Journal of Tropical Ecology (2005) **21**:121–125. Copyright © 2005 Cambridge University Press
DOI: 10.1017/S0266467404001956 Printed in the United Kingdom

SHORT COMMUNICATION

Is camera-trapping an efficient method for surveying mammals in Neotropical forests? A case study in south-eastern Brazil

Ana Carolina Srbek-Araujo and Adriano Garcia Chiarello[1]

Programa de Pós-Graduação em Zoologia de Vertebrados, Pontifícia Universidade Católica de Minas Gerais, Av. Dom José Gaspar, 500, Bairro Coração Eucarístico, CEP 30535–610, Belo Horizonte, Minas Gerais, Brazil
(*Accepted 18 May 2004*)

Key Words: Atlantic forest, camera traps, mammal survey, neotropical forests, survey methods

Although highly diverse (Fonseca *et al.* 1996), the Atlantic forest mammal fauna is still poorly known, with very few sites exhaustively inventoried or subjected to long-term studies (Passamani *et al.* 2000). Although the first surveys using camera traps were carried out in the 1920s (e.g. Chapman 1927), most studies are rather recent (Karanth & Nichols 1998). This is not different in Brazil, where few studies have been published (Marques & Ramos 2001, Santos-Filho & Silva 2002, Silveira *et al.* 2003, Trolle 2003, Trolle & Kéry 2003). Given this, the objective of this paper is to assess the efficiency of camera trapping as an inventory technique for Neotropical forests in general and Atlantic forest in particular. The study was conducted at the Santa Lúcia Biological Station (SLBS), a biologically rich Atlantic Forest preserve located in south-eastern Brazil (Mendes & Padovan 2000) where mammals have been intensively live-trapped, observed from line-transects or had indirect evidence of their presence (faeces, footprints, scratches, etc.) recorded in earlier years (Passamani *et al.* 2000).

The Santa Lúcia Biological Station (19°57′10″–19°59′00″ S, 40°31′30″–40°32′25″ W), is located in the municipality of Santa Teresa, in the state of Espírito Santo, Brazil (Mendes & Padovan 2000). It has an officially protected area of 440 ha, but the forest area including neighbouring private proprieties totals *c.* 900 ha. The topography is hilly with altitudes varying from 550 to 950 m asl. The climate is wet and hot from October–March and dry and cool from April–September (Cfa type according to Köppen's classification). Average annual precipitation and temperature are 1868 mm and 19.9 °C, respectively (Thomaz & Monteiro 1997). Predominant vegetation is dense ombrophilous forest (IBGE 1993). The forest is mostly primary and biologically very rich (Passamani *et al.* 2000, Thomaz & Monteiro 1997).

Data were systematically collected in two periods: 15 February–21 November 2002 (first period; 10 mo) and 21 November 2002–18 January 2004 (second period; 14 mo). In the first period, three camera traps model Wildlife Pro Camera, commercially sold by Forest Suppliers Inc. (USA) were used. Cameras were loaded with 200 ASA colour negative films with 36 exposures. Each camera trap is composed of an automatic Yashica T5 35 mm camera housed in a plastic, weatherproof compartment with four C cell alkaline batteries and an electronic circuit that operates an infrared passive sensor. The equipment was adjusted to operate continuously 24 h a day, and to record consecutive pictures at the shortest possible intervals (20 s in the model used). The three camera traps were checked every 15 d for maintenance, cleaning and battery change, when necessary. The cameras were positioned on tree trunks > 15 cm in diameter at breast height and *c.* 45 cm from the forest floor. Location and placement of cameras followed a random choice of sampling locations, but we tried to maximize the number of pictures by placing them along trails or the margins of small creeks. Selected sites generally contained signs, footprints or odours indicating recent mammal activity. The number of days a given camera trap was left in a particular sampling site depended on the number of pictures it took since the last check by the researchers (every 15 d). When the number of pictures recorded during the previous 15 d was < 1 picture every 2–3 d, the camera trap was moved to another place, but kept in place if the picture rate was higher than that value. For the second period, the same protocol was followed, except that camera traps were installed in pairs to produce pictures of both sides of a given mammal, which would

[1] Corresponding author. Email: bradypus@pucminas.br

https://doi.org/10.1017/S0266467404001956 Published online by Cambridge University Press

allow a quantitative analysis of population size and density of selected species (to be discussed elsewhere). Six cameras in three pairs were used during the second period: one pair of Wildlife Pro Cameras and two pairs of Deer Cam cameras (Deer Cam – Scouting Camera, made by Non Typical Inc., USA). Locations where cameras were installed had their geographic position taken by a Garmin GPS (global positioning system) and the sampling sequency of localitions was randomized. The area covered by camera traps (123 ha in the first, 131 ha in the second and 158 ha in the two periods) was measured using the minimum polygon method with 100% of locations. No baits were used.

Each photograph taken by the camera traps was considered a record. Pictures taken during camera placement and maintenance were disregarded, as were pictures of other taxonomic groups (Aves and Reptilia) and humans. All remaining pictures were considered effective records of mammals. These were subdivided into total (all pictures taken) and independent (excluding pictures of the same individual or species taken at intervals of < 5 min). Sampling effort was calculated as: number of camera traps $\times$ number of sampling days (1 d = 24 h), and the sampling success was expressed as percentage, using the formula: (number of independent records/sampling effort) $\times$ 100. The same formulae were used for the second period, except that each pair of cameras was considered a single unit. The efficiency of camera traps was assessed comparing our data with results of a detailed inventory carried out previously in SLBS (Passamani *et al.* 2000), which gave the richness parameter for the mammal fauna of the study site. Taxonomic nomenclature follows Wilson & Reeder (1993).

Considering the two periods, the sampling effort of 1849 camera-days, or the equivalent of 44 376 h of camera trapping, produced 369 independent records and a capture success of 20.0% (369/1849 $\times$ 100; Table 1). The records included a total of 21 species of indigenous mammal (333 independent records) and one domestic species (domestic dog, *Canis familiaris*), from 13 families and six orders. The species most frequently photographed were agouti (*Dasyprocta leporina*; n = 71), and common opossum (*Didelphis aurita*; n = 61), followed by domestic dog (n = 36), ocelot (*Leopardus pardalis*, n = 26) and paca (*Agouti paca*; n = 23; Table 1). Hairy armadillo (*Euphractus sexcinctus*), naked-tailed armadillo (*Cabassous* sp.) and jaguarundi (*Herpailurus yaguarondi*) had never been observed nor collected in SLBS before.

The second period had a sampling effort 24% longer than the first, a slightly higher number of recorded species (n = 20) but a lower capture success (17.4% vs. 23.1%). Nevertheless, the number of records per species were significantly correlated between periods (Spearman Rank Correlation; $r_s = 0.726$; n = 24; $P < 0.001$). Two species recorded in the first period were not recorded in the

Table 1. Number of independent records of mammals obtained during the two periods of sampling in Santa Lúcia Biological Station (camera-trapped), and list of species previously recorded for this reserve, with corresponding type of record, according to Passamani *et al.* (2000).

Order/Family/Species	Camera traps			Previous records
	Period 1	Period 2	Total	
Didelphimorpha				
Didelphidae				
Caluromys philander				TR, SE
Didelphis aurita	34	27	61	TR, SE
Gracilinanus microtarsus				TR, SE
Marmosa murina				TR
Marmosops incanus				TR, SE
Metachirus nudicaudatus	12	9	21	TR, SE
Micoureus demerarae				TR
Philander frenata	0	1	1	TR, SE
unidentified species	2	0	2	
Xenarthra				
Dasypodidae				
Cabassous sp.	3	2	5	
Dasypus novemcinctus	11	10	21	SE
Euphractus sexcinctus	0	1	1	
Myrmecophagidae				
Tamandua tetradactyla				CO
Bradypodidae				
Bradypus torquatus				SE
Primates				
Callitrichidae				
Callithrix flaviceps				SE
Callithrix geoffroyi				SE
Cebidae				
Alouatta fusca				SE
Callicebus personatus				SE
Cebus apella				SE
Carnivora				
Canidae				
Canis familiaris	8	28	36	
Cerdocyon thous	2	4	6	SE
Procyonidae				
Nasua nasua	7	8	15	SE
Potos flavus				SE
Procyon cancrivorus	16	2	18	CO, FO
Mustelidae				
Eira barbara	3	0	3	SE
Galictis sp.				SE
Lontra longicaudis				SE, FO, FE
Felidae				
Herpailurus yaguarondi	0	2	2	
Leopardus pardalis	10	16	26	FO
Leopardus tigrinus	2	0	2	FO, FE
*Leopardus wiedii**				CO
Puma concolor	3	10	13	FO, FE
Perissodactyla				
Tapiridae				
Tapirus terrestris **				FO, FE
Artiodactyla				
Cervidae				
Mazama americana	8	6	14	SE, FO
Tayassuidae				
Pecari tajacu	4	4	8	SE, FO
Rodentia				
Sciuridae				
Sciurus aestuans	3	1	4	TR, SE

https://doi.org/10.1017/S0266467404001956 Published online by Cambridge University Press

Table 1. Continued.

Order/Family/Species	Camera traps Period 1	Period 2	Total	Previous records
Muridae				
Akodon cursor				TR
Delomys dorsalis				TR
Nectomys squamipes				TR, SE
Oecomys trinitatis				TR
Oligoryzomys nigripes				TR
Oryzomys intermedius				TR
Oxymycterus hispidus				TR
Rhipidomys mastacalis				TR, SE
unidentified	4	4	8	
Caviidae				
Cavia fulgida				TR
Erethizontidae				
Sphiggurus villosus				SE
Hydrochaeridae				
Hydrochaeris hydrochaeris	0	1	1	SE, FO, FE
Agoutidae				
Agouti paca	8	15	23	SE
Dasyproctidae				
Dasyprocta leporina	45	26	71	SE
Echimyidae				
Chaetomys subspinosus				SE
Echimys sp.				TR, SE
Kannabateomys amblyonyx				SE, CO
Trinomys iheringi				TR, SE
Lagomorpha				
Leporidae				
Sylvilagus brasiliensis	6	1	7	TR, SE
Total number of records	191	178	369	–
Total number of identified species	18	20	22	49
Camera traps × nights	826	1023	1849	–
Capture success (%)	23.1	17.4	20.0	–

Abbreviations for type of record in Passamani *et al.* (2000): captured in live-traps (TR); seen by researchers during line-transect sampling (SE); footprints observed by researchers (FO); faeces observed by researchers (FE), specimen collected in SLBS and deposited in Mello Leitão Biological Museum (CO).

*A run-over *Leopardus wiedii* was collected in a paved road near SLBS after the study of Passamani *et al.* (2000). The skin and skull of this animal are deposited in the collection of Mello Leitão Biological Museum.

**Last confirmed record in 1991, now locally extinct.

second, conversely, four species recorded in the second were not photographed in the first. Although data from the two periods are not truly comparable, the observed decrease in capture success in the second period is likely due to differences of equipment. Using data from the second period only, capture success (25.3%) and number of recorded species (n = 16) were much higher for the pair of Wildlife Pro Cameras than the other two pairs of Deer Cam cameras (12.2 and 7.9% of capture success, respectively, with 9 species recorded each). Athough the second period had double the number of camera traps (six cameras in three pairs), the number of locations being monitored at any given moment at SLBS was the same in the two periods (n = 3 locations). Therefore, two out of three locations sampled at any given moment in the second period were occupied with camera traps with a lower efficiency. Photographs with clearly printed time and date (n = 280) were used to analyse differences in capture rate between day (05h01–17h00) and night (17h01–05h00). Overall, nocturnal period produced a higher number of records (n = 178), species (n = 19) and capture success (19.3%) then the diurnal period (101 records, 14 species and a capture success of 10.9%). The highest capture success (15.5%) was observed at 21h01–01h00 interval, and the late afternoon—early evening (17h01–19h00) produced the highest number of species (n = 13). Excluding dawn/dusk period, three species were recorded solely during the day (*Sciurus aestuans*, *Hydrochaerys hydrochaerys* and *Herpailurus yaguarondi*) and four only at night (*Dasypus novemcinctus, Euphractus sexcinctus, Sylvilagus brasiliensis* and *Philander frenata*).

Except for primates, most Neotropical mammals are active both during the day and night or are predominantly nocturnal. This is especially true for the vast majority of small mammals, armadillos, felids and canids. It is not surprising, therefore, that most photographs, and a higher number of species, were recorded at night. This difference can also be due to a stronger contrast between the background temperature and the body temperature of a mammal during the night. As the infrared sensor detects not only motion but also changes in temperature, a given mammal has a higher chance of being detected in the cooler environmental temperature characteristic of nights.

Camera traps recorded species that are extremely difficult to detect using line-transects, such as the naked-tailed armadillo (*Cabassous* sp.) and the crab-eating raccoon (*P. cancrivorus*), or species that are becoming rare in the region due to hunting or habitat fragmentation such as the brocket deer (*M. americana*) and the agouti (*D. leporina*). The method was also efficient in recording species of the order Carnivora (eight species; 38% of the total), which are generally rare and extremely shy to human presence. Similar results were observed by Marques & Ramos (2001), Santos-Filho & Silva (2002), Trolle (2003) and Silveira *et al.* (2003). As remarked by Carbone *et al.* (2001), camera trapping is an efficient method for recording species that move long distances, that occur in low densities, which are solitary or live in small groups. All these characteristics are common to several species that inhabit Neotropical forest areas in general (Carbone *et al.* 2001).

The number of mammal species recorded by the cameras in SLBS (22 in total, 21 indigenous) was higher than other studies carried out in the Brazilian Pantanal (n = 18; Trolle 2003), and the Brazilian Cerrado (Santos-Filho & Silva 2002, Silveira *et al.* 2003, n = 17 in both studies), and much higher than the eight species recorded by Marques & Ramos (2001), in a mixed forest (*Araucaria*

https://doi.org/10.1017/S0266467404001956 Published online by Cambridge University Press

angustifolia) site in southern Brazil. These results are not truly comparable, however, as vegetation type and sampling efforts were different among studies (1849 camera-days in this study against 450–1035 camera-days in the other studies). Another important aspect to be considered is that the studies by Trolle (2003) and Santos-Filho & Silva (2002) both used baits to attract animals to the camera traps, a practice not used here. The lack of standard methods hampers faunal comparisons among differing habitat types and indicates the need to conduct studies designed specifically to test differences in equipment and the influence of baits when comparisons of mammal communities via camera traps are intended (Cutler & Swann 1999). As mentioned above, the two brands of camera trap used in the present study showed, for example, substantial differences in capture success. Researchers, thus, must take these differences into account when planning their studies.

Using a variety of methods and a much larger period of sampling for both small (live-trapping) and medium- to large-sized mammals (line transect sampling), Passamani *et al.* (2000) recorded 49 species of eight orders and 22 families of non-volant mammals for SLBS. It should be noticed, however, that the tapir, *Tapirus terrestris*, was last recorded in SLBS in 1991 and is now considered locally extinct (pers. obs.). The three additional species photographed by the cameras in the present study (*Euphractus sexcinctus*, *Cabassous* sp. and *Herpailurus yaguarondi*) bring the total number of 51 species of non-volant mammals confirmed for this reserve. The 21 species (excluding the domestic dog) recorded by the camera traps represent, therefore, 41% of the non-volant mammals currently inhabiting this reserve. As expected, small mammals (< 1 kg of body weight) were under-sampled, as only four species were recorded – 21 species are known to be present in SLBS (Table 1). Other studies showed similar limitations (Santos-Filho & Silva 2002, Trolle 2003). On the other hand, camera traps recorded 17 species (58.6%) of medium- to large-sized mammals present in the reserve (29 species). Armadillos (Dasypodidae), racoons and coatis (Procyonidae), foxes (Canidae), wild cats (Felidae), deer (Cervidae), peccaries (Tayassuidae), agoutis (Dasyproctidae), pacas (Agoutidae), squirrels (Sciuridae) and rabbits (Leporidae) were relatively well represented by photographs (66.7 – 100% of the species present in each family). However, the placement of the cameras near the forest floor biased results in favour of terrestrial and scansorial species and hampered recording of primates (five species) and other arboreal species (one species of sloth and two species of tree-porcupines), which are nevertheless present in SLBS (Table 1). Excluding small mammals and arboreal species there remain 21 confirmed species in SLBS, 80.9% of which ($n = 17$) were recorded by the cameras. Among species previously recorded, the ocelot (*L. pardalis*), the oncilla (*L. tigrinus*), the puma (*P. concolor*) and the crab-eating racoon (*P. cancrivorus*) had been confirmed solely on the basis of footprints or faeces (Passamani *et al.* 2000), therefore pictures of these animals represent the first direct evidence of their presence in the study site. Even though SLBS had been the focus of intensive studies by the naturalist Augusto Ruschi since 1939 (Mendes & Padovan 2000) and, more recently, by Passamani *et al.* (2000), three species (mentioned above) escaped detection by these researchers.

We considered sampling of medium- to large-sized mammals by camera traps a practical, non-intrusive method (when baits are not used) that requires little effort (field hours by trained researchers) when compared to alternative methods. On average, two researchers spent 1–2 d only to maintain, clean and relocate 3–6 cameras monthly in SLBS. One important constraint, though, is the high initial costs of the equipment (*c.* US$ 500 each). Films and batteries, which need to be replaced every month or two, add significantly to this, especially so in poor tropical countries, where these products, being frequently imported, are priced in US dollars. The cost of line-transect sampling represents, without doubt, lower expenditure in equipment, but training, food and accommodation costs for the researchers are higher. All this must be carefully weighed when deciding the best method of sampling for a given site.

In conclusion, results demonstrate that camera traps can yield satisfactory results in the inventory of terrestrial, medium- to large-sized mammals of Neotropical forests. It requires no substantial investment in training and man-hours in the field, and the results (prints) provide accurate identification for most species. Small mammals and arboreal species are, however, poorly inventoried and alternative methods should be used for sampling these groups.

ACKNOWLEDGEMENTS

We are greatly indebted to all the staff of Museu de Biologia Prof. Mello Leitão, specially its director Helio de Queiroz B. Fernandes and secretary Rose Loss. Luciana Barçante, Marina Nogueira dos Santos, Leandro Santana Moreira, Paula Lara Ruiz, Rodrigo Lira Meyer, Pedro Amaral, Valeska Buchemi de Oliveira, Sérgio Pimenta Costa and Oscar Echevery kindly helped with data collection. This project was funded by Fundo de Incentivo à Pesquisa – PUC Minas (grant # FIP 2002/06 – TLE). Results here presented are part of a major and long-term project entitled 'Biodiversidade da Mata Atlântica no Estado do Espírito Santo', funded by the Brazilian Science Council (CNPQ grant # 469.321/2000–8).

https://doi.org/10.1017/S0266467404001956 Published online by Cambridge University Press

LITERATURE CITED

CARBONE, C., CHRISTIE, S., CONFORTI, K.,COULSON, T., FRANKLIN, N., GINSBERG, J. R., GRIFFITHS, M., HOLDEN, J., KAWANISHI, K., KINNAIRD, M., LAIDLAW, R., LYNAM, A., MACDONALD, D. W., MARTYR, D., MCDOUGAL, C., NATH, L., O'BRIEN, T. O., SEIDENSTICKER, J., SMITH, D. J. L., SUNQUIST, M., TILSON, R. & WAN SHAHRUDDIN, W. N. 2001. The use of photographic rates to estimate densities of tigers and other cryptic mammals. *Animal Conservation* 4:75–79.

CHAPMAN, F. M. 1927. Who treads our trails? *National Geographic Magazine* 52:331–345.

CUTLER, T. L. & SWANN, D. E. 1999. Using remote photography in wildlife ecology: a review. *Wildlife Society Bulletin* 23:571–581.

FONSECA, G. A. B., HERRMANN, G., LEITE, Y. R., MITTERMEIER, R. A., RYLANDS, A. B. & PATTON, J. L. 1996. Lista Anotada dos Mamíferos do Brasil. *Occasional Papers in Conservation Biology* 4:1–38.

IBGE 1993. *Mapa de Vegetação do Brasil*. Fundação Instituto Brasileiro de Geografia e Estatística. Rio de Janeiro.

KARANTH, K. U. & NICHOLS, J. D. 1998. Estimation of tiger densities in India using photographic captures and recaptures. *Ecology* 79:2852–2862.

MARQUES, R. V. & RAMOS, F. M. 2001. Identificação de mamíferos ocorrentes na Floresta Nacional de São Francisco de Paula/IBAMA, RS com a utilização de equipamento fotográfico acionado por sensores infravermelhos. *Divulgações do Museu de Ciências e Tecnologia* 6:83–94.

MENDES, S. L. & PADOVAN, M. P. A. 2000. Estação Biológica de Santa Lúcia, Santa Teresa, Espírito Santo. *Boletim do Museu de Biologia Mello Leitão* 11/12:7–34.

PASSAMANI, M., MENDES, S. L. & CHIARELLO, A. G. 2000. Non-volant mammals of the Estação Biológica de Santa Lúcia and adjacent areas of Santa Teresa, Espírito Santo, Brazil. *Boletim do Museu de Biologia Mello Leitão* 11/12:201–214.

SANTOS-FILHO, M. & SILVA, M. N. F. 2002. Uso de habitats por mamíferos em área de Cerrado do Brasil Central: um estudo com armadilhas fotográficas. *Revista Brasileira de Zoociências* 4:57–73.

SILVEIRA, L., JÁCOMO, A. T. A. & DINIZ-FILHO, A. F. 2003. Camera trap, line transect census and track surveys: a comparative evaluation. *Biological Conservation* 114:351–353.

THOMAZ, L. D. & MONTEIRO, R. 1997. Composição florística da Mata Atlântica de encosta da Estação Biológica de Santa Lúcia, município de Santa Teresa – ES. *Boletim do Museu de Biologia Mello Leitão* 7:3–48.

TROLLE, M. 2003. Mammal survey in the southeastern Pantanal, Brazil. *Biodiversity and Conservation* 12:823–836.

TROLLE, M. & KÉRY, M. 2003. Estimation of ocelot density in the Pantanal using capture–recapture analysis of camera-trapping data. *Journal of Mammalogy* 84:607–614.

WILSON, D. E. & REEDER, D. M. 1993. *Mammal species of the World. A taxonomic and geographic reference*. Smithsonian Institution, Washington and London. 1207 pp.

https://doi.org/10.1017/S0266467404001956 Published online by Cambridge University Press