Experimenting usage of camera-traps for population dynamics study of the Asian elephant *Elephas maximus* in southern India

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To evaluate the application of camera-trap technology in population dynamics studies of the Asian elephant, indigenously designed, cost-effective, infrared-triggered camera-traps were used. Usability of pictures was defined based on quality, clarity and positioning of the subject. With 99 pictures of 330 elephants, 20 sequences were obtained and 44 distinct individuals were identified. It was found that 38.6% were adult females, 4.5% adult males, 13.6% sub-adult females, 6.8% sub-adult males, 20.4% juvenile females, while juvenile males were poorly represented (2%), and 13.6% were calves. These results were surprisingly identical with those of other systematic and long-term studies.

Keywords: Camera-trap, *Elephas maximus*, population, sampling efforts, technology.

CAMERA-traps have been used for documentation of wildlife since the early 1900s[1]. Despite the availability of this technology for more than a century, only recently have there been attempts to use camera-traps systematically to study wildlife populations[2–8]. This technology has a significant scientific, conservation and management advantage for a variety of wildlife species ranging in size from elephants to the smallest mammals or birds[7,8]. It aids in appreciating their habitat, population dynamics, activity pattern, identification of ‘problem animals’ (habitual crop raiders or human property destroyers or killers, for instance).

The Asian elephant has been considered as one of the most suggestive cultural symbols of the people of Asia and it also stands for the need of safeguarding sufficient natural forest areas; however the survival of the species has been endangered due to a number of conservation issues[9]. For meaningful species and habitat-based conservation and management approaches, there is a requirement of understanding the population status of the species. Several established methods of assessing population densities are available[10–13]. The possibility of using camera-trap technique for population dynamics studies of Asian elephants has never been tested or validated for the species. For elephants, if a ‘unit’, defined as all or maximum individuals of a group, is photographed through camera-traps, it is possible to identify different individuals based on distinct features. Here we relate our experience in using camera-traps to classify elephants into different age and sex classes for population structure and dynamics studies of the species. Our approach, with a multi-disciplinary team, presents the advantage to incorporate both the technology design expertise as well as the knowledge of the species and its habitat. More importantly, this expertise is available to take care of most of the field or technology based needs at any situation, and it was not developed for any commercial advantage. The idea behind this study was to explore if any useful information could be extracted from the collection of photographs obtained randomly during field testing of the camera trap units. We looked for patterns, if any, that emerge from such pictures, and could be used for quantification. They could also help in evaluating the method and getting insight for proper planning and for devising strategies for further action.

Objectives

In this study a collection of random pictures obtained with camera-traps was used to estimate the Asian Elephant population structure (age and sex) in the area under study. The data collected and processed here qualify to be ‘opportunistic’ as the usage and placement of camera-traps were arbitrary, since the purpose was only to test the equipment in the field. Hence this particular analysis is based on no sampling, protocol or design efforts and no particular planning. It is based only on events and may be termed as a random approach. However, if any result emerges through this, it would point to the usability of the camera-trap technique in elephant age and sex classification. If no conclusion could be drawn, this study could still be used for evaluating the plan of setting the cameras, sampling design, protocol and efforts. This approach was carried out in places where density of elephants are known to be reasonably high[9].

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Material and method

Survey sites

The survey was carried out in tropical mixed deciduous forests of Bandipur National Park (BNP), Mudumalai Wildlife Sanctuary (MWLS) and Biligirirangaswamy Temple Wildlife Sanctuary (BRT WLS) under Chamrajnagar Division, southern India (Figure 1). BNP lies between 11°37′–11°54′N and 76°07′–76°52′E, has an area of 874 km^2 and lies southwest of the Nagarhole National Park, north of the MWLS and west of the Wynad Wildlife Sanctuary. The MWLS is situated in the Nilgiri district, Tamil Nadu and part of the BNP forest complex; the sanctuary lies between 11°13′–11°39′N and 76°27′–76°43′E and comprises a total area of 312 km^2. BRT WLS lies between 11°43′–12°08′N and 77°00′–77°15′E, and has an area of 510 km^2. Mixed dry deciduous forest types dominate BNP and MWLS. Most of the hills and valleys of BRT WLS are covered with moist deciduous forest type, the foothills and abutting cultivated lands bear dry deciduous and scrub forests, and sub-tropical hill forests are found on hilltops. A detailed description of the geography, vegetation type, fauna and other features of the survey sites is available elsewhere[13–20].

Status of the species

These three regions support a high density of elephants; BNP has an estimated population between 1200 and 1936 elephants (density of 1.37 to 2.2 animals/km^2), MWLS has between 517 and 1059 elephants (1.6 to 3.2 animals/km^2), while BRT WLS has between 691 and 914 elephants (1.4 to 1.8/animals/km^2)[9]. These regions are also known for their long-term and well-established studies and surveys of various aspects of the species and habitat[9,21–23].

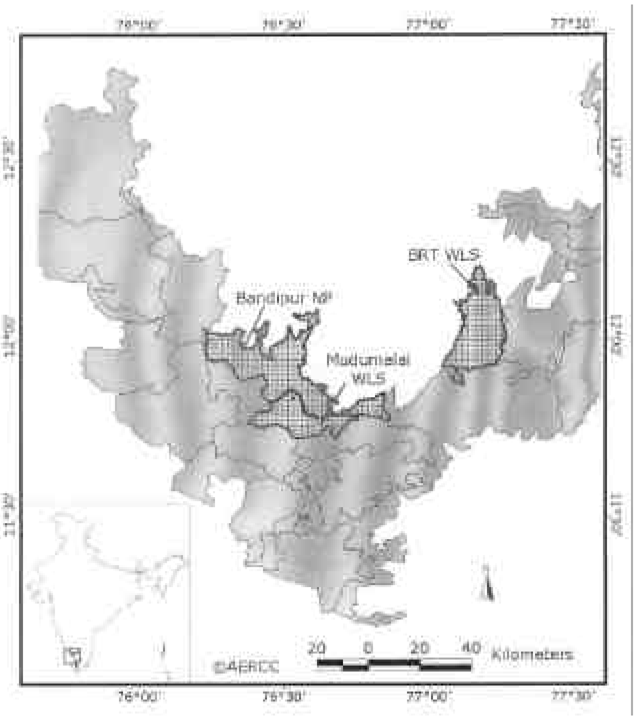

Figure 1. Map showing location of the three study areas, Bandipur National Park, Mudumalai Wildlife Sanctuary and Biligirirangaswamy Temple Wildlife Sanctuary (checkered).

Equipment

The camera-traps used in this study were developed at the Centre for Electronics Design and Technology (CEDT), Indian Institute of Science (IISc), Bangalore. They consist of a motion detection circuit, a controller and a camera, all three packaged in a weather and vermin-proof enclosure (Figure 2 *a* and *b*). The motion detection circuit uses a Fresnel lens, a passive pyrolytic infrared detector and the associated amplifier and filter. The detector reacts to any moving body having a temperature different from ambient. The controller receives an input from the detec-

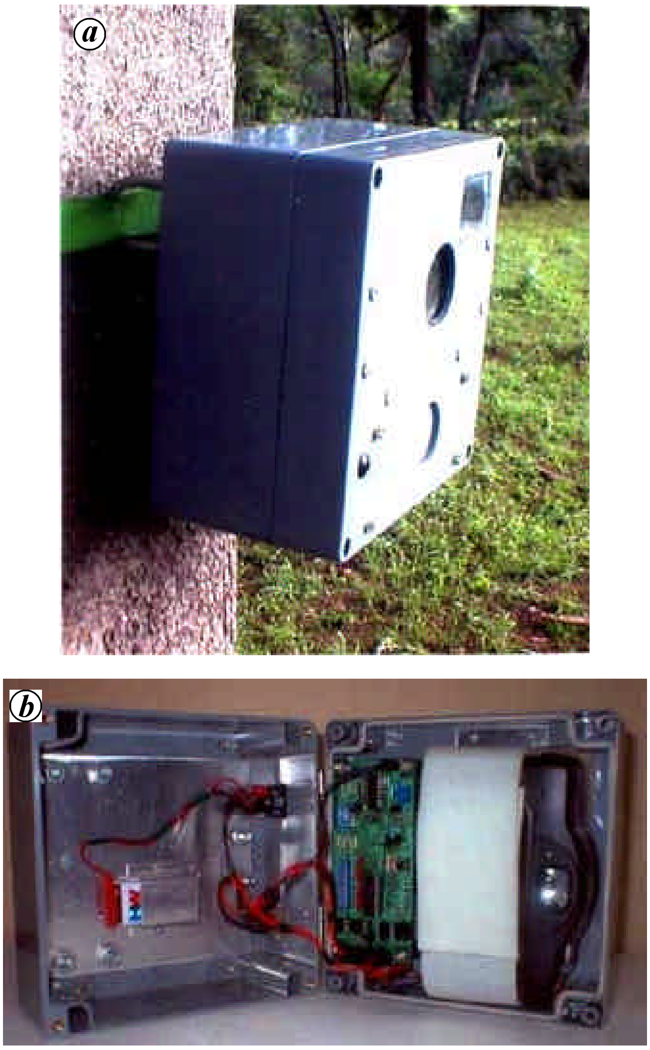

Figure 2. ***a***, Trap developed and used for the study. ***b***, Inside view of the camera trap.

tor and then triggers the camera according to settings made by the user. Those settings could be the number of pictures to take for each event, the minimum time between pictures, whether pictures should be taken only at night or only during daytime or at any time, etc. The sensitivity of the detector can be adjusted electronically. In normal conditions, the system detects the motion of a human being up to more than 15 m. It has also shown to react to a medium-sized bird (myna) at more than 6 m. It is therefore suited for a large range of animals, from very small birds to large animals like elephants. The placement of the system and the time at which it is used determine to a large extent the type of animals that are captured.

The cameras used have fixed focal length, usually with relatively wide angle (35 mm). The placement of the camera decides the field width. We would recommend 5 to 6 m to capture single elephants and up to about 15 or even 20 m to get a comprehensive view of a herd of elephants (ten or more animals). The picture quality is good enough to identify/classify animals at 20 m during day. For night picture, the flash-reach is a limiting factor. The in-built flash has a reach of no more than 5 to 6 m, which is only adequate for usage on a trail. We can extend the flash-reach up to about 10 to 15 m using a slave flash. For this study we used pictures from systems with a regular 35 mm roll (argentic) cameras, as well as with digital cameras.

The design of the CEDT camera-trap system offers a great amount of flexibility to the users. The present design allows to quickly tailor the system to specific user requirements by simply reprogramming the controller according to a list of desired specifications. In this case, working closely with the users, the technical team ensured that the system is best suited for their specific requirements.

The uniqueness of these systems lies in their features and the low production cost. The present design has the following features: Adjustable detector sensitivity; programmable camera refresh intervals; selectable mode: single, double picture, mini-video; selectable day, night or day-and-night operation; selectable minimum delay between pictures; battery test (battery low indicator); light emitting diode indicator on front panel for test mode; external input/output for advanced applications; splash proof/vermin proof enclosure; simple tree mounting using self-locking strap; simple securing with chain and padlock; simple operation with only two switches (ON–OFF and TEST–TRIGGER); critically, the camera records the time of picture (and usage of flash for digital camera) and the camera-trap costs around Rs 9000 (approx. US $200) to build with a 35 mm argentic camera and Rs 18,000 (approx. US $400) with a digital camera (the running costs of which are substantially less).

Identification of suitable location

The first concern when using camera-traps is to identify suitable locations for their placement. Elephants are known to spend a reasonable amount of time at each of their visits to a waterhole. It could be assumed that at least once in a day (frequency may increase or decrease depending on seasons) all or most of the individuals from a population would visit a waterhole. This points to waterholes as the prime location of camera-traps for our study.

Pattern of elephants visit to waterholes

From these pictures, it was observed that elephants visiting are photographed through a certain pattern. The 'picturization' of a given group of elephants in the field of view of the camera-trap, from the first one entering the field to the last one exiting it, is referred to as a 'sequence' (see Figure 3 as an example of a sequence). Each sequence is captured by a set of photographs adjacent in time, even if not equally spaced.

For the sequence to be usable for us, it should clearly establish the approximate size of the group (from one to many) and allow classification (sex + age) of a significant percentage of individuals in the group.

In general, such a sequence may start from the time elephants approach the waterhole and ends when they leave. The entry or exit may happen as all members of a unit come or leave together or as individuals, and also with respect to a group, which initiates or leads the entry or exit. Such sequences may provide usable information about the population structure, as explained below.

Usability of the pictures from sequences

The collection of random photographs obtained from the camera-traps consists in 99 pictures of 330 individuals (elephants) belonging to 20 sequences. These pictures and sequences were processed for usability by rating them on a scale of 0 to 10. The photographs that get a rating of 5 or above qualify to be usable pictures. Distinct groups or individuals could be identified from usable pictures of rating 5 to 10 (the picture could be of an entire group or a solitary animal). The rating of pictures was based on their quality, clarity and also position of the elephants in the frame as follows:

– Quality refers to how usable a picture is for age and sex classification of the elephants – which implies that all or most of the individuals from a group have been captured by the camera-trap on the given picture.
– Clarity communicates how good a picture is: whether the animal has been 'captured' in good light, if the flash has reached the object, if the picture is focused or not, or if it is over or under-exposed.
– Positioning refers to the occurrence of the animal within an 'optimal distance' from the camera, the head and tail of all or most of the individuals being visible (see Figure 4 *a* and *b* as example of good and bad positioning).

Figure 3. Example of 15 pictures sequence.

Figure 4. Example of good positioning (***a***) and bad positioning (***b***).

Even if a picture has good clarity and positioning, it may be unusable if the quality of the information is not adequate (see Figures 5 *a* and *b* as examples of rating seven and zero).

In addition, if there are no directly usable pictures present in a given sequence, using all the pictures of that sequence (which could be rating of 1 to 4), we can try to reconstruct the group and identify a maximum number of distinct individuals.

As mentioned earlier, the information could be related to solitary or group of elephants. The solitary animal could be identified by its age and sex, or by adjacent pictures in time showing no other animals. Elephants being social animals maintain close proximity to each other and another individual of a group cannot be missed. The sizable proportion of the individuals for a given picture could be referred as a group. Even a small group (e.g. only mother and calf) can be identified from a picture or a sequence if no part of body (leg, tail, trunk or head) of other individuals is visible in the picture or in the entire sequence. Once all or most of the individuals of the group are identified through discrete recognition, then duplicate pictures can be eliminated.

Identification of distinct individuals or groups

For proper data interpretation, it is critical to avoid duplication when classifying individuals or groups from photographs. Number of duplicates or distinct units with respect to an individual or a group of elephants can be sorted out based on a qualified identification exercise, where many factors can be taken into consideration like: the number of individuals; the number of individuals in each age class and identification marks of individuals.

Figure 5. Example of rating seven (***a***) and rating zero (***b***).

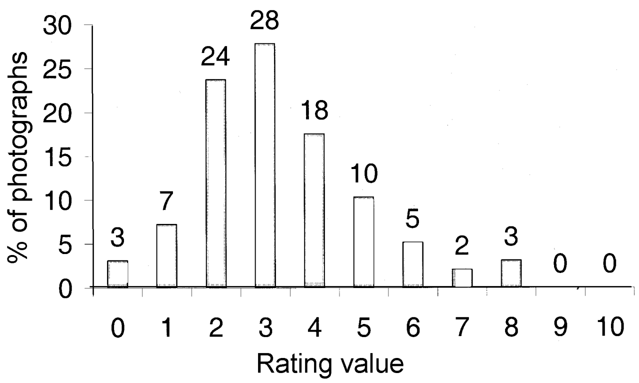

Figure 6. Frequency distribution of individual photograph ratings.

Results and discussion

Ratings of the pictures

As first excursive, an average rating of all individual photographs has been calculated and it was observed that mean rating of the picture was 3.36 ($N = 99$, SE = 0.16 and % CV 4.75). The frequency distribution of the ratings is presented in Figure 6.

It was observed that 80% of pictures taken by the camera-trap technique was unusable (ratings from 0 to 4) and only 20% usable (ratings 5 to 8). There were no pictures of ratings 9 or 10. No groups qualified for the rating of 8, and it was only solitary adult males that were qualified for that rating. If rating 8 is not considered (as it is only of individual males, but not for groups), only 17% pictures are individually usable.

The 99 pictures collected were then brought under 20 sequences. The number of pictures per sequence ranged from 1 to 25, with an average of 4.75 ($N = 20$, SE = 1.4 and %CV = 30). For each sequence, the proportion of usable and unusable pictures was calculated (Table 1).

Table 1. Proportion of usable and proportion of unusable photographs for each sequence

Sequence code	No. of pictures	Usable proportions	Unusable proportions
1	1	0	1
2	25	0.24	0.76
3	7	0.14	0.86
4	4	0.5	0.5
5	13	0.15	0.85
6	15	0.2	0.8
7	2	0	1
8	1	0	1
9	3	0	1
10	2	0	1
11	1	0	1
12	1	1	0
13	2	1	0
14	4	1	0
15	2	0	1
16	2	0	1
17	3	0	1
18	2	0	1
19	4	0	1
20	1	1	0
Mean	4.75	0.261	0.739
SE	1.40	0.091	0.091
CV %	29.6	35.0	12.4

There is a clear indication that there are more unusable pictures in individual sequences and also in all the sequences put together. The average proportion of usable pictures for all the sequences is low (0.26) and the standard error associated with the average is high (35%). Overall, individual ratings of all the photographs in individual sequences or combination of all sequences showed an overriding role of unusable pictures. However some sequences did have usable pictures and interestingly, out of 20 sequences, nine (45%) have usable pictures (sequence nos 2–6, 12–14 and 20). From these primary usable sequences, distinct individuals were identified and classified according to their age and sex. Notably, all the usable pictures of sequences

Table 2. Classification (age and sex) based on nine primary usable sequences out of 20 (45%)

Age and sex class	AF	AM	SAF	SAM	JF	JM	Calf	Total
Number	17	2	6	3	9	1	6	44
Percentage	38.6%	4.5%	13.6%	6.8%	20.4%	2.3%	13.6%	100%

AF, Adult female; AM, Adult male; SAF, Sub-adult female; SAM, Sub-adult male; JF, Juvenile female; JM, Juvenile male.

Table 3. Classification (age and sex) based on 11 extended usable sequences out of 20 (55%)

Age and sex class	AF	AM	SAF	SAM	JF	JM	Calf	Total
Number	20	2	6	4	9	3	6	50
Percentage	40%	4%	12%	8%	18%	6%	12%	100%

come from one region (Bandipur) of the three forests surveyed.

The results presented in Table 2 show that out of 44 distinct individuals subjected for age and sex classification, 38% are adult females and 4.5% are adult males. Juvenile males are poorly represented, with only 2%. It is possible that juvenile males are not easily identifiable through camera-trap, as they may be concealed under the groups or their tusks are not visible and they may be wrongly identified as juvenile females. Also, the sample size of this survey may not be adequate to conclude anything on juvenile males.

Further, to increase the number of usable sequences, we reprocessed carefully every discarded sequence (sequences with no usable individual pictures) to see if relevant information could be still extracted from them. This time we scrutinized all pictures of each unusable sequence, looking at the possibility of re-constructing a distinct group from them. A careful scrutiny allowed us to reconstruct more groups from two sequences previously discarded (sequence nos 17 and 19), and thus identify and classify six more individuals. The result of this extended approach is reported in Table 3.

The results reported in Tables 2 and 3 do not show much difference for adult females and males, sub-adult females and males, and calves; however, it did make a difference for juvenile females and males. This indicated the need to increase the sample sizes to obtain statistically relevant data, especially for juveniles.

Comparison of results from different studies

To validate the result obtained by camera-trap survey, they were compared with results of other studies carried out in BNP[24] and MWLS[25] of southern India. Although the sample size of the camera-trap study was small and the survey itself was opportunistic, the results are surprisingly close (Table 4).

This comparison provided valuable inputs; it endorsed our doubt of juvenile males being wrongly classified as juvenile females. The percentage of juvenile females for the camera-trap study is relatively high, whereas it is low for juvenile males. If the frontal position of juvenile males is not visible or the light in the picture is not adequate to distinguish the tusks of juvenile males, they could be wrongly identified as juvenile females; this calls for careful processing of the photographs. As adult male elephants are subjected to poaching pressure[22,26,27], it is valuable to know the percentage of adult males that are captured by camera-trap survey and validate these results with other surveys, particularly those carried out in the same study area. From Table 4, we can observe that the results regarding the percentage of adult males in the study area (Bandipur) are identical. Table 4 shows both surveys at Bandipur reporting a higher percentage of adult male elephants than was recorded in the Mudumalai survey. It is true that the number of male elephants that could be encountered in Mudumalai is relatively lower than that at Bandipur[25,28] and there could be number of ecological reasons or anthropological influences associated with it.

The results and insights obtained using this technique suggest that these kind of opportunistic surveys do provide valuable information. As there was no sampling protocol followed, there was uncertainty or scepticism and discomfort in processing the data; however, the results of the survey do imply that the technique is usable for population studies of species like elephants. The results also advocate the need for accepting the concept of 'optimal sampling effort' for elephant age and sex classification studies. It is known that conservation priorities are not only determined by efficient and reliable methods but also by cost or sampling effort and rapid assessments of the given species and their habitat[29]. If the results of age and sex classification of 44 individuals through camera-traps are comparable to classification of 142 or 2756 elephants by direct observation, it suggests that manpower, resource and time involved in classification of elephants could be brought down through optimal sampling efforts. Our experiences do suggest the need for increasing or redefining the sampling effort and calculating the cost involved in terms of

Table 4. Comparison of results of different studies of classification of elephants by age and sex

Region	Source	Number of elephants classified	AF (%)	AM (%)	SAF (%)	SAM (%)	JF (%)	JM (%)	Calf (%)
Bandipur	Camera-trap	44	38.6	4.5	13.6	6.8	20.4	2.3	13.6
Bandipur	Surendra Varma[24]	142	39.4	4.2	18.3	13.8	8.4	9.2	7
Mudumalai	CES[25]	2756	38.7	2.2	15.0	6.4	14.2	11.0	12.4

equipment, field trips and other expenses for the camera-trap surveys. It would also be interesting to carry out parallel surveys through camera-traps and traditional approach; this would enable a comparison of results.

Conclusion

The analysis of a collection of photographs obtained randomly while testing camera-traps has shown good potential to use such technology for the study of population structure of the Asian elephant. The results obtained in such an 'opportunistic' manner compare closely with similar classification worked out at much greater effort with traditional means. This suggests that the camera-trap technology combined with a good knowledge of the species, could be a useful tool for population study. With proper design, strategy and planning, one could obtain useful data with relatively low effort and investment. The other important advantage of the technique is that, unlike other methods, specialists would not need to be in the field for extended periods of time at all locations. The initial camera tests and subsequent analysis of the photographs obtained have brought to light a number of criteria regarding the optimum placement and operation of the camera-traps for such specific study. It clearly establishes that the technology needs to be tuned to the specific requirements of a given research activity.

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