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REPORT ON THE SURVEY OF THE ELEPHANTS OF THE ZIAMA FOREST RESERVE (JULY – DECEMBER 2004)

CITES/MIKE, GOVERNMENT OF GUINEA , AND CONSERVATION INTERNATIONAL

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SUMMARY

A dung count survey of the elephant population of the Ziama Forest Reserve (*Forêt Classée de Ziama*) was conducted in November and December 2004. Fifty-four transects were arranged in the "systematic segmented trackline" design recommended by MIKE. The half-normal key plus cosine adjustment provided the best fit to the perpendicular distance data and the mean density of dung-piles was estimated to be 542 per sq km (confidence interval from 382 to 768).

Two hundred and fifty-four dung-piles were marked between July and October for the dung decay experiment. The mean survival time was estimated at 57.79 days. These estimates were combined with Tchamba's (1992) estimate for forest elephant defaecation rate to give an estimate of 214 elephants with a CV of 18.5% and confidence intervals from 141 to 295.

A multivariate analysis showed that three variables were most important in determining the distribution of elephants: distance from the transect to the nearest *sous-préfecture*, distance from the transect to the main *route nationale* and the proportion of marsh in the transect. The first two apply year-round, while the third will change seasonally.

1. INTRODUCTION

The system for Monitoring the Illegal Killing of Elephants (MIKE) was established following a resolution of the parties to CITES in 1997. The main objective of MIKE is to provide information for elephant management and to build capacity within each range state. Other objectives are to measure levels and trends in the illegal killing of elephants, to determine changes in these trends over time, to determine the possible factors influencing such changes, and to assess to what extent observed trends are a consequence of CITES decisions.

There are between one and three MIKE sites in each of the elephant range states. MIKE intends to estimate elephant numbers every two or three years at each site, using standardised methods, in order to estimate the trend in elephant populations. The Ziama Forest Reserve (*Forêt Classée de Ziama*) is Guinea's MIKE site. The elephant population at Ziama was estimated at 108 in 1998 by the *Direction Nationale des Forêts et Faune* (1999, cited in Blanc *et al*, 2003), and at 200 in 2000 by M. Cécé Papa Condé (pers. comm.) and his colleagues. The survey reported here is the first time that the Ziama elephants have been surveyed using the standardised methods prescribed by MIKE.

The field work started in July 2004 when the field team marked a sample of fresh dung-piles as the first step in the dung decay experiment. Further groups of dung-piles were marked at regular intervals until the end of October. The transect survey was conducted in November and December 2004 and the data were analysed at N'Zérékoré in January 2005.

2. DESCRIPTION OF THE STUDY AREA

The following paragraphs are a summary of the detailed description in PROGERFOR (1995).

The Ziama forest is part of the administrative region of *Guinée Forestière* in the south-east of the country. It is situated between latitudes N 8°03' and N 8°32' and between longitudes W 9°08' and W 9°32' near the dense humid forests of Liberia and Côte d'Ivoire (Fig. 1). It was gazetted in 1942 and then re-classified as a biosphere reserve in 1981. The forest covers 1,190 sq km.

The Ziama massif forms part of the "*dorsale guinéenne*" which is characterised by areas of very broken relief and mountains. Between the mountains there is a peneplain with some low-lying areas. Numerous streams cut through the forest. The combination of broken terrain and heavy precipitation makes the Ziama massif an essential component of the hydrological system of the region.

The climate is humid tropical. The nearby town of Macenta experiences rainfall of about 2,700 mm per annum falling on about 170 days. The wet season lasts from March to November inclusive, and the ambient humidity varies from 81% to 96%.

The forest is situated mainly on the Precambrian granitic shield. It is dense evergreen or semi-deciduous forest. There are two principal forest types in *Guinée Forestière* : lower and montane. The first includes at Ziama the plant formations of the plains, situated at the foot of the mountains as well as the slopes up to an altitude of 950-1000 m. The low-lying formations merge gradually into those of the higher altitudes. The elephant range is to be found in the lower-lying forests (Fig. 2). The plant formations of this zone comprise primary forest (including climax vegetation or dry-land forest and edaphic vegetation) and secondary formations (secondary forest, regrowth, fallow, etc). There are also reafforestation plantations. See PROGERFOR (1995, pages 21-26) for further details.

One hundred and twenty-four species of mammal have been found in the Ziama forest, and 286 bird species. This forest is a refuge for several rare, vulnerable or threatened species. Elephants are found in the southern part and use an area of 452 sq km (Fig. 2).

Fig. 1. Map of Guinea showing the position of the F.C. Ziama.

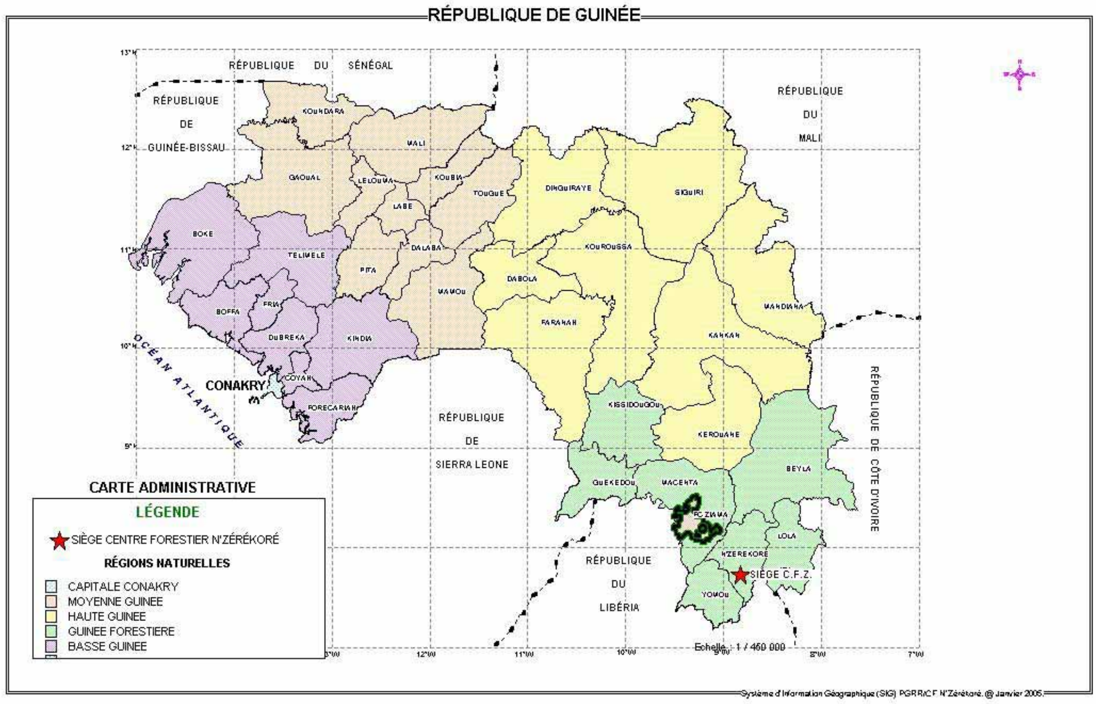
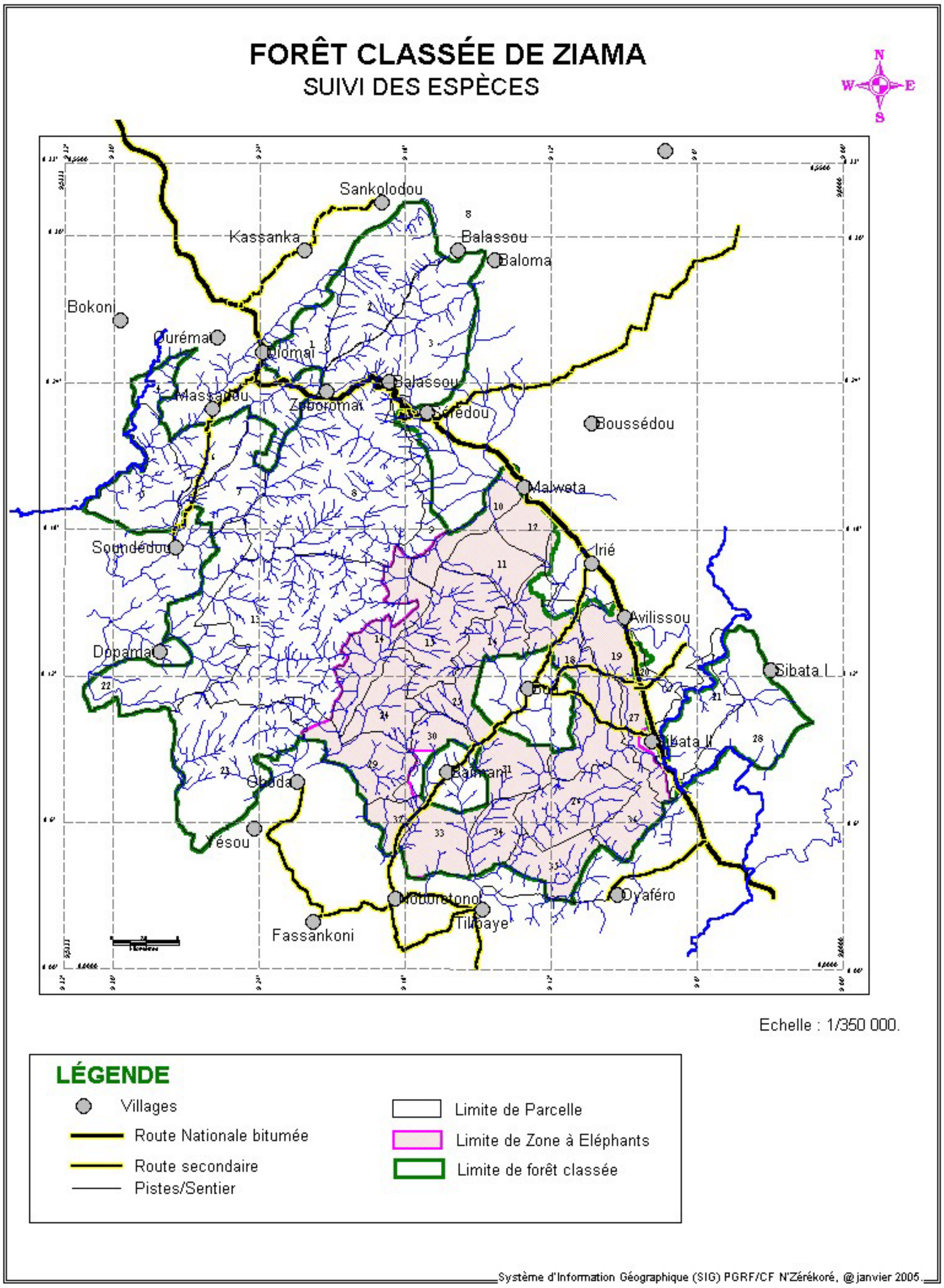


Fig. 2. Map of the F.C. Ziama showing the area used by elephants “zone à elephants”.



3. METHODS

3.1. Estimation of dung density

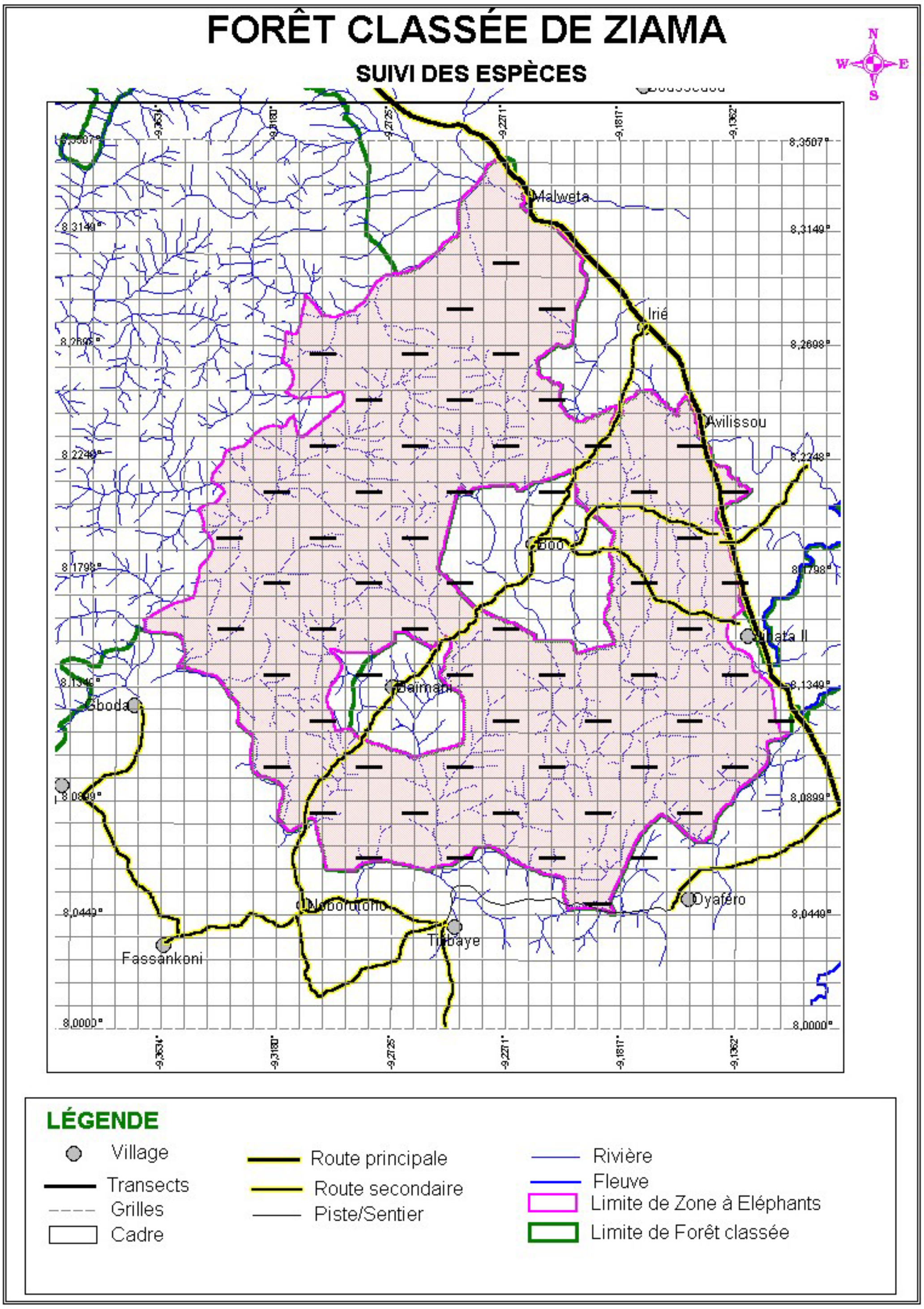
It is impossible to count elephants directly in forests such as that of the Ziama massif because of the poor visibility. Instead, we conducted a dung count survey, using the line transect method (Burnham *et al.*, 1980; Buckland *et al.*, 1993, 2001) adapted for forest elephants (e.g. Barnes *et al.*, 1997). A software package (DISTANCE 4.1) is available for the analysis of the data (Thomas *et al.*, 2002).

3.2. Distribution of transects

The dung count survey was made with a network of 54 transects, each one km in length. The transects were distributed systematically over the study area. Using the MAPINFO software package, a grid with cells 2 km by 2 km was placed at random over the site. The intersections of the lines then formed the starting point for each transect. This gave 54 transects that conformed to the *systematic segmented line transect* design required by MIKE (Fig. 3).

Transect orientation was perpendicular to the main drainage lines of the region. Since the main rivers flow from north to south, our transects ran from west to east.

Fig. 3. Map of the study site showing the distribution of transects.



3.3. Transect methods

We navigated with compass and GPS to reach the starting point of each transect. Once on the transect, only those dung-piles seen from the transect centre-line were recorded.

Four or five people marched in line along the transect. The compass man sighted on a stake held by another. Once the stake was correctly aligned, all marched in Indian file towards the stake, scrutinising the undergrowth on either side for dung-piles. The length of the transect was measured with a topofil.

The following notes were made each time a dung-pile was recorded :

- the distance along the transect, measured by the topofil.
- the perpendicular distance from the dung-pile to the transect centre-line, measured with a tape-measure.
- the state of decay of the dung-pile from S1 to S4.

The stages of decay are defined as (MIKE, 2004) :

- S1 : all the boli are intact.
- S2 : one or more boli are intact
- S3 : no boli are intact.
- S4 : the dung-pile no longer contains any faecal matter, only traces (e.g. plant fibres) remain.

Other notes were made along the transect, particularly of ecological factors that might explain the distribution of elephants :

- vegetation type.
- type of terrain.
- water sources.
- signs of human activity.

Using the GIS we measured the distance between each transect and the following features : the nearest *sous-préfecture*, nearest village, the main road (*route nationale*), nearest secondary road, the nearest forest edge. Table 1 shows all the variables recorded for each transect.

Table 1. List of the variables recorded for each transect.

Variable	Description of variable
X1	Distance to the nearest *sous-préfecture* (km)
X2	Distance to the nearest village (km)
X3	Distance to the main road or *route nationale* (km)
X4	Distance to the nearest secondary road (km)
X5	Distance to the nearest path or track (km)
X6	Distance to the Liberian frontier
X7	Distance to the nearest place where an elephant was shot (km)
X8	Distance to the nearest large river (km)
X9	Distance to the nearest small river (km)
X10	Distance to the nearest forest guard post (km)
X11	Percentage of swamp in the transect (excluding *Raphia* swamp)
X12	Percentage of *Raphia* swamp in the transect
X13	Percentage of young secondary forest in the transect
X14	Percentage of old secondary forest in the transect
X15	Percentage of secondary forest in the transect (both young and old)
X16	Percentage of forest plantation in the transect
X17	Number of signs of human activities seen in the transect
X18	Date that the transect was walked
X19	Distance to the forest edge (km)
X20	Percentage of all types of swamp in the transect
X21	Number of fruiting trees seen in the transect

3.4. Estimation of dung decay rate

To estimate the rate of dung decay in the Ziama forest, six cohorts of fresh dung-piles were marked at regular intervals between July 2004 and October 2004 (Laing *et al*., 2003). The study area was stratified taking into account the ecological variables likely to influence the decay of dung-piles. Thus five strata were defined : closed forest in the montane zone (FF/ZM), open forest in the montane zone (FO/ZM), closed forest on the plain (FF/ZP), open forest on the plain (FO/ZP) and secondary forest on the plain (FS/ZP). If one considers secondary forest on the plain to be similar to open forest, then there are four strata. On six occasions, at regular intervals of three weeks, fresh dung-piles were marked in these different strata. A search was made 24 to 48 hours before each marking period to find fresh signs of elephant activity. The presence of insects, smell and moisture of the surface enabled us to recognise fresh dung-piles. Each marked dung-pile was given an identification code and:

its state of decay was recorded.
its position was fixed by GPS.
the spot was marked by a coloured tape on which the code was written.
the diametre of some boli were recorded where it was possible to do so without disturbing the dung-pile.

Two hundred and fifty-four dung-piles were marked during the period before the transects were started. After the twenty-fifth transect, that is half way through the transect survey, all the marked dung-piles were revisited. Each was re-located using the GPS and compass and its state of decay was recorded.

3.5. Distribution of elephants

Counts of elephant dung-piles on transects are usually not normally distributed. In addition, they consist of integers and there are usually many zeroes (i.e. transects on which no dung-piles are seen). Generalised linear models, assuming a Poisson distribution and fitted by maximum likelihood, usually provide the best fit to these types of data, (McCullough & Nelder, 1989; Crawley, 1994). Such models have been applied to elephant dung data in both forest and savanna in Ghana (Sam *et al*., 2000; EBM/WD/MIKE, 2002; Barnes *et al*, 2003). In this case the statistics package GENSTAT was used. The data appeared to be slightly over-dispersed and so the dispersion parameter was calculated by GENSTAT (instead of assuming it to be one). The goal was to build a mathematical model that described the distribution of elephants and then incorporate the model with the GIS to generate a contour map of elephant abundance.

4. RESULTS

4.1. Density of dung-piles

Two hundred and two dung-piles were recorded on 54 transects. The perpendicular distances are shown in Fig. 4. This shows a typical visibility curve for dung counts in the forest. No dung-piles were seen beyond 9 metres from the center-line.

Using DISTANCE 4.1 we applied the six models recommended by Buckland *et al* (2001). The results are shown in Table 2. The most useful criterion is Akaike's Information Criterion (AIC): the smaller this value the better the fit of the model. Table 2 shows that the half-normal+cosine and half-normal+hermite polynomial gave the best fits. In fact they gave identical results. All further analyses were conducted with the half-normal+cosine model.

Buckland *et al* (2001) recommend that one truncates the data, that is one runs the analyses after deleting a few of the most distant dung-piles (those furthest from the transect line). We ran the model first by reducing the maximum strip width to 7 metres, and then to 6 metres and 5 metres. Usually truncation improves the fit of the model, but here it made little difference to the estimate of dung-pile density and caused the CV to increase. In other words, the precision of the estimate was reduced by truncation, and so we decided not to truncate in further analyses.

The half-normal+cosine model without truncation gave an estimate of 542 dung-piles per sq km (confidence interval from 382 to 768) and a CV = 17.6%.

Fig. 4. Histogram produced by DISTANCE showing the perpendicular distances and the fitted visibility curve (half-normal + cosine).

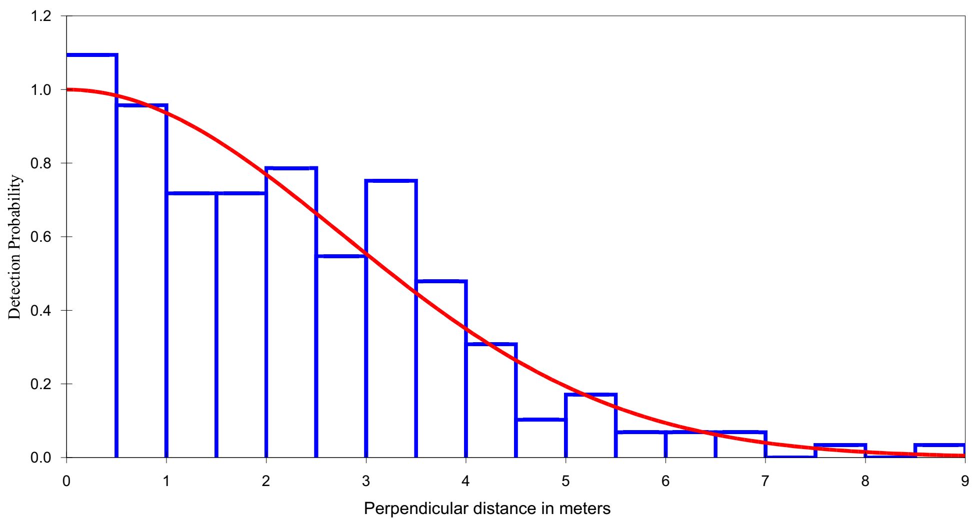


Table 2. The parameters estimated by each of the six models fitted to the line transect data. Density is the number of dung-piles per sq km; χ^2 compares the fit of the visibility curve to the histogram of the perpendicular distance data and $P(\chi^2)$ is the probability of χ^2; AIC is the Akaike Information Criterion (Buckland *et al*, 2001).

Parameter	Uniform + cosine	Uniform + simple polynomial	Half-normal + cosine	Half-normal + hermite polynomial	Hazard rate + cosine	Hazard rate + simple polynomial
f(0)	0.2887	0.1740	0.2896	0.2896	0.2742	0.2399
Density (km^{-2})	540	325	542	542	513	449
CV (%)	17.4	17.0	17.6	17.6	19.3	17.6
Upper CL	762	456	768	768	750	634
Lower CL	383	232	382	382	351	317
χ^2	10.80	74.77	14.06	14.06	8.84	11.55
$P(\chi^2)$	0.77	<0.0001	0.59	0.59	0.84	0.71
AIC	983.00	1046.70	982.71	982.71	983.02	983.85

4.2. Dung decay rate

Two hundred and fifty-four dung-piles were marked in six cohorts, but 11 (or 4%) could not be relocated, leaving 243 for the analysis (Table 3). All dung-piles except one in the first three cohorts had decayed to S4 ("disappeared"), or had completely disappeared, by the time they were re-inspected in late November. All those in the sixth cohort were readily visible when re-inspected (Table 3).

We applied the method of Laing *et al*. (2003) and the software module written by R.W. Burn for GENSTAT. This gave an estimated mean survival time of 57.79 days (or an estimated decay rate of 0.017 per day) and SE = 2.398 or CV = 4.15%.

It is clear that there are differences in decay rate between habitat types but more detailed analyses must await another day.

Table 3. Numbers of dung-piles marked and relocated for each cohort during the dung decay experiment.

Cohort	Number of dung-piles marked	Number of dung-piles relocated and inspected	Median age of dung-piles at final inspection (days)	Per cent still surviving at final inspection
1	55	48	134	0
2	43	43	112	2
3	33	31	90	0
4	50	48	70	33
5	34	34	49	50
6	39	39	27	100
Total	254	243	88	0.30

4.3. Estimation of elephant numbers

Having estimated the number of dung-piles on the ground and the mean survival time, if one takes an estimate of defaecation rate from elsewhere then one can proceed to calculate the number of elephants. We took the defaecation rate from Tchamba (1992) since this is the study of defaecation with the largest sample. The data in Tchamba's Table 1 gives a mean of 19.77 defaecations per day and a variance of 0.911.

The three variables were combined in the following equation:

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

where E was the elephant density, Y was the estimate of dung density per sq km, s was the estimated mean survival time and D was the estimated defaecation rate. This calculation was conducted with a spreadsheet that used the delta method (Seber, 1982; Buckland *et al*, 2001) to calculate the standard error of E. This gave an estimate of 0.47 elephants per sq km (SE = 0.09, CV = 18.7%). When multiplied by the area of the survey zone, an estimate of 214 elephants was obtained (confidence interval from 135 to 293).

DISTANCE provides the facility to do this calculation automatically, using multipliers. It also provides different methods for calculating the variance. The resulting estimates of elephant density are shown in Table 4a and the estimates of population size in Table 4b. Note that DISTANCE produces estimates with asymmetrical confidence limits. The estimate with the narrowest confidence limits came from the 2.5% and 97.5% quantiles of bootstrap estimates, so we retain this as our best estimate: 214 elephants (confidence intervals from 141 to 295)

Table 4a. Estimates of elephant density from DISTANCE with different methods of estimating the variance.

Method of calculation	Estimate of elephant density (per sq km)	%CV	Lower 95% confidence interval	Upper 95% confidence interval
Standard method (page 77 of Buckland *et al* (2001)	0.47	18.7	0.33	0.69
Bootstrap SE and log-normal 95% intervals	0.47	18.5	0.33	0.68
2.5% and 97.5% quantiles of bootstrap estimates	0.47	18.5	0.31	0.65

Table 4b. Estimates of elephant numbers from DISTANCE with different methods of estimating the variance.

Method of calculation	Estimate of elephant numbers	%CV	Lower 95% confidence interval	Upper 95% confidence interval
Standard method (page 77 of Buckland *et al* (2001)	214	18.7	148	311
Bootstrap SE and log-normal 95% intervals	214	18.5	148	309
2.5% and 97.5% quantiles of bootstrap estimates	214	18.5	141	295

4.4. Distribution of elephants

The distribution of dung-piles is shown in Fig. 5. The number of dung-piles per transect varied from 0 to 22 . A large number of variables could explain the distribution of elephants at the time of the survey. Some were measured from the GIS, while others were extracted from the field data-sheets (Table 1). The number of dung-piles per transect was plotted against each potential predictive variable (e.g. Figs 6 – 10). These graphs show that there is no single variable that clearly determines elephant distribution. They also indicate that some variables have a complex non-linear relationship with elephant density..

Each potential predictive variable was in turn added by itself to the null generalised linear model. The variable that explained the greatest reduction in deviance was the distance to the nearest *sous-préfecture* (*X1*) when expressed as a quadratic (Table 5a):

$$Y = \exp(-5.15 + 1.12X1 - 0.046(X1)^2)$$

Where *Y* was the number of dung-piles seen in each transect. The second step was to add each of the other potential predictive variables to the model that included *X1* and $(X1)^2$. The distance to the main road or *route nationale* (*X3*) emerged as the most important, again in quadratic form (Table 5b). In the third step the percentage of marsh (all marshes, including those with *Raphia*) was the most important. Once again, the relationship was quadratic (Table 5c). Thus we now had a model that appeared to explain the distribution of elephants with three variables, all in quadratic form.

The percentage of marsh was not normally distributed, because there were several points on the right hand side that exerted a disproportionate effect on the model (Fig. 10). Therefore we tried an arcsin transformation (Sokal & Rohlf, 1981). This considerably improved the distribution of *X20*, except for the gap at the left between the zero values and the next set of values (Fig. 11). The model with the arcsin transformation is shown in Table 5d.

These are the best models, that is the ones that produce the greatest reduction in deviance. Is one better than the other? The one in Table 5c gives the greater reduction in deviance, but one transect has a disproportionate leverage. The alternative model (Table 5d) explains less of the deviance, but fits the data well. In addition it is more parsimonious, that is, it has five variables rather than six.

These models allow us to calculate the number of dung-piles expected in a given transect at a given distance from the nearest *sous-préfecture* and a given distance from the main road, assuming a given percentage of marsh in that transect. The next step is to use the GIS to draw contours of elephant density for the model including *X1* and *X3*, assuming *X20* remains constant.

Table 5a. The first step in building a model that explains the distribution of elephant dung-piles per transect. This step explains elephant abundance in terms of distance to the nearest *sous-préfecture* (*X1*). This model produces a reduction of 60.7 in the deviance ($P < 0.01$).

	Estimate	S.E.	t_{51}	P
Constant	-5.15	2.71	-1.90	0.063
X1	1.124	0.420	2.68	0.010
$(X1)^2$	-0.0457	0.0160	-2.85	0.006

Table 5b. The second step in building a model that explains the distribution of elephant dung-piles per transect. This step explains the distribution of elephant dung-piles per transect in terms of distance to the nearest *sous-préfecture* (*X1*) and distance to the main road (*X3*). This model produces a reduction of 96.6 in the deviance ($P < 0.001$).

	Estimate	S.E.	t_{49}	P
Constant	-4.69	2.35	-1.99	0.052
X1	0.918	0.374	2.46	0.018
$(X1)^2$	-0.0394	0.0143	-2.76	0.008
X3	0.2742	0.0982	2.79	0.007
$(X3)^2$	-0.01230	0.00421	-2.92	0.005

Table 5c. The third step in building a model that explains the distribution of elephant dung-piles per transect. This model explains the distribution of elephant dung-piles per transect in terms of distance to the nearest *sous-préfecture* (*X1*), distance to the main road (*X3*) and the percentage of marsh in the transect (*X20*). Note that each predictive variable is significant (P < 0.05), except for $(X20)^2$. This model produces a reduction of 118.9 in the deviance (P < 0.001).

	Estimate	S.E.	t_{47}	P
Constant	-4.54	2.33	-1.95	0.057
X1	0.803	0.369	2.18	0.034
$(X1)^2$	-0.0354	0.0140	-2.52	0.015
X3	0.3206	0.0962	3.33	0.002
$(X3)^2$	-0.01410	0.00415	-3.40	0.001
X20	0.0528	0.0211	2.51	0.016
$(X20)^2$	-0.000643	0.000349	-1.84	0.072

Table 5d. The model that explains the distribution of elephant dung-piles per transect in terms of distance to the nearest *sous-préfecture* (*X1*), distance to the main road (*X3*) and the arcsin transformation of percentage of marsh in the transect (Arcsin√*X20*). Note that each predictive variable is significant (P < 0.05). This model produces a reduction of 113.3 in the deviance (P < 0.001).

	Estimate	S.E.	t_{48}	P
Constant	-4.35	2.38	-1.82	0.074
X1	0.766	0.382	2.01	0.050
$(X1)^2$	-0.0339	0.0145	-2.35	0.023
X3	0.3036	0.0948	3.20	0.002
$(X3)^2$	-0.01325	0.00406	-3.27	0.002
Arcsin(√*X20*)	0.343	0.158	2.17	0.035

Fig. 5. Map showing the distribution of elephant dung-piles. The digits above each line show the transect identification number, while that below is the number of dung-piles.

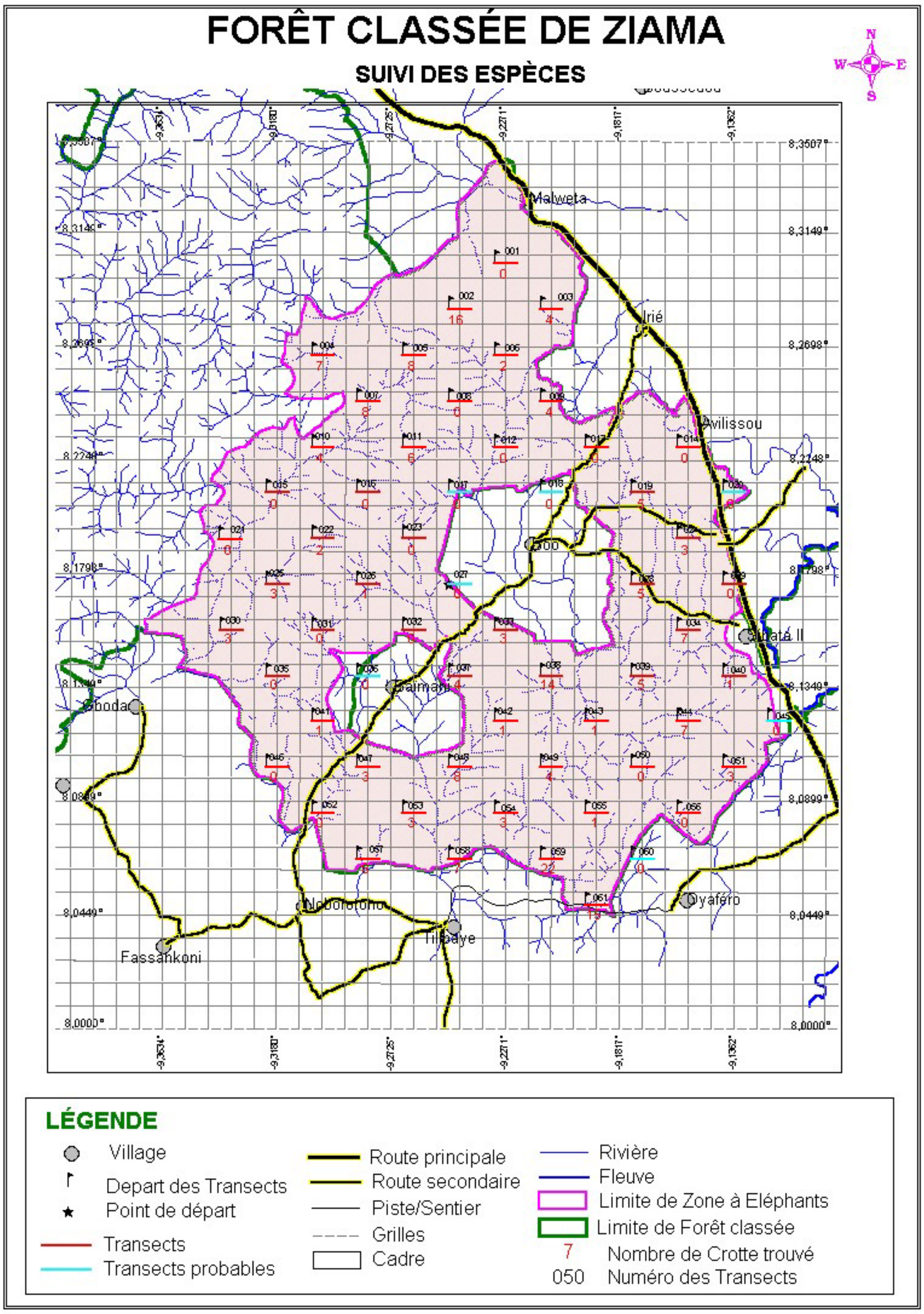


Fig. 6. Graph showing the relationship between the number of dung-piles per transect (*Y*) and distance to the nearest *sous-préfecture* (*X1*).

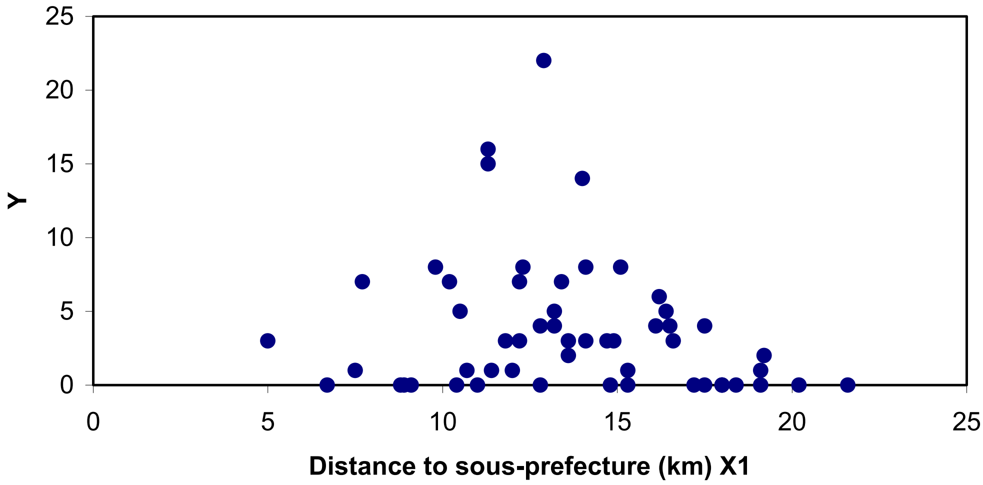


Fig. 7. Graph showing the relationship between the number of dung-piles per transect (*Y*) and distance to the nearest village (*X2*).

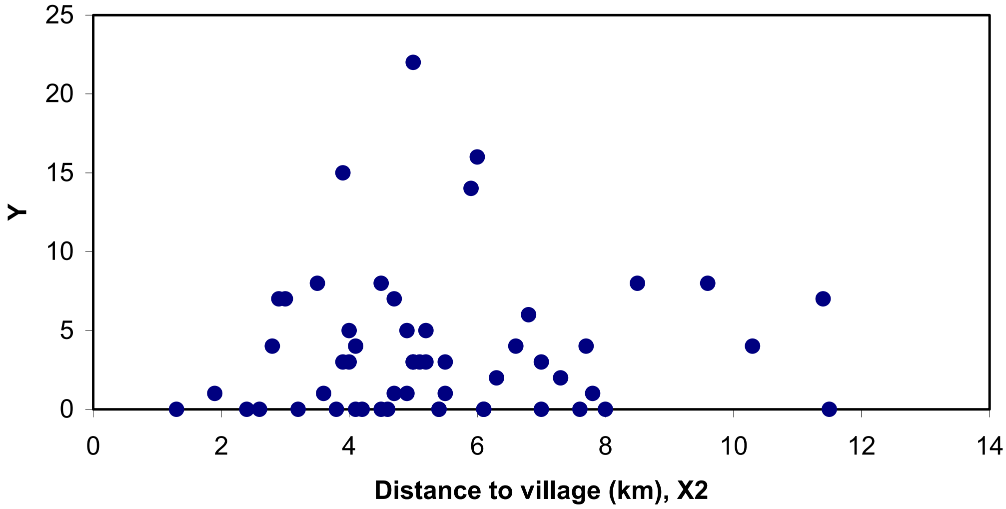


Fig. 8. Graph showing the relationship between the number of dung-piles per transect (*Y*) and distance to the nearest main road (*X3*).

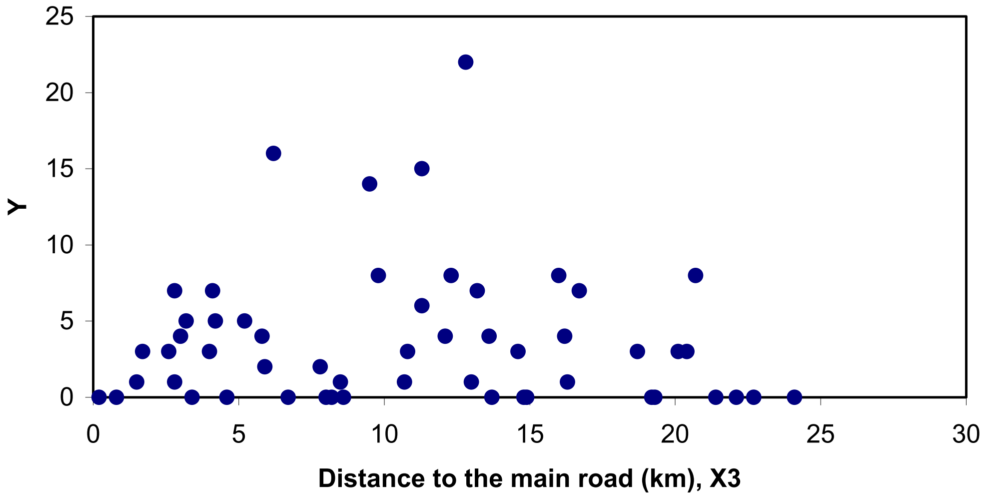


Fig. 9. Graph showing the relationship between the number of dung-piles per transect (*Y*) and the number of signs of human activities (*X17*).

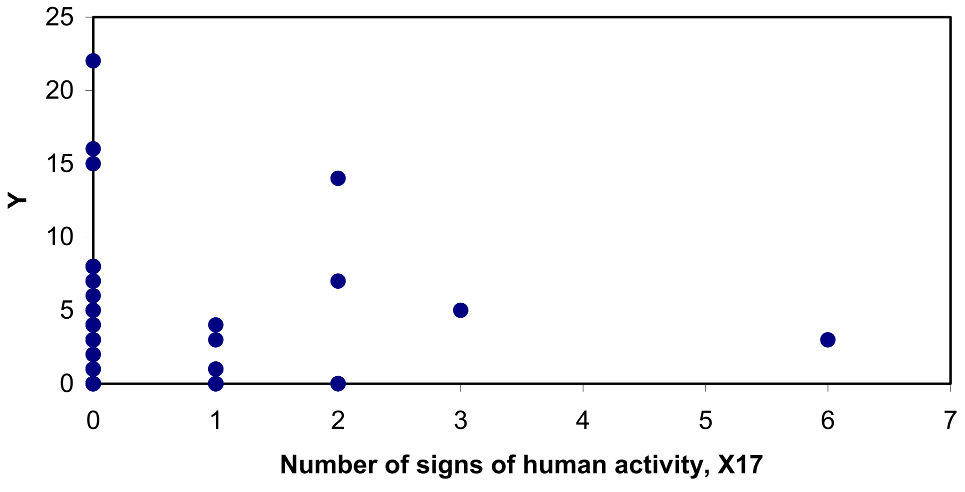


Fig. 10. Graph showing the relationship between the number of dung-piles per transect (*Y*) and the percentage of all types of swamp in the transect (*X20*).

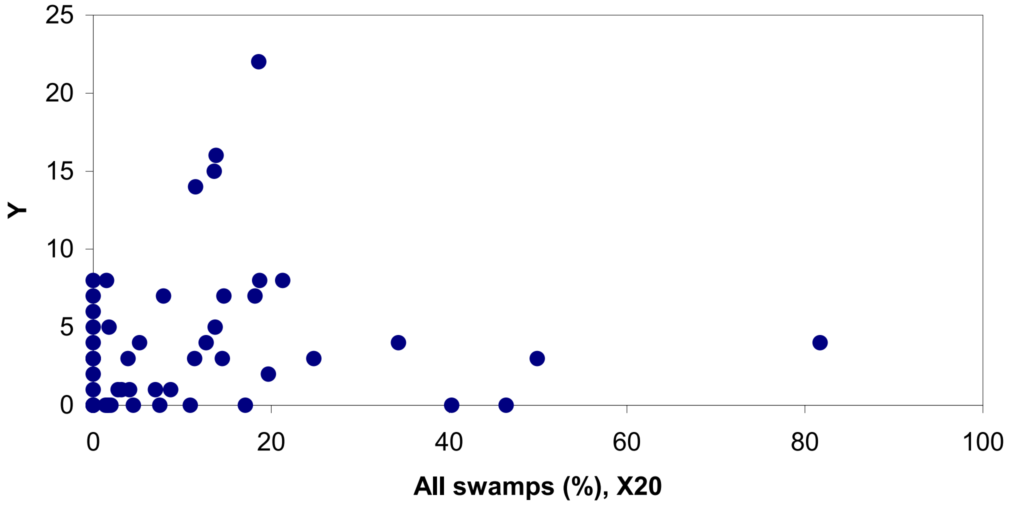
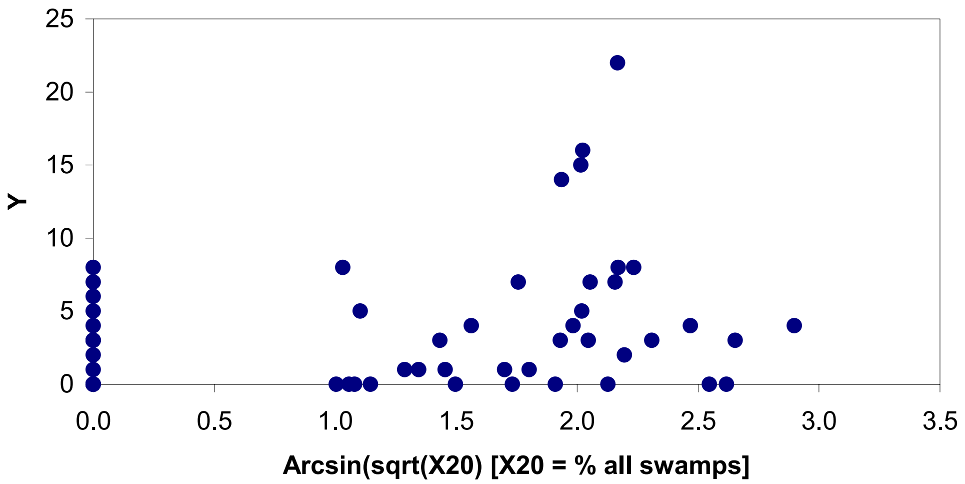


Fig. 11. Graph showing the relationship between the number of dung-piles per transect (*Y*) and the arcsin transformation of the percentage of all types of swamp.



5. DISCUSSION

5.1. Estimate of population size

This estimate of 214 elephants should not be compared with the estimates of the Ziama elephant population made in 1997 and 2000 because different sampling methods were used. Comparisons should only be made between counts using the same methods.

Many people have doubted the value of dung counts to estimate elephant numbers, but the available evidence indicates that they give good estimates with reasonable confidence limits (Jachmann, 1991; Plumptre & Harris, 1995; Barnes, 2001, 2002; Eggert *et al*, 2003). The weakest link in the method used here is the defaecation rate taken from Tchamba's (1992) study in southern Cameroun. In fact estimates of defaecation rates in forest elephants seem to vary little. It is possible that MIKE will decide to use a different figure for the defaecation rate in the West African forests, in which case the calculations can be easily revised.

5.2. Distribution of elephants

Three variables emerged as determinants of elephant distribution at this particular time of year (November-December). Distance to *sous-préfecture* (*X1*) was the most important. The *sous-préfecture*s are small towns that are a hub of human activity. Not only are there more people and they are therefore a source of general human disturbance, but there are restaurants that offer bushmeat so they are also a centre of hunting activity. At night there are generators producing noise that travels far.

The *sous-préfecture*s on the *route nationale* are larger than those on secondary roads. It comes as no surprise that the *route nationale* (*X3*) should also be an important variable. There is constant traffic, night and day. In the forests of Gabon we found that roads explained a large part of the variance in elephant distribution, with the highest elephant densities in the remotest forests (Barnes *et al*, 1997). At Kakum we conducted studies of infra-sound communication in collaboration with the Laboratory of Ornithology at Cornell University. These showed that trucks on the main road produce sound of wavelengths that travels far at night, even through the forest. The main roads are also a source of hunters. Bushmeat hunters may disturb elephants: gunshots alarm elephants and human scent trails leave a reminder that people are walking about in the forest.

We had expected that villages (*X2*) would emerge as an important variable. Although they clearly do have an effect (Fig. 7), the *sous-préfecture*s have a much greater influence.

Note that the two most important variables are *external* to the forest. We did not identify any disturbance *inside* the forest that influences elephant distribution. While *X17* (human activities) did show the expected negative influence (Fig. 9), it was weak and not statistically significant.

These two variables (*X1* and *X3*) are not seasonal but will operate throughout the year. On the other hand, swamps will have a seasonal effect. In the dry season swamps will probably have a stronger influence on elephants.

The equation that expresses elephant abundance in terms of *X1* and *X3* will be incorporated into the GIS to create a contour map that shows the relative distribution of elephants throughout the forest.

5.3. Crop-raiding by elephants

Wherever you have both cultivation and elephants there will be conflict between people and elephants. The type of farming practiced in the forest zone of West Africa creates a vegetation mosaic that is particularly favoured by elephants (Barnes, 2002; Barnes *et al*, 2003a, 2003b). The tragedy of the situation is that while struggling to feed their families, farmers are creating the conditions that attract elephants (Barnes, 2002). Human-elephant conflict is thus an inevitable consequence of a forest like Ziama that holds elephants but which is surrounded by cultivation. The situation is exacerbated by the two enclaves in the middle of the forest. Satenin & Sagnah (2000) pointed out that it is necessary to elaborate a land use plan for the area around Ziama to mitigate the problem, and to find ways for the people to benefit from the presence of elephants.

In some instances it has been possible to prevent crop raiding with electric fences. One possibility is to fence the two enclaves. But that would be a very expensive option: there will be not only the capital cost of constructing the fence but also annual maintenance costs. The fence will have to be maintained until the end of time; if the fence is poorly maintained then elephants will break through. There are many cases where electric fences have not worked, or have worked but failed after a few years due to insufficient maintenance. See Barnes *et al* (2003b) for further discussion of electric fences in the forest context.

Thus one may have to accept the inevitablility of crop damage caused by elephants. Nevertheless, it may be possible to take measures to reduce the risk of crop raiding, by farming in such a way as to reduce the attraction of the farming landscape to elephants. Many lessons were learnt from our study of crop-raiding in southern Ghana (Barnes *et al*., 2003). Some of those lessons could be applied around Ziama. The situation around Ziama differs from Kakum, and so other lessons from Kakum may not be applicable. A study of crop-raiding around Ziama is clearly necessary in order to identify the features that increase the risk of damage by elephants.

6. ACKNOWLEDGEMENTS

Thanks to the Guinea Authorities in general for the facilities provided during this survey. We offer our sincere thanks to the Director-General of the *Centre Forestier*, M. Aliou Nadhel Diallo, who placed himself and the facilities of the Centre entirely at our disposition. We thank the National Coordinator of MIKE, Mme Christine Sagno, for the collaboration of the MIKE programme in Guinea. M. Kouyaté Salim undertook all the GIS analyses for which we will always be grateful. We thank the members of the field team (see Annex 1) for their efforts and their companionship in the field. We thank the principal drivers of the *Centre Forestier*, M. Mahoro Béavogui and M. Tanou Dopavogui, who guided us with care around the study area.

The funds were provided by the Critical Ecosystem Partnership Fund and the Smart Family Foundation via Conservation International's support for M. Nandjui Awo..

Conservation International made an important contribution to this project through its collaboration with MIKE. We wish to thank Dr Léonie Bonnehin, the former representative of Conservation International in Côte d'Ivoire. The Division of Biological Sciences of the University of California at San Diego provided office space, library facilities and email service.

We are grateful for the guidance provided by Mr. Nigel Hunter, the Director of MIKE, and M. Massalatchi Sani, the sub-regional coordinator of MIKE in West Africa.

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ANNEX 1: List of the members of the survey team

Name	Position
Koi Gouavogui	Former *Chef d'Antenne de Ziama*
Nicolas Londiah Delamou	Current *Chef d'Antenne de Ziama*
Mohamed Camara	Former *Chef de brigade de Ziama*
Lah Gbamou	Current *Chef de brigade de Ziama*
Mohamed Samoura	*Assistant de la surveillance*
Seny Koivogui	*Surveillant*
Nestor Kondiano	*Surveillant*
Laurent Bore	*Surveillant*
Nema Soua Lamah	*Surveillant*
Siba Jacob Grovogui	*Surveillant*
Ouo Ouo Monemou	*Surveillant*

ANNEX 2: RESULTS FROM *DISTANCE* PACKAGE

ANNEX 2A: ESTIMATE OF DUNG DENSITY---RESULTS FROM *DISTANCE* : HN+COSINE + BOOTSTRAP

HALF-NORMAL + COSINE 17 Janvier 2005

Estimation Options Listing

Parameter Estimation Specification

Encounter rate for all data combined
Detection probability for all data combined
Density for all data combined

Distances:

Analysis based on distance intervals
Width specified as: 9.000000
Left most value set at: 0.0000000

Estimators:

Estimator 1
Key: Half-normal
Adjustments - Function : Cosines
- Term selection mode : Sequential
- Term selection criterion: Akaike Information Criterion (AIC)

Estimator selection: Choose estimator with minimum AIC
Estimation functions: constrained to be nearly monotone non-increasing

Variances:

Variance of n: Empirical estimate from sample
Variance of f(0): MLE estimate

Goodness of fit:

Based on grouped distance data intervals

Detection Fct/Global/Model Fitting

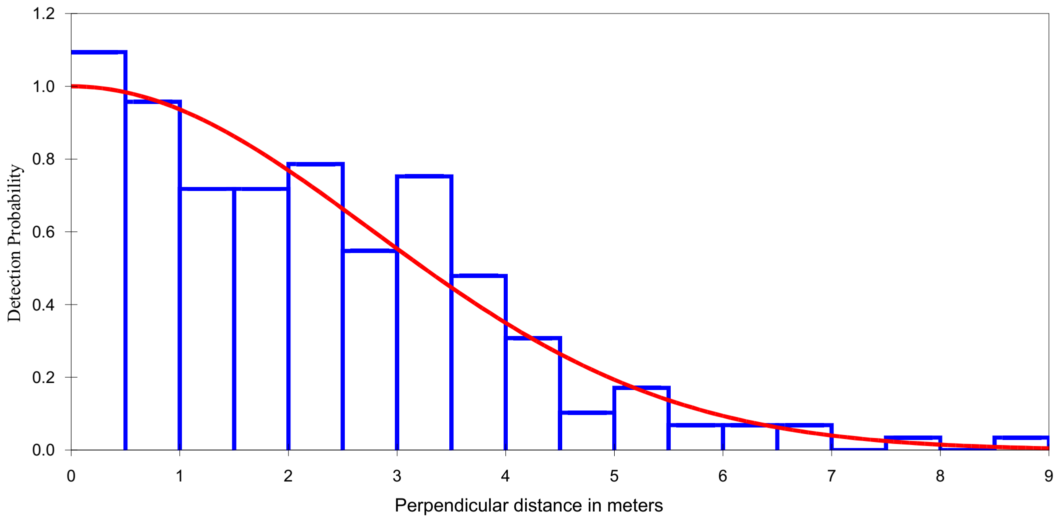
```
Effort      :   54.00000
# samples   :   54
Width       :   9.000000
Left        :    0.0000000
# observations:   202



Model  1
  Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))
    Results:
    Convergence was achieved with    7 function evaluations.
    Final Ln(likelihood) value =  -490.35670
    Akaike information criterion =   982.71338
    Bayesian information criterion =   986.02167
    AICc =   982.73340
    Final parameter values:   2.7585074


Model  2
  Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))
  Cosine adjustments of order(s) :  2
    Results:
    Convergence was achieved with   11 function evaluations.
    Final Ln(likelihood) value =  -490.27770
    Akaike information criterion =   984.55542
    Bayesian information criterion =   991.17194
    AICc =   984.61572
    Final parameter values:   2.7128483    -0.51869103E-01

  Likelihood ratio test between models  1 and  2
    Likelihood ratio test value    =     0.1580
    Probability of a greater value =   0.691008
*** Model  1 selected over model  2 based on minimum AIC
```

Detection Fct/Global/Parameter Estimates

```
Effort      :   54.00000
# samples   :   54
Width       :   9.000000
Left        :    0.0000000
# observations:   202
```

Model
Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95 Percent Confidence Interval	
A(1)	2.759	0.1430			
f(0)	0.28956	0.14825E-01	5.12	0.26178	0.32030



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Detection Fct/Global/Chi-sq GOF Test

Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	0.500	32	29.09	0.292
2	0.500	1.00	28	28.15	0.001
3	1.00	1.50	21	26.36	1.091
4	1.50	2.00	21	23.90	0.351
5	2.00	2.50	23	20.96	0.198
6	2.50	3.00	16	17.79	0.181
7	3.00	3.50	22	14.62	3.728
8	3.50	4.00	14	11.62	0.487
9	4.00	4.50	9	8.94	0.000

10	4.50	5.00	3	6.66	2.010
11	5.00	5.50	5	4.80	0.008
12	5.50	6.00	2	3.35	0.542
13	6.00	6.50	2	2.26	0.030
14	6.50	7.00	2	1.48	0.187
15	7.00	7.50	0	0.93	0.932
16	7.50	8.00	1	0.57	0.324
17	8.00	8.50	0	0.34	0.338
18	8.50	9.00	1	0.19	3.363

Total Chi-square value = 14.0623 Degrees of Freedom = 16

Probability of a greater chi-square value, P = 0.59407

The program has limited capability for pooling. The user should judge the necessity for pooling and if necessary, do pooling by hand.

Goodness of Fit Testing with some Pooling

Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	0.500	32	29.09	0.292
2	0.500	1.00	28	28.15	0.001
3	1.00	1.50	21	26.36	1.091
4	1.50	2.00	21	23.90	0.351
5	2.00	2.50	23	20.96	0.198
6	2.50	3.00	16	17.79	0.181
7	3.00	3.50	22	14.62	3.728
8	3.50	4.00	14	11.62	0.487
9	4.00	4.50	9	8.94	0.000
10	4.50	5.00	3	6.66	2.010
11	5.00	5.50	5	4.80	0.008
12	5.50	6.00	2	3.35	0.542
13	6.00	6.50	2	2.26	0.030
14	6.50	7.00	2	1.48	0.187
15	7.00	9.00	2	2.03	0.001

Total Chi-square value = 9.1064 Degrees of Freedom = 13

Probability of a greater chi-square value, P = 0.76486

Density Estimates/Global

Effort : 54.00000
samples : 54

Width : 9.000000
Left : 0.0000000
observations: 202

Model 1
Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
f(0)	0.28956	0.14825E-01	5.12	0.26178	0.32030
p	0.38372	0.19645E-01	5.12	0.34690	0.42445
ESW	3.4535	0.17681	5.12	3.1221	3.8200
n/L	3.7407	0.62957	16.83	2.6753	5.2304
D	541.59	95.274	17.59	382.09	767.67

Measurement Units

Density: Numbers/Sq. kilometers
ESW: meters

Component Percentages of Var(D)

Detection probability : 8.5
Encounter rate : 91.5

Estimation Summary - Encounter rates

	Estimate	%CV	df	95% Confidence Interval	
n	202.00				
k	54.000				
L	54.000				
n/L	3.7407	16.83	53.00	2.6753	5.2304
Left	0.0000				
Width	9.0000				

Estimation Summary - Detection probability

	Estimate	%CV	df	95% Confidence Interval
Half-normal/Cosine				
m	1.0000			
LnL	-490.36			
AIC	982.71			
AICc	982.73			

BIC	986.02				
Chi-p	0.76486				
f(0)	0.28956	5.12	201.00	0.26178	0.32030
p	0.38372	5.12	201.00	0.34690	0.42445
ESW	3.4535	5.12	201.00	3.1221	3.8200

Estimation Summary - Density&Abundance

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	D	541.59	17.59	63.12	382.09	767.67

ANNEX 2B: ESTIMATE OF ELEPHANT DENSITY: RESULTS FROM *DISTANCE* : HN+COSINE + MULTIPLIERS + BOOTSTRAP

Fichier: Elephant density estimate—HN+cosine+BOOTSTRAP.doc
Date: le 19 Janvier 2005

Estimation Options Listing

Parameter Estimation Specification

Encounter rate for all data combined
Detection probability for all data combined
Density for all data combined

Distances:

Analysis based on distance intervals
Width specified as: 9.000000
Left most value set at: 0.0000000

Estimators:

Estimator 1
Key: Half-normal
Adjustments - Function : Cosines
- Term selection mode : Sequential
- Term selection criterion: Akaike Information Criterion (AIC)

Estimator selection: Choose estimator with minimum AIC
Estimation functions: constrained to be nearly monotone non-increasing

Multipliers:	Value	SE
Defn	0.50582E-01	0.25073E-02
Survival	0.17304E-01	0.71863E-03

Variances:

Bootstrap variance/confidence intervals for density. Random number seed = 1953049.
Re-sampling will be across defined strata
Samples will be re-sampled
Variance of n: Empirical estimate from sample
Variance of f(0): MLE estimate

Goodness of fit:

Based on grouped distance data intervals

Effort : 54.00000
samples : 54
Width : 9.000000
Left : 0.0000000
observations: 202

Model 1
Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))
Results:
Convergence was achieved with 7 function evaluations.
Final Ln(likelihood) value = -490.35670
Akaike information criterion = 982.71338
Bayesian information criterion = 986.02167
AICc = 982.73340
Final parameter values: 2.7585074

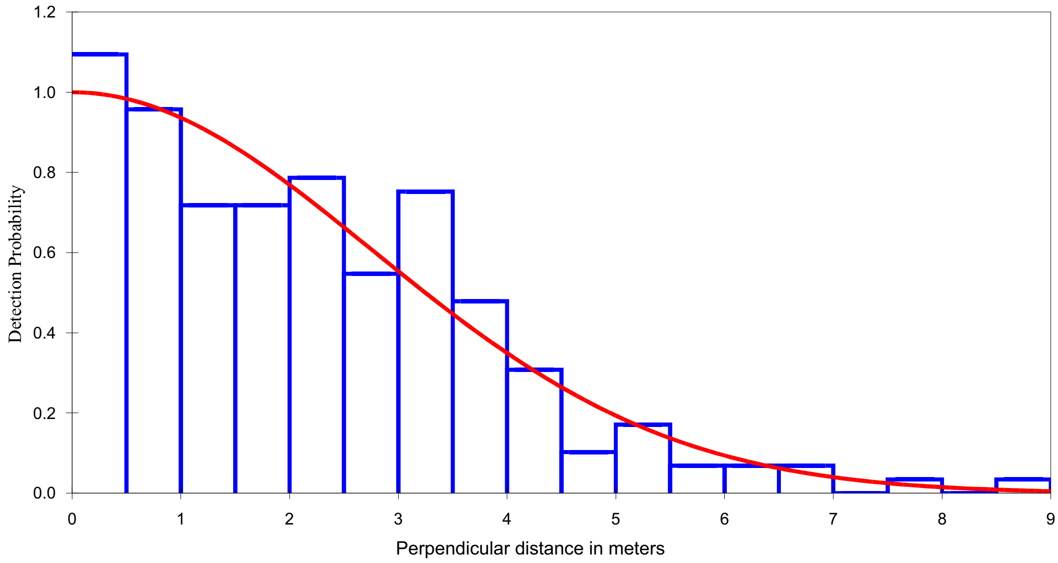
Model 2
Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))
Cosine adjustments of order(s) : 2
Results:
Convergence was achieved with 11 function evaluations.
Final Ln(likelihood) value = -490.27770
Akaike information criterion = 984.55542
Bayesian information criterion = 991.17194
AICc = 984.61572
Final parameter values: 2.7128483 -0.51869103E-01

Likelihood ratio test between models 1 and 2
Likelihood ratio test value = 0.1580
Probability of a greater value = 0.691008
*** Model 1 selected over model 2 based on minimum AIC
Detection Fct/Global/Parameter Estimates

Effort : 54.00000
samples : 54
Width : 9.000000
Left : 0.0000000
observations: 202

Model
Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95 Percent Confidence Interval	
A(1)	2.759	0.1430			
f(0)	0.28956	0.14825E-01	5.12	0.26178	0.32030



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Detection Fct/Global/Chi-sq GOF Test

Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
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2	0.500	1.00	28	28.15	0.001
3	1.00	1.50	21	26.36	1.091
4	1.50	2.00	21	23.90	0.351
5	2.00	2.50	23	20.96	0.198

6	2.50	3.00	16	17.79	0.181
7	3.00	3.50	22	14.62	3.728
8	3.50	4.00	14	11.62	0.487
9	4.00	4.50	9	8.94	0.000
10	4.50	5.00	3	6.66	2.010
11	5.00	5.50	5	4.80	0.008
12	5.50	6.00	2	3.35	0.542
13	6.00	6.50	2	2.26	0.030
14	6.50	7.00	2	1.48	0.187
15	7.00	7.50	0	0.93	0.932
16	7.50	8.00	1	0.57	0.324
17	8.00	8.50	0	0.34	0.338
18	8.50	9.00	1	0.19	3.363

Total Chi-square value = 14.0623 Degrees of Freedom = 16

Probability of a greater chi-square value, P = 0.59407

The program has limited capability for pooling. The user should judge the necessity for pooling and if necessary, do pooling by hand.

Goodness of Fit Testing with some Pooling

Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	0.500	32	29.09	0.292
2	0.500	1.00	28	28.15	0.001
3	1.00	1.50	21	26.36	1.091
4	1.50	2.00	21	23.90	0.351
5	2.00	2.50	23	20.96	0.198
6	2.50	3.00	16	17.79	0.181
7	3.00	3.50	22	14.62	3.728
8	3.50	4.00	14	11.62	0.487
9	4.00	4.50	9	8.94	0.000
10	4.50	5.00	3	6.66	2.010
11	5.00	5.50	5	4.80	0.008
12	5.50	6.00	2	3.35	0.542
13	6.00	6.50	2	2.26	0.030
14	6.50	7.00	2	1.48	0.187
15	7.00	9.00	2	2.03	0.001

Total Chi-square value = 9.1064 Degrees of Freedom = 13

Probability of a greater chi-square value, P = 0.76486

Density Estimates/Global

Effort : 54.00000
samples : 54
Width : 9.000000
Left : 0.0000000
observations: 202

Model 1
Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
f(0)	0.28956	0.14825E-01	5.12	0.26178	0.32030
p	0.38372	0.19645E-01	5.12	0.34690	0.42445
ESW	3.4535	0.17681	5.12	3.1221	3.8200
n/L	3.7407	0.62957	16.83	2.6753	5.2304
D	0.47404	0.88847E-01	18.74	0.32701	0.68717

Measurement Units

Density: Numbers/Sq. kilometers
ESW: meters

Component Percentages of Var(D)

Detection probability : 7.5
Encounter rate : 80.6
Defn : 7.0
Survival : 4.9

Estimation Summary - Encounter rates

	Estimate	%CV	df	95% Confidence Interval	
n	202.00				
k	54.000				
L	54.000				
n/L	3.7407	16.83	53.00	2.6753	5.2304
Left	0.0000				
Width	9.0000				

Estimation Summary - Detection probability

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	m	1.0000				
	LnL	-490.36				
	AIC	982.71				
	AICc	982.73				
	BIC	986.02				
	Chi-p	0.76486				
	f(0)	0.28956	5.12	201.00	0.26178	0.32030
	p	0.38372	5.12	201.00	0.34690	0.42445
	ESW	3.4535	5.12	201.00	3.1221	3.8200

Estimation Summary - Density&Abundance

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	D	0.47404	18.74	63.12	0.32701	0.68717

Bootstrap Summary - Encounter rates

		Estimate	%CV	#	df	95% Confidence Interval	
Half-normal/Cosine							
	n/L	3.7407	16.39	999	53.00	2.6986	5.1853
						2.6111	4.9630

Note: Confidence interval 1 uses bootstrap SE and log-normal 95% intervals.
Interval 2 is the 2.5% and 97.5% quantiles of the bootstrap estimates.

Bootstrap Summary - Detection probability

	Estimate	%CV	#	df	95% Confidence Interval	
Half-normal/Cosine						
f(0)	0.28956	8.56	999	201.00	0.24468	0.34268
					0.23633	0.33361

Note: Confidence interval 1 uses bootstrap SE and log-normal 95% intervals.
Interval 2 is the 2.5% and 97.5% quantiles of the bootstrap estimates.

Bootstrap Summary - Density&Abundance

	Estimate	%CV	#	df	95% Confidence Interval	
Half-normal/Cosine						
D	0.47404	18.54	999	63.12	0.32828	0.68452
					0.31151	0.65289

Note: Confidence interval 1 uses bootstrap SE and log-normal 95% intervals.
Interval 2 is the 2.5% and 97.5% quantiles of the bootstrap estimates.

ANNEX 3: CALCULATION OF DUNG DECAY RATE

INPUT LOG

```
%CD 'C:/My Documents'
"Data taken from File: \
C:/MIKE/Ziama/Ziama---effectif elefs/Ziama crottes pour
MeanDecayGen.xls"
DELETE [Redefine=yes] _stitle_: TEXT _stitle_
READ [print=*;SETNVALUES=yes] _stitle_
'Data imported from Excel file: C:\MIKE\Ziama\Ziama---effectif
elefs\Ziama crottes pour MeanDecayGen.xls'
' on: 19-Jan-2005 9:37:36'
' taken from sheet ""Sheet1"", cells A2:B244':
PRINT [IPrint=*] _stitle_; Just=Left
DELETE [redefine=yes] DAYS,STATE
UNITS [NVALUES=*]
VARIATE [nvalues=243] DAYS
READ DAYS
138 138 138 138 138 138 138 138 44 44 134 134 134 134 134 134 134 134
134
134 134 134 134 134 134 71 71 71 71 71 71 71 71 71 71 71 71 49 49 49 49
49
49 49 49 28 28 28 28 28 28 28 28 28 28 132 132 133 133 133 133 133 133
133
133 133 133 112 112 112 112 112 112 112 112 112 112 112 112 112 112 112
112
112 112 112 91 91 91 90 90 90 90 90 90 90 70 70 70 70 70 70 70 69 69 49
49
49 49 49 49 49 49 49 27 27 27 27 27 27 27 27 27 131 131 131 131 131 131
131
110 110 110 110 110 110 110 110 110 110 110 110 110 110 110 110 110 88
88 88
88 88 88 88 88 88 88 88 67 67 67 67 67 67 67 67 67 67 67 67 67 67 67 67
67
67 46 46 46 21 21 21 21 21 21 21 21 21 21 136 136 136 136 136 136 115
115
115 115 115 115 115 95 95 95 95 95 95 95 95 95 95 73 73 73 73 73 73 73
73 73
52 52 52 52 53 53 53 53 53 53 53 53 32 32 32 32 32 32 32 32 32 32 :
VARIATE [nvalues=243] STATE
READ STATE
0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 1 1 1 1 1 1 0
1 1
1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0
0 0
1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0
0 0 0 0 0 0 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1
1 0
```

```
0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 0 0 0 0 1 0
0 0
1 1 0 1 0 1 1 1 1 1 1 1 1 1 1 :

"   Calculates mean decay time & s.e & c.v for retrospective dung/nest
decay survey data."
"   Data should consist of two variables:   DAYS  = age in days"
"                                           STATE = 0 if decayed, = 1
otherwise"
"   First read in data from spreadsheet (or otherwise) and then execute
the following commands."
"   To do this, do ctrl-W to submit the commands in this window."
"   Fit logistic regression model to STATE on DAYS"
MODEL [DISTRIBUTION=binomial; LINK=logit; DISPERSION=1] STATE;
NBINOMIAL=1
FIT [PRINT=model,summary,esti; FPROB=yes; TPROB=yes] DAYS

"   Save estimates, variances and covariance"
RKEEP; VCOVARIANCE=vcov; ESTIMATES=beta

"   Calculate mean decay time"
CALC mean_decay = -(1+EXP(-beta$[1]))*LOG(1+EXP(beta$[1]))/beta$[2]

"   Calculate s.e. & c.v. by delta method"
&    var0    = vcov$[1;1]
&    var1    = vcov$[2;2]
&    cov     = vcov$[2;1]
&    deriv0  = -(1-EXP(-beta$[1])*LOG(1+EXP(beta$[1])))/beta$[2]
&    deriv1  = -mean_decay/beta$[2]
&    se_mean = SQRT(var0*deriv0**2 + 2*cov*deriv0*deriv1 +
var1*deriv1**2)
&    cv_mean = se_mean/mean_decay

"   Display results"
PRINT mean_decay, se_mean, cv_mean; DEC=4
```

OUTPUT

```
GenStat Release 7.2  (PC/Windows Me)             19 January 2005
09:35:33
Copyright 2004, Lawes Agricultural Trust (Rothamsted Experimental
Station)

                  ________________________________________

                  GenStat Seventh Edition (SP1)
                  GenStat Procedure Library Release PL15
                  ________________________________________

   1   %CD 'C:/My Documents'
   2   "Data taken from File: \
  -3   C:/MIKE/Ziama/Ziama---effectif elefs/Ziama crottes pour
MeanDecayGen.xls"
```

```
   4  DELETE [Redefine=yes] _stitle_: TEXT _stitle_
   5  READ [print=*;SETNVALUES=yes] _stitle_
   9  PRINT [IPrint=*] _stitle_; Just=Left

 Data imported from Excel file: C:\MIKE\Ziama\Ziama---effectif
elefs\Ziama
crottes pour MeanDecayGen.xls
  on: 19-Jan-2005 9:37:36

  taken from sheet ""Sheet1"", cells A2:B244


  10  DELETE [redefine=yes] DAYS,STATE
  11  UNITS [NVALUES=*]
  12  VARIATE [nvalues=243] DAYS
  13  READ DAYS

    Identifier   Minimum      Mean   Maximum    Values   Missing
          DAYS     21.00     82.93     138.0       243         0

  25  VARIATE [nvalues=243] STATE
  26  READ STATE

    Identifier   Minimum      Mean   Maximum    Values   Missing
         STATE    0.0000    0.3004     1.000       243         0

  34
  35  "   Calculates mean decay time & s.e & c.v for retrospective
dung/nest decay survey data."
  36  "   Data should consist of two variables:   DAYS  = age in days"
  37  "                                           STATE = 0 if decayed,
= 1 otherwise"
  38  "   First read in data from spreadsheet (or otherwise) and then
execute the following commands."
  39  "   To do this, do ctrl-W to submit the commands in this window."
  40  "   Fit logistic regression model to STATE on DAYS"
  41  MODEL [DISTRIBUTION=binomial; LINK=logit; DISPERSION=1] STATE;
NBINOMIAL=1
  42  FIT [PRINT=model,summary,esti; FPROB=yes; TPROB=yes] DAYS
42..........................................................
.........


***** Regression Analysis *****

 Response variate: STATE
  Binomial totals: 1
     Distribution: Binomial
    Link function: Logit
     Fitted terms: Constant, DAYS


*** Summary of analysis ***

                                      mean  deviance approx
              d.f.     deviance   deviance     ratio chi pr
Regression       1        162.2   162.1645    162.16  <.001
```

```
Residual       241        134.9       0.5597
Total          242        297.0       1.2275
* MESSAGE: ratios are based on dispersion parameter with value 1

Dispersion parameter is fixed at 1.00
* MESSAGE: The following units have large standardized residuals:
         Unit     Response    Residual
          196         1.00        3.18
* MESSAGE: The residuals do not appear to be random;
           for example, fitted values in the range 0.01 to 0.06
           are consistently larger  than observed values
           and fitted values in the range 0.73 to 0.96
           are consistently smaller than observed values
* MESSAGE: The error variance does not appear to be constant:
           large responses are more variable than small responses


*** Estimates of parameters ***

                                                         antilog of
                  estimate         s.e.      t(*)  t pr.   estimate
Constant             4.992        0.737      6.77  <.001      147.2
DAYS               -0.0871       0.0117     -7.42  <.001     0.9166
* MESSAGE: s.e.s are based on dispersion parameter with value 1

  "   Save estimates, variances and covariance"
  RKEEP; VCOVARIANCE=vcov; ESTIMATES=beta

  "   Calculate mean decay time"
  CALC mean_decay = -(1+EXP(-
beta$[1]))*LOG(1+EXP(beta$[1]))/beta$[2]

  "   Calculate s.e. & c.v. by delta method"
  &    var0    = vcov$[1;1]
  &    var1    = vcov$[2;2]
  &    cov     = vcov$[2;1]
  &    deriv0  = -(1-EXP(-beta$[1])*LOG(1+EXP(beta$[1])))/beta$[2]
  &    deriv1  = -mean_decay/beta$[2]
  &    se_mean = SQRT(var0*deriv0**2 + 2*cov*deriv0*deriv1 +
var1*deriv1**2)
  &    cv_mean = se_mean/mean_decay

  "   Display results"
  PRINT mean_decay, se_mean, cv_mean; DEC=4

  mean_decay     se_mean     cv_mean
     57.7878      2.3982      0.0415
```

Therefore mean decay rate = 0.01730 per day

ANNEX 4: EXPERIMENT TO FIND THE OPTIMUM SAMPLE SIZE FOR ESTIMATING DUNG DECAY RATE

Two hundred and forty-three dung-piles were located (96% of the those marked). There were between 31 and 48 dung-piles in each cohort (Table 3). Laing *et al.* (2003) suggested marking about 20 per cohort, but we deliberately marked a number that was larger than necessary, so that we could later do a simulation experiment to estimate the optimum sample size.

We examined the effect of taking a certain number of dung-piles from each cohort. For this experiment we took the cohorts 3 to 6, that is those dung-piles that were less than 100 days old when re-inspected (see Table 3). There were 152 of these dung-piles. First we randomly selected 5 dung-piles from each cohort and calculated the mean survival time. Then we randomly selected 10 from each cohort and calculated the mean survival time. We repeated this exercise, gradually increased the sample size up to 30 dung-piles per cohort.

Fig. A4.1 shows that ten dung-piles per cohort (i.e. a total sample size of 40 dung-piles) gave a good estimate of mean survival time, with a CV that was less than 10% (Fig. A4.2). The precision of the estimate increased (that is, the CV declined) as the sample size increased. Thus, 25 dung-piles per cohort or more were needed to bring the CV below 5% (Fig. A4.2).

Note that this experiment was conducted with only four cohorts, because the two oldest cohorts had only one dung-pile that survived to re-inspection. Laing *et al.* (2003) advised marking five or six cohorts with about 20 dung-piles each. Since four cohorts with 25 dung-piles each would give a good estimate (i.e. n = 100), we suggest that five cohorts each of 20 dung-piles should be adequate in future---this experiment using data from the field confirms the opinion of Laing *et al.* (2003). Thus if the survey of Ziama were to be repeated at the same time of year, then we recommend marking the first cohort about 3 months before the scheduled mid-point of the transect survey, with five cohorts equally spaced in time, and with 20 dung-piles per cohort. In order to allow for loss of marked dung-piles, an extra two or three dung-piles per cohort would be useful.

Fig. A4.1 Results of the simulation experiment to estimate survival time in relation to the number of dung-piles in each of four cohorts.

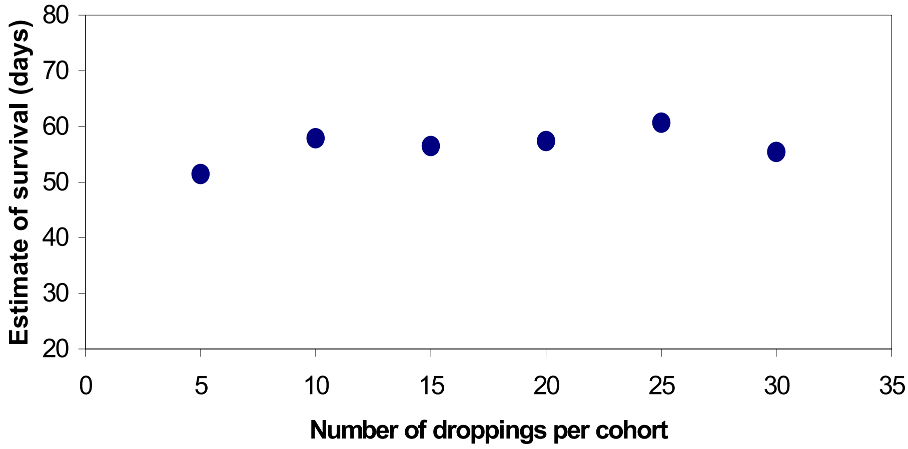

Fig. A4.2. Results of the simulation experiment showing the decline of the CV with increasing number of dung-piles in each of four cohorts.