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HOW TO COUNT ELEPHANTS IN FORESTS

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INTRODUCTION

The rain forests of central Africa cover well over one and a half million square kilometres. Elephants range throughout this area but nobody knows in what numbers. Ignorance of the numbers and status of elephants in this region is a major obstacle to assessing the impact of ivory exploitation on the continental elephant population. At the national level wildlife and forestry departments cannot manage one of their most important wildlife resources until they have elephant population estimates.

Counting elephants in forests is more difficult that in open country and there are more sources of error to trap the unwary. Estimating the numbers of elephants in the equatorial rain forests will need the participation of a large number of people in six different countries. It is important, therefore, to standardise methods.

The field methods described here were designed specifically for use in the vast remote forests of central Africa. We found that the dropping count methods used by Wing and Buss (1970), Short (1983), Jachmann and Bell (1984), and Merz (1986) were impractical because one cannot make repeat visits to permanent transects situated in remote forests where access is difficult, time-consuming, and expensive. Our field methods are simple and require no special skills beyond a knowledge of the general principles of censusing mammals (such as those described by Norton-Griffiths, 1975; Caughley, 1977; Van Lavieren, 1977). But the mathematics underlying the simple field methods may be too complicated for many biologists. Therefore we will offer a free data-analysis service to all those who need it.

We hope that this guide will be used by all those concerned with the ecology and management of elephants in forests. It may also prove useful to those working on other forest mammals.

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USING DROPPING COUNTS TO ESTIMATE ELEPHANT NUMBERS

It is impossible to make direct counts of elephants in forest because it is so difficult to see them in the dense vegetation. Therefore one is obliged to use indirect methods. If one needs an estimate of the numbers of elephants then one must do a dropping census because this is the only index of abundance that can be converted to an estimate of elephant numbers.

Wing and Buss (1970) used dropping counts to estimate elephant numbers in the Kibale Forest of Uganda but doubted the accuracy of their results. A big step forward was made when Jachmann and Bell (1984) confirmed the validity of dung counts by using an aerial census to check their estimates. Short (1983) and Merz (1986) have censused forest elephants in West Africa using methods similar to those of Jachmann and Bell (1984).

The methods described by these workers involved cutting permanent transects to which the counters returned at intervals. There are three drawbacks to permanent transects:

1. Elephants, like humans, prefer to walk down paths. Therefore dropping densities are likely to be higher on the transect than in the surrounding forest. Wing and Buss found that this was not the case in the Kibale Forest, but in Gabon it is true in secondary forest, and probably in primary forest too. It depends upon the thickness of the understorey. Permanent transects should be avoided unless you have established beyond doubt that the transect dropping densities are representative of the forest.
2. Access to remote areas of forest is expensive, so a programme requiring repeat visits to permanent transects can become very costly.
3. If you have to visit each transect three times during the census programme, then you will only be able to do one third the number of transects you could do in a survey where each transect was visited once only.

The method we describe in this guide differs in two important respects from other forest elephant census methods:

1. Instead of transects of fixed-width, we use transects of variable width ("line-transects").
2. By assuming a steady-state system, one need only pass once down a transect – one collects the data as one cuts the transect (a "one-off" transect).

Transects of Variable Width

Sampling by quadrats should be avoided in forest elephant censuses because of the clumped distribution of droppings which gives a large sample error. Transects are a more efficient method of sampling than quadrats (Norton-Griffiths, 1975).

Most large mammals censuses in Africa have used transects with a predetermined fixed width. But fixed-width transects are not appropriate in a situation where there is a sharp drop in visibility on either side of the transect. In the forest a dung-pile quickly breaks down to form an amorphous flat mass which is difficult to see in the undergrowth, especially as it is soon covered by fallen leaves. In our preliminary survey of N.E. Gabon (Barnes and Jensen, 1986), an observer walking down the centre-line of the transect found all droppings within one metre of the centre-line,but only 50% of those between one and two metres, and less that 25% of those between two and three metres (Fig. 1).

If you decide to use fixed-width transects in the forest, then you must justify your decision by including in your final report a histogram that demonstrates that droppings towards the outer edge of the transect are recorded with the same frequency as those in the middle of the transects

The data in Fig. 1 are ideally suited to the line-transect analysis described by Burnham *et al* (1980). Their method is based on the principle that the probability of detecting an object decreases with increasing distance from the transect centre-line. It is clearly the most appropriate method for use in habitats where visibility is poor. For example, it has been used to count antelope droppings in the Ituri forest (Dr. John Hart, pers. comm.).

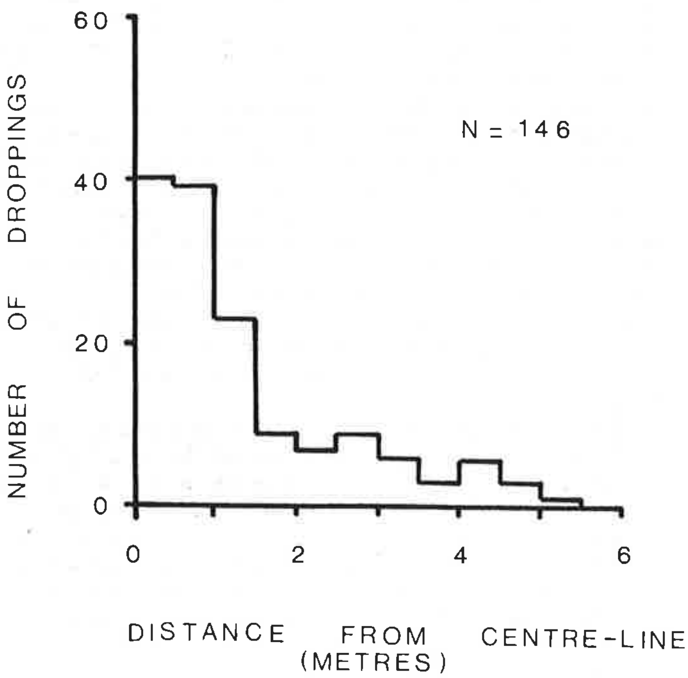
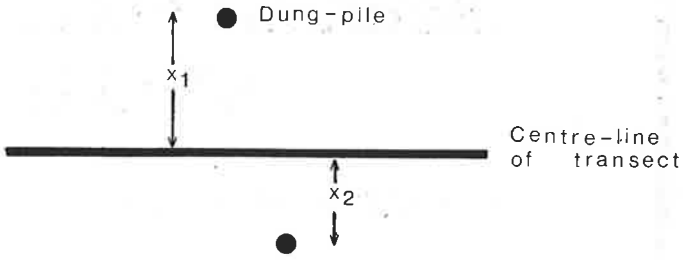


Figure 1. A frequency histogram showing how the visibility of droppings decreases with increasing distance from the transect centre-line. An observer walked down the centre-line of each transect scanning the ground on either side. The histogram shows the number of droppings in each distance category seen by the observer. The data come from 10 transects in N.E. Gabon.

Figure 2. Diagram illustrating the perpendicular distance (xi) from the transect centre-line to each dung-pile.



When a dropping is seen by the observer walking down the transect centre-line, its distance x_i from the centre-line is measured (Fig 2). The x_i values for all the droppings are used to estimate the *probability density function* f(x). This is the probability of finding a dropping at a particular distance x from the centre-line. From the probability density function one obtains an estimate for f(O), which is an estimate of frequency with which droppings occur on the centre-line. The equations for calculating f(O) are complicated and are given in detail by Burnham *et al.* (1980: pages 56-57).

For each transect the estimate of dropping density Y is given by:

$$Y = \frac{n\, f(O)}{2\, L}$$

where n is the number of dung-piles in the transect, and L is the total length of the transect.

There is a choice of formulae for calculating the variance and confidence limits (Burnham *et al.* 1980: pages 51-55).

Many biologists will find the equations described by Burnham *et al.* to be incomprehensible. Some field workers may be able to understand the mathematics but will not have access to a computer. For these people we will offer a free data analysis service. They should write to us and we will send the results back immediately.

The Steady State Assumption

Consider a block of forest, 100 sq km in area, from which elephants have been absent for a long time. The dropping density (number of dung-piles per sq km) is zero. Now imagine that 10 elephants move into the area and stay there. The density of droppings in this forest will rise rapidly (Fig. 3). If the dropping decay rate is constant, the same *percentage* of droppings disappears each day. Therefore, as the dropping density increases the *number* of dung-piles disappearing each day will rise until it equals the *number* of dung-piles deposited each day. At this stage the system is in equilibrium and the number of droppings per sq km remains constant from day to day. The system is in a steady state. The assumption that a steady state has been reached gives us a simple method of converting an estimate of dung-piles per sq km to elephants per sq km (McClanahan, 1986).

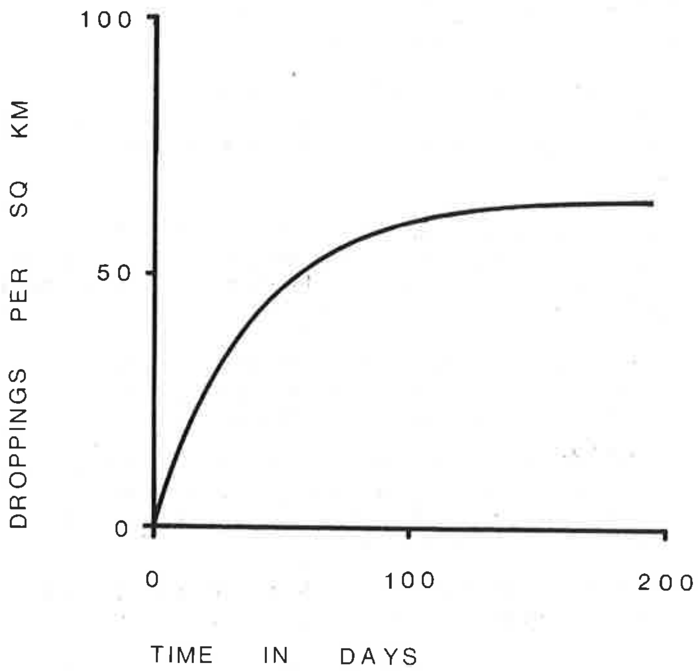
When the system is in a steady state the number of dung-piles produced per day equals the number disappearing through decay:

$$E \times D = Y \times r$$

where E is the number of elephants per sq km, D is the number of droppings produced per elephant per day, Y is the number of droppings per sq km, and r is the daily rate of decay. Therefore:

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

Figure 3. A computer simulation showing the change in dung density in a forest following the arrival of 10 elephants on day zero. The area of the forest is 100 sq km so the elephant density is 0.1 per sq km. The defaecation rate is 17 droppings per elephant per day, and the daily dung decay rate is 0.026. The vertical scale shows the dung density (number of droppings per sq km).



See McClanahan (1986) for a more formal presentation.

ESTIMATING THE NUMBERS OF ELEPHANTS

There are four steps to obtaining an elephant population estimate:

1. Estimating the density of droppings using line-transects.
2. Estimating the number of droppings produced per elephant per day.
3. Estimating the rate of decay of droppings.
4. Combining the estimates of defaecation rate, dropping density, and decay rate to obtain an estimate of elephant density.

For many purposes, such as studies of elephant distribution and differential habitat use, one does not need estimates of elephant density. For these studies an index of elephant abundance will suffice and one need go no further than Step One.

Step One: Dropping Density

In this guide we use the terms "dropping" and "dung-piles" interchangeably to mean a pile of boli produced at one time by one elephant

Take a map and draw on it the outlines of the census zone. Divide the census zone into strata according to the distribution of human activity and the distribution of important vegetation types such as secondary forest (see Appendix). Calculate the area of each stratum using a dot-grid or planimeter.

Draw a base-line across each stratum, preferably along the longer axis of the stratum and parallel to the drainage system. Decide on the number of transects to be positioned in each stratum (see Appendix). Use a random number table to determine the position of each transect on the base-line. The transects should lie perpendicular to the base-line so that they cross the main drainage lines (see Norton-Griffiths, 1975). Work out the bearing of each transect. Remember that grid north on the map usually differs from magnetic north on your compass: the deviation will be shown in the legend of the map.

In the field you will need to employ two labourers to cut the transect. They must be closely supervised to ensure that the transect is dead straight

The observer walks slowly down the centre of the transect scanning the forest floor on either side. When a dropping is seen, he must record:

1. Distance along the transect, measured by a topofil*. Do NOT use a pedometer, which is too inaccurate for this sort of work.
2. The perpendicular distance x_i; of the dropping from the transect centre-line (Fig. 2). Use a steel tape; other types may stretch.
3. Stage of decomposition (A to D) of the dung-pile (see "Dung Decay Rates").
4. Vegetation type (e.g. primary forest with open under-storey, primary with dense under-storey, secondary with canopy height >5 m, secondary with canopy height <5m, thicket, marsh, seasonally inundated, etc – see Tutin and Fernandez (1987).

Although these are transects of variable width, one may set a maximum distance beyond which droppings are not recorded (Burnham *et al* 1980). In the forest this maximum distance will be set for you by the limits of visibility. For instance, Fig. 1 shows it to be about 5 or 6 metres in N.E. Gabon.

Record all changes in vegetation as you proceed down the transect, and also features such as streams, marshes, and ravines. It is useful to record signs of animals other than elephants and also all signs of human activity (footprints, snares, cartridge cases, gunshots, camps etc).

Record all data on check-sheets (Table 1). This ensures that the data are collected in a standardised manner, and that when you are hot, tired, and hungry you do not forget to record something. Checksheets facilitate data-analysis, and especially transfer of the data onto a computer.

Step Two: Defaecation Rates

The most dificult data to obtain are the number of dung-piles produced per day per elephant. One can obtain an estimate by following wild elephants (Wing and Buss, 1970; Merz, 1986) or by observing tame elephants, but only if they are in their natural habitat and not receiving artificial food such as hay.

Defaecation rates vary by habitat and by season (for an extreme example, see Barnes, 1982) and so estimates from savanna, bushland, or woodland cannot be used for forest elephants. The best data for elephants in forests were collected by Wing and Buss (1970). If you cannot get good data for your census zone, then you will have to use Wing and Buss' figure of 17 droppings per elephant per day.

Step Three: Decay Rates

To obtain an estimate of dung decay rates you will need to find at least 50 newly-laid dung-piles. Mark each one and return to it at weekly intervals to observe its state of decay.

It is important to grade each dung-pile by its state of decomposition:

Stage A Boli intact, very fresh, moist, with odour.

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*A topofil is an accurate device for measuring the length of a transect. It is a box containing a reel of cotton thread. The loose end of the thread is tied to a peg at the beginning to the transect. As one proceeds down the transect the thread unwinds and passes over a spindle attached to a meter which shows the distance walked. A convenient-sized topofil (called "the Hip Chain") can be purchased from Forestry Supplies Inc., 208 West Rankin Street, P.O. Box 8397, Jackson, Mississippi 39204, U.S.A.).

Table 1. Example of a check-sheet to use in line-transect surveys.

Starting point: Road, 3,4 km west of Minkovala.

km	A — D	Xi	Elephant Sign	General Notes	Vegetation Type
0.00				Start from road	Secondary forest, canopy >5 m
0.27					Secondary canopy <5 m (recently abandoned plantation)
0.65					
0.93					Secondary, canopy >5 m
1.34					Marsh
2.00				Alarm call of grey-cheeked mangabey	Primary forest with with dense under-storey
3.62				Ravine	
3.73			Footprints signs of feeding		
3.94	D	1.7	Dropping		
4.17					
4.21	C2	0.6	Dropping		Abandoned village, secondary canopy >5m
5.22	D	2.4	Dropping		
5.23				Gorilla nests (group of 5)	
5.24					
5.27				Stream	Marsh
5.28					
5.29				Hunter's camp	Primary forest with dense understorey

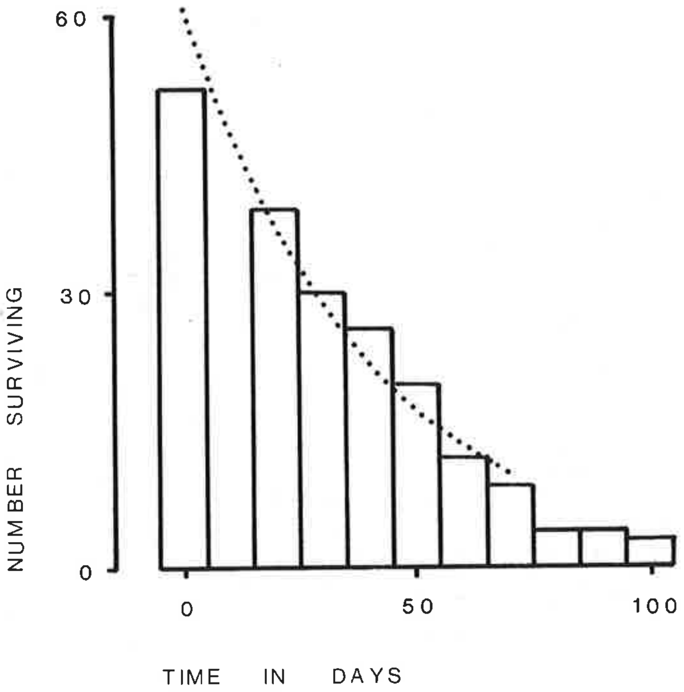
B Boli intact, fresh but dry, no odour.
C1 Some of the boli have disintegrated, but more than half are still distinguishable as boli.
C2 <50% of the boli are distinguishable; the rest have disintegrated.
D All boli completely disintegrated; dung-pile now forms an amorphous flat mass.
E Decayed to the stage where it would be impossible to detect at 2 metres' range in the undergrowth; it would not be seen on a transect unless directly underfoot.

Note that boli often break up when they land. During our study of dung decay rates in Gabon, we found that over three-quarters of newly-deposited dung-piles (under 1 week old) were classed as C1, C2, or D when first found.

Stage E droppings are not recorded in the transect. In other words, once a dropping passes from stage D to stage E it is deemed to have disappeared. The precise stage at which you set the point of transition from D to E is not important, as long as you are consistent in defining this point in both your observations of dung decay rate and in your transects.

You will find considerable variation in the time it takes for droppings to decay to stage E: some droppings will last only a few days while others will survive for many weeks, even when laid on the same day in the same patch of forest. A graph of the numbers of droppings surviving to a particular time t (see Fig. 4) will show a negative exponential curve. This means that the mean daily rate of decay is constant and we can use the equation of exponential decay to estimate the mean daily rate of decay of droppings.

Figure 4. The survival curve for a sample of 52 droppings. The droppings were found when fresh and visited at weekly intervals. When each dropping passed from stage D to E, it was deemed to have disappeared. The histogram shows the number still remaining at 10 days, 20 days . . . 100 days: A negative exponential curve has been fitted to the data.



When a large proportion (at least two-thirds) of the droppings have disappeared you will be able to calculate that rate of decay by the following method. Consider the example in Fig. 4 where we started with 52 droppings on day zero, and after 60 days there were 12 droppings left. Assuming exponential decay:

$$N_t = N_o e^{-rt}$$

where N_o is the initial number of droppings, N_t is the number left after t days, and r is the rate of decay. Taking natural logs (ln or $\log_e$)

$$\ln(N_t) = \ln(N_o) - rt$$

$$r = \frac{\ln(N_o) - \ln(N_t)}{t}$$

$$r = \frac{3.951 - 2.485}{60}$$

$$r = 0.024$$

Thus the daily rate of decay is 0.024 (which is equivalent to about 2.5% per day).

Step Four: Calculating the Elephant Density

Having estimated the dropping density Y, the mean daily rate of decay r, and the defaecation rate D, one can calculate the elephant density E from the equation:

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

As an example, a preliminary study in N.E. Gabon (Barnes and Jensen, 1986) found that Y = 292 droppings per sq km, r = 0.026 per day, and we used Wing and

Buss' (1970) estimate of D = 17 droppings per elephant per day, so:

$$E = \frac{292 \times 0.026}{17}$$

E = 0.45 elephants per sq km

SOURCES OF ERROR

A major source of error in the estimated dropping density, Y, is caused by inadequate supervision of the labourers cutting the transect. When the compass bearing runs close to a parallel animal trail there is a temptation for the labourers to edge the transect over so that it runs along the trail. This temptation is especially strong in secondary vegetation when the undergrowth is very difficult to cut through and there are numerous elephant paths. Since elephant dung is more likely to be found on the trail than to one side, a badly-cut transect which runs along a convenient trail will produce smaller values of x_i. This will result in a biased estimate of f(O) and therefore of Y. Thus it is essential to cut a dead straight transect.

A precise estimate is one with a low sample error and therefore narrow confidence limits; and an accurate estimate is one that is close to the true number of animals (for a detailed explanation see Norton-Griffiths, 1975). Elephant censuses in the forest will always be imprecise because of the non-random distribution of droppings. They will also be inaccurate because the elephant density E is calculated from three values (Y, r, and D), each of which is an estimate. Errors in one or more of these variables will result in errors in E. The errors are additive, so that small errors in each of Y, r, and D will result in a large error in E.

If the steady state assumption does not hold, then you will obtain an inaccurate estimate of E. Seasonal changes in defaecation rates, dung decay rates, and elephant distribution mean that steady state does not apply throughout the year (McClanahan, 1986):

1. The defaecation rate depends upon food quality which is a function of rainfall (Barnes, 1982). Table 3 of Wing and Buss (1970) suggests that forest elephant defaecation rates drop from 17 per day in the wet season to 11 per day in the dry.
2. Dung decays more slowly in the dry season. (But note that in the dry season the combination of lower rates of both defaecation and decay may result in a dung density that is little different from the wet season).
3. Elephants often move out of certain areas in the dry season. The number of droppings per sq km will fall during their absence. It will start to rise when they return, but several weeks will pass before it reaches its equilibrium value (Fig. 5). Thus a dropping census made soon after the elephants return will underestimate the numbers of elephants because the system has not yet attained the steady state.

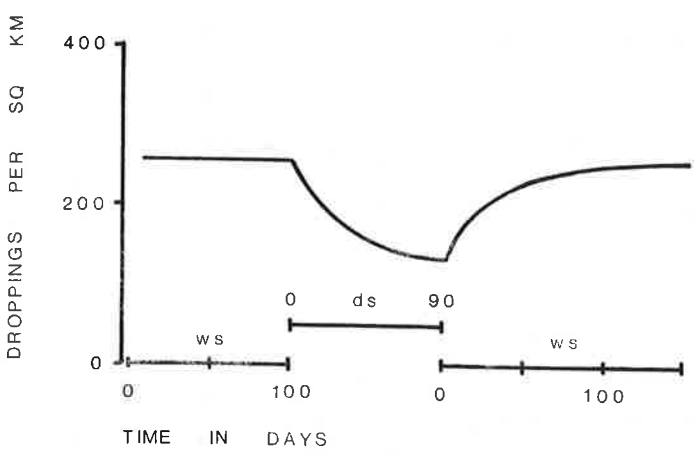
SHORT-CUT CENSUS METHODS

The line-transects described above give the most accurate estimates of dung density. But they are expensive: it takes a lot of time and labour to cut straight transects. As a consequence, one can only complete a small number of transects per unit time. There are two quicker methods one can use when time and funds are limiting and one needs only an approximate index of abundance. These give a less accurate estimate of dung density, but allow one to cover a much larger area.

Path Counts

By walking along animal trails and hunters' paths and counting droppings, one can use the mean number of droppings per km as an index of elephant abundance. Distance walked can be measured with a pedometer,

Figure 5. A computer simulation showing changes in the dung density (number of dung-piles per sq km) due to seasonal movements of elephants. The elephant density (number of elephants per sq km) is constant all through the wet season, but at the beginning of the dry season half the elephants move away and then return at the beginning of the wet season. In this simulation there were no seasonal changes in the defaecation and decay rates. ws = wet season; ds = dry season.



because the accuracy of the method does not justify the use of a topofil.

These path counts give an index of elephant abundance which is less accurate than one obtained from line-transects. But one can cover much greater distances, and one need employ fewer people.

Frequency of Elephant Sign

One can also use tracks and other signs as an index of abundance. We divided our line-transects into segments of 500 metres and recorded whether or not elephant sign (tracks and signs of recent feeding, but not including droppings) was seen in each segment. As an index of abundance, we used the frequency of elephant sign, which was the number of segments with elephant sign divided by the total number of segments.

There was a good correlation between the dung density estimated from the line transects and the frequency of elephant sign. This means that people working in the forest on other projects, (e.g. foresters, botanists, cartographers,geologists, and primatologists) could be asked to keep records of elephant sign in their transects. Their records could then be used to calculate indices of abundance for areas where elephant census teams cannot go for reasons of cost.

CONCLUSION

Elephant censuses in forest will never be as accurate as those in more open habitats where one can see the animals one is counting. Our confidence in the accuracy of forest elephant counts will be increased when we have more detailed information on three topics:

1. Elephant defaecation rates in relation to seasonal changes in rainfall.
2. Dung decay rates in relation to temperature, humidity, and rainfall.
3. Seasonal movements of elephants and their effects on dung density.

APPENDIX: OPTIMUM SIZE AND NUMBER OF TRANSECTS

Counts of elephant droppings in forest show very high variation between transects. Sample error will be reduced by stratifying, which means dividing the census zone into sub-zones, each of which is relatively homogeneous. The two most important variables determining elephant distribution are human activities and secondary forest. Therefore, one stratum should include all roads, towns, villages, and plantations, as well as areas where there is heavy hunting. As a rule of thumb, this stratum should enclose all areas within 7-10 km of human settlement. The rest of the census zone could be divided into one stratum in which either secondary forest predominates or a mosaic of secondary and primary forest occurs, and another stratum covered only by primary forest. You may need another stratum to cover areas with a high proportion of marsh.

For a given total length of transect, a large number of short transects will give a lower sample error than a small number of long transects (Norton-Griffiths, 1975). Our work in N.E. Gabon showed that 5 km is the optimum length for a transect, and that the minimum number of transects per stratum is 10 and the optimum is about 15.

However, the proportion of dead time is high during forest census work, even at the best of times. Dead time is the time spent moving from the end of one transect to the beginning of the next, when you are not collecting data but you are still spending money on wages and rations or fuel. With a large number of short transects the ratio of dead time to data-collecting time rises, especially when working in remote areas where travel is difficult. It may then become necessary to compromise and have a smaller number of longer transects, despite the loss of statistical efficiency.

Whatever the number and length of transects, you must ensure that you record at least 40 droppings in your survey. This is the minimum number of x_i values needed for an efficient estimation of f(O) (Burnham *et al.*, 1980; Dr. John Hart, pers. comm.).

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REFERENCES

BARNES R.F.W. (1982). Elephant feeding behaviour in Ruaha National Park, Tanzania. African Journal of Ecology, 20: 123-136.

BARNES, R.F.W. and JENSEN, K.L. (1986). Forest Elephant Survey Progress Report 1985-1986. New York Zoological Society. Typescript Report.

CAUGHLEY, G. (1977). Analysis of Vertebrate Populations. Wiley, Chichester.

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

JACHMANN, H. and BELL, R.H.V. (1984). The use of elephant droppings in assessing numbers, occupance, and age structure: a refinement of the method. African Journal of Ecology, 22: 127-141.

McCLANAHAN, T.R. (1986). Quick population survey method using faecal droppings and a steady state assumption. African Journal of Ecology, 24: 37-39.

MERZ, G. (1986). Counting elephants (*Loxodonta africana cyclotis*) in tropical rain forests with particular reference to the Tai National Park, Ivory Coast. African Journal of Ecology, 24: 61-68.

NORTON-GRIFFITHS, M. (1975). Counting Animals. African Wildlife Leadership Foundation, Nairobi.

SHORT, J.C. (1983). Density and seasonal movements of the forest elephant (*Loxodonta africana cyclotis* Matschie) in Bia National Park, Ghana. African Journal of Ecology, 21: 175-184.

TUTIN, C.E.G. and FERNANDEZ, M. (1984). Nationwide census of gorilla (*Gorilla g. gorilla*) and chimpanzee (*Pan t. troglodytes*) populations in Gabon. American Journal of Primatology, 6: 313-336.

VON LAVIEREN, L.P. (1977). Methodes d'Inventaire des Populations de Grandes Mammiferes. Ecole Pour la Formation des Specialistes de la Faune, Garoua, Cameroun.

WING, L.D. and BUSS, I.O. (1970). Elephants and forest. Wildlife Monographs, 19: 1-92.