	0	0	0	0	100	0	5
29	0	0	33,33	0	0	0	0	66,67	3

Appendix 1 continued

Groups	Predicted groups									
	1	2	3	4	9	12	28	29	31	*N*
Right hind										
1	80	0	0	0	0	0	0	0	20	5
2	0	100	0	0	0	0	0	0	0	4
3	0	0	83,33	0	0	16,67	0	0	0	6
4	0	0	0	90	10	0	0	0	0	10
9	0	0	0	0	75	25	0	0	0	8
12	0	0	14,29	0	14,29	42,86	28,57	0	0	7
28	20	0	0	0	0	0	80	0	0	5
29	0	0	0	0	0	0	40	60	0	5
31	0	0	0	0	0	0	0	25	75	4

Groups	Predicted groups								
	1	3	4	9	10	12	28	29	36
Left hind									
1	80	0	0	0	0	0	0	0	0
3	0	66,67	0	16,67	0	16,67	0	0	0
4	0	0	100	0	0	0	0	0	0
9	0	0	0	85,71	14,29	0	0	0	0
10	0	0	0	20	80	0	0	0	0
12	0	22,22	0	11,11	0	66,67	0	0	0
28	0	0	0	0	0	0	100	0	0
29	0	0	0	0	0	0	0	83,33	0

Appendix 2

Statistics of habitat use by forest cover, using χ2 and Bonferroni (α=0.10) intervals of confidence. Habitats are native vegetation (forest predominant) and plantations of pinus, eucalyptus, and araucaria. The proportion of available area (pi0) is compared with the theoretical proportion of occurrence (pi) to determine if the hypothesis is accepted or rejected, i.e., pi=pi0. If pi0>pi the species is using the habitat (k) less than expected, if pi0<pi it is using more than expected.

Species	Habitat (k)	Proportion of available area (pi_0)	Number observed	Number expected	χ^2	Proportion observed in each area (pi)	Confidence interval on proportion of occurrence (pi)	Habitat selection
Capybara (groups)								
	Native vegetation	0.41	13	11	0	0.46	$0.35 \le p_1 \le 0.58$	=
	Pinus	0.37	14	10	1	0.50	$0.39 \le p_2 \le 0.61$	+
	Eucalyptus	0.16	1	4	3	0.04	$0.00 \le p_3 \le 0.08$	-
	Araucaria	0.07	0	2	2	0.00	$0.00 \le p_4 \le 0.17$	=
Coati (groups)								
	Native vegetation	0.41	103	125	4	0.34	$0.30 \le p_5 \le 0.37$	-
	Pinus	0.37	153	112	15	0.50	$0.46 \le p_6 \le 0.53$	+
	Eucalyptus	0.16	38	48	2	0.12	$0.10 \le p_7 \le 0.15$	-
	Araucaria	0.07	13	20	3	0.04	$0.03 \le p_8 \le 0.06$	-
Collared peccary (groups)								
	Native vegetation	0.41	153	198	10	0.32	$0.29 \le p_9 \le 0.34$	-
	Pinus	0.37	225	178	13	0.46	$0.44 \le p_{10} \le 0.49$	+
	Eucalyptus	0.16	64	75	2	0.13	$0.11 \le p_{11} \le 0.15$	-
	Araucaria	0.07	43	32	4	0.09	$0.07 \le p_{12} \le 0.10$	=
Grey brocket deer								
	Native vegetation	0.41	104	402	221	0.11	$0.09 \le p_{13} \le 0.12$	-
	Pinus	0.37	495	355	50	0.50	$0.48 \le p_{14} \le 0.52$	+
	Eucalyptus	0.16	304	153	150	0.31	$0.29 \le p_{15} \le 0.33$	+
	Araucaria	0.07	83	80	5	0.08	$0.07 \le p_{16} \le 0.09$	=
Nine-banded armadillo								
	Native vegetation	0.41	22	35	5	0.20	$0.20 \le p_{17} \le 0.31$	-
	Pinus	0.37	42	31	4	0.43	$0.43 \le p_{18} \le 0.56$	+
	Eucalyptus	0.16	14	13	0.05	0.12	$0.12 \le p_{19} \le 0.21$	=
	Araucaria	0.07	7	6	0.34	0.05	$0.05 \le p_{20} \le 0.12$	=
Prehensile-tailed porcupine								
	Native vegetation	0.41	11	13	0	0.33	$0.24 \le p_{21} \le 0.43$	=
	Pinus	0.37	15	12	1	0.45	$0.35 \le p_{22} \le 0.56$	=
	Eucalyptus	0.16	6	5	0	0.18	$0.10 \le p_{23} \le 0.26$	=
	Araucaria	0.07	1	2	1	0.03	$0.00 \le p_{24} \le 0.07$	=
White-lipped peccary (groups)								
	Native vegetation	0.41	92	116	5	0.32	$0.29 \le p_{25} \le 0.36$	-
	Pinus	0.37	101	104	0	0.36	$0.32 \le p_{26} \le 0.39$	=
	Eucalyptus	0.16	51	44	1	0.15	$0.03 \le p_{27} \le 0.21$	=
	Araucaria	0.07	40	19	24	0.14	$0.12 \le p_{28} \le 0.17$	+

Statistics of habitat use by blocks, using χ2 and Bonferroni (α=0.10) intervals of confidence. Block 1 contained 60-69% of natural forest, block 2 contained 50-59%, block 3 contained 40-49%, and block 4 contained only 20-39% natural forest. The proportion of available area (pi0) is compared with the theoretical proportion of occurrence (pi) to determine if the hypothesis is accepted or rejected, i.e., pi=pi0. If pi0>pi the species is using the blocks (k) less than expected, if pi0<pi it is using more than expected.

Species	Habitat (k)	Proportion of available area (pi_0)	Number observed	Number expected	χ^2	Proportion observed in each area (pi)	Confidence interval on proportion of occurrence (pi)	Habitat selection
Capybara (groups)								
	Block 1	0.23	17	5	26	0.74	$0.35 \leq p_1 \leq 0.58$	+
	Block 2	0.40	6	9	1	0.26	$0.39 \leq p_2 \leq 0.61$	=
	Block 4	0.37	0	9	9	0.00	$0.00 \leq p_3 \leq 0.08$	-
Coati (groups)								
	Block 1	0.23	45	29	9	0.36	$0.27 \leq p_4 \leq 0.44$	+
	Block 2	0.40	57	50	1	0.45	$0.36 \leq p_5 \leq 0.54$	=
	Block 4	0.37	24	47	11	0.19	$0.12 \leq p_6 \leq 0.26$	-
Collared peccary (groups)								
	Block 1	0.23	53	42	3	0.29	$0.25 \leq p_7 \leq 0.32$	+
	Block 2	0.40	36	74	19	0.20	$0.17 \leq p_8 \leq 0.22$	-
	Block 4	0.37	95	68	10	0.52	$0.48 \leq p_9 \leq 0.55$	+
Grey brocket deer								
	Block 1	0.23	116	102	2	0.26	$0.24 \leq p_{10} \leq 0.28$	=
	Block 2	0.40	175	178	0	0.39	$0.37 \leq p_{11} \leq 0.42$	=
	Block 4	0.37	155	165	1	0.35	$0.32 \leq p_{12} \leq 0.37$	=
Nine-banded armadillo								
	Block 1	0.23	10	5	5	0.45	$0.35 \leq p_{17} \leq 0.56$	+
	Block 2	0.40	11	9	1	0.50	$0.39 \leq p_{18} \leq 0.61$	=
	Block 4	0.37	1	8	6	0.05	$0.00 \leq p_{19} \leq 0.09$	-
Prehensile-tailed porcupine								
	Block 1 and 2	0.52	8	9	0	0.47	$0.35 \leq p_{20} \leq 0.59$	=
	Block 3 and 4	0.48	9	8	0	0.53	$0.41 \leq p_{21} \leq 0.65$	=
White-lipped peccary (groups)								
	Block 1	0.23	33	22	5	0.14	$0.11 \leq p_{22} \leq 0.17$	=
	Block 2	0.40	42	38	0	0.18	$0.15 \leq p_{23} \leq 0.21$	=
	Block 4	0.37	43	36	1	0.15	$0.18 \leq p_{24} \leq 0.21$	+

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