KARNATAKA ELEPHANT CENSUS 2010

Technical Report to

The Karnataka Forest Department

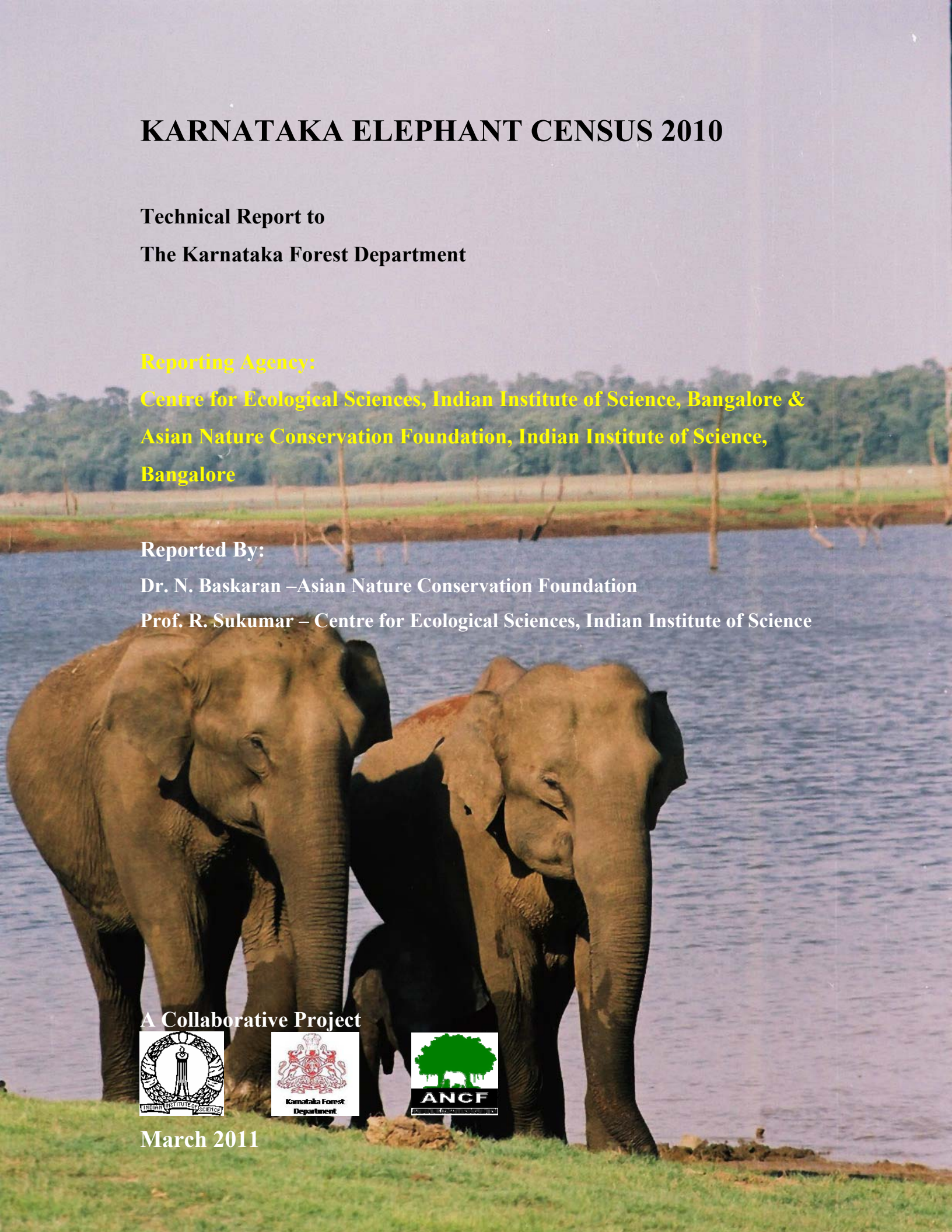
Reporting Agency:

Centre for Ecological Sciences, Indian Institute of Science, Bangalore & Asian Nature Conservation Foundation, Indian Institute of Science, Bangalore

Reported By:

Dr. N. Baskaran –Asian Nature Conservation Foundation

Prof. R. Sukumar – Centre for Ecological Sciences, Indian Institute of Science



A Collaborative Project

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ACKNOWLEDGEMENTS

This report was prepared at the request of the Karnataka Forest Department to produce comprehensive documentation for the state on the Synchronized Elephant Census 2010. We thank Shri B. K. Singh, IFS, Chief Wildlife Warden Karnataka and Shri. Ajay Mishra IFS, Chief Conservator of Forest, Project Elephant, Karnataka Forest Department, for offering our Centre the opportunity to compile the 2010 elephant census data.

We would like to thank Shri. Ajay Mishra IFS, Chief Conservator of Forest, Project Elephant, for providing the technical details needed for the report compilation, and consistent interest on the report compiled. The task of report preparation was made easier through timely supply of additional details to Dr. N. Baskaran by the Deputy Conservators of Forests from elephant-bearing forest divisions of Karnataka, and Mr. Albert of the CCF Project Elephant Office, Mysore and we thank every one of them.

We also thank Ms Meghana S. Kulkarni, Ms Mane Mira Baban and Mr. Guruprasad, Project Assistants, Centre for Ecological Sciences, Indian Institute of Science, for their support in data entry and formatting, Mr. M. Saravanan, ANCF, for assisting in data analyses and Dr. C. Arivazhagan for providing the cover photo.

SUMMARY

Background: The Karnataka Forest Department, in coordination with three other states in southern India (Kerala, Tamil Nadu and Andhra Pradesh), carried out the 2010 Synchronized Elephant Census for a period of three days from 15th to 17th May 2010.

Objectives: The objectives of this exercise were to: (i) estimate the population size of elephant numbers by direct (sample block) and indirect (line transect dung count) methods, and (ii) assess population structure (age-sex composition and sex ratio) using sample block and waterhole count methods in all the forest divisions that fall under the Project Elephant Reserve in the state.

Area covered: Karnataka state has presently one notified Elephant Reserve termed as Mysore Elephant Reserve (MER) that comprises 15 Forest Divisions from Bhadra on the northern-western side to Bandipur at the southern side along the Western Ghats, and from Chamarajnagar to Bannerghatta along the Eastern Ghats. There are four elephant bearing forest divisions on the southern side of Bhadra (Koppa, Kudremuku, Chikamagalur and Mangalore) along the Western Ghats that are not part of the MER. However, as these forest divisions are part of the single population in the state (whereby 2010 synchronized census was actually proposed), the present census exercise also covered these four divisions to have a comprehensive estimate for the given population in the state.

Methods: A workshop was conducted on April 27, 2010 at Bandipur Tiger Reserve by the Karnataka Forest Department to plan for the field exercise and discuss the field techniques to be used for the population estimation. The forest managers (Conservator, Deputy Conservator, and Assistant Conservator of Forests) of the 19 elephant-bearing forest divisions participated in the workshop. Technical experts, Prof. R. Sukumar, Indian Institute of Science, Bangalore and Mr. Ajay A. Desai, Project Elephant Steering Committee Member and Co-Chair of IUCN, Asian Elephant Specialist Group, made detailed presentations on (i) sample block count, (ii) line transect dung count method and (iii) age-sexing elephants using simple field methods. The workshop included discussion of sampling procedures, data collection, and analyses and field demonstration of line transect dung count method. Sampling units, which represent the diverse conditions such as vegetation types, altitudinal and disturbance gradients prevalent in the forest divisions, were selected to estimate population size. Based on suggestions of experts, the size of each sample block was restricted to 4–6 km^2 to maximize the chances of counting the elephants within a block, and line transect for dung count to 2 km, with a minimum of 30 samples each for the sample block and dung count methods per forest division. Data on population size were analyzed for individual divisions and for population level analysis using two methods: (i) by summing up the population estimates arrived for the individual division and (ii) analyzing the pooled data from 19 forest divisions on each method (sample block and dung count methods) using standard procedures and formulae as used for individual division data analysis.

Results

Population size estimate by sample block count: In total, 2843 elephants were counted from 657 sample blocks covering 4980 km^2 (50%) out of 10001 km^2 of elephant habitat in Karnataka, giving an estimated mean population of 5740 elephants (range = 5301–6179) across the 19 forest divisions. Similarly, mean population size arrived at for the state by summing up the estimates of elephant numbers for individual forest divisions show a comparable figure of 5616 elephants but with wider confidence interval (4041–7226). The estimate of elephant population size arrived by sample block count method (mean: 5740, range: 5301–6179 elephants) is considerably higher compared with that of the 2007 synchronized elephant census estimate (mean = 4205, range 3800–4610). The elephant populations of the Mysore Elephant Reserve of Karnataka form part of

a larger elephant population that ranges into the adjoining states of Kerala and Tamil Nadu. Therefore, difference in the total number of elephants between the years could be a function of climate-related spatiotemporal variation in distribution pattern or movement of elephants within the population's range (landscape) that spreads into the adjoining states.

Population estimate by line transect dung count: In total, 10721 dung piles were recorded over 597 km of line transects, sampled across 19 forest divisions, working out to a mean density of dung: 1120.6±14.00/km^2 (range: 1094-1148) and elephant density of 0.7 elephant/km^2 (range 0.4–1.0 elephant km^2). This translates to a mean population of 6299 elephants (95% confidence interval: 3761–9213). Bandipur Tiger Reserve recorded the highest density of elephants (1.8/km^2) followed by Nagarahole (1.6/km^2) and BRT (1.4/km^2).

Population structure and sex ratio: The population structure assessed based on 4573 elephants that were age-sexed show that adults constitute 52% of the population (males 16%, female 36%). The remaining (48%) population consists of younger age classes such as sub-adults (24%—male 6% and female 18%), juveniles (13%—male 4% and female 9%) and calves (11%). The overall male-to-female sex ratio is 1:2.1 (irrespective of age) with skew being 1:2.2 at adult segments, dropping to 1 male for every 2.9 females at the sub-adult stage, decreasing again to 1:2.2 at the juvenile segment.

Natality and mortality: A crude birth rate based on 500 calves and 1655 adult females recorded during 2010 sample block and waterhole counts was 0.30 calves/adult female/year; such a high rate would not be sustained from one year to another. Annual mortality (crude estimate) based on 126 mean annual elephant deaths (from 2009–2011) out of 5616 elephants estimated in 2010 works out to 2.2%, with the male segment experiencing higher mortality (2.9%) compared to female segment (1.8%).

Conclusions: Overall, the dung count method (6299 elephants) yielding approximately 500 elephants more than sample block count (5740) method, by analyses of pooled data. Where as by summation, the trend is reverse *i.e.* dung count (5166 elephants) yielding approximately 500 elephants less than that of sample block method (5616 elephants). Possible reasons for such differences are discussed in detail.

The percentage of adult male elephants is likely to be much lower than 16% of the population. This inaccuracy in population structure indicates insufficient experience in age-sexing elephants among the field staff and, hence, calls for better training.

Data available on mortality indicate that the elephant population of Karnataka is unlikely to be decreasing and most likely to be either stable or growing. Thus, there need to be no cause for concern on account of a declining wild elephant population, but rather the need to plan for appropriate management of an increasing population in the state.

Recommendations: Based on the experience of the current census, recommendations are derived to overcome these lacunae in future exercises to assess the population size and structure with better accuracy and precision.

I. BACKGROUND

The Asian elephant (*Elephas maximus*), an "Endangered" species (IUCN, Red List 2010) listed in Schedule I of the Indian Wildlife Protection Act (1972), once ranged over a large area of the Indian sub-continent. However, its distribution is now restricted to five discontinuous distributions (North, North East, Central, and Southern India). The present population of elephants in the wild in India is close to 28,000 (Project Elephant 2007–08) which constitutes 60% of the global Asian elephant population, distributed across 13 Asian countries. Nilgiri-Eastern Ghats population (ranging over the Nilgiri-Mysore-Wyanad Landscape) in southern India ranging across about 13,000 km^2 is not only the largest known elephant population in India but also in Asia.

The Asian elephant, a wide-ranging species, requires large natural habitat to meet its food, water and shade requirements. Of late, with the increasing trend in landscape transformation and fragmentation, human–elephant conflict is escalating in most elephant ranges, resulting in decreased tolerance among the affected people. This could, in due course of time, lead to animosity towards the conservation of the Asian elephant. Therefore, the conservation and management of this require adequate knowledge of its distribution and numbers in order to assess the habitat and population viability. Population size and structure are of great relevance to the survival of this species in the long run considering the multifaceted conservation issues involved. In this context, Project Elephant (Ministry of Environment and Forests, Government of India) advocated the need for periodic population estimation of the species using at least one direct and one indirect method.

Synchronized elephant population estimation, across various regional populations, at periodic intervals, would help in assessing the population trend and its implications for the management of the species. The major aims of the census, undertaken in May 2010, were to: a) estimate elephant numbers by direct (sample block count) and indirect (line transect dung count) methods, b) assess population structure and sex ratios based on data collected from sample block and waterhole counts, and c) make recommendations for management of the species and fine-tune the methods for future population assessments.

At the request of the Chief Wildlife Warden, Karnataka, the Centre for Ecological Sciences, Indian Institute of Sciences (CES, IISc), Bangalore with the technical help from N. Baskaran, Senior Scientist, Asian Nature Conservation Foundation (ANCF), IISc, Bangalore, produced this technical report from data on the elephant census 2010 provided by the department. The report presents the results of population size obtained using both direct and indirect methods, population structure obtained by block and waterhole counts during the 2010 Synchronized Elephant Census, and also highlights the lacunae in the present exercise and measures to overcome them in future exercises.

2.1 Area covered

In Karnataka, the Asian elephant is distributed over the Eastern and the Western Ghats with the latter region supporting >60% of the state's population. Presently, elephants are found in about three populations, a small one (about 50) in the north of the state distributed thinly in the Belgaum, Uttara Kannada districts and other forests adjoining Goa and Maharashtra, a population of about 500 elephants in the Malnad plateau (primarily Bhadra WLS and adjoining areas) in Shimoga district, and a larger one (several thousand) from Chikamagalur–Kodagu–Mysore plateaus into the Eastern Ghats up to Bangalore (Bannerghatta).

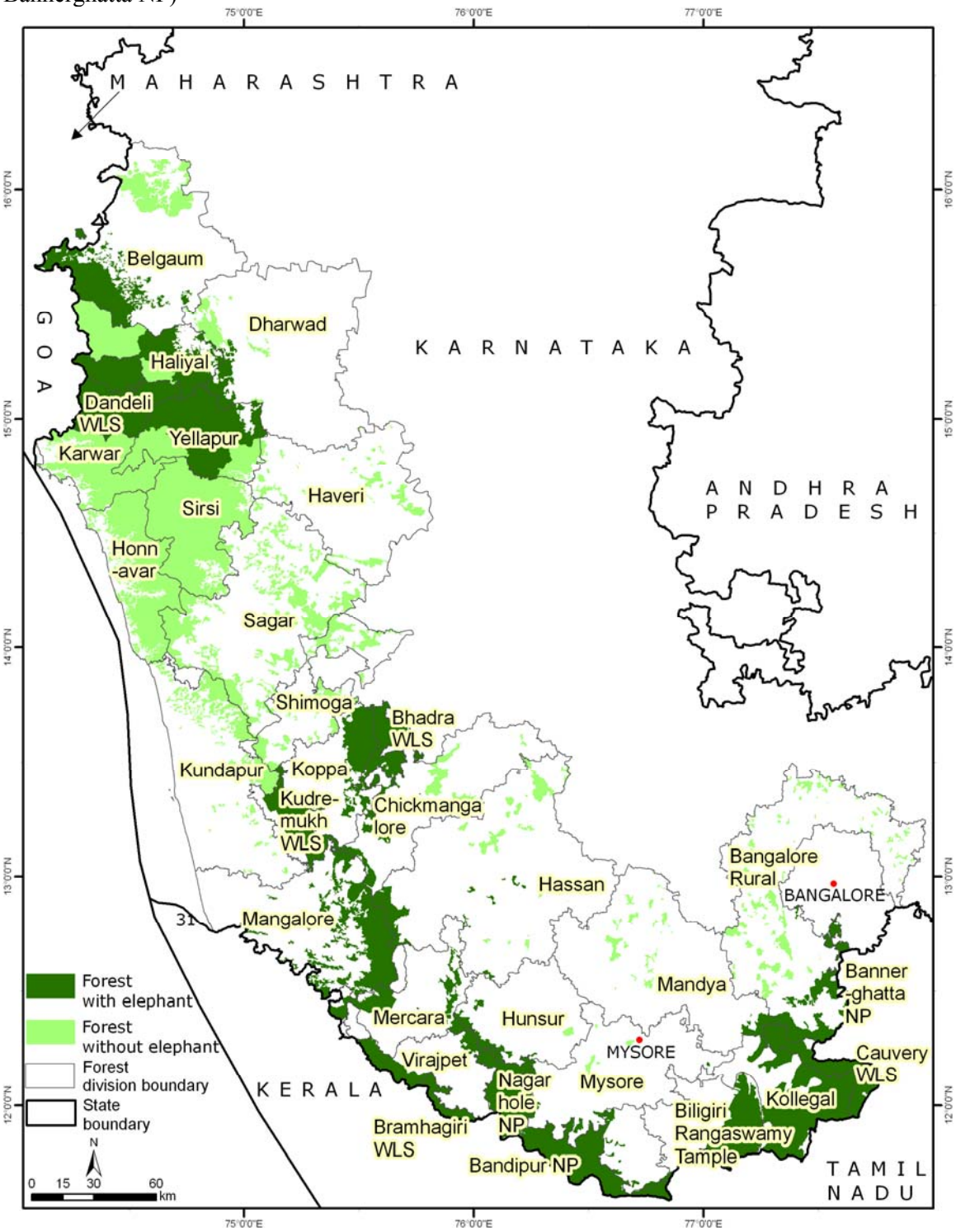
Out of the 31 forest divisions shown in the Figure 1, wild elephants are found in 24 forest divisions of Karnataka and the total area of distribution is approximately 14,500 km^2. Seven forest divisions shown as non-distribution area of elephants are Karwar, Honnavar, Sirsi, Haveri, Sagar, Kundapur, and Shimoga, but some of these are occasionally used by elephant, mainly solitary bulls. The state has declared the major elephant-bearing forest divisions (n =15) that spread over 6463 km^2 in the state as the Mysore Elephant Reserve (MER), under Project Elephant, a Government of India supported conservation initiative. The MER includes forest divisions such as Bhadra WLS and those from Hassan, Madikeri territorial & wildlife, to Bandipur in the Western Ghats as well as those in the Eastern Ghats from Bilgiriranganswamy temple (BRT) WLS to Bannerghatta NP. Although the current census was supposed to focus on the Project Elephant Reserve, the present exercise covered all the forest divisions from (Bhadra WLS) Malnad to Mysore plateau and Eastern Ghats that constitute a single population range in the state.

The Directorate of Project Elephant has recommended the use of at least two different methods to estimate the population size, including a direct method (in this case, sample block count) and an indirect method (line-transect dung count). To obtain data on population structure, apart from including the sightings under the direct method (sample block count), a waterhole count was also suggested wherever possible in view of the better visibility to age and sex the animals.

2.2 Workshop on elephant population estimate

The Karnataka Forest Department held a workshop on elephant population estimate for forest managers from the Mysore Elephant Reserves (MER) on April 27, 2010, at Bandipur Tiger Reserve. Field mangers (CFs, DCFs, and ACFs) from forest divisions belonging to the four MER were invited for the workshop. Chief Wildlife Warden, Karnataka, chaired the workshop and spoke about the overall plans and requirements of Project Elephant from the Census. Technical experts, Prof. R. Sukumar Indian Institute of Science, Bangalore and Ajay A. Desai, Project Elephant Steering Committee Member and IUCN, Asian Elephant Specialist Group Co-chair made presentations on various sampling methods and procedures including data collection and analyses by splitting the participants into two groups. The technical experts made a field demonstration of line transect dung count method including laying of the transects, data collection procedure.

Fig. 1. Map showing the forest divisions with wild elephants and its adjoining forest divisions in Karnataka (Synchronized Elephant Census 2010 covered 19 forest divisions from Bhadra WLS to Bannerghatta NP)



2.3. Population Size Estimate

2.3.1 Sample block count method: The population estimate was carried out using sampling method. Therefore, sample blocks were selected from each forest division taking into account the diverse vegetation types, altitudinal and disturbance gradients. Based on prior experience, the experts suggested an optimal block size of 4–6 km^2 for a survey team to perambulate thoroughly and maximize the chances of counting elephants. Hence, the size of each sample block was mainly restricted to 4-6 km^2 but varied overall between 0.5 and 87 km^2 area (mean of 7.6). Each sample block chosen for the exercise was covered by a team of 3–4 persons, comprising two forest staff and a volunteer/researcher. The team began the survey around 0630 h and perambulated the entire sample block systematically. Upon sighting elephants, care was taken to count all the individuals first, age-sex them wherever possible, and record these details in the data sheet supplied to them (Appendix I). In total, 657 sample blocks, covering an area of 4980 km^2 or 50% of total elephant habitat (10001 km^2) available within the population range in the state, were sampled using block count method (Table 1).

Statistical Analyses: To arrive at estimates of mean elephant density, number of elephants and statistical confidence limits for each forest division, the sample block count data of each division were analyzed separately using the formula provided in Lahiri-Choudhury (1991, see below). Total number of elephants for the Elephant Reserve of Karnataka was estimated using the following two methods: (1) The pooled sample block counts (n = 657) from 19 forest divisions were analyzed using the same formula used for division-wise analysis mentioned below, given that the number of sample blocks per unit area and total sampled area for various forest divisions were uniform across the state (as alternative blocks/beats/compartments were sampled). (2) In this method, the mean population size and 95% Confidence Interval (upper and lower limits) for the state were arrived at by summing up the individual estimates for the 19 forest divisions.

Formula used for sample block count data analysis

i) Estimate of elephant population (Y) is

$$\mathbf{Y = (y_{/}\ x) \times X}$$

Y = Estimate of total number of elephants in the region or forest division

ii) Estimate of variance (v) is

$$\mathbf{v = \frac{X^2}{(n(n-1))} \times \sum_{j=1}^{n} \frac{(yj-y)^2}{(xj-x)^2}}$$

v = Estimate of the variance of total elephant population for a given forest division or stratum

iii) Estimate of standard error is

$\sqrt{\mathbf{(v)}}$ = standard error of the Estimate of total elephant population

iv) Estimate of 95% Confidence Interval (CI) is

$$\mathbf{CI = (Estimate(Y) - 1.96 \times \sqrt{(v)}\ ,\ Estimate(Y) + 1.96 \times \sqrt{(v)}\ )}$$

CI = Estimate of the upper and lower confidence interval of total elephant population for a given forest division or stratum

Notations and other explanation

X = Total Area of the Region (Forest Division)

n =Total No. of blocks in that region (Forest Division)

$\mathbf{y_j}$ = no of elephants in the jth block j=1,2..n

$\mathbf{x_j}$ = Area in km^2 of jth block

$\mathbf{y} = \Sigma^{n}_{j=1} (y_j)$

(y = Total number of elephants counted in all sample blocks)

$= (y_1 + y_2 + y_3 + y_4 + y_5 + \ldots + yn)$

$\mathbf{x = \Sigma^{n}_{j=1} (x_j)}$ (x= Total area (in km^2) of sample all sample blocks)

$= (x_1 + x_2 + x_3 + x_4 + x_5 + \ldots + xn)$

$\mathbf{(y_/ x)}$ = Estimate of elephant density/ km^2

2.3.2 Line transect dung count method: Line transects (Burnham *et al*. 1980) were laid in all the forest divisions in the same blocks where sample block count was undertaken. In each sample block, a transect of a maximum length of 2 km was laid across an altitudinal gradient and walked once to enumerate dung piles. On sighting dung piles, the perpendicular distance of the dung pile from the line was recorded in the data sheet supplied to the team (Appendix II). In total, 597 transects, covering a distance of 1193 km, were laid to estimate dung density across nineteen forest divisions from the Mysore ER as well as those in between or adjoining the ER in the state within the population range (Table 1).

***Statistical Analyses*:** Line-transect dung count data were used to estimate dung density using computer programme DISTANCE Version 6.1 (Buckland *et al.* 2003). This density was converted into elephant density through Monte Carlo simulations using the programme GAJAHA Ver. 2.0 (Archana and Sukumar 2007) by incorporating elephant defecation rate and elephant dung decay rate following Barnes & Jenson (1987). In the absence of specific data for different elephant habitats in the state, the defecation rate (16.33 dung piles/day and SE = 0.8) calculated by Watve (1992) and the decay rate of 0.0097 dung piles/ day (SE = 0.002) calculated by Varman *et al.* (1995), both at Mudumalai Wildlife Sanctuary (Nilgiri ER), were used in the present analysis.

$$E = \frac{Y \times r}{D}$$

E = Density of elephants per unit area
Y = Density of dung per unit area
r = rate of dung decay/ per day
D = Number of defecations/elephant/day

Table 1. Details of areas covered by sample block and dung count methods in the forest divisions under various elephant reserves of Karnataka surveyed during Synchronized Elephant Census 2010

S. No.	Elephant Reserve and Name of forest division	Elephant habitat (km^2)	Sampling area		
			Block in km^2 (number)	Line transect dung count km (No.)	Waterhole sampled (Elephant counted)
	Mysore Elephant Reserve				
1	Bandipur TR	906	529 (108)	210 (105)	114 (968)
2	Bannerghatta NP	104	89 (15)	26 (13)	29 (25)
3	Bhadra WLS	492	171 (27)	22 (11)	10 (15)
4	Cauvery WLS	519	190 (38)	62 (31)	30 (74)
5	Chamarajnagar (BRT WLS)	540	197 (52)	104 (52)	77 (208)
6	Hunsur (T)	71	61 (12)	26 (13)	0 (0)
7	Hunsur WL (Nagarahole)	643	425 (49)	114 (57)	34 (183)
8	Kollegal	1222	592 (78)	124 (62)	68 (193)
9	Madikeri*	892	892 (50)	88 (44)	50 (3)
10	Madikeri WL	379	160 (30)	54 (27)	22 (39)
11	Mandya	97	41 (8)	16 (8)	11 (1)
12	Mysore	177	81 (10)	20 (10)	9 (39)
13	Ramanagara (Bangalore Rural)	353	129 (25)	52 (26)	26 (75)
14	Virajpet	337	110 (17)	58 (29)	29 (24)
15	Hassan	250	56 (12)	23 (12)	12 (5)
	Forest Divisions under Non-elephant Reserve				
16	Chikamagalur	139	139 (15)	30 (15)	12 (0)
17	Koppa	1151	110 (12)	24 (12)	15 (0)
18	Kudremukh NP	600	524 (32)	22 (11)	33 (0)
19	Mangalore	1128	484 (67)	118 (59)	67 (47)
20	**Total**	**10001**	**4980 (657)**	**1193 (597)**	**648 (1899)**

*Area sampled includes private forest (actual forest area in the division is 373km^2)

The dung count data were analyzed by evaluating different models of detection probability (half-normal, uniform and hazard rate) with cosine adjustment available in the software DISTANCE (*version* 6.1). The best-fit model for each dataset was assessed using *Akaike's Information Criterion* (AIC) value (Appendix III). The analyses were carried out using appropriate cut-off for perpendicular distance (typically at 15–20m) separately for each forest division. Similarly, the overall mean dung density for the state was estimated using pooled data from 19 forest divisions.

2.4. Population Structure Assessment

The data on population structure were collected during the sample block count on May 15, 2010 and by monitoring waterholes on May 17, 2010, in all the forest divisions (except for Hunsur T

using the later method), as age-sexing elephant is easier at the waterhole due to better visibility. During both the sample block and waterhole counts, apart from recording the number of elephants, the age and sex of the elephants seen were also recorded, wherever possible. The sex was differentiated based on presence or absence of tusk for animals above two years. Individuals <2 years were not sexed, and enumerators were trained in trying to differentiate tuskless males (*makhna*) based on characteristic features such as the presence of penis sheath, slanting back, broad musculature at trunk base and the social context of the individual (solitary sub-adult or adult without tusks). The age of elephants was classified into four major classes based on their shoulder heights following Sukumar *et al*. (1988). The categories are calf (<1 yr old; up to 120 cm height), juvenile (1–5 yrs old; 121–180 cm), sub-adults (5–15 yrs old; 181–210 cm for female and 181–240 for male) and adults (15 yrs; >210 cm for female and >240 cm for male) (Appendix IV). Individuals were recorded as 'Unidentified' if they could not be categorized into a specific age and sex. Details were systematically entered into the data sheet supplied (Appendix V).

3.1 Population size

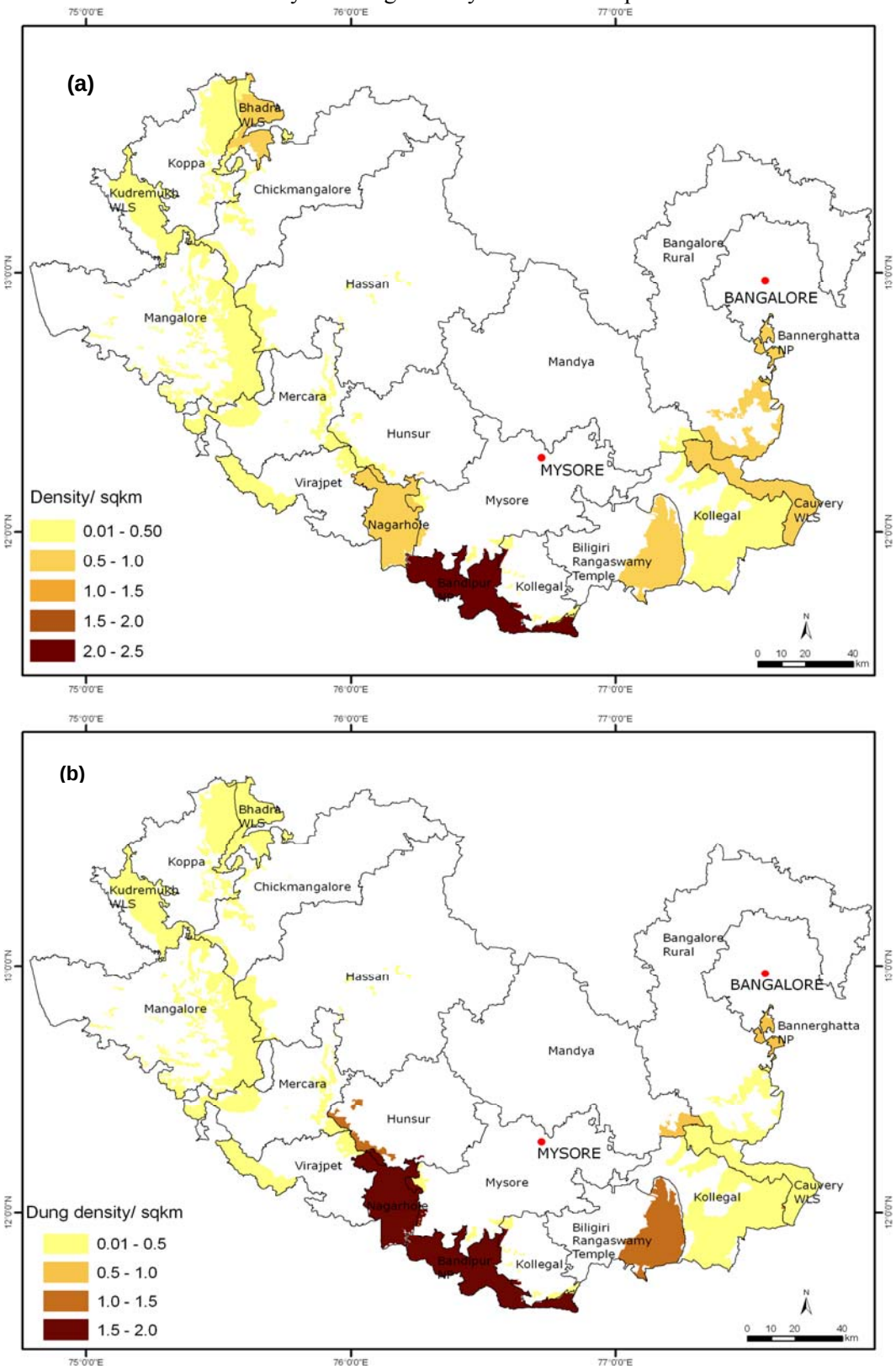
3.1.1. Population estimate by sample block count method: In total, 2843 elephants were counted over an area of 4980 km^2 by sample block count method across 19 forest divisions (Table 2). The estimated overall population for the 19-forest divisions (by summing up the total number of elephants estimated for the 19-forest divisions) was a mean of 5616 elephants with 95% Confidence Intervals of 4041–7226 elephants. However, the estimated overall population of the state by analysis of pooled data of 657 sample blocks from 19 forest divisions was a mean of 5740 elephants, with a narrower 95% CI (5301–6179 elephants). Among 19 forest divisions, Bandipur TR had the highest elephant density (2.4 elephants/km^2) (Figure 2a). Nagarahole, which was expected to have a density similar to that of Bandipur, had just 1.0 elephant/km^2. Divisions such as Bannarghata, Bhadra, Cauvery, BRT, Ramnagara (previously Kanakapura) had a moderate density of 0.7–1 elephant/km^2. The vast majority of elephants in the state are found in Bandipur, Nagarahole, BRT, and Kollegal including Cauvery, with >400 elephants each based on the sample block count method.

Table 2: Elephant population estimated by sample block count method in different forest divisions of Karnataka during Synchronized Elephant Census 2010

Forest division	Elephant habitat (km^2)	Sample size		Density / km^2	Estimated elephants population		
		Block area (number)	Elephant counted		Mean	LCL (min.)	UCL (max.)
Bandipur TR	906	529 (108)	1244	2.4	2130	1727	2534
Bannarhatta NP	104	89 (15)	65	0.7	76	36	117
Bhadra WLS	492	171 (27)	112	0.7	325	198	497
Cauvery WLS	519	190 (38)	195	1.0	535	361	704
C.Nagar WL (BRT WLS)	540	197 (52)	161	0.8	443	320	563
Chikamagalur	139	139 (15)	11	0.1	11	5	17
Hassan	250	56 (12)	15	0.3	67	27	107
Hunsur	71	61 (12)	27	0.4	31	13	50
Hunsur WL (Nagarahole)	643	425 (49)	408	1.0	617	443	792
Kollegal	1222	592 (78)	285	0.5	589	457	720
Koppa	1151	110 (12)	0	0.0	0	0	0
Kudremukh NP	600	524 (32)	0	0.0	0	0	0
Madikeri*	892	892 (50)	50	0.1	50	36	64
Madikeri WL	379	160 (30)	76	0.5	180	114	245
Mandya	97	41 (8)	6	0.2	15	3	26
Mangalore	1128	484 (67)	24	0.1	56	42	69
Mysore	177	81 (10)	30	0.4	66	21	110
Ramanagara	353	129 (25)	92	0.7	251	150	351
Virajpet	337	110 (17)	57	0.5	175	88	260
Overall (Sum of divisions)	**10001**		**2843**		**5616**	**4041**	**7226**
Overall (Analysis of pooled data)	**10001**	**4980 (657)**	**2843**	**0.6**	**5740**	**5301**	**6179**

* Area sampled by sample block count method is exceeding the elephant habitat available within the division (as private forest under tea estates were sampled), thus used the total area of sampling by block count method as elephant habitat.

Fig. 2: Map showing the density distribution of elephants by (a) block count and (b) dung count method in 19 forest divisions surveyed during 2010 synchronized elephant census



3.1.2. Population size estimate by line transect dung count method:

The indirect, dung count method was also carried out in all the 19-forest divisions where sample block count method was adopted (Table 3). The overall population for the 19-forest divisions (by summing up the total number of elephants estimated for each of these divisions) works out to 5166 elephants with 95% CI of 2764–7989 elephants. However, the overall population arrived by analysis using pooled data from 19-forest divisions yielded a mean figure of 6299 elephants with 95% CI of 3761–9213 elephants. Among 19-forest divisions, Bandipur again showed the highest density of 1.8 elephants/km^2 followed by Nagarahole (1.6 elephants/km^2) (Figure 2b). Forest divisions such as BRT wildlife sanctuary, Hunsur (T) and Bannerghatta were also estimated to have densities in the range of 1 to 1.5 elephants/km^2 (Table 3).

Overall, the population size for the state estimated by line transect dung count method (mean by summation for forest divisions = 5166 elephants) is not very different from estimates from sample block count method (mean by summation of all sample blocks for the state and by pooled analysis were 5616 and 5740 elephants, respectively). The two estimates are not directly comparable, as the block count reflects the elephant population on the day of the census, while the dung count is an average estimate of the population over an approximately 3-month period prior to the census in May 2010.

Table 3: Elephant population estimated by dung count method in different forest divisions of Karnataka during Synchronized Elephant Census 2010

Forest Division	Elephant habitat (km^2)	Density / km^2				Estimated elephant population		
		Dung (SE)	Elephant	LCL (min)	UCL (max)	Mean	LCL (min)	UCL (max)
Bandipur TR	906	3010.3 ± 571.02	1.8	0.98	2.79	1622	888	2529
Bannerghatta NP	104	1582.2 ± 137.98	0.9	0.57	1.32	97	59	137
Bhadra WLS	492	460.2 ± 75.13	0.3	0.15	0.41	133	74	202
Cauvery WLS	519	589.7± 29.11	0.4	0.22	0.48	182	114	249
Chamraj Nagar (BRT WLS)	540	2357.5 ± 285.94	1.4	0.82	2.02	756	443	1091
Chikmagalore	59	253.9 ± 35.40	0.2	0.08	0.23	9	5	14
Hassan	250	342.6± 49.21	0.2	0.11	0.32	52	27	80
Hunsur T	71	1935.4 ± 174.12	1.2	0.71	1.61	82	51	115
Hunsur WL (Nagarahole)	643	2608.0 ± 395.44	1.6	0.91	2.3	997	585	1480
Kollegal	1222	220.0 ± 8.72	0.1	0.08	0.17	159	98	208
Koppa	1151	640.14 ± 268.26	0.4	0.05	0.83	449	58	955
Kudremukh NP	600	Too small sample size to estimate elephant density						
Madikeri	373	670.5 ± 74.41	0.4	0.24	0.57	146	90	213
Madikeri WL	379	738.0 ± 60.30	0.4	0.24	0.67	163	91	254
Mandya	97	1336.4 ± 107.37	0.8	0.49	1.11	77	47	108
Mangalore	1128	56.4 ± 6.48	0.03	0.01	0.04	34	11	45
Mysore	177	769.1 ± 63.62	0.5	0.28	0.64	80	49	113
Ramnagara	353	179.3 ± 15.83	0.1	0.06	0.16	35	19	56
Virajpet	337	460.8 ± 27.53	0.3	0.16	0.42	94	54	142
Overall (by summation)	**9401**					**5166**	**2764**	**7989**
Overall (by analysis)	**9401**	**1120.6 ± 14.00**	**0.67**	**0.40**	**0.98**	**6299**	**3761**	**9213**

3.1.3. Elephant density in different vegetation types

Overall, the elephant habitats surveyed across 19 forest divisions showed a mean density of 0.57 elephants /km^2. However, density varied considerably across vegetation types, with dry deciduous forest supporting the highest density (nearly 1 elephant/km^2), followed by moist deciduous and dry thorn forests (Table 4). The evergreen/semi-evergreen forests had the lowest density of elephants (0.24/km^2) during the month of May. Overall, it is evident from the results that the density of elephants was higher in secondary forests (deciduous and dry thorn) than the primary forest (evergreen and semi-evergreen). Elephant density seems to increase from evergreen forests (high rainfall) to moist and dry deciduous forests (medium rainfall) and again declines in dry thorn forest (low rainfall) (Figure 3). The reason that forest divisions such as Bandipur, Nagarahole and BRT have density of about >1 elephant/km^2 is perhaps due to the large tract of secondary vegetation, mainly of moist and dry deciduous as well as dry thorn forest, available to the elephants within these divisions.

Figure 3. Estimate of elephant density in different vegetation type during the month of May based on sample block count data from 19 forest divisions (Error bar = 95% CI)

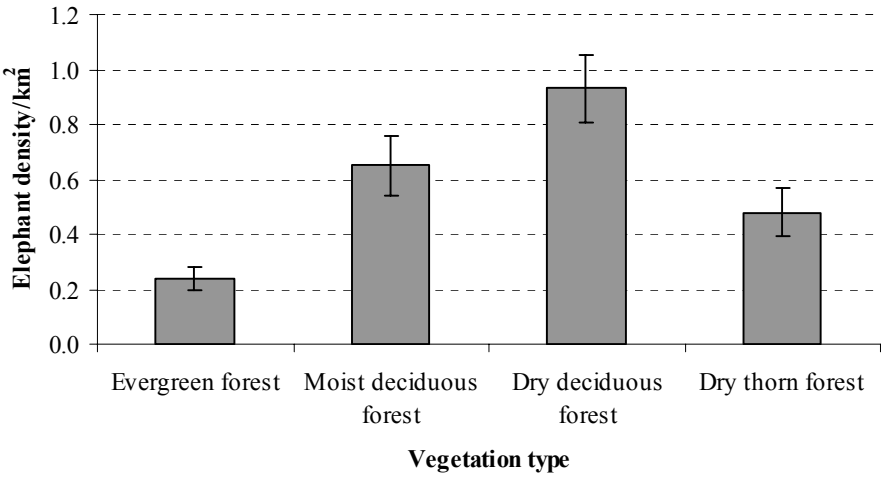


Table 4: Details of sampling and density of elephants estimated in different vegetation types based on sample block count data from 19 forest divisions surveyed during 2010 Synchronized Elephant Census in Karnataka

S. No.	Vegetation type	Sample size		Density of elephants/km^2		
		Block area (number)	Elephant counted	Mean	LCL (Min.)	UCL (Max.)
1	Evergreen forest	1487 (155)	353	0.24	0.20	0.27
2	Moist deciduous forest	1149 (120)	750	0.65	0.54	0.77
3	Dry deciduous forest	1414 (254)	1313	0.93	0.81	1.04
4	Dry thorn forest	930 (128)	442	0.48	0.39	0.56
5	**Overall**	**4980 (657)**	**2858**	**0.57**	**0.53**	**0.62**

3.2. Population Structure

Age structure: Overall, 4757 elephants were counted during the sample block and waterhole counts in 19 forest divisions. Of this, 4573 elephants (96%) were age-sexed, and the rest were either unidentified or not aged (*n* = 184 or 4%). Age-sex composition of these 4573 elephants shows that 52.4% of the population comprised adults and the rest (47.6%) of younger classes such as sub-adults, juveniles and calves (Table 4), with sub-adult females constituting a significant proportion (17.6%).

Sex ratio: Overall, male to female ratio for all the divisions together was 1:2.1 (Table 5). However, when we look at the sex ratio of various age classes there are only marginal differences that may not reflect the real situation. For example, among adults the male to female ratio was 1:2.3, while the skew increases to 1 male for every 2.9 females at the sub-adult stage and drops to 1:2.2 in the juvenile segment. It is unlikely that elephant populations would have such patterns in sex ratios considering that the elephant is a polygynous species, where sex ratio at birth is expected to be equal and begin skewing towards females gradually with increasing age. Therefore, skew is expected to be higher in the adult segment than in the sub-adult and juvenile segments. In Asian elephants we also have to consider the human factor (ivory poaching and conflict-related deaths), which can be expected to selectively remove adult and sub-adult males (tuskers) from the population; thus the skew is expected to be even higher than the natural condition (i.e. without any ivory poaching or conflict-related deaths) in the adult class as compared to sub-adult or juvenile classes. Therefore, Karnataka is unlikely to have a sex ratio of 1:2.2 among adults as the census figures show, but a more skewed figure.

Table 5: Overall age-sex composition and sex ratio of elephants obtained by sample block and waterhole counts from 19 forest divisions of Karnataka during 2010 Synchronized Elephant Census (*n* = 4573) * assumed

Age class	**Age structure (%)**			**Sex ratio**
	Male	**Female**	**Total**	**M : F**
Adult	16.2	36.2	52.4	1: 2.2
Sub-adult	6.0	17.6	23.6	1: 2.9
Juvenile	4.1	9.0	13.1	1: 2.2
Calf	5.45	5.45	10.9	1:1.0*
Total	**31.7**	**68.3**	**100**	**1:2.1**

The reason for higher skew in sub-adult age class than in the adult age class appears to result from misclassification of age class of elephants in the census data, a common problem we have encountered in the south for several years. For example, age structure estimated by a more scientific study (Arivazhagan and Sukumar 2005) in Nagarahole National Park has shown that the adult, sub-adult, juvenile and calves comprised 43.5%, 26.3%, 22.7% and 7.4% of the elephant population, respectively. In comparison, the 2010 census data of Nagarahole (Table 6) showed considerable variation in age structure (51.3% adult, 28.2% sub-adult, 11.2% juvenile and calf 9.3%) in age structure. Even the elephant population in Periyar Tiger Reserve, Kerala, with a significantly lower birth rate compared to Nagarahole has only 48.4% of individuals in the adult segment (Arivazhagan and Sukumar 2005). Therefore, it is highly unlikely for either Nagarahole (with relatively high birth rate) or the entire Karnataka region to have an adult segment greater than 50% of the population as indicated in the census data (this is most likely to be under 45% of the population).

***Makhna* versus tusker ratio:** In total 13 *makhna* (tuskless male) sightings were reported from sample block (n = 10) and waterhole counts (n = 3). Since the age category was not specifically reported for the *makhna* sightings in all instances, it can be assumed that these are likely to be adult and sub-adult animals. Considering the total number of adult and sub-adult male sightings (n = 635) reported during block count, the ten *makhna* sightings work out to one *makhna* for every 63 adult and sub-adult males. This is again likely to be a considerable underestimate given that it is not always possible to differentiate a sub-adult *makhna* within a group of adult females by inexperienced observers. Our observations suggest that there could be more than one *makhna* for every tusked male among sub-adult and adult bull elephants presently in Karnataka.

3.3. Natality

The crude birth rate, estimated by dividing the total number of calves by the number of mature females (number of calves/adult female/year) in the population works out to 0.30 calves/adult female/year (based on 500 calves and 1655 adult females recorded during sample block and waterhole counts) (Table 6). Among 17 forest divisions where elephants were actually sighted during the 2010 census, Bhadra WLS, followed by Chikamagalur and Mandya, reported higher number of calves per adult female (Table 6). The mean fecundity rate (0.3) estimated for the overall elephant population in Karnataka is higher than the estimate (0.2) by Arivazahgan and Sukumar (2005) for the Nagarahole elephants based on longer term observations (2001-03). Although a birth rate of 0.3 calves/adult female/year is certainly possible in a particular year, it is unlikely to remain so over a longer period of 3-5 years because of inter-annual variations in climate, long gestation and anestrous resulting in longer inter-calving interval in elephants (Douglas-Hamilton 1972 and Sukumar 1989). It therefore seems likely that the classification of 597 juveniles (representing individuals 1-5 years) is an under-representation when compared to 500 calves (representing individuals 0-1 year); some juveniles may have been wrongly classified as calves resulting in overestimate of calves in the population.

3.4. Mortality

Mean annual mortality rate can be estimated using the records of 126 annual elephant deaths in the state (averaged from 2009-10 and 2010-11) and 5616 elephants (mean) estimated in May 2010 by sample block count (summation) method. Overall estimate of the annual mortality works out to 2.2% (Table 7), with the male segment experiencing higher mortality (2.9%) compared to female segment (1.8%) that can be expected in a polygynous mammal such as the elephant (Sukumar 1989). This is obviously the minimum death rate as the chances of not detecting and recording elephant carcasses in dense forest are high, especially so in the case of calves and juveniles. Of the 126 dead elephants recorded, age was not recorded in eight male cases, and eleven female cases (total of 19 elephants), and for two cases neither age nor sex was recorded. The available data indicates that mortality was highest in the adult segment (2.2%), and lower at sub-adult (1.4%), juvenile (1.9%) and calf (1.4%) segments. In large-bodied, long-lived species such as the elephant the calf and juvenile mortality can generally be expected to be higher than of older age classes.

Population models show that an elephant population in which the birth rate is higher than about 0.2 calves/adult female/year and adult female mortality less than about 2.5% to 3% per year is likely to be stable or increasing. Even assuming some under representation of adult female deaths, the available records indicate that the elephant population of Karnataka is unlikely to be decreasing and most likely to be either stable or growing. Thus, there need to be no cause for concern on account of a declining wild elephant population, but rather the need to plan for appropriate management of an increasing population in the state.

Table 6: Age-sex composition and sex ratio of elephants obtained by sample block count and waterhole count methods in different forest divisions of Karnataka recorded during 2010 Synchronized Elephant Census

Division (*n* = No. of elephants age-sexed)	**Female (%)**				**Male (%)**				**Calf**	**Male to Female Ratio**			**Fecundity (Calf/AF)**
	Adult	**Sub-adult**	**Juvenile**	**Overall***	**Adult**	**Sub-adult**	**Juvenile**	**Overall***		**Adult**	**Sub-adult**	**Juvenile**	
Bandipur (2132)	34.7	20.5	11.8	**66.9**	12.9	5.9	5.1	23.8	9.3	1: 2.7	1: 3.5	1: 2.3	0.3
Bannerghatta (77)	41.6	13.0	5.2	**59.7**	15.6	3.9	3.9	23.4	16.9	1: 2.7	1: 3.3	1: 1.3	0.4
Bhadra (100)	34.0	4.0	3.0	41.0	24.0	11.0	2.0	**37.0**	22.0	1: 1.4	1: 0.4	1: 1.5	**0.6**
Cauvery (286)	42.5	19.0	7.8	**69.4**	11.2	1.9	1.9	14.9	15.7	**1: 3.8**	1: 10.2	1: 4.2	0.4
C. Nagar (BRT) (360)	43.3	14.2	6.1	**63.6**	12.2	3.1	3.3	18.6	17.8	**1: 3.5**	1: 4.6	1: 1.8	0.4
Chikamagalur (11)	18.2	9.1	0.0	27.3	63.6	0.0	0.0	**63.6**	9.1	1: 0.3	0	0	0.5
Hassan (20)	25.0	0.0	0.0	25.0	40.0	0.0	25.0	**65.0**	10.0	1: 0.6	0	5: 0	0.4
Hunsur (25)	20.0	16.0	4.0	40.0	40.0	8.0	4.0	**52.0**	8.0	1: 0.5	1: 2.0	1: 1	0.4
Nagarahole (571)	34.5	18.4	8.4	**61.3**	16.8	9.8	2.8	29.4	9.3	1: 2.1	1: 1.9	1: 3	0.3
Kollegal (470)	42.3	14.5	3.6	**60.4**	20.4	3.4	3.0	26.8	12.8	1: 2.1	1: 4.3	1: 1.2	0.3
Koppa (0)	-	-	-	-	-	-	-	-	-	-	-	-	-
Kudremukh (0)	-	-	-	-	-	-	-	-	-	-	-	-	-
Madikere (53)	34.0	15.1	9.4	**58.5**	20.8	7.5	1.9	30.2	11.3	1: 1.6	1: 2.0	1:5	0.3
Madikeri WL (111)	25.2	12.6	12.6	50.5	24.3	14.4	3.6	**42.3**	7.2	1: 1.0	1: 0.9	1: 3.5	0.3
Mandya (7)	28.6	0.0	0.0	28.6	57.1	0.0	0.0	**57.1**	14.3	1: 0.5	0	0	0.5
Mangalore (62)	19.4	21.0	3.2	43.5	38.7	3.2	11.3	**53.2**	3.2	1: 0.5	1: 6.5	1: 0.3	0.2
Mysore (69)	23.2	20.3	0.0	43.5	37.7	10.1	0.0	**47.8**	8.7	1: 0.6	1: 2.0	0	0.4
Ramanagara (164)	41.5	13.4	12.8	**67.7**	15.2	7.3	1.8	24.4	7.9	1: 2.7	1: 1.8	1: 7	0.2
Virajpet (73)	37.0	5.5	1.4	43.8	28.8	9.6	8.2	46.6	9.6	1: 1.3	1: 0.6	1: 0.2	0.3
Grand Total (4573)	**36.2**	**17.7**	**9.0**	**62.9**	**16.1**	**6.1**	**4.0**	**26.1**	**10.9**	**1: 2.3**	**1: 2.9**	**1: 2.3**	**0.3**

*Overall excluding calves

Table 7: Mean annual mortality rates (in percentage) estimated using 126 elephants (averaged from 2009-10 & 2010-11) mortality records and 5616 elephants estimated in May 2010 by sample block count method

Years	**Male**		**Female**		**Overall**	
	Mortality rate	*n**	Mortality rate	*n**	Mortality rate	*n**
Adult	2.7	910	2.0	2033	2.2	2943
Sub-adult	2.4	337	1.0	988	1.4	1325
Juvenile	3.1	230	1.3	505	1.9	736
Calf	1.8	306	1.0	306	1.4	612
Overall	**2.9**	**1783**	**1.8**	**3833**	**2.2**	**5616**

Age was not recorded in eight male, and eleven female cases (together 19 elephants) and in two cases both age and sex was not recorded. These cases were included only in the overall analyses.

4.1. Elephant population size data

A comparison of sample block and dung count methods show considerable differences in elephant density in many of the forest divisions. The sample block count yielded higher density than dung count method in nine forest divisions (Figure 4) with estimates being higher by former method (Table 8). On the other hand, the sample block count method also returned a lower density than the dung count method in the remaining nine forest divisions. Some variation between the two methods can be explained by the different time periods the estimates pertain to – the day of the census in the case of the block count and an average over a 3-month period prior to the census in the case of the dung count; thus seasonal movements of elephants could result in these variations in density estimates by the two methods. The two methods also cannot be directly comparable because of differences in the nature of their underlying variables and assumptions. Problems in the line transect, dung count method such as the relevance of the 'steady state assumption' in dung decay and deposition, the absence of estimates of dung decay rates for the concerned forest divisions in Karnataka prior to the field exercise, and inaccuracies in recording data (e.g. line length, perpendicular distance, recording dung piles detected by multiple observers walking away from the line instead of a single observer walking along the line, rounding-off measurements, etc.) could reduce the robustness of density estimates. Similarly, data collection in sample block count method may suffer from incomplete counts (with no indication of what proportion of animals within a block is actually detected) as well as inaccurate estimation of the area of the sampled blocks (see below).

Fig. 4. Differences in elephant density estimated by sample block count compared to dung count

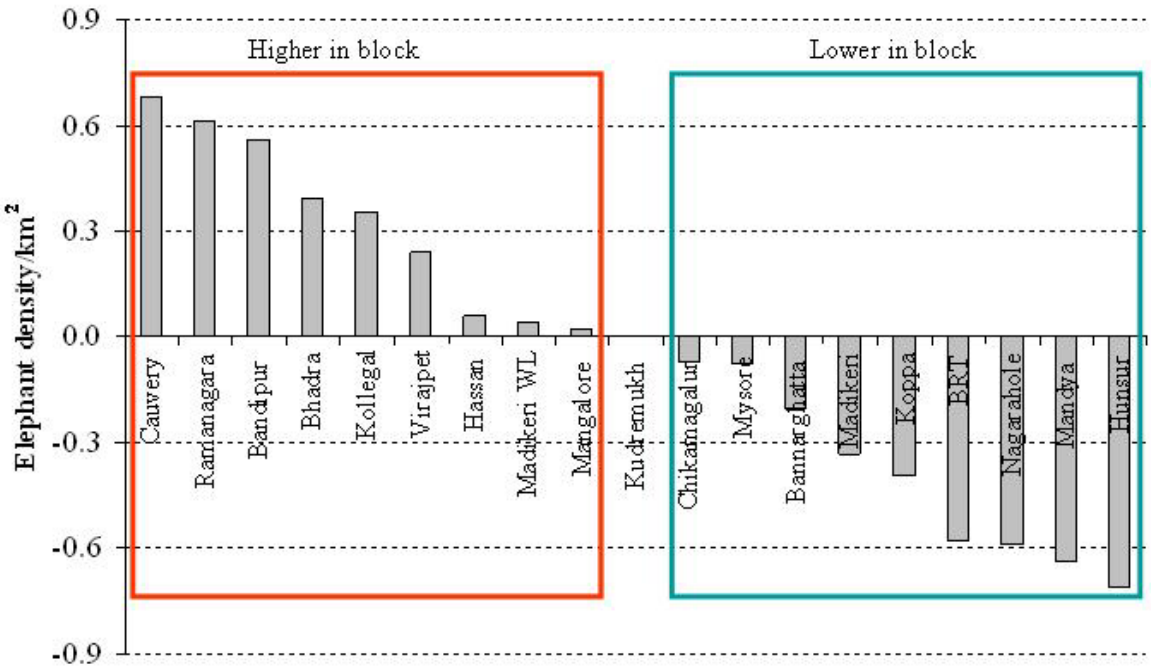


Table 8: Differences in density of elephants estimated by sample block counts compared to dung count method in different forest division

S. No.	Division	Elephant habitat (km^2)	Elephant density/ km^2		
			Mean by block count	Mean by dung count	Difference: block minus dung counts (%)
1	Cauvery	519	1.03	0.35	0.7 (194)
2	Ramanagara	353	0.71	0.10	0.6 (610)
3	Bandipur	906	2.35	1.79	0.6 (31)
4	Bhadra	492	0.66	0.27	0.4 (144)
5	Kollegal	1222	0.48	0.13	0.4 (271)
6	Virajpet	337	0.52	0.28	0.2 (86)
7	Hassan	250	0.27	0.21	0.1 (29)
8	Madikeri WL	379	0.47	0.43	0.0 (10)
9	Mangalore	1128	0.05	0.03	0.0 (68)
10	Kudremukh	600	0	0	-
11	Chikamagalur	139	0.08	0.15	-0.1 (47)
12	Mysore	177	0.37	0.45	-0.1 (18)
13	Bannerghatta	104	0.73	0.93	-0.2 (22)
14	Madikeri	892	0.06	0.39	-0.3 (86)
15	Koppa	1151	0.00	0.39	-0.4 (100)
16	BRT WLS	540	0.82	1.40	-0.6 (41)
17	Nagarahole	643	0.96	1.55	-0.6 (38)
18	Mandya	97	0.15	0.79	-0.6 (81)
19	Hunsur	71	0.44	1.15	-0.7 (62)

4.1.1. Lacunae in sample block count method

- **Under estimates of sample block areas:** A large number of divisions have shown all or large majority of their sample blocks of uniform size (e.g. 5 or 6 or 7 km^2) (Table 9), something quite unlikely under field conditions. The sampling units were supposed to be based on the entire or partial compartment/block/beat using natural landscape features such as streams, rivers, steep hill ridges etc. Thus, the sample block areas marked on a map could be expected to vary even within one forest division. However, the survey records (sample block sizes) in many forest divisions show uniform sample blocks (e.g. 5 km^2 in Cauvery WLS, see Table 9) or majority with uniform size (e.g. Hunsur (T), Kollegal, Mandya, Ramnagara and Virajpet). These appear to be artificial figures of area that have not been actually measured on maps of the concerned divisions.

- **Too large sample blocks to be covered by the survey team:** Recommended block size (4–6 km^2) for sample block count was ignored in some forest divisions (e.g. 87 km^2 in Kollegal, 69 km^2 in Madikeri Division, for more details see Table 9). Perambulating over about 5 square kilometers would be practically impossible for the census team in forest conditions; this would result in underestimate by sample block count method.

Table 9: Details of the sample blocks used for 2010 synchronized elephants census in different forest divisions

Division	Block details (area in km^2)				
	n	**Mean ± SE**	**Min**	**Max**	**% blocks of the same size (size of blocks)**
Bandipur	108	4.9 ± 0.12	2.8	12.8	-
Bannerghatta	15	5.9 ± 0.68	0.43	9.5	-
Bhadra	27	6.3 ± 0.57	2.5	15	-
Cauvery WLS	38	5 ± 0	5.0	5.0	100 (5)
Chamarajagar (BRT)	52	3.8 ± 0.11	1.4	5.6	-
Chikamagalur	15	9.3 ± 2.88	3.0	49.0	-
Hassan	12	4.7 ± 0.68	1.35	10.0	-
Hunsur (T)	12	5.1 ± 0.08	5.0	6.0	92 (5)
Hunsur WL-Nagarahole	49	8.7 ± 0.78	1.9	25	
Kollegal	78	7.6 ± 1.39	1.2	86.9	90 (5)
Koppa	12	9.1 ± 1.09	4.5	17.7	-
Kudremukh	32	16.4 ± 2.62	2.0	56.6	-
Madikeri Division	50	17.8 ± 2.37	3.5	69.4	33 (6)
Madikeri WL	30	5.3 ± 0.14	3.3	6.4	
Mandya	8	5.1 ± 0.06	5.0	5.5	89 (5)
Mangalore	67	7.2 ± 0.79	0.31	35.6	21 (5) & 12 (6)
Mysore	10	8.1 ± 2.43	0.86	24.6	-
Ramanagara	25	5.2 ± 0.88	5.0	9.4	96 (5)
Virajpet	17	6.5 ± 0.43	1.62	7.8	29 (5) & 53 (7.82)
Grand Total	**657**	**7.6 ± 0.34**	**0.31**	**86.9**	

4.1.2. Lacunae in line transect dung count method

- Although there has been some improvement in the quality of data collected by the Line Transect Dung Count during 2010 census, as compared to earlier censuses in 2002, 2005 and 2007, there is still scope for further improvement to obtain reliable estimates. From the data it is evident that most of the important forest divisions such as Bhadra, Bandipur, and Nagarahole yielded elephant density estimates significantly higher or lower than the sample block count method. Intrinsic problems in the methodology such as those discussed above (in section 4.1) could contribute to a lack of precision. The line transect data in some forest divisions recorded the line length for every dung pile observed instead recording the perpendicular distances. Better training would contribute to more accurate field records.

4.2. Population structure data

- Overall, there appears to be some errors in the age classification of elephants. It is unlikely that elephant populations would show the observed patterns in sex ratios (with skew being 1:2.2 at adult segment which rises to 1:2.9 at the sub-adult stage and then drops again to 1:2.2 at juvenile stage) considering that the elephant is a polygynous species where sex ratio at birth is expected to be equal and may skew towards females gradually with increasing age. In a population where ivory poaching pressure is relatively low as in northeastern India (Sukumar *et al*. 2003), owing to the high proportion of *tuskless* males (*makhnas*), sex ratio among adults is about 1:2.5–1:3 (male to female). As southern India has experienced much higher poaching pressure than northeastern India (Sukumar 2003), Karnataka is unlikely to have a sex ratio of 1:2.2 among adults as the census figures show. The reason for such errors in sex ratio could be the result of sub-adult males being misclassified as adults, as the total number of sub-adult males counted [n = 277] was significantly lower than adult males [n = 739] across the state. Adult males mostly lead a solitary life. However, not all solitary males are adults, because sub-adult males (around 10–14 years) often temporarily move away from maternal herds before permanent dispersal and adulthood; there are also chances of permanent dispersal at late sub-adult stage (about 12–14 years). Further, it is possible to misclassify a sub-adult male as an adult male when a sub-adult male is alone as there are no adult animals for comparison while aging. Similarly, there appears to be some misclassification of adult females as sub-adult females as we find records of female herds without adult females but only with sub-adults female, juveniles and calves (e.g. Bandipur, Cauvery). Overall, such misclassification of adult females as sub-adult females, sub-adult males as adult males and juveniles as calves results in more unrealistic age structure and sex ratio of the population.

5.1. Population estimate planning and involvement of Scientific Institutions

- Advanced planning is essential to obtain robust estimates of population size and structure through better training, field execution, and analyses. Criteria such as systematic selection of sampling area for block and dung count methods, dung decay rate and defecation rate experiments (details given below) and more accurate population structure data for estimating natality and mortality rates require at least six months' planning time. Similarly, it is important to involve reputed scientific institutions from the planning phase onwards in order to improve the quality of data collection. However, most of the past synchronized elephant census programmes in the south were planned within only a month or two gap prior to execution (with the possible exception of the 2005) and researchers were not involved from the planning phase onwards in all the exercises (with the exception of 2002). We strongly urge the departments concerned to plan future exercises well in advance to improve the quality and reliability of the results.

5.2. Sample block count

- To conduct a systematic population estimate in each forest division, sample areas (sample blocks and line transects) need to be selected by stratifying different vegetation types and marking them on topographic sheets clearly for the census team to follow. Large blocks/compartments/beats should be divided into smaller units measuring 4–6 km^2 using natural landscape features such as stream, river, steep hill ridge, etc. for the field team to perambulate the sampling area easily. The extent of area sampled has to be estimated precisely for all the sampling units in any one standard unit of measurement (preferably km^2) and marked on the sampling area map. These could be done easily using GIS software in a centralized place where all the Survey of India topographic maps with forest division, range, block boundary details including land-use vegetation data are available.

- A separate column needs to be added in sample block and water hole count data sheets to record *makhna* sighting in case of adult class to fulfill the Project Elephant requirement.

5.3. Dung count method

- It is mandatory to carry out dung decay rate experiment with dung samples representing various forest types and climatic conditions. The experiment has to begin at least three months in advance of the field census date by utilizing field staff and experts from research institutions.

- Carrying out the dung count method during the month of May for elephant population estimation may not be appropriate as it is a transitional period between the dry and wet seasons. The 'steady-state assumption' for the dung may not hold in such a transition period. Similarly, the dung count method during the month of May could also suffer from dry season forest fire that may burn the dry dung piles as experienced in the 2002 exercise.

- Hence it is desirable to carry out the exercise in the middle of dry (February) and wet (August-September) seasons.

- Further, it is important to move ahead from the present exercise of one-time estimate per census exercise to at least twice a year (one time each in the dry and wet seasons) to obtain more reliable estimates and a better understanding of seasonal influence on the

dynamics of elephant dung piles in the system and on the distribution pattern of elephants.

- Adequate training has to be given to the field staff and volunteers of the region periodically on population estimate techniques, especially dung count and the use of field equipment. Although Karnataka harbours the major share of the elephant population of southern India and deserves special importance, no targeted training programmes have been conducted for the field staff unlike in Tamil Nadu and Kerala. It is therefore essential that all field level staff need to be exposed to new methods like the line transect method through a special training programme.
- Preparation of a simple field manual on population estimation techniques and its translation into vernacular language would be useful for training field staff. Adequate number of equipment, necessary for the exercise, including GPS, field compass, measuring tapes need to be supplied to all forest divisions.

5.4. Population structure data collection

- The field staff involved in the enumeration will have to receive adequate training in ageing elephants. Visits to elephant camps where animals of known age are kept could aid in this training. It would be ideal to train a selected number of skilled staff from each forest division in population structure data collection.
- Systematic collection of population structure data by trained staff on a regular basis (when they go for routine field perambulation) together with the recording of accurate annual mortality data would greatly help achieve more detailed and accurate demographic analyses including the assessment of natality, mortality, fecundity and so on.

5.5. Data compilation and reporting

- All forest divisions must be encouraged to send a soft copy of all census data (block, dung count and water hole count) in EXCEL format and a hard copy (for verification) to the compilers.

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Appendix I

ELEPHANT CENSUS BLOCK COUNT DATA SHEET

Date	:	General vegetation type	:
Forest Division	:	Weather (Sunny/Cloudy/Rainy)	:
Forest Range	:	Starting Time	:
Location of Block	:	Ending time	:
Area of Block	: km^2	Observer's Name	:

Sl No.	Sighting Time	Number of individuals	Elephant classification								Remarks
			AF	SAF	JF	AM	SAM	JM	Calf	UI	
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

AF: Adult female > 7 ft, SAF: Sub-adult female > 5–7 ft, JF: Juvenile female 4–5 ft,
AM: Adult male > 8 ft, SAM: Sub-adult male > 5–8 ft, JM: Juvenile male 4–5 ft, Calf: 3–4 ft, UI = Unidentified Individual

Appendix II

LINE TRANSECT DUNG COUNT DATA SHEET FOR ELEPHANT POPULATION ESTIMATION

Date:
Vegetation type:
Forest Division:
Transect length (Km):
Forest Range:
Location (Beat/Com.):
S. Point GPS reading:
E. point GPS reading:

Sl No.	Perpendicular distance of dung pile from transect (in m up to 1 decimal)	Remarks
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

Tally mark at every 50 m transect measurement using a nylon rope

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40

Appendix III

Details of line transect sampling, sample size, density of dung piles estimated and other distance sampling parameters used

Division name	Transect distance (*n*)	Sample size	Dung density			AIC (min)	% CV	Function key	Model
			Mean (SE)	LCL	UCL				
Bandipur TR	210 (105)	3396	3010.3 ± 571.02	2082	4352	6399	19.0	Hazard Rate	H. polynomial 15m CI
Bhannarghatta NP	26 (13)	492	1582.2 ± 137.98	1333	1877	1230	8.7	Hazard Rate	S. polynomial 15m CI
Bhadra WLS	22 (11)	121	460.2 ± 75.13	334	635	634	16.3	Hazard Rate	H. polynomial
BRT WLS	104 (52)	1787	2357.5 ± 285.94	535	650	1444	12.1	Uniform	S. polynomial 15m CI
Cauvery WLS	62 (31)	599	589.7± 29.11	1860	2988	4002	4.9	Hazard Rate	Cosine 20m CI
Chikmagalore	30 (15)	61	253.9 ± 35.40	192	335	144	13.9	Half-normal	Cosine 15m CI
Hassan	23 (12)	64	342.6± 49.21	257	455	278	14.4	Hazard Rate	Cosine
Hunsur T	26 (13)	502	1935.4 ± 174.12	1622	2309	1199	9.0	Hazard Rate	S. polynomial 15m CI
Nagarhole TR	114 (57)	1176	2608.0 ± 395.44	3192	3917	7454	15.2	Hazard Rate	Cosine
Kollegal	124 (62)	582	220.0 ± 8.72	204	238	1594	4.0	Half-normal	Cosine 15m CI
Koppa	24 (12)	88	640.14 ± 268.26	288	1424	89	41.9	Hazard Rate	Cosine 20m CI
Kudremukh NP	22 (11)	2	10.62 ± 0.000	11	11	6	0.0	Uniform	Cosine
Madikeri	88 (44)	458	670.5 ± 74.41	539	833	883	11.1	Hazard Rate	S. polynomial 15m CI
Madikeri WL	54 (27)	338	738.0 ± 60.30	629	867	676	8.2	Hazard Rate	Cosine 15m CI
Mandya	16 (8)	201	1336.4 ± 107.37	1141	1566	377	8.0	Half-normal	Cosine 20m CI
Mangalore	118 (59)	67	56.4 ± 6.48	44	72	167	12.1	Uniform	Cosine 15m CI
Mysore	20 (10)	151	769.1 ± 63.62	653	905	322	8.3	Half-normal	Cosine 20m CI
Ramnagara	52 (26)	162	179.3 ± 15.83	151	213	923	8.8	Hazard rate	S. polynomial
Virajpet	58 (29)	226	460.8 ± 27.53	410	518	525	6.0	Hazard rate	Cosine 16m CI
Overall	**1193 (597)**	**10721**	**1120.6 ± 14.00**	**1094**	**1148**	**24099**	**1.3**	**Half-normal**	**Cosine 15m CI**

Appendix IV

Guidelines for aging elephants using shoulder height parameter (Source: Sukumar 1989)

Age and growth parameters in Asian elephants

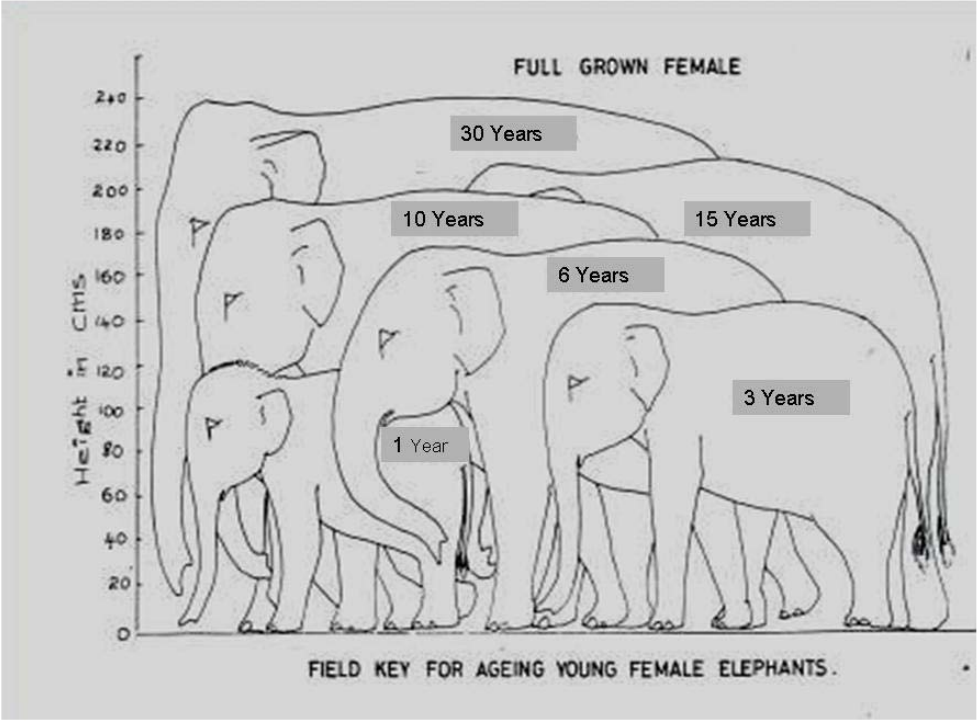
Age (years)	Height (cm)		Weight (kg)		Tusks in males	
	M	F	M	F	CTLL (cm)	Weight (kg)
0	90	89	120	120	—	—
1	121	119	330	310	—	—
2	139	135	520	470	—	—
3	155	149	705	610	7.6	0.1
4	169	161	920	710	9.8	0.2
5	180	170	1130	810	11.9	0.4
6	190	177	1340	930	13.8	0.7
7	198	183	1540	1055	15.7	1.1
8	205	188	1730	1180	17.4	1.5
9	212	193	1900	1300	19.0	2.1
10	217	197	2065	1415	20.5	2.6
11	222	200	2200	1525	21.9	3.2
12	225	203	2320	1635	23.3	3.9
13	228	206	2400	1735	24.5	4.6
14	231	209	2500	1830	25.7	5.3
15	235	213	2645	1925	26.8	6.1
20	250	228	2970	2300	31.3	10.0
25	262	234	3400	2560	34.6	13.6
30	268	238	3650	2740	37.0	16.8
40	272	240	3800	2930	40.0	21.4
∞	274	240	3900	3000	43.4	27.4

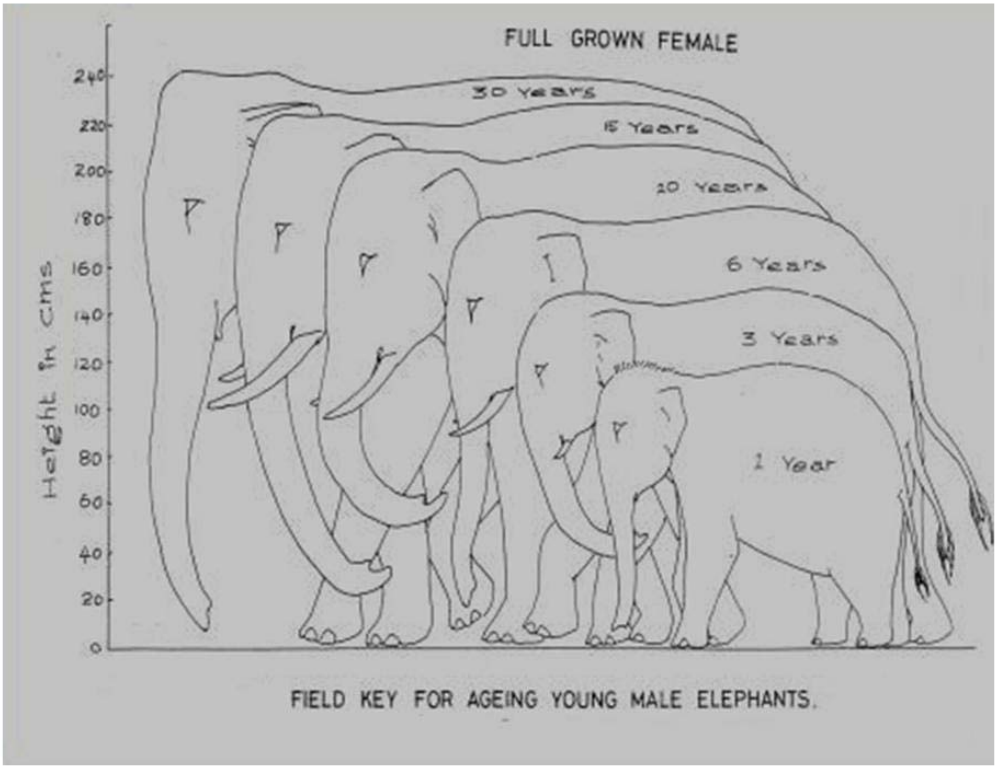
The height is twice the circumference of the front foot (CFF) for all ages.
Weights in juvenile animals are based on small sample sizes.

Continued…

Appendix IV

Pictorial guidelines for aging elephants using shoulder height parameter in comparison with adult individuals (Source: Sukumar 1989)





Appendix V

ELEPHANT WATERHOLE COUNT

Date :
Forest Division/WLS/NP/TR :
Forest Range :
Waterhole :
GPS Reading :

General vegetation type :
Weather (Sunny/Cloudy/Rainy) :
Location (Beat/Com.) :
Starting Time :
Ending Time :

Sl No.	Arrival Time	Number of individuals	**Elephant classification**								Departure Time	Remarks
1			AF	SAF	JF	AM	SAM	JM	Calf	UI		
2												
3												
4												
5												
6												
7												
8												
9												
10												

AF: Adult female > 7 ft, SAF: Sub-adult female > 5–7 ft, JF: Juvenile female 4–5 ft,

AM: Adult male > 8 ft, SAM: Sub-adult male > 5–8 ft, JM: Juvenile male 4–5 ft, Calf: 3–4 ft, UI = Unidentified Individual

Observer's Name:

APPENDIX VI

Comparison of 2010 block count data with earlier census

The present estimates [mean 5616 (by summation) or 5740 (by analysis)] for the state are comparable with that of 2002 estimates arrived by summation (mean 5848, 95% CI = 3974 to 7718 elephants – Appendix VII) but considerably higher as compared to the estimates of May 2005 (mean 4347 95% CI = 2375 to 6784 elephants Appendix VIII), and 2007 (mean 3935, 95% CI = 2677–5196). Such differences in the estimate of elephants among 2010, 2005 and 2007 for the state may not necessarily reflect any significant population size increment overall in the region but could also be due to changes in (i) visibility between years due to inter-annual variation in rainfall (ii) sampling effort or area coverage (number divisions surveyed) and (ii) spatial distribution of elephants within the landscape (that spread across interstate) during May 2005, 2007 and 2010; a factor mostly influenced by inter-annual variation in climatic conditions. It is worth mentioning here that the rainfall was significantly lower during 2002 as compared to 2005 and 2007 across the region. The elephants from Karnataka also range into adjoining forest divisions of Kerala and Tamil Nadu, as the elephant in Karnataka is part of larger the lager landscape contiguous to the adjoining states. Thus, for wide ranging species like elephants, a comprehensive assessment at population or landscape scale covering the forest divisions of contiguous elephant habitats in various states is essential to understand any fluctuations in the population size within a state or region. For example, in Kerala the estimated total number of elephants was 3850 during 2002 and it decreased marginally (3565 elephants) in 2005 and in 2007 the number rose drastically to 6068 elephants. Similarly Tamil Nadu also experienced considerable fluctuation between the three estimates (from 3052 elephants in 2002, it rose to 4015 elephants in 2005 and decreased to 3358 elephants in 2007 and 3328 elephants in 2010). Therefore, the increase in elephant numbers in Karnataka may have been due to their movement from adjoining contiguous habitats of Kerala and Tamil Nadu during May 2010.

Continued…..

Appendix VII

Elephant population estimated using block count method for various divisions in Karnataka during 2002 synchronized elephant census.

S. No	Division	No. of blocks sampled	No. of elephants counted	Total area km^2	Mean density and range of elephant numbers			Mean number of elephants
					Mean (number / km^2)	LCL	UCL	
1	Bandipur TR	59	843	874	2.26	1469	2487	1975
2	Nagarahole NP	57	555	642	1.78	842	1439	1143
3	Cauvery WLS	29	369	510.5	1.58	509	1109	807
4	BRT WLS	42	240	560.35	1.06	411	774	594
5	Kollegal	19	29	1145	0.31	190	518	355
6	Bhadra WLS	37	106	492.46	0.61	204	401	300
7	Brahmagiri WLS	13	32	181	0.65	50	184	118
8	Madikeri TT	36	42	373.32	0.23	64	105	86
9	Hunsur TT	8	33	104	0.7	18	126	73
10	Mysore	12	72	104	0.65	49	87	68
11	Bannerghatta NP	9	53	104	0.68	21	121	71
12	Hassan	2	27	384.8	0.22	27	85	56
13	Virajpet	34	25	336.96	0.15	33	68	51
14	Madikeri WL	11	24	197.66	0.25	18	81	49
15	Nugu WLS	3	25	32.32	0.82	12	41	27
16	Dandeli	34	3	834.74	0.02	11	23	17
17	Karwar	11	3	338.22	0.05	6	28	17
18	Belgaum	61	10	1448.82	0.015	21	22	22
19	Mandya	5	14	??		14	14	14
20	Chikamagalur	58	5	??		5	5	5
21	Haliyal	27	Nil	1165.9	NS	-	-	-
22	Yellapur	4	Nil	548.48	NS	-	-	-
	Karnataka	571	2510	10378.5	0.67	3974	7718	5848

LCL = Upper Confidence Limit, UCL = Upper confidence Limit
NIL – No sighting of elephant
?? – Block sizes and Total area of the Division not mentioned
TT – Territorial, WLS – Wildlife Sanctuary
WL – Wildlife Division, NP – National Park, TR – Tiger Reserve

Appendix VIII

Elephant population estimated using sample block count for the forest divisions of Karnataka during 2005 synchronized elephant census

S. No.	Division	No. of elephants sighted	No. of blocks [area sampled, km^2]	Mean elephant density/ km^2	Division Area km^2	Estimated population size	95% CL	
							LCL	UCL
1	Bandipur	459	38 [459]	1.34	906.32	1217	825	1610
2	Nagarahole	328	21 [262]	1.25	643.36	804	459	1149
3	Bhadra WLS	135	10 [124.4]	1.09	492.3	534	178	891
4	BRT WLS *	173	NA [207.7]	0.83	583.67	486	173	1052
5	Virajpet	60	28 [60]	0.88	337	297	142	332
6	Cauvery WLS	202	36 [236.6]	0.85	510.5	445	255	636
7	Kollegal	49	66 [398.5]	0.12	1145	151	114	188
8	Madikeri [T]	26	12 [131]	0.2	373.22	75	32	116
9	Bannerghatta *	52	4 [73.5]	0.71	104	74	52	160
10	Hunsur [T] *	16	4 [22.2]	0.72	142.7	16	16	114
11	Madikeri - WL	26	8 [82]	0.32	197.66	63	16	110
12	Hassan *	42	13 [140.22]	0.3	249.6	75	42	222
13	Bangalore Rural*	29	8 [84.12]	0.34	84.12	29	29	51
14	Mysore [T] *	11	4 [67.42]	0.16	131.52	17	11	47
15	Brahmagiri	7	5 [53.69]	0.07	181	13	6	21
16	Chikamagalur **	8	16 [NA]	NC	??	8	8	8
17	Mandya *	7	4 [85.4]	0.08	96.9	8	7	18
18	Dandeli *	5	59[346.09]	0.02	894.53	26	5	37
19	Belgaum	2	84 [NA]	-	1448.82	2	2	2
20	Karwar *	2	62 [455.5]	0.004	1421.78	6	2	19
21	Shimoga	1	NA		826.6	1	1	1
22	Haliyal	0	147 [359]	-	1421.78	0	0	0
23	Yellapur	0	100[??]	-	548.8	0	0	0
24	Koppa	0	46 [NA]	-	??	0	0	0
25	Bangalore Urban	0	1 [11.8]	-	??	0	0	0
26	Sirsi	0	60 [NA]	-	??	0	0	0
	Total	1640			12741.2	4347	2375	6784

* Divisions where LCL figure was towards minus side due to poor sample size or non-availability of block sizes, number of elephants sighted during the block count is shown as LCL.

** Block sizes and total area of the division of the division not available

Appendix IX

Elephant population estimated using sample block count for the forest divisions of Karnataka during May 2007

S. No.	Division	Elephants sighted	No. of blocks [area sampled, km^2]	Mean elephant density/ km^2	Division area km^2	Estimated mean elephant population	95% CL	
							LCL	UCL
1	Bandipur	486	57 [438.48]	1.1	906.3	1005	741	1268
2	Nagarahole	300	36 [326.44]	0.9	643.4	591	395	787
3	BRT WLS	331	49 (309.72)	1.08	540.0	581	417	745
4	Bhadra WLS	106	30 [158.97]	0.6	492.3	331	210	452
5	Cauvery WLS	129	22 (235.33)	0.6	519.0	285	163	406
6	Kollegal	136	47 (608.37)	0.2	1222.0	273	194	352
7	Virajpet	41	34 [95.5]	0.4	337.0	159	105	213
8	Bannerghatta	87	9 [61.33]	1.4	104.0	148	105	191
9	Mysore [T] *	34	5 [57.18]	0.59	176.7	105	34	208
10	Hunsur [T]*	54	7 [39.5]	1.37	71.4	98	54	117
11	Mandya	24	4 [44.5]	0.53	96.9	52	29	75
12	Brahmagiri	19	10 [97.6]	0.19	181.0	35	27	44
13	Dandeli WL	3	29 [182.07]	0.02	894.5	15	9	20
14	Hassan	13	4 [172.7]	0.08	249.6	23	14	25
15	Chikmagalur *	7	10 [59]	0.12	59.0	7	7	12
16	Madikeri - WL	2	14 [77.1]	0.03	197.7	5	2	8
17	Madikeri [T]$	16	16 (45.47)	0.26	373.2	98	47	149
18	Bangalore Rural @	115	26 (353)	0.33	353	115	115	115
19	Nugu WLS@	9	2 (20.32)	0.4	20.32	9	9	9
20	Koppa	0	0	0	??	0	0	0
21	Karwar	0	0	0	??	0	0	0
22	Haliyal	0	0	0	??	0	0	0
23	Yellapur	0	0	0	549	0	0	0
	Total for the State+	**1912**	**411 [3381. 58]**	**0. 57**	**7437. 25**	**4205**	**3800**	**4610**
	Total for the State!	**1912**	**411 [3381.58]**			**3935**	**2677**	**5196**

* In divisions where LCL figures were less than the elephants counted during sample block count, the number of elephants counted during the block count is treated as LCL.

$ Of the 37 blocks sampled, block sizes are given only for 16 blocks, which also vary widely from 15 - 0.1 km^2 and appear as approximate sizes.

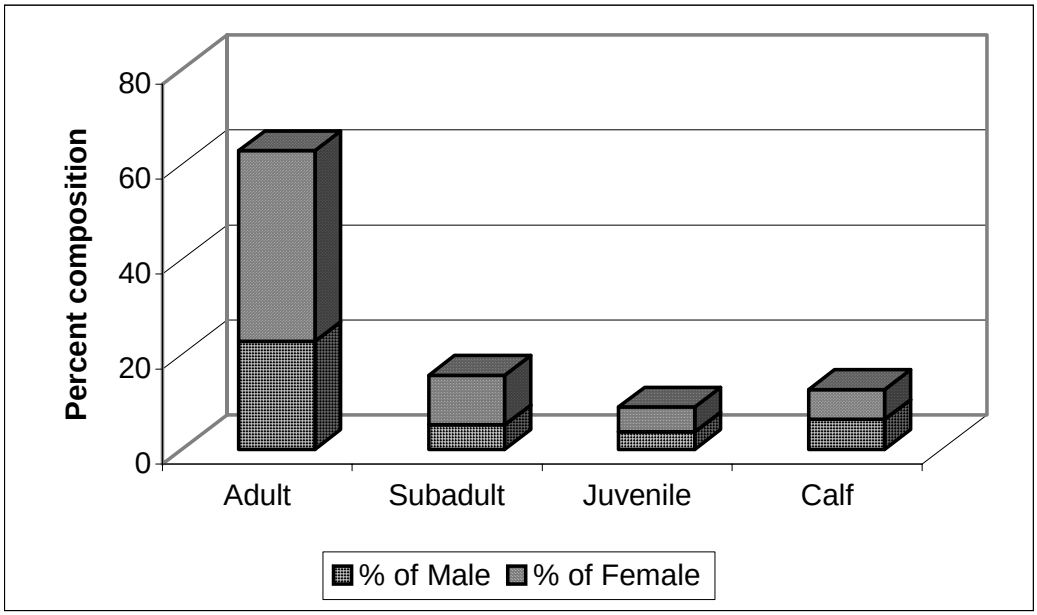
@ Total count

+ Pooled data of 19 forest divisions (excluding Koppa, Karwar, Haliyal and Yellapur Forest Divisions where no elephants sighted)

! Total for the state has been arrived by adding the figures of all the forest divisions.

Appendix X: Population structure recorded during earlier censuses

Fig. Age structure of elephants recorded in various forest divisions of Karnataka during the 2005 synchronized elephant census (includes data from sample block and waterhole counts: *n* = 2030).



The high % of adult class compared to other classes indicates that there could be misclassification of sub-adult class as adult class and juveniles as calves.

Table: Percentage of various age and sex classes of elephants recorded during sample block and waterhole counts in various Forest Divisions of Karnataka during May 2007 (*n* = 2404)

Age class	**Age structure (%)**			**Sex ratio M : F**
	Male	**Female**	**Total**	
Adult	16.8	35.3	52.0	1: 2.1
Sub-adult	4.5	15.1	19.5	1: 3.4
Juvenile	4.4	9.7	14.1	1: 2.2
Calf	7.2	7.2	14.4	1: 1.0
Total	**32.8**	**67.2**	**100**	**1: 2.0**