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Using GPS Collars to Study Mountain Tapirs (*Tapirus pinchaque*) in the Central Andes of Colombia

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Introduction

Probably the least known of the four tapir species is the mountain tapir (*Tapirus pinchaque*), which occurs, in the high Andes (2000-4800 m) of Colombia (Acosta *et al.* 1996; Lizcano *et al.* 2002), Ecuador (Downer 1996) and northern Peru (Lizcano & Sissa 2003). The mountain tapir is the smallest of all the tapir species, and is currently threatened by hunting and the destruction of its habitat, tropical montane forests and páramos (*i.e.* Neotropical alpine plant formations).

Understanding the factors determining the distribution and movements of animals around the landscape is a major objective for scientists, conservationists and natural resource managers alike. It is only through developing this knowledge that animal populations can be managed to meet conservation, sporting or natural heritage objectives. Researchers have long battled with the logistics of gathering information on the movement and distribution of individuals and populations, often relying on tedious visual observation or VHF technology to gather data. Development of Global Positioning Satellite (GPS) technology has offered the opportunity to overcome a number of these limitations. However, whilst there has been a growing interest in the use of GPS amongst biologists, there has only been limited uptake to date. In part this reflects the expense of the units and the weight of the battery supply, which, until recently, has prohibited the use of collars except for larger animals. However, it also reflects the lack of information available to biologists as to what equipment is available and the experience of others in its use.

In every study area, environmental influences on animal radio tracking signals are different. Different methods to overcome the problem of inaccurate bearings and errors have been discussed (Kenward 2001; White & Garrot 1990), but this is a bigger problem in inaccessible mountains where signals bounce and where the common technique of "homing-in" cannot be used. In addition, the highly complex topography and harsh weather conditions complicate the taking of bearings and the movements of investigators. To gain some knowledge on mountain tapir natural history and to gain experience in GPS technology we report results from our pilot study of two GPS collars in a study of mountain tapirs in the Central Andes of Colombia.

Study area

This study was carried out on the western slope of the Central Andes of Colombia (4° 42'N, 75° 29'W), within Los Nevados National Park and Ucumari Regional Park, in Risaralda State. The region is the watershed of the Otún and Barbo rivers. There are deep valleys, high mountains and rocky cliffs. Mature and secondary montane forest *sensu* (Grubb 1977) cover the region. The montane forests in this area are mostly continuous. In a study of vegetation cover of 147,000 ha in this region, there were 98,000 ha of montane forests (1200-3600 m) and 19,200 ha of pastures, mostly at lower altitudes (Lizcano & Cavelier 2000b). The rest of the area was covered by páramo (Smith & Young 1987). Upper montane rain forest can be found between 2500 and 3700 m elevation, in contact with lower montane rain forest (1500-2500) and páramo vegetation (above 3700 m). At the lower altitude, the canopy is much higher (30-35 m), and is dominated by *Brunellia goudotii*, *Miconia* sp., *Weinmannia* cf. *hirtella*, *Weinamannia rollottii*, *Nectandra* sp. and *Ocotea* sp. The understory is dominated by *Chusquea* and tree ferns *Cyatheacea* (Cleef *et al*. 1983). The epiphytic flora includes abundant *Bromeliaceae* and mosses. The canopy of the secondary forest is 2-10 m and this is dominated by *Weinmannia pubescens*, *Miconia* spp. and *Tibouchina grossa*. The forest is usually open, with small to large patches of the introduced grass *Penisetum clandestinum*. The secondary forest is 15 years old, and has resulted from the abandonment of pastures originally created during the 1950's for high altitude cattle ranching (Londoño 1994). The original mature forests were cleared for the extraction of fine woods and for the production of charcoal. Weather varies from mild to cold as the altitude increases. Mean annual rainfall decreases from 2500 mm at 2120 m (Estación El Cedral; 4° 42' N, 75° 32' W) to 980 mm at 4000 m (Estación Laguna del Otún; 4° 47' N, 75° 25' W). Rainfall is distributed in a bimodal way with drier seasons during December and July - August. Mean annual temperature at 4000 m is 5.58°C and 15.8°C at 2120 m.

Methods

Two adult mountain tapirs, a male and a female were captured, darted and anaesthetised in June 2000 with the assistance of an experienced veterinary surgeon and trained dogs. A male of about 180 kg and a female of 200 kg were captured using a solution of Detomidine, 100 mg of Ketamine, 500 mg of Tiletamine/Zolazepam and 5 mg of Atropine, as a single mixture inside an anaesthetic dart (Lizcano *et al.* 2001a; Lizcano *et al.* 2001b; Mangini *et al.* 2001). Each captured animal was inspected for parasites, measured, examined to determine sex and age and marked with a 2.5 cm diameter coloured plastic tag (Rototags, Dalton House, Newtown Road, Henley-on-Thames, Oxon, RG9 1HG) in each ear. Captured animals were fitted with a GPS collar (Model GPS-1000, Lotek Inc., Canada). Tapirs were placed in a secluded location and monitored from a distance until they recovered.

Each GPS collar was equipped with a traditional telemetry signal, a six-satellite GPS engine, an environmental temperature sensor, an activity sensor, a data storage device, and a drop-off mechanism activated by time. Additionally, each GPS collar was equipped with a radio modem link that allows the transmission of data from the collar to a laptop computer without recapturing the animal. The weight of each collar was 1,600 g, which is less than one percent of the weight of an adult mountain tapir. The collars were programmed to take three locations per day at different hours, and once a week, locations each hour during a 24-hour period of time. The drop-off mechanism was programmed to release the collar after six months. Once recovered, the data were downloaded onto a computer and analysed in ArcView 3.2 (ESRI, Redlands, California) with the extension Animal movement 1.1 (Hooge P. & Eichenlaub 1997). Home range was defined as the area where animals travelled in their normal activities (Caughley & Sinclair 1994) and was estimated using Minimum Convex Polygon and Kernel methods (White & Garrot 1990) taking into account surface area relation provided by topography. Home ranges were calculated for individual tapirs by season and differences among periods were tested using chi square tests and G tests (Zar 1996). Montecarlo simulations were carried out to detect the effect of sample size in home range area and movement pattern. Activity was measured by the collar's sensor in a 1-200 index, where 1 is total inactivity in the past minute and 200 is full activity during the last minute. Correlations were made to search for patterns between several variables.

Results

After six months of collecting data on mountain tapirs, the GPS collars were found by traditional telemetry in February 2001 after intensive searching for three weeks. The male's collar was found in a deep valley near Barbo River at 3200 m. This region is covered by mature mountain forest with a dense understory. The female's collar was found at 3400 m, in a small stream near Otún River – secondary forest and grasslands cover this region. The collars were found in good condition externally. However, water had permeated inside the female's collar and damaged the data recovery mechanism. A month before the collar was recovered, the female was located in order to try and download the data using the radio modem link but without success. The data from the male's collar were recovered and downloaded to a computer easily. This collar had fixed 343 locations of total programmed locations (1236) during six months. Average dilution of position index (DOP) was 3.6 and more than 50% of locations showed a DOP of less than 2.5. The average number of hours between locations was nine hours with a maximum number of days without locations of four days. Total travelled distance during six months was 91.4 km. The average distance travelled between fixed locations was 326 meters at an average speed of 0.6 km/h. The observed movement was more constrained than random movement paths (Montecarlo simulation, n=100 number of random movement paths, p = 99.0099). Fixed locations showed a regular pattern (nearest neighbour analysis, R=1.89, p=0.045) close to a uniform distribution.

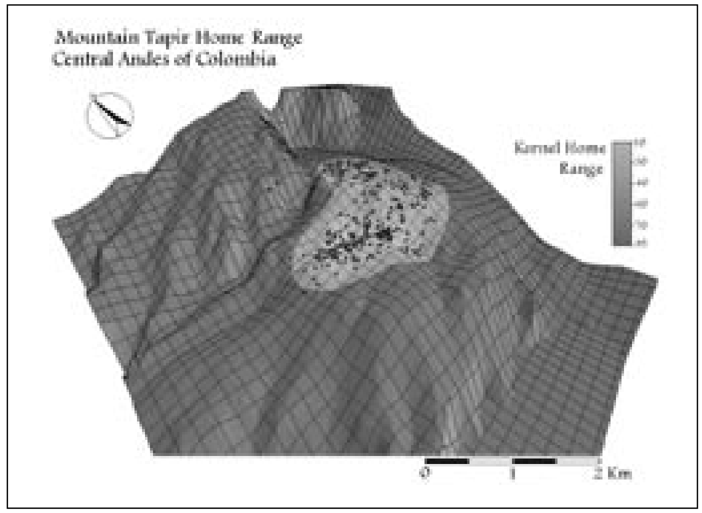

Figure 2. 3D representation of Kernel home range of a male mountain tapir (*Tapirus pinchaque*) in the Central Andes of Colombia.

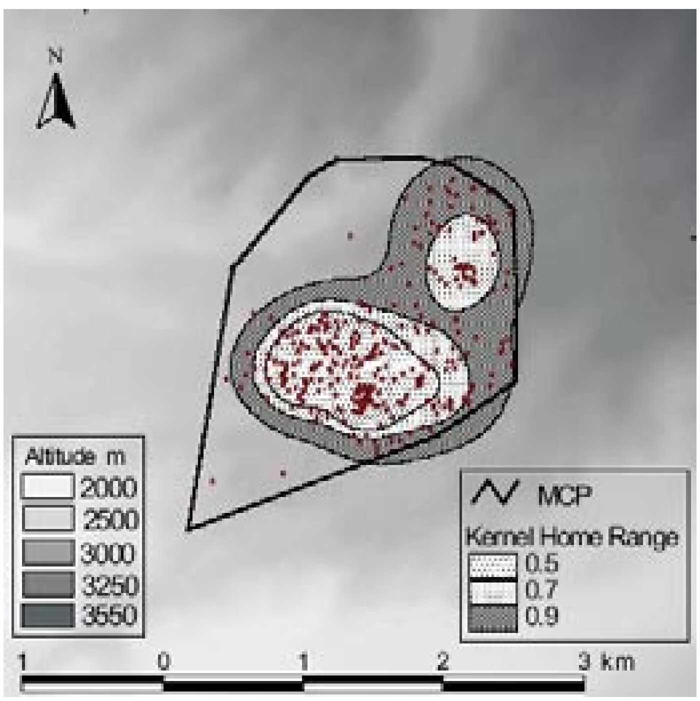

Figure 1. Flat representation of the home range of a male mountain tapir (*Tapirus pinchaque*). The double line represents minimum convex poligon method (MCP). Kernel home range method is the single line shadowed polygon with 50, 70, 95% probability polygons. Areas are; MCP 3.5 km^2, Kernel 2.5 km^2. Notice how MCP is influenced by a few separate points.

Home range calculated by Minimum Convex Polygon (MCP) was 3.5 km^2 and 2.5 km^2 using the fixed Kernel method (Fig. 1) and, if the surface - area relation is taken into account, the surface home range is bigger (Table 1, Fig. 2) this difference is statistically significant (G-test significant and Chi square > 0.05). Seasonal differences in home range were not statistically significant.

Bootstrap analysis using the GPS data set with an interval size of 5 and 300 simulations (Fig. 3) suggest that there is an influence of sample size on home range and that the sample size is not enough to get a representative home range. No correlations were found between DOP, slope and altitude. There was a statistically significant negative correlation between temperature and activity (P = -0.63) indicating that when temperature decreases activity increases and the opposite is also true (Fig. 4). Activity was higher between 7:00 - 8:00 hours and 13:00 - 14:00 hours, showing a three modal pattern with a decrease in activity at noon and in the late afternoon.

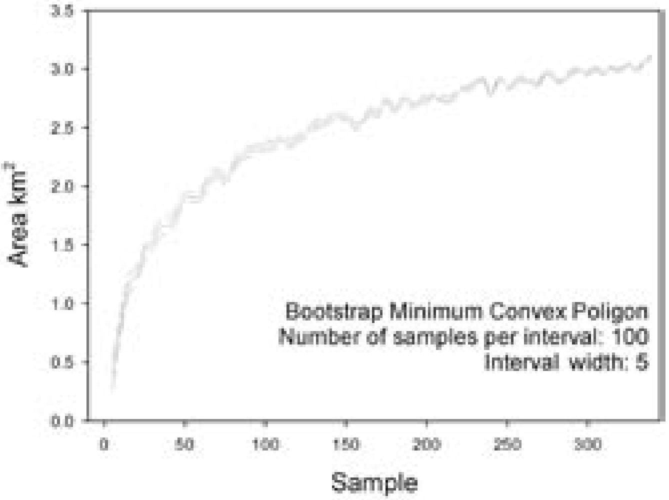

Figure 3. Montecarlo simulation of fixed points. Number of samples per interval = 100, interval width = 5. Notice that the curve did not reach a stabilization point with 340 fixes. Non-continuous line represents standard error.

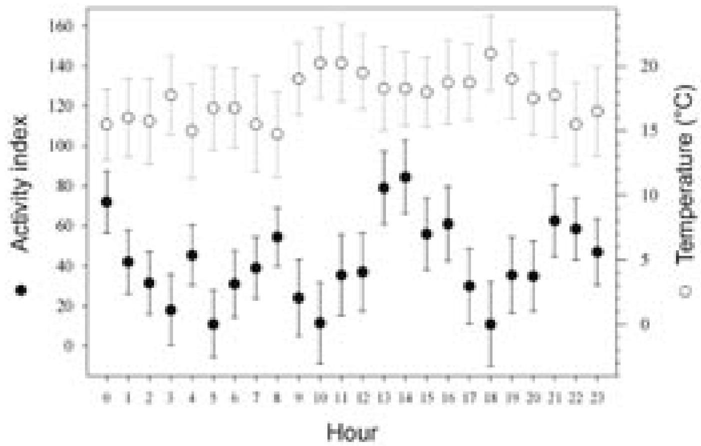

Figure 4. Activity and temperature correlation. There is a negative, statistically significant relation between activity and temperature (p = -0.62). Tapirs are more active when the weather is cooler.

Discussion

In spite of the complex topography, the cloudy sky and dense forest cover, the collar fixed 28% of total programmed points. The number of fixed points (343) in six months is an average of two locations per day, which corresponds to a higher average number of positions per day than many traditional radio-tracking studies use (Kenward 2001). Additionally dilution of position index DOP of fixed points was low. DOP is a measure of accuracy of each point. This index is the sum of square errors in all dimensions including time and satellite geometry and it depends on the position of the satellites: how many satellites you can see, how high they are in the sky, and the bearing towards them. For example, a DOP of two means that whatever the input errors were, the final error will twice as big. Usually it is considered that a DOP of three or less is an accurate position probably closer to being correct. Additionally, GPS data obtained in this study were after the Selective Availability, the random error, which the USA government intentionally add to GPS signals, was disabled. So, we considered that average error in our data ranges varied between 15 and 40 meters, taking into account that DOP average in our data is 3.6. This error is less than average in traditional telemetry where the triangulation of large mammals introduces a bigger error (Haller *et al.* 2001), which can range between 50-100 m for each location.

Home range data provided by this study are probably not representative of a mountain tapir population because the data is from one animal for only six months, but it constitutes an interesting exercise to be compared with other studies and traditional telemetry. There is only one other study using radio tracking on mountain tapirs. In this study, three adult mountain tapirs were tracked for a year and the home range size was 8.8 km² of flat area in Sangay National Park in Ecuador (Downer 1996). The differences in home ranges could be due to the number of animals tracked or to the effect of sample size on home range size (Fig. 3). Montecarlo simulations (300) of the fixed points-home range and the equation of their curve ($y = 629518Ln(x) + 416691$, $R^2 = 0.9955$), indicate that a sample size of 650 could be enough to saturate the home range accumulation curve. The differences in home range are even bigger if we compare mountain tapir and Baird's tapir, which has an average annual home range of 10.7 km² (Foerster 2001). These data are from an extensive study of 26 animals over five years. It is important to highlight the significant difference between flat areas and areas which constitute mountainous regions, which include much more surface area when home range is calculated for animals in mountains. We did not find any evidence indicating that mountain tapir shift home range areas, but slight seasonal shifts in home range can occur when habitat use is correlated with the core area of a seasonal home range. Many local people living within mountain tapir distributions suggest that mountain tapir present altitudinal migrations correlated with the seasons and lunar phases. However, our data in this study are not conclusive, but a correlation between the lunar phase and mountain tapir activity was found in a previous study in the same area (Lizcano & Cavelier 2000a).

An interesting correlation between activity and tem-

Table 1. Home range areas by season and discriminated by flat area and surface area. * significant differences

Season	Method	Area (flat)	Area (surface)	n
Dry	MCP	3.3	4.0	171
	Kernel 95	2.5	2.8	171
	Kernel 50	0.4	0.5	171
Rainy	MCP	2.8	3.1	172
	Kernel 95	2.0	2.3	172
	Kernel 50	0.4	0.6	172
Both	MCP *	3.5 *	4.1 *	343
	Kernel 95 *	2.5 *	2.9 *	343
	Kernel 50 *	0.6 *	0.7 *	343

perature was found (Fig. 3) indicating that mountain tapirs rest in hotter locations or during the hours when temperatures are high. Activity was higher between 7:00 - 8:00 hours and 13:00 - 14:00 hours, showing a three modal pattern with a decrease in activity at noon and late afternoon. A similar pattern was found in a previous study in the same area (Lizcano & Cavelier 2000a) using camera traps. The variations in temperature during the day are because the study area is located in a mountain forest, very close to the páramo where temperature variation during the day is higher than average temperature variation during the year (Smith & Young 1987). In the páramo, temperatures vary from 1-3ºC below zero before sunrise to 20-25ºC in the afternoon.

In spite of the failure in the sealing mechanism of one of our GPS collars and the low percentage of fixes (28%), we believe that the use of GPS collars is a good option to study mountain tapirs, and even better than traditional telemetry for several reasons. Error due to triangulation is higher (50-100 m) in VHF telemetry than in GPS collars and it increases much more when there are signal bounces, which occur in mountainous areas. In a study of mountain ungulates to evaluate VHF telemetry and GPS collars, an average triangulation angle error of 14.5 degrees resulted in an average error in distance of 342.9 m. The average distance error with non-differential GPS collars was 78.8 m (Haller *et al.* 2001). Traditional telemetry demands high logistical support; paths, trails or fixed stations and trained personal continuously tracking the animals. This situation is hard to attain in the study of large mammals in the high Andes, where there are very inaccessible areas and the topography is very complex. In this case GPS collars can have the advantage, because they do not require continuous tracking. This also means less human disturbance in the study area. GPS collars are expensive but with the arrival of two new brands on the market in the last three years, prices are decreasing. If we compare costs, a long term GPS project can be less expensive than a traditional telemetry project because it does not present hidden costs such as trail station maintenance, wages of trained personnel in the field continuously tracking the animals and all the logistics that that represents.

In the future the development of more sensitive GPS receiving antennae will allow greater deployment on species inhabiting forested and mountainous habitats. Advances in fuel and solar cell technology will raise battery power density while battery longevity will be enhanced by the move to less voltage GPS technology. Both advances will enable longer deployment, greater data acquisition and, if required, the development of smaller collars, all of which will allow a greater understanding of the biology of tapirs and many other animals. The integration of GPS with mobile phone technology is now a reality (Hulbert 2001). This development will provide flexible data retrieval and will assist in gaining a greater understanding of the movement and behaviour of many non-recoverable animals. GPS telemetry offers many opportunities, but perhaps the greatest are the quality and quantity of data potentially available that no other tracking tool can provide.

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