Plenary Paper Two
Indirect methods for counting elephants in forest

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Introduction

The techniques for counting elephants in open habitats have been intensively studied, but those for counting elephants in forest have received much less attention. This paper will discuss the two methods most frequently used for estimating forest elephant numbers: guesses and dung counts.

Guesses

Many opinions about the abundance of forest elephants are subjective impressions based on brief peramulations in the forest. These are guesses, not estimates. Guesses for the number of elephants in the central African forests range from 106,000 (Pfeffer, 1990) to 500,000 or three million (Anon, 1982). Elephants are not unusual in being the subject of wildly varying guesses. For example, in 1924 very different guesses of both number and trend of the Kaibab deer ***(Odocoileus hemionus)*** population were made by people familiar with the area (Rasmussen, 1941; Caughley, 1970). Andersen (1953) described how forest rangers guessed the numbers of roe deer ***(Capreolus capreolus)*** in a Danish wood to be one third of the number actually there. Similarly, 80 Asian elephants ***(Elephas maximus)*** were thought to live in a patch of forest in Sumatra Selatan, but 232 were flushed out (Santiapillai, 1991).

These examples show how people familiar with an area grossly under-guessed the numbers of animals or had completely different impressions of the population trend. Therefore people who have only a superficial knowledge of a forest are likely to make guesses which are even less reliable.

Another reason for mistrusting guesses is shown by Figure 1. Studies in Gabon, Congo, CAR, and eastern Zaire show that forest elephant densities increase with distance from roads or villages (Barnes *et al*, 1991; Fay, 1991; Fay & Agnagna, 1991; Alers *et al*, 1992). Most people who go into the forest leave from a road. Travel in the forest is slow and the paths meander. One can spend all day in the forest and return exhausted to the road without having traveled more than 10 km from the road as the crow flies. Most people who pontificate on forest elephant abundance have never been deep into the forest where the high elephant densities are found.

Photo by: Ralph Klumpp

Indices of Abundance

Indirect counts are those where animal signs (e.g. burrows, tracks, calls, nests, or droppings) are counted to give an index of abundance. Such indices fall into two categones: non-convertible and convertible. Convertible indices can be transformed into an estimate of animal numbers, but only if estimates of other variables are available. The density of elephant dung-piles is a convertible index.

The earlier dung counts in forest were made on permanent transects or plots (Wing & Buss, 1970; Jachmann & Bell, 1979,1984; Short, 1983; Merz, 1986). Barnes & Jensen (1987) worked in remote forests where revisits were impractical. They were also worried about elephants walking on permanent transects and leaving misleading quantities of dung to be recorded. They adopted the line-transect technique and assumed a steady state (McClanahan, 1986) which allowed them to pass only once down each transect. The method described by Barnes & Jensen (1987) was then critically evaluated and then adopted by the Asian Elephant Specialist Group (Sale, Johnsingh, & Dawson, 1988; Dawson, 1990). During the last two years there have been further developments in both field and analysis methods (Dawson, 1990; Hiby & Lovell, 1991; Tchamba, 1992; Barnes & Barnes, 1992). A "how-to-do-it" manual has been pro≠duced by Dawson & Dekker (1992).

Stratification and Sampling

The accuracy and precision of dung counts can be improved by better sample design: stratification and the arrangement of transects. The type of stratification will be determined by the scale on which one is working. Elephant densities on a small scale are often determined by vegetation type, especially secondary forest, which is the preferred habitat (Merz, 1986; Barnes *et al*, 1991), and one should stratify accordingly. But on a large scale, e.g. a province or country, people are the prime determinant of elephant numbers and distribution, even in the remotest forests (Barnes *et al*, 1991). Therefore stratification should account for: intensity of ivory poaching, human population density (a measure of general human disturbance), and distance to the nearest source of human disturbance (village, road, or major river).

For surveys in huge areas like a province of Congo or Cameroun, where the daily costs of employing

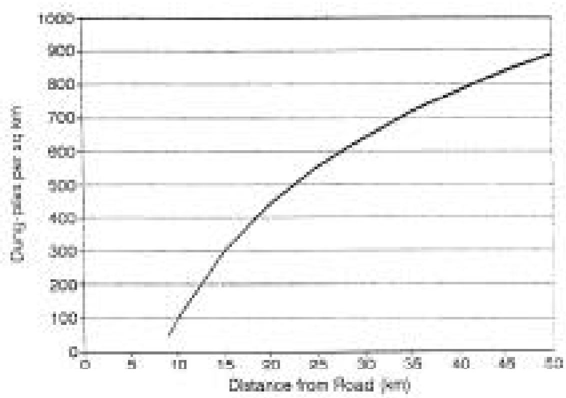

Figure 1: The distribution of dung-piles in relation to roads in Gabon. The curve is described by $Y=491 \log_e X - 1031$ (unpublished data)

porters and labourers are high, one must minimise the dead time spent moving from the end of one transect to the beginning of the next. One solution is to cut a base-line perpendicular to the road (or river), and then cut transects randomly spaced along the base-line (Figure 2a). In each stratum there might be two or three sets of transects like this. The data would then be used to estimate the parameters describing the curve in Figure 1. Another solution is appropriate where there is no apparent relationship between elephant density and distance to road or village, e.g. where human disturbance is uniform overt the census area. In this case, the transects are arranged in a zig-zag or sawtooth design (Figure 2b). This is used for marine mammal surveys which face the same problems of minimising logistical costs (*e.g* Hiby & Hammond. 1989).

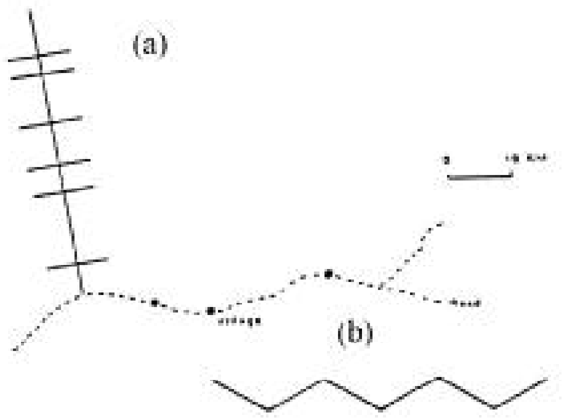

Figure 2: Two possible designs for forest elephant survey.
(a) Transects randomly distributed along a 50 km baseline
(b) Sawtooth pattern. Each element is treated as one transect

Estimating Dung Density

Strip transects are not suitable for dung counts in forest because the visibility of dung-piles falls rapidly with distance from the centre line of the transect. Line transects give estimates that are less biased and have a lower standard error than strip transects *(Burnham et al,* 1985). A comprehensive description of the line transect method is provided by Burnham *et al* (1980), while a concise summary is given by Krebs (1989: pages 113-121). A new tome (Buckland *et al,* 1993) will soon become the standard reference work. Field methods are simple and are described by Buraham *etal* (1980), Barnes & Jensen (1987), and Dawson & Dekker (1992). Methods of analysis are more complicated. A user-friendly computer programrrme intended for field workers has been written by Dekker & Dawson (1992), while Laake (1991) has produced a more complex package offering a choice of models. Up to now the Fourier series model has been used for forest elephant dung counts because it is a robust all-purpose model. However, other models, such as those discussed by Buckland (1985) and Buckland *et al* (1993), need to be tested with dung data. For example, White (1992) used the hazard-rate model.

Converting Dung-Piles to Elephants

If a steady-state is assumed, then one can estimate the numbers of elephants (E) using estimates of three variables; dung-pile density (Y), elephant defaecation rate (D), and dung decay rate (r) (McClanahan, 1986; Barnes & Jensen, 1987):

$$E = \frac{Y.r}{D} \qquad (1)$$

However, the steady state assumption does not always hold. Hiby & Lovell (19910 have devised an alternative method which does not require a steady state. The practical drawback of their method is that dung-piles need to be located two months or more before the transects are cut.

Before starting the process of estimating defeacation and decay rates, one should pause to reflect upon the goals of the survey. Is an estimate of elephant numbers really necessary? For many purposes, e.g. estimating trends or distribution, an index of abundance will suffice. Converting dung-piles to elephants is fraught with so many complications and potential errors that it should be avoided unless it is essential to know the number of elephants.

Defaecation rates can be estimated by observing elephants for long periods (e.g. Tchamba, 1992). Decay rates are estimated by monitoring dung-piles until they "disappear", i.e. until they pass from morphological stage D to stage E (Barnes & Jensen, 1987). Some droppings will disappear quickly while others may last for months. At first dung decomposition was assumed to be a random process similar to radioactive decay and so it was logical to apply a negative exponential model (Short, 1983; Merz, 1986; McClanahan, 1986; Barnes"& Jensen, 1987). However, observations on much larger samples (Grimshaw & Foley, 1990; Reuling, 1991; Dawson, 1990; and L.J.T. White, pers. comm.) showed that a period of slow decay precedes the exponential phase, resulting in a reverse sigmoid curve (Figure 3). Some methods for calculating decay rates are described by Barnes & Barnes (1992).

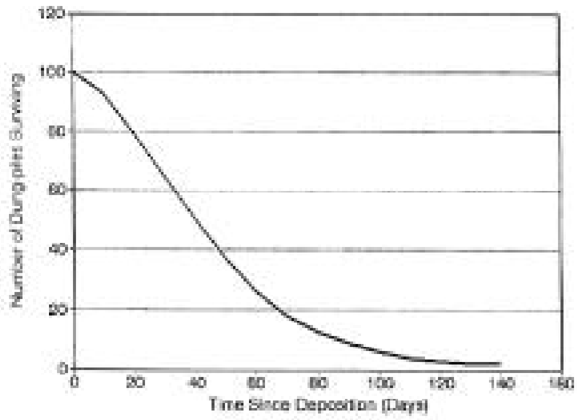

Figure 3 : An example of a survival curve for forest elephant droppings, adapted from Barnes & Barnes (1992)

It is useful to distinguish between the proximate and ultimate factors governing decay rates. The proximate factors are: (a) mammals which rummage through dung-piles in search of seeds (e.g. bushpigs, duikers, mandrills, apes); (b) invertebrates like termites and dung beetles; (c) the rest of the decomposer community, such as fungi and bacteria. Dung beetles probably play a minor role in the lowland equatorial forest compared with the savanna. The activity of these organisms (except perhaps the mammals) is determined by rainfall, temperature, and relative humidity, which are therefore the ultimate factors. Microclimatic variations caused by soil, drainage, slope, aspect, and canopy cover are also important.

Calculating Confidence Limits for E

Elephant estimates based on dung counts will always have wide confidence limits. This is because the estimates of Y, r, and D each have their own standard error (SE) which will contribute to the SE of elephant numbers. There are three methods for estimating the variance in the final estimate of E. The first requires calculating the variance of a product and a ratio. The variance of a product is (Goodman, 1960):

$$var(Y.r) = var(Y).var(r) + Y^2.var(r) \pm r^2.var(Y) \quad (2)$$

where var(Y) is the variance of Y, etc. The variance of the ratio (Y.r)/D is (Rice, 1988):

$$var(E) = var(D). \frac{(Y.r)2}{D^4} + \frac{var(Y.r)}{D^2} \quad (3)$$

Second, an approximate value can be estimated using the expression:-

$$CV^2(E) = CV^2(Y) \pm CV^2(r) \pm CV^2(D) \quad (4)$$

where the CV is the coefficient of variation (CV = SE/mean).

The third method is a Monte Carlo technique, combining replicate estimates of r and Y from bootstraps (e.g. Barnes & Barnes, 1992) with estimates of D. For example, one might have a series of estimates of Y, a series of estimates of r, and a series of estimates of D (such as those from Table 1 in Tchamba, 1992). A value of each variable is selected at random with replacement. The estimate of E is calculated E = Y.r/D . Then this repeated say 1000 times to give 1000 independent estimates of E. Because E is the result of a product it will be lognormally distributed and therefore the confidence limits will be asymmetrical.

Sources of Error

The recent estimates of forest elephant numbers have been criticised, partly because the critics have not troubled to read the methods (e.g. Pfeffer, 1990), and partly because people cannot accept dung counts as a valid census method. How much credence can we give to counts of excrement as a means of estimating animal numbers? Dung counts have the advantage that the distribution of dung at any one moment represents the accumulated distribution of elephants over the preceding one or two months. In contrast, a direct count of elephants records the instantaneous distribution and is more prone to sample error (Jachmann, 1991). Dung counts have long been used in the USA as a means of assessing deer abundance. In Australia they have been shown to be an accurate means of assessing wallaby densities (Johnson & Jarman, 1987). As for elephants, Jachmann & Bell (1984) established that dropping counts gave an estimate close to that from an aerial survey. Dawson (1990) used dung counts to estimate that there were 1.77 elephants per km^2 in the Mudumalai Wildlife Sanctuary in India. Elephant sightings from a vehicle using the line transect method gave estimates of 1.75 and 1.56 per km^2, and total counts gave 1.39 and l.25 per km^2 (Sukumar et al, 1991). Finally, Jachmann (1991) tested different methods of counting elephants on the Nazinga Game Ranch, including direct sample counts from the air and from the ground. He found that a dropping count using the steady state assumption gave both the most accurate and most precise estimate. Thus dung counts are indeed a valid method for estimating animal numbers.

Nevertheless, there are several potential or perceived sources of error. The first five points below refer to deriving the index of abundance (i.e. dung-piles per km^2) while the last two are concerned with turning the index into an estimate of elephant numbers.

1. Dung-pile visibility The visibility of a dung-pile depends upon its shape or stage of decomposition. However, Barnes et *al* (1988) found no difference in visibility between between two categories of dung-pile, those where all or some of the boli retained their shape (morphological stages A to C2), and those where all the boli had broken down to the cow-pat form (stage D).

2. Observer efficiency Barnes *et al* (1988) used a computer simulation to test estimates of dung-pile density from good and poor observers using the line transect method. They found that poor observers produced surprisingly good estimates. This is because the smaller number of dung-piles recorded by the poor observers was counter-balanced by narrower effective strip width resulting from the steeper probability density curve. In other words, variations caused by differences in observer efficiency or the undergrowth may not have a marked effect on the dung-pile estimate.

3. One dung or two? Often an elephant defaecates when walking. Because dung-pile in the forest break down quickly into a cow-pat shape, it is difficult to tell whether two adjacent cow-pats represent two separate defaecations or one defaecation by a moving animal.

4. Cut-off point There is a stage beyond which dung-piles rapidly become invisible (stage E). The boundary between stage D (visible) and stage E has to be clearly defined at the beginning of a census. It is sometimes difficult to decide whether a border-line dung-pile is a late D or early E. This potential error can be minimised by carrying reference photographs.

5. "What if an elephant has diarrhoea?"
This is the most common question posed by civil servants and foresters. Defaecation rates, like most physiological processes, will be normally distributed and therefore a few high or low values are to be expected.

6. Steady state If the system is not in a steady state - e.g. if rainfall is irregular or if the census zone is small and elephants are moving in and out - then one of the principal assumptions is violated and the subsequent estimate of E will be wrong. Violation of the steady state assumption is probably the greatest source of error in calculating elephant numbers from dung counts.

***7.* Biases in Y, r, and D** Any biases in estimating dung-pile density, defaecation or decay rates will be reflected in the final estimate of elephant numbers. Biases in Y, r, and D are additive and will give a biased estimate of E (Barnes & Jensen, 1987).

A Universal Theory of Defaecation and Decay

It is in estimating defaecation and dung decay rates that the most work needs to be done to improve the accuracy of elephant estimates of dung counts. Can general equations be developed which will predict rates of dung decay or defaecation for a given set of conditions? The most practical predictors of these rates are the ultimate factors. Thus dung decay rate (r) is probably a function of rainfall (R), temperature (T), and humidity (H). So in any particular habitat type,

$$r = f(R) + f(T) + f(H) \qquad (5)$$

Similarly, defaecation rate is likely to depend upon food quality which is dependent upon rainfall, so defaecation rate D may be some function of rainfall in the current month (R_t) and possibly in the preceding month (R_{t-1}) too:-

$$D_t = f(R_t) \pm f(R_{t-1}) \qquad (6)$$

Note, however, that Tchamba (1992) did not detect any seasonal variations in defaecation rate.

The points from different habitats may all lie on the same line, or perhaps on parallel lines. Multivariate models for both dung decay and defaecation rate could be constructed from data collected by the various dung surveys being conducted in both Africa and Asia. Then a dung surveyor going into a new area need not undertake decay or defaecation measurements. Instead he would measure mean R, T, and H during his survey to estimate the values of r and D from the appropriate equations.

Other Methods for Counting Forest Elephants

Can we use infra-sound calls as an indirect census method? Elephants have passed much of their evolutionary history in the forest and the phenomonen of infra-sound communication probably evolved as a means of communicating in forest. There will have to be major advances in technology before the necessary equipment is small enough to carry in the forest. Then there will be the problem of translating calls received per unit time into elephant densities. It will be a long time before the accuracy of infra-sound counts approaches that of dung counts.

Another possibility is infra-red. However, Prinzivalli's (1992) theoretical calculations and experiments with live elephants suggest infra-red will not work in the forest.

Conclusion

Estimating abundance and distribution is only the first step in elephant management. The estimates now available for elephants in the forest zone are not yet of the quality necessary to provide the basis for elephant management. More work needs to be done to improve the methods. We need to:

(a) Study the distribution of elephants in relation to human pressures and then work out the optimum sampling design. We need to improve geographic information systems for stratifying the forest to account for vegetation types, management practices such as logging, and the gradient of declining human disturbance with distance from roads.

(b) Investigate the optimum probability density models to fit to the dung-pile data recorded in the transects.

(c) Examine the assumptions of the steady state, and how deviations bias estimates of E.

(d) Elucidate the factors determining defaecation and decay rates and develop general equations.

Improving estimates of dung-pile density is relatively simple compared to the problem of grappling with defaecation and decay rates and the steady state assumption. In many cases it is not necessary to do so, for an immense amount of information about elephants can be gleaned just from the distribution of their dung-piles (e.g. *Barnes et al,* 1991).

It took many years for the methods of aerial survey to be worked out in the savanna zone, yet AESG members continue the struggle to improve them. The methods of counting elephants in forests are only now beginning the same evolutionary process. There is still a long way to go.

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