

Comparing methods for sampling large- and medium-sized mammals: camera traps and track plots

Maria Carolina Lyra-Jorge · Giordano Ciocheti ·
Vânia Regina Pivello · Sérgio Tadeu Meirelles

Received: 1 February 2008 / Revised: 31 May 2008 / Accepted: 5 June 2008 / Published online: 17 July 2008
© Springer-Verlag 2008

Abstract Activities involving fauna monitoring are usually limited by the lack of resources; therefore, the choice of a proper and efficient methodology is fundamental to maximize the cost–benefit ratio. Both direct and indirect methods can be used to survey mammals, but the latter are preferred due to the difficulty to come in sight of and/or to capture the individuals, besides being cheaper. We compared the performance of two methods to survey medium and large-sized mammal: track plot recording and camera trapping, and their costs were assessed. At Jataí Ecological Station (S21°31'15"–W47°34'42"-Brazil) we installed ten camera traps along a dirt road directly in front of ten track plots, and monitored them for 10 days. We cleaned the plots, adjusted the cameras, and noted down the recorded species daily. Records taken by both methods showed they sample the local richness in different ways (Wilcoxon, $T=231$; $p<0.01$). The track plot method performed better on registering individuals whereas camera trapping provided records which permitted more accurate species identification. The type of infra-red sensor camera used showed a strong bias towards individual body mass ($R^2=0.70$; $p=0.017$), and the variable expenses of this method in a 10-day survey were estimated about 2.04 times higher compared to track plot method; however, in a long run camera trapping becomes cheaper than track plot recording. Concluding, track plot recording is good enough for quick surveys under a limited budget, and camera trapping is best

for precise species identification and the investigation of species details, performing better for large animals. When used together, these methods can be complementary.

Keywords Animal survey method · Camera trap · Track plot

Introduction

Different methods can be used to monitor fauna populations or communities. Surveys of medium and large mammals often adopt indirect methods such as the identification of dung, footprints, and other vestiges, due to the great difficulty to come in sight of, or to capture such animals. Although being practical and objective, indirect methods are not always very accurate (Smallwood and Fitzhugh 1995). Among them, probably the oldest method used to survey medium and large mammals is the identification of their footprints in the ground (Bider 1968). The identification of dung, nests, path trails, and scratches also came to be used. Nowadays, more systematic methodologies are also available such as line transects (Rudran et al. 1996), vocal call identification (Jones et al. 1996), camera trapping (Wemmer et al. 1996; Cutler and Swann 1999), or video recording (Reif and Tornberg 2006; Scheibe et al. 2008).

Whichever method chosen to study medium and large mammals it will always reveal different levels of accuracy and precision, as well as different cost–benefit ratios (Gaidet-Drapier et al. 2006). A good choice of a survey method requires clear research objectives and the awareness about the method efficiency and limitations towards the desired objectives. Limitations may vary as much as from operational conditions—such as accessibility to the area, or the interaction with local people (Gaidet-Drapier et al. 2006)—to the project execution timing, or the available

Communicated by: H. Kierdorf

M. C. Lyra-Jorge (✉) · G. Ciocheti · V. R. Pivello ·
S. T. Meirelles
Departamento de Ecologia, Universidade de São Paulo,
Rua do Matão, Travessa 14, 321,
CEP 05508900 Cidade Universitária, São Paulo, Brazil
e-mail: carolina_ecologia@hotmail.com

budget. Activities involving fauna monitoring are frequently limited by the lack of resources, and consequently it is essential to analyze the relation between the method performance and its cost.

Two of the most commonly applied methods to survey large- and medium-sized mammals are the track plot recording and camera trapping, both non-invasive methods which permit the estimation of species presence and/or abundance (Wemmer et al. 1996; Cutler and Swann 1999), especially of animals that are very shy to human presence. A comprehension of their efficacy and costs is essential to assist researchers to adequately prepare studies to document mammal species presence, richness, and activity patterns, making possible the planning of conservation strategies and monitoring programs (Sadler et al. 2004; Barea-Azeón et al. 2007).

A number of authors agree that investigations on the performance of different sampling methods in a variety of regions and focusing on distinct animal groups are extremely necessary but still scarce (Voss and Emmons 1996; Cutler and Swann 1999; Carbone et al. 2002; Janelle et al. 2002; Srbek-Araújo and Chiarello 2005, 2007; Gaidet-Drapier et al. 2006; Barea-Azeón et al. 2007). In this sense, this study aimed at investigating the strengths and weaknesses of these two methods—track plot recording and camera trapping—for registering mammal species richness, together with a cost-benefit analysis. Our specific objectives were: (1) to compare the performance between the track plot and the camera trap methods in terms of detection rates of large- and medium-sized mammals, (2) to verify if any of these detection methods is biased towards the animal size, and (3) to assess and compare the costs and benefits of both methods.

Material and methods

The experiment was carried out at the Jataí Ecological Station (EEJ) (São Paulo State, Brazil: 21°31'15"S–21°44'24"S; 47°34'42"W–47°52'01"W) in July 2006 (dry season). The regional vegetation is composed of remnant fragments of semideciduous forest and savanna forms, dispersed in an agricultural matrix (mainly eucalyptus and sugar cane monocultures). In the EEJ, the predominant vegetation is the woodland savanna (*cerradão*), on sandy soils. The EEJ represents one of the last few savanna remnants in São Paulo State (Shida 2005).

Field data were collected inside the EEJ, where ten track plots and ten camera traps were distributed along a dirt road. We tested the performance of the national camera trap (“Trapa-camera Company”: <http://trapacamera.com>) against an imported make Stealth Cam (<http://www.stealthcam.net>), and the national ones showed more adequate in our tropical

weather conditions (high temperature and air humidity) besides being considerably cheaper; sensitivity and detection zone were also satisfactory (according to Swann et al. 2004). National camera traps with digital cameras were not available in the market by the time the field work was carried out (they are available now). For these reasons we chose the national camera traps with automatic photographic cameras. The films used in the cameras allowed 36 photos, a sufficient number of pictures for the study period and ecological conditions (Lyra-Jorge et al. 2008).

The cameras used were equipped with infra-red movement sensor, having a coverage area of 90° horizontally and 30° vertically, reaching up to 8 m of distance. Movements of infra-red sources within the coverage area were detected by the sensor which automatically triggered the camera. Approximately 1 s was the time lag between the animal detection by the infra-red sensor and the triggering. The sensitivity of the sensor was adjusted through a photoelectric cell, becoming higher when infra-red sources in the environment decreased; consequently, the maximum sensitivity occurred at night.

Ten track plots (length=1.5 m, X dirt road width ≈4 m) were created along the dirt road using the road sandy soil, and arranged every 700 m (since 7,000 m was the maximum continuous distance in adequate condition of soil and topography). The camera traps were installed facing each track plot. Each paired camera trap plus track plot formed a “sampling unit”.

Track plots and camera traps were checked once a day during ten consecutive days in July (dry season), when the recorded footprints in each plot and the number of photographs taken by each camera were noted down. After collecting the data, the plots were cleaned to eliminate animal records from that day. Records of the same species in the same day and in the same track plot were counted only once, and so were the sequential photographs of the same species. The species registered in track plots were identified in situ by two skilled researchers with large experience in the task.

We considered each point/day as one sample, totaling 100 samples (10 points × 10 days). Since data (photos or footprints) distribution was not normal, the Wilcoxon test was used to compare the performance of both methods (Zar 1999).

Detection rate of each method was assessed dividing the number of effective records (photos or footprints where the animal could be identified) by the number of hours of exposure (240 h).

Dependence between the number of records obtained through each method was assessed by a Chi-square test with Yates correction, using a 2 × 2 contingency table (Zar 1999). When a species was not registered by one of the methods, we tested the dependence between species average body mass and the number of records taken with each method through Spearman correlation. Even though

the animal size could be represented by its volume or surface, body mass is also a good indicator of the animal total heat (infra-red source) and this kind of data is available in the literature. Species body mass values were based on Silveira's data (1999). We used the program BioStat 3.0 (Ayres et al. 2003) for statistical analyses.

The cost of each method consisted of fixed and variable expenses (Martins 2003). Fixed expenses were those which did not change throughout the project, i.e. global positioning system set, the value of the vehicle used, and its depreciation. As the fixed costs were the same for both methods here tested they were kept out of the calculations. Variable expenses changed according to project activities (Martins 2003), and included:

- Camera trap method: camera traps, photographic films, batteries (five per camera trap), film development, fuel, researcher's daily allowance, field assistant's daily allowance;
- Track plot method: fuel, researcher's daily allowance, field assistant's daily allowance.

We estimated and compared costs of a 10-day survey and a 30-day survey (as this is the maximum time interval to replace camera films and batteries under the ecological conditions of the present study) using both methods. We considered ten camera traps, ten track plots, ten or 30 sampling days, and a distance of about 100 km to the sampling area. The camera trap method considered 2 days of researcher's allowance: one to set up camera traps and another day to interpret the photos, for both time-interval surveys. Although in the present study the field assistant checked the cameras every day, this is not necessary in a conventional survey; after a monitoring period and assuring the system is working well, the cameras can be left unaided in the field for several days (up to a month in this study ecological conditions) and field assistant will be required only at the beginning of the time interval, to set up camera traps together with the researcher, and at the end of the interval, to change films and batteries or to remove the equipment. The track plot method considered 1 day of field assistant's allowance—to prepare the plots—and 10 or 30 days of researcher's allowance, as the researcher is needed every day in the field to correctly identify the footprints. Costs were converted from the local currency (real) to American dollar (average exchange rate of April/2008: US\$1.00≈R\$1.66).

Results

We obtained 17 records of six species through camera traps, and 28 records of six taxa through track plots (Table 1). Two genera—*Mazama* and *Dasypus*—are known to have

more than one species in the region, and the identification at species level was only possible through camera trapping.

The Wilcoxon test resulted highly significant ($T=231$, $p<<0.01$) indicating that detection by both methods is not the same. Detection rates of camera trap and track plot methods were respectively 0.071 and 0.117. The Chi-square independence test was significant for animals of higher body mass and non-significant for smaller animals, suggesting that the efficiency of both traps is similar for larger animals but unlike for the smaller mammals (Table 1). Detection through camera trap was dependent on the species body mass, and such a tendency was confirmed by the Spearman correlation test ($R^2=0.70$; $p=0.017$).

The per-day costs of variable expenses estimated for both methods in a 10-day survey and in a 30-day survey were, respectively, US\$ 305.13 and US\$ 101.71 for camera trapping, and US\$ 149.90 and US\$ 145.89 for the track plot recording (Table 2).

Discussion

Camera trapping and track plot recording tended to sample large- and medium-sized mammals in different ways. Although sampling units did not have spatial independence, this was not a problem in this study since variables such as land cover, the distribution of camera traps and track plots, number of hours of exposure (240 h), and the average body mass of the individuals were the same for both methods, therefore, different results should relate to the sampling method.

Some advantages and inconveniences could be perceived in both methods. The track plot method showed better detection efficiency, 1.65 times higher than that of camera trapping. However, species identification in track plots is strongly dependent on the researcher's ability to identify the recorded footprints. For that reason, the researcher himself is required in the field most of the time, instead of a field assistant. Ground characteristics may occasionally bewilder the researcher concerning the animal size, since the same animal footprint gets larger in softer grounds (Stander 1998); in addition, hard and dry substrata are not adequate to record footprints. In this study, some days the soil was so dry that we could not securely identify footprints usually easily identifiable, as of *Puma concolor*. The track plot method efficiency also depends on weather conditions during the sampling period, since a strong rain or wind can eliminate some records. If the footprint stays in the dry soil for several hours, the wind carries the soil particles away and the footprint begins to fade. It is also challenging even for a skilled person to identify species whose footprints are very similar, as some deer (*Mazama americana* and *Mazama guazoubira*) for example. Still,

Table 1 Records of mammal species surveyed through camera traps and track plots, and the values of Chi-square (X^2) independence test with Yates correction, comparing both survey methods

Species	Number of records		Body mass (kg)	X^2
	Track plot	Camera trap		
<i>Puma concolor</i>	6	8	70.0	29.84*
<i>Chrysocyon brachyurus</i>	6	4	23.0	20.18*
<i>Mazama</i> sp. ^a	2	1	30.0	49.49*
<i>Conepatus semistriatus</i>	6	2	3.0	0.13
<i>Dasypus</i> sp. ^a	4	1	1.0	0.42
<i>Sylvilagus brasiliensis</i>	4	1	2.0	0.27
Total	28	17		

Species body mass according to Silveira (1999)

* $p < 0.01$

^a More than one species of the genus is known in the area; identification at species level was not possible through track plot recording

such a method demands long time in the field, as the plots have to be frequently checked and cleaned.

The camera trap method, even though showing lower detection efficiency, certainly provides more accurate records as once photographed the mammal can be easily identified to species level. For some species, especially those having spotted skin, it may be possible to identify individuals (Rudran et al. 1996) that can be very useful when working on capture-mark-recapture of animals; if the marker is well visible (e.g., bright colors in the body or ear

rings) it will show in the photograph and the photo itself may function as a recapture, saving costs and lowering the risk of wounding and stressing both the animal and the researcher (Tomas and Miranda 2003), and may allow the estimation of population density (Trolle et al. 2007). In some situations, the reproductive condition of the animal can also be recognized in the photos (Srbek-Araújo and Chiarello 2005). Besides, the camera trap method offers conditions to analyze activity patterns of the photographed species, since it is possible to record the time when each

Table 2 Comparison of the estimated costs of different items (variable expenses) for both methods used to sample mammals (camera trapping and track plot recording), considering a 10-day survey and a 30-day survey, under this study ecological conditions

	Variable expenses (US\$)		10-day survey		30-day survey	
	Item	Unit value	Quantity	Total	Quantity	Total
Camera trapping	Camera traps	240.96	10	2,409.60	10	2,409.60
	Films	6.02	10	60.20	10	60.20
	Batteries	1.66	50	83.00	50	83.00
	Film development	9.03	10	90.30	10	90.30
	Diesel	1.17 (1 l)	2×20 l (field ≈100 km distance; 2 return field trips)	46.80	2×20 l (field ≈100 km distance; 2 return field trips)	46.80
	Researcher's day allowance	120.48	2 days	240.96	2 days	240.96
	Field assistant's day allowance	60.24	2 days	120.48	2 days	120.48
Total				3,051.34		3,051.34
Per-day cost				305.13		101.71
Track plot recording	Diesel	1.17 (1 l)	10×20 l (field ≈100 km distance; 10 return field trips)	234.00	30×20 l (field ≈100 km distance; 30 return field trips)	702.00
	Researcher's day allowance	120.48	10 days	1,204.80	30 days	3,614.40
	Field assistant's day allowance	60.24	1 day	60.24	1 day	60.24
Total				1,499.04		4,376.64
Per-day cost				149.90		145.89

Values in US\$, average exchange rate of April/2008: US\$1.00≈R\$1.66

photo is taken. Time recording also permits to assess the presence of different individuals of the same species at different times in the same day, while records in track plots do not allow such a differentiation, as footprints of the same species in the same plot and in the same day are reckoned as only one register.

Another advantage of camera trapping is that the researcher is not required to monitor the equipment constantly, as the cameras can be left unaided in the field for several days and any trained person is able to change camera films (if not digital cameras) and batteries. In another study in the same region (Lyra-Jorge et al. 2008) we verified that it was necessary to change 36-picture films only once a month, and the researcher was required in the field only to install the cameras (1 day) plus an additional period to analyze the photos taken.

On the other hand, detection by camera traps showed a strong dependency on the animal body mass, performing in favor of large species. Such a tendency has also been reported by other researchers, since the earliest infra-red camera traps (Wemmer et al. 1996) to the more recent ones (Carbone et al. 2002; Silveira et al. 2003). Other potential failures for infra-red camera traps can be pointed. The cameras used in this study take about one second between the animal detection by the sensor and the triggering, and in some cases the animal can run away before being photographed. This is a possible reason for lower detection rates of the camera traps compared to the track plot method. Also, as the sensor detects motion and changes in temperature, the camera performance reduces in hot days, when the environmental temperature becomes close to the animal body temperature. This is also a reason for higher detection at night, when the contrast between the animal body and the environment temperature is higher (Srbek-Araújo and Chiarello 2005). Higher detection at night was also noticed in this study, what can be in part due to that condition and in part because most of the animals detected here have nocturnal habit (Emmons 1997; Reis 2006; G. Ciochetti unpublished data).

Still related to the camera temperature-detection system was the initial difficulty in calibrating the infra-red sensor under hot weather conditions, as it would trigger with temperature oscillation. This problem was much easier to overcome with the national *Trapa-camera* than with the imported make (Stealth Cam MC2-GV, 35 mm), as the national camera trap was adjusted for tropical conditions. Its sealing system was also more effective, therefore humidity and excess heat did not damage the mechanism.

Camera avoidance behavior in mammals has been noticed, especially in long term studies in which the cameras remain in the same sites, as the animals “remember” the camera presence and avoid the flash. This may be the reason for a higher detection rate at the beginning of

long term studies (Wemmer et al. 1996; York et al. 2001; Wege et al. 2004; Jackson et al. 2006). In an 18-month sampling study we also noticed camera shyness (Lyra-Jorge et al. 2008) but not in the present short-time sampling study.

Despite the cost of camera trapping being high at first sight, this method produces permanent records and the cameras can be re-used in other projects. In a medium/long run project, per-day cost of this method lessens with time because the equipment can stay unaided in the field for up to a month, saving travel and personnel expenses. On the other hand, track plot recording method requires daily field visits. Comparing a 10-day with a 30-day survey, camera trapping per-day costs decreased from US\$ 305.13 to US\$ 101.71 whereas per-day cost of the track plot method remained almost the same (US\$ 149.90 against US\$ 145.89). If using digital cameras, the cost would be even lower because films (and films development) would not be necessary. Most researchers who evaluate costs and benefits of mammal recording methods agree that more expensive methods, if more accurate, are the best for long term studies and/or when different research groups share field equipment, and that the combination of two or more methods always result in better quality data, especially when surveying rare or secretive species (Stander 1998; Silveira et al. 2003; Sadlier et al. 2004; Gaidet-Drapier et al. 2006; Barea-Azeón et al. 2007; Scheibe et al. 2008).

Considering the benefits and shortcomings of both methods in relation to performance and costs we can conclude that the track plot method is satisfactory when the purpose is to assess local species richness through quick surveys and under a limited budget. Camera trapping, although being more expensive and biased towards larger animals permits precise species identification, the investigation of species activity patterns, and sometimes, the estimation of population density (through individualized records) (Voss and Emmons 1996; Srbek-Araújo and Chiarello 2005); it is an efficient method especially to record vagile animals which are solitary, in low density or live in small groups (Carbone et al. 2001). Both methods can be used together, enhancing field data quality and providing complementary results.

Acknowledgements We are grateful to Msc. Milton Cezar Ribeiro and to Dr. Carlos Piña for the suggestions and to Dr. Valentine Lance for revising the text. We also thank NGC—Neotropical Grassland Conservancy and CNPQ—Conselho Nacional de Pesquisa e Tecnologia for financial support. This research was conducted according to Brazilian environmental laws and regulations.

References

- Ayres M, Ayres M Jr, Ayres DL, Santos AS (2003) BioStat 3.0. Sociedade Civil Mamirauá/MCT-CNPq. Belém, PA. Brasil

- Barea-Azeón, JM, Virgós, E, Ballesteros-Duperón, E, Moleón, M, Chiroso, M (2007) Surveying carnivores at large spatial scales: a comparison of four broad-applied methods. *Biodivers Conserv* 16:1213–1230 doi:10.1007/s10531006-9114-x
- Bider, JR (1968) Animal activity in uncontrolled terrestrial communities as determined by sand transect technique. *Ecol Monogr* 38:269–308 doi:10.2307/1948530
- Carbone, C, Christie, S, Conforti, K, Coulson, T, Franklin, N, Ginsberg, JR et al (2001) The use of photographic rates to estimate densities of tigers and other cryptic mammals. *Anim Conserv* 4:75–79 doi:10.1017/S1367943001001081
- Carbone, C, Conforti, C, Coulson, T, Franklin, N, Ginsberg, JN, Griffiths, M et al (2002) The use of photographic rates to estimate densities of tigers and other cryptic mammals: response to Jannelle et al. *Anim Conserv* 5:121–132 doi:10.1017/S1367943002002172
- Cutler, TL, Swann, DE (1999) Using remote photography in wildlife ecology: a review. *Wildl Soc Bull* 27:571–581
- Emmons, L (1997) Neotropical rainforest mammals: a field guide. University of Chicago Press, USA
- Gaidet-Drapier, N, Fritz, H, Bougarel, M, Renaud, PC, Poilecot, P, Chardonnet, P et al (2006) Cost and efficiency of large mammal census techniques: comparison of methods for a participatory approach in a communal area, Zimbabwe. *Biol Conserv* 15:735–754
- Jackson, RM, Roe, JD, Wangchuk, R, Hunter, DO (2006) Estimating snow leopard population abundance using photography and capture-recapture techniques. *Wildl Soc Bull* 34:772–781 doi:10.2193/00917648(2006)34[772:ESLPAU]2.0.CO;2
- Jannelle, CS, Runge, MC, Mackenzie, DI (2002) The use of photographic rates to estimate densities of tigers and other cryptic mammals: a comment on misleading conclusions. *Anim Conserv* 5:119–120 doi:10.1017/S1367943002002160
- Jones, C, McShea, WJ, Conroy, M, Kunz, TH (1996) Capturing mammals. In: Wilson, DE, Cole, FR, Nichols, JD, Rudran, R, Foster, MS (eds) *Measuring and monitoring biological diversity. Standard methods for mammals*. Smithsonian Institution, USA, pp 115–176
- Lyra-Jorge MC, Ciochetti G, Pivello VR (2008) Carnivore mammals in a fragmented landscape in northeast of São Paulo State, Brazil. *Biodivers Conserv* 17(7):1573–1580, June
- Martins, E (2003) *Contabilidade e custos*. Editora Atlas, São Paulo
- Reif, V, Tornberg, R (2006) Using time-lapse digital video recording for a nesting study of birds of prey. *Eur J Wildl Res* 52(4):251–258, December
- Reis NR (ed) (2006) *Mamíferos do Brasil*. Universidade Estadual de Londrina, Paraná Brasil
- Rudran, R, Kunz, TH, Jarman, SC, Smith, AP (1996) Observational techniques for nonvolant mammals. In: Wilson, DE, Cole, FR, Nichols, JD, Rudran, R, Foster, MS (eds) *Measuring and monitoring biological diversity. Standard methods for mammals*. Smithsonian Institution, USA, pp 81–114
- Sadlier, LMJ, Webbon, CC, Backer, PJ, Harris, S (2004) Methods of monitoring re foxes *Vulpes vulpes* and badgers *Meles meles*: are field signs the answer? *Mammal Rev* 34:75–98 doi:10.1046/j.03051838.2003.00029.x
- Scheibe, KM, Eichhorn, K, Wiesmayr, M, Schonert, B, Krone, O (2008) Long-term automatic video recording as a tool for analyzing the time patterns of utilization of predefined locations by wild animals. *Eur J Wildl Res* 54:53–59 doi:10.1007/s1034400701080
- Shida, CN (2005) Caracterização física do cerrado Pé-de-Gigante e uso das terras na região. Evolução do uso das terras na região. In: Pivello, VR, Varanda, EO (eds) *Cerrado Pé-de-Gigante. Parque Estadual de Vassununga. Ecologia e Conservação*. SEMA, São Paulo, pp 25–47
- Silveira L (1999) *Ecologia e conservação dos mamíferos carnívoros do Parque Nacional das Emas, Goiás*. MsC thesis. Universidade Federal de Goiás. Brazil
- Silveira, L, Jácomo, AT, Diniz-Filho, JA (2003) Camera trap, line transect census and track surveys: a comparative evaluation. *Biol Conserv* 114:351–355 doi:10.1016/S00063207(03)000636
- Smallwood, KS, Fitzhugh, EL (1995) A track count for estimating mountain lion *Felis concolor californica* population trends. *Biol Conserv* 71:251–259 doi:10.1016/00063207(94)00034-N
- Srbek-Araújo, AC, Chiarello, AG (2005) Is camera-trapping an efficient method to surveying mammals in neotropical forest? *J Trop Ecol* 21:121–125 doi:10.1017/S0266467404001956
- Srbek-Araújo, AC, Chiarello, AG (2007) Armadilhas fotográficas na amostragem de mamíferos: considerações metodológicas e comparação de equipamentos. *Rev Bras Zool* 24:647–656
- Stander, PE (1998) Spoor counts as indices of large carnivores populations: the relationship between spoor frequency, sampling effort and true density. *J Appl Ecol* 35:378–385 doi:10.1046/j.13652664.1998.00313.x
- Swann, DE, Hass, CC, Dalton, DC, Wolf, SA (2004) Infra-triggered cameras for detecting wildlife: an evaluation and review. *Wildl Soc Bull* 32:357–365 doi:10.2193/00917648(2004)32[357:ICFDWA]2.0.CO;2
- Tomas WM, Miranda GHB (2003) Uso de armadilhas fotográficas em levantamentos populacionais. In: Cullen Jr L, Rudran R, Valladares-Pádua C (eds) *Métodos de estudo em biologia da conservação e manejo da vida silvestre*. Editora UFPR, pp 243–268
- Trolle, M, Noss, AJ, Lima, E, De, S, Dalponte, JC (2007) Câmera-trap studies of maned wolf density in the Cerrado and the Pantanal of Brazil. *Biol Conserv* 16:1197–1204
- Voss, RS, Emmons, LH (1996) Mammalian diversity in neotropical lowland rainforest: a preliminary assessment. *Bull Am Mus Nat Hist* 230:1–115
- Wegge, P, Pokheral, C, Jnawali, SR (2004) Effects of trapping effort and trap shyness on estimates of tiger abundance from camera trap studies. *Anim Conserv* 7:251–256 doi:10.1017/S1367943004001441
- Wemmer, C, Kunz, T, Lundie-Jekins, G, McShea, W (1996) *Mammalian Sign*. In: Wilson DE, Cole FR, Nichols JD, Rudran R, Foster MS (eds) *Measuring and monitoring biological diversity. Standard methods for mammals*. Smithsonian Institution, USA, pp 157–176
- York, EC, Moruzzi, TL, Fuller, TK, Organ, JF, Sauvajot, RM, De Graff, R (2001) Description and evaluation of a remote camera and triggering system to monitor carnivores. *Wildl Soc Bull* 29:1228–1237
- Zar, JH (1999) *Biostatistical analysis*. Prencinton Hall, New Jersey