In : A week with elephants. Eds. J.C. Daniel and H.Datye, Bombay Natural History Society, Bombay and Oxford University Press, New Delhi. Pp.331-339. (1995)

DIRECT AND INDIRECT METHODS OF COUNTING ELEPHANTS: A COMPARISON OF RESULTS FROM MUDUMALAI SANCTUARY

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(With a text-figure)

A study comparing density estimates of elephants from direct and indirect (dung) counts was carried out in Mudumalai Wildlife Sanctuary during 1991-1992. Line transect method as outlined by Burnham *et al.* (1980) for direct counts, and the dropping count method developed by Barnes and Jensen (1987) for indirect count were followed. The sanctuary was divided into several zones based on location and habitat type. Four permanent transects of 3-4 km each were cut for the direct count and walked twice each month. For the indirect count, transects of 1-4 km each were cut and enumerated each of the three (dry, I wet, II wet) seasons. Experiments were set up each season to estimate dung decay rates, while defecation rates were obtained from Watve (1992). Results obtained by the two methods are compared. The estimate of mean density from the direct count was higher (3.09 elephants/sq km, 95% CI = 1.40-4.78) than that obtained by the indirect count (1.54 elephants/sq km, 95% CI = 1.01-2.10). The strengths and weaknesses of both methods are discussed.

INTRODUCTION

The line transect method (Burnham *et al.* 1980) has been extensively used for estimating animal densities for a variety of taxa and habitats. Elephants densities have been estimated using this method either through direct counts (Karanth and Sunquist 1992) or indirect counts (Barnes and Jensen 1987, Sale *et al.* 1990, Dawson and Dekker 1991).

During a workshop on censusing elephants in forests (Ramakrishnan *et al.* 1991), the line transect method was recommended as the most robust, wherever trained personnel are available. The direct count was to be adopted in areas of good visibility and high elephant density, while in areas of low elephant density (as in tropical rain forests) the indirect (dung) count was recommended as being the most suitable. There has however been no comparison made of estimates from these two methods in the same habitat over the same time period. Such an exercise was carried out in Mudumalai Wildlife Sanctuary during 1991-92 in order to check whether or not the two methods gave comparable results.

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STUDY AREA

The study was conducted in Mudumalai Wildlife Sanctuary, Tamilnadu, south India (11°32' to 11°43' N, 76°22' to 76°45' E) (Fig. 1). Three seasons can be defined: dry (January-April), I wet (May-August) and II wet (September-December). A distinct rainfall gradient extends from west to east, with a corresponding change in vegetation type from moist deciduous forest through dry deciduous forest to dry thorn forest (Sukumar *et al.* 1992). The forests of Mudumalai Wildlife Sanctuary (321 sq km), Bandipur National Park (874 sq km), Wynad Sanctuary (251 sq km), Sigur plateau and the northern and eastern slopes of the Nilgiris (700 sq km) form a contiguous elephant habitat which supports one of the largest elephant populations in Asia.

METHODS

The basic line transect method as outlined by Burnham *et al.* (1980) was used. The study area was divided into 7 zones based on topography and vegetation type. For the line transect direct count, four permanent transects were cut (Fig. 1), which ran through different habitat types. The total length of the transects in each of the habitat types was approximately proportional to the area of that habitat type. Each transect was walked twice a month, once between 7.00 hr. and 9.00 hr and again between 16.00 hr and 18.00 hr. On observing an animal/herd, the perpendicular distance from the animal/centre of the herd to the transect line was noted using a range finder along with group size. If possible the age and sex of each individual was noted.

Statistical analysis: The density of groups was arrived at using the program TRANSECT (White 1987). Data were grouped into distance classes of 20 m interval for analysis; sightings beyond 140 m distance were not used. Fourier series function was used to estimate the mean density of groups and its standard error. To estimate the elephant density, the density of groups was multiplied by the mean group size. The standard error (SE) of elephant density was estimated using the formula (N.V. Joshi, per. comm.):

$$(SE(D))^2 = \{(SE(Y))^2 \times (SE(Z))^2\} + \{Y^2 \times (SE(Z))^2\} + \{Z^2 \times (SE(Y))^2\}$$

where

D = density of elephants; Z = density of groups; Y = mean group size.

For the line transect indirect count (Barnes and Jensen 1987, Dawson and Dekker 1991), transects of 1-4 km length were cut afresh for each count (one-off transect). Transects were cut for each of the three seasons (dry, I wet and II wet) and for the different habitat types. Length of

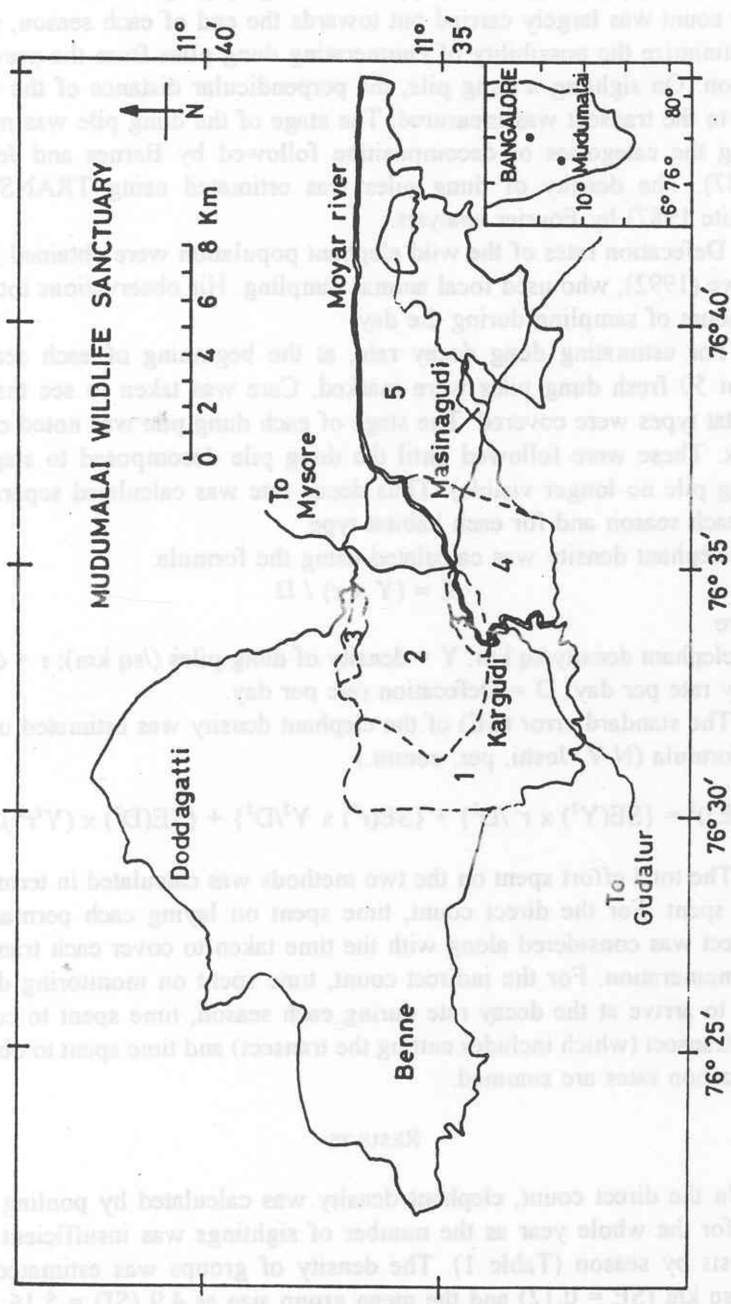

Fig. 1 Map of the study area showing the habitat zones.
1. Moist deciduous forest; 2. Dry deciduous forest (tall grass); 3. Riparian forest;
4. Dry deciduous forest (short grass); 5. Dry thorn forest.

transect in a particular habitat type was roughly proportional to its area. The count was largely carried out towards the end of each season, so as to minimize the possibility of enumerating dung piles from the previous season. On sighting a dung pile, the perpendicular distance of the dung pile to the transect was measured. The stage of the dung pile was noted, using the categories of decomposition followed by Barnes and Jensen (1987). The density of dung piles was estimated using TRANSECT (White 1987) by Fourier analysis.

Defecation rates of the wild elephant population were obtained from Watve (1992), who used focal animal sampling. His observations totalled 88 hours of sampling during the day.

For estimating dung decay rate, at the beginning of each season, about 50 fresh dung piles were marked. Care was taken to see that all habitat types were covered. The stage of each dung pile was noted every week. These were followed until the dung pile decomposed to stage E (dung pile no longer visible). Thus decay rate was calculated separately for each season and for each habitat type.

The elephant density was calculated using the formula:

$$E = (Y \times r) / D$$

where

E = elephant density/sq km; Y = density of dung piles (/sq km); r = dung decay rate per day; D = Defecation rate per day.

The standard error (SE) of the elephant density was estimated using the formula (N.V. Joshi, per. comm.):

$$(SE(E))^2 = \{SE(Y^2) \times r^2 /D^2\} + \{SE(r^2) \times Y^2/D^2\} + \{SE(D^2) \times (Y^2r^2)/D^4\}$$

The total effort spent on the two methods was calculated in terms of time spent. For the direct count, time spent on laying each permanent transect was considered along with the time taken to cover each transect for enumeration. For the indirect count, time spent on monitoring dung piles to arrive at the decay rate during each season, time spent to cover each transect (which includes cutting the transect) and time spent to obtain Defecation rates are summed.

RESULTS

In the direct count, elephant density was calculated by pooling the data for the whole year as the number of sightings was insufficient for analysis by season (Table 1). The density of groups was estimated as 0.63/sq km (SE = 0.12) and the mean group size as 4.9 (SD = 5.16, SE = 0.97, n=28). The elephant density worked out to 3.1 elephants/sq km (SE=0.86, 95% CI = 1.55 to 4.36).

TABLE 1

ESTIMATE OF ELEPHANT DENSITY BY DIRECT COUNT

Period	Total distance covered (km)	No. of sightings	Mean group size (SE)	Group density/km² (SE)	Elephant density/km² (95 % CI)
Sep'91 to Aug'92	352	28	4.9 (0.97)	0.63 (0.12)	3.1 (1.4-4.8)
Feb'91 to Dec'92	675	68	5.6 (0.57)	0.71 (0.08)	4.0 (2.7-5.2)

When data for two years (1991 and 1992) are combined, the mean density works out to 4.0 elephants/sq km (SE=0.64, 95% CI = 2.75 to 5.27).

For the indirect count, the dung density estimate for the whole year was found to be 2561 piles/sq km (SE = 113.9). The Defecation rate at waterholes/saltlicks was found to be 1.15/hour, while it was only 0.66/hr in the forest (Watve 1992).

Assuming that elephants spend about one hour per day on average at waterholes, the Defecation rate was taken to be 16.33/day (we do not have a precise estimate of standard error; this has been assumed to be 0.8 for the purpose of our calculations based on Coe 1972).

The overall rate of dung decay per day in all seasons and all habitats combined was found to be 0.0097 (SE=0.002) (Table 2). The elephant density worked out to 1.54 elephants/sq km (SE=0.27, 95% CI=1.01-2.08).

TABLE 2

ESTIMATE OF ELEPHANT DENSITY BY INDIRECT COUNT

Period	Total Distance covered(km)	No of dung piles recorded	Dung Density/km² (SE)	Decay rate/day (SE)	Defecation rate/day (SE)	Elephant density/km² (95 % CI)
Sep'91 to Aug'92	64	992	2561 (112.9)	0.0097 (0.002)	16.33 (0.8)	1.54 (1.01-2.08)

Table 3 shows the elephant density in the three seasons as summarized below:

Dry season : 1.32 elephants/sq km (SE = 0.07, 95% CI = 1.19 - 1.47).
I wet season : 2.58 elephants/sq km (SE = 0.14, 95% CI = 2.26 - 2.86).
II wet season : 1.30 elephants/sq km (SE = 0.08, 95% CI = 1.10 - 1.46).
The average of the seasonal densities is 1.74 elephants/sq km.

TABLE 3

SEASONAL ELEPHANT DENSITY

Season	Dry	Wet I	Wet II
Dung density (SE)	2126 (76.3)	3069 (148.9)	2706 (182.4)
Decay rate/day (SE)	0.010 (0.0012)	0.013 (0.0013)	0.007 (0.0004)
Defecation rate/day	16.33	16.33	16.33
Elephant density (95 % CI)	1.32 (1.19-1.47)	2.58 (2.26-2.86)	1.30 (1.10-1.46)

Effort (in terms of time spent) is summarized in table 4. The total time spent on the direct count was 182 hours (352 km of transect covered) for one year (1991). For the indirect count, the total time spent was 376 hours (129 hours to cover 64 km of transect lines, 159 hours for monitoring dung decay and 88 hours for direct observations on wild elephant Defecation).

TABLE 4
EFFORT IN TERMS OF TIME SPENT FOR DIRECT AND INDIRECT COUNT

Method	Effort (hrs.)	Coefficient of variation
DIRECT COUNT (Sep'91 to Aug'92)	182.0	28 %
DIRECT COUNT (Feb'91 to Dec'92)	316.0	16 %
INDIRECT COUNT (Sep'91 to Aug'92)		
a, Decay rate experiments	158.9	
b, Observations on Defecation rate	87.9	
c, Estimating dung density	129.2	
Total (for indirect count)	376.0	22 %

DISCUSSION

The estimate of mean elephant density obtained by the direct count method is almost double that obtained by the indirect count. However, the two means are not statistically significantly different for the same period (z=1.73, p > 0.05). Even then the two-fold difference in density estimate calls for an explanation if such a difference were to be consistently true across habitats.

There are several unresolved problems with both the methods which might consistently bias the results in one direction. Based on our field experience, it would appear that the direct count is an overestimate. Our suspicion is strengthened by the fact that Karanth and Sunquist (1992) obtained a very similar result (mean density of 3.3 elephants/sq km, 95% CI = 1.97-4.70) by using the same method at Nagarhole National Park, an area with similar vegetation and fauna. They too felt that the true population mean might lie closer to the lower confidence limit of 1.9 elephant/sq km. What could be possible reason for a bias in the direction of an overestimate?

The group size frequency distribution of elephants is not normally distributed but positively skewed. Thus the mean group size may not be the best indicator of central tendency, but perhaps the median group size would be a more appropriate figure to use. As the median would be lower than the mean in a positively skewed distribution, a density estimate that combines the mean density of groups with the median group size would return a lower estimate of mean elephant density than would an estimate based on the mean group size. In our case using the median group size gives an estimate of 1.9 elephant/sq km for 1991 and 2.8 elephant/sq km for 1991-92 combined.

Another factor that might bias the results towards an overestimate might be the permanent transect lines used in the direct count. There is a possibility that elephants might be attracted towards a cleared line and violate the assumptions of a random distribution. The frequency distribution of distance classes of sightings showed that a very large proportion (57% in 1991 and 55% for 1991-92 combined) of sightings were in the 0 to 20 m class interval, indicating that such a bias might be occurring.

The indirect count too faces several problems. The estimate of elephant density is based on three (rather than two as in direct count) variables and is thus subject to greater overall uncertainty. The estimate of mean dung density, however, is a much more precise estimate than is the estimate of mean group density because of the much larger sample sizes (of dung) recorded. Since the transect lines are not permanent there is also no chance of any bias through elephants being attracted towards the line. There is some uncertainty however in determining what constitutes one defecation (Jachmann and Bell 1984).

The highest uncertainty seems to be in determining the mean dung decay rate. Decay is influenced by several factors including temperature, rainfall, humidity, fire (which can burn dry piles), animal action (dung beetles, termites, jungle fowl foraging, trampling by other animals in areas of high density) and diet constitution. We found that the time taken for a dung pile to go from fresh stage (which may be A, B or C) to stage E varies from 5 to 273 days. Thus it seems important to set up the decay experiments carefully. If micro-environment is an important determinant of decay, the experimental set-up should also simulate to the extent possible the range of micro-environments in which dung piles are deposited.

As the dung decay rate fluctuates seasonally, a more appropriate estimate of annual elephant density might be to calculate the seasonal densities and take their average. This gave us an estimate of 1.74 elephant/sq km which is higher than the estimate obtained from pooling the annual data. A re-calculation of the density estimate for Mudumalai during 1989 by Sale *et al.* (1990) by taking a weighted mean of high- and low-use strata also gives a comparable estimate of 1.77 elephant/sq km.

A problem with the data on elephant Defecation rate is that no observations were made during the night. Although some studies have stated that there is no difference in the day and night Defecation rate (Sale *et al.* 1990, Coe 1972, Wing and Buss 1970) other studies indicate that Defecation rate is in fact higher at nigh[illegible] Ananthasubramaniam 1992)

Defecation rates may also vary seasonally due to shift in diet (Sukumar 1989) and this calls for more study.

A comparison of actual time spent on the two methods shows that, in our study, effort spent on the direct count was less than half that in the indirect count during a year. The results obtained by the indirect count were found to be more precise with a co-efficient of variation of 22% as against 28% in the direct count. However, with an increase in effort for the direct count to a level roughly equal to that for the indirect count (by using two years' data on direct count), the coefficient of variation decreases to 16% for the direct count.

Thus, our results indicate that in Mudumalai, a high-density elephant area, the line transect direct count method would give a more precise estimate of elephant density than would the indirect method for equal effort, if all the baseline variables for the indirect count have to be established afresh. However, once the Defecation rates and dung decay rates have been firmly established (and thus effort is not wasted on these) the indirect count would only involve estimating dung density. In such case the indirect count would give a more precise estimate per unit effort than would the direct count. The indirect method might thus be more appropriate for long-term monitoring of a population in a given area.

There still remains the problem of which method is more accurate (as opposed to more precise), i.e. gives an estimate of elephant density that is closer to the population mean. More work, both theoretical and empirical, is clearly needed to resolve this problem.

ACKNOWLEDGEMENTS

This study was funded through grants by the Ministry of Environment and Forests. Government of India, to the Centre for Ecological Sciences, and by World Wide Fund for Nature through grants to the Asian Elephant Conservation Centre. We also thank N.V. Joshi, Anil Gore and J.A. Santosh for spending long hours in discussion, and C.M. Bharaniah, C.M. Annadurai and Shivaji for field assistance.

REFERENCES

ANANTHASUBRAMANIAM, C.R. (1992): Some aspects of elephant nutrition. *In:* Silas, E.G., Krishnan Nair, M. & Nirmalan, G. (eds) The Asian Elephant, Kerala Agricultural University, Trichur, India.

BARNES, R.F.W. & K.L. JENSEN (1987): How to count elephants in forests. *IUCN African Elephant & Rhino Specialist Group Technical Bulletin 1:* 1-6.

BURNHAM, K.P., D.R. ANDERSON & J.L. LAAKE (1980): Estimation of density from line transect sampling of biological populations. *Wildlife Monographs 72:* 1-202.

COE, M.J. (1972): Defecation by African elephant. *E. Afr. Wildl. J. 10:* 165-174.

DAWSON, S. & A.J.F.M. DEKKER (1991): Methods for counting Asian elephants in forests: a field techniques manual. FAO, Bangkok.

JACHMANN, H. & R.H.V. BELL (1984): The use of elephant droppings in assessing numbers, occupation and age structure : a refinement of the method. *Afr. J. Ecol. 22:* 127-141.

KARANTH, K.U. & M.E. SUNQUIST (1992): Population structure, density and biomass of large herbivores in the tropical forest of Nagarhole, India. *Journal of Tropical Ecology 8:* 21-35.

RAMAKRISHNAN, U., J.A. SANTOSH & R. SUKUMAR (Eds) 1991: Censusing elephants in forests : Proceedings of an international workshop. Asian Elephant Conservation Centre, Indian Institute of Science, Bangalore.

SALE, J.B., A.J.T. JOHNSINGH & S. DAWSON (1990): Preliminary trials with an indirect method of estimating Asian elephant numbers. A report prepared for the IUCN/SSC Asian Elephant Specialist Group.

SUKUMAR, R. (1989): The Asian elephant : ecology and management. Cambridge University Press, Cambridge, U.K.

SUKUMAR, R., H.S. DATTARAJA, H.S. SURESH, J. RADHAKRISHAN, R.VASUDEVA, S. NIRMALA & N.V. JOSHI (1987): Long-term monitoring of vegetation in tropical deciduous forest in Mudumalai, southern India. *Current Science 62:* 608-616.

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

WHITE, G.C. (1987): Program TRANSECT - Line transect Data Analysis Program. Colorado State University, Fort Collins.

WING L.D. & I.O. BUSS (1970): Elephants and forests. *Wildlife Monographs 19:* 1-92 pp.