REPORT ON THE POPULATION STATUS SURVEY OF ELEPHANTS (LOXODONTA AFRICANA) IN THE SAPO NATIONAL PARK, LIBERIA

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By

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SUMMARY

Dung counts are widely used to estimate abundance and distribution of elephants in tropical forests and are known to give reliable and precise estimates. A population survey was undertaken with the aim of having updated information on the status of elephants. The most recent Sapo elephant population estimates by Barnes and Dunn dates back to a survey conducted in 1989, but reported in 2002.

Prior to the survey, eighteen (18) Liberia Forestry Development Authority field officers were trained in forest survey techniques. The FDA staff together with elephant survey experts then undertook a pilot survey in June 2009. A comprehensive population survey was carried out in November and December. The standard line transect method was used (Buckland *et al*. 2001).

A total of 44 km transects were surveyed and 82 elephant dung piles were observed in an estimated area of 630 sq km where we found elephant signs. The dung density was estimated to be 303.02 per sq km (confidence intervals from 125.82 to 729.80).

Two hundred and twenty seven dung piles were marked for their decay study from June to October. The mean survival time for elephant dung piles was estimated as 77.69 days (standard error = 2.41). These estimates combined with Tchamba's (1992) forest elephant defecation rate of 19.77 dung piles per day and the estimated area of 630 sq km gave an estimate of 124 elephants with confidence intervals from 44 to 242.

Elephant distribution was influenced by human activity, while elephant density was affected by the presence of raphia swamps, proximity to mining settlements and the park boundary. Where elephants are present, their abundance was negatively affected by proximity to the mining settlements and the park boundary. Since mining settlements are found deep inside the park, and given the oblong shape of the park, the area where the abundance of elephant is relatively high is limited to a small section in the western half of the park. You cannot get very far from the mining settlements without getting close to the park boundaries.

Mining activity was on- going at the time of the field survey. It was a threat to the ecological integrity of the park and had the potential to divide the elephant population into two isolated, inviable groups. Poaching signs recorded to the east of the delimited big mining zone was higher than to the west. We suggest that the low staff strength be augmented and equipped with firearms to intensify patrols in the park especially in and around the areas the miners had been moved out in order to secure the eastern elephant population.

1.0 INTRODUCTION

Protected area managers need credible monitoring information to be able to plan field programmes and direct conservation activities. The International Union for the Conservation of Nature (IUCN), the CITES programme for the Monitoring of Illegal Killing of Elephants (MIKE) and the Wild Chimpanzee Foundation (WCF) in collaboration with Forestry Development Authority of Liberia (FDA) undertook the survey of elephants and chimpanzees in Sapo National Park with the aim of having updated information on the two flagship species. Sapo National Park has been the bastion of hope for elephant and chimpanzee conservation in West Africa as the near pristine forest is surrounded by pockets of low human populated settlements.

West Africa elephant population contributes about 5% of the total population of elephants at the continental scale (Blanc *et al.* 2007). Viewed from the perspective of forest and savanna elephants, the forest elephant population is about one third of that found in the savanna zone.

Sapo National Park forms part of the Upper Guinean forest ecosystem and it is the second largest tropical rainforest National Park in West Africa after the Tai National Park in Côte d'Ivoire. It is one of the CITES-MIKE sites in West Africa from which updated information on its elephant's population has been lacking. A multi species bio-monitoring programme has been established since 2001 in the park by Flora and Fauna International (Waitkuwait 2001) but the programme is not targeted at producing estimates of elephant abundance. It has therefore been on the priority lists of CITES-MIKE and WCF/GRASP to undertake the survey of the elephants and chimpanzee populations in the Sapo National Park. In 2002, CITES-MIKE undertook the training of four Liberian Wildlife Officers in Ghana as part of the effort to roll- out the survey of the elephant population in Sapo National Park but this programme was interrupted by the unstable political climate and the civil conflict that existed in Liberia at that time.

The most recent Sapo elephant population estimates by Barnes and Dunn dates back to a survey conducted in 1989, but reported in 2002. This outdated information on elephants made conservation planning and management decision-making on the species difficult.

As part of the effort to provide current information on the status of the species, a pilot survey was undertaken in the park in June 2009 to be able to plan for a comprehensive survey of the population. The pilot survey also served as capacity building platform for the Liberian Conservation Department to have a cadre of Field Officers from various reserves trained to effectively contribute to a comprehensive survey of the elephants and chimpanzees in the Sapo National Park. This report focuses on the elephant aspect of the survey since WCF has reported on the chimpanzee survey.

The specific objectives related to the elephant survey were to:

1. determine the density, abundance and spatial distribution of African elephants in Sapo National Park;
2. identify the threats and other factors influencing the distribution and density of elephants in Sapo NP and their inter-relationships understood;
3. build the capacity of Liberia Wildlife Officers in population monitoring techniques for elephants;

4. provide a model of collaboration between different organizations in surveying multiple flagships Species by harmonizing methodologies, eliminating duplication of effort and minimizing costs is provided; and
5. make a contribution to the updating of the management plan for Sapo NP to help ensure the long-term survival of elephants and their habitats.

The survey was undertaken by an elephant expert from CITES-MIKE, a Field Officer from Conservation International (CI) and eighteen Liberian Wildlife Field Officers. An elephant expert from WWF, Côte d'Ivoire also participated in the pilot survey phase.

2.0 MATERIALS AND METHODS

2.1 Description of the study area

Sapo National Park is a fragment of the Upper Guinean forest which lies in the south-eastern corner of Liberia. It falls between latitudes N 5°-6°and longitudes W 8°-9° (figure 1). The park was established in 1983 and it is the first National Park in Liberia. The old boundary was extended in 2003 and now covers about 1549.49 sq km. The park is largely buffered by a belt of community forest and it is generally hilly to the north east.

Rainfall peaks in May and August and the wettest months are from May to October and the driest months, November-April. Sapo is replete with rivers. The principal river, the Sinoe River drains from north-east to south-west. The average elevation ranges from about 100m in the south- west to about 400 to the north.

Sapo National Park is a biodiversity hotspot. About 125 species of mammals and 590 species of birds have been recorded in the park including endangered species such as the pigmy hippopotamus *Hexaprotodon liberiensis*, red colobus *Procolobus badius* and diana monkeys *Cercopithecus diana*. Old logging signs are evident in the western extension of the Park but the intensity, extent and the impact of the logging on the mammal species is uncertain.

The staff strength stands at 45 including auxiliaries from the communities close to the park. Sapo is managed by FDA and supported by Conservation International (CI), Flora and Fauna International (FFI) and the World Bank through a Global Environmental Facility programme.

Illegal settlers in the park were engaging in illicit gold mining and poaching. The settlers numbering about 700 (Theo Freeman, personal communication.) entered the park in 1996 but were moved out in 2000. They returned to the park to carry on their illegal activities in 2004.

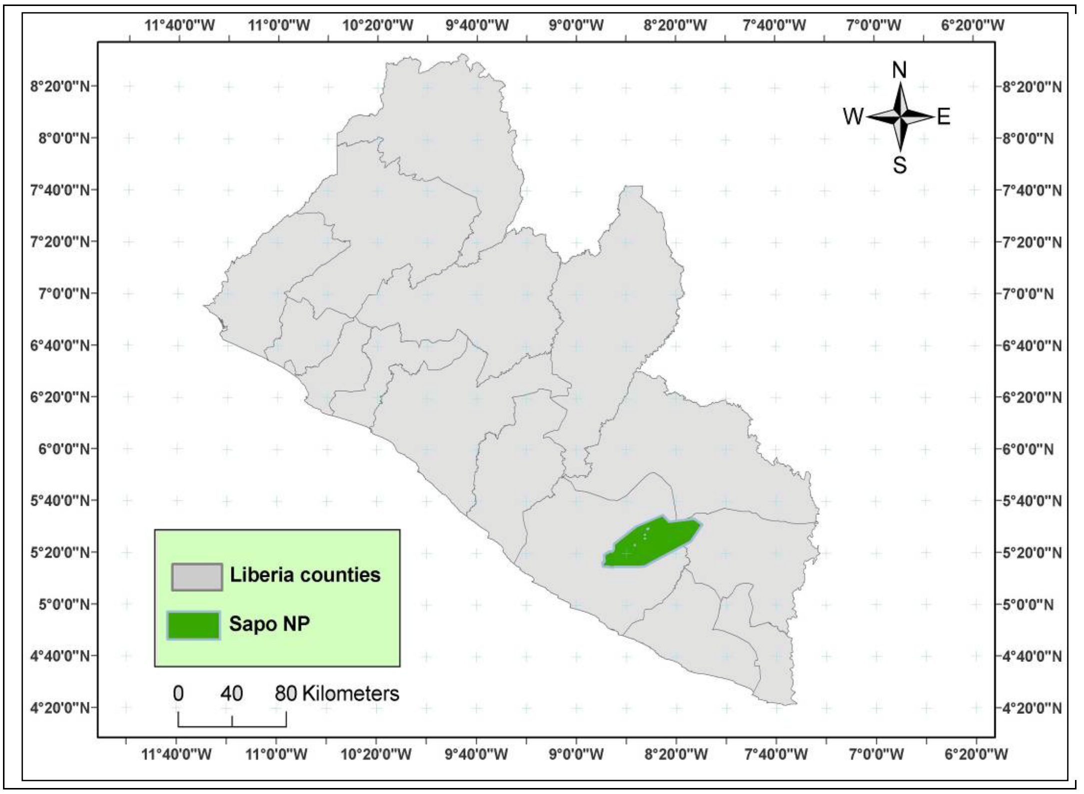

Figure 1: Location of Sapo National Park in Liberia.

2.2 *Training and Pilot survey*

We trained 18 FDA Wildlife Field Officers in forest survey techniques (Annex 1, list of trainees). The training enhanced the competencies of the staff in the area of:

- Navigation using compasses, GPS units and maps, and the use of other technical materials for surveying large mammals
- Line transect method
- The retrospective dung decay experiment
- Identification and classification of elephant dung piles and
- Basic forest ecology

The trainees assisted to undertake a pilot survey in June 2009. Four teams of four each were formed for the survey. The reconnaissance survey transects method of Walsh and White (1999) was modified for the pilot survey. The teams walked on the line of least resistance but did not deviate greatly from the predetermined compass bearing. The normal data collection protocol for the line transects was followed except that perpendicular distances of the dung piles seen were not measured. The pilot phase was used to test the field methods and ascertain whether both elephants and chimpanzees could be surveyed on the same transect. It was also used to predict any logistical challenge likely to be encountered during the main survey.

2.3 Elephant dung pile decay study

Dung counts are commonly used to estimate abundance and distribution of elephants in the West African forest and are known to give reliable and precise estimates (Barnes 2001, 2002). In order to convert dung into elephant, two other variables are needed namely for elephants, the decay rate of the dung piles and defecation rate. Studies on elephant dung piles decay rates have been done in West Africa forest (Barnes *et al*. 1994, Merz 1986, Short 1983). But Laing *et al.* (2003), and the MIKE dung survey standards (Hedges and Lawson 2006) recommend that where possible in-situ dung and nest decay experiment should precede transect surveys. A dung decay study was therefore undertaken in Sapo prior to start of the survey.

Seven batches of elephant dung piles to be studied were marked at three-week intervals. The search and markings started in June but heavy rainfall and flooding in July made most section of Sapo inaccessible. The third marking phase was therefore delayed until mid August.

Fresh elephant trails were searched and followed for fresh dung piles in the S1 and S2 category. Fresh dung piles seen were flagged, given an identification number and its location noted with GPS. The following were also noted each time a dung pile was marked; date found, vegetation type and altitude. Seven batches of dung piles totalling 227 were marked from June to October.

2.4 Transect survey

Transect surveys of the elephant dung piles were undertaken in November and December. A square grid of 4 km by 4 km was randomly placed on the map of Sapo using Arcview 9.2 and the intersection of the grid was used as the starting point of the transect (figure 2). Transects were distributed in a systematic segmented manner and each was 1km. All transects that fell in the mining zone of the park were not surveyed for security reasons.

We used the standard line transect method (Buckland *et al*. 2001) for the survey. GPS and compass were used to navigate to the start of transect. Four teams of four each were formed for the survey. Each team was led by a compass man who aligned a machete man to a ranging pole. The machete man then cut the dead straight line and all walked in an Indian file on the defined transect line. The perpendicular distances of all elephant dung piles seen were measured with a tape measure from the transect centre line defined by the hip chain. The hip chain was also used to measure the distance covered on transect.

The stage of decay of elephant dung piles observed was classified according to the MIKE ‘S’system (Hedges and Lawson 2006), thus:

S1: all the boli are intact.
S2: one or more boli are intact
S3: no boli are intact.
S4: dung pile no longer contains faecal material only traces eg. of plant fibre remain
S5: No faecal material including plant fibres is present

Ecological factors that could help explain distribution, for example, the vegetation type, signs of illegal human activities, fruiting trees and water sources were also recorded on the transects. Illegal activities observed during navigation between transects were noted. Other GIS- based data were obtained using Arc view 9.2. For example, the distance of each transect to the following features:

-Nearest wildlife guards post

-Nearest park boundary

-Nearest major and minor mining settlements

-Distance to the Sinoe River

-Nearest major road, village etc.

A transect survey team posed for the cameras at the team's resting point (Photo 1).

Photo 1: A transect team reposing during trekking through the forest for camping.

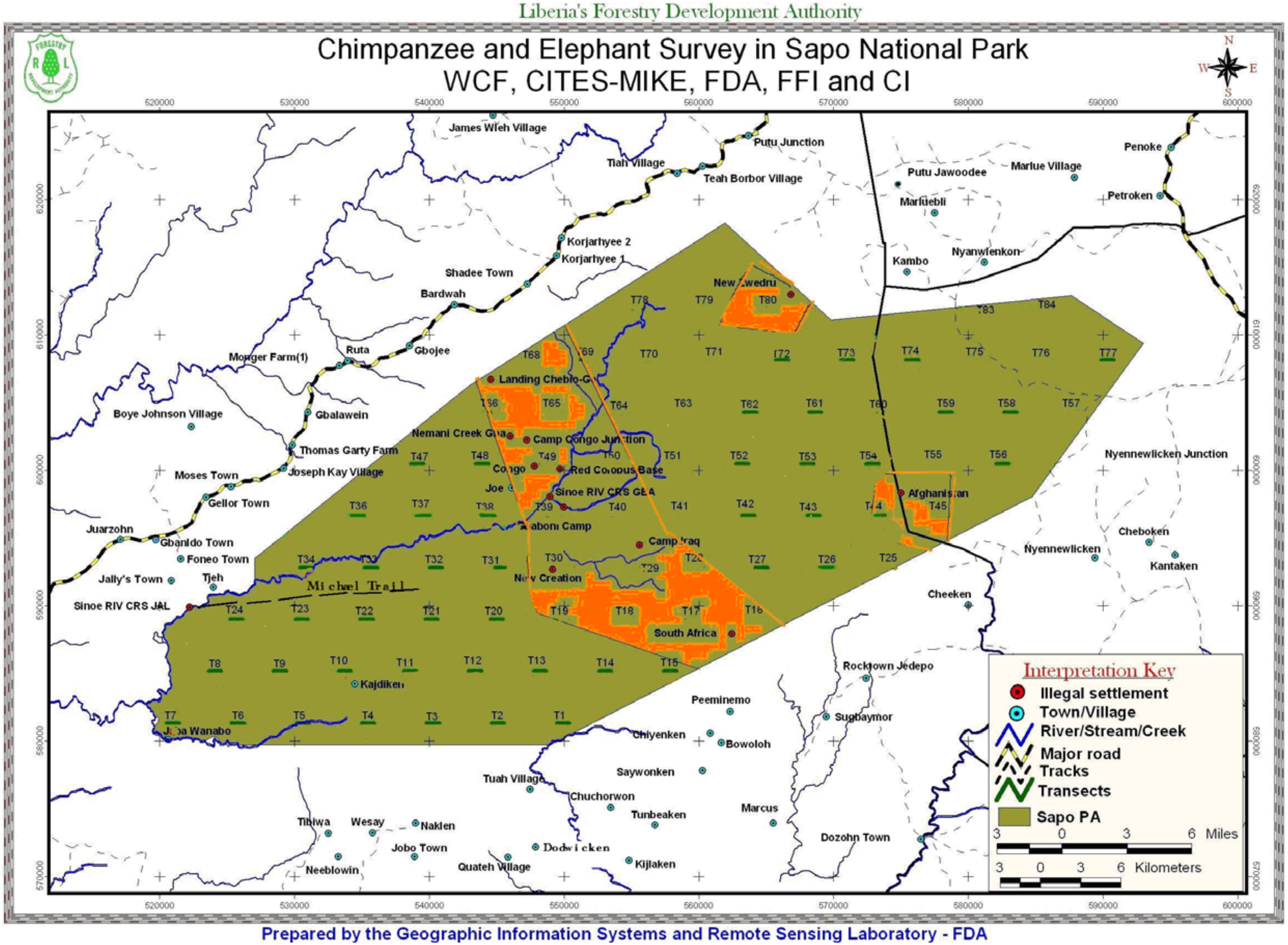

Figure 2: Map showing the design of transects planned for the survey. Those sampled are underlined green (The mining zone is delimited by the orange line and partly coloured. All modifications including the limits of the mining zones are that of the author's and cannot be attributed to FDA).

2.5 ***Data analyses***

2.5.1 *Pilot survey*

The total length of transect to be walked during the main survey was estimated using Buckland *et al.* (2001) formula:

$L=b/ \{ CV_t (E)\}^2 \times (L_o/n_o)$ ------------------ Eqn 1

where
L=estimate of the total transect length to be walked in the main survey to achieve a target precision.
b=dispersion factor
CV_t = the target precision for the main survey
E= density estimate
$L_{o=}$ total transect length walked during the pilot phase
n_o= total number of dung piles or nests found on all the pilot transects

Estimating the dispersion factor is problematic but a range of 1.5-3 has been suggested by Buckland *et al.* (2001) but for planning purposes, b =3 is recommended. Using b=3 as the dispersion factor will demand more resources for the survey since more transects would have to be walked. Encounter rates of elephant dung piles (number of dung piles/km) in all the sections of Sapo sampled were computed.

2.5.2 *Estimation of elephant dung piles decay rates*

During the relocation and revisit of each marked dung pile, if it had completely decayed or 'disappeared', it was denoted by 0 and when present, denoted by 1. A logistic curve was fitted to this binary data coupled with the number of days between visits to give an estimate of the mean number of days it took to disappear. The GENSTAT programme with mean decay plug-in written by R.W. Burn was used to calculate the mean time to decay.

2.5.3 *Estimation of elephant density*

The DISTANCE 6.0 programme by Thomas *et al.* (2009) was used to analyse the elephant dung pile data to obtain dung densities. The dung density was converted to elephant density by using Laing *et al.* (2003) formula:

$D_a = \dfrac{D_s}{(p \times t)}$ -------------- ------- Eqn 2

where

D_a = Elephant density

D_s is dung density per sq km, p is defaecation rate per day and t is the decay rate or the mean dung piles survival time. Since there is no elephant defaecation rate estimates for Sapo, Tchamba (1992) rate from forest elephants, p =19.77 dung piles/ day, variance = 0.911 from Cameroon was used. The density obtained was then multiplied by the area of the survey zone to obtain the elephant numbers.

The precision of the elephant density estimate depends on the precisions of the three variables in eqn 2. It was estimated using eqn 3 by Plumptre (2000).

$$[cv\,(Da)]^2 = [cv\,(Ds)]^2 + [cv\,(t)]^2 + [cv(p)]^2 \quad \text{------------------------} \qquad \text{Eqn 3}$$

where cv (t) is the coefficient of variation of t, defined as its standard error divided t, and similarly for other terms.

2.5.4 Factors that influence elephant distribution

The numbers of dung piles seen on transect are usually not normally distributed. They usually consist of integers and many zeros, that is, transects with no dung piles detected. Twenty one (21) possible predictor covariates were recorded but after the initial exploratory analysis, these were whittled down to fourteen. The variables used in the modelling are presented in Table 1.

Table 1: Description of variables used in the modelling.

Variables	Description
Poaching activities excluding human signs	All illegal activities such as traps, spent cartridges, gunshots, poachers camps etc.
Other human activities	Poaching paths , footprints, cuttings etc
All poaching signs	All illegal activities including poachers footprints, cuttings, paths etc
Open forest	Easy to move without cutting. Horizontal visibility greater than 10m
Disturbed forest	Minimum cutting required. Horizontal visibility less than 10m
Raphia swamp	Swampy sections with raphia stands
Swamp forest	Swamp without raphia
Gap length	Openings in the forest canopy that make the sky visible without obstruction
Fruiting spots	Fruits patches on the forest floor
Water sources	All water points irrespective of size
Proximity to park boundary	Distance of transect midpoint to the nearest boundary of the park
Major road	Distance of transect midpoint to the nearest trunk road
Wildlife post	Distance of transect midpoint to the nearest wildlife guard post
Mining settlement	Distance of transect midpoint to the nearest miners settlement
Nearest village	Distance of transect midpoint to the nearest village around the park

We first explored the univariate relationships between the response variable (number of dung piles per transect) and each of the potential explanatory variables, for example, illegal activities, vegetation types, fruiting trees etc. This is the first step towards building a mathematical model that best explains the distribution and could be used to predict dung densities on the transects. A generalised linear model (McCullagh and Nelder 1989) that assumes a Poisson distribution of errors and fitted by maximum likelihood is popularly known to fit count data. The R language and environment for statistical computing by R Development Core Team (2010) was used for this type of analysis. We tested any display of spatial autocorrelation in the response variable data to ensure independence by using the Moran's Index test. We also tested for autocorrelation in the residuals of the final model.

The basic assumption of Poisson distribution (mean of Y = variance) was not met. The distribution of Y is suggestive of a negative binomial distribution. Y also has excess zeroes (25 out of the 44 transects had zero dung piles and the median of Y is zero). This suggests that a zero-inflated negative binomial model may be more appropriate than the standard negative binomial (Long 1997). A zero-inflated negative binomial model is a mixture model in which the count of zeroes is modelled separately from (but simultaneously with) the counts where $Y>0$.

We started by first fitting a negative binomial regression model which was constructed in a stepwise fashion – adding one explanatory variable at a time and retaining those with the lowest values of AICc (Akaike information criterion corrected for small samples; see Burnham and Anderson 2002), which indicate better fit. We compared the initial negative binomial model obtained to the null model, that is, the intercept only model which assumes homogenous distribution of elephant dung piles in the survey area. The explanatory variables found in the best fitting negative binomial model were retained for the next round, that is, the zero inflated binomial model construction. The Vuong test was used to judge the superiority of one model function over the other. The modelling process is further explained in page 20.

3.0 RESULTS

3.1 Pilot survey

A total of 77.6 km reconnaissance transects was walked and 145 elephant dung piles were detected. If the precision of the final population estimate is pegged at 20% of the estimate and a dispersion factor b=3 is used, then the total length of transect to be surveyed is estimated from equation 1 as:

$L= 3/\{ (0.2)^2 \} \times (77.6/145)$
$L= 140$ km

For b=1.5, and the same precision, L= 70 km.

Information gathered from the park field staff and the on- going FFI ecological monitoring programme indicated that elephants were rarely found in the north eastern section which could not be sampled during the pilot survey. Based on this, and the need to optimise the resources for the survey, we planned for 70 transects for the whole park survey including the mining zone.

The encounter rate of the number of elephant dung piles in the various parts of the park walked was not statistically significant *(*Kruskal-Wallis one-way analysis of variance by ranks H =8.55, NS). At this stage, there was no clear need to stratify the study area for elephants hence the entire area minus the mining zone was considered as one stratum.

3.2 *Abundance of elephants during the main survey*

A total of 44 km of transects was walked and 82 elephant dung piles were observed. The number of dung piles seen per transects range from 0 to 35. No elephant sign was detected in the entire north- eastern extension of the park. We found dung piles on less than half (43%) of the total number of transects surveyed.

3.3 Post facto stratification of elephant dung piles and estimation of dung density

Excluding the mining zone, two strata where elephant activities were found can be distinguished, namely; stratum 1 (an area of 425 km^2 west of the designated big mining enclave) and stratum 2 (an area of 205 km^2 east of the mining enclave), figure 3. The encounter rate of elephant dung piles (number of dung piles seen per transect) in the two strata did not differ significantly (Mann-Whitney test z = 0.15, NS), Table 2. Therefore the dung piles in the two strata were combined and analysed as one. The north-eastern section with no sign of elephants was excluded from the analysis at this stage.

Table 2: Post facto stratification of the number of dung piles seen

Stratum	Area (km^2)	Total length of transects, L (km)	Total number of dung piles seen (n)	Encounter rate (n/L)
Stratum 1	425	24	70	2.92
Stratum 2	205	10	12	1.20
Post facto stratum (total)	**630**	**34**	**82**	**2.41**

Various models of the DISTANCE programme were fitted to the perpendicular distance data. Buckland *et al.* (2001) recommend the removal of a small percentage (about 5%) of the largest values of the perpendicular distance data by adjusting the maximum perpendicular distance in order to improve the fit of the models. We therefore fixed the maximum perpendicular distances at 6, 7 and 8m and the models ran but this did not improve the precision of the results. However, truncation at 8.8m improved the precision of the density estimates. Generally, the Half normal model with all the adjustments (Cosine, Simple polynomial and Hermite) gave consistent results and the lowest AIC values (Table 3). There was no difference in the parameter estimates between the Half normal with cosine adjustments and the Half normal with simple polynomial adjustments. The latter was thus retained as the best fitting model. The visibility profile of the best fitting model with truncation at 8.8m is as shown in figure 4.

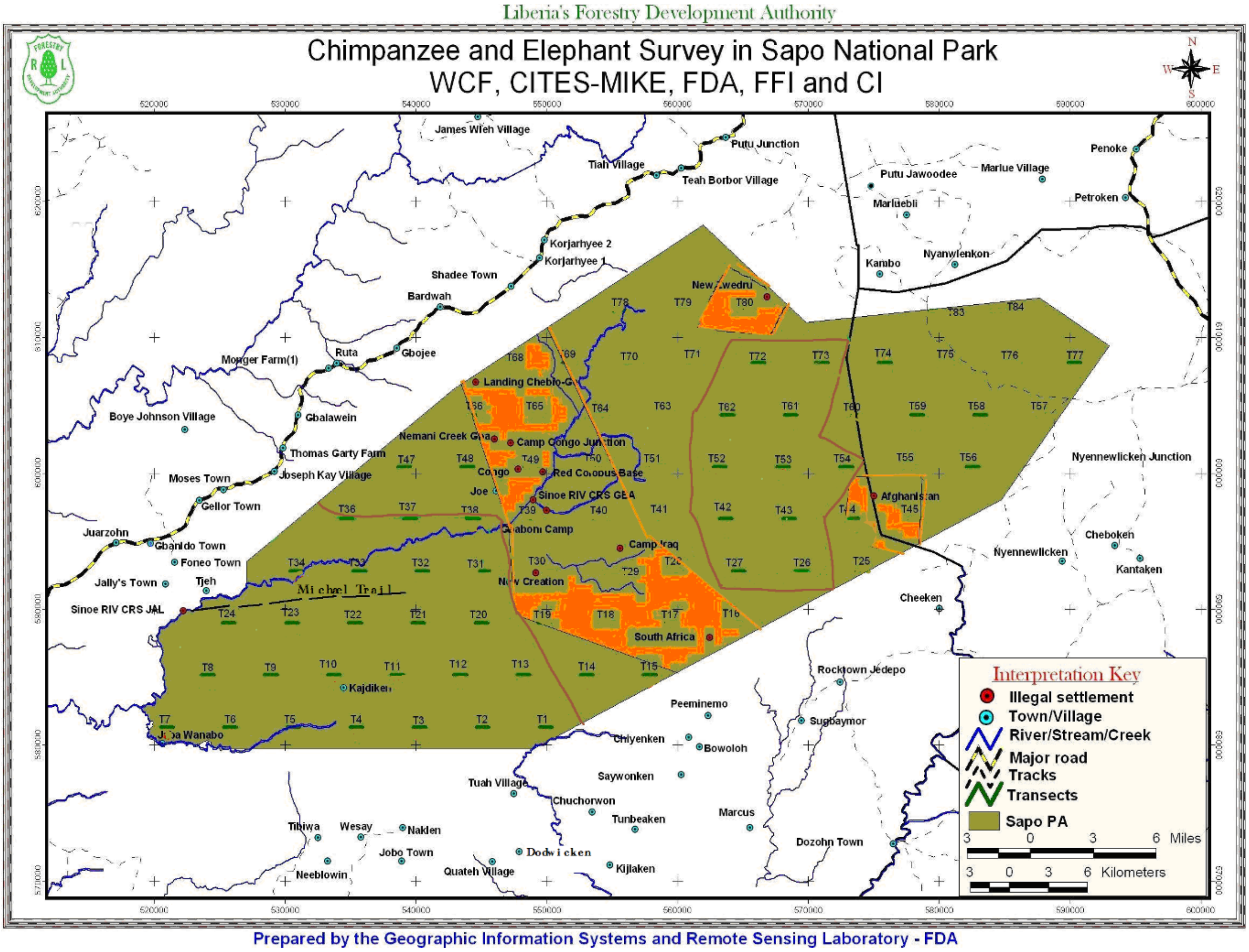

Figure 3: Map showing the range of the elephants at the time of the survey (delimited by the chocolate lines).

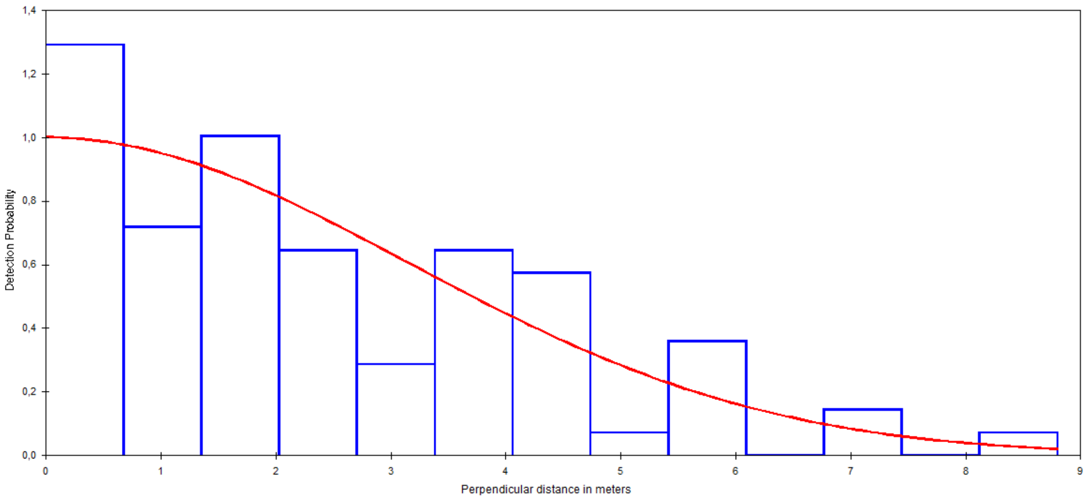

Figure 4: Visibility profile of the Half normal model with simple polynomial adjustments fitted to the perpendicular distance data.

The dung density was estimated to be 303.02 per sq km with the lower and upper confidence intervals from 125.82 to 729.80, Table 3 and Annex 2a. This estimate was used for further analysis in the elephant density estimation.

Table 3: Summary results of elephant dung density from line-transect survey after post facto stratification (maximum strip width =8.8m).

Parameters	Half normal + cosine	Half normal + Simple polynomial	Uniform + cosine	Hazard rate +cosine	Hazard rate + Hermite polynomial
[1]f(0)	0.25	0.25	0.26	0.25	0.25
[2]AIC	301.07	301.07	302.06	304.24	304.24
Dung density (km^{-2})	303.02	303.02	311.78	294.05	294.05
[3] χ^2	15.44	15.44	15.66	17.50	17.50
[4]$P(\chi^2)$	0.16	0.16	0.11	0.064	0.064
SE	137.60	137.60	142.35	135.88	135.88
%CV	45.41	45.41	45.66	46.21	46.21
Lower CL	125.82	125.82	128.97	120.64	120.64
Upper CL	729.80	729.80	753.69	716.73	716.73

[1] Values of the probability density function at perpendicular distance of zero for the transect line.
[2] Akaike Information Criterion (AIC) also indicates the fit of the model to the data. The lower the AIC the better the fit.
[3]Chi- square (χ^2) :The lower the value the better the fit of the visibility curve to the histogram of the perpendicular distance data.
[4]$P(\chi^2)$: Probability of the chi square value.

3.4 Dung decay rate estimation

Two hundred and twenty seven dung piles were marked for their decay study from June to October, Table 4. Out of this, two hundred and twenty two were relocated and inspected in December. About 20 dung piles are needed to be marked per batch. The first batch of dung piles marked was less than 15 but the attempt to mark a 7th batch and exclude the 1st in the decay study returned 5 droppings. We calculated the mean time to decay based on 217 dung piles by excluding the 7th batch.

Table 4: Number of dung piles marked for each batch and relocated during the decay study.

Batches of dung-piles	Number of dung-piles found and marked	Number of dung-piles relocated and inspected	Per cent surviving at the final inspection
1	12	12	0
2	31	31	0
3	27	25	0
4	40	40	17.5
5	52	49	79
6	60	60	70
7	5	5	100
Total	227	222	42

The mean survival time for elephant dung piles was estimated as 77.69 days (SE= 2.405) and the decay rate per day which is the inverse of the mean survival time was 1.287x 10^{-2} (SE=3.985x 10^{-4}), Annex 3.

3.5 Estimation of elephant numbers

From equation 2, that is,

$$D_a = \frac{D_s}{(p \times t)}$$

We plugged in the following estimates: Cameroun forest elephant defecation rate (p) of 19.77 from Tchamba (1992), the estimated dung density (D_s=303.02 per sq km) and mean survival time (t=77.69 days) in a spreadsheet form that uses the delta method to calculate standard error (Seber, 1982), the density of elephants, D_a was estimated as 0.1973 per km. This estimate multiplied by the area of Sapo where we found elephant signs (630 sq km) gives an estimate of 124 elephants with confidence intervals from 8 to 240.

The DISTANCE programme using multipliers can also be used to calculate the density directly. It also gave the density as 0.1973 elephants /sq km. The only difference here is that the confidence intervals of the bootstrapped estimate, that is, the 2.5% lower and 97.5% upper quantiles (0.0701 to 0.3848) is asymmetric and narrower, Annex 2b. These estimates multiplied by the area (630 sq km) gives 124 elephants (CI from 44 to 242). This is chosen as the best estimate of elephant numbers in Sapo National Park.

3.6 Distribution of elephants

Elephant concentration for the greater part of the study period was within 10 to 15km from the Sinoe River boundary on the Jally'stown side close to the Michael trail. However, this picture did not clearly pan out during the pilot phase. Elephants moved within one kilometre of the Sinoe River boundary in the Jally'stown side in October. Elephant signs were not found in the entire north- eastern extension of the park (figure 5).

In June-July, the elephants moved within 1km of the park boundary at the Dodwicken side where we found old elephant dung piles in the community forest, south of the park. Crop raiding, however, is not an issue in Sapo. In December, elephants crossed the Gellor side of the park to the adjacent forest reserve on the other side of the Juarzohn-Putu Junction main road.

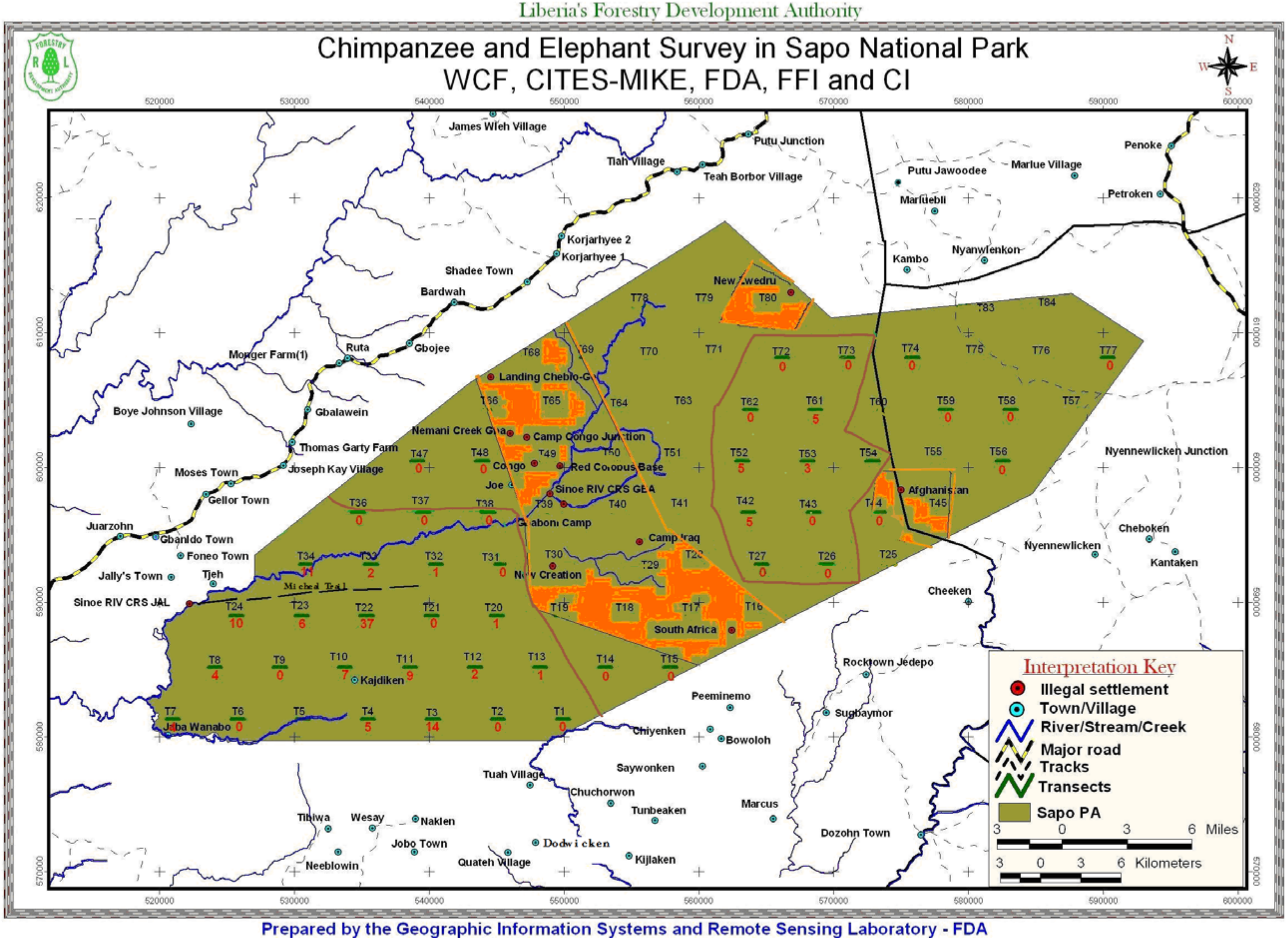

Figure 5: Map showing the distribution of all elephant dung piles found on transect. The digits in red are the number of dung piles (including dung piles in the S4 and S5 decay categories) and the codes above are the transect number.

3.7 Factors influencing abundance and distribution of elephants

The relationship of each of the fourteen ecological and GIS-based variables with dung piles encounter rate per km was investigated and mining settlements was found to significantly influence dung piles abundance, Table 5.

Table 5: Spearman rank correlations coefficients (r_s) between the number of dung piles per transect and the suite of ecological variables recorded on transects (The sample size is 39 transects).

Description of variables	r_s	P
All poaching signs/km	-0.11	>0.05
Fruiting spots	-0.19	>0.05
All rivers	-0.20	>0.05
Distance to mining settlements (km)	0.32	<0.01
Distance to wildlife guard post (km)	-0.54	>0.05

3.7.1 Mining and elephant distribution

A new mining satellite camp was found between Transect T72 and T61 with four tented accommodation. Wide, well trodden human paths (presumably made by the miners) were crossed in Stratum 2. Transects close to the mining settlements (<5km away from the enclaves), had fewer dung piles on them (figure 6) and were devoid of other mammals, for example, the duikers. A quadratic regression fitted (figure 6) to the number of dung piles per transect and distance to mining settlement was not significant (R^2 =0.133, NS). The highest (35) dung piles point is influential but there is no justification for deleting, since it exemplifies the clumped distribution of the elephant population.

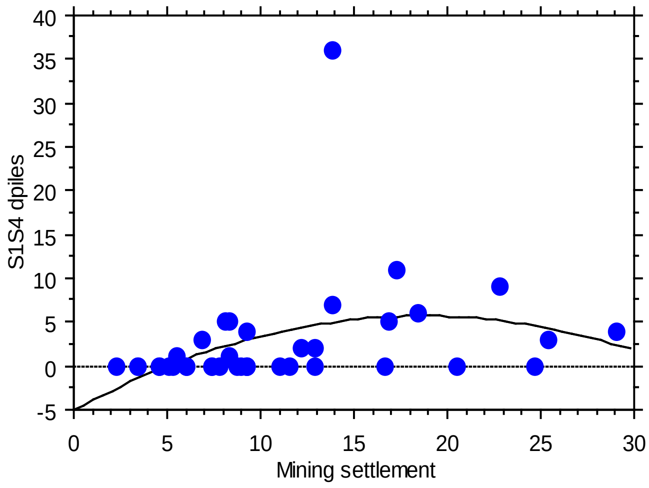

Figure 6. Graph showing the number of dung piles per km and distance to the mining settlements.

3.7.2 Poaching activities

A total of 64 signs were observed but they were dominated by human activities such as poaching paths and poachers cuttings (Table 6). The encounter rate excluding the poaching paths and poacher cuttings is 0.25/km. The encounter with poachers (4 out of the five seen) was on transects 21 and 22, an area we found to be rich in wildlife. A group of over 20 red colobus and lots of duiker footprints were observed in that area. Two of the poachers carrying guns and smoked bush meat pretended to be lost and were bold to walk to the survey team to be shown the way out of the park.

Table 6: Evidence of poaching on transects.

Poaching signs*	Total seen	Encounter rate/km
Poachers	5	0.11
Poaching camps	0	0
Gunshots	3	0.07
Shot gun shells	2	0.05
Snares	1	0.02
Other human signs (eg. poaching paths etc)	53	1.2
All poaching signs	64	1.45

* Only signs seen by the four member team positioned strictly on the transect line for the elephants survey are reported here. All signs seen by the two additional members that walked on the flanks for chimpanzee are discounted.

The relationship between the number of dung piles/km and all the poaching signs observed on transects (figure 7) was not significant (R^2= 0.0003, NS).

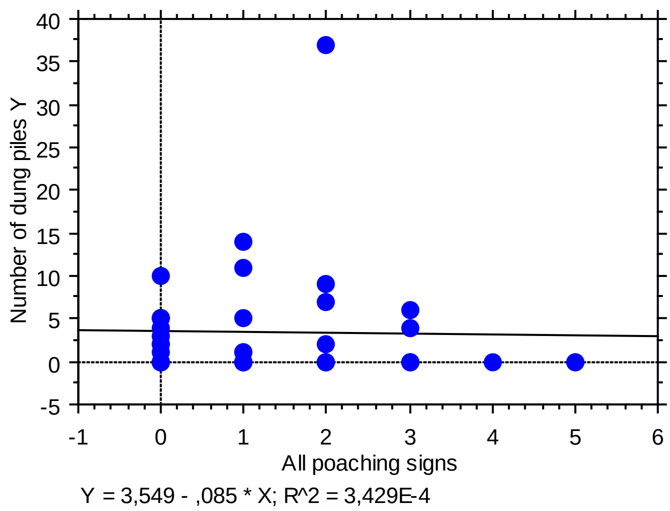

Figure 7: Relationship between number of dung piles and all poaching signs.

Generally, less poaching signs were found in stratum 1 (the high elephant density zone) than stratum 2 during navigation between transects. The encounter rates per km of some of the poaching signs observed in stratum 1 were: gunshots (0.2), shotgun shells (0.24), poachers encountered (0) and poaching camps (0.28). Four out of the seven poaching camps seen off transects were found towards Gbalawein from transect 48. We also found many timber stock survey cut lines in the Gellor's Town part of the park (near T36 and T37) with many old trapping spots.

Stratum 2 encounter rates off transects were: gunshots (0.38/km), shotgun shells (0.38/km), poachers' encountered (0.15/km) and poaching camps (0.04/km). Two of the gun bearing poachers observed in stratum 2 approached our base camp to request for a sieve for mining but bolted when they realized that it was an FDA survey team.

We explored the modelling of the response variable (Y) on each of the explanatory variables (Xi) using the generalised linear models. The basic Poisson assumption (variance of Y equals to its mean) was not. Y was 13 times its mean. We thus fitted negative binomial regression model as the first step towards identifying variables with strong explanatory powers.

Table 7: Coefficients of some predictor variables after fitting the negative binomial regression model (link function=log).

Description of variables	Estimate	Standard Error	z value	Probability (>|z|)
Null model (Intercept only model)	1.2192	0.3208	3.801	0.000144
(Intercept) All poaching signs/km, X3	1.4040 -0.1372	0.3951 0.1676	3.553 -0.818	0.00038 0.41317
(Intercept) Fruiting spots, X10	1.4873 -0.1535	0.4751 0.1923	3.130 -0.799	0.00175 0.42451
(Intercept) Distance to mining settlements, X20	-1.4936 0.2029	0.6315 0.0474	-2.365 4.285	0.0180 1.83×10^{-5}

The coefficient estimates of the variables: all poaching signs and fruiting spots on transects with the exception of distance to mining settlements were not significant. The expected change in log (Y) for a unit increase in distance to mining settlement is 0.2029. Thus the relationship between dung piles density and distance to mining settlement can be expressed as:

$$\log Y = 0.2029\, X20 - 1.4936$$

Generally, the negative binomial model did not fit well the data because of the many zeros in the response data. An alternative model was further explored.

3.7.3 Modelling to explain dung distribution

The distribution of the response variable is shown in figure 9.

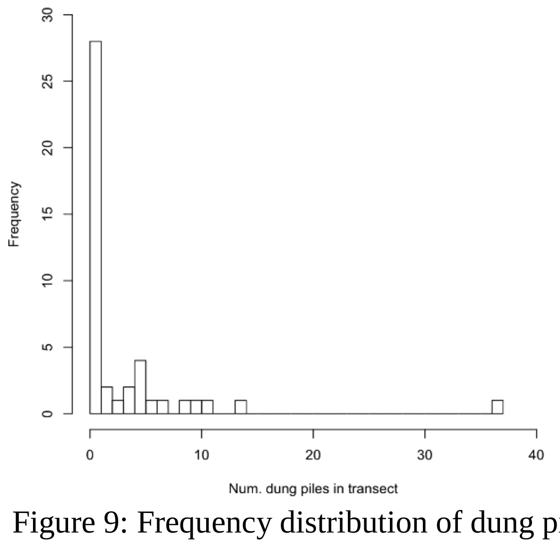

Figure 9: Frequency distribution of dung piles on transects

As aforementioned, an exploratory analysis suggested that a zero-inflated generalised linear model with negative binomial error distribution and a log link function was the most appropriate type of model to use. We began the modelling by constructing a negative binomial model, and then expanded that into a zero-inflated negative binomial, checking whether the latter provides a better fit than the former. The process of adding variables to the negative binomial model was iterated until AICc stopped declining. A decline of 4 or more in AICc was judged necessary for the retention of a variable. During the round of variable additions, models were assessed on the basis of AICc differences and AICc weights (Burnham and Anderson 2002). The effect of interactions between the selected variables were then investigated by adding interactions to the model one at a time, and only retaining them if they resulted in a substantial drop in AICc (of 4 or more). None of the interactions were found to be important.

Once the negative binomial model had been selected, the selected variables were retained in a zero-inflated negative binomial, and variables were added again one at a time as explanatories for the prevalence of zeroes, using the same criteria and indicators described above. In addition, Vuong tests were used to determine the better models.

The best models found for each round of variable addition, together with their AICc values, are shown in Table 8. The table also shows a comparison of the models in terms of their AICc differences (Δ_i) and AICc weights. Amongst the models shown in the table, the last one (bolded), which is the zero-inflated negative binomial containing X1 (other human signs) as a single explanatory for zero inflation and X20 (distance to mining settlement), X17 (distance to park boundary) and X6 (length of raphia swamp), carries 87% of the weight. The evidence ratio of each model compared to the preceding one is also shown in Table 8. The first model, glm.nb20 is compared with the null model y~1. The evidence ratio indicates how many times a given model is better than the previous one. Thus glm.nb20 is 11.6 times better than the null model; model glm.nb20.17 is nearly 8 times better than glm.nb20, and so on.

Table 8: Comparison of the negative binomial regression models fitted to the data (the log link function was used). The highlighted result is the zero-inflated negative binomial model.

Model (figures indicate variable numbers included in the model)	AICc	AICc Δ_i	AICc weight	Evidence ratio
glm.nb20	169.83	13.29	0	11.6
glm.nb20.17	165.71	9.18	0.01	7.83
glm.nb20.17.6	160.56	4.02	0.12	13.16
t1zi_glm.nb20.17.6	**156.53**	**0**	**0.87**	**7.48**

The summary coefficients of the best fitting model are shown in table 9a with the inflation model portion in table 9b. All the three predictor variables: X20, X17 and X6 are significant.

Table 9a: Summary of the parameter estimates of the best fitting zero-inflated negative binomial regression model (negative binomial with log link was used).

Count model	Coefficients estimate	Standard error	z value	Probability (>|z|)	Probability level
(Intercept)	-4.839606	1.387591	-3.488	4.87×10^{-4}	0.001
Distance to mining settlements, X20	0.261905	0.063613	4.117	3.84×10^{-5}	0.001
Distance to park boundary, X17	0.418453	0.128583	3.254	1.137×10^{-3}	0.01
Length of raphia swamp,X6	0.007195	0.002472	2.910	3.614×10^{-3}	0.01
Log(theta)*	-0.232506	0.406448	-0.572	5.6729×10^{-1}	

*Log (theta) is the dispersion parameter

Table 9b: Zero-inflation model coefficients (binomial with logit link):

Model	Estimate	Standard error	z value	Probability (>|z|)
(Intercept)	-65.26	76022.73	-0.001	1
Other human signs, X1	20.88	25340.82	0.001	1

NB: Theta = 0.7925; Log-likelihood: -69.71 on 7 Df.

A Vuong test revealed the zero-inflated negative binomial model to be superior to the standard negative binomial model (Vuong test statistic = -1.724; $p<0.05$). In addition, a likelihood ratio test revealed good fit of the chosen model ($\chi^2 = 29.292$, df = 3, $p<0.0001$).

We thus obtained the model function of the form:

$$Y \sim X20 + X17 + X6 \mid X1$$

Which reads as Y (number of dung piles on transect) is a function of distance to mining settlement, distance to the park boundary and the length of raphia swamp traversed given other human signs. The above function equation with the coefficients can be written as

$$\log Y = 0.2619 X20 + 0.41845\, X17 + 0.0072\, X6 \mid X1$$

Thus the expected change in log (Y) for a unit increase in raphia swamp, for example, was 0.0072. Each of the three variables; presence of raphia swamps, proximity to mining settlements and the park boundary were statistically significant and thus influence elephant density.

The response variable Y displayed strong spatial autocorrelation by using the Moran's Index test (Moran's I: 0.048; expected: -0.0233± 0.020, $p<0.0005$), but autocorrelation disappeared in the residuals of the final model (Moran's I: -0.006; $p<0.5$). In other words, accounting for the effects of the important predictors removed autocorrelation in the data.

4.0 A contribution to the updating of the Sapo National Park management plan to ensure long-term survival of elephants and their habitats.

The extensive ground coverage has provided firsthand information on previously unknown mining enclaves, areas of high poaching pressure and densities of elephants. Information on other endangered species, for example, the pigmy hippopotamus and Jentink's duiker are also available in the report produced by the Wild Chimpanzee Foundation (WCF), our partner in the field survey work. With this baseline information, the biodiversity management component of Sapo management plan which is in preparation will reflect the current status of the species. The indicator of success of the park management in the long term can be gauged on how effective elephants and other endangered species are managed. The promotion of tourism and research, for instance, should be based on factual and well packaged information. This study has provided the needed biological information for integration into the plan.

5.0 Capacity building in population monitoring techniques and processing of data using MIKE standards.

The Sapo field officers were first trained in June before the commencement of the fieldwork. They were retrained in November prior to the main survey. Theoretical and practical training was organised together with our colleagues from WCF. Section 2.2 covers some aspects of the training. The pilot survey was used as the practical period for the trainees. Two elephant survey experts, Yaw Boafo (CITES- MIKE, West Africa) and Nandjui Awo (WWF Côte d'Ivoire) facilitated the training for the elephant part. The field practical section was led by one elephant expert and a chimpanzee survey expert.

In addition, the Park warden and two administrative staff were trained in GPS data uploading, downloading and storage. The competencies of the staff in biological data collection have been strengthened to help sustain the on-going multi species monitoring programme being undertaken by FFI. The training of the Park warden and the administrative staff will contribute indirectly to the park's anti poaching efforts since law enforcement data can be uploaded into the GPS and downloaded after patrols. Patrol operations can therefore be tracked. The patrol staff skill improvement in the use of field equipments such as GPS and compasses could make a significant contribution to the park's law enforcement monitoring programme.

6.0 Support of the local population for the conservation of the Sapo National Park by including them in the survey activities and providing income.

It is remarkable that Sapo National Park authorities rely heavily on trained local people called auxiliaries or volunteers in its bio-monitoring programme. Of the 18 people we trained for the survey, six were auxiliaries (Annex 1). The locals also helped in transporting the teams on motorbikes, set up our camping bases, guarded the camps and assisted in cooking for the teams. All services were remunerated.

It is noteworthy that choosing local people to participate in projects of this nature should be done in consultation with the park management. This is to avoid exposing crack poachers to the heart of the park where they could easily ply their trade. We took advantage of locals' involvement to explain the need to help conserve the Sapo biological diversity.

7.0 A model of collaboration between different organizations in surveying multiple flagship species by harmonizing methodologies, eliminating duplication of effort and minimizing costs.

The partnership between IUCN and WCF was worthwhile. Working together helped to cut down costs to each organisation right from placing a single order for field equipments to using the same team to collect field data. The FDA authorities were concerned that cutting a network of transects will expose the park to novice poachers to enter and poach. But their fears were allayed when the elephant and chimpanzee teams collected field data on the same transects and we were mindful to leave a toe print but not bold footprints in Sapo. We have demonstrated that even though few challenges may crop up, working together on the field for a common purpose should be encouraged (Massalatchi and Boafo 2010). This partnership is fostering joint coordination and networking not only at the field level, but also high up the organisational ladder of the two organisations.

8.0 DISCUSSION

8.1 Abundance of elephants

The conservative density estimate of 0.20 elephants per sq km obtained in this study is close to what Barnes and Dunn (2002) found about two decades ago (0.24 per sq km). This, however, does not suggest that the population has been stable over the decades that they collected their field data (since 1989). Our estimated dung density of 303.02 dung piles/sq km is about twice what they obtained (152 dung piles/sq km). The procedure used to convert dung density to elephant density differed from that of Barnes and Dunn (2002). They used the rainfall model (Barnes *et al*. 1997a) developed in the Ghanaian forest to estimate density in the absence of dung decay rate for Sapo.

Precise population estimates enable trends in the population to be determined, but our coefficient of variation of over 40% is high. Many short transect returns precise estimates (Vanleeuwe 2008) when matched with the effort. We could have increased the precision of the density estimate by concentrating much effort in the now identified high density zone. This observation did not pan out during the pilot survey. We surveyed the more hilly terrain to the northeast that could not be prospected during the pilot survey phase and found no elephants. This effort only improved the precision of the chimpanzee density estimate provided by the Wild Chimpanzee Foundation. Chimpanzees and elephants were surveyed on the same transects and the former were found to be more widely distributed than elephants.

Contrary to our expectation, the Sapo rainy season dung survival time (77.69 days, SE= 2.41) was higher than the dry season estimate from the Ghanaian forest, for example, Kakum National Park (67.0424, SE =3.4620, Danquah 2004). The flooding of Sapo due to heavy rainfall after the second batch dung piles marking made the park's section with elephants impossible to access. This compelled the field team to delay the marking of the third batch for 5 weeks instead of the recommended 3 weeks (Laing *et al.* 2003). This could have affected the decay rate estimate. However, using the Kakum NP decay rate and the same defecation rate from Tchamba (1992), for instance, would have increased the Sapo elephant population estimate by 16%, that is, from 124 to 144, and hence our estimate is more conservative. We marked seven batches for the decay study in Sapo but the first and last batches were far fewer than the minimum of 20 dung piles per batch that is needed. The Sapo dung survival time based on 5 batches of the decay data (discarding the 1st and 7th batches) was estimated as

77.71days (SE=2.42) which would not have considerably changed our estimate of elephant numbers.

8.2 Distribution of elephants

There was a wide range in the number of dung piles recorded per transect (0 to 35). The highest dung piles density was found around transect 22 where we also found the highest concentration of *Sacoglottis gabonensis* fruiting spots (24 sacoglottis trees/km walk) compared to other transects where no *Saccoglottis* fruits was found. Generally, fruiting spots was not found to significantly affect the Sapo elephant distribution, Table 7 but *Sacoglottis gabonensis and Tieghmella hecklii*, for example, has been found to influence forest elephant distribution in the Lopé Reserve, Gabon and Ghana Kakum National Park respectively (White 1994, Dudley *et al.* 1992).

8.3 Factors influencing elephant abundance and distribution

The level of human pressure if unchecked has the potential to cause a rapid decline in the large mammal population which has least resistance to poaching (Oates *et al*. 2000). However, human activities other than poaching were found to best explain the absence of elephants in some sections of Sapo. Generally, the level of poaching activities was low (0.25/km), excluding poachers cuttings and paths compared to other forest parks in West Africa, for example, Ghana Kakum National Park (0.97/km, Boafo 2004), and Côte d'Ivoire Tai National Park (1.09/km), Annex 4. Where elephants are absent, their abundance is negatively affected by proximity to the mining settlements and the park boundary. Since mining settlements are found deep inside the park, and given the oblong shape of the park, the area where the abundance of elephant is relatively high is limited to a small section in the western half of the park. You cannot get very far from the mining settlements without getting close to the park boundaries. Barnes *et al.* (1991) found elephants avoiding human settlements in northeastern Gabon.

The elephant distribution was also positively related to the presence of raphia swamp. It could be that the sections with raphia swamps are better habitat for elephants in terms of, for example, food quality or it could simply be that they are less accessible to people. We found people avoiding the swamps because of perhaps the difficulty in walking through those areas with ease.

This study has established that elephants are using about half of the area of Sapo National Park and that there is a high elephant concentration area to the west of the park. The correct estimation of the area where elephants are found will avoid the tendency to under estimate or over estimate the density of the population.

9.0 CONCLUSION AND RECOMMENDATIONS

This is the first ever comprehensive survey after the civil conflict in Liberia to ascertain the status of the elephant population in Sapo National Park. Even though the Sapo elephant population is small, it is significant by West Africa standards. It could currently be ranked (for elephant surveys less than 10 years old) the 4th highest population in terms of the number of elephants in the Upper Guinean rainforest parks in the West African sub region.

This project served as a capacity building platform for the FDA field staff which will enhance the on-going biological monitoring programme in Sapo. FDA field operations stand to benefit immensely not only of the equipments left for the park but the field staff enhanced competences to use them. The field staffs are equipped to be able to replicate this survey elsewhere in Liberia.

We advise that future survey teams should concentrate more efforts in the identified elephant concentration zone since it could increase the precision of the estimates. Chimpanzees were more widely distributed than elephants. Any planned survey of this two flagship species at the same time should consider stratifying the study area for elephants.

The Sapo elephants were found to cross the main road between the Gellor and Gbalawien to the adjoining forest. It is therefore important to extend the protection of the elephants to the adjoining forest to prevent them from being killed by poachers.

The mining activity that was on-going at the time of the field survey posed serious threat to the ecological integrity of the park and had the potential to divide the elephant population into two inviable groups. Poaching signs recorded to the east of the delimited big mining zone was higher than to the west. We suggest that the low staff strength be augmented and equipped to intensify patrols in and around the areas the miners had been moved out to secure the eastern group of elephants from being exterminated.

10.0 ACKNOWLEDGEMENTS

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Our sincere gratitude also goes to Blamah Goll, former Sapo Park Warden, for his courage and leadership role during the pilot study. We acknowledge the dedication and untiring support of the entire field team leaders particularly, Lassana Curley, Korvah Vanyambah, Samuel M. Freeman, John G. Smith and the administrative staff (Johnson Jallah, Zoryou Somah) that enabled the survey to be successfully completed. The FDA GIS section headed by Mr Augustin Johnson provided the maps for the survey. We thank the cooks, especially Elizabeth Sanwon, housekeeper, Ojuku Breeze, and our drivers (Edward Dahn, Robert Nyamah and Fayiah Taylor) for safely driving the teams.

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12.0 ANNEXES

Annex 1: List of FDA staff trained that participated in the survey.

Name of Trainees	Status	Protected Area of Trainees
1. Blamah S. Goll	FDA Park warden	Zone 1 (Sapo)
2. Samuel M. Freeman	FDA	Zone 2 (Sapo)
3. Korvah Vanyambah	FDA Biologist	East Nimba Nature reserve
4. Jerry D. Johnson	FDA	Zone 3 (Sapo)
5. Lassana Curley	FDA Biologist	Lake Piso Multiple use
6. Maxwell Congein	FDA	Zone (Sapo)
7. Jefferson Kannah	FDA	Zone 1 (Sapo)
8. Isaiah Jayswen	Auxiliaries	Zone 3 (Sapo)
9. Sargbeh Flahn	FDA	Zone 2 (Sapo)
10. Nathaniel Naklen	FDA	Zone 3 (Sapo)
11. David Tarlue	FDA	Zone 1(Sapo)
12. George Worjloh	Auxiliaries	Zone 2 (Sapo)
13. Augustine Nimeley	FDA	Zone 1 (Sapo)
14. Milton Tarnewon	Auxiliaries	Zone 2 (Sapo)
15. Abonoco Tarpeh	FDA	Zone 2 (Sapo)
16. Laswson Wesseh	Auxiliaries	Zone 2 (Sapo)
17. Jerome Tarley	Auxiliaries	Zone 2 (Sapo)
18. Touray Pardeah	Auxiliaries	Zone 2 (Sapo)

Annex 2a: DISTANCE 6 Release 2 programme, abridged output: Sapo post facto stratification. Model: Half normal + simple polynomial adjustments

```
Parameter Estimation Specification
 ---------------------------------
 Encounter rate for all data combined
 Detection probability for all data combined
 Density for all data combined

 Distances:
 ----------
 Analysis based on exact distances
 Width specified as:    8.800000
```

Estimators:

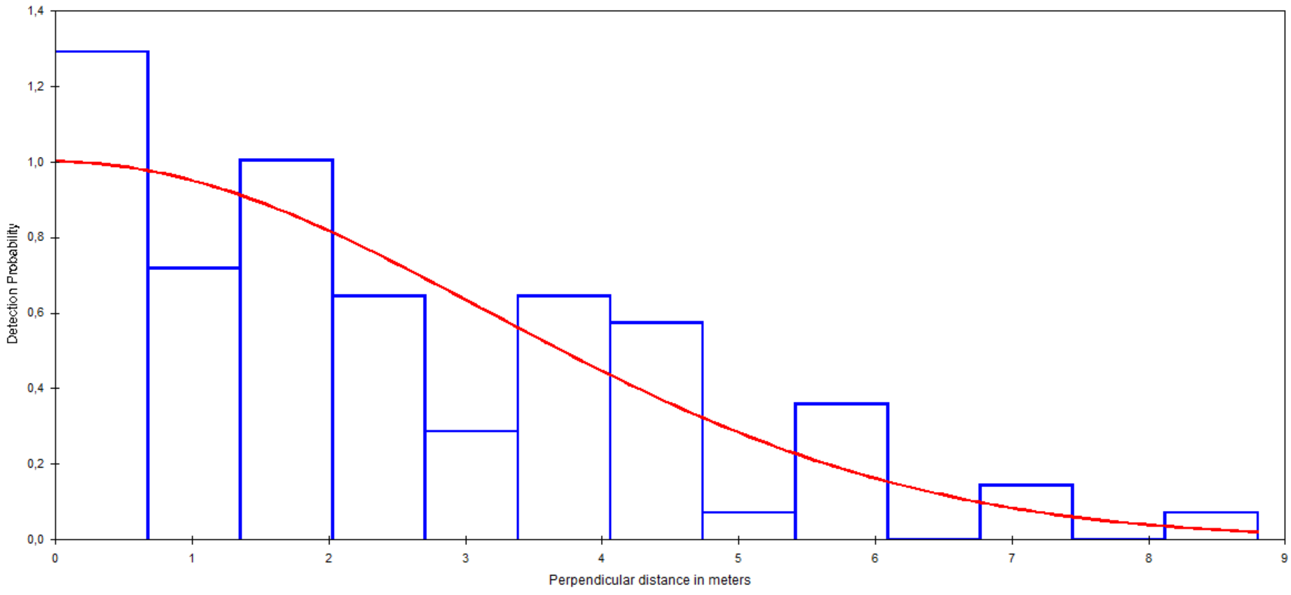
Estimator 1
Key: Half-normal
Adjustments - Function : Simple polynomials
- Term selection mode : Sequential
- Term selection criterion : Akaike Information Criterion (AIC)
- Distances scaled by : W (right truncation distance)

Effort : 34.00000
samples : 34
Width : 8.800000
observations: 81

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)	3.153	0.2587			
f(0)	0.25439	0.19918E-01	7.83	0.21774	0.29721
p	0.44670	0.34976E-01	7.83	0.38234	0.52190
ESW	3.9310	0.30779	7.83	3.3646	4.5927

Detection Fct/Global/Plot: Detection Probability 3



Perpendicular distance in meters

Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	0.677	18	13.84	1.249
2	0.677	1.35	10	13.22	0.785
3	1.35	2.03	14	12.06	0.312
4	2.03	2.71	9	10.51	0.217
5	2.71	3.38	4	8.75	2.575
6	3.38	4.06	9	6.95	0.604
7	4.06	4.74	8	5.28	1.404
8	4.74	5.42	1	3.83	2.088
9	5.42	6.09	5	2.65	2.083
10	6.09	6.77	0	1.75	1.753
11	6.77	7.45	2	1.11	0.719
12	7.45	8.12	0	0.67	0.669
13	8.12	8.80	1	0.39	0.981

Total Chi-square value = 15.4370 Degrees of Freedom = 11.00

Probability of a greater chi-square value, P = 0.16335

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	0.677	18	13.84	1.249
2	0.677	1.35	10	13.22	0.785
3	1.35	2.03	14	12.06	0.312
4	2.03	2.71	9	10.51	0.217
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7	4.06	4.74	8	5.28	1.404
8	4.74	5.42	1	3.83	2.088
9	5.42	6.09	5	2.65	2.083
10	6.09	6.77	0	1.75	1.753
11	6.77	8.80	3	2.16	0.325

Total Chi-square value = 13.3944 Degrees of Freedom = 9.00

Probability of a greater chi-square value, P = 0.14556

Density Estimates/Global

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
D	303.02	137.60	45.41	125.82	729.80

N 0.19090E+06 86687. 45.41 79266. 0.45977E+06
--------- ----------- ----------- -------------- ----------------------

Measurement Units

Density: Numbers/Sq. kilometers
ESW: meters

Component Percentages of Var(D)

Detection probability : 3.0
Encounter rate : 97.0

Estimation Summary- Encounter rates

	Estimate	%CV	df	95% Confidence Interval	
n	81.000				
k	34.000				
L	34.000				
n/L	2.3824	44.73	33.00	0.99924	5.6799
Left	0.0000				
Width	8.8000				

Estimation Summary- Detection probability

	Estimate	%CV	df	95% Confidence Interval	
Half-normal/Polynomial					
m	1.0000				
LnL	-149.54				
AIC	301.07				
AICc	301.12				
BIC	303.47				
Chi-p	0.14556				
f(0)	0.25439	7.83	80.00	0.21774	0.29721
p	0.44670	7.83	80.00	0.38234	0.52190
ESW	3.9310	7.83	80.00	3.3646	4.5927

Estimation Summary- Density & Abundance

	Estimate	%CV	df	95% Confidence Interval	
Half-normal/Polynomial					
D	303.02	45.41	35.04	125.82	729.80
N	0.19090E+06	45.41	35.04	79266.	0.45977E+06

Annex 2b: DISTANCE program output abridged- Model: Half normal + Simple polynomial adjustments + Bootstrapping + Multipliers

Parameter Estimation Specification

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

Distances:

Analysis based on exact distances
Width specified as: 8.800000

Estimators:

Estimator 1
Key: Half-normal
Adjustments - Function   : Simple polynomials
            - Term selection mode   : Sequential
            - Term selection criterion : Akaike Information Criterion (AIC)
            - Distances scaled by   : W (right truncation distance)

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

Multipliers: Value   SE   DF

Dung Disap time   .12872E-01 .39851E-03 Inf
Dung Prod rate   .50582E-01 .24421E-02 Inf

Variances:

Bootstrap variance/confidence intervals for density. Random number seed = 19020333.
    Re-sampling will be across defined strata
    Samples will be re-sampled
Variance of n: Empirical estimate from sample
            (design-derived estimator R2/P2)
Variance of f(0): MLE estimate

Goodness of fit:

Cut points chosen by program

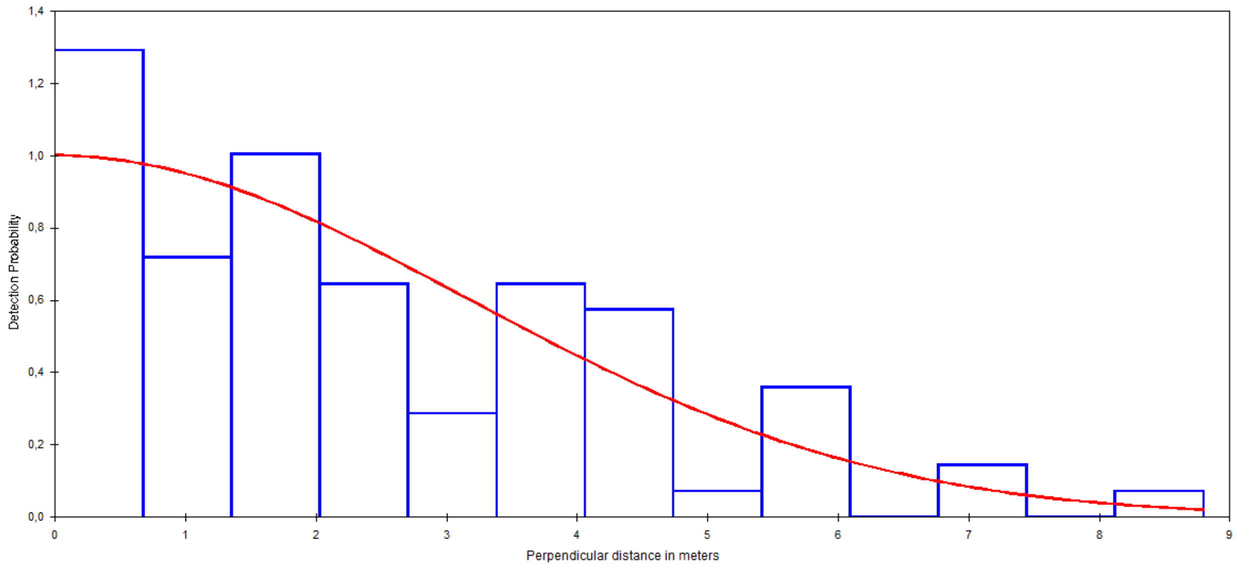
Effort   :   34.00000
samples   :   34
Width   :   8.800000
observations: 81

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 = -149.53545

Akaike information criterion = 301.07092
Bayesian information criterion = 303.46536
AICc = 301.12155
Final parameter values: 3.1530380

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95 Percent Confidence Interval	
A(1)	3.153	0.2587			
f(0)	0.25439	0.19918E-01	7.83	0.21774	0.29721
p	0.44670	0.34976E-01	7.83	0.38234	0.52190
ESW	3.9310	0.30779	7.83	3.3646	4.5927

Detection Fct/Global/Plot: Detection Probability 3



Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	0.677	18	13.84	1.249
2	0.677	1.35	10	13.22	0.785
3	1.35	2.03	14	12.06	0.312
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8	4.74	5.42	1	3.83	2.088
9	5.42	6.09	5	2.65	2.083
10	6.09	6.77	0	1.75	1.753
11	6.77	7.45	2	1.11	0.719
12	7.45	8.12	0	0.67	0.669

13	8.12	8.80	1	0.39	0.981

Total Chi-square value = 15.4370 Degrees of Freedom = 11.00

Probability of a greater chi-square value, P = 0.16335

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	0.677	18	13.84	1.249
2	0.677	1.35	10	13.22	0.785
3	1.35	2.03	14	12.06	0.312
4	2.03	2.71	9	10.51	0.217
5	2.71	3.38	4	8.75	2.575
6	3.38	4.06	9	6.95	0.604
7	4.06	4.74	8	5.28	1.404
8	4.74	5.42	1	3.83	2.088
9	5.42	6.09	5	2.65	2.083
10	6.09	6.77	0	1.75	1.753
11	6.77	8.80	3	2.16	0.325

Total Chi-square value = 13.3944 Degrees of Freedom = 9.00

Probability of a greater chi-square value, P = 0.14556

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
D	0.19729	0.90299E-01	45.77	0.81478E-01	0.47772
N	124.00	56.754	45.77	51.000	301.00

Measurement Units

Density: Numbers/Sq. kilometers
ESW: meters

Component Percentages of Var(D)

Detection probability : 2.9
Encounter rate : 95.5
Dung Disap time : 0.5
Dung Prod rate : 1.1

Estimate %CV df 95% Confidence Interval

----

n	81.000				
k	34.000				
L	34.000				
n/L	2.3824	44.73	33.00	0.99924	5.6799
Left	0.0000				
Width	8.8000				

	Estimate	%CV	df	95% Confidence Interval	
Half-normal/Polynomial					
m	1.0000				
LnL	-149.54				
AIC	301.07				
AICc	301.12				
BIC	303.47				
Chi-p	0.14556				
f(0)	0.25439	7.83	80.00	0.21774	0.29721
p	0.44670	7.83	80.00	0.38234	0.52190
ESW	3.9310	7.83	80.00	3.3646	4.5927

Estimation Summary- Density & Abundance

	Estimate	%CV	df	95% Confidence Interval	
Half-normal/Polynomial					
D	0.19729	45.77	36.17	0.81478E-01	0.47772
N	124.00	45.77	36.17	51.000	301.00

Bootstrap Summary- Encounter rates

	Estimate	%CV	#	df	95% Confidence Interval	
Half-normal/Polynomial						
n/L	2.4022	42.04	999	33.00	1.0572	5.4580
					0.88235	4.5588

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/Polynomial						
f(0)	0.25481	9.93	999	80.00	0.20920	0.31036
					0.20878	0.31018

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/Polynomial						
D	0.19983	44.04	999	36.17	0.85096E-01	0.46925
					0.70141E-01	0.38479
Half-normal/Polynomial						
N	125.88	44.05	999	36.17	54.000	296.00
					44.000	242.00

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: Input and output files from GENSTAT programme

```
CD 'C:/Users/uicn/Documents'
"Data taken from File: \
C:/Users/uicn/Desktop/Sapo decay phase/Sapo Dung_Decay_Study DATABASE 2 May
24.xls\
"
DELETE [Redefine=yes] _stitle_: TEXT _stitle_
READ [print=*;SETNVALUES=yes] _stitle_
'Data imported from Excel file: C:\Users\uicn\Desktop\Sapo decay phase\Sapo
Dung_Decay_Study DATABASE 2 May 24.xls'
' on: 30-Jul-2010 17:35:21'
' taken from sheet ""corrected for 1dung"", cells E2:F218':
PRINT [IPrint=*] _stitle_; Just=Left
DELETE [redefine=yes] DAYS,STATE
UNITS [NVALUES=*]
VARIATE [nvalues=217] DAYS
READ DAYS
161 161 161 161 161 161 161 161 161 161 161 163 151 151 151 150 150 150 150
150 150 150 150 150 150 150 150 150 150 150 150 150 150 150 150 150 150 150
152 152 152 152 152 109 109 109 109 109 109 109 109 109 109 109 109 109 109
109 109 109 109 109 109 109 109 109 109 109 89 89 89 89 89 89 89 89 89 89
89
89 89 89 89 89 89 89 89 89 89 89 89 89 89 94 93 93 93 93 93 93 93 93 93 93
93 93 93 93 77 77 77 77 77 77 77 77 77 77 77 77 77 77 77 77 77 77 77 77 77
77 77 79 79 79 79 79 76 75 75 75 75 75 75 75 75 75 75 75 75 75 75 75 75 74
74 74 74 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57
57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57
57 57 57 57 57 57 57 56 57 57 57 57 57 :
VARIATE [nvalues=217] STATE
READ STATE
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 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 0 0 0 1 0
0 0 0 0 0 1 0 0 0 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 0 1 1 1 1 1 1 0 1 1 1 1 1 0 0 0 0 1 1 1
1 0 0 0 1 1 1 1 1 1 1 1 1 0 0 1 1 0 0 1 1 1 1 1 1 0 1 0 0 0 0 0 0 0 1 1 1 0
0 1 0 1 0 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 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 file

```
GenStat Release  7.22 DE  (PC/Windows)              30 July 2010 17:34:36
Copyright 2008, VSN International Ltd

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research purposes in qualifying countries. A list of qualifying countries
can
be viewed at http://discovery.genstat.co.uk. Commercial use of the
GenStat Discovery Edition is strictly prohibited.

                 ________________________________________

                 GenStat Discovery Edition 3
                 GenStat Procedure Library Release PL15.2
                 ________________________________________

   1  %CD 'C:/Users/uicn/Documents'
   2  "Data taken from File: \
  -3  C:/Users/uicn/Desktop/Sapo decay phase/Sapo Dung_Decay_Study DATABASE
2 May 24.xls\
  -4  "
   5  DELETE [Redefine=yes] _stitle_: TEXT _stitle_
   6  READ [print=*;SETNVALUES=yes] _stitle_
  10  PRINT [IPrint=*] _stitle_; Just=Left

 Data imported from Excel file: C:\Users\uicn\Desktop\Sapo decay phase\Sapo
Dung_Decay_Study DATABASE 2 May 24.xls
  on: 30-Jul-2010 17:35:21

  taken from sheet ""corrected for 1dung"", cells E2:F218


  11  DELETE [redefine=yes] DAYS,STATE
```

```
  12  UNITS [NVALUES=*]
  13  VARIATE [nvalues=217] DAYS
  14  READ DAYS

    Identifier   Minimum      Mean   Maximum    Values   Missing
          DAYS     56.00     92.63     163.0       217         0

  25  VARIATE [nvalues=217] STATE
  26  READ STATE

    Identifier   Minimum      Mean   Maximum    Values   Missing
         STATE    0.0000    0.4055     1.000       217         0

  33
  34  "   Calculates mean decay time & s.e & c.v for retrospective
dung/nest decay survey data."
  35  "   Data should consist of two variables:   DAYS  = age in days"
  36  "                                           STATE = 0 if decayed, = 1
otherwise"
  37  "   First read in data from spreadsheet (or otherwise) and then
execute the following commands."
  38  "   To do this, do ctrl-W to submit the commands in this window."
  39  "   Fit logistic regression model to STATE on DAYS"
  40  MODEL [DISTRIBUTION=binomial; LINK=logit; DISPERSION=1] STATE;
NBINOMIAL=1
  41  FIT [PRINT=model,summary,esti; FPROB=yes; TPROB=yes] DAYS

41............................................................................
.....
***** 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        104.1     104.1471    104.15  <.001
Residual       215        188.9       0.8785
Total          216        293.0       1.3566
* MESSAGE: ratios are based on dispersion parameter with value 1

Dispersion parameter is fixed at 1.00
* MESSAGE: The residuals do not appear to be random;
           for example, fitted values in the range 0.00 to 0.24
           are consistently larger  than observed values
           and fitted values in the range 0.47 to 0.51
           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             5.694        0.872      6.53  <.001      297.2
DAYS               -0.0736       0.0111     -6.63  <.001     0.9291
* MESSAGE: s.e.s are based on dispersion parameter with value 1

  42
  43  "   Save estimates, variances and covariance"
  44  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
   77.6895      2.4053      0.0310
```

Therefore the mean decay rate per day=0.01287

Annex 4. Indices of Illegal activities in some West African Parks.

Protected Area Year and Season	Ankasa NP Ghana 2007 WS*	Kakum NP Ghana 2001 WS	Tai NP Côte d'Ivoire August 2007-March 2008 bio monitoring report
Total no. of illegal activities	22	32	371
Total transect length (km)	50	36.30	339.5
Indices/km	0.44	0.97	1.09

2007WS* : wet season survey undertaken in 2007. These figures exclude poaching paths and poachers cuttings.