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Validation of the results from Large Mammal Census and Long-term Study from Rajiv Gandhi National Park (Nagarahole NP)

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Note; Figures 3a, b d, e 5a, 6b, 7b, and 7c are not from the landscape, but are included to illustrate the species investigated

Contents

Preface

Conservation and management of wildlife species depend on the knowledge we have on their number. The only source for population estimates for many of the wildlife species in India is the seasonally, annually or periodically conducted census operations on them. The country has a long history of managing wildlife in different parts, but except for a few studies, no long term studies by wildlife scientists, on any species have been carried out. The knowledge gained through census operations, stays within the department offices. Efforts put to use them for management practices are not visible and the numbers estimated are not validated to test the reliability. Scientific investigations, if they are any, focus on individual or institutions' interests and in most of the cases, do not appear to match with the forest department's needs and at times they are not even available to validate the census numbers.

India has a long history of counting many wildlife species,; for a species like elephants vigorous and systematic census operations have been initiated only from 2002. The elephant census operations use block count, line transect (indirect) and water-hole count for estimating the population and the demography. If these census operations results are to be validated, nowhere in India, block count method is used in long term studies. Line transect (indirect) methods have been used in only a few places and no efforts seems to be visible using water-hole count to estimate elephant or any other species. The line transect (direct or indirect) count methods need scientific protocols. They do not allow any compromise in using straight lines to detect the animals. Without range finders or compass, sighting distance and angle cannot be calculated. If animal census is to be carried out using line transect (direct) method, these instruments can not be distributed to a large set of man power across the whole country. For indirect count, data on important variables such as defecation and decay rate are not available and not possible to obtain by an untrained census team.

But, elephant census operations use block count method, and there is no need to have range finders or compass. For block count methods there is no need to obtain results of defecation and decay rates of dung piles. However, the manpower needed has to be trained to look for elephants; if elephants are located, volunteers have to be trained to count them. While counting, if photographs of elephant groups are taken, these photographs coming from large set of volunteers could help in knowing the group size, age classes of different individuals and other related parameters.

Interestingly, block count method depends on the availability of large man-power. If there is an argument that census has to be done scientifically, it is not possible to have large set of scientists or qualified personnel for a long time. Gathering large set of researchers in a short notice, in a specific landscape is not possible. Given all these issues, if census operations cannot be conducted scientifically by scientific community, why conduct census? If there is a decision that census will not be conducted, all these uncertainties are solved. But, is it the right decision? Can we depend only on scientific community for population estimations?

Institutions may be doing good science on population estimations. They may come forward to conduct census programs scientifically. But, results may not be available for long term for all the locations and for all the species. Studies are carried out only for short term, the interests get fragmented due to availability of funds or other factors. Given this situation, is it possible to improve the quality and reliability of census operations and validate these results with the long term studies conducted by the scientific community?

To answer these questions, it's important to know about the situations where both long term or even short term studies and census operations have been carried out in same locations. There are locations in India, where both long term studies on population number and census were carried out. But, unfortunately the methods adopted were different and there is no scope for comparing or validating the results. The only available option for India comes from Nagarahole National Park. Even in this location, a long term study was conducted for one period (1992) and the census was conducted in another period (1997). However, this combination can be used as the method followed was the same, and the time period of census and long term studies are not far from each other.

There are may be some other limitations in comparing results of different methods; Census operation can be done only in one season, and it can be designed to cover entire region of the study area. Long term studies can be conducted for different seasons, but they cover only smaller regions of the study region. As census method covers the entire region and long term studies cover small regions across seasons, both the methods can complement each other.

Comparison of the results of block count methods with results of only those blocks where long term studies are carried out will not make any sense as different methods of estimation are used. Line transect methods even with efforts on a large scale, give small sample size of some of the species. Even long term studies do not provide opportunity to compare results across the seasons due to the small sample size obtained for some species. Given this constraint, comparison of results of line transect across different seasons to obtain the knowledge of seasonal animal densities and their influence of density estimate made by different methods are not possible.

The only available opportunity was explored and that resulted in this document. It takes credit in creating specific protocol in designing block count method. It used existing line transects laid for the long term studies. During the census operation, block count and line transect method were conducted in the same period. The results were compared across these methods, across the species of large mammals. The results were also validated with the long term study. Thus, this document has key findings. It does suggest that block count method could be used for species such as the Elephant. For other species, this method underestimated their number.

The results may be influenced by the area covered and number of individuals counted for those species. Relative low density of elephants and their dispersal mechanism suggest that they are found only in a few locations of the block and the experienced forest staff are able to locate them and count them all. Relatively high density, clumped distribution of other species, and being unable to locate all of them, their numbers are underestimated.

The validation of the results of census operation and a long term study, even it was done after a long period of time, has specific message to the 'Project Elephant', Government of India and its synchronized elephant operation using block count. Without any validation of results using existing opportunities, block count method has been severely criticized. With this experience and results (comparison of census operation and a long term study), it's argued that, instead of criticizing the block count and suggesting it has to be phased out from the methodology of future elephant census operations, it is important to validate the census results available across the years. As we review the results or observations of elephant sightings by block count methods for areas such as Bandipur,

Nagerhole (Karnataka) and Mudumalai (Tamil Nadu), volunteers have sighted elephants only where they are known to be seen in these regions.

With the growing interests of counting animals, and the need for validation of the results, it assumed that the document would be of some value to specific users. It may also help in identifying constraints and motivate others to initiate both periodical census operations and long studies using same methods, compare the results to assess the reliability of the estimates.

Acknowledgment
Census operation was carried out as a part of annual mammal census operation, and the Asian Elephant Research Conservation Centre, Bangalore, provided the technical support for the program. Forest department staff of Rajiv Gandhi National Park has shown considerable interest in attending and participating in the training program and the census operation.

Our former colleague Dr. Arun Venkatraman provided valuable support while designing and executing the program. The census data was reanalysed with the support provided by Archana Prasad of Centre for Ecological Sciences, and Santanu Datta of the Asian Nature Conservation Foundation (ANCF) provided GIS support. Dr. Renee M. Borges and Dr. N.V. Joshi (Centre for Ecological Sciences) have gone through the earlier version of the document and were the motivation for this publication.

Abstract
Population estimates of mammals provide considerable insights to conservation strategies, but only a few systematic population studies and annual census operations have given some direction to this effort. Even in these attempts, the methods adopted for estimating numbers vary substantially, and are usually not coupled with efforts to validate the results obtained. The closest comparison of census operation with the results of long-term mammal population study is possible only with the 1997 annual mammal census operation of Rajiv Gandhi National Park, southern India.

Here the methods adopted for both these operations were relatively similar to each other. Given this single opportunity, the census data were reanalyzed with the updated versions of data processing protocols. The results show overall that the density estimates of all the species by the census operation by block counts were an underestimation while line transect estimates were overestimates for many species. It is suggested that well-planned census operations with the help of focused training programs and involvement of experts may provide reasonably acceptable estimates.

Introduction

Estimating population density of animal species, more specifically the mammalian species that attract conservation interest (Krishnan 1972; Ramachandran et al 1986) is an important tool for their conservation and population management (Karanth and Sunquist 1992; Varman and Sukumar 1995; Sutherland 1997; Varman 1988). However estimating animal numbers in tropical forest habitat is difficult mainly because of poor visibility and relatively low density of some species resulting in inadequate sample sizes for obtaining statistically precise results (Koster and Hart 1980; Varman and Sukumar 1995). The other important aspect related to this issue is that, except in a few locations, no systematic or scientific approaches have been followed to estimate population densities. For example the Asian elephant is distributed in 25500 km^2 (Sukumar et al. 2006) of habitat in south India.

However, only in one or two places, covering about 2.5 - 4% of its distribution area, have systematic or vigorous population estimations of the species been carried out (Karanth and Sunquist 1992; Varman and Sukumar 1995). Population numbers that are available for species such as the Asian elephant or prey species of large carnivores originate only from census programs. Only for the Asian elephants, systematic census programs have been initiated since 2002 and since the inception of this practice three favourable census operations have been conducted for the species (AERCC 2002; AERCC 2006; ANCF 2007). Although these census operations are systematic or assumed to be successful, their results are neither validated nor compared with any other long-term population studies on the species.

Comparison of the results from long-term study regions are also not possible for all species as census programs focus only on one or two charismatic species, and the methods adopted for population density studies by both these approaches are substantially different. Long-term population studies (Karanth and Sunquist 1992; Varman and Sukumar 1995) follow the line transect direct method (Burnham et al 1980, Buckland et al 1993) of density estimates, while census programs depend on the combination of randomised block counts, direct or indirect line transect methods and waterhole counts (AERCC, 2002; AERCC, 2006; ANCF, 2007). The most rigorous comparison of methods originate from the census program carried in Rajiv Gandhi National Park in 1997, where both the line transect direct method and randomised block counts were followed to estimate the population densities of mammals (Varma and Venkataraman 1998). This is also a region where a rigorous application of the line transect direct method was made by Karanth and Sunquist (1992) to estimate densities of similar taxa.

Although, since 2002 there has been substantial interest in estimation of mammal population numbers, no comparable effort towards a validation of census results has been made. Due to the absence of long-term studies on population estimates and the fact that the methods adopted by long term studies and census operations are largely different; it was decided to reanalyse the results of the 1997 census with updated versions of data processing protocols. The aim was to estimate population densities for large mammals arrived at through both randomised block count and line transect methods. The goal also was to compare the results obtained through either block or line transect methods or from a long-term study, and identify the advantage and disadvantages of using either block or line transect methods or both these methods. It is believed that this validation of the census results would act as a benchmark, particularly in taking a decision on choice of methods for future census operations.

Materials and method

Study area and mammals

The Rajiv Gandhi National Park (formerly known as Nagarahole NP) is located between 11^0 50' - 12^0 15' N and 76^0 0'- 76^0 15′ E, adjoining Bandipur National Park in Karnataka and Wayanad Wildlife Sanctuary in Kerala (Figure 1). The terrain of the park is undulating with small hills and

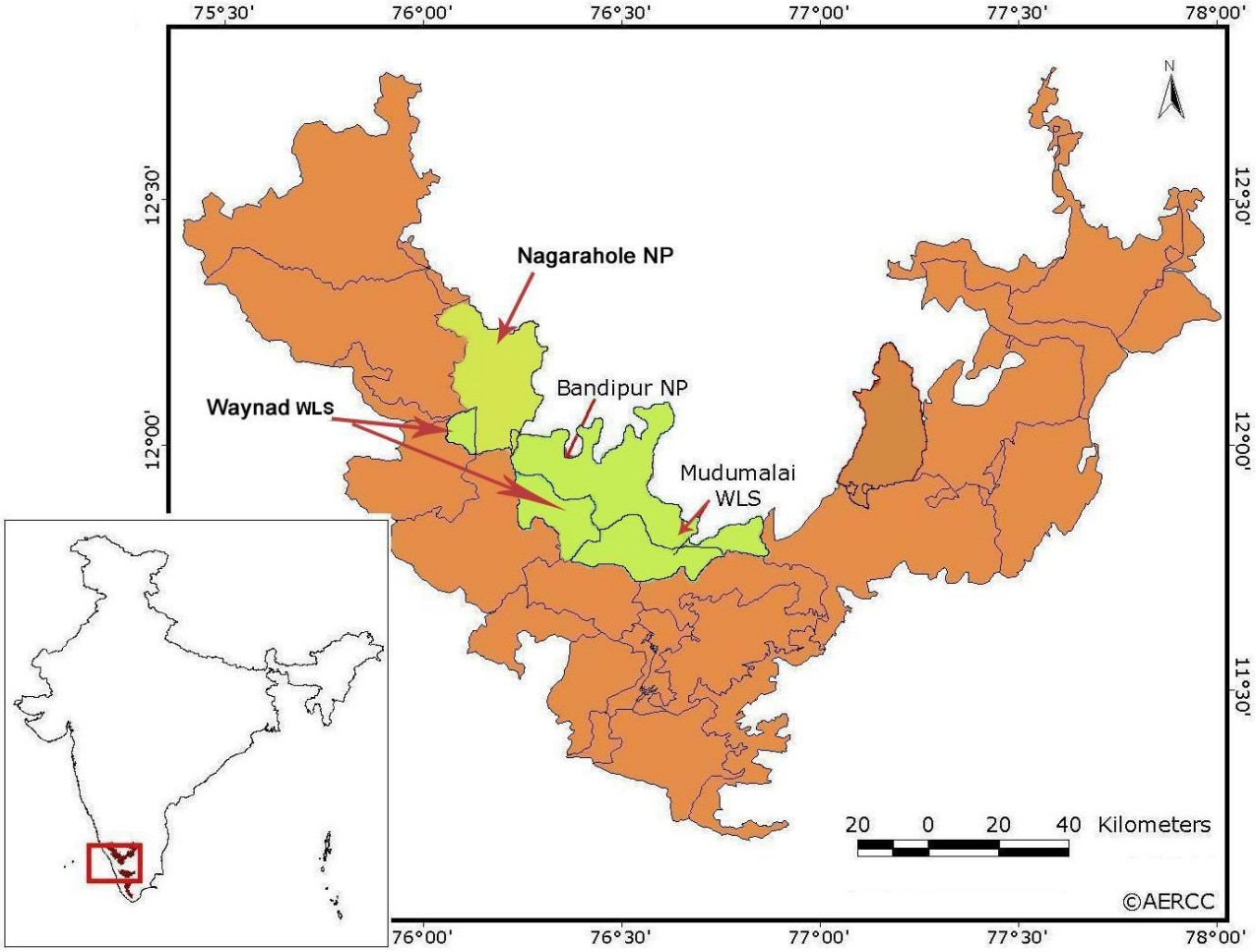


Figure 1: Showing Rajiv Gandhi National Park and ad joining forest divisions among different elephant divisions in Elephant Reserve Number-7.

the average elevation is around 800 m asl with the highest point occurring at Masal *betta* (950m asl). The major water sources for the park are the rivers Lakshmanatirtha, Sarati Hole, and Nagarhole and there are also a number of other perennial streams and seasonal streams. The annual rainfall declines from west to east, from 1500 to 900 mm, most of the rainfall occurring between June - September.

The vegetation type (Figure 2) of the park is dominated by mixed deciduous forests. The other forest types found in this area are dry deciduous, moist deciduous, semi-evergreen forests and scrub forests. Apart from these forest types, microhabitats such as swampy grassland are also found. The park has man-made forests, with teak (*Tectona grandis*) and eucalyptus (*Eucalyptus* sp) plantations and before the park was declared, an extensive teak plantation covering 9000 ha was raised. The

weeds, lantana (*Lantana camara*) and eupatorium (*Chromolaena odoratum*) are proliferating in the park.

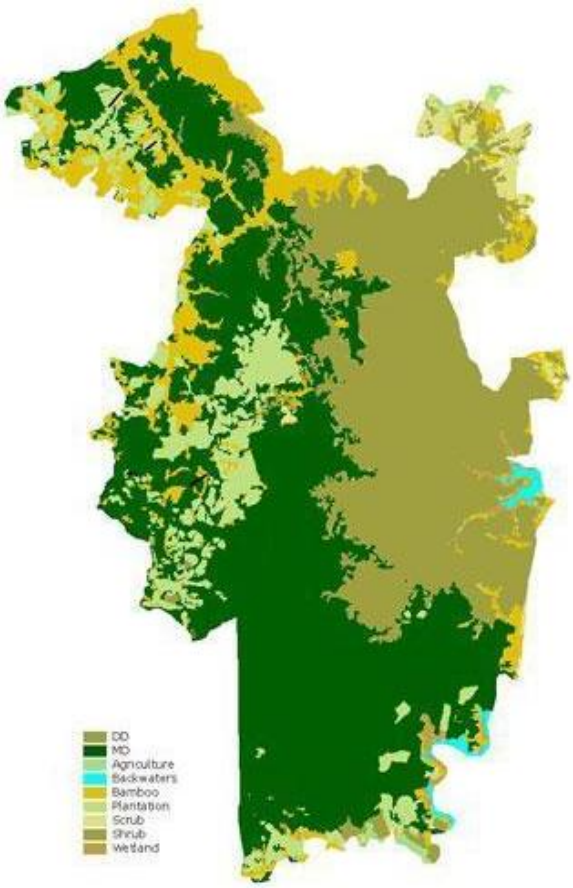


Figure 2: Vegetation types of Rajiv Gandhi National Park (Courtesy: FED, NRSA/Wildlife department, Karnataka Forest Department)

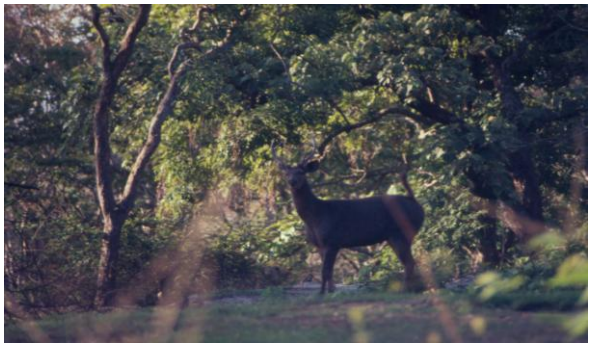
The mammals (Figures 3a, b, c, d, e and f) considered for the long-term study and census operation were spotted deer (*Axis axis*), sambar (*Cervus unicolor*), Indian muntjac (*Muntiacus muntjak*), Asian elephant (*Elephas maximus*), gaur (*Bos gaurus*), Hanuman langur (*Semnopithecus entellus*) wild pig (*Sus scrofa*) and Indian giant squirrel (*Ratufa indica*). Common and scientific names used for these mammals are based on Menon (2003).

a

b

c

d



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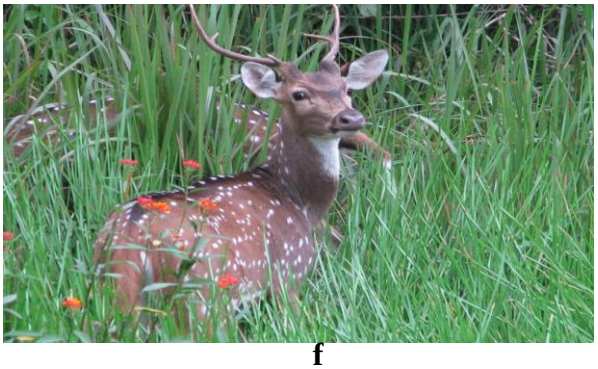

f

Figures 3a, b, c, d & f: Examples of mammalian species reported for the study region; a: India Gaur, B: Common Langur, c: Asian Elephant, d: Muntjack, e; Sambar Deer & f; Spotted Deer.

Methods

Block count

A randomised block count method (Figure 4) was used during the 1997 census. A total of 23 blocks (compartments) were chosen (from a total of 62 blocks identified for the park) with the expectation that this would represent the proportions of three different vegetation types, i.e. dry deciduous, moist deciduous and teak plantations. A total of 15 blocks for dry deciduous forest, 5 for moist deciduous forest and 4 for the teak plantation were chosen and the total sampled area covered was 294 km^2. This constituted 151 km^2 in dry deciduous forest, 55 km^2 in moist deciduous forest and 89 km^2 in teak plantation. The proportions of the sampled area falling in the three vegetation types did not reflect the actual proportion of vegetation types in the park (see Table 1). A total of 23 field parties walked in their respective blocks from morning (6.00 am) to evening (6.00 pm) covering as much area as possible and counting the animals actually sighted. For each sighting, the number of animals seen, their age and the sex class were noted.

Line transect method

Permanent transect lines of 2-4 km (see Figure 4) which were laid in different habitats by Karanth & Sunquist (1992) were walked on a regular basis during the survey. The total distance walked during this period was 252 km. Each transect was covered once in the morning (7.00 am to 9.30 am) and once in the evening (4.00 pm to 6.30 pm). For each animal sighting, the perpendicular

distance from the centre of the group to the transect line was recorded, in addition to details of age, sex and group composition.

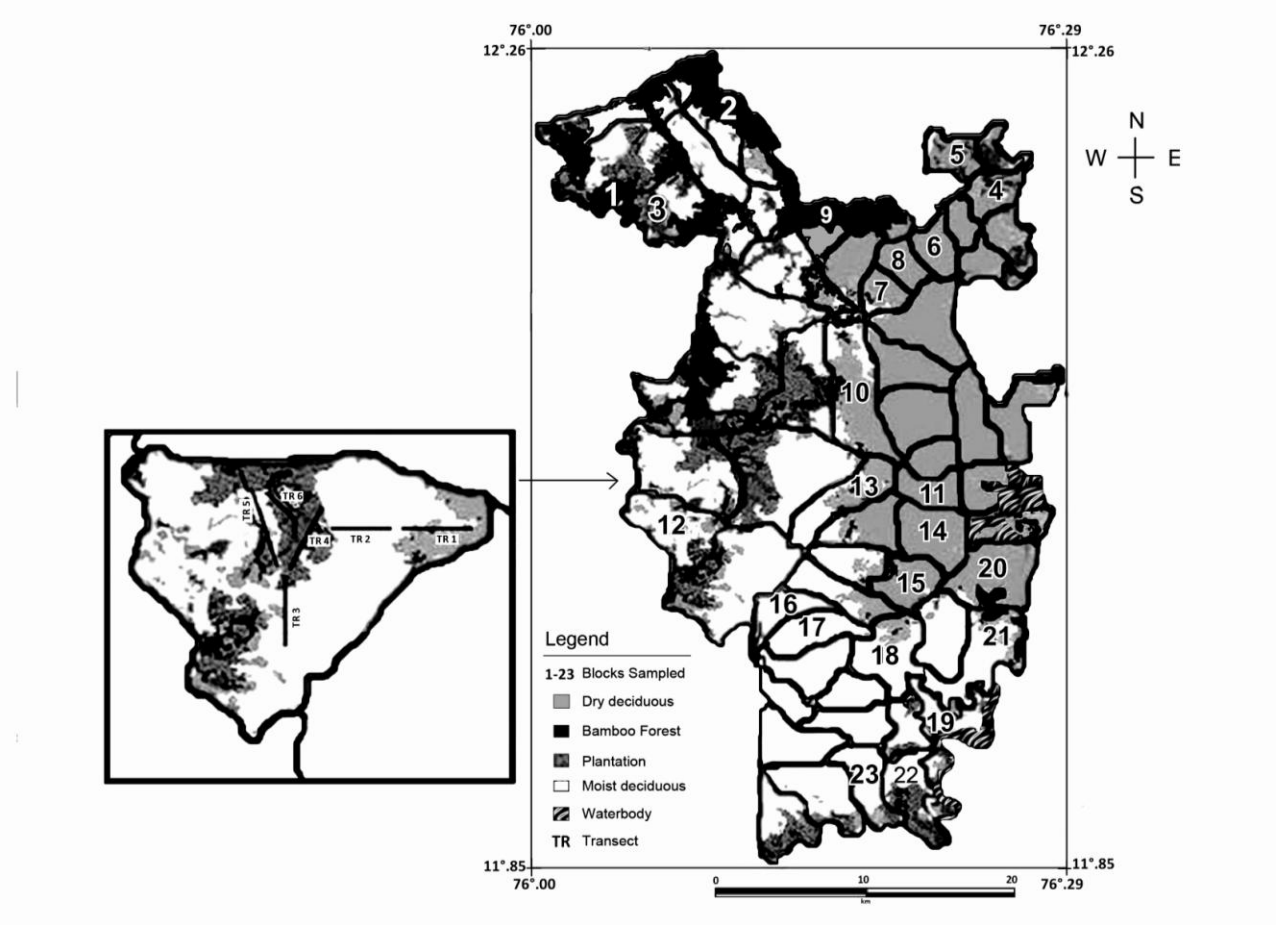

Figure 4: Rajiv Gandhi National park with vegetation types, blocks sampled and the location of transect lines used for the census operation.

Data processing

Block count

The area for each block and the vegetation type was calculated by digitising vegetation and forest compartment (blocks) maps (Fig 1). The block map was superimposed on the vegetation map. The dominant vegetation type in each block was noted and the area falling under that vegetation type was added to the total area of that vegetation type. Initially the areas of the blocks were calculated using GIS software IDRISI for windows (version 1) and later it was updated through ERDAS 8.4 (LEICA Geosystems).

Densities of mammals were calculated by dividing the number of animals sighted in a given vegetation type within the sampled area by the area of the vegetation type within the sampled area. Since the proportion of area covered by the three vegetation types in the sampled area was not similar to the actual proportions existing in the park, densities were calculated separately for each vegetation type. The extrapolated density for a given species occurring in each vegetation type was

calculated by multiplying the sampled area density within each vegetation type by the total area occupied by that vegetation type in the park. This gave the abundance of each species sighted during the census for each species for each habitat type.

As the sample size obtained for each species was very low for each vegetation type, no attempts were made to calculate the 95% confidence interval for the numbers estimated for each habitat. However sightings for all the habitats were pooled together and the lower and upper limits of 95% confidence intervals were calculated for total number of individuals estimated for each species for the entire park. This was achieved through the following measures: variance for the number of individuals counted for each species for each block and area of each block was calculated using the following formula (Choudhury 1991).

The total number of individuals of each species was divided by the value of total area of the blocks sampled to obtain the population density of each species. The population density was multiplied by the total area of the park to arrive at the total number of individuals for each species. The variance and standard error (SE) associated with the total number of individuals for each species was calculated to arrive at 95 % confidence intervals of the total number estimated for each species (Choudhury 1991).

Line transect method

For the basic analysis, animal sightings were categorised into 10m distance class intervals (from 0 to 100 m). The density of groups was arrived at using the program DISTANCE 5.0. To estimate animal density, the density of groups was multiplied by the mean group size. The standard error (SE) of the mean estimate was arrived at following Goodman (1960), and 1.96 SE was taken as the 95% confidence interval (see Varman and Sukumar, 1995 for more details).

Results

Block count

The proportion of area representing the three vegetation types, number of sightings, density and total number of animals for each species are tabulated in Table 1. The density of spotted deer was highest in all three vegetation types, followed by elephants. In the three habitats put together a total of 705 elephants were estimated and the number of animals estimated for species such as spotted deer, Hanuman langur, gaur, sambar, muntjac, and Indian giant squirrel was only 1162, 351, 169, 96, 59 and 41 respectively (Table 1). The density estimated for most of the species through this approach was very low; however the pattern gave a clear picture of their habitat usage pattern. Spotted deer densities were much higher followed by elephants compared to other species in all three habitats. After spotted deer and elephants, gaur densities were greater in the teak plantation, followed by dry and moist deciduous forests. Sambar utilised both teak plantation and moist deciduous forest equally and the results for other species are presented in Table 1.

The results of population density and numbers for the park, estimated through block count based on pooled data of all the three habitats are presented in the table 2. Even without any comparison, the number estimated by block count methods for different species of mammals were low, and for species such as spotted deer, sambar, gaur and muntjac the density estimate by this method were substantially lower than expected.

Line transect method

The results of the line transect survey carried out during the census operation suggest that the number of sightings of spotted deer was greatest followed by langur, Indian giant squirrel and elephant. However the density estimated for spotted deer was the greatest followed by langur and gaur. The number of sighting for both sambar and gaur was relatively low, but the density of gaur was greater than Indian giant squirrel. Sample size, mean group size, group density and individual density are given for the eight species in Table 3. The overall pattern of the results of habitat usage by the line transect method was slightly different from that of the block count as density estimated for spotted deer by line transect method was highest followed by hanuman langur.

The comparison of the results of the block count versus line transect methods (Table 4) of census operation provide very interesting insights. The density estimates of all the species by block count were an underestimation and line transect estimates appeared to be on higher side for all the species (Table 3). The results of the differences across these methods were statistically significant (for all species $p < 0.001$, see table 4 for z and p values).

To compare the density results obtained from a long-term study of mammals (Karanth and Sunquist 1992), the distance covered, sample size, mean group size, group density and individual densities of mammals estimated by the long-term investigation are tabulated in Table 5. If the mean densities estimated by the line transect methods of census operation and the long-term study (Karanth and Sunquist 1992) are subjected to a statistical test for their significance, then the results will be as follows. Mean densities of chital, sambar, gaur and muntjac were not statistically significant (see table 6 for z and p values). There were clear differences for mean density estimates of elephant ($z = 1.98$, $p > 0.05$) and langur ($z = 3.1$, $p < 0.001$).

The comparison of the results of the block count and long-term study by the line transect method show that for elephants, the differences of densities' estimates across these two methods were not statistically significant ($z = 1.73$, $p > 0.05$), but for all other species the differences were highly significant ($p < 0.001$, see table 6 for z and p values).

Discussion

As seen from the results, for species such as spotted deer (Figure 5) sambar, gaur, and muntjac, the block count method underestimates their number considerably. Without any information on the actual area of habitat used by different species of mammals, the density estimates cannot be extrapolated to the entire park. If this is the situation, the total number projected by block count would be even lower, and clearly this is an underestimate for most species.

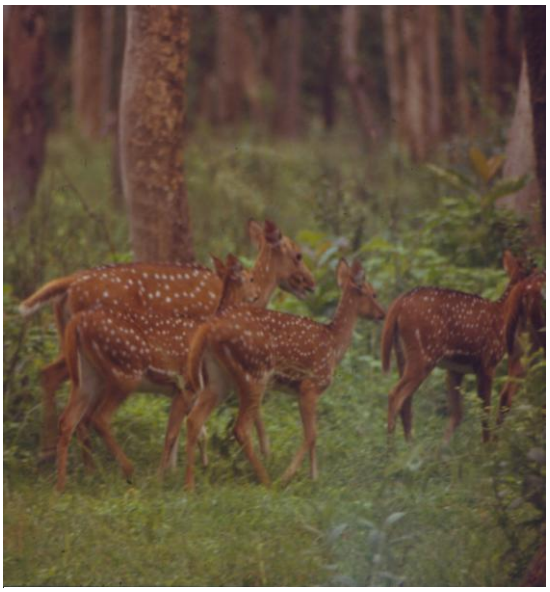

Figure 5: Spotted deer, one of the examples the species could be under estimated by the block count.

For species such as sambar, spotted deer, gaur and muntjac both long-term or short-term annual census - based line transects could be an appropriate method for

estimating their number. However, the estimated percentage of coefficient of variance (% CV) for most of the species during the census operation was high, the values were above 20% and ranged up to 35%. The values may be influenced by the sample sizes obtained for some of these species and more efforts are needed to increase these sample sizes. Increase in the sample sizes may decrease the % CV to an acceptable level (say ≤ 15%) and this can be evident from the results of the line transects based on long-term population monitoring (see table 3 and 5 for sample size and % CV values).

For elephants (Figure 6a), the short-term or census-based line transect method may not be an appropriate method. This could be due to their seasonal movement and this constraint may be to some extent applicable for gaur (Figure 6b) also. For elephants, using census operation results (of line transect method), when the density was extrapolated to the entire area, the total number for the park was about 7664 and the density estimated by the census operation for elephants was on the higher side. The total elephant population estimated for 24 forest divisions in southern India is only about 9,950 elephants (Sukumar, et al, 2006). Hence, the density estimated for the sample area should not be extrapolated to the entire area. One of the reasons for the higher density estimate could be due to the number of sightings during the particular period of the census being very high. Karanth and Sunquist (1992) encountered 46 groups of elephants in a 462 km transect survey, whereas in the census operation, the number of groups sighted for the 250 km transect was 57. If the census operation was conducted in higher density areas or seasons, the density of elephants estimated for the survey would not be the true representation for the entire region or seasons.

a

b

Figure 6a&b: Gaur (a) elephants their seasonal movement may influence the number estimated.

The other reason for a higher density estimate by census than by the line transect method could be due to the influence of mean group size. The mean group size estimated by Karanth and Sunquist (1992) for the elephant was 3.6, and the census estimate was 6.5. However, the group density estimate by Karanth and Sunquist (1992) was lower than that of the census operation. The higher group density and mean group size would have contributed to the higher density of elephants estimated by the census operation. Information connected to the deviation or error associated with mean group size was not available for the Karanth and Sunquist (1992) study and it was not possible to look at the statistical significance across the mean group sizes of these two approaches. Karanth and Sunquist (1992) estimated a density of 3.3 (95 % CI: 1.9 - 4.7) and felt that the density

may have been an overestimate and the actual density may be close to the lower confidence limit. This impression may match with the overall density estimate of the block count method of census operation.

Based on this experience, it can be concluded that for species that are very alert, or shy in nature, active more during early morning or late evenings, small in size or found in low density, the block count method is not an appropriate method. For elephants, block count method could be an appropriate method. If a population estimate for elephants is to be made, it should be done through long-term line transect method while the block count method may provide reasonable estimates for census operation. Depending on the season of the operation, short-term transect method may over or underestimate the number of the species.

The major drawback of the census operation is that during the operation, particularly for the line transect method, the perpendicular distance measurements were arrived at based on the visual estimations, as no range finder or other instruments were used. Distance measurements appeared to be more sensitive to error for elephant (Figure 7a) and arboreal species like Hanuman langur (Figure 7b). Fixing the geometrical centre of the group for distance measurements (Figures 7c) may be difficult for these two species and the absence of range finders may further complicate this issue. The services of untrained personnel and the absence of these instruments could have led to the underestimation of the sampled area and the overestimation of the animal numbers.

a b c

Figure 7a, b & c: Common Langur (a) and Elephant (b) may be sensitive to distance measurement (c).

It should be noted that long-term population studies cover only less than 1% of the total population size or geographical distribution area of most of the species and these investigations are restricted only to certain periods of time. Except for one investigation of long-term population monitoring of mammals in Mudumalai (CES 1991 to 2007), no study has been carried out in more than three years. Therefore, the regular census programs may have some scope for understanding fluctuations in population numbers of most of the species. If census results are processed properly, they also have the advantage of providing details of the habitat utilisation patterns for most of the species.

The options available to the wildlife managers are to critically review the outcome of the earlier census operations and based on the findings improve the quality of future census programs. If these reviews disqualify census operations altogether, resource that have been earmarked for census operation only should be invested into long-term investigations as resource used for short-term census program can be meaningfully used for the long-term studies. With the given man power and

resource limitation, the census operation has shown results reasonably comparable with those of long-term study carried out in a region where the biomass of ungulate is very high (Karanth and Sunquist 1992). This may indicate two basic facts: well-planned census operations with trained personnel and the knowledge gained from the experts in the field may improve the quality of the results and provide reasonably acceptable numbers. More specifically, the outcome of the exercise (some of the results matching with long-term investigation) may be due to a chance factor and more rigorous evaluations have to be carried out for meaningful conclusions. The findings also suggest that future census operations should consider carrying out the exercise in regions where long-term population investigations are on and where the method adopted for both these approaches are compatible.

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Table 1: Number of sightings, density and abundance of large mammals through block count method for different vegetation types in Rajiv Gandhi National Park

Forest type	Sampled area	Total area	S.no	Species	Number of sightings	Number of animals	Density/km^2 for sampled area	Total number of animals for the total area
DDF	151	452	1	Muntjac	11	15	0.1	42
			2	Elephant	28	180	1.2	508
			3	Gaur	5	46	0.31	130
			4	IGS	8	8	0.05	22
			5	Langur	13	106	0.7	299
			6	Spotted deer	27	325	2.16	918
			7	Sambar	5	17	0.11	48
MDF	55	96	1	Muntjac	8	9	0.16	15
			2	Elephant	13	84	1.53	146
			3	Gaur	2	9	0.16	15
			4	IGS	6	8	0.15	14
			5	Langur	4	30	0.55	52
			6	Spotted deer	12	92	1.67	160
			7	Sambar	10	23	0.42	40
TP	89	128	1	Muntjac	2	2	0.02	2
			2	Elephant	6	36	0.4	51
			3	Gaur	5	17	0.19	24
			4	IGS	4	4	0.04	5
			5	Langur	0	0	0	0
			6	Spotted deer	13	59	0.66	84
	295	676	7	Sambar	4	6	0.07	8

IGS: Indian giant squirrel DDF: Dry Deciduous Forest, MDF: Moist Deciduous Forest, TP: Teak Plantation.

Table 2: The abundance of mammals estimated through block count method

S.no	Species	Density/km^2	Estimated number of animals for the park	LCL	UCL
1	Muntjac	0.1	70	59	81
2	Elephant	1.19	807	681	932
3	Gaur	0.35	239	202	277
4	Indian giant squirrel	0.06	40	34	47
5	Hanuman langur	0.54	366	309	423
6	Spotted deer	1.89	1281	1082	1480
7	Sambar	0.18	124	104	143

Table 3: Sample size, mean group size, group density and individual density estimated for different species of mammals through line transect method

S.No	Species	Sample Size	Mean Group Size	SE	Group Density/km^2	SE	Individual Density/km^2	SE	95% CI		
									LCL	UCL	% CV
1	Muntjac	38	1.19	0.12	3.95	1.05	4.7	1.34	2.08	7.32	28.43
2	Elephant	56	6.54	0.87	1.82	0.38	11.92	2.95	6.14	17.7	24.73
3	Gaur	24	7.46	1.56	1.51	0.42	11.28	3.98	3.48	19.08	35.3
4	IGS	53	1.28	0.07	3.91	0.70	5.01	0.94	3.18	6.84	18.67
5	Langur	66	7.08	0.67	2.49	0.43	17.64	3.47	10.84	24.43	19.66
6	Spotted deer	106	8.58	1.15	6.39	0.81	54.86	10.16	34.95	74.77	18.52
7	Sambar	29	2.17	0.21	1.64	0.41	3.55	0.95	1.69	5.42	26.74
8	Wild pig	22	2.82	0.57	1.47	0.3	4.15	1.2	1.79	6.51	29.02

IGS: Indian giant squirrel, Density is expressed in km^2, SE = Standard Error, LCL: Lower Confidence Interval, UCL: Upper Confidence Interval, %CV: Coefficient of Variation.

Table 4: Density and total number estimated for block and line transect method during the census operation.

		Line transect		Block count	
S.no	Species	Mean Density/km^2	Total number	Mean Density/km^2	Total number
1	Muntjac	4.7	3050	0.1	70
2	Elephant	11.92	7736	1.19	807
3	Gaur	11.28	7321	0.35	239
4	Langur	17.64	11448	0.54	366
5	Spotted deer	54.86	35604	1.89	1281
6	Sambar	3.55	2304	0.18	124

Table 5 Sample size, mean group size, group density and individual density estimated for Rajiv Gandhi National Park by Karanth & Sunquist 1992

S.no	Species	Sample size	Mean group size	Group density	Individual density	95% CI		CV %
						LCL	UCL	
1	Muntjac	92	1.15	3.64	4.2	2.8	5.6	17
2	Elephant	56	3.59	0.92	3.3	1.9	4.7	22
3	Gaur	67	6.99	1.37	9.6	5.9	13.2	20
4	Langur	240	5.73	4.16	28.8	16.3	31.4	16
5	Spotted deer	376	6.27	8.08	50.6	38.5	62.7	12
6	Sambar	94	1.7	3.23	5.5	3.7	7.4	17

Density is expressed in km^2, LCL: Lower Confidence Interval, UCL: Upper Confidence Interval, %CV: Coefficient of Variation

Table 6: Comparisons of the results of different methods of population estimation of large mammals by census and a long term study at Rajiv Gandhi National Park

	Block count	Line transect			Line transect	Long term study			Block count	Long term study		
Species	**Mean density/km^2 (SE)**	**Mean density/km^2 (SE)**	**Z Value**	**P value**	**Mean density/km^2 (SE)**	**Mean density/km^2 (SE)**	**Z Value**	**P value**	**Mean density/km^2 (SE)**	**Mean density/km^2 (SE)**	**Z Value**	**P value**
Muntjac	0.1 (0.01)	4.7 (1.34)	4.0	<0.001	4.7 (1.34)	4.2 (1.4)	0.2	> 0.05	0.1 (0.01)	4.2 (1.4)	3.5	<0.001
Elephant	1.19 (0.09)	11.92 (2.95)	6.2	<0.001	11.92 (2.95)	3.3 (1.4)	2.0	<0.001	1.19 (0.09)	3.3 (1.4)	1.7	> 0.05
Gaur	0.35 (0.03)	11.28 (3.98)	5.4	<0.001	11.28 (3.98)	9.6 (3.6)	0.2	> 0.05	0.35 (0.03)	9.6 (3.6)	4.8	<0.001
Langur	0.54 (0.04)	17.64 (3.47)	9.2	<0.001	17.64 (3.47)	28.8 (9.1)	3.1	<0.001	0.54 (0.04)	28.8 (9.1)	9.1	<0.001
Spotted deer	1.89 (0.15)	54.86 (10.16)	16.5	<0.001	54.86 (10.16)	50.6 (12.1)	0.2	> 0.05	1.89 (0.15)	50.6 (12.1)	13.9	<0.001
Sambar	0.18 (0.01)	3.55 (0.95)	3.4	<0.001	3.55 (0.95)	5.5 (1.9)	1.2	> 0.05	0.18 (0.01)	5.5 (1.9)	3.8	<0.001

Population estimates of mammals notably help in developing conservation plans for them. However, India has only a few long term studies and annual census operations to give some knowledge of large mammals population numbers. This document based on validation and comparison of large mammal census and a long term study provide some interesting insights on using block count and line transect methods. The results also highlight that well planned census operations with the help of focused training programmes and involvement of experts on the subject may advance the value of estimates.