RESEARCH

Status of the Sapo National Park elephant population and implications for conservation of elephants in Liberia

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Abstract

Dung counts are used to estimate abundance and distribution of elephants in tropical forests and give precise population estimates (Barnes, 2002). The most recent elephant population estimates for Sapo National Park date back to two decades ago. A survey was carried out in November and December 2009 using the standard line transect method (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 km^2 where we found elephant signs. Prior to the survey, 222 dung piles were marked for decay study. The mean survival time was estimated as 77.69 days (standard error = 2.41). We estimated a population of 124 elephants with 95% confidence limits from 44 to 242. More elephants were found in the western than the eastern section of the park, which points up the need for stratification in future surveys. Mining activity was on-going at the time of the survey and elephant distribution was influenced by human activity, while elephant density was affected by presence of raphia swamps, proximity to mining settlements and the park boundary. There were more poaching signs recorded to the east of the mining zone. We suggest that the low staff strength be augmented and equipped with firearms to intensify patrols in the old mining enclaves to secure the elephant population.

Key words: Sapo, elephants, dung count,decay, mining settlement, raphia, park boundary

Résumé

On utilise les comptages de crottes pour estimer l'abondance et la distribution des éléphants dans les forêts tropicales et ils donnent des estimations précises (Barnes 2002). Les estimations les plus récentes de la population d'éléphants du Parc national de Sapo remontent à il y a deux décennies. On a réalisé un recensement en novembre et décembre 2009 en utilisant la méthode standard de la ligne de transect (Buckland et al, 2001). On a parcouru un total de 44 km de transects et on a observé 82 crottes d'éléphants sur une superficie estimée à 630 km^2 où des signes d'éléphants se trouvaient. Avant le recensement, nous avions marqué 222 crottes pour en étudier la dégradation. La durée de vie moyenne était estimée à 77,69 jours (erreur type = 2,41). Nous avons estimé une population de 124 éléphants avec des limites de confiance de 95% de 44 à 242. Nous avons retrouvé plus d'éléphants dans la section ouest du parc que dans l'est, ce qui met en évidence la nécessité de stratification dans les études à venir. L'activité d'exploitation minière était en cours au moment du recensement et la distribution des éléphants était influencée par l'activité humaine, alors que la densité d'éléphants était affectée par la présence de marécages de raphia, la proximité des peuplements miniers et les limites du parc. Il y avait plus de signes de braconnage enregistrés à l'est de la zone minière. Nous suggérons que les effectifs faibles de personnel soient accrus et équipés d'armes à feu pour intensifier les patrouilles dans les vieilles enclaves minières pour sécuriser la population d'éléphants.

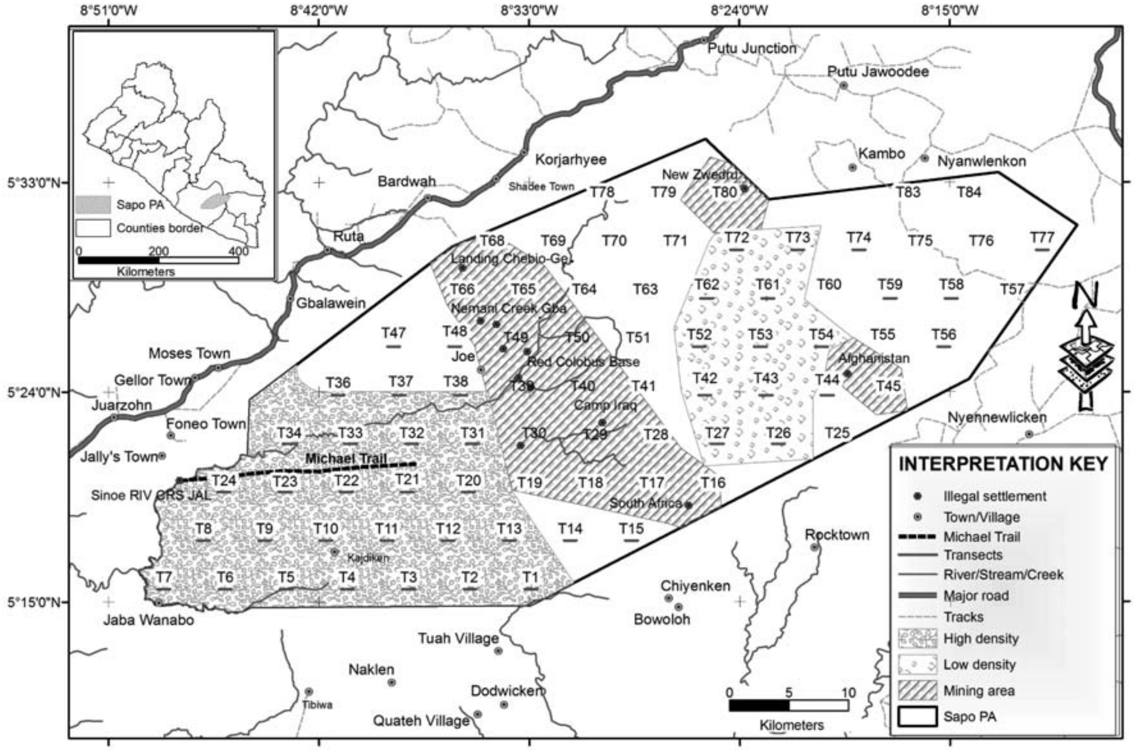

Figure 1. Map showing location of Sapo NP in Liberia (inserted), the distribution of transects and the post facto stratification of the study area after the survey.

Introduction

Sapo National Park (SNP) is a CITES–MIKE site where the elephant population is being monitored as part of a global programme to evaluate the impact of CITES decisions on the illegal killing of elephants in Africa. SNP has been on the priority list of CITES–MIKE to ascertain the status of its elephant population after the civil strife in 2003. In 2002, CITES–MIKE in collaboration with Conservation International Ghana undertook the training of four Liberian Wildlife Officers in Ghana as part of the effort to roll-out the planned survey of the elephant population in the park. But this programme was kept on hold due to the unstable political climate that existed in Liberia at that time. According to the SNP management, the park was a refuge for some people during the conflict period; their impact on the park is largely unknown. The Flora and Fauna International on-going multi species bio-monitoring programme in SNP (Waitkuwait, 2001) is not targeted at producing updates on the status of the elephant population. The most recent Sapo elephant population estimates date back to two decades ago when Dunn conducted a survey in 1989, which was reported in 1993. The unreliable information on elephants has made conservation planning and management decision-making on the species difficult.

IUCN, the CITES–MIKE programme and the Wild Chimpanzee Foundation (WCF) in collaboration with the Forestry Development Authority of Liberia (FDA) undertook the survey of elephants and chimpanzees in SNP in 2009 with the aim of gathering information on the two flagship species. SNP has been the bastion of hope for elephant and chimpanzee conservation in West Africa as the near pristine forest is surrounded by pockets of sparsely populated human settlements. The specific objectives of the survey were to determine abundance and spatial distribution of the elephants and to identify threats and other ecological variables influencing the density and distribution.

Study area

SNP is a fragment of the Upper Guinean forest belt and lies in the south-eastern corner of Liberia between latitudes N 5'–6' and longitudes W 8'–9'. The park was established in 1983 as Liberia's first National Park but the old boundary was extended eastwards in 2003 and westwards up the Sinoe River, which drains from north-east to south-west. SNP, which covers about 1549.49 km^2 and is largely buffered by a belt of community forest. About 125 mammals species have been identified in SNP, including endangered species such as the pigmy hippopotamus (*Hexaprotodon liberiensis*) and red colobus (*Procolobus badius*). Old logging signs are evident in the extended section up the Sinoe River. Rainfall peaks in the months of May and August whilst the driest months are from November to April. At the time of the survey, illegal settlers numbering over 700 (Theophilus Freeman, pers. comm., 2009) were in the park engaging in illicit gold mining and poaching but they were evacuated in March 2010. The mining enclave runs through the middle of the park in a north–south division (Fig. 1).

Materials and Methods

Transect survey and dung pile decay study

Dung counts are commonly used to estimate abundance and distribution of elephants in the forest and give accurate and precise estimates (Barnes, 2001, 2002). Using Arcview 9.2, we placed a grid designating 4 by 4 km squares on the map of SNP and the intersection of the grid was used as the transect starting point. Transects were distributed in a systematic segmented fashion of 1 km each in length. Those 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 each transect. Four teams of four people were formed for the survey in November and December 2009. The team led by a compass person, who aligned a machete person to a ranging pole. The person with a machete then cut a dead straight line and all walked in single file on the defined line. We measured perpendicular distances of all elephant dung piles seen from the transect centre line with a tape measure and used a hip chain to measure distance covered along the transect. The stage of dung decay was classified according to the MIKE 'S' system (Hedges & Lawson, 2006). Ecological variables that could explain distribution and the anthropogenic factors observed on each transect were recorded. Off transect poaching activities were also noted. Other GIS-based data were obtained using Arc view 9.2.

An *in situ* elephant dung decay study was conducted prior to the survey in order to convert the dung counts into elephant numbers. We marked six batches of fresh dung piles totalling 222 and each batch was separated from the other at three-week intervals. The search and markings started in June but heavy rainfall and flooding in July made most section of SNP inaccessible. This delayed the third marking until mid-August and the last was in October. Laing et al. (2003) and the MIKE dung survey standards (Hedges & Lawson, 2006) detail how we conducted the dung decay study.

Calculation of dung piles decay rate and elephant density

Dung piles that were present or had completely decayed during relocation and revisit at the middle of the transect survey were denoted by 1 and 0 respectively. We fitted a logistic curve to this binary data coupled with the number of days between the marking and revisits of the dung piles to give an estimate of the mean survival time. The GENSTAT programme with mean decay plug-in written by R.W. Burn was used to calculate the mean time to decay.

Thomas et al. (2009) DISTANCE 6.0 programme was used to analyse the dung pile data to obtain dung densities. The same programme using multipliers: defecation rate per day of 19.77 dung piles, variance = 0.911 from Cameroon forest elephants (Tchamba, 1992) and our decay rate estimates were used to estimate elephant density.

Modelling to explain dung distribution

The response variable Y (number of dung piles per transect) had excess zeroes; 25 out of the 44 transects had zero dung piles. The median of Y was zero. A generalized linear model (McCullagh & Nelder, 1989) that assumes a Poisson distribution of errors and fitted by maximum likelihood is known to fit count data. Our data did not meet the basic assumption of Poisson distribution: mean of Y = variance of Y. We found a zero-inflated negative binomial model to be more appropriate than the standard negative binomial. A zero-inflated model is a mixture model in which the count of zeroes is modelled separately from (but simultaneously with) the counts where Y>0. The R language and environment for statistical computing (R Development Core Team, 2010) was used for the analysis. We first tested for spatial autocorrelation in Y to ensure independence using the Moran's Index test. We also tested for autocorrelation in the residuals of the final model. A negative binomial regression model was first fitted to Y and the predictor variables by adding one predictor variable at a time and retaining those with the lowest AICc values: Akaike information criterion corrected for small samples (Burnham & Anderson, 2002). The explanatory variables found in the best fitting negative binomial model were retained for the zero- inflated binomial model construction. 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. The Vuong test was used to judge the superiority of one model over the other.

Results

Abundance of elephants

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 eastern extension of the park. Excluding the mining zone, two strata where elephant activities were found can be distinguished: high density stratum (area of 425 km^2 west of the mining enclave) and low density (area of 205 km^2 east of the enclave). The encounter rate of elephant dung piles in the two strata did not differ significantly (Mann–Whitney test z = 0.15, NS). Therefore the dung piles in the two strata were combined and analysed as one. The eastern section with no sign of elephants was excluded from the analysis. The various models of the DISTANCE programme were fitted to the perpendicular distance data and about 5% of the largest values were discarded in order to improve the fit of the models (Buckland et al., 2001). With truncation at 8.8 m, the Half normal model with all the adjustments (Cosine, Simple polynomial and Hermite) gave consistent results and the lowest AIC values (Table 1). The dung density was estimated to be 303.02 per km^2 with the lower and upper confidence intervals from 125.82 to 729.80.

Estimation of dung decay rate and elephant numbers

We calculated the mean time to decay based on 217 dung piles since five dung piles could not be relocated. The mean survival time for the 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 1.287×10^{-2} (SE=3.985×10^{-4}). The DISTANCE programme using multipliers gave the density as 0.1973 elephants/sq km with the confidence intervals from 0.0701 to 0.3848. These estimates multiplied by the area (630 km^2 where we found elephant signs) gives 124 elephants (CI from 44 to 242).

Distribution of elephants and modelling the factors influencing density and distribution

The concentration of elephants for the greater part of the study period was within 10 to 15 km from the western boundary of the park. Elephants were absent in the entire eastern extension of the park. More poaching signs were found in the LD stratum than in the HD stratum and the encounter rate of poaching signs was higher off transect (0.89/ km) than on transect (0.25/ km). Poaching signs that were observed off transects were, in deceasing abundance, spent shells, gunshots, poaching camp, poachers seen and snaring.

The variance of the response variable Y was 13 times its mean. We explored the univariate relationships between Y and 14 predictor variables measured. Only distance to mining settlement X_m had significance influence on dung pile abundance after fitting negative binomial regression model as a first step towards identifying variables with strong explanatory powers (Table 2). Thus the expected change in log (Y) for a unit increase of X_m is 0.2029. The relationship can be expressed as:

$$Y= \exp(0.2029 X_m-1.4936)$$

After rounds of explanatory variable additions and deletion, model selection and testing, the zero-inflated negative binomial containing X_h (other human signs) as a single explanatory for zero inflation, X_m, X_{db} (distance to park boundary) and X_{rs} (length of raphia swamp), carried 87% of the AICc weight. The summary coefficients of the best fitting model are shown in table 3a with the inflation model portion in table 3b. All the three predictor variables: X_m, X_{db} and X_{rs} are significant. A Vuong test revealed the zero-inflated negative binomial model to be superior to the standard negative binomial model containing the same variables (Vuong test statistic = -1.724; $p<0.05$). In addition, a likelihood ratio test revealed good fit of the chosen zero-inflated model ($x^2 = 29.292$, df = 3, $p<0.0001$). The function equation with the coefficients can be written as:

$$\log Y = 0.2619X_m + 0.41845\, X_{db} + 0.0072\, X_{rs} \mid X_h$$

Thus, given other human signs, the expected change in log (Y) for a unit increase in raphia swamp, for example, was 0.0072. Y displayed strong spatial autocorrelation (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; $p<0.5$).

Discussion

Abundance of elephants

Our conservative density estimate of 0.20 elephants per km^2 is close to what Barnes and Dunn (2002) found two decades ago (0.24 per km^2). This does not suggest that the population has been stable over the decades they collected their field data in 1989. The dung density we estimated is about twice what they obtained (152 dung piles/sq km) and the area we found elephants signs was about half what they used in their elephant number estimation.

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 west section of the park. Some of our effort was dissipated in the entire northeastern extension of the park where we found no elephants signs. Chimpanzees and elephants were surveyed on the same transects and the former were found to be more widely distributed than elephants.

Table 1. Summary results of elephant dung density from line-transect survey of 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
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
SE	137.6	137.6	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	729.8	729.8	753.69	716.73	716.73

Table 2. Coefficients of some predictor variables after fitting the negative binomial regression model (link function = log)

Description of variables	Estimate	Standard Error	z value	Probability (>lzl)
Null model	1.2192	0.3208	3.801	0.000144
(Intercept only model)				
(Intercept)	1.404	0.3951	3.553	0.00038
All poaching signs/km X_p	-0.1372	0.1676	-0.818	0.41317
(Intercept)	1.4873	0.4751	3.13	0.00175
Fruiting spots X_f	-0.1535	0.1923	-0.799	0.42451
(Intercept)	-1.4936	0.6315	-2.365	0.018
Distance to mining settlements X_m	0.2029	0.0474	4.285	1.83×10^{-5}

We advise that any planned survey of elephants at the same time should consider stratifying the study area for elephants and put more effort in the western section.

Factors influencing elephant abundance and distribution

The level of poaching activities on transect in SNP was low (0.25/km) 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). Two elephants were reported killed by SNP management in 2009 but their carcasses were not found by the survey team. Where elephants are absent, their abundance is negatively affected by proximity to the mining settlements and the park boundary. Mining settlements are 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. One 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. Perhaps, the sections with raphia swamps are better habitat for elephants in terms of, for example, food quality or that they are less accessible to people as we found people avoiding the swamps because of the difficulty in walking through them to the elephants.

Conclusion and management implications

This is the first ever comprehensive survey after the civil conflict in Liberia to ascertain the status of the elephant population. It has been established that elephants are using about half of the area of SNP and that the correct estimation of the area where elephants are found could help avoid the tendency to underestimate or overestimate the numbers. The mining activity that was on-going at the time of the field survey posed a serious threat to the ecological integrity of the park. Now that the miners have been moved out, we suggest that the staff be strengthened and equipped to intensify patrols in and around the old mining enclaves to secure the eastern group of elephants from being exterminated. Future surveys should be extended to the mining enclaves that we did not survey. The Sapo elephants were found to cross the main road between Gellor and Gbalawien to the adjoining patches of forest; it is therefore important to extend the protection of the elephants to those areas. Liberia is a hotspot for endangered species in the West African subregion. This project exposed the field rangers to the ins and outs of the park. It is thus necessary to consolidate this effort for effective law enforcement monitoring.

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Table 3a. 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 (>lzl)**	**Probability level**
(Intercept)	-4.8396	1.3876	-3.488	4.87×10^{-4}	0.001
X_m	0.2619	0.0636	4.117	3.84×10^{-5}	0.001
X_{db}	0.4184	0.1286	3.254	1.137×10^{-3}	0.01
X_{rs}	0.0072	0.0025	2.91	3.614×10^{-3}	0.01
Log(theta)*	-0.2325	0.4064	-0.572	5.6729×10^{-1}	

*Log(theta) is the dispersion parameter

Table 3b. Zero-inflation model coefficients (binomial with logit link)

Model	**Estimate**	**Standard error**	**z value**	**Probability (>lzl)**
(Intercept)	-65.26	76022.73	-0.001	1
X_h	20.88	25340.82	0.001	1

References

Barnes, R.F.W. (2002). 'The problem of precision and trend detection posed by small elephant populations in west Africa'. *African Journal Ecology* 40:179–185.

Barnes, R.F.W. (2001). 'How reliable are dung counts for estimating elephant numbers?' *African Journal of Ecology* 38:1–9.

Barnes, R.F.W. and Dunn, A. (2002). Estimating forest elephant density in Sapo National Park (Liberia) with a rainfall model. *African Journal of Ecology* 40:159–63.

Barnes, R.F.W., Barnes, K.L., Alers, M.P.T. and Bloom, A. (1991). 'Man determines the distribution of elephants in the rainforests of northeastern Gabon'. *African Journal of Ecology* 29:54–63.

Boafo, Y. (2004). Biomass distribution and habitat use by forest elephants, (*Loxodonta africana cyclotis*), bongos (*Tragelaphus eurycerus eurycerus*) and duikers (*Cephalophus spp.*) in the Kakum Conservation Area'. MPhil thesis, Kwame Nkrumah University of Science and Technology, Ghana. 106p.

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. and Thomas, L. (2001). *Introduction to Distance sampling: Estimating abundance of biological populations*. UK: Oxford University Press.

Burnham, K.P. and Anderson, D.R. (2002). *Model Selection and Multimodel Inference: a practical Information-Theoretic Approach*. Second Edition. New York, USA: Springer-Verlag New York, Inc.

Dunn, A. (1993). *An Elephant Survey of Sapo National Park, Liberia*. Unpublished report to the WWF and the Forestry Development Authority, Monrovia.

Hedges, S. and Lawson, D. (2006). *Dung survey standards for the MIKE programme*. Nairobi. CITES–MIKE. Available at http://www.citesmike.org

Laing, S.E., Buckland, S.T., Burn, R.W., Lambie, D., and Amphlett, A. 2003. 'Dung and nest surveys: estimating decay rates'. *Journal of Applied Ecology* 40:1102–1111.

Long, J.S. (1997). *Regrssion Models for Categorical and Limited Dependent Variables*. Thousand Oaks, CA: Sage Publications.

McCullagh, P. and Nelder, J.A. (1989). *Generalized Linear Models*. 2nd edition. London, UK: Chapman & Hall.

R Development Core Team. (2010). *R: A language and environment for statistical computing*.

R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org.

Tai National Park (August 2007–March 2008). *State of Tai National Park: Report on the bio-monitoring programme. Phase 3*. Unpublished report.

Tchamba, M.N. (1992). 'Defecation by the African forest elephant (*Loxodonta africana cyclotis*) in the Santchou reserve, Cameroon'. *Mammalia* 56:155–158.

Thomas, L., Laake, J.L., Strindberg, S., Marques, F.F.C., Buckland, S.T., Borchers, D.L., Anderson, D.R., Burnham, K.P., Hedley, S.L. and Pollard, J.H. (2009). *Distance 6.0, Release 2*. UK: Research Unit for Wildlife Population Assessment, University of St. Andrews.

Vanleeuwe, H. (2008). 'Counting elephants in Montane forests: sources of error'. *African Journal of Ecology* 47:167–174.

Waitkuwait, W.E. (2001). *Report on the establishment of a community-based bio-monitoring programme in and around Sapo National Park*. Unpublished.