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A Camera Trapping and Radio Telemetry Study of Lowland Tapir (*Tapirus terrestris*) in Bolivian Dry Forests

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Abstract

This article is the first reported use of camera trapping to estimate population densities of lowland tapirs *Tapirus terrestris* according to capture-recapture statistics, applying a systematic survey methodology developed for tigers in Asia and recently applied to jaguars in Latin America. We survey three sites in the Kaa-Iya del Gran Chaco National Park, representing Chaco thorn scrub vegetation and Chaco-Chiquitano transitional dry forest, and one site in the San Miguelito private reserve, representing Chiquitano dry forest. We acquired too few photographs at Ravelo to estimate population densities, but density estimates from camera trapping at the other sites range from 0.22-0.80/km^2, surprisingly high estimates for these dry forest habitats. This indicates that the vast Kaa-Iya National Park protects a major tapir population. The article is also the first reported comparison for any species of density estimates derived from camera trapping and radio telemetry at the same site. At the Cerro Cortado site, prior to the camera trap surveys, we tracked five tapirs for 22-29 months each. The two methodologies provide similar information on ranging and activity patterns, but the density estimate from radio telemetry would appear to be considerably higher. We discuss reasons for these differences, the costs and benefits of the two methodologies, and the potential of camera trapping for tapir research.

Introduction

The lowland or Brazilian tapir (*Tapirus terrestris*) is vulnerable to local extinction throughout its range as a result of continued habitat conversion and hunting (Bodmer & Brooks, 1997). Given its large size, it is an important food source for indigenous peoples in the Bolivian Chaco as elsewhere across its geographic distribution (Brooks & Eisenberg, 1999). While researchers have studied the species in humid lowland forests, its status in dry forests has remained unknown. The titling and zonification of extensive lands to indigenous groups in Bolivia (including the 19,000 km^2 Izoceño-Guaraní Tierra Comunitaria de Orígen), where subsistence hunting activities are permitted, the zonification of immense national parks (the 34,400 km^2 Kaa-Iya del Gran Chaco National Park) to include certain resource exploitation in certain areas (Taber *et al.,* 1997) and the creation of nature reserves on private lands (Rumiz *et al.* 2002), have all together motivated increasing attention to management plans that assure the sustainable use of wildlife and other natural resources.

In support of community wildlife management and long-term biodiversity conservation in Bolivia's dry forests, we have focused attention on the tapir as one of the species most vulnerable to hunting pressure (Noss, 2000). This article describes research using camera traps and radio telemetry to study *Tapirus terrestris* in the Chaco and Chiquitano dry forests of Bolivia. In addition to activity patterns and ranging behavior, both methods provide estimates of population density, upon which sustainable harvest models and conservation recommendations depend. Recently, researchers have begun to employ camera trapping methodologies to study several species of tapirs, for example to determine the status of the species (Lynam, 1999; Holden *et al.,* 2003; Kawanishi *et al.,* 2002), or to study habitat use (Lizcano & Cavelier, 2000a; Montenegro, 1999). This is the first reported use of camera trapping to estimate population densities of tapirs according to capture-recapture statistics, and the first reported comparison for any species of density estimates derived from camera trapping and radio telemetry at the same site.

Study Area

1. Kaa-Iya del Gran Chaco National Park: This 34,400 km^2 protected area covers the northern end of the Gran Chaco, and includes four principal landscape systems (Figure 1: Navarro & Fuentes, 1999). The two purely Chacoan forest landscape systems are the Chaco alluvial plain forest (13,800 km^2) and the Chaco riverine forest (500 km^2). The two other landscape systems are transitional forests: the Chaco transitional landscape system (9,100 km^2) and the Chiquitano transitional landscape system (11,500 km^2).

Figure 1. Study Sites in Bolivian Chaco and Chiquitano Dry Forests: 1=Cerro Cortado, 2=Tucavaca, 3=Ravelo, 4=San Miguelito.

1.a. During 1997, we established a field camp at Cerro Cortado (19° 31.60' S, 61° 18.60' W) in the Chaco alluvial plain landscape system, on the border between the Kaa-Iya National Park and the adjacent Izoceño indigenous territory. Annual precipitation at the site averages 500 mm. During the 6-8 month dry season, surface water disappears for extended periods. A single road runs through the study site, which was unused for over a decade until we reopened it to establish our research camp. We opened a grid of 2-4 km study trails off the road. The area is not subject to hunting or livestock pressure.

1.b. During 2001, we established a field camp at Tucavaca (18° 30.97' S, 60° 48.62' W) in the Chiquitano transitional landscape system, on the Bolivia-Brazil gas pipeline and 85 km south of the town of San José de Chiquitos. Annual precipitation at the site averages 800 mm. During the six month dry season, surface water disappears for extended periods. Existing roads include the gas pipeline itself (30 m-wide right-of-way, with a 3-6 m-wide road to one side or in the centre), a gravel road north to San José, and an overgrown road south to Paraguay. We opened a square grid of 5 km study trails, enclosing a 100 km^2 study area centred on the field camp and the gas pipeline. Scrub patches remain where the forest was burned roughly 30 years ago, but the area is not subject to hunting or livestock pressure.

1.c. During 2001 we established a third field camp towards the southern end of the same landscape system at Ravelo (19° 17.72' S, 60° 37.23' W), near the Paraguayan border. Annual precipitation at the site averages an estimated 650 mm, with a 6-month dry season, but, unlike the previous site, water points (springs, lagoons) persist year-round in all but the driest years. A single road crosses the area, from the city of Roboré to the northeast, passing through Ravelo military outpost, and on to Paraguay. Several overgrown roads also exist, unused for over 10 years: one leads west to the large salt pans within the Kaa-Iya National Park and from there north to Tucavaca and San José, others were opened in a grid of oil exploration lines. We re-opened several of these roads as footpaths/study trails, as well as cutting additional new study trails 3-5 km long to cover the study area. The dozen soldiers at the Ravelo military outpost maintain a small number of cattle (30) and several donkeys, while the nearest cattle ranch 15 km to the southeast at Palmar de las Islas maintains roughly 300 cattle. Livestock is not fenced in and therefore strays between Ravelo and Palmar along the main road.

2. The San Miguelito Private Reserve comprises approximately 25 km^2 within a 400 km^2 cattle ranching property 200 km to the east of Santa Cruz, and north of the Kaa-Iya National Park (17° 05.52' S, 61° 47.32' W). The landscape system is Chiquitano dry forest, with an average annual rainfall from 1000 to 1500 mm (Rumiz *et al.,* 2002). Cattle ranching is the principal economic activity outside the private reserve itself, with patches of forest cleared for pasture. The ranch maintains a system of roads through the reserve, in addition to which we opened a number of study trails 1-3 km in length. A small river runs through the private reserve, and several permanent springs and artificial ponds also provide surface water for wildlife during the 6-month dry season.

Methods

Radio Telemetry

The radio telemetry study at Cerro Cortado of five individual tapirs followed standard procedures and has been described previously by Ayala (2002; 2003). However, we continued to track the tapirs for 15 months after Ayala completed his fieldwork (Barrientos & Maffei, in press), until the radio-collar batteries failed. We tracked animals for 4-6 hour periods both day and night, registering location information every hour, and activity every 15 minutes. Radio collars marked activity by varying the number of pulses per 30 seconds from 26 (no movement of the collar) to 52 (maximum movement). We determined locations by triangulation from three separate marked points along study trails or the road, estimating position using the Locate II software (Version 1.5, Pacer-Canada). We then analysed positions in Arcview 3.2, estimating home range from minimum convex polygons described by 95% of the positions for each animal (eliminating outliers). We estimated density in turn based on the observed home ranges for individual animals and overlap among home ranges.

Camera Trapping

The camera trapping methodology consisted of a systematic camera trap survey, whose primary objective was to survey jaguar *Panthera onca* populations and estimate population densities of this species (Maffei *et al*., 2002, under review; Silver *et al*., under review). Cameras were active continuously (24 hours a day). We set them in pairs facing each other across a trail/road in order to simultaneously photograph both sides of any animal passing between them along the trail/road, with a distance of 1-2 km between camera sets. In addition, the cameras function continuously and record the date and time of photographs, allowing us to describe activity patterns by counting records per time period.

At Tucavaca, during eight months (May-December, 2001), we rotated 12 camera traps among sites on the study trails and the gas pipeline, for a total of 2520 trap-nights. During an intensive 60-day survey period (19 January-20 March 2002), we installed 32 pairs of camera traps on the same study trails and pipeline road, for a total of 1920 trap-nights. Following the intensive survey a set of seven cameras continue to be rotated around the study trails.

At Cerro Cortado, we have conducted two intensive 60-day surveys. During the first survey (1 April-30 May 2002), we installed 34 pairs of camera traps along the road and study trails, in addition to two single cameras at water holes and two single cameras at salt licks. During the second survey (28 November 2002-28 January 2003), we installed 26 pairs of camera traps along the road and on the study trails. We installed one single camera at a salt lick and another single camera at a pond. Trapping effort totaled 2280 and 1680 trap nights respectively.

At Ravelo, we conducted pilot camera trapping efforts (May-December, 2001) on study trails and at seasonal ponds for a total of 1248 trap-nights. During a single intensive 58-day survey (February 10-April 10, 2003), we installed 37 pairs of camera traps: 10 on roads, 17 on study trails, 8 around a saltpan, and 2 at ponds. Trapping effort totaled 2170 trap nights.

At San Miguelito we conducted an intensive 60-day survey (20 September-20 November, 2002), installing 22 pairs of camera traps on existing roads and study trails. We also installed four pairs of cameras along the edge of the river, one pair at a salt lick and one pair at a spring. Trapping effort totaled 1695 trap nights (Rumiz *et al.,* 2003).

We used the time information recorded on all camera trap photographs of tapirs to describe activity patterns at each site, according to the proportion of photographs of the species during each time period. We also compared capture frequencies at different types of locations within each site: roads, trails, salt licks, and ponds.

A number of unique features serve to distinguish individuals: scars, white spots and stripes on the stomach or legs, black spots on the face or sides, white markings at the base and fringe of the ears, torn or missing ears, toenail markings or colour, tail length and white markings on the tail (Emmons, pers. comm.; Holden *et al.,* 2003; Montenegro, 1999). Coat colour and body structure also varies among individuals, and gender can often be determined from the photographs. We took care not to use temporary markings as identifiers, for example marks from mud or shallow scratches that could disappear during the two-month survey period. We also took care to account for the differences in the observed features resulting from differences in camera angle, tapir body position, and lighting conditions. In cases where definitive identifications were not possible, no more than 20% of photographs for each survey, we tentatively attributed the photographs to one of the previously identified individuals from the same area. In other words, we did not assume that a photograph represented a new individual unless we could definitively distinguish it, according to one or more of the features described above, from all other previously identified individuals.

Based on the number of "captures" and "recaptures" during each intensive survey, it is possible to estimate population abundance using the closed population models of the programme CAPTURE (Rexstad & Burnham, 1991; White *et al.,* 1978). To estimate densities for each study site, we divided the abundance calculated above by the effective sample area. The effective sample area included a circular buffer around each camera trap site, whose radius was half the mean maximum distance among multiple captures of individual tapirs during the survey period (Wilson & Anderson, 1985). At the two sites where we repeated surveys, we treated the two surveys as independent, and did not attempt to cross-identify the two sets of individuals obtained for the site.

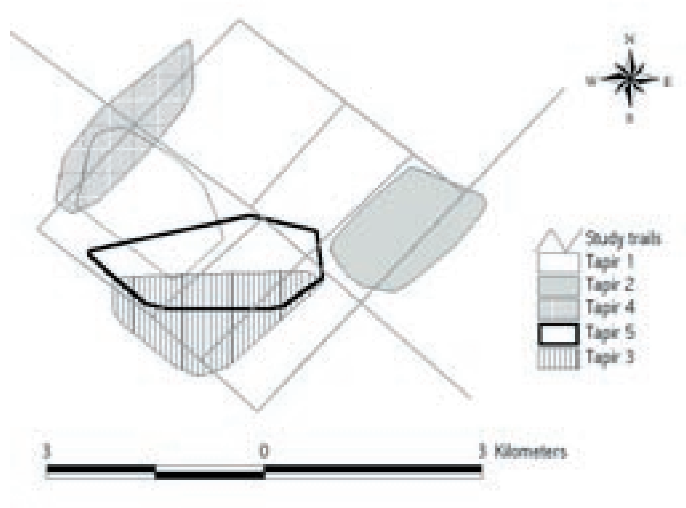

Figure 2. Home Ranges of Radio-collared Tapirs at Cerro Cortado.

Results

Table 1 presents complete telemetry results by individual tapir at Cerro Cortado (individual, sex, months, locations, area, maximum distance). During 22-29 months of radio-tracking for each animal, we recorded between 645-955 locations per animal, and estimate home ranges of five individuals, according to 95% of observations (eliminating outliers), to cover 1.9-3.0 km^2 (Figure 2). Based on these ranges, and on the observed overlap of 32-55% (average 43.5%) in home ranges of the four neighbouring animals, we estimate an average "exclusive" home range of 1.4 km^2. Assuming that tapirs occupy the landscape evenly and completely in this fashion, population density at this site is 0.71/km^2 (SE=0.23, 95% confidence limits 0.26-1.16). It is important to note that we recorded all three possible types of overlap: male-male, female-female, and male-female. Figure 3a presents activity patterns, based on the proportion of observations per time period when the animals were active.

Table 2 presents relative abundance based on capture frequencies during camera trapping among the three survey sites and by type of location. Activity patterns are decidedly nocturnal (Figure 3b) in all forest types, even where hunting does not occur. Relative use of trails versus roads varies among sites and over time at particular sites. Tapirs have shown certain preference for salt licks, according to capture frequencies across camera trap locations. However, tapir visits to salt licks are brief, generally less than five minutes, in comparison to gray brocket deer (10-20 mn), white-lipped peccary (10 mn) and collared peccary (20-60 mn).

Table 3 provides the details for each intensive camera trap survey of the population density estimation. Figure 4 provides maps of each study site indicating camera trap positions and the effective survey area defined by the buffer around each camera position. At Ravelo with no recaptures we were unable to calculate a buffer and estimate the survey area, and have used 1 km as a hypothetical buffer. With few observations and no recaptures, the analysis by Capture is also tentative and the standard error correspondingly high. For several animals at each site, we also estimate a minimum home range based on the minimum convex polygon uniting the points where each animal has been recorded by camera traps (Figure 4): from 0.97-3.74 km^2 for four individuals in the first survey and 1.03-4.83 km^2 for four animals in the second survey at Cerro Cortado, and 0.50-5.78 km^2 for six individuals at San Miguelito.

Discussion

In general, the *Tapirus terrestris* density estimates based on camera trapping from Chaco and transitional Chaco-Chiquitano dry forests are below figures of approximately 0.5/km^2 cited for lowland rainforest sites across the Amazon basin (Peres, 2000), as well as density estimates for Baird's tapir

Table 1. Radio Telemetry of *Tapirus terrestris* at Cerro Cortado.

Individual	Sex	Months	Locations	Area (km^2, minimum convex polygon)	Maximum distance (km)
1	M	29	955	2.57	2.3
2	M	28	918	2.19	2.2
3	F	24	645	2.70	2.9
4	M	22	670	1.90	2.9
5	F	24	646	3.02	3.2
Average		25.4	767	2.48	2.7

Table 2. Camera Trap Capture Frequencies (Observations per 1000 Trap Nights) for *Tapirus terrestris*.

	Total	Road	Trail	River	Salt lick	Salt pan	Pond/spring
San Miguelito	60	57	63	50	94	--	81
Tucavaca	11	15	10	--	--	--	--
Ravelo	2	5	0	--	--	2	8
Cerro I	26	23	29	--	50	--	0
Cerro II	51	68	32	--	175	--	50

Table 3. Estimated Densities for *Tapirus terrestris* Based on Camera Trapping Records.

	Individuals	Abundance*	Buffer km	Area km^2	Density per km^2 ± SE	95% confidence limits
San Miguelito	34	41 ± 5.01	1.24	49	0.80 ± 0.09	0.64-0.96
Tucavaca	11	25 ± 7.85	0.93	84	0.29 ± 0.04	0.22-0.36
Ravelo**	5	7 ± 12.25	(1.00)	(81)	(0.09 ± 0.15)	(0.00-0.38)
Cerro I	16	17 ± 5.14	1.24	76	0.22 ± 0.03	0.16-0.28
Cerro II	19	22 ± 3.72	1.30	78	0.28 ± 0.03	0.22-0.35

* Abundance is estimated by Capture, using heterogeneity model M(h) and jackknife estimator.

** Hypothetical buffer estimated for analytical purposes, as we recorded no multiple captureswith which to calculate the buffer. Corresponding standard error in density estimate is derived from abundance estimate only. Negative lower confidence limit converted to 0.

(*T. bairdii)* from Costa Rica (Naranjo, 1995), and for mountain tapir (*T. pinchaque)* in montane forests of Colombia and Ecuador (Lizcano & Cavelier, 2000b). However, the camera trap estimate from Chiquitano dry forest at San Miguelito and the radio telemetry estimate from Cerro Cortado exceed all but Foerster's (2002) estimate for *T. bairdii* in Costa Rica of 1.6/km^2. These density estimates derived from a variety of methodologies are not directly comparable. However, it is clear from our data that dry forests can sustain relatively high population densities of tapirs, when these animals are protected from hunting. Tapirs have successfully adapted to conditions of seasonal drought, and to diets that include a large proportion of cactus fibre in the Chaco (Soto, 2002). Tapirs may be limited in some habitat types by dietary minerals: Herrera *et al.* (1999) report on a tapir periodically travelling over 5 km to visit a salt lick, whereas the radio-collared tapirs at Cerro Cortado never made long-distance forays out of their ranges which measured 3.2 km across or less, and we located several salt licks in the study area.

Of the three sites described above, the highest camera trap density estimate comes from the Chiquitano forest site (San Miguelito) with the highest annual rainfall, as we would expect, despite any effects that forest fragmentation, domestic livestock, and sporadic hunting may have on tapir populations here. The other density estimates are similar for both Chaco (Cerro Cortado) and transitional Chaco-Chiquitano dry forests (Tucavaca and Ravelo). The higher rainfall at the latter sites (800 mm versus 500 mm), and year-round surface water points in Ravelo, evidently do not improve resource availability to support significantly higher tapir populations. Variation in density estimates for the same site between the two Cerro Cortado camera trap surveys (eight months apart) is not statistically significant (confidence limits overlap – see Table 3), even though "capture" rates were twice as high during the second survey (wet season) as compared to the first survey (beginning of dry season). Capture rates during the wet season survey at Ravelo were the lowest of any site.

No tapirs with collars were photographed in the first survey at Cerro Cortado, but two were photographed in the second survey. The capture-recapture analysis attempts to correct for animals present in the study area that are not "captured" by the camera traps, by estimating a population abundance greater than the number of observed animals. However, we may have under-estimated the tapir population by attributing incomplete photographs to previously identified individuals when they may have been new individuals. On the other hand, using radio telemetry information from only four or five animals, we may over-estimate tapir densities if other portions of the study area are less suitable for or unoccupied by tapirs. Camera traps cover a larger survey area and population estimates incorporate information on a larger number of individuals. The buffer we estimated from mean maximum distance covered by individual tapirs during the camera trap surveys, 1.24-1.30 km, is very close to the average of half the distance across home ranges of the five radio-tracked individuals (1.35 km). This would confirm that we have measured the effective survey area appropriately. We recorded between two and four different individuals at several of the camera trap sites, confirming the overlap among home ranges observed in the telemetry study.

The methodology for estimating population densities was developed and applied to survey jaguar populations. A key element of the design is the spacing of the camera traps, attempting to cover the greatest survey area without leaving any gaps that might encompass an entire home range for an individual of the target species, meaning that this individual would have zero capture probability. Jaguars occupy larger home ranges than do tapirs, therefore the camera spacing for a jaguar survey may not be appropriate to survey tapirs. The survey area is defined by the buffer around the camera traps, and the buffer calculated from observations of the particular species. At our sites, the respective buffers demarcate continuous survey areas at San Miguelito and Cerro Cortado, but not at Tucavaca. Any individuals whose home ranges overlap with the survey area have a capture probability greater than zero, whether the survey area is continuous or discontinuous. However, capture probabilities decrease from the centre towards the edge, and a discontinuous area maximizes the edge effect. Therefore, we would expect the density estimate from Tucavaca to be valid, though less precise than the estimates derived from continuous survey areas.

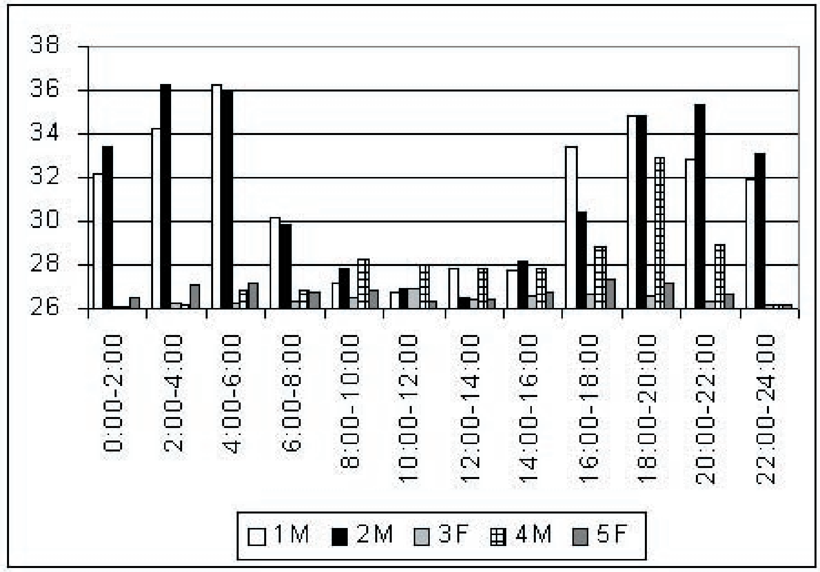

Figure 3a. Activity Patterns for Tapirus terrestris According to Radio Telemetry.

Note: Radio-collars emit pulses at a rate of 26-52/30 seconds, with 26 representing inactivity and 52 maximum activity. The y-axis indicates the average pulse rate during the activity period.

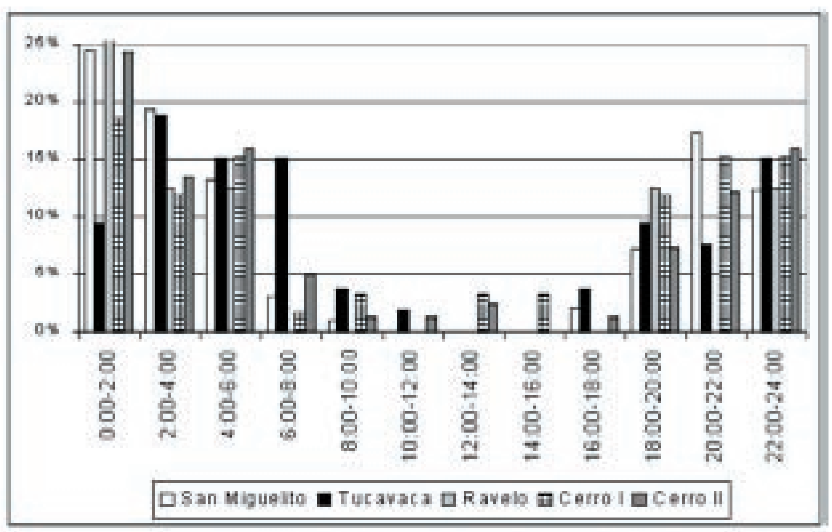

Figure 3b. Activity Patterns for Tapirus terrestris According to Camera Traps - Proportion of Observations per Time Period.

Note: With the small number of total observations from Ravelo (N=8), 50% of observations are in 0:00-2:00 time period.

Camera trapping provides an important alternative method for monitoring *Tapirus terrestris*, permitting the identification of individuals and description of their ranging behaviour, and in turn the estimation of population densities. As we demonstrate in this paper, the information provided by camera trapping on activity patterns and ranging patterns coincides with radio telemetry data at the Cerro Cortado site where we have applied both methodologies. While the density estimate

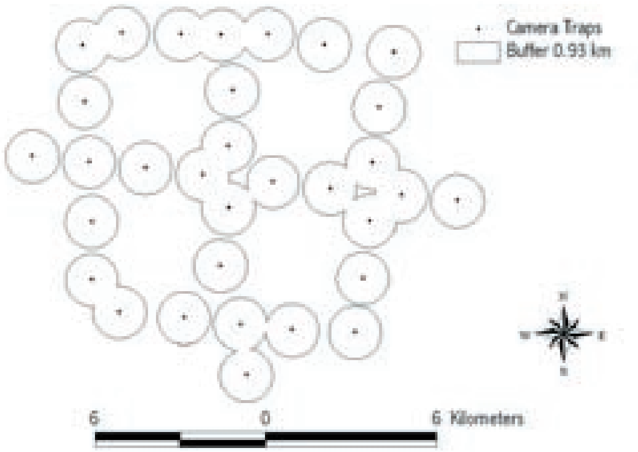

Figure 4a. Tucavaca I Camera Trap Location and Survey Area.

from radio-telemetry would appear to be much higher than those from camera trapping, the first is so imprecise that the 95% confidence limits of the three estimates overlap and the differences therefore are not statistically significant. Camera trapping provides considerably more precise density estimates, whereas radio telemetry provides considerably more precise and complete information on ranging patterns.

Both camera trapping and radio telemetry imply important costs, particularly to open and maintain study trails, to purchase equipment, and to support field staff. But camera trapping offers several important benefits over radio telemetry. First, telemetry requires animal capture and immobilization, which can be risky and stressful for both tapirs and biologists. Second, a systematic camera trapping survey lasts two months, with results of analysis available within three months of beginning fieldwork, whereas telemetry studies normally extend for a year or more. Third, camera trapping can simultaneously provide similar information for other species in the area: density estimates for jaguar, puma and ocelot; and activity patterns for these and other relatively abundant species (Maffei *et al*., 2002; Rumiz *et al*., 2003).

Camera traps have previously been used to monitor activity of *T. pinchaque* in Colombia (Lizcano & Cavelier, 2000a). However, only preliminary results regarding relative abundance of tapirs are available from other systematic camera trap surveys. The capture frequencies reported here for Bolivian dry forests (11-60/1000 trap nights) surprisingly exceed those reported from Bolivian lowland moist tropical forest in Madidi (7/1000 trap nights, Wallace *et al.,* 2002). Capture frequencies for *T. bairdii* in the rainforest of Belize (12/1000 trap nights - Kelly, under review), and for Malay tapir (*Tapirus indicus)* in lowland rainforest and hill dipterocarp forest of Sumatra, Indonesia (4-19/1000 trap nights, Holden *et al*., 2003) are also at the low end of the Bolivia dry forest range.

The minimum time tapirs remain during visits to salt licks in these dry forests coincides with data from lowland tropical rainforest in Bolivia's Noel Kempff Mercado National Park (Herrera *et al.,* 1999). We have not recorded any extended stays as reported for *T. pinchaque* in Colombia (Lizcano & Cavelier, 2000a). These differences presumably derive from differences in quality and composition of food resources for tapirs in lowland and montane forests. Alternatively, the quality for tapir of the salt licks under surveillance may have varied among sites.

Our surveys at three sites within the vast Kaa-Iya del Gran Chaco National Park (33,400 km^2), with tapir densities from

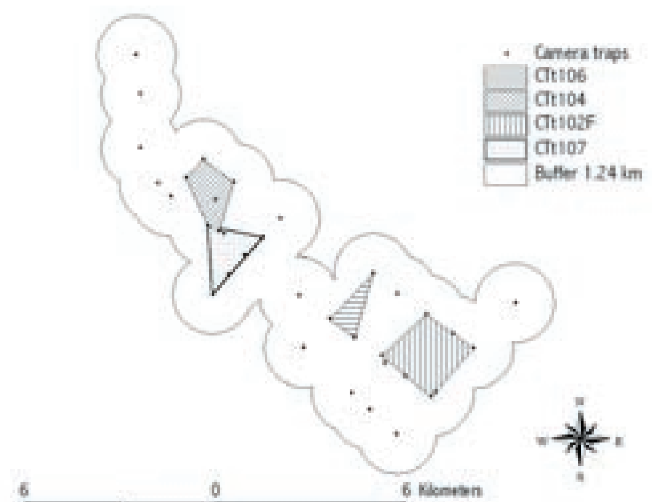

Figure 4b. Cerro Cortado I Camera Trap Location, Survey Area and Tapir Ranges.

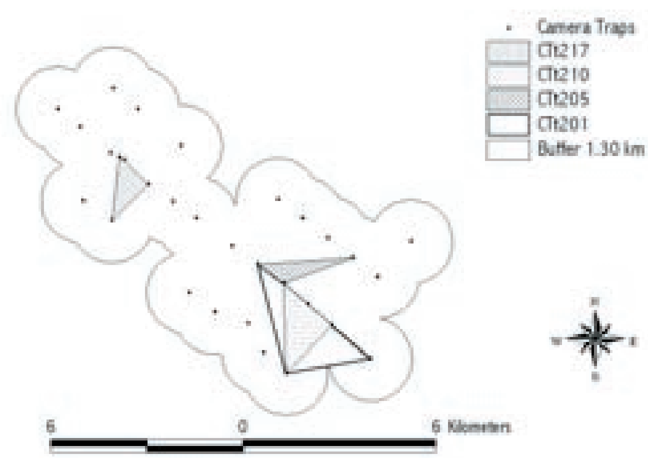

Figure 4c. Cerro Cortado II Camera Trap Location, Survey Area and Tapir Ranges.

0.20-0.29/km^2 according to camera traps, and potentially much higher according to radio telemetry, confirm the conservation value of this incredible wilderness as a stronghold where *Tapirus terrestris* can maintain a viable population, probably exceeding 6000 individuals, over the long-term. The protected area also appears to be an important "source" area that can provide benefits over the long-term for hunters in nearby indigenous community "sinks" such as the 19,000 km^2 Izoceño-Guaraní indigenous territory. Finally, our survey at San Miguelito suggests that even small, protected areas within fragmented agricultural landscapes can maintain tapirs at high densities and, therefore, private reserves can provide important conservation benefits, particularly when such reserves maintain connections to other protected areas to ensure long-term population viability (Rumiz *et al.,* 2002). We will continue to test and refine camera trapping methods by repeating the intensive surveys at our long-term research sites in order to monitor populations and individuals over time. We will also survey additional sites within Kaa-Iya's unsurveyed landscape systems to determine more precisely the species' status within the protected area.

Acknowledgements

Work in the Chaco was made possible by support from the Agency for International Development (USAID/Bolivia Cooperative Agreement No. 511-A-00-01-00005). The opinions expressed here represent the authors and do not necessarily reflect the criteria of USAID. We also thank CABI and the Kaa-Iya National Park who authorized and supported the fieldwork, and the WCS Jaguar Conservation Programme for financial support and training. The study at San Miguelito was also financed by the WCS Jaguar Conservation Programme, and received logistical support and dedication from personnel of WCS-ConFauna and the Noel Kempff Mercado Natural History Museum. For their interest and support, we would like to thank Ronald Larsen, owner of San Miguelito, and his administrator William Parada, during the fieldwork. We also thank the following assistants and students for their support in the field: Romoaldo Peña, Telmo Dosapey, Bernardino Julio, Florencio Mendoza, Filemón Soria, Julian Ity, Leoncio Rojas, Edwin Rossell, Roly Peña, Alejandra Valdivia and Edilberto Pardo. Robert Wallace provided valuable comments on an earlier draft of this manuscript.

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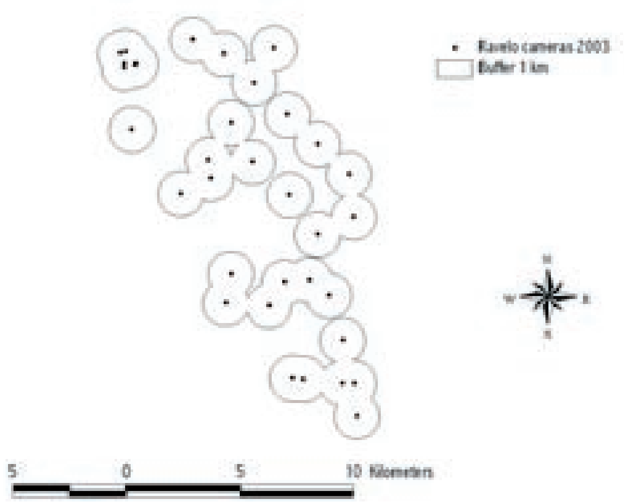

Figure 4d. Ravelo Camera Trap Location and Hypothetical Survey Area.

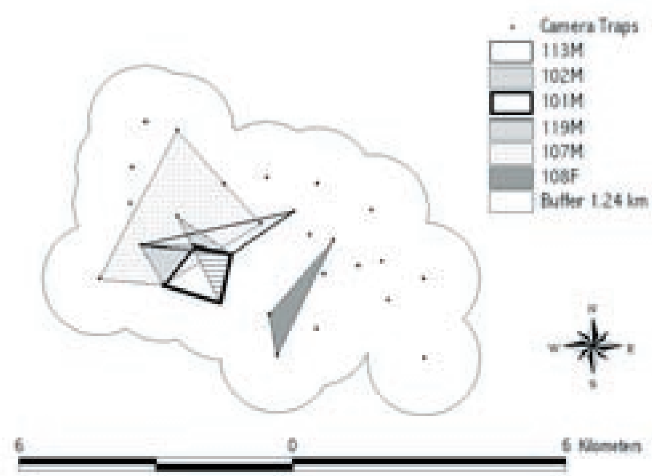

Figure 4e. San Miguelito Camera Trap Location, Survey Area and Tapir Ranges.

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