GPS AS AN EFFECTIVE TOOL FOR STUDY OF THE HOME RANGE OF BLACK-AND-GOLD HOWLERS (*ALOUATTA CARAYA*) IN RIPARIAN FORESTS, SOUTHERN BRAZIL

Gabriela Ludwig[1], Lucas M. Aguiar[2] and Fernando C. Passos[3]

[1]Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), Centro Nacional de Pesquisa e Conservação de Primatas Brasileiros, Bolsista ProbioII-Femptec, João Pessoa, Brasil, E-mail: <gabiludwig@gmail.com>
[2]Universidade Federal da Integração Latino-Americana (UNILA), Foz do Iguaçu, Brasil, E-mail: <lucas.aguiar@unila.edu.br>
[3]Universidade Federal do Paraná (UFPR). Laboratório de Biodiversidade, Conservação e Ecologia de Animais Silvestres, Departamento de Zoologia, E-mail: <fpassos@ufpr.br>

Abstract

The effectiveness of using Global Position Systems (GPS) to estimate primate home ranges in tropical forests has been questioned. The aim of this study was to test the efficacy of this tool by comparing quadrat methods with the help of a compass and tape measure (CT) and using GPS in estimating the size of the home range of two groups of *Alouatta caraya*; one group on a 1,050-ha, riparian-forest island, and the other on the mainland of the Upper Paraná River. They were monitored from October 2004 through September 2005, on two full days in each month per group, GPS readings (fixes) and tag marks were taken every 30 min. A 0.25-ha grid was used for the home range estimate. A home range of 4 ha was obtained for the island group by means of GPS, and 4.5 ha with CT. The mainland group used 14.75 ha, as estimated by both methods. However, some quadrats were incompatible in positioning between the methods in each environment. The annual and seasonal home ranges did not differ between the methods, showing that GPS was effective. The quadrats that were computed based on GPS and absent on CT indicated, however, a small error in the home range as defined by the GPS. Therefore, the greater the precision of the instrument when taking fixes, the better the result. The smaller the home range of the group, the more marked the error can become. For GPS to be even more effective in the study area or regions of similar vegetation, it is noted that the fixes should be taken at shorter intervals and the fixes should be taken with the best precision possible. We discuss the efficacy of the two methods as applied to studies of the spatial behavior of *A. caraya* in riparian environments.

Key Words: GIS; comparative methods; Neotropical primates; space use.

Resumo

A efetividade do uso de Sistemas de Posicionamento Global (GPS) para estimar a área de uso de primatas em florestas tropicais tem sido questionada. O objetivo do presente estudo foi testar a eficácia dessa ferramenta em comparação com o método quadrado com a ajuda de um compasso e fita métrica (CF) para estimar a área de uso de dois grupos de *Alouatta caraya*. Um grupo ocupava uma ilha de mata ciliar de 1.050 ha, e o outro terra firme no alto do Rio Paraná. De outubro de 2004 até setembro de 2005, pontos de GPS foram obtidos a cada 30 minutos para cada grupo, durante dois dias completos em cada mês por grupo. Um quadrante de 0,25 ha foi usado para estimar as áreas de uso dos animais. Uma área de uso de 4 ha foi obtida para o grupo da ilha com o auxílio do*GPS*, e de 4,5 ha com o método CF. O grupo de terra firme usou 14,75 ha, segundo ambos os métodos. Entretanto, alguns quadrantes foram incompatíveis em posicionamento quando comparados entre os dois métodos tanto na ilha como na terra firme. As áreas de uso anuais e sazonais não diferiram entre os métodos, mostrando que o uso de GPS foi eficiente. Para os quadrantes que foram computados de acordo com o GPS e sem considerar CF, observamos um pequeno erro na área de uso. Portanto, quanto maior a precisão do equipamento ao obter pontos fixos, melhor será o resultado. Quanto menor a área de uso do grupo, mais marcante o erro pode se tornar. Para o GPS ser ainda mais eficiente numa área de estudo ou regiões de vegetações semelhantes, é notado que: os pontos fixos deveriam ser obtidos em pequenos intervalos e com a melhor precisão possível. Nós discutimos a eficácia dos dois métodos usados em estudos de comportamento espacial em *A. caraya* em ambiente ribeirinho.

Palavras-Chave: GIS, métodos comparativos, primatas Neotropicais, uso do espaço.

Introduction

The Global Positioning System (GPS) technology can be a useful tool for collecting and plotting data (fixes and tracks, for example), which can be transferred to maps, providing a wide range of information for different ecological applications (Phillips et al., 1998; Burgman and Fox, 2003). Its efficacy varies according to the habitat and behavior of the

animal (Sprague et al., 2004). This method (GPS) is frequently used for studies of different species of mammals such as those mainly inhabiting open environments; artiodactyls, canids, and felines in North America (see review in Sprague et al., 2004; Haines et al., 2006; Burdett et al., 2007), canids and dolphins in South America (Juarez and Marinho-Filho, 2002; Wedekin et al., 2007), and elephants and primates in Africa (Blake et al., 2001; Doran-Sheehy et al., 2004; Markham and Altmann, 2008). However, its effectiveness is questionable in closed-canopy forests (Sigrist et al., 1999), such as for primate studies when estimating home range (Phillips et al., 1998; Blake et al., 2001; Marques 2006; Markham and Altmann, 2008; Nascimento et al., 2011). In these cases, the use of GPS is compromised by the loss of reception of satellite signals, thereby decreasing accuracy and making it impossible to mark accurate points, which leads to the use of other methods, such as compass and tape measure (CT method) to take the locations (Nascimento et al., 2011). Satellite reception, and hence location accuracy, determines whether GPS technology is a suitable tool (Ren et al., 2008).

Relatively few studies of the home range of primates have been conducted by means of the GPS method but its use is increasing, due to the recent advances GPS telemetry systems, like GPS radiocollars (Walter et al., 2011). Some examples of studies conducted in tropical closed-canopy forests are those of *Ateles geoffroyi yucatanensis* and *Alouatta pigra* in Mexico (Ostro et al., 1999; Valero and Byrne, 2007), *A. geoffroyi* and *Cebus capucinus* in Costa Rica (Campbell, 1994), *Alouatta clamitans* and *Sapajus nigritus* in southern and southeastern Brazil (Steinmetz, 2000; Aguiar et al., 2003; Ludwig et al., 2005), and *Rhinopithecus bieti* in China (Grueter et al., 2009; Ren et al., 2008). Home ranges of *Gorilla gorilla gorilla, Papio cynocephalus*, *Macaca fuscata,* and *Colobus angolensis ruwenzorii* were also studied using GPS, but the first two cases were conducted in open environments (African savannas), while the last two cases were developed in a "mixed habitat" formed by open and closed habitats (Doran-Sheehy et al., 2004; Sprague et al., 2004; Fashing et al., 2007; Markham and Altmann, 2008).

Marques (2006), in a review of home ranges of *Alouatta clamitans,* excluded results obtained by Steinmetz (2000), arguing that the data were obtained with the use of equipment (GPS) with a precision too low for this type of study. It was noted that the instrument bears an intentional error created by the United States Department of Defense to prevent military uses (at least 100 m off). However, selective availability was ended in 2000, improving the precision of civilian GPS. Still, the viable use of this instrument and the direct comparison between methods is also questionable. Therefore, the aim of this study was to compare the quadrat method with the help of a compass and tape measure (CT method) versus the use of GPS for calculating the home ranges of two groups of black-and-gold howler monkeys *Alouatta caraya* in riparian forests, and thereby the efficacy of GPS in determining primate home ranges in forested environments.

Material and Methods

Study sites

Black-and-gold howler monkeys live on an island and the opposite banks of the Upper Paraná River, in northwestern Paraná state near the town of Porto Rico (22º45'59"S, 53º18'58.4"W), southern Brazil (Aguiar et al., 2007a; 2009; 2011). For this study, howlers were studied in two riparian forests along the Upper Paraná River. One area was an island (Mutum Island) and the other extended along the adjacent left bank. The climate of the region is humid subtropical with 1,200–1,300 mm average annual rainfall (Romagnolo and Souza, 2000). The forests have relatively low tree species diversity (Romagnolo and Souza, 2000), with two types of vegetation: alluvial seasonal semideciduous forest (SSF) (flooded forest) present on the islands and plains (altitude of about 220 m), and a sub-montane SSF, mainly on the left bank of the river, on hillier ground (up to 250 m in altitude) (Campos and Souza, 1997). This stretch belongs to the Environmental Protection Area (APA) of Islands and Floodplains of the Upper Paraná River and has been the target of ecological and behavioral studies of primates (Aguiar et al., 2005, 2007a, 2007b, 2011; Ludwig et al., 2007; Rocha et al., 2007; Ludwig et al., 2008, Aguiar et al., 2009).

Mutum Island is the largest (1,050 ha) island near Porto Rico. The study area included a riparian forest that extends along the bank of the river and up to 160 m inland. The island has areas in various stages of regeneration, marshes, and lagoons and is dominated by the arboreal species *Cecropia pachystachya* Trec. (4 to 7 m in height). So, the canopy is relatively low with a height of 10 to 15 m and emergent trees with a maximum of 25 m, and is open with many clearings that can facilitate satellite signals reception. Along the left bank of the Paraná River is nearly extinct seasonally submontane SSF (Campos and Souza, 1997). This portion, where the study took place, comprises forest that most resembles the original state of this forest type (M. C. Souza, unpubl. data) despite human alterations in the region. The forest here extends inland up to 260 m from the river edge. In this area, the tree layer is higher than on the island, with a more closed canopy formed by trees 15 to 30 m tall. The arboreal species *Lonchocarpus guillemineanus* (Tul.) Malme dominates, with emergent trees reaching 30 m in height, which could impede the reception of satellite signals.

Data Collection

Howlers were observed from October 2004 to September 2005, after a five-month habituation period. Both the island and the mainland groups were observed from sunrise to sunset twice per month (306 h, $\overline{X}$: 12.45 ± 1.17 h per day; 288 h, $\overline{X}$: 12.63 ± 0.77 h per day, respectively). The composition of the group on Mutum Island (MG) varied

from 9 to 11 individuals (2–4 adult males, 5–6 adult females, 1–2 subadult males, 0–2 infants), and the mainland group (PG) included 11–13 individuals (1–3 adult males, 4–5 adult females, 1–2 subadult males, 2 juveniles, 1–3 infants (age classes following Rumiz 1990). The groups were approximately 2,600 m distant from each other.

Two methods for collecting home range data were used: marking locations with tags in the field to be measured later using a compass and tape measure (CT), as the control method, and GPS readings (fixes) (Garmin, model E-trex Venture; geographical coordinates obtained in UTM; South America 1969). Both are subject to errors, but here it is assumed that the CT method is the more precise. The use of a laser range finder or a clinometer can make maps potentially more accurate than compass and tape but at the cost of increased resources. The location was obtained from the center of the groups. Because black-and-gold howlers are relatively inactive for much of the day (Bicca-Marques, 1993; Bravo and Sallenave, 2003), markings (tags and GPS points) were standardized every 30 minutes (Fashing et al., 2007), to attempt to decrease the statistical dependence (Setz and Hoyos, 1986). In every location where a georeferenced point was marked by GPS, a tag with the same number was tied on a tree.

The points marked with tags in the field were measured with a compass and tape measure (50 m) from trails previously registered and plotted on a paper map on a 1:500 scale. The points and range used were analyzed seasonally. For GPS readings, we waited for the reception of the highest possible number of satellites (minimum of three) to minimize the estimated positional error, displayed with greatest precision of the instrument (which could vary from 5 to 19 m, depending on the density of the canopy), in order to obtain a reliable reading (Valero and Byrne, 2007). The fixes were loaded into the program GPS TrackMaker 11.8.

The grid cell method, by far the most commonly applied to studies on primates, was used, with quadrats of 0.25 ha for both methods (NRC, 1981; Ostro et al., 1999; Grueter et al., 2009). This method establishes that all quadrats visited by the animals are included in the home range. Next, the total home range size was obtained by summing the areas of all the grid cells where points occurred. The positioning of the grid plotted on the paper map was first established according to GPS TrackMaker 11.8. Ideally, this program could have continuously recorded the GPS readings; however, this procedure requires enormous storage and battery power, and satellite reception was often lost, which makes it inapplicable for the GPS model used in this study. To test for significant differences in home range results between the two methods, the number of quadrats used was compared by the nonparametric test of Friedman and Siegel's C table, considering a minimum significant difference (MSD) of 15 and alpha = 0.047.

Results

In summing all 594 h of monitoring of the animals (306 h for MG and 288 h for PG), the cumulative curve demonstrated that the home range size for both the island and mainland groups stabilized by the ninth month (CT method) (Fig. 1). The island group used an area of 4.5 ha based on CT and 4 ha based on the GPS method, a result that did not show any statistical difference ($0.001<p<0.01$) (Table 1). However, there were differences in the positioning of some quadrats (Fig. 2). The GPS method showed the use of one quadrat that was not computed, and three others that were absent when compared to the CT method.

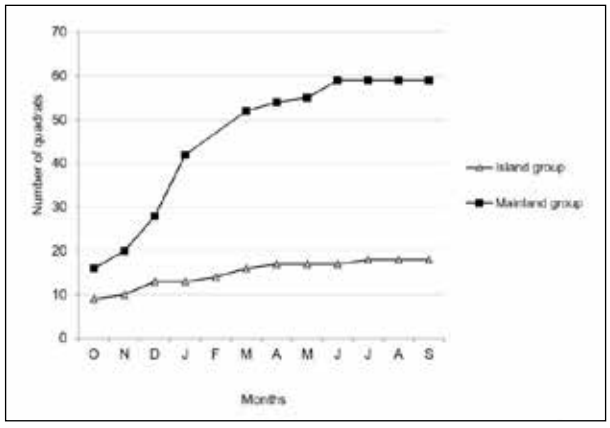

Figure 1. Cumulative curves of the use of quadrats for the island and mainland groups of *Alouatta caraya* over a period of 12 months of monitoring along the Upper Paraná River (October 2004 to September 2005) carried out by the scanning method with compass and tape measure (the month of February could not be sampled in the mainland group).

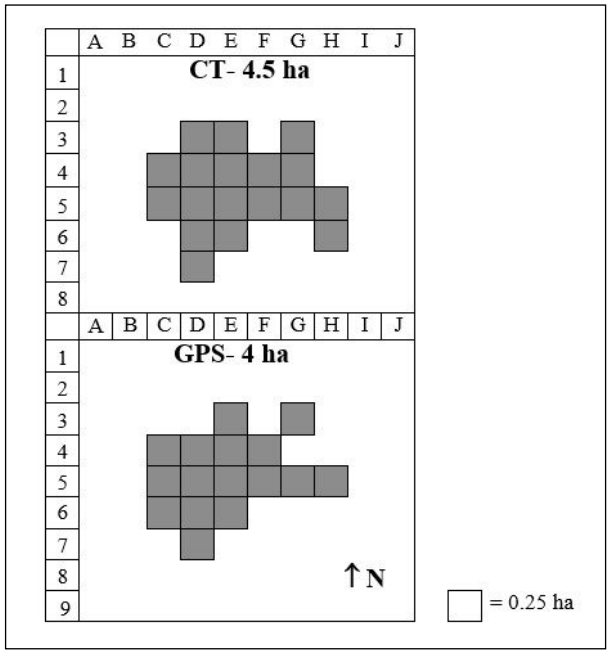

Figure 2. Total home range of island group of *A. caraya* on the Upper Paraná River obtained by the compass and tape measure (CT) method (gray quadrats, above) and by the GPS method (gray quadrats, below).

This resulted in four quadrats with incompatible positions. The mainland group indicated a home range of 14.75 ha with both methods (Table 1), and there was also no statistical difference ($0.01<p<0.001$). However, 12 quadrats (3 ha) showed different positions when the two methods were compared (Fig. 3). The seasonal analyses of both groups also indicated no significant differences between the two methods, showing a minimum difference of 0.25 ha in the spring for both groups and in the summer for the mainland group, a maximum difference of 0.5 ha in the summer and fall in the island group, and 1.5 ha for the mainland group in the winter (Table 1).

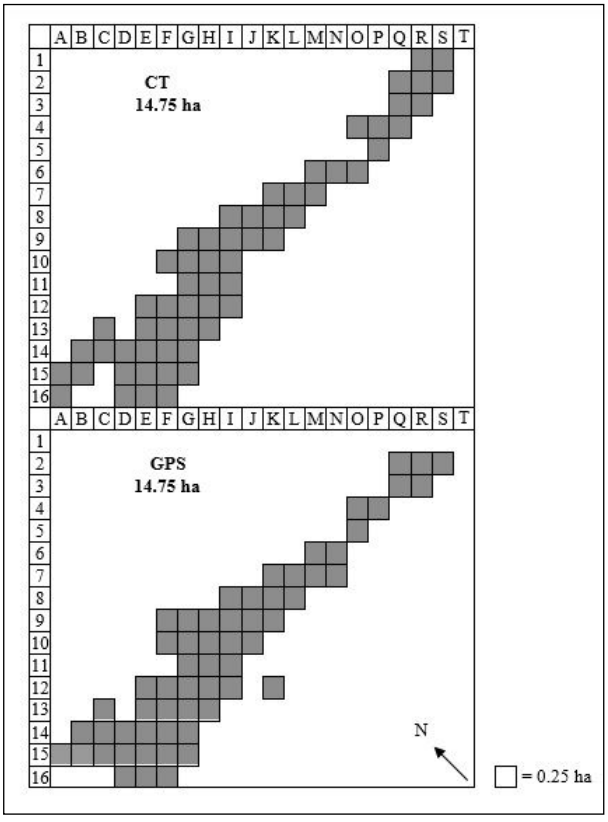

Figure 3. Total home range of mainland group of *A. caraya* on the Upper Paraná River, obtained by the compass and tape measure method (CT) (gray quadrats, above) and by the GPS method (gray quadrats, below).

Table 1. Seasonal and total home ranges of island and mainland groups of *Alouatta caraya* along the Upper Paraná River, based on two different methods (grid cell method by means of compass and tape measure, and by GPS).

Group	Season	Method / Home range (ha)	
		Compass and tape measure	GPS
Island	Spring	3.25	3.5
	Summer	3.0	2.5
	Fall	3.0	2.5
	Winter	2.75	2.75
	Total	**4.5**	**4.0**
Mainland	Spring	7.0	7.25
	Summer	10.25	10.0
	Fall	10.0	10.0
	Winter	8.0	9.5
	Total	**14.75**	**14.75**

Discussion

The results obtained through the use of a compass and tape measure and GPS in the groups studied did not differ significantly, showing that GPS is an efficacious technology for the analysis of home ranges of howlers and arboreal primates in general in forests of different physiognomies (sub-montane SSF and alluvial SSF). However, this method showed some inconsistencies with respect to the positioning of some quadrats when compared to the control method (CT). Quadrats that were computed by GPS and that were absent in the analysis with the compass and tape measure reflected the small error in the home range as defined by the GPS. However, this error did not compromise the results for the seasonal and total areas.

It can also be seen that the better the precision of the instrument in the location where the fixes are taken, the more precise is the estimate of the size of the area utilized by the animals. However, the smaller the home range of the group, the more evident this error can be, leading to a more representative result. For example, for the group with the smaller home range (MG), the positional incompatibility of the estimated quadrat was proportionally greater [approximately 1:1 (incompatible quadrat/ home range)], when compared to the mainland group with a larger home range (0.8:1), even though this group lives in a more mature forest. However, in the final summation, the numerical results obtained for the home range for the two methods were very similar, showing no significant difference for the two groups. This absence of statistical differences can be explained by the numerical compensation of the quadrats that appeared in different positions as estimated with the GPS. This error was probably due to the lower precision in fixes taken in the denser areas within the forest (personal observation) or satellite position. If the satellites are all directly overhead, the resulting error will be higher than if the three satellites are spread out (some on the horizon, for example). While canopy density is an important impediment to accuracy, satellite position may be also a key.

Therefore, for GPS to be considered even more effective for use in calculating the home range in this study or in areas with similar vegetation, in which the canopy allows for the use of this method, some important information is noted here: 1) the points should be taken as precisely as possible (preferentially down to 15 m), so that the error does not drastically affect the results, also attempting to diminish the positional incompatibilities of the quadrats; 2) the GPS readings should be taken at shorter intervals for more precise data collection, for example, every 15 min (for howler monkeys). The interval stipulated in this study (30 min)

did not allow the marking of all the quadrats that the animals utilized, since they passed through several different locations during the course of the day outside the marking time of the point. For example, in Figure 3 there is an isolated box, suggesting that the animals traveled quickly to and from there, presumably the monkeys passed through the uncolored space to arrive at this ¼ hectare. The collection rate should depend on primate speed, and the size of the quadrats: more frequent for faster moving animals, and for smaller quadrats. If large quadrats are used, data points can be collected less frequently.

Although the system using the CT method is more precise, it is extremely laborious, because it requires the help of others to measure the points (and later to collect the data) and calls for more trips to the field in addition to those for monitoring the animals. On the other hand, in relation to the cost/benefit of GPS, the work of the investigator is made easier. Also, it is very easy now to upload GPS points directly into a computer, which saves lots of time and transcription errors and facilitates analysis of points in computer programs. Burgman and Fox (2003) pointed out that this technology has improved the spatial accuracy of field sampling relative to traditional map-based methods. Furthermore, it is rapidly being improved with better batteries, antennas, and electrical efficiency, enhancing the acquisition and number of reliable positions (Sprague et al., 2004). Besides, the market cost of the equipment is becoming increasingly more accessible to the consumer, and computer programs that run their analyses can be obtained from the internet without charge. The results of this comparative methodological study revealed the importance of the cost/benefit ratio for the use of GPS in the analysis of home range studies of primates in riparian environments. Studies in similar fields can become easier using this equipment because these forests are naturally low [(e.g., the Brazilian "caatinga" or semiarid scrub forest, and the "cerrado" or savanna) or perturbed areas (e.g., riparian forests, mangroves, and secondary forests)]. The instrument can be considered, therefore, an efficacious tool for this type of ecological study in appropriate environments in the Neotropical domain, facilitating and providing important analyses that contribute to the conservation of primates and other mammals.

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