TROPICAL ECOLOGY, ASSESSMENT AND MONITORING INITIATIVE

Camera Phototrapping Monitoring Protocol

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September 2004

Version 2.0

The TEAM Monitoring Protocols are published by:

The Tropical Ecology, Assessment and Monitoring (TEAM) Initiative
The Center for Applied Biodiversity Science (CABS)
Conservation International
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Washington, D.C. 20036, USA
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ACKNOWLEDGEMENTS

I thank Dr. Mel Sunquist, University of Florida, for his input and suggestions.

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INTRODUCTION

Biodiversity monitoring is the repeated execution of a systematic program for collecting biodiversity information in the same place over a specific period of time. Because the number of individuals of all species that use a certain area within each habitat type is generally not possible to monitor, we extrapolate estimates of overall biodiversity trends using monitoring data on certain focal species. This is the heart of the TEAM approach to biodiversity monitoring—rather than attempt to monitor the entire range of biodiversity in a particular tropical forest, TEAM researchers monitor a selective core of its components. For instance, instead of monitoring all mammal fauna, TEAM researchers target certain medium and large mammals because, among mammal species, they are most sensitive to specific threats such as landscape-scale changes, direct and indirect hunting pressure, or changes in ecological processes such as fire and climate change (Lambeck 1997). Moreover, many large mammals lend themselves to individual identification and thus function well as focal species (Lambeck 1997). For example, spotted cats of various sizes and large herbivores such as tapirs and elephants are good focal species because they are sensitive to a variety of threats and, as individuals, they can be easily identified and tracked. Threatened mammal species are also ideal focal species for monitoring, particularly those on the IUCN Red List (Lawler *et al.* 2003).

Monitoring focal species groups—such as spotted cats and some large herbivores—whose individuals are easy to identify also allows TEAM researchers to measure over time the density of species, i.e., the number of individuals per unit area. Species density measurements are only possible when (1) individuals can be identified and (2) the size of the area being sampled can be determined based on knowledge, validated through fieldwork, of the home range of the species under study (Wemmer *et al.* 1996). Yet in the case of focal species with large ranges, the individual's entire range generally cannot be monitored simultaneously. Another limitation is that individuals vary in their probability of being detected by monitors during a particular time interval. To overcome these limitations, TEAM researchers monitor a subset of a particular species' range and then infer the species' density and abundance over its entire range using mathematical software (Karanth & Nichols 2002).

A major challenge to the focal-species monitoring approach described above is that large carnivores, particularly those in tropical forests, are often elusive and not easily observed by humans. Some are nocturnal or move about the landscape using dense cover. They also typically range widely and, because of their low population densities, occur infrequently over large parts of their home range (Sunquist & Sunquist 2002). These aspects of their behavior and basic ecology make their populations inherently difficult to monitor through direct observation. Yet these difficulties are worth overcoming because large-carnivore population and habitat information provide a robust view of the general status of an area's biodiversity (Balmford *et al.* 2003).

Camera phototraps are an effective tool for overcoming the challenges of monitoring carnivore and herbivore focal species in tropical forests. While automatic cameras have been used to capture photographs of wildlife for at least 100 years (Anon. 1926, Chapman 1927, Shiras 1906, Nesbit 1926), a new generation of phototrapping equipment and well-developed capture-recapture models have vastly improved remote surveying and monitoring methods for most terrestrial and some arboreal mammals (Karanth & Nichols 2002, Jones *et al.* 1993, Joslin 1977). For instance, new technology allows both sides of individuals to be photographed simultaneously, facilitating identification of individuals of focal species. This, in turn, allows for more accurate population estimates of focal species, estimates that can then be used, as Carbone *et al.* (2001) suggest, to calculate relative abundance indices for animals that cannot be individually identified using phototraps. For instance, Karanth (1995) used phototrapping data to estimate tiger densities in four national parks in India. Similarly, Trolle and Kéry (2003) used camera phototrapping to estimate ocelot densities for part of the Pantanal in Brazil.

Camera phototrapping is a central part of the TEAM approach to biodiversity monitoring. TEAM-specific guidelines for setting up camera phototraps in a sampling area, acquiring the proper equipment, carrying out a sampling effort, and then analyzing the resulting data are described in the sections that follow.

Figure 1. This jaguar (*Panthera onca*), captured on film in Ducke Reserve, Manaus, Brazil, is at the top of the terrestrial food chain and an important indicator of healthy prey populations.

SPATIAL LAYOUT

Camera phototraps should be placed at favored spots and routes of travel, identified by at least a month of study before the sampling effort begins. Statistical models assume that all individuals in the population have a nonzero capture probability, i.e., cameras should be placed to ensure that no individuals live between cameras and thus have no probability whatsoever of being photographed. If individuals share similar capture probabilities, the resulting variances within the sample will be lower, but cameras need not be positioned to ensure identical capture probabilities for all individuals in the monitoring area. Cameras should be placed at least 1.5-2.0 km from any neighboring sample areas. Avoid placing camera phototraps in IMAs.

The home ranges of focal species are an important consideration when placing camera phototraps. Some knowledge of the home range size of each focal species is therefore necessary to effectively place phototraps. For example, the home ranges of felids are generally proportional to their body size (Sunquist & Sunquist 2002), so small felids require a finer camera trapping grid than larger felids. Standardizing camera trapping grids for a particular species can be difficult because a species' home range can vary from region to region. The home ranges of focal species are large enough, even for small cats and herbivores, to encompass several microhabitats. Consequently, camera phototrap placement should be based on species' behavior rather than microhabitat usage.

Square grids, hexagonal grids, or other familiar geometric figures will likely not provide adequate area coverage for phototrap sampling. Rather, camera locations should generally be chosen using maps and a geographic information system. Once approximate locations have been selected, camera phototraps should be placed at obvious favored spots or travel routes.

Though many medium and large mammals will be monitored in the course of a phototrapping sample effort, the focal species for TEAM monitoring are ones that can be easily identified as individuals. This allows TEAM analysts to use mark-recapture methods, which require that individuals be identified, to extrapolate biodiversity trends from camera phototrapping samples. Therefore, two camera phototraps will be mounted at each camera location and set to face each other so that both sides of an individual will be photographed when a phototrap is triggered. This enables identification of individuals.

EQUIPMENT LIST

Capital equipment refers to equipment that is purchased once and used repeatedly for more than one sampling effort. This includes camera phototraps, elastic cords, and, if necessary, chains and locks. Other non-capital equipment, such as film, batteries, and desiccants, are recurring costs because they must be replaced regularly. Specific equipment requirements include the following:

Capital equipment

- 32 camera phototrap units (2 per site, 16 sites) that (1) have passive sensors activated by heat-in-motion, (2) are robust to environmental hazards such as excessive rain and moisture, and (3) use batteries that are widely available. Units should use 35mm cameras that record the day of the month and the time with each photo taken.
- 32 elastic cords for securing each camera to a tree or rock.
- Suggested: 32 lock-and-chain sets (one per phototrap unit), which can be used to discourage theft.

Other equipment

- If phototraps are equipped with PhotoScout Game Scouting Cameras (manufactured by PTC Technologies, Inc.), 192 AA batteries will be required for each two-month sampling period, or 6 per phototrap unit (4 to operate the sensor and 2 for the camera). A total of 384 AA batteries would thus be required for the two sampling periods (wet season and dry season). Rechargeable batteries can be used if they are available. Other cameras will have different battery requirements.
- 128 rolls of ASA 400 36 exposure Kodak® print film. Film should be changed monthly in each camera, so 4 rolls per camera are required to cover both sampling periods (4 rolls x 32 cameras x 4 months = 128 rolls). Kodak film is thicker and hence less susceptible to moisture damage.
- 32 units of a suitable desiccant, to control moisture build-up in the cameras. Silica gel or high absorbency cotton (e.g., tampons) both work well.

METHOD

Each camera phototrapping sample area should be monitored twice—once during the dry season and a second time during the wet season, using the same camera placements for both sample periods. Each of these two sampling efforts should last 60 days. Steps for setting up and carrying out a sampling effort are as follows:

Setting up camera phototraps

1. **Inspect area for optimal phototrap placement.** Prior to placing camera phototraps, inspect the area selected for monitoring for at least 30 days to identify all locations that show preferential usage by medium and large mammals. Using a GPS unit, record and map the identified locations.

2. **Choose locations for phototraps.** Drawing on information gathered in Step 1, select 16 camera phototrap locations that together (1) provide optimal opportunities for recording focal species and (2) adequately cover the home ranges of focal species (see section on “Spatial Layout” above). Generally speaking, camera phototraps should be placed approximately 1.5 km apart, which will result in a sampling area of approximately 28 km^2.

3. **Place phototraps.** Camera phototraps should be placed in pairs at each of the 16 locations identified in Step 2. Place phototraps approximately 50 cm above and parallel to the ground on a tree, rock, or stake. Set pairs of phototraps to face each other, at a distance of between 4 and 5 m, so that both sides of an individual will be photographed when the trap is triggered. This facilitates identification of individuals (Karath & Nichols 2002, Trolle & Kéry 2003).

4. **Configure phototraps.** Set camera phototraps to run continuously with a 1-2 minute delay between photos. For each pair of phototraps, be careful to ensure that the cameras do not fire simultaneously as this will cause the films of both cameras to be overexposed. Make sure cameras are set to record the day and time using a 24-hour clock. Set each phototrap to the “on” position and load a fresh roll of film in each camera.

5. **Record phototrap locations.** For each pair of phototraps, record GPS location, time and day of camera phototrap activation, and habitat description. Assign each phototrap location its own number (1-16). Assign letters A and B to the cameras in each pair.

6. **Test phototraps.** Test each pair of phototraps by sitting between the camera phototraps and displaying the location number as the cameras take a picture. This dual purpose test (1) demonstrates that cameras are properly set, and (2) causes the trap location to be recorded on film so that, once the rolls of film are developed, there is no question as to their origin.

Carrying out sampling effort

7. **Monitor and adjust phototraps during sample effort.** Inspect each pair of camera phototraps every 15 days if possible. If at least one of the cameras at a phototrap location has taken more than 18 photographs, exchange the film in both of the trap’s cameras. Otherwise, change film monthly in all cameras to avoid moisture damage. Cameras that are consistently recording few pictures can be switched to 24-exposure ASA 400 film. If cameras are taking excessive photographs of the same individuals (as often happens with peccaries or large terrestrial birds), their delay can be increased to 5-10 minutes.

8. **Retrieve final rolls of film.** After 60 days of sampling, retrieve all film. Be sure to record the day and time each film roll was retrieved.

9. **Scan photographs and assign file names.** Scan all photographs in high-resolution JPEG format and store them in DiGiTEAM. Assign file names to images using the following format: XXXXXIDxNNddmmyyyyhhmm.jpg where “XXXXX” is the field station acronym, “IDx” identifies the camera (ID is the phototrap number; x is A or B, referring to each camera in the pair), NN is the species number on the Excel spreadsheet, “dd” is day, “mm” is month, “yyyy” is year, “hh” is hour, and “mm” is minute.7

DATA FORMS

Two data forms are used to gather camera phototrapping data for TEAM monitoring. The first is a summary data form for all camera trap locations. The second is a record of each photograph at each camera.

Data form #1: Phototrap information

Camera Trapping Data Sheet (Ver.2.0)
16 September, 2004 (effective March 2004)
TEAM Station:
Day-month-year:
Created by:
Creation date:
Modified by:
Modification date:

	Site 1	Site 2	…	Site 16
Position ID (number, letter, or both)	1	2	…	16
Camera ID (if camera is label)	1 A-B	2 A-B	…	16 A-B
Habitat (forest, grassland, stream)				
UTM Easting (7 digit integer)				
UTM Northing (7 digit integer)				
Latitude (deg-min-seconds)				
Longitude (deg-min-seconds)				
Start date (day/month/year)				
Start time (24 hour clock hour-min)				
Stop date (day/month/year)				
Stop time (or time when film finished)				
Comments (broken, batteries died, etc.)				
Total trap hours (decimal)				
Total trap days				
Number of pics of known mammals				
Number of pics of known birds				
Number of pics of known other				
Total number of known pictures				
Number of unknown pics (integer)				
Total number of pictures				
Trap Index: mammals/day				
Trap Index: birds/day				

Data form #2: Camera record of photographs

TEAM Station:
Day-month-year:
Data Sheet ID:

For each of 16 sites:

Site 1

	Genus	Species	Day	Time	Number of individuals	Photograph 1-A	Photograph 1-B
Species 1							
Species 2							
…							
Species 40							

DATA ENTRY

All data including scanned images of photographs will be entered into DiGiTEAM.

DATA CHECKING

Care should be taken to record all data carefully. The genus, species, date, and time of each photograph must be verifiable if the data are to be analyzed properly.

DATA ANALYSIS

As mentioned above, camera phototrapping data can be used to calculate the relative abundance of species in a particular area. An example from TEAM's Caxiuana National Forest monitoring station in Brazil illustrates how this is accomplished. Drawing on a year's worth of camera trapping data obtained at the Caxiuana station, TEAM researchers were able to estimate the relative abundance of several medium and large terrestrial mammals and terrestrial birds in the area. First, we filtered the photo data based on the assumption that multiple photographs of a male or female species (or group in the case of peccarys and birds) taken at a single camera location during any 24-hour period (beginning at midnight) represented a single individual or group, unless we could determine otherwise. That is, if a deer of unknown sex was photographed at a single site three times during a 24-hour period then the three photographs were counted as a single photograph of the same deer (Table 1). Second, we divided the total number of filtered photographs for each species by the total number of photographs taken during the sample period to determine a preliminary measure of relative species abundance (Table 2). Next, we refined our estimates of relative abundance based on photographs of species we could identify by individual. Specifically, we were able to individually identify all photographed felids from their spot patterns (Karanth & Nichols 1998, Trolle & Kéry 2002) and were thus able to determine that one jaguar, one puma, and one ocelot were present in our study area. Our initial relative abundance estimates were slightly higher for these three species, so these new, lower felid numbers caused our estimates for the other species to increase (Table 3).

We also calculated the most conservative estimate possible of relative abundance by defining the camera trapping occasion to be the length of the study, which meant that we counted all photographs of a single species at each camera trap site only once per site for the entire length of the study. For example, even if paca were photographed multiple times at eight different sites during the study, each of the eight sites would be recorded to have photographed only a single paca throughout the study. No camera trap could be counted as having recorded more than one occurrence of a species unless individuality or sex could be determined (Table 4). Finally, we recorded activity patterns for those species photographed at least 10 times (Table 5).

Table 1. Filtered photograph data for one-year sampling period at Caxiuana National Forest. During one year of camera trapping at 12 sites in Caxiuana, 348 photographs were recorded. Assuming that repeated photographs of the same species during a 24-hour period were of the same individual (unless otherwise indicated), we determined that approximately a third of the 348 photographs were repeated occurrences of the same individuals and thus were only counted once.

Species	Number of unfiltered photographs	Number of filtered photographs
Agouti paca	23	21
Dasyprocta agouti	67	47
Dasypus sp.	30	24
Didelphis marsupialis	2	2
Eira Barbara	1	1
Leopardus pardalis	6	5
Mazama Americana	34	27
Mazama gouazoubira	50	36
Mitu tuberosa	29	11
Myrmecophaga tridactyla	1	1
Nasua nausa	22	8
Panthera onca	1	1
Priodontes maximus	4	4
Psophia vividis	22	17
Puma concolor	5	4
Tapirus terrestris	27	15
Tayassu tajacu	24	12
Total	**348**	**236**

Table 2. Initial estimates of relative species abundance in Caxiuana National Forest. We initially calculated the relative abundance of each species recorded by dividing the total number of photographs of each species by the total number of photographs taken during the sampling effort. The most abundant species was *Dasyprocta agouti* and the least abundant was the *Panthera onca*.

Species	Total pictures	Average pics/day	Relative abundance (%)
Agouti paca	21	0.0074	8.90
Dasyprocta agouti	47	0.0166	19.92
Dasypus sp.	24	0.0085	10.17
Didelphis marsupialis	2	0.0007	0.85
Eira barbara	1	0.0004	0.42
Leopardus pardalis	5	0.0018	2.12
Mazama americana	27	0.0095	11.44
Mazama gouazoubira	36	0.0127	15.25
Mitu tuberosa	11	0.0039	4.66
Myrmecophaga tridactyla	1	0.0004	0.42
Nasua nausa	8	0.0028	3.39
Panthera onca	1	0.0004	0.42
Priodontes maximus	4	0.0014	1.69
Psophia vividis	17	0.0060	7.20
Puma concolor	4	0.0014	1.69
Tapirus terrestris	15	0.0053	6.36
Tayassu tajacu	12	0.0042	5.08
Total	**236**	**0.0831**	**100**

Table 3. Adjusted relative abundance estimates based on identification of all felid individuals. For three species of felids we were able to individually identify each individual. This reduced the relative abundance of each felid species and increased the relative abundance of all other species.

Species	Total pictures	Average pics/day	Relative abundance (%)
Agouti paca	21	0.0074	9.17
Dasyprocta agouti	47	0.0166	20.52
Dasypus sp.	24	0.0085	10.48
Didelphis marsupialis	2	0.0007	0.87
Eira barbara	1	0.0004	0.44
Leopardus pardalis	**1**	0.0004	0.44
Mazama americana	27	0.0095	11.79
Mazama gouazoubira	36	0.0127	15.72
Mitu tuberosa	11	0.0039	4.80
Myrmecophaga tridactyla	1	0.0004	0.44
Nasua nausa	8	0.0028	3.49
Panthera onca	**1**	0.0004	0.44
Priodontes maximus	4	0.0014	1.75
Psophia vividis	17	0.0060	7.42
Puma concolor	**1**	0.0004	0.44
Tapirus terrestris	15	0.0053	6.55
Tayassu tajacu	12	0.0042	5.24
Total	**229**	**0.0807**	**100**

Table 4. Conservative estimate of relative abundance. The most conservative estimate of relative abundance is based on the assumption that each camera site photographed the same individual repeatedly during the sample period unless the photographs prove otherwise. In the case of the Caxiuana sample, this implied that each species could be photographed at most 12 times (the total number of trap sites). Based on this assumption, the total number of photographs is reduced considerably, but relative abundance percentages, surprisingly, were not altered significantly.

Species	Total pictures	Average pics/day	Relative abundance (%)
Agouti paca	5	0.0018	6.85
Dasyprocta agouti	9	0.0032	12.33
Dasypus sp.	7	0.0025	9.59
Didelphis marsupialis	1	0.0004	1.37
Eira barbara	1	0.0004	1.37
Leopardus pardalis	1	0.0004	1.37
Mazama americana	6	0.0021	8.22
Mazama gouazoubira	8	0.0028	10.96
Mitu tuberosa	8	0.0028	10.96
Myrmecophaga tridactyla	1	0.0004	1.37
Nasua nausa	5	0.0018	6.85
Panthera onca	1	0.0004	1.37
Priodontes maximus	4	0.0014	5.48
Psophia vividis	6	0.0021	8.22
Puma concolor	1	0.0004	1.37
Tapirus terrestris	6	0.0021	8.22
Tayassu tajacu	3	0.0011	4.11
	73	**0.0257**	**100**

Table 5. Activity patterns for species photographed at least 10 times. Activity is measured as the number of photographs per species in each two-hour period in a day, beginning at midnight. *Mitu tuberosa* and *Psophia vividis* showed similar activity patterns and so are combined as "Birds." Note that *A. paca* began nocturnal foraging at 19:16 and *D. agouti* were active until 18:49, so these species showed no activity overlap. With some exceptions, activity patterns are clear.

Time	*A. paca*	*D. agouti*	*D. sp.*	*M. sp.*	*T. terrestris*	*T. tajacu*	Birds
0-2	1		5	3	2		
2-4	6		5	6			
4-6	2		4	4	2		
6-8		12		15		2	10
8-10		9	1	5	1	2	3
10-12		2		5			3
12-14		5		6	1	2	4
14-16		5	1	4	1	2	3
16-18		7	1	2		1	5
18-20	5	7	2	5	2	2	
20-22	5		4	4	5		
22-24	2		1	2	1		

Figure 2. The giant armadillo (*Priodontes maximus*), photographed here in Brazil's Caxiuana National Forest, only appears in pictures taken at night and so is apparently nocturnal.

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APPENDIX 1: EQUIPMENT SUPPLIERS

PhotoScout Game Scouting Cameras, manufactured by PTC Technologies, Inc., are available from

Highlander Sports
104 Yeager Court
Huntsville, AL 35806 USA
Phone: 01-256-858-9658
Fax: 01-256-858-9657
Email: smoke@ptctechnologies.com
Web: http://www.HighlanderSports.com

All other equipment can be obtained locally.