Synchronized Population Estimation of the Asian Elephant in Forest Divisions of Karnataka -2012

Final report submitted to Karnataka Forest Department – December 2012

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by

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With inputs from
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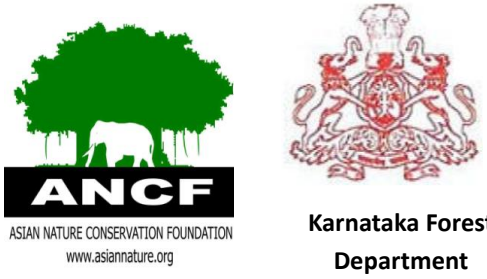

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Contents

Background

Karnataka Forest Department, in coordination with neighbouring southern states (Kerala, Tamil Nadu, Andhra Pradesh, Maharashtra and Goa), conducted a synchronized elephant census from 23rd to 25th May 2012 in the state. The aim of this exercise was to estimate the population of wild elephants by direct (sample block count) and indirect (line transect dung count) methods as recommended by Project Elephant Directorate, Ministry of Environment and Forests, Government of India, and also to assess population structure (age-sex composition and sex ratio) using data from direct sightings of elephants in block counts and observations at waterholes in these forest divisions. Wild elephants have been reported in 32 forest divisions of Karnataka and the total area of elephant distribution is approximately 11,300 km^2. Two forest divisions (Kundapura and Sagar) do not report elephants, though the occasional use of some of these areas by solitary bulls and herds cannot be ruled out. Karnataka state has presently one notified Elephant Reserve termed as Mysore Elephant Reserve (MER) that comprises forest divisions from Bhadra Wildlife Division in Malnad to Bandipur NP in the south along the Western Ghats, and from BRT WLS (Chamarajnagar) to Bannerghatta NP along the Eastern Ghats. This encompasses an area of nearly 11,300 km^2, ranging from wet evergreen forest through deciduous forest to dry thorn forest, harbouring one of the largest populations of Asian elephants.

Training programme and population estimation methods

A planning-cum-training workshop, held on May 10, 2012 at Bandipur National Park, Karnataka, was attended by forest managers (Conservator, Deputy Conservator and Assistant Conservator of Forests) along with technical experts from all the southern states. Criteria for selection of sample blocks, location of line transects and surveying of water-holes was discussed at this workshop and later finalized by the concerned officials for various forest divisions. The field enumeration (sample block count –Figure 1a- and line transect indirect (dung) count) and demographic profiling (water-hole observations-Figure 1b) was then executed (see appendix 1 for details on methods used) by the forest staff with the help of volunteers during May 23-25, 2012.

a

b

Figures 1a & b: Elephants sighted during population estimation through block count (a) and water hole observations (b)

Population data were analyzed (see appendix 1 for data processing) for individual forest divisions and also for the entire state.

Results

Sample block count based population estimation was carried out in 31 divisions (Figure 2), of which only 20 divisions reported elephants sighted in the sampled blocks. Line transect dung count was also carried out in 31 divisions (Figure 2) of which dung were encountered in 22 divisions (Table 1).

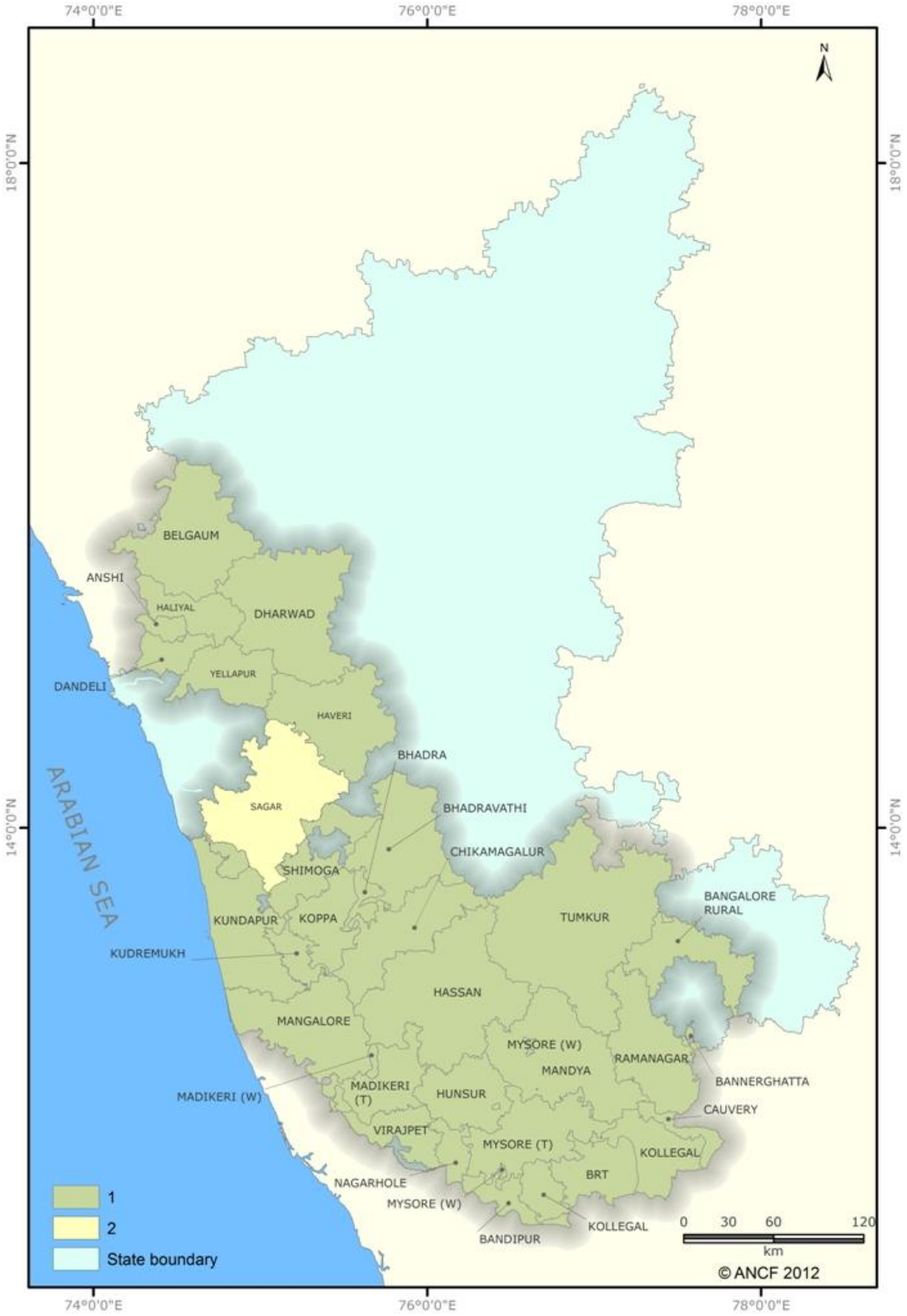

Figure 2: Map showing forest divisions where population estimation using sample block count and line transect indirect (dung) count methods was carried out (1, in green; in other divisions (2, in yellow) this exercise was not carried out.

Table 1: Details of number of blocks sampled and elephant counted, and transect length and numbers of dung piles encountered in various forest divisions in Karnataka.

Name of the Elephant Reserve	S. No	Forest Divisions	Block Count		Dung count	
			Number of blocks sampled	Elephants counted	Transect length (km)	No of dung piles
Mysore Elephant Reserve	1	Bandipur	61	662	122	61
	2	Bangalore Rural	2	0		
	3	Bannerghatta	16	78	55	28
	4	Bhadra	33	73	65	33
	5	BRT	50	208	98	49
	6	Cauvery	15	89	48	24
	7	Chikmagalur	14	8	41	21
	8	Hassan	9	15	19	9
	9	Hunsur (T)	13	70	26	13
	10	Kollegal	34	94	80	40
	11	Madikeri (T)	32	64	68	34
	12	Madikeri (W)	27	74	54	27
	13	Mandya	5	3	16	8
	14	Mysore (T)	9	3	20	10
	15	Mysore (W)	3	51	6	3
	16	Nagarahole	50	619	100	50
	17	Ramanagara	24	28	68	34
	18	Virajpet	41	65	70	35
	19	Tumkur	0	0	5	0
Proposed Dandeli Elephant Reserve	1	Anshi-Dandeli	39	32	96	48
	2	Belgaum	5	0	140	71
	3	Dharwad	29	0	4	0
	4	Haliyal	6	0	6	0
	5	Haveri	6	0	6	0
	6	Yellapura	37	0	37	0
Others*	1	Bhadravathi	9	0	17	9
	2	Koppa	18	0	38	19
	3	Kudremukh	42	0	-	-
	4	Kundapura	31	0	-	-
	5	Mangalore	119	4	208	104
	6	Sagar	-	-	-	-
	7	Shimoga (W)	10	1	-	-

(T): Territorial Forest Division; (W): Wildlife Division; *: Divisions with occasional elephant presence; - : no population estimation by dung or block was made.

Sample block count

The sizes of the sampled blocks varied considerably; while most of the blocks were in the range of 1-20 km^2, some blocks were smaller or much larger, exceeding 100 km^2. Results of elephants counted to area ratio (for each of the block size-classes from about 1 to >13 km^2) indicate that block sizes of 3 to 7 km^2 would maximize detection and elephant count. This ratio peaked (at 1.04) for block sizes of 5 to 6 km^2,

(see appendix 2 for more details) implying that in future population estimation exercises, block size must be maintained at this size (i.e. 5-6 km^2) as clearly instructed in past years to maximize detection of elephants (Figures 3a & b) and ensure the least biased estimate of the population.

a

b

Figures 3a & b: Illustration of sample blocks enumerated for elephants; (a) perambulation of block by a team (b) sighting of an elephant in a block (note the poor visibility in this block that reduces elephant detection)

Elephant density varies widely across the state with the highest densities found in the Mysore Elephant Reserve (Figures 4a & b). Apart from making estimates of elephant densities (Figures 5) and numbers for each forest division, we also computed elephant density separately for the Mysore Elephant Reserve (MER) by pooling data from blocks sampled within the reserve.

As including data from all sampled blocks would result in underestimate of elephant density, we used only data from blocks <12.3 km^2 (from 19 forest divisions, fall within Mysore Elephant Reserve with elephant distribution area of 7336 km^2, excluding Tumkur and Bangalore Rural Divisions that do not normally have elephants).

a

b

Figures 4a & b: Elephants sightings in Mysore Elephant Reserve during sample block count method

This gave a density estimate of 0.81 elephant/km^2 with corresponding elephant population estimate of 5945 (5556–6333; 95% CI) individuals for the MER. To this figure has to be added 127 (range 92-155) elephants from 11 forest divisions (as ascertained by the local forest officials) that have very sparse elephant distribution and meaningful sample block was not possible or carried out. Thus, the elephant population for the state from pooled data for MER using sample block counts is estimated at 6072 (5648-6488; 95% CI)-Table 2.

Table 2: Estimated Elephant number for Karnataka State, based on the results of pooling forest divisions of Mysore Elephant Reserve, Proposed Dandeli Elephant Reserve and other forest division that have occasional elephant presence

S. No	Region	Elephant number	95% LCL	95% UCL
1	32 Forest Divisions	**6072**	5648	6488

Estimates for individual forest divisions using the same method incorporating only data from blocks <12.3 km^2 are provided in Table 3.

Table 3: Elephant numbers estimated for different forest divisions in Karnataka. Divisions 1-19 represent areas falling with the Mysore Elephant Reserve. LCL and UCL represent 95% CI.

	S.No	Forest Division*	Area km^2	Elephant number	LCL	UCL
Mysore Elephant Reserve	1	Bandipur	906	**1697**	1223	2171
	2	Bannerghatta	104	**78**	77	89
	3	Bhadra	492	**188**	123	253
	4	BRT	540	**480**	345	614
	5	Cauvery	527	**255**	255	550
	6	Chikamagalur	79	**8**	4	12
	7	Hassan	299	**75**	23	127
	8	Hunsur	78	**70**	30	110
	9	Kollegal	1227	**278**	278	601
	10	Madikeri (T)	1052	**273**	176	369
	11	Madikeri (W)	344	**192**	118	266
	12	Mandya	97	**3**	3	6.9
	13	Mysore (T)	56	**3**	1	5
	14	Mysore (W)	30	**51**	51	125
	15	Nagarahole	643	**1320**	950	1690
	16	Ramanagara	746	**169**	106	232
	17	Virajpet	116	**65**	46	84
	18 & 19	Tumkur & Bangalore Rural	1108	**0 (5)**	4	6
Proposed Dandeli Elephant Reserve	20	Anshi-Dandeli	824	**47**	32	62
	21	Belgaum	36	**0 (6)**	6	8
	22	Dharwad	247	**0 (8)**	6	8
	23	Haliyal	1183	**(15)**	10	20
	24	Haveri	331	**(7)**	4	8
	25	Yellapur	1660	**(20)**	18	22
Others	26	Bhadravathi	322	**3**	1	3
	27	Koppa	165	**0 (-)**	-	-
	28	Kudremukh	252	**0 (7)**	5	8
	29	Kundapura	1037	**0 (-)**	-	-
	30	Mangalore	742	**5**	4	6
	31	Shimoga (W)	55	**1 (3)**	1	3
	32	Sagar	1218	**(1)**	-	-

- Elephant numbers in brackets are based on information obtained from Karnataka Forest Department. In Sagar Division no census was carried out.

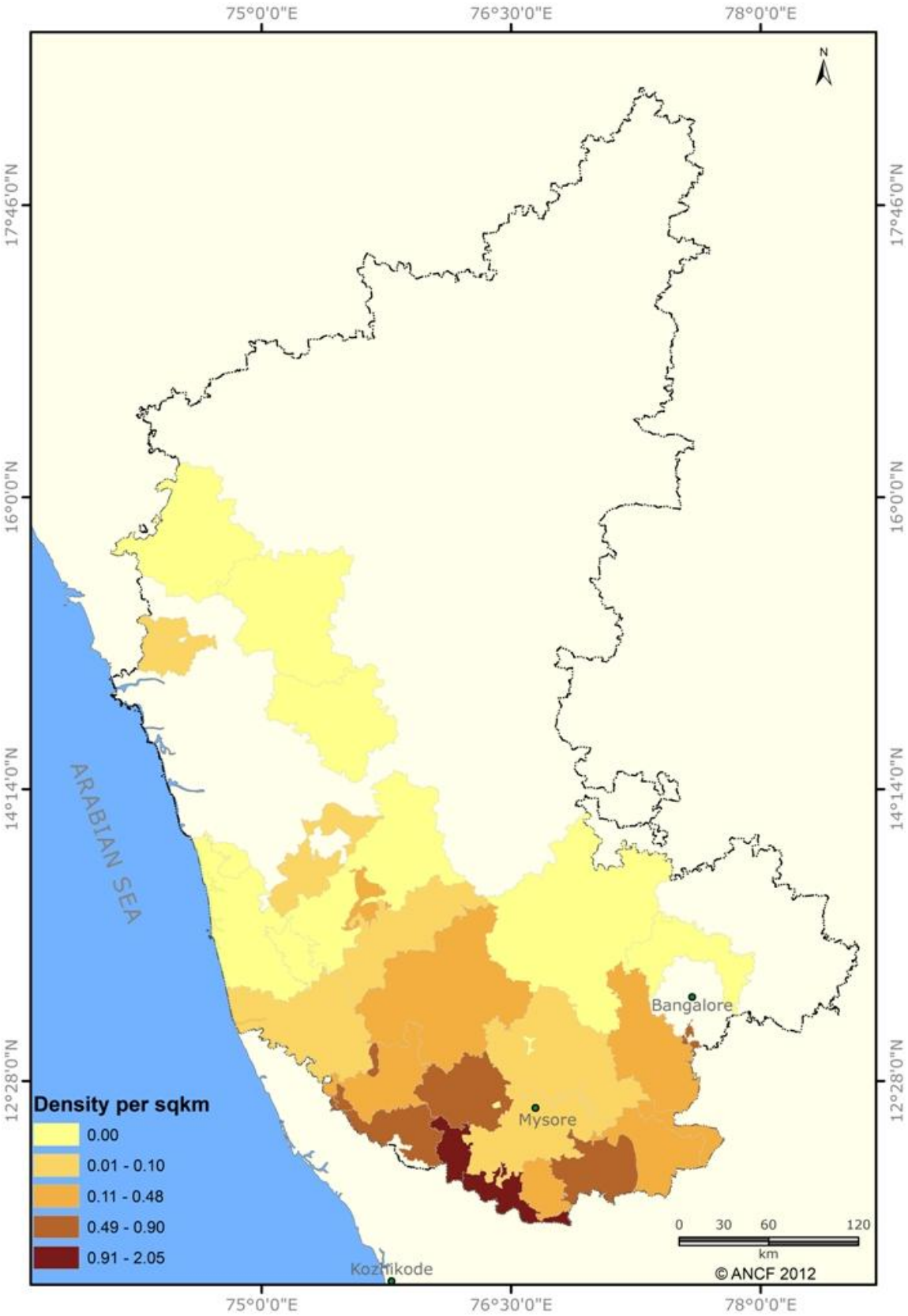

Figure 5: Map showing density of elephants (individuals per sq. km) by sample block count method for forest divisions in Karnataka

Line transect indirect (dung) count

In total, 770 transects covering a length of 1536 km were laid to estimate dung density across 22 forest divisions of Mysore ER as well those adjoining the ER in the state. Of 9921 dung piles, 96% were used in estimation of dung density by truncation of data at a perpendicular distance of 12m. Elephant numbers estimated for individual forest divisions are given in Table 4 & Figure 4.

Table 4: Elephant population estimated by dung count method in different forest divisions of Karnataka

S. No	Forest Division	TL	NT	DD	SE	ED	LL	UL	H	EN	LCL	UCL
1	Bandipur	122	61	2333	277.2	**1.39**	0.74	2.21	906	**1263**	674	2000
2	Bannerghatta	55	28	2140	560.2	**1.27**	0.48	2.39	104	**133**	50	250
3	Bhadra	65	33	1993	293.2	**1.19**	0.63	1.9	492	**586**	312	936
4	BRT	98	49	1910	206.7	**1.14**	0.62	1.81	540	**617**	335	976
5	Cauvery	48	24	596	85.4	**0.36**	0.2	0.58	527	**187**	103	303
6	Chikamagalur	41	21	593	185	**0.40**	0.1	0.7	79	**28**	9	51
7	Hassan	19	9	252	48.7	**0.15**	0.26	7.44	299	**45**	*	*
8	Hunsur (T)	26	13	2274	394	**0.36**	0.69	2.26	78	**28**	54	176
9	Kollegal	80	40	439	81.5	**0.26**	0.13	0.45	1227	**319**	161	548
10	Madikeri (W)	54	27	676	125	**0.40**	0.19	0.67	344	**138**	65	230
11	Madikeri (T)	68	34	813	126.7	**0.49**	0.25	0.8	1052	**512**	266	845
12	Mandya	16	8	517	88.4	**0.31**	0.15	0.52	97	**30**	15	50
13	Mysore (T)	20	10	435	138.9	**0.26**	0.5	7.42	56	**15**	28	418
14	Mysore (W)	6	3	690	321.1	**0.42**	0.9	1.73	30	**13**	*	*
15	Nagarahole	100	50	2810	265.1	**1.68**	0.97	2.55	643	**1078**	622	1637
16	Ramanagara	68	34	438	114.2	**0.27**	0.1	0.48	746	**199**	77	352
17	Virajpet	70	35	437	92.2	**0.26**	0.13	0.45	116	**30**	15	52
18	Tumkur	0	0	0	0	**0**	0	0	0	**0**	0	0
19	Bangalore Rural	-	-	-	-	-	-	-	-	-	-	-
20	Anshi-Dandeli	96	48	145	48.5	**0.10**	0.2	2.3	824	**66**	*	*
21	Belgaum	140	71	4.9	2.7	**0**	2.7	7	36	**0**	99	251
22	Dharwad	0	0	0	0	**0**	0	0	0	**0**	0	0
23	Haveri	0	0	0	0	**0**	0	0	0	**0**	0	0
24	Haliyal	-	-	-	-	-	-	-	-	-	-	-
25	Yellapur	-	-	-	-	-	-	-	-	-	-	-
26	Bhadravati	17	9	79	23.5	**0.05**	1.52	8.75	47	**2**	*	*
27	Koppa	38	19	311	94.4	**0.20**	0.3	6.3	166	**31**	*	*
28	Kudremukh	-	-	-	-	-	-	-	-	-	-	-
29	Kundapura	-	-	-	-	-	-	-	-	-	-	-
30	Mangalore	208	104	67	19.7	**0**	1.3	7.5	742	**30**	*	*
31	Shimoga (W)	-	-	-	-	-	-	-	-	-	-	-
32	Sagar	-	-	-	-	-	-	-	-	-	-	-
		1536	770						9395			

TL: Transect length in km; NT: Number of Transects; DD: Dung density/km^2; SE: Standard Error; **ED: Elephant density/km^2**; H: Habitat area in km^2; LCL: Lower 95% Confidence Limit; UCL: Upper 95% Confidence Limit; **EN: Elephant numbers** *CI values are meaningless due to very low sample size of dung

When data from 17 forest divisions of MER are pooled for analysis, a mean density of 0.89 elephant/km^2 (95% CI = 0.54-1.13) was estimated over an elephant distribution area of 7336 km^2; this translates into 6521 elephants (3973-9530, 95% CI) for Mysore Elephant Reserve (Table 5).

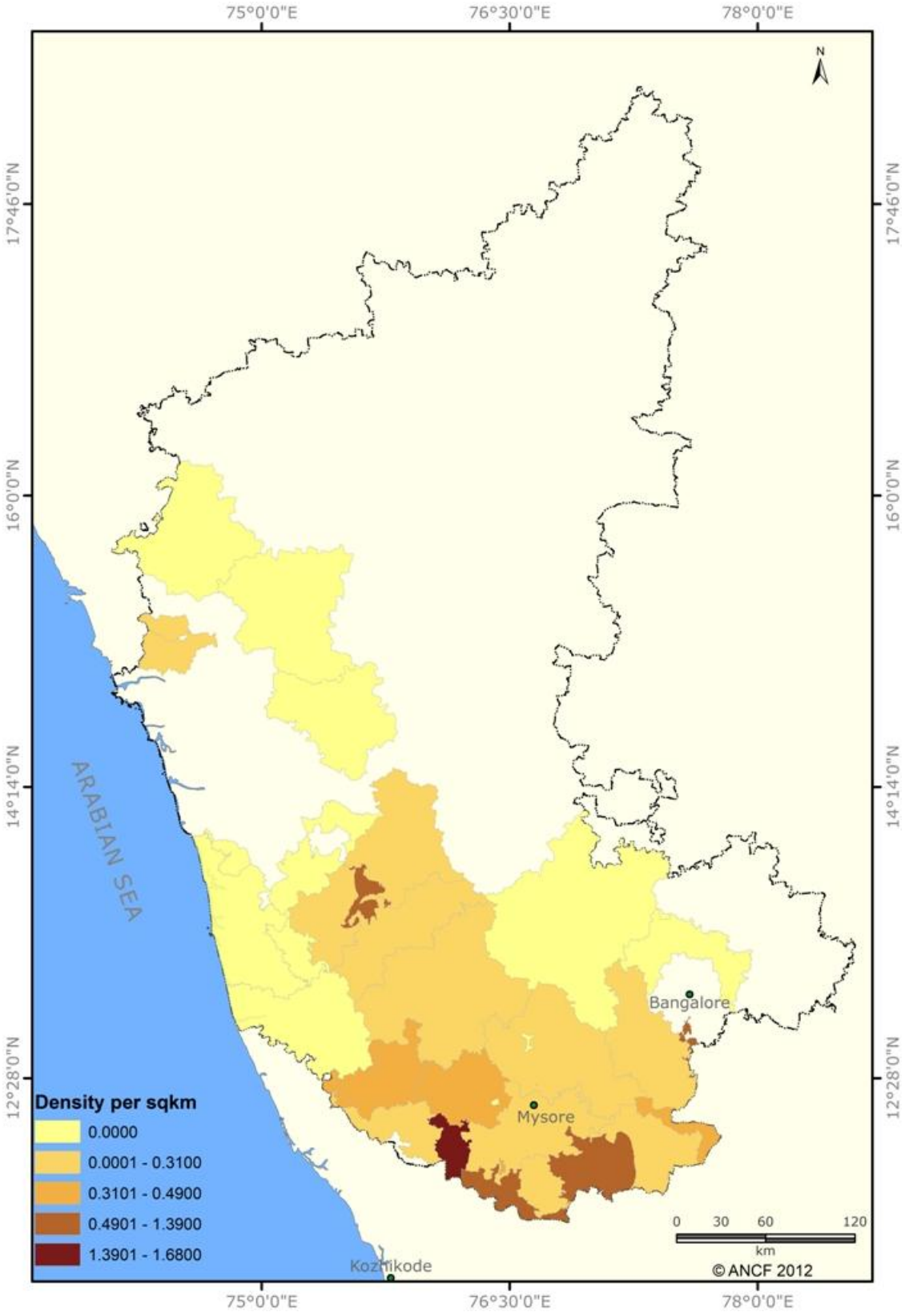

Figure 6: Map showing density of elephants by line transect indirect (dung) count method for forest divisions in Karnataka

Table 5: Elephant density and number estimated based on pooling 17 forest divisions of Mysore Elephant Reserve, 2 divisions of Anshi-Dandeli & Belgaum, and 4 divisions of Koppa, Kudremukh, Mangalore & Bhadravati.

S. no		TL	NT	DD	SE	ED	LCL	UCL	H	EN	LCL	UCL
1	Mysore Elephant Reserve	936	500	1491.9	81.3	**0.89**	0.54	1.13	7336	**6521**	3973	9530
2	Anshi-Dandeli & Belgaum	238	119	64.2	20.5	**0.03**	1.20	7.30	860	**26**	-	-
3	Koppa-Kudremukh-Mangalore & Bhadravati-	359	181	130.0	26.9	**0.08**	0.13	3.82	1207	**97**	-	-

TL: Transect length in km; NT: Number of transect; DD: Dung density/km^2; SE: Standard Error; **ED: Elephant density/km^2**; H: Habitat area in km^2; LCL: Lower 95% Confidence Limit; UCL: Upper 95% Confidence Limit; **EN: Elephant numbers**.

Overall status of elephant and their distribution in Karnataka

Results of the sample block and dung count, together with information obtained from forest officials, provide information on the current status of elephants and their spatial distribution in the state (Figure 7). The Mysore Elephant Reserve (MER) constitutes the major elephant region of the state, comprising about 65% of the elephant distribution area but 98 % of the wild elephant population. However, within the 19 forest divisions of MER, elephant movements in 2 divisions, namely, Tumkur and Bangalore (rural) Divisions are seasonal.

About 4 to 5 elephants from Savandurga RF of Ramanagara Division move into these divisions on occasion. In Bangalore (rural) Division, only Nelamangala Range with an area of 22.5 km^2 (11% of the total area of division) is reported to have elephants. Bannerghatta and Kanakapura regions are the source for elephants to Tumkur Division during December and January. Most of elephant habitat area of Ramanagara has been added to Bannerghatta NP and currently 20-30 elephants have been reported in this division.

Outside the MER, the presence and movement of elephants is diffuse and often seasonal, making it difficult to obtain objective estimates. Within the proposed Dandeli Elephant Reserve, the main elephant distribution area falls in the Anshi-Dandeli Forest Divisions. Kalgatgi Range of Dharwad Division and Hanagal Range of Haveri Division have occasional movements of 6 to 7 elephants from areas in and around Dandeli Wildlife Sanctuary. Deputy Conservator of Forests (Dharwad) has recently reported 8 adult and 3 calves/juvenile elephants in Dharwad Division. Only 3% of Haveri Division constitutes elephant habitat area, with elephants being sighted from October to December, reportedly coming here from Yellapur Division. Up to 40 elephants have been reported in Yellapur Division, with about half of them being resident and the rest moving here from Anshi-Dandeli especially during crop season from June to January. Elephants from Yellapur also visit Haliyal. Belgaum also has seasonal occurrence of 6-8 elephants coming from Dandeli during June to January.

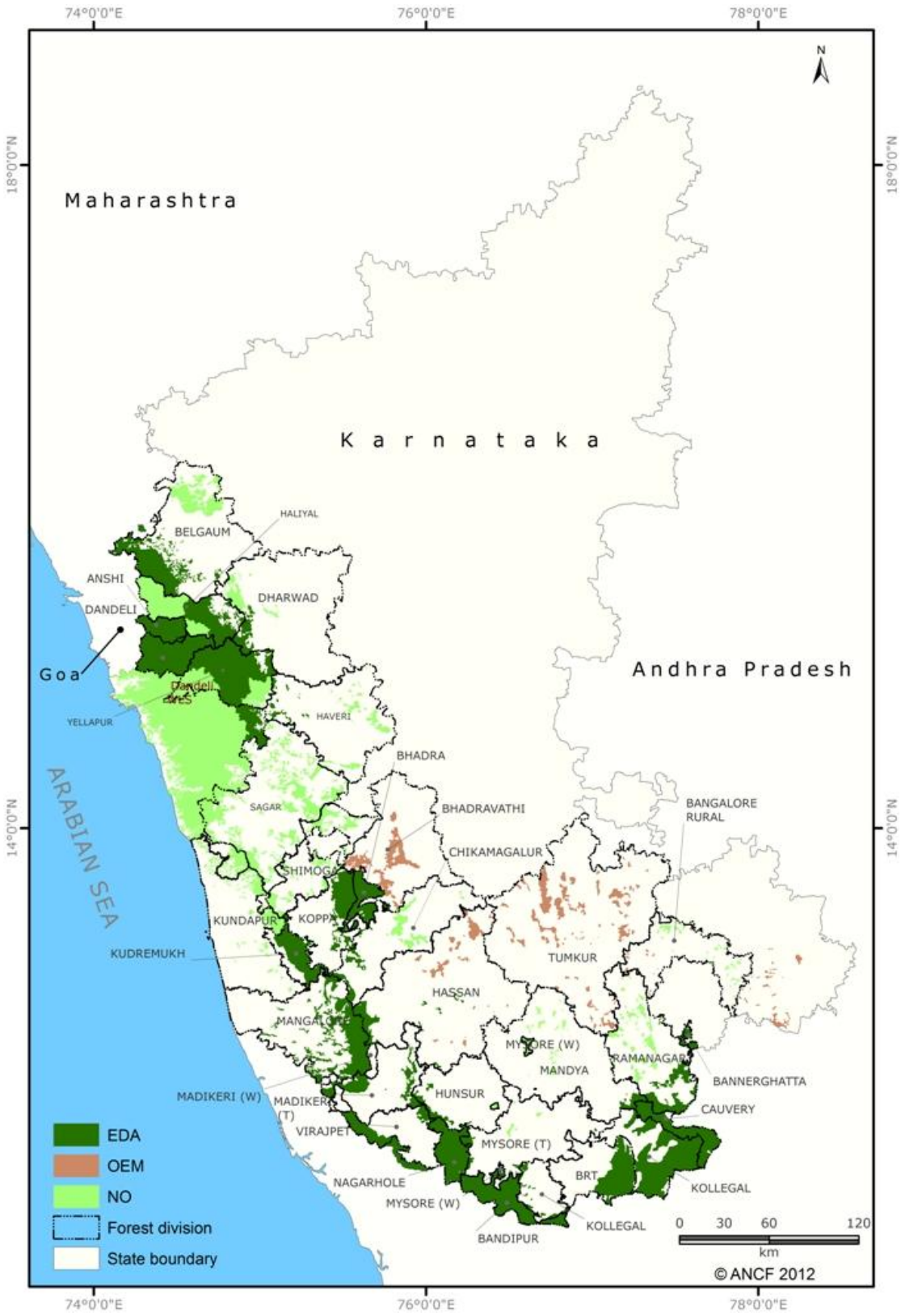

Figure 7: Map showing the distribution of Asian elephant in Karnataka (EDA: Elephant distribution area; NO: No elephants, OEM: Occasional elephant movement)

Sagar Division is not part of proposed Dandeli Elephant Reserve; however, this division report rare occurrence of a tusked elephant said to be from Dandeli. Certain parts of Sagar Division such as Sagar Range also had elephant movement reportedly from the Koppa Division in the past few years (observed during 2011 and 2012). Tarikere Range of Bhadravathi Division has occasional presence of 4 to 5 elephants from Bhadra Wildlife Division.

This division has 7 forest ranges of which 2 ranges (Tarikere & Shantisagar) report presence of elephants and about 34% of area of the division is said to be elephant habitat area. In Kudremukh Division, 6 to 7 elephants are reported. Only one elephant was sighted in 2009 in Kundapur Division. Mangalore has 7 ranges of which 5 ranges report the presence of 4-5 elephants. Shimoga Wildlife division has 3 resident elephants in Shettihalli Wildlife Sanctuary adjoining the areas of Bhadra Wildlife Division.

Population Structure (Sex and age classification)

The population structure assessed based on 3007 elephant sightings that were age-sexed show that adults constitute 53% of the population (males 14%, female 39%). The remaining (47%) population consists of younger age classes such as sub-adults (male 6% and female 16%), juveniles (male 6% and female 7%) and calves (13%). The overall male-to-female sex ratio is 1:2.4 (irrespective of age) with skew being more visible at 1:2.7 in the adult age class.

Salient observations of the 2012 enumeration

Bandipur NP and Nagarahole NP were the only protected areas with more than 1000 elephants each as estimated using both methods.

Bandipur and Nagarahole National Parks showed densities of more than one elephant per square kilometer by both sample block count and dung count methods (Bandipur NP-1.9, 1.4; Nagarahole NP-2.1, 1.7). Bannerghatta, BRT and Hunsur (T) showed medium densities at 1.0 to 1.4/ km^2 using both methods. All other forest divisions had densities below 1 elephant/km^2.

The overall elephant population estimates were higher by the dung count method as compared to the sample block count method in which a certain degree of underestimation can be expected due to incomplete detection of elephants, especially in the larger blocks. Estimated numbers of elephants by the two methods were, however, not statistically different from both the methods for 16 forest divisions.

There were no elephant sightings in 7 divisions and no dung piles encountered in 4 divisions because of very low density. Estimates for these divisions were based on inputs from the forest officials.

The sex ratio of adults is unlikely to be accurate as the male:female ratio of 1:2.7 deviates markedly from elephant population data from research studies over the past ten years at places such as Nagarahole and Bandipur National Parks.

Summary of Recommendations

1. Sample block counts:

a) It is important for sample blocks to be selected at random, as any bias in selection would result in inaccurate density estimation.

b) It is essential that block sizes have to be kept to the recommended optimum size of 5-6 km^2 to maximize detection of elephants and minimize bias toward underestimation. Blocks have to be demarcated on maps using natural features (streams, ridges) and roads such that the frontline staff engaged in enumeration clearly understand the extent of area they have to perambulate. While surveying, those with access to GPS units can use it in track mode in order to know the exact area covered.

c) Trained researchers may be deputed to each of the forest divisions (or at least the major elephant divisions) to assist in selecting beats and water-holes for survey purpose. The effort put in by the staff and volunteers would be wasted if there were flaws in the design of the survey itself.

Considering the work load of staff at the officers' level in the forest department, it would be less of a burden for them if observers or researchers were involved in training field staff in the survey methods and concepts. This would ensure that the normal schedule of officials is not interrupted during the survey.

2. Indirect line transect dung count:

a) The major shortcoming of the dung count method is the failure to carry out dung decay rate experiments beginning several months prior to the line transect exercise. This has consistently happened during every major elephant census exercise and should be rectified in the next census.

3. Waterhole count for population structure:

a) For the survey on age-sex classification, inputs from observers are invaluable; this, however, does not eliminate the need for taking photographs. Photographs should be the basis for age-sex classification. It has been observed that volunteers with equipment and opportunity to photograph elephants during the survey do not provide copies of the same to the survey staff (either due to oversight or otherwise).

Selected supervisors for each beat/range/division could check that copies of any photos taken are handed to the staff. Copies of all photographs (from staff or volunteers) of elephants have to be stored in a computer or a compact disc and maintained by the department.

b) Enumerators need better training in aging elephants, especially adult male elephants. They tend to consistently overestimate the age of male elephants, resulting in incorrect male: female ratios.

Captive elephant population:

Karnataka also has 161 elephants in captivity (Table 6) of which 56% is found in different forest camps, and 18% are kept in 2 zoos and one biological park. Elephants belonging to temples and private individuals contribute the remaining 26% of the total captive elephant population of the state.

Table 6: Status of captive elephants in Karnataka (in 2012)

S. No	Type of facility	Name of the location	Number	Total
	Forest department camps			
1		Nagarhole	34	
2		Bandipur	18	
3		BRT	3	
4		Madikeri	19	
5		Shimoga	17	91
	Zoos & Biological park			
6		Mysore Zoo	8	
7		Bannerghatta	19	
8		Pilikula, Nisargadhama	2	29
9	Temple	Temples	31	
10	Private	Private	10	41
		Total	161	

Appendix 1:
Methods of population estimates and demographic profiling

Population estimation methods
Given the practical challenges in estimating the population of even a large mammal such as the elephant. a prudent approach would be to use more than one method in this exercise to look at the degree of convergence of the results. Among various methods in vogue over the past 3-4 decades in estimating elephant populations, two have been consistently employed in Karnataka since 2002 considering their relative simplicity and the capacity of a large force of frontline forest staff to employ the methods in the field with least possible training:

- Direct sighting of elephants using "sample block count" method
- Indirect estimate using "line transect dung count" method

Sample block count
Sample block count involves direct sighting of elephants by the survey team in each selected block and is conducted simultaneously across the state on a given day. During the training programme it was emphasized that block sizes should ideally be about 4-6 km^2. In practice, however, blocks of sizes ranging from 0.02 to 133 km^2 (mean 8.20 km^2, 49% of blocks were between 4 and 7 km^2) were sampled in the state. The number of blocks sampled depended on the size of the forest division; the goal was to sample 30-50% of the area of a forest division. It should be noted that block size would be approximate as there are no boundary markers to separate them in the field though the area was marked on maps using natural features such as streams, ridges and roads. In each block, two to three personnel (Figure 8a) perambulated the area carefully trying to locate the presence of elephants from sounds of animals feeding, moving through the forest, or vocalizing. Care was taken to avoid double counts and making sure all elephants detected were counted (Figure 8b) and, if possible, age-sex classified.

a

b

Figures 8a & b: Sample block count; (a) team of enumerators (b) sighting of elephants in a sample block

Data Analysis: Data collected from the field exercise, that includes details of number of elephants counted (y_i), the area sampled (x_i) and total area of the division (X_i) was used in a formula given in Lahiri-Choudhury 1991 for sample blocks of unequal size;

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

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

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

where

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 j^{th} block j=1,2..n

$\mathbf{x_j}$ = Area in km2 of j^{th} block

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

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

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

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

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

(y/ x) = Estimate of elephant density/ km2

Line transect dung count method

Dung count using line transect surveys (Burnham *et al*. 1980) are indirect estimates of an animal population from three variables, namely, dung density, dung decay rate and dung defaecation rate (Barnes and Jensen 1987). Line transects were laid in all the forest divisions in the same blocks where sample block count was undertaken to estimate dung density.

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 (Figures 9a), the perpendicular distance of the dung pile from the line was recorded (Figure 9b) in the data sheet supplied to the team. From the data on perpendicular distance to dung piles and transect length the dung density is estimated. Using dung density estimates, elephant density is calculated using specific software.

a

b

Figures 9a & b: Line transect indirect (dung) count method; (a) sighting of a dung pile; (b) recording perpendicular distance of the dung pile from the transect line

Data collection

Transects were laid in beats selected by the department, each transect serving to cover a beat. This was done in 28 forest divisions. Length of the transect line was generally 2km. On a given day, all transects were walked by teams of local staff and volunteers throughout the selected divisions (ranges, beats). Each team comprised of three persons: one to maintain the transect, one to spot dung piles while walking on the line and another to measure the perpendicular distance.

Data recorded for each transect line were the following:
Division, range and beat name
GPS readings of start and end of transect line
Vegetation type
Transect length
Perpendicular distance (m) to observed dung pile
Remarks (any observations on the dung pile, etc)

Data processing

The data received from the forest department was in two forms: stored in a Compact Disc and as datasheets (hard copy). These were analyzed to obtain density estimates of elephants.

This involved the following operations:

- Arranging the data in a format amenable for processing— from word files to spreadsheets and formatting data in spreadsheets to suit analysis
- Arranging the data in uniform units of measurement (kilometers and meters)
- Checking the data for errors by comparing with entered data in the sheets
- Arranging the data range-wise and division-wise

The data thus arranged were used for estimation of dung density for each division. Density estimation was arrived at using DISTANCE (version 6.0, release 2) a program meant for arriving at density estimates using the perpendicular distances recorded on line transect under certain assumptions (Buckland et al. 1993; Thomas et al. 2010).

Dung density estimates were then converted to elephant density estimates for the region using the stochastic simulation program GAJAHA Ver. 2.0 (Prasad and Sukumar 2007; also see Santosh and Sukumar 1995) using the formula developed by Barnes and Jensen (1978). As dung decay rate experiments were not carried out in the state nor defaecation observations made, the default dung decay rate of 0.0097 (SE= 0.002) (Varman et al. 1995) and defecation rate of 16.33 (SE= 0.08) (Watve 1992) were used.

Elephant density was estimated by using the formula:
$E = (Y \times r)/D$

where

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

Thus, density estimations are a function of both decay rate and defecation rate. While the latter does not vary much, it is essential that dung decay rates are estimated prior to the line transect survey for several regions with different climatic regimes in the state following internationally accepted protocols (Hedges and Lawson 2006).

Population demography assessment

Data on population structure were collected during the sample block count and by monitoring waterholes in forest divisions. During both the sample block count and waterhole observations (Figures 10 & b), apart from recording the number of elephants, the age and sex of the elephants seen were also recorded, wherever possible. Sex was differentiated based on presence or absence of tusks for animals above two years. Individuals <2 years were not sexed, while enumerators were also trained to try and 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). Individuals were recorded as 'Unidentified' if they could not be categorized into a specific age and sex (see also Arivazhagan and Sukumar 2005).

a

b

Figures 10a & b: Waterhole observations; (a) observers near a river waiting for the arrival of elephants, (b) a herd of elephants at a river where they can be clearly seen and classified.

Appendix 2:

Exploratory analysis of detection of elephants in blocks of varying sizes

It was found during exploratory analysis of data that 362 out of 701 blocks (nearly 50%) were less than or equal to the stipulated 5 km^2 block size (Table 6). It was seen from a calculation of Elephant to Area ratio (for each of the block size-class from 1 to 13 km^2) that block sizes 3 to 7 km^2 would maximize elephant count. This ratio peaked for block sizes of 5 to 6 km^2 with a value of 1.04 (Table 1). We must emphasize that a value close to 1 does not imply complete detection but merely reflects a density value of one animal per square kilometer (this value is obviously a mere coincidence and would vary depending on the density of elephants in a region). We can, however, conclude that in future population estimation exercises block size must be maintained as instructed around 3-7 km^2 to ensure proper estimation and Table 7 gives a detailed representation of frequency and cumulative frequency of elephants and blocks in their respective block size-class

Table 7: Detailed representation of frequency and cumulative frequency of elephants and blocks in their respective block size-class

Block size class (km^2)	Frequency of block size	Cumulative frequency of block size	Number of elephants sighted	Total area of sampled blocks (km^2)	Cumulative area of sampled blocks (km^2)	Cumulative frequency of elephants sighted	Elephant to Area ratio
0 to 1	41	41	0	9.3	9.3	0	0
1 to 2	33	74	26	55.5	64.7	26	0.5
2 to 3	27	101	23	71.5	136.3	49	0.3
3 to 4	63	164	177	228.2	364.5	226	0.8
4 to 5	198	362	679	950.4	1314.9	905	0.7
5 to 6	**81**	**443**	**470**	**451.0**	**1765.8**	**1375**	**1.0**
6 to 7	65	508	326	426.2	2191.9	1701	0.8
7 to 8	29	537	105	217.2	2409.2	1806	0.5
8 to 9	29	566	70	246.8	2655.9	1876	0.3
9 to 10	27	593	33	259.3	2915.3	1909	0.1
10 to 11	15	608	79	158.0	3073.0	1988	0.5
11 to 12	12	620	17	140.0	3213.0	2005	0.1
12 to 13	7	627	0	87.0	3300.0	2005	0.0
>13	74	701	236	2462.0	5762.0	2241	0.1

For the given data, however, since a fairly large proportion of the block sizes was larger than the stipulated, it was decided to eliminate block sizes above a certain size as these could creating noise in the data and also bias towards underestimation (accounting for large areas but very few elephant numbers and do not form part of the larger dataset) by using a box-plot in R version 2.9.2 with a cut-off of 12.20 km^2. By eliminating the outliers (Figure 11), a total of 53 elephant counts were removed from an area of 1937 km^2. Although an area of 5 km^2 been recommended for sample block count method in order to satisfy the assumptions, it was not been possible to ensure this in this field.

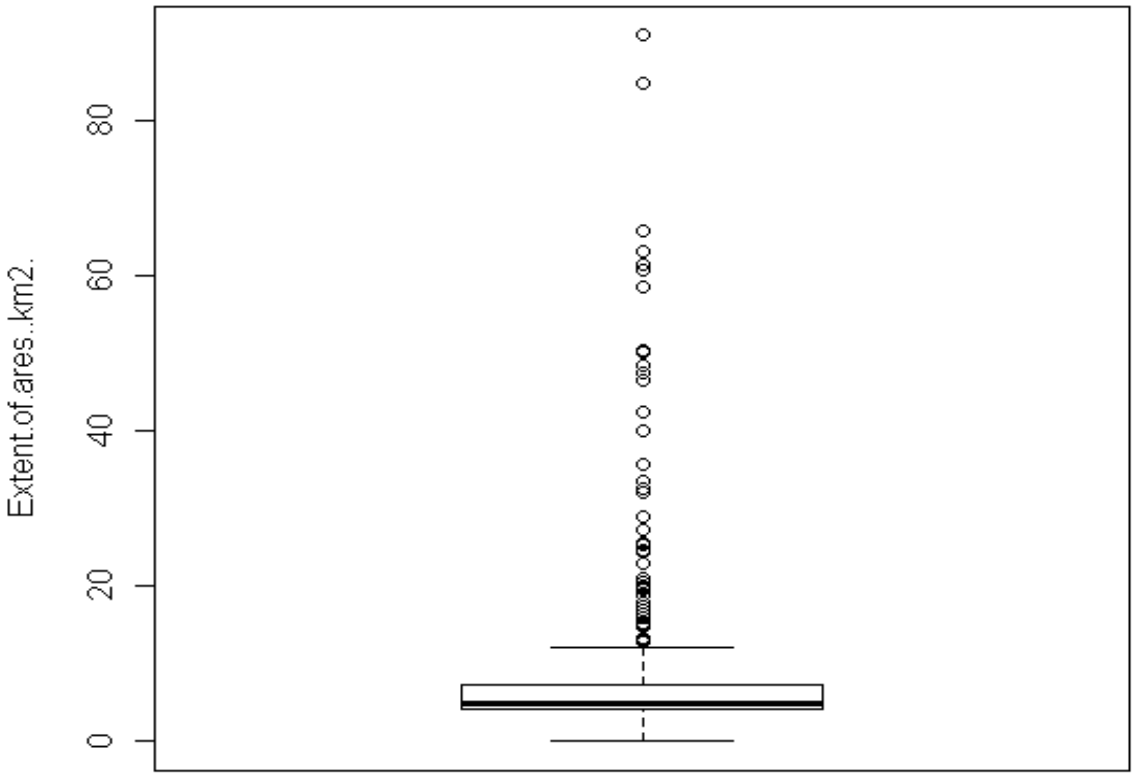

Figure 11: Box plot used for identifying optimal block size

Thus the quality of the data was improved, taking care in the meantime not to lose out on large number of elephant sightings (as large sample sizes are important to estimate numbers with greater precision). This technique ensured that unusable data (from very large block sizes) could be eliminated while retaining other data for ensuring greater precision in the population estimates.

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References

Arivazhagan, C., and Sukumar, R. (2005). Comparative demography of Asian elephant (*Elephasmaximus)* populations in southern India. Technical Report No. 106. Centre for Ecological Sciences, Indian Institute of Science, Bangalore – 560 012

Barnes, R.F.W., and Jenson, K.L. (1987). How to count elephants in forests. *IUCN African and Rhino Specialist Group, Technical Bulletin* **1**, 1-6.

Buckland, S.T., Anderson, D.R., Burnham, K.P., and Laake, J.L. (1993). *Distance Sampling: Estimating Abundance of Biological Populations.* Chapman & Hall, London.

Burnham, K. P. Anderson, D. P., and J. L. Laake. (1980). Estimation of density from line transect sampling of biological populations. *Wildlife Monograph* **72**, 1-202.

Hedges, S., and Lawson, D. (2006). *Dung survey standards for the MIKE Programme*. CITES MIKE Programme, Nairobi.

Lahiri Choudhury, D.K. (1991). Direct count of elephants in Northeast India. In: Censusing elephants in forests: Proceedings of an international workshop, Technical Report 2: Asian Elephant Conservation Center of IUCN/SSC Asian Elephant Specialist Group, pp. 33-45.

Prasad, A., and Sukumar, R. (2006). *Gajah 2.0 Based on Monte Carlo simulation*, Centre for Ecological Sciences and Asian Nature Conservation Foundation, Indian Institute of Science, India (http://www.ces.iisc.ernet.in/gajaha).

Santosh, J.A., and Sukumar, R. (1995). Some solutions to problems in estimation of elephant densities. In: *A week with elephants*. Proceedings of the International seminar on the Conservation of Asian elephants (J. C. Daniel and H.S. Datye, eds.), pp. 394-404. Bombay Natural Society, Bombay and Oxford University Press, New Delhi.

Sukumar, R., Joshi, N.V., and Krishnamurthy. V. (1988). Growth in the Asian elephant. *In:* Proceedings of the Indian Academy of Science (*Animal Sciences*), **97**, 561-571.

Thomas, L., Buckland, S. T., Rexstad, E. A., Laake, J. L., Strindberg, S., Hedley, S. L., Bishop, J. R. B. Marques, T. A., and Burnham, K. P. (2010). Distance software: design and analysis of distance sampling surveys for estimating population size. *Journal of Applied Ecology* **47**, 5–14.

Varman, K.S., Ramakrishnan, U., and Sukumar, R. (1995). Direct method of counting elephants; A comparison of results from Mudumalai Sanctuary. In: *A week with elephants* (J. C. Daniel and H.S. Datye, eds.), pp. 331-339. Bombay Natural Society, Bombay and Oxford University Press, New Delhi

Watve, M.G. (1992). Ecology of host-parasite interactions in wild mammalian host community in Mudumalai, southern India. Ph.D. thesis, Indian Institute of Science, Bangalore, India.