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A model illustrating the changes in forest elephant numbers caused by poaching

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Summary

A geographic information system (GIS) was used to analyse field data on the abundance of elephant dung-piles. For each country, the GIS was used to create contours representing distances from roads or rivers. The area of forest between each contour was then calculated. The curvilinear relationships between dung-pile density and distance to the nearest road or village were then used to calculate the numbers of dung-piles between contours and the total for each country. Comparisons between undisturbed and heavily poached elephant populations suggest that the total forest elephant population in central Africa has been reduced by about 44% as a result of ivory poaching. Forest elephants may be more vulnerable to poaching than previously thought because, for example, two-thirds of Congo's elephants live within two days' walk of a road or navigable river.

Key words: dung, forest elephants, GIS, ivory, poaching

Résumé

On a employé un système d'information géographique (en anglais GIS) pour analyser les données sur la présence des excréments d'éléphants. Pour chaque pays, le GIS a servi à créer des tracés représentant les distances par rapport aux routes et aux rivières. On calculait alors la zone forestière comprise entre chaque tracé. Les relations curvilinéaires entre la densité des excréments et la distance par rapport à la route ou au village les plus proches étaient alors employées pour calculerle nombre d'excréments entre les tracés, et le total pour chaque pays. La comparaison entre les populations d'eléphants non dérangées et celles qui sont lourdement braconnées laisse penser que la population totale d'éléphants de forêt en Afrique centrale a été réduite de près de 44% à cause du braconnage pour l'ivoire. Les éléphants de forêt sont plus vulnérables qu'on ne le pensait avant au braconnage parce que, au Congo par exemple, 2/3 des éléphants vivent à moins de deux jours de marche d'une route ou d'une rivière navigable.

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Introduction

The greatest unknown quantity in the debate about the ivory trade has been the number of elephants (*Loxodonta africana* (Blumenbach)) remaining in the central African forests. The equatorial forests present the wildlife surveyor with immense problems: neither aerial surveys nor direct counts on the ground can be used because of the dense canopy and thick undergrowth. Indirect methods have to be used instead (Wing & Buss, 1970; Short, 1983; Merz, 1986; Barnes & Jensen, 1987; Koster & Hart, 1988). Furthermore, the forests cover immense areas, there are few roads, river travel is very costly, and movement on foot is slow. Thus survey work in the forest zone is both expensive and time-consuming. The amount of data one can collect per dollar spent is much less than in the grassland/woodland biome. Therefore, there is a greater need to maximize the information that can be extracted from the field data. This paper describes an analysis of dung-pile survey data using the ARC/INFO geographic information system (GIS) at UNEP/GRID in Nairobi. The goal was to obtain a preliminary estimate of forest elephant numbers in six central African countries: Cameroun, Central African Republic (C.A.R.), Congo, Equatorial Guinea, Gabon, and Zaire.

An earlier version of this paper formed part of the 1989 report of the Ivory Trade Review Group (Cobb, 1989).

Methods

This paper is concerned only with data collected before September 1989. Field surveys were conducted in Gabon between October 1985 and September 1988. They showed that human activity is the single most important factor determining elephant distribution in the forest. In particular, the density of elephants rises with increasing distance from roads and villages (Barnes *et al.*, 1991). Therefore, the subsequent surveys in 1989 in Cameroun, C.A.R., Congo, and Zaire (Fay, 1991; Fay & Agnagna, 1991; Alers *et al.*, 1992; Barnes *et al.*, 1993) were designed to show the relationship between elephant dung-pile densities and distance to the nearest road or village. These 1989 surveys were not stratified sample surveys but preliminary reconnaissances intended to (a) provide an overview of the status of forest elephants prior to the 1989 CITES meeting, and (b) furnish preliminary data on numbers and distribution of forest elephants as an aid to planning detailed sample surveys.

The African elephant GIS set up by Burrill & Douglas-Hamilton (1987) at the UNEP/GRID facility in Nairobi was modified for the central African region by adding two data layers: (a) all roads, and (b) major rivers thought to be navigable. For each country, a set of contours showing the distance from the nearest road or major river was generated. The first contour was at 7·5 km from the road or river and subsequent contours were at 4 km intervals. The area of the bands between the contours was then calculated using a computer. This procedure was conducted only for those areas of forest within the known range of elephants.

A regression equation relating dung-pile density to the nearest road was used to estimate the dung-pile density for each band. The product of the dung-pile density and the area of the band gave the total number of dung-piles in each band, and the sum of all bands gave the total number of dung-piles for that country.

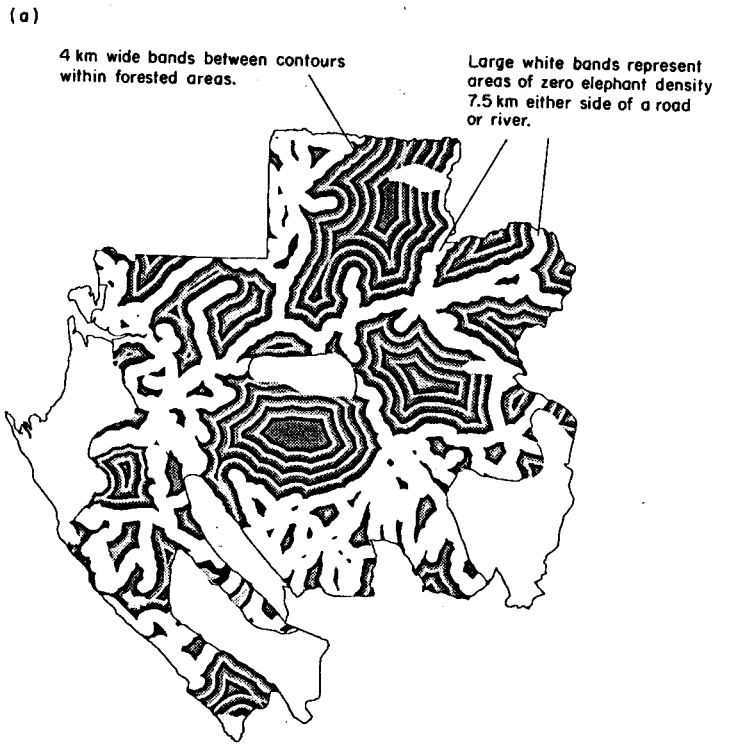

Fig. 1. GIS map showing computer-generated contours for (a) Gabon, (b) Congo, and (c) Cameroun. The contours are at 4 km intervals and represent distances from roads and major rivers. They are shown for the known range of elephants within the forest zone. The boundaries of the forest zone are those defined by White's (1983) vegetation map. Arbitrary shading of contours to delineate potentially important elephant zones.

The number of elephants can be calculated from the number of dung-piles if it is assumed that the system is in a steady state, and if estimates of elephant defaecation and dung decay rate are available (McClanhan, 1986; Barnes & Jensen, 1987). We used Tchamba's (1992) estimate of 20 dung-piles per elephant per day in the forests of Cameroun, and Barnes & Barnes' (1992) dung decay estimate of 0·0233 per day from N.E. Gabon.

Results

Distribution

The contour maps for 1989 are shown in Fig. 1 for Cameroun, Congo, and Gabon. The maps for C.A.R., Equatorial Guinea, and Zaire cannot be shown clearly at a small scale. These maps show the areas that are important for

Fig. 1. (b) (See caption on previous page).

elephants. The area of available habitat decreases exponentially with distance from roads (see Fig. 2a for Congo).

Figure 3 shows the curves relating dung-pile densities to roads or villages for Gabon, where there has been little organized poaching, at least at the time of the survey. There is little difference between dung-pile-to-village (A) and dung-pile-to-road curves (B). A flatter curve (C) is formed from the pooled data of those countries where there has been heavy poaching for many years (Congo, C.A.R. and Zaire). Thus the difference between curves B and C represents the impact on forest elephant populations of ivory poaching.

Figure 2b shows the number of elephant dung-piles calculated to lie in each band for Congo. The area of forest within 11·5 km of the roads accounts for 59% of Congo's forest area, but because elephants avoid areas of human activity close to roads, only 2% of dung-piles lie in that area. In contrast, forest lying more than 51·5 km from roads accounts for only 2% of the forest habitat but for 14% of elephant droppings. The majority of elephants (64%) are to be found between 11·5 and 33·5 km away from roads.

Numbers

These data allow us to calculate estimates of forest elephant numbers (a) for the period before the recent surge in ivory poaching, which started in the

Fig. 1. (c) (See caption on p. 91).

mid-seventies, and (b) for 1989, after about 15 years of poaching. For the era before the poaching upsurge, the numbers of elephants were estimated by using the dung-pile-to-road curve for Gabon and assuming that elephants occupied the whole forest zone. This gave a total estimate for the region of 263×10^6 dung-piles or 306,000 forest elephants (Table 1a).

The 1989 elephant populations were estimated by using the updated forest elephant distribution maps compiled by the African Elephant & Rhino Specialist Group, which were digitally combined with the GIS maps in Fig. 1. Thus the estimates were only made for forested regions within the known elephant range. The flatter dung-pile-to-village curve (C) was used to calculate the dung-pile density in each band. The exception was Gabon, for which curve B was used. The total estimate for the forest zone was 147×10^6 dung-piles or 171,000 elephants (Table 1b). These figures suggest a reduction of 135,000 elephants, or 44% of the pre-poaching total. Part of this is due to the reduction in elephant

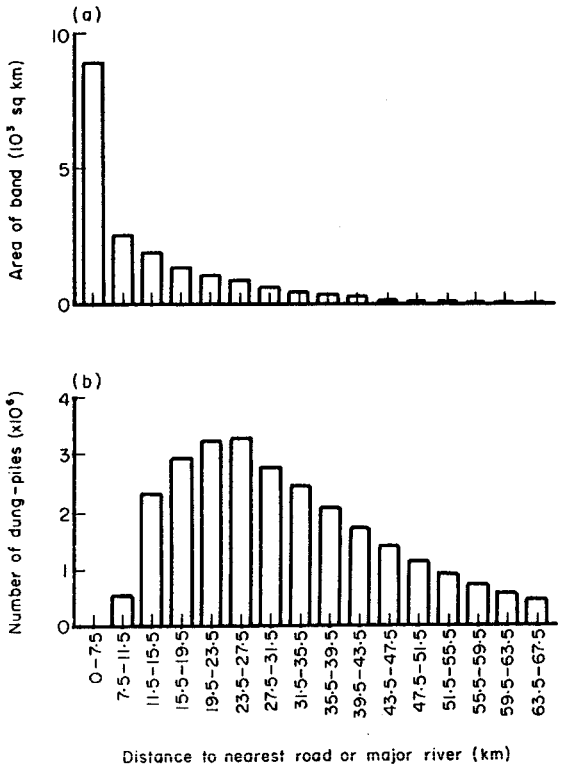

Fig. 2. (a) Area of forest habitat in each band between contours in Congo. (b) Estimated number of elephant dung-piles in each band between contours in Congo.

range within the forest zone, and part is due to the reduction in elephant densities in those forests where they still occur.

According to Table 1, four countries (Cameroun, C.A.R., Equatorial Guinea, and Zaire) have each lost about half their forest elephants, while Congo has lost about a third. The slight drop in the estimate for Gabon is due to the disappearance of elephants from the forests around the capital.

Discussion

Limitations of the methods used

These estimates must be viewed with extreme caution. First, the sample sizes were small, except for Gabon.

Secondly, there are errors in the maps from which the features were digitized. Many of the maps of central Africa are based on cartographic surveys conducted in the 1960s. Some roads shown on the maps have since disappeared, while elsewhere new roads have been constructed. Then there is the problem of

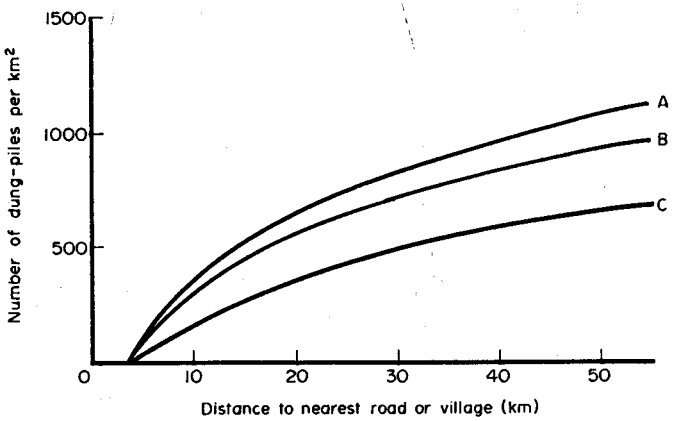

Fig. 3. Curves showing the relationship between dung-pile densities and distance to either the nearest village or the nearest road. (A) Dung-pile density in relation to villages in Gabon (Barnes *et al.* unpubl.). $Y=563\ln(X_v)-1174$. (B) Dung-pile density in relation to roads in Gabon (Barnes *et al.* unpubl.). $Y=491\ln(X_{rd})-1031$. (C) Dung-pile density in relation to villages; pooled data from Congo, C.A.R. and Zaire (WCI, 1989). $Y=900-1167\exp(-0{\cdot}0298X_v)$.

deciding whether a river is navigable, and therefore digitized, or not. Our model is based on a small sample size which is extrapolated to a large area, and thus any small errors in digitizing the features may result in large errors in the final elephant estimate.

Thirdly, the estimate of elephant numbers depends upon the estimates of defaecation and dung decay rates. While savanna elephant defaecation rates show wide variations (e.g. Barnes, 1982), those for forest elephants fall within a fairly narrow range: 17 dung-piles per elephant per day (Wing & Buss, 1970), 18 per day (Merz, 1986), and 20 per day (Tchamba, 1992). Furthermore, Wing & Buss's (1970) estimates show little seasonal variation, and Merz' (1986) opinion that 'for the forest elephants significant seasonal variations are unlikely' was confirmed by Tchamba (1992). Tchamba's (1992) estimates came from elephant groups that were followed for 24 hours or more, thus accounting for any diurnal rhythms in defaecation. Nevertheless, applying a defaecation rate from one site in Cameroun to the whole central African zone may result in errors. For example, the lower rate of 17 defaecations per day would have given pre-poaching and post-poaching elephant estimates of 360,092 and 201,570, respectively, instead of 306,077 and 171,334 in Table 1. The same problems arise with the estimate of dung decay rate. The possibility of seasonal variations in dung decay was eliminated by doing the field work in the wetter months, but there are still likely to be within-season and place-to-place variations in dung decay. The figure we used came from the wet season in N.E. Gabon (Barnes & Barnes, 1992). Data from western Gabon, where rainfall is higher, gave an identical rate of decay (A. Blom & M. P. T. Alers, unpubl. data).

Fourthly, because we have no data for the swamp forests of eastern Congo, we have assumed that elephant densities there will be the same as in the dryland forests of Congo. But elephant densities may be lower in the swamp forests

Table 1. Estimates of dung-pile and elephant populations in the central African forests (a) before and (b) after the surge in ivory poaching, (c) shows the reduction of elephant range and dung-pile population

(a) ~ 1974

Country	Range (km^2)	Numbers of droppings $\times 10^6$	Numbers of elephants
Cameroun	200,945	20·24	23,579
C.A.R.	40,350	2·84	3,308
Congo	228,148	41·31	48,126
Eq'l Guinea	25,713	0·79	920
Gabon	198,539	47·12	54,894
Zaire	1,199,261	150·43	175,250
Total	1,892,956	262·73	306,077

NB This is for forests only

(b)

Country ~ 1989	Range (km^2)	Number of droppings $\times 10^6$	Numbers of elephants
Cameroun	135,578	10·16	11,836
C.A.R.	40,350	1·42	1,654
Congo	196,689	26·51	30,884
Eq'l Guinea	25,713	0·35	407
Gabon	197,982	47·08	54,848
Zaire	875,968	61·55	71,705
Total	1,472,280	147·07	171,334

(c)

Country	Reduction in range (%)	Reduction in dung-pile population (%)
Cameroun	33	50
C.A.R.	0	50
Congo	14	36
Eq'l Guinea	0	56
Gabon	0	0
Zaire	27	59
Total	22	44

(J. M. Fay, pers. comm.). This is supported by evidence from three transects in N.E. Gabon: low dung-pile densities were recorded in the swamp forests along the Djoua River, which forms part of the frontier between Gabon & Congo (Barnes *et al.*, 1991: Fig. 3).

Finally, the calculations do not take into account the fact that elephants have been eliminated from large areas of the Zaire forests (Alers *et al.*, 1992). We do not yet know the extent of these areas and so cannot yet delineate them in the GIS. These last two provisos mean that the present populations in Congo and Zaire could well be much lower than Table 1b suggests. In other words, the estimates in Table 1 may be too optimistic. We suspect that the situation is much worse than the numbers suggest.

On the other hand, the relationship between elephant densities and roads is a general one and the GIS is the best means of using this relationship to produce elephant estimates for each country. Without the GIS it would have been difficult to estimate accurately the area of each band between the contours. The GIS is a valuable tool for efficiently stratifying the forest, enabling more efficient use to be made of the limited funds available for elephant surveys in the immense equatorial forests.

Further elephant surveys are planned to obtain better estimates of the dung-pile-to-road curve for each country and to further exploit the potential of the GIS. Thus the numbers here provide very preliminary estimates which will be revised as more data become available. The value of this paper is not so much in presenting preliminary estimates of forest elephant abundance but rather in illustrating the magnitude of the decline in elephant numbers caused by ivory poaching.

Distribution of elephants

The equatorial forests are the most sparsely populated parts of Sub-Saharan Africa. They are traversed by few roads. A surprising result of this analysis is the finding that few places (2% of the habitat) lie more than 50 km from a road or navigable river. Two-thirds of Congo's elephants are to be found <40 km, or less than two days' march, from a road or large river. This means that forest elephants are more vulnerable than previously realized.

Numbers of elephants

These results, although preliminary and flagged with warnings of caution, are the first objective estimates of forest elephant numbers based on data from the field. They are a considerable advance on the previous situation, which was one of ignorance and guesswork. For example, the forests of Zaire were suspected to be a refuge for large numbers of elephants, and in the early 1980s some commentators spoke of a million or more elephants remaining in Zaire alone (Anon, 1982; Douglas-Hamilton & Douglas-Hamilton, 1992). Table 1 suggests that, even before large-scale ivory poaching got under way, the forests of Zaire held much less than a quarter of a million elephants. As for the whole equatorial forest block, an initial population of about 300,000 does not signify a vast reservoir of elephants. And now, having lost perhaps half their elephants, the equatorial forests cannot be considered a refuge.

Elephant numbers have declined because of both the loss of range and the reduction in density caused by poachers in the forests where they still occur (i.e. the difference between curves B and C in Fig. 3). The reduction in forest elephant range shown in Table 1 is due partly to habitat loss, e.g. in Cameroun to the

south and south-west of Yaounde, but mainly because of the elimination of elephants from forests by poaching or other forms of human disturbance. For example, in southern Congo elephants have disappeared from parts of the Mayombe and du Chaillu forest blocks where there is still plenty of suitable habitat.

The comparison of the estimates before and after the poaching surge demonstrates the impact of ivory poaching on elephants in central Africa. The estimated numbers of elephant dung-piles have decreased by 44%. If one excludes Gabon, where organized commercial poaching has yet to get a grip, the decrease is 54%. However, the GIS method over-estimates the 1989 numbers for Zaire, because it does not account for the elimination of elephants from many forests. Alers *et al.* (1992) tried to take this into account and calculated that Zaire's forest elephants may number about 64,000. If they had used a conversion factor of 0·001165 as we have done, instead of 0·0018, their extrapolation would have given about 41,000 elephants. This would reduce the estimate of the total number of forest elephants in equatorial Africa to about 140,000. If it turns out that the Congo swamp forests hold few elephants, then the remaining forest elephant population may be even less than that.

The difference between the before and after elephant estimates is 135,000. If most of these were killed between the mid-1970s and the late 1980s, then about 10,000 elephants were killed per annum. During the decade 1979–88, 2822 tonnes of ivory (both savanna and forest elephants) were exported from these countries (Luxmoore, Caldwell & Hithersay, 1989), representing the deaths of about 219,000 elephants (Barnes, Blom & Alers, unpubl. MS). Although these ivory export figures include both savanna and forest elephants, they suggest that our estimates of the numbers of elephants killed may be conservative.

If the 1989 figure of 170,000 is accurate, and if the killing were to continue at a rate of 10,000 per annum, then elephants would be eliminated from the equatorial forests shortly after the turn of the next century.

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