REPORT ON THE SURVEY OF ELEPHANTS IN THE TAÏ NATIONAL PARK IN SOUTH WESTERN CÔTE D'IVOIRE

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This report is dedicated to the memory of Nandjui Awo, the co-author who passed away when the report was at the draft stage. Nandjui dedicated his life to the conservation of elephants in West Africa. He will greatly be missed for his passion for the work**.**

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SUMMARY

The Taï National Park is one of the sites in Côte d'Ivoire whose elephant population is being monitored by the CITES-MIKE programme. It is also a priority landscape of the WWF Species Action Plan. The CITES-MIKE programme in collaboration with the WWF African Elephant Programme and the Côte d'Ivoire Division of National Parks and Reserves undertook a comprehensive elephant survey by dung counts in the Taï National Park with the aim to have updated information on the status of the elephant population.

Eighty systematically distributed transects each 1km were surveyed between February and April 2010 by using the standard line transect method. The elephant dung density was estimated to be 144. 27 sq km with confidence intervals from 73.60 to 282.82.

Before the transect survey, we marked five batches of fresh dung piles totalling ninety from October 2009 to January 2010 and their stages of decay were monitored for the estimates of dung decay rate. We estimated the mean dung piles survival time at 57.8278 days with standard error of the mean, SE to be 4.0519. These estimates combined with Tchamba's (1992) forest elephant defecation rate of 19.77 dung piles per day and the area where we found elephant signs (1495.21 sq km) gave an estimate of 189 elephants with confidence intervals from 54 to 324.

The spatial distribution of the elephant population was negatively influenced by poaching activity and the density of elephants was affected by proximity to water sources. Elephant density for example, increased close to the water points. The two predictor variables exerted equal influence on the population. The third variable that seemed to exert some influence was raphia swamp but once water sources and anthropogenic activities have been accounted for, its influence became insignificant.

We found two elephant concentration areas: one near the Tai Research centre and the other at the Mont Nienokoué area. These two areas also had relatively less poaching activity. Patrol team's coverage between the Tai and Guiroutou sectors were not overlapping leaving room for poachers to exploit at the Nigré village area. We suggest that sector managers keep an eye on the Nigré area and a close tabs on the elephant concentration areas to ensure the long-term survival of the population.

1.0 INTRODUCTION

The West African elephant populations have been on the decline since the turn of the 20th century leaving the elephant populations in about 70 small, fragmented and isolated ranges (Barnes *et al.*, 1999). The Taï-Grebo forest complex is the largest rainforest range for the elephants in the Upper Guinean forest ecosystem.

Dung counts are usually used to estimate the abundance and distribution of elephants in the forest and are known to provide reliable and precise estimates (Barnes 2001, 2002). The determination of the status of elephants has been a priority for wildlife managers in the entire West African sub region (AfESG 1999).

Many studies have been undertaken to establish the abundance and distribution of the Taï National Park elephants (Merz 1986, Hoppe-Dominik, 1989, Eggert 2004a) but the sampling intensity of most of the studies was low and methods used in sampling were also different, making comparison of the studies difficult. This left room for doubt as to the true status of the Taï elephant population. The Wild Chimpanzee Foundation in collaboration with the Ivorian Division of National Parks and Reserves has instituted a multi-species monitoring programme in the Taï National Park since year 2005 to date. It is intended to provide biological information to inform decision- making. This monitoring programme served as the baseline for the current study.

The Taï National Park is one of the sites in Côte d'Ivoire whose elephant population is also being monitored by the CITES-MIKE programme. It forms part of a priority landscape of the WWF Species Action Plan. The latest Taï elephant survey by CITES- MIKE used the DNA extracted from dung piles to give a genetic estimate of numbers (Eggert 2004a). The genetic survey was limited in terms of coverage of the study area due to time constraints. The CITES-MIKE programme in collaboration with the WWF African Elephant Programme and the Côte d'Ivoire Division of National Parks and Reserves (OIPR) undertook a comprehensive elephant survey of the Taï National Park by using the standardised MIKE procedures in elephant survey (Hedges and Lawson 2006). The overall goal was to have updated statistics on the status of the elephant population in order to enhance planning and long-term management of the species.

The specific objectives of the survey were to:

1. provide updated statistics on the density, abundance and spatial distribution of the elephant population in the Taï National Park.
2. identify the threats and other factors influencing the density and distribution of elephants in the park and understand their inter-relationships.
3. enhance the capacity of the Taï ecological monitoring team in the standard techniques for forest elephants monitoring.

2.0 METHODS

2.1 *Study Area*

The Taï National Park falls within latitudes 5°08'- 6°24' N and longitudes 6°47'- 7°25' W (figure 1) and between two main rivers, the Cavally and Sassandra. The Taï forest was declared a forest reserve and wildlife refuge in 1926 and designated a National Park in 1972 with an area of 3,500 sq km. It was recognized as a UNESCO Biosphere Reserve in 1978 and as a Natural World Heritage Sites in 1982.

The vegetation type is an evergreen lowland forest, rich in biological diversity. About 1300 plant species have been identified in the park. Detail profile of the park flora is given by Merz (1986). Of the 140 mammals species identified, 12 species, for example, the pigmy hippopotamus *Hexaprotodon liberiensis*, diana monkeys (*Cercopithecus diana)*, Jentink's duiker (Cephalophus jentinki) and zebra duiker (*Cephalophus zebra*) are endemic. The western chimpanzee (*Pan troglodytes*) and pigmy hippos, for instance, are classified as 'Endangered" in the IUCN Red List of Threatened Species. Tai National Park is an important site for primate research in West Africa.

The annual average temperature is between 24 and 30°C (Anderson *et al.*, 2005) and the annual rainfall ranges from a mean of 1700 mm in the north to 2200 mm in the southwest with bimodal peaks. The main wet season starts from April to July and a shorter wet period from September to October. The park is drained by the tributaries of River Meno and Hana.

The Taï forest is under laid by Precambrian granite peneplain of migmatites, biotites and gneiss and it is relatively flat except for the highest point such as Mont Nienokoué that reaches up to 396 m (DPN 1998).

The park is confronted with diverse threats such as poaching, mineral exploitation and cultivation (Marc Patry; UNESCO internet site accessed on 08 February 2011). It is surrounded by over 70 villages.

2.2 Dung decay study

Laing *et al.* (2003), Hedges and Lawson (2006) recommend that a retrospective dung decay study should be undertaken prior to the start of dung survey. The decay study enables dung piles decay rate to be obtained. It is one of the variables needed to convert dung densities to elephant densities.

Five cohorts of elephant dung piles were marked at three-week intervals. The search began in October 2009 and ended in January 2010. The plan was to mark six cohorts of dung piles but fresh dung piles could not be found and marked during the 6th field mission. Fresh elephant trails were searched and followed for fresh dung piles in the S1 and S2 category (Hedges and Lawson, 2006). The dung piles were flagged with red glo material, given an identification number and its location noted with GPS. Other notes made on each marked dung pile include; date found, number of intact boli, vegetation type and altitude. All the dung piles were relocated with the aid of GPS and revisited during the middle of the transect survey to assess if present or has completely disappeared.

2.3 *Transect survey*

A GIS software package ArcView 3.2 was used to lay a 5 km by 5 km grid square on a map of Taî NP. The intersection of the lines was taken as the starting point for each transect. The first transect was randomly placed whilst subsequent ones were systematically distributed in a *systematic segmented* design (Hedges and Lawson 2006). Transects were oriented perpendicular to the major drainage lines. We located transects starting point on the field by navigating with compass and GPS.

The line transect method (Buckland *et al.*, 2001) was used during the survey. A compass man aligned a ranging pole held by a machete man. The machete man then cuts a dead straight line and all team members led by the compass man then marched in an Indian file on the line looking to their left and right for dung piles.

Ninety five transects were distributed but 80 were surveyed. Each transect was 1km in length except for two that were 0.68 and 0.52 km (figure 1). Six survey teams of four persons each (excluding porters and a wildlife ranger who provided security) were maintained throughout the survey to ensure consistency in the data collection procedures. Three field missions were organized between February and April and each mission lasted on average twelve days.

The following notes were taken each time a dung pile was sighted: the perpendicular distance of the dung from the transect centre-line was measured using a tape-measure, distance along transect was measured using topofil. Notes on dung piles and illegal activities seen off transects, that is, during navigation between transects were also made. The stages of decay of dung piles on the transect walks was classified according to the *MIKE S System* (Hedges and Lawson 2006):

S1 : all 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, for example, plant fibre.
S5: No faecal material including plant fibres is present.

Some of the habitat variables, illegal activities and other notes taken including GIS- derived variables for each transect are shown in Table 1.

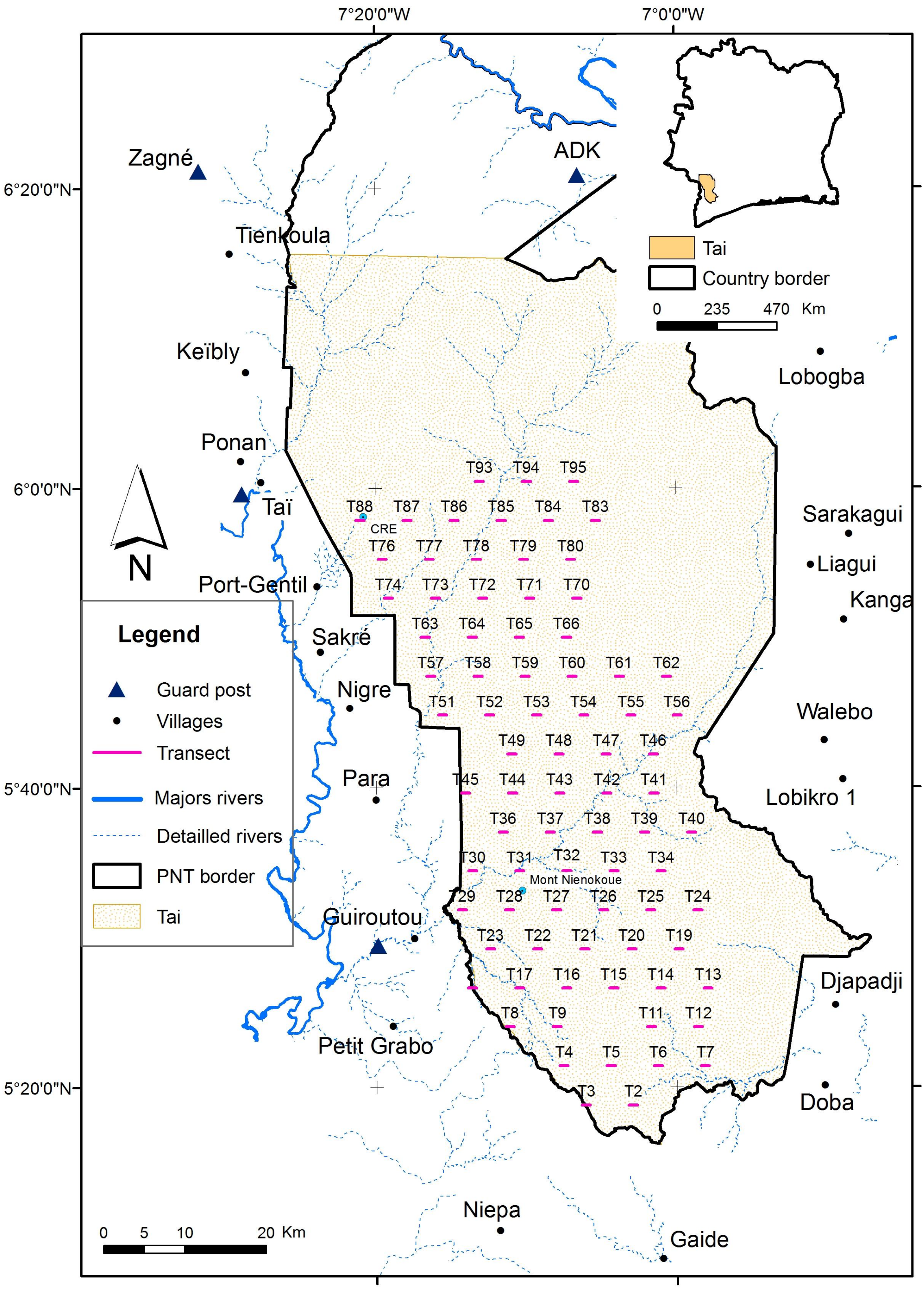


Figure 1: Map showing the location of Tai in Côte d'Ivoire, the transect design and distribution for the elephant survey.

Table 1: List of some variables recorded on transects or derived by using GIS.

Variables	Description
X1	Number of poaching activities excluding for example, footpaths, poacher cuttings etc
X2	Number of other human signs (footpaths, poacher cuttings, footprints etc).
X3	Number of all poaching signs on the transect
X4	Length of open forest
X5	Length of secondary forest
X6	Length of inundated forest
X7	Length of raphia swamp
X8	Number of gaps in the upper canopy
X9	Length of gaps in the upper canopy
X10	Number of fruiting trees on the transect
X11	Number of water sources
X12	Percentage of swamp forest (inundated and raphia swamp combined)
X13	Distance to park boundary (km)
X14	Distance to the nearest road (km)
X15	Distance to nearest village settlement (km)
X16	Distance to the nearest water sources (km)

2.4 Data analyses

2.4.1 Dung piles decay rates estimation

We ranked each marked dung pile 0 if it had completely disappeared or 1 when present during the revisit period. We fitted a logistic regression curve to this binary data and the number of days between the marking and the revisit for each dung pile in order to estimate the mean time to decay. We used the GENSTAT programme with mean decay plug-in written by R.W. Burn to calculate the mean survival days.

2.4.2 Elephant density estimation

The DISTANCE 6.0 programme (Thomas *et al.* 2009) was used to analyse the dung pile perpendicular distance data to obtain dung densities. Laing *et al.* (2003) formula:

$$D_a = \frac{D_s}{(p \times t)} \qquad \text{---------------------------- eqn 1}$$

was used to covert dung density to elephant density, where

D_a is elephant density, D_s is dung density per sq km, p is defecation rate per day and t is the mean dung piles survival time. Merz (1986) has estimated the Taï elephant's defecation rate but his estimate was based on few samples and did not also account for possible seasonal variation. Tchamba (1992) forest elephant's defecation rate from Cameroon which so far is the best study of forest elephant dung deposition rate in the Upper Guinean forest was used. D_a was calculated using a spreadsheet that uses the Delta method to estimate standard error (Seber 1982). The density multiplied by the area (in sq km) where we found elephant signs gave the number of elephants.

The DISTANCE programme was also used to directly calculate the elephant density by bootstrapping using the same decay and defecation rate variables. This gives an asymmetric and usually narrow lower and upper quantiles confidence intervals of the density estimate.

2.4.3 Identifying factors that influence elephant distribution

Our count data consisted of many zeros; transects where no dung piles was recorded. It was not normally distributed. The initial univariate relationships between the response variable Y (number of dung piles/km) and each of the explanatory variables was explored. We performed a principal component analysis using R to assess patterns and identify possible correlations in the explanatory variables. The objective was to have the least predictor variables that capture the greatest variation in Y. Twelve variables that could possibly influence the distribution were identified out of the 17 variables recorded. A generalised linear model (McCullagh and Nelder 1989) that assumes a Poisson distribution of errors and fitted by maximum likelihood did not fit our count data. The basic assumption for Poisson; mean of Y equals variance was not met. In other words, the count data exhibits over dispersion. The distribution of Y was indicative of a negative binomial distribution. Thus the negative binomial regression model was fit to response variable and each of the explanatory variables. But we found that a zero-inflated negative binomial model fit our data better than the standard negative binomial (Long 1997). A zero-inflated regression model is in two parts: the count of zeroes, the inflated part is modelled separately but simultaneously with the counts where Y>0. The R language and environment for statistical computing by R Development Core Team (2010) was used for the analysis. Section 3.4.4 gives more details about the modelling process.

Moran's test was first used to find out possible spatial autocorrelation in the response variable data. Possible autocorrelation in the residuals of the final model was also examined.

3.0 RESULTS

3.1 Dung density estimation

In all, 84 dung piles were recorded on a total of 79.2 km transects. The number of dung piles per transect ranged from 0 to 22. The dung piles were recorded on nineteen transects out of the 80 transects we sampled. A post facto stratification of the study area was therefore undertaken before the dung density estimation. Two strata could be defined: one surveyed but with no elephant signs and the other where we found signs (an area of 1495.21 sq km). Thus the number of dung piles spotted remained the same but the effort reduced to 56.52 km. All transects surveyed outside the redefined zone (figure 2) had no elephant signs.

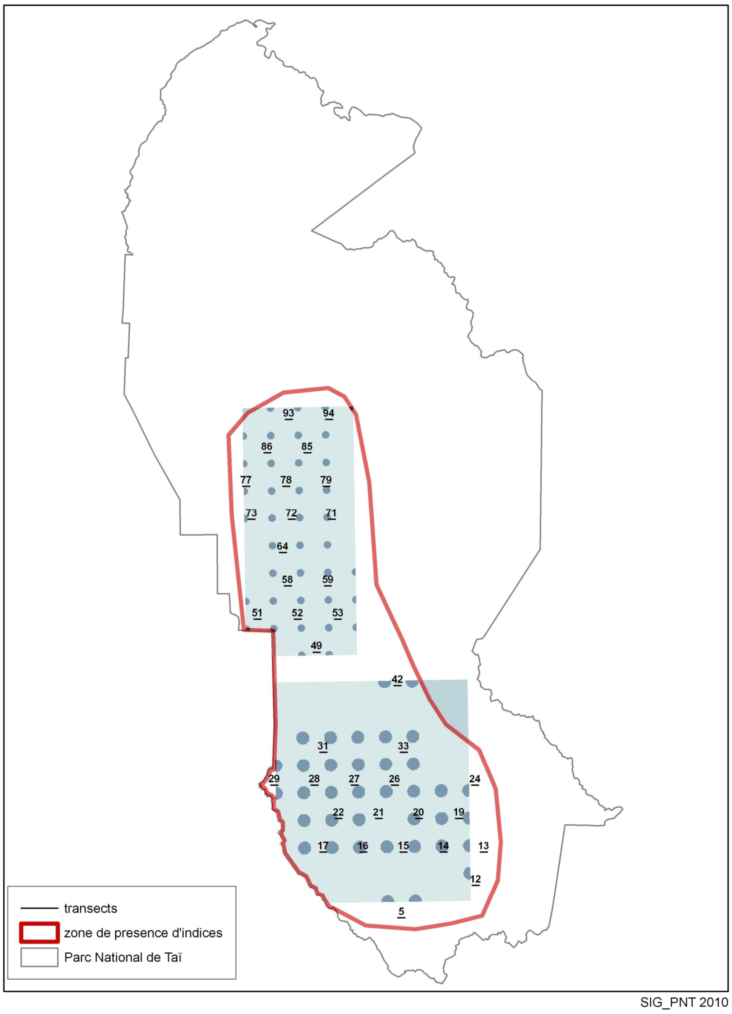


Figure 2: Possible range of elephants delimited in red and the zones with elephant signs during this study are indicated by the two polygons in blue (map by Yapi Fabrice).

The models of the DISTANCE programme were fitted to the histogram of the perpendicular distance data. About 5% including outliers of the perpendicular distance data were removed in order to improve the fit of the various models to the data (Buckland *et al.* 2001). The maximum strip widths were fixed at 14 m, 10 m and 8 m and the programme ran for each model. The model with the lowest Akaike Information Criterion (AIC value); Half normal with cosine adjustments with maximum strip width set at 8 m was chosen as the best model (Table 2). The visibility profile of the chosen model is shown in figure 3.

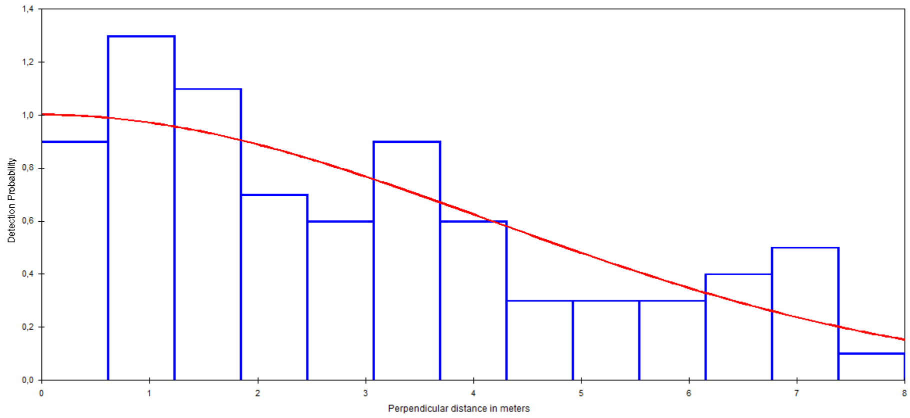


Figure 3: Visibility profile of the Half normal model with cosine adjustments fitted to the histogram of the perpendicular distance data.

The dung piles density was estimated as 144. 27 per sq km with 95% Confidence interval from 73.60 to 282.82.

Table 2: Summary results from the DISTANCE programme with truncation of the perpendicular distances at 8m.

Parameter	Uniforrn + cosine	Uniform + Hermite polynomial	Half normal + cosine	Half normal + Hermite polynomial	Hazard + cosine	Hazard + Hermite polynomial
[1]D (km^{-2})	144.31	129.28	144. 27	144.27	161.33	161.33
[2]f(0)	0.20	0.18	0.20	0.20	0.23	0.23
[3]AIC	316.44	317.87	316.42	316.42	317.18	317.18
SE	49.53	43.91	50.03	50.03	62.0	62.0
% CV	34.32	33.96	34.68	34.68	38.43	38.43
Lower CL	74.07	66.75	73.60	73.60	77.19	77.19
Upper CL	281.19	250.37	282.82	282.82	337.19	337.19
[4]χ^2	7.78	9.98	8.27	8.27	6.55	6.55
n/L	1.42	1.42	1.42	1.42	1.42	1.42

[1] D is the number of dung piles per sq km.
[2]Values of the probability density function at perpendicular distance of zero from the transect line.
[3] Akaike Information Criterion (AIC) indicates the fit of the model to the data. The lower the AIC the better the fit.
[4]χ^2: Chi- square compares the fit of the visibility curve to the histogram of the perpendicular distance data. The lower the value the better the fit. n/L is the number of dung piles per kilometre.

3.2 Dung decay rate

Ninety dung piles were found and marked for the estimates of decay rate. The dung piles were in five cohorts and each cohort ranged from 13 to 24 (Table 3). Out of the 90 dung piles, four could not be relocated during the revisits period. Our decay rate estimates was therefore based on 86 dung piles.

Table 3: Number of dung piles marked per cohort and relocated during the decay study.

Cohort 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	17	17	0
2	24	20	0
3	20	20	0
4	13	13	46
5	16	16	87
Total	90	86	23

The mean survival time was estimated as 57.8278 days and standard error of the mean, SE= 4.0519. The decay rate per day, that is, the inverse of the mean survival time was estimated as 0.01729 ± 00121.

3.3 Estimation of Elephant numbers

The decay rate from this study and the defecation rate by Tchamba (1992) that is, 19.77 dung piles/ day ± variance = 0.911 were plugged into equation 1 to estimate density. We estimated the density to be 0.1262 sq km with 95% Confidence limits ± 0.0904. The density multiplied by the area where we found elephant signs (1495.21 sq km) gives 189 elephants (Confidence limits from 54-324).

Using the DISTANCE programme, the multipliers and bootstrapping the variances of the multipliers gives slightly higher density of 0.1409 per sq km and 2.5% and 97.5% quantiles of the bootstrap estimated CL from 0.0557 to 0.2622. We retained the estimate from the standard method: 189 elephants (Confidence limits from 54-324) as our best conservative estimate of elephant numbers in the Taï forest.

3.4 Investigating factors influencing the elephant distribution

The number of dung piles per transect varied from 0 to 22. There were two high concentration areas indicating a possible clump distribution: one group was close to River Meno, East of the Taï Research centre (abbreviated CRE in figure 1) and the other at Mont Nienokoué in the southern part of the park, figures 4 and 5. Figure 5 is a refinement of figure 4 and combines observations made (dung piles/km) both on and off transects.

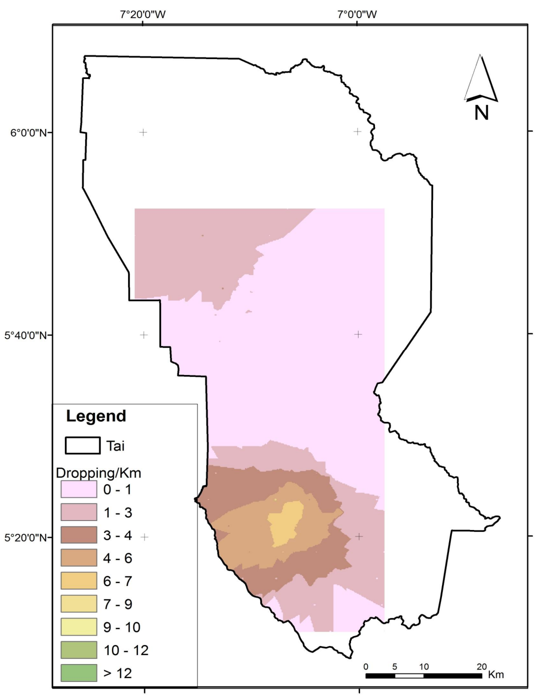


Figure 4: Distribution of dung piles on transect.

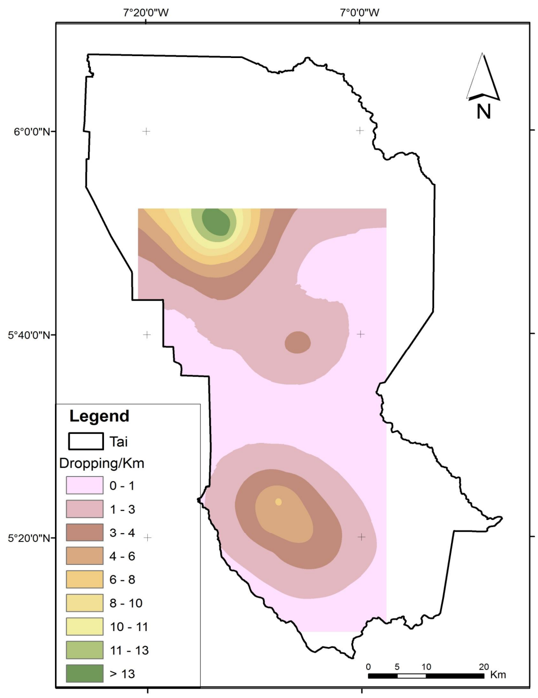


Figure 5: Distribution of dung piles on and off transect.

The Taï forest is surrounded by cocoa, cafe and rubber plantations with reports of crop raiding by the elephants (Ouattara *et al.* 2010). Crop depredation, however, does not appear to be a major problem. Any possible impact of the plantations on elephant distribution was not covered by this study.

3.4.1 Poaching and dung piles distribution

With the exclusion of the paths and poachers cuttings, poaching signs found on and off transect were dominated by spent shells (Table 4).

Table 4: Poaching activities on and off transects

	On Transect		Off Transect	
Evidence of poaching	Total signs	signs/km	Total	signs/km
Poachers seen	0	0	0	0
Poacher camps	2	0.02	4	0.02
Gunshots heard	1	0.01	23	0.12
Spent cartridges	21	0.26	63	0.33
Snares	3	0.04	8	0.04
Other human signs (eg. poaching paths etc	41	0.52	NA	

NB: Off transect sampling were made on 188.84 km. Speed of survey team during navigation between transects was higher than on transect.

The highest number of spent cartridges, 5/km was picked on the outlying transect (T57) at Nigré. No poacher was encountered and poaching camps observed were old. Generally, the indices of poaching on and off transects were similar with the exception of spent cartridges found during navigation between transects (Table 4). It is noteworthy that snares found off transects are likely to be underestimated because the survey team did not spend much time scanning the forest floor. The spatial distribution of poaching signs on transect (figure 6) and on and off transect (figure 7) indicate the Guiroutou area; the south west pinkish-white zone and the Tai research area (northernmost pinkish-white zone) as zones with the least poaching.

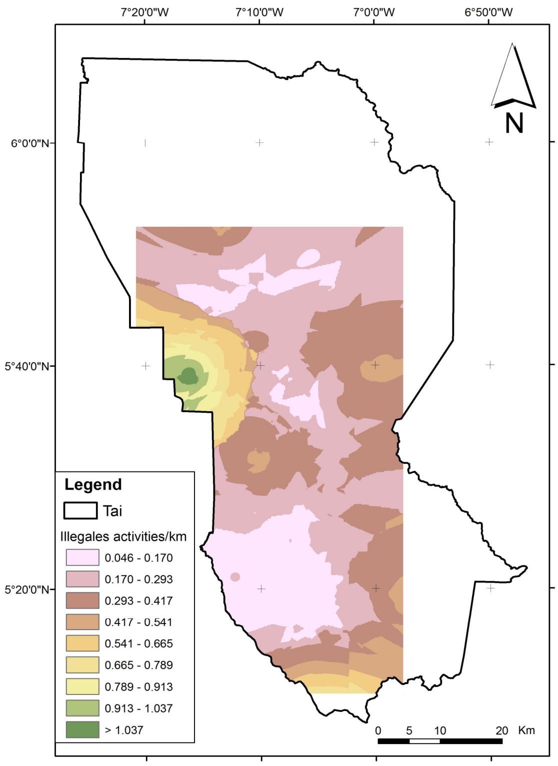


Figure 6: Spatial distribution of poaching signs on transects.

The Nigré area was the zone with intense poaching (green coloured). About 200 sq km area of the Taï Research centre was a 'no go' area for poachers. Poaching picked up beyond the Research Centre. The highest number of gunshots (14) per night was recorded at about 26 km northeast of the Research centre.

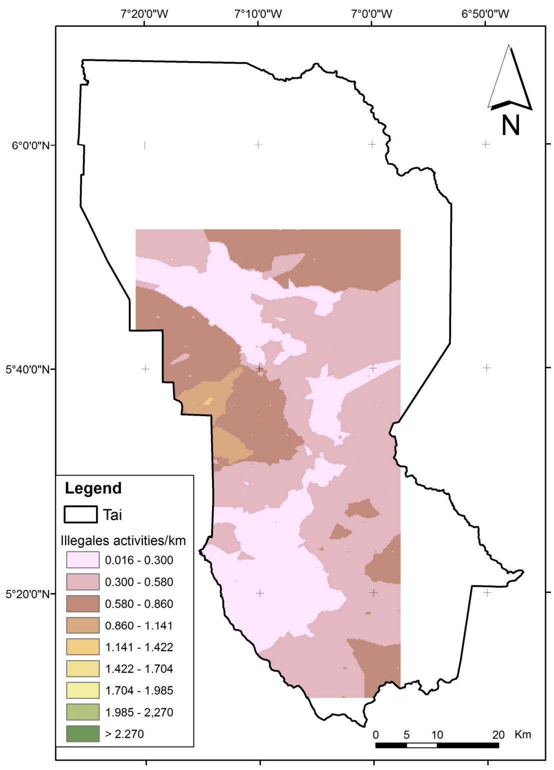


Figure 7: Spatial distribution of poaching signs found on and off transects.

The difference in the intensity of poaching at the eastern section compared to the above figure is a matter of spatial interpolation. The range of data used for these figures are not the same. Thus the prediction of areas with no data using nearby dataset will be different. Figure 7 however, is figure 6 refined with data obtained off transect.

The relationship between indices of dung pile distribution and suites of some possible explanatory variables are shown in figures 8 to 11. There is seemingly no clear relationship between dung piles abundance per transect and poaching signs observed on the transect at this stage (figure 8).

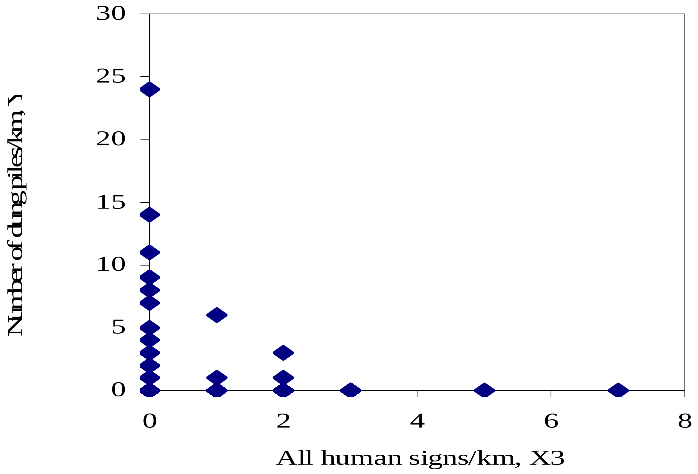


Figure 8: Graph of dung piles abundance and poaching signs seen on transects.

3.4.2 Swamp forest and dung piles distribution

The big swamp forest at the River Meno area, East of CRE, for example, attracts diverse mammal species. Two live elephants and lots of bongo and hippo activities were all observed there. The relationship between dung piles abundance and the swamp forest is as shown in figure 9.

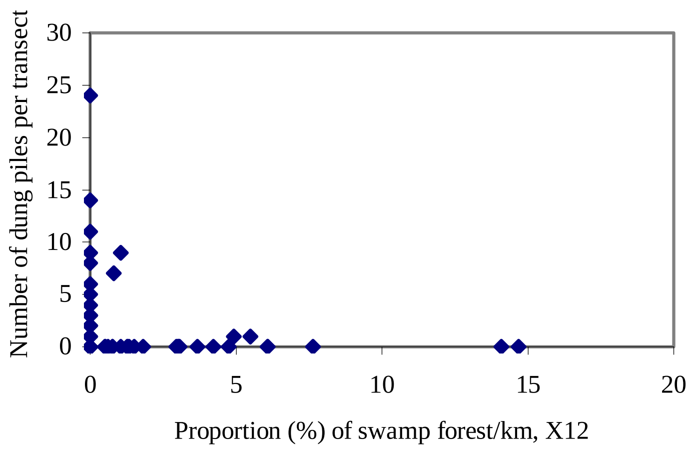


Figure 9: Graph of dung piles abundance and the proportion of swamp forest on the transects.

3.4.3 Human settlements, Roads and dung piles distribution

Figures 10 and 11 respectively show the relationships between number of dung piles per transect and human settlements and roads around the park.

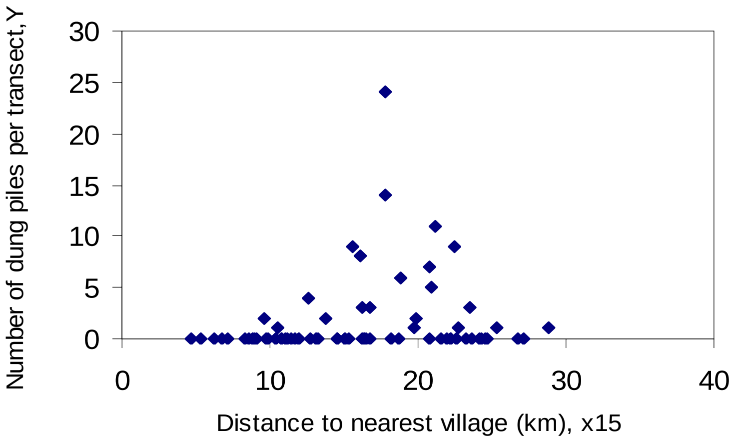


Figure 10: Graph of dung piles abundance and distance to the nearest village settlement.

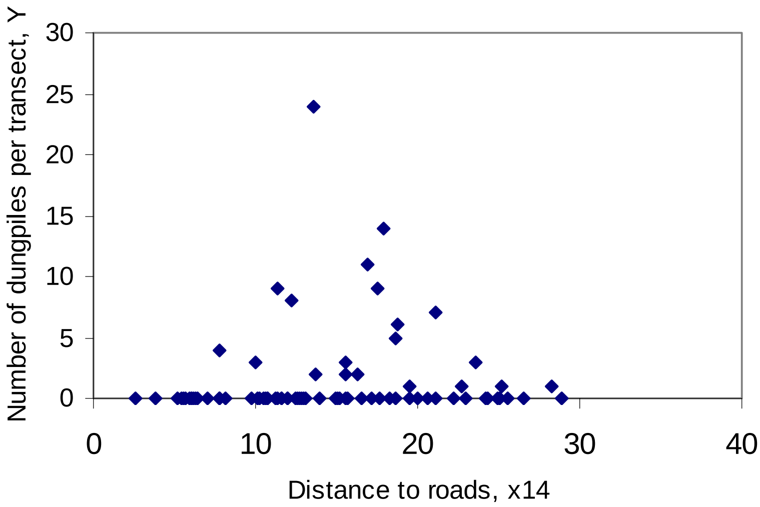


Figure 11: Graph of dung piles abundance and distance to nearest road.

Figures 8 to 11 do not show linear relationships an indication that one single variable cannot clearly explain the relationships. Our count data was also not normally distributed neither was it Poisson distributed. A negative binomial regression model fit to the response variable and each of the possible explanatory variables, for example, poaching signs, proportion of swamp forest and village settlements showed significant relationships (Table 5).

Table 5: Summary coefficients of some explanatory variables after the negative binomial model fit (link function= log).

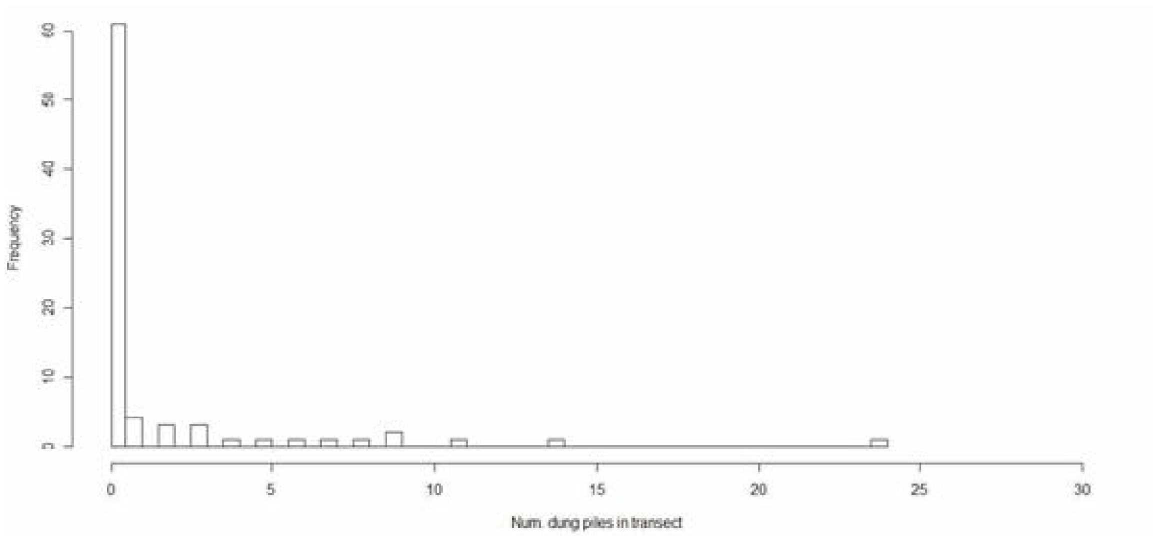
Description of variables	Estimate	AICc	Standard Error	z value	Probability (>|z|)
Null model (Intercept only model)	0.3716	202.44	0.3474	1.069	0.285
(Intercept)	0.7568		0.3789	1.997	0.04578
All poaching signs, x3	-1.1357	197.77	0.4101	-2.770	0.00561
(Intercept)	0.6093		0.3699	1.647	0.0995
Percentage of swamp forest, x12	-0.0093	200.20	0.0047	-1.980	0.0477
(Intercept)	-1.45036		0.69747	-2.079	0.03758
Distance to park boundary, x13	0.16344	201.70	0.05691	2.872	0.00408
(Intercept)	-3.06952		1.05447	-2.911	0.00360
Distance to nearest village, x15	0.19856	200.14	0.05934	3.346	0.00082

The relationship between Y (number of dung piles/ km) and poaching activity which is significant, for instance, can be expressed as:

$$Y = exp\ (0.7568-1.1357X3)$$

3.4.4 Modelling the factors to explain distribution

Figure 12 shows the distribution of the response variable, *Y*. The variance of Y is 9.8 times the mean.



With the violation of the basic assumption for Poisson distribution (Y variance= mean), we first fit a negative binomial regression model by adding the explanatories one at a time in a stepwise fashion and retaining the model with the lowest AICc values, that is Akaike information criterion corrected for small samples (Burnham and Anderson 2002). The initial negative binomial model obtained was compared with the intercept only model, that is, the null model that assumes homogenous distribution of the dung piles. The explanatory variables in the best fitting negative binomial model were retained for a zero inflated model construction. Variable addition to the negative binomial model was iterated until AICc stopped declining. Variables that caused a decline of 2 or more in the AICc values were retained. We expanded the negative binomial model chosen at this stage into a zero inflated model and the round of variables additions was again repeated.

Possible interactions of the selected variables in the zero inflated model was investigated by adding the interaction terms one at a time and retaining the ones that caused a drop of two or more in the AICc values. None of the interactions was significant. The Vuong test was used to assess the superiority of the initial standard negative binomial model and the zero inflated one. List of some of the candidate models found together with their AICc values are shown in table 6. Models were compared based on the evidence ratio (the number of times a model is better than the previous one), AICc differences and AICc weights, table 6. Thus the first negative binomial model involving two explanatory variables (x3 and x7) is 72 times better than the null model. The second model is 1.5 times better than the first and so on. The last but two models (bolded) are the zero inflated ones and the variables involved are x3 (poaching signs), x7 (raphia swamp), x15 (distance to nearest village settlements) and x16 (distance to nearest water sources). These variables in the last zero inflation model carries 54% of the AICc weight.

Table 6: Comparison of candidate models with binomial log link function.

Candidate models (figures indicate variable numbers included in the model)	AICc	AICc Δ_i	AICc weights	Evidence ratio
glm.nb3.7	193.89	4.59	0.05	72
glm.nb3.7.16	193.13	3.83	0.08	1.46
glm.nb3.7.15.16	192.97	3.67	0.08	1.08
t15zi_glm.nb3.16	190.70	1.40	0.26	3.12
t15zi_glm.nb3.7.16	**189.30**	**0**	**0.54**	**2.01**

Table 7a shows the summary coefficient of the parameters estimates of the chosen best fitting zero inflation model with log link function.

Table 7a: Summary coefficients of the zero inflation negative binomial model.

Model variables	Coefficients estimate	Standard error	z value	Probability (>|z|)	Significant level
(Intercept)	2.093	0.5562	3.763	1.68×10^{-4}	0.001
Poaching signs, x3	-1.079	0.4407	-2.448	1.437×10^{-2}	0.05
Length of raphia swamp, x7	-1.902	1.04×10^{5}	-1.83×10^{-5}	9.999×10^{-1}	NS
Proximity to water sources, x16	-0.2758	0.1121	-2.460	1.389×10^{-2}	0.05
Log(theta)*	-1.144	0.3956	-2.893	3.816×10^{-3}	0.01

The variable x7 is not significant but the other two: x3 and x16 are statistically significant. The inflation model part which includes the logit coefficients for predicting excess zeros is shown in Table 7b. The predictor of excess zeros: proximity to human settlement, x15 is not significant.

Table 7b: Zero-inflation model coefficients

Model variables	Coefficients estimate	Standard error	z value	Probability (>|z|)
(Intercept)	6.7166	3.8588	1.741	0.0818
Proximity to human settlement, x15	-0.5207	0.3235	-1.610	0.1074

Theta = 0.3184, Log-likelihood: -86.87 on 7 Df

Our chosen zero inflation model was found to be better than the standard negative binomial model involving the same predictors: x3, x7, x15 and x16 (Vuong test-statistic= -1.4023, p <0.0805). The Chi square goodness of fit test also shows better fit of our chosen model (χ^2 =22.681, df =3, p <0.00014) suggesting that the model is statistically significant. Moran's Index test also showed the response variable Y displaying weak and insignificant spatial autocorrelation at the initial stage before the modelling (Moran's I: -0.079: expected: -0.0126±0.0511, p< 0.191).

We can best express the relationship between the number of dung piles per transect and the predictor variables at the time of the survey as:

$$\text{Log } Y = 2.093-1.079X3 - 0.2758X16 \mid X15$$

This reads as thus: Y is a function of poaching activity and distance to water sources given distance to village settlements around the park. It means that the expected change in log (Y) for a kilometre increase in distance to water sources, for example, is 0.2758. The density of elephants was negatively and significantly influenced by proximity to water sources. The relationship between elephant distribution and poaching activities was also negative.

4.0 Enhancing the capacity of the Taï ecological monitoring team in the standard techniques for forest elephants monitoring.

Twelve members of the park's ecological monitoring team (EMT) based at the Guiroutou, V15 and the Taï sectors of the park were trained in the use of the standard techniques in surveying forest elephants. This excludes the patrol rangers and the fringing communities' members who formed part of the survey team. Even though, the EMT had good knowledge in navigation and surveying in general, it was imperative to ensure that all the field teams have the necessary technical knowledge and competencies for the fieldwork. The standard line transect method, the MIKE 'S' system of dung piles decay stage classification, measurement of perpendicular distance of scattered dung piles, assessing whether a dung pile is one or two etc were the highlights of the training. The theoretical training sections were organised at the Guiroutou and Tai sectors (see cover page for the Tai group photo). The Guiroutou section lasted five days and it was dominated by the fringe communities members recruited to support the EMT in the survey.

5.0 DISCUSSION

5.1 Elephant numbers

We estimated the number of elephants to be 189 which is within the limits found by Herbinger (2008) in the on- going multi-species biological programme by the Wild Chimpanzee Foundation. Over two decades ago, Alers, in Douglas-Hamilton *et al.* (1992) estimated the population as 300 but Hoppe-Dominik (1998) reported it had declined to 75. Eggert (2004a) estimated approximately 60 individuals based on the DNA extracted from dung with samples from two elephant concentration areas of the park. It is noteworthy that the methods used by the researchers differed making it difficult to establish the trend in this population. What is certain is that our estimate is derived from the most intensive sampling of the population so far undertaken.

The bootstrapping confidence interval estimate resulted in a much wider CL than expected.
Precise population estimates are needed to enable trends in the population to be monitored over time. Our coefficient of variation is high 35.79 even though significant effort was put into the sampling of the population. Improving the precision using the same sampling method needs to be weighed against the cost of the extra effort since it will not be cost effective in the final analysis. The genetic method of sampling (Eggert 2004a) could be used in future if the cost of genetic survey becomes comparable to that of the standard line transect and there is availability of laboratory to analysis dung samples for DNA-based population parameter estimates. Also stratification will be needed in future dung surveys by putting much more effort in the two elephant concentration areas: close to River Meno, East of the Taï Research centre and at the Mont Nienokoué area in the southern part of the park (figure 5).

Our early dry season mean dung piles survival time (57.83 days) was similar to what was estimated in the Guinea Ziama forest during the raining season (57.79 days) by Barnes and Nandjui (2005). We marked five batches of dung piles with a mean per batch of 18 dung piles instead of the six batches with a minimum of 20 dung piles per batch initially planned and also recommended (Laing *et al*. 2003). To reduce the effort required in locating fresh elephant dung sites in Tai for a decay study, future studies should concentrate their efforts in locating the two elephant concentrations areas. Five batches of marked dung piles (about 20 per batch) are enough to give a good estimate of the decay rate.

5.2 Distribution of elephants

The two elephant concentration areas found by this study confirms the observation by Eggert (2004a). However, it was not possible to determine from the dung count if the two populations occasionally come into contact as reported by the field rangers. We found a spatial gap with no sign of elephants between the two clump populations (figure 2). The Tai Research centre and it environs were found to be a safe haven for the population of elephants located there.

The elephant density was negatively related to distance to water sources. In other words, elephant concentration was high close to water points. Human activity such as poaching also had a negative relationship with the distribution of the population. The influence of poaching on most elephant populations in West Africa has been well documented (Blanc *et al.* 2007). Poaching activity found off transects excluding the path (0.47/km) was higher than what was found on transects 0.34/km**.** Generally**,** less poaching signs was found than reported (1.09/km) during the phase three monitoring period **(**August 2007 to March 2008) by the Wild Chimpanzee Foundation. The intensity of poaching on the transects is also similar to what was found at the Sapo national park, 0,25/km (Boafo, 2010). Poaching was less in the Tai Research centre and the Guiroutou sections (figure 7) due perhaps to the constant presence of researchers and rangers. In the Guiroutou sector, for instance, a chimpanzee habituation programme by WWF was on-going making staff to frequent this area. The routine deployment of patrol rangers was on-going prior to our field study with the arrest of poachers. Also, the bio-monitoring team carried out their routine monitoring two weeks prior to our survey. These could account for the generally low encounter of poaching signs or it could simply be an indication of a declining trend in poaching.

6.0 CONCLUSIONS AND MANAGEMENT IMPLICATIONS

This is the most comprehensive survey so far undertaken for the elephants in the Tai forest. The population could be ranked the second highest after Ziama in terms of elephant numbers in the protected areas of the Upper Guinean rainforest for known field survey records dating back to year 2000.

The Tai Research centre area is safe for the elephant population there as long as constant human presence is maintained. Even though, the Tai population appears clumped, it could be a healthy one. The populations in the two areas were not found to be genetically discrete and distinct but have individuals of both sexes in each area (Eggert 2004a). The global sex ratio in 2002 was estimated as 62% female and 38% male (Eggert 2004a).

Patrolling activities of rangers may not be overlapping creating a void for intense poaching between the Tai and the Guiroutou sectors at the Nigré area. There is the need to intensify patrols at Nigré and at the elephant enclaves particularly at the Mont Nienokoué area where the highest number of spent cartridges (on and off transect combined) were found in order to ensure the long-term conservation of the population.

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8.0 ACKNOWLEDGEMENTS

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9.0 ANNEXES

Annex: DISTANCE 6.0 Release 2 Output abridged-Model Half normal + cosine adjustments: max perpendicular distance fixed at 8m

Estimation Options Listing

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

 Distances:
 ----------
 Analysis based on exact distances
 Width specified as:    8.000000

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

Variances:
 ----------
 Bootstrap variance/confidence intervals for density. Random number seed =  50453865.
     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        :    56.52000
 # samples     :    57
 Width         :    8.000000
 # observations:    80
 Model  1
    Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))
      Results:
      Convergence was achieved with    8 function evaluations.
      Final Ln(likelihood) value =  -157.21091
      Akaike information criterion =   316.42181
```

Bayesian information criterion =   318.80386
AICc =   316.47308
Final parameter values: 4.1324258

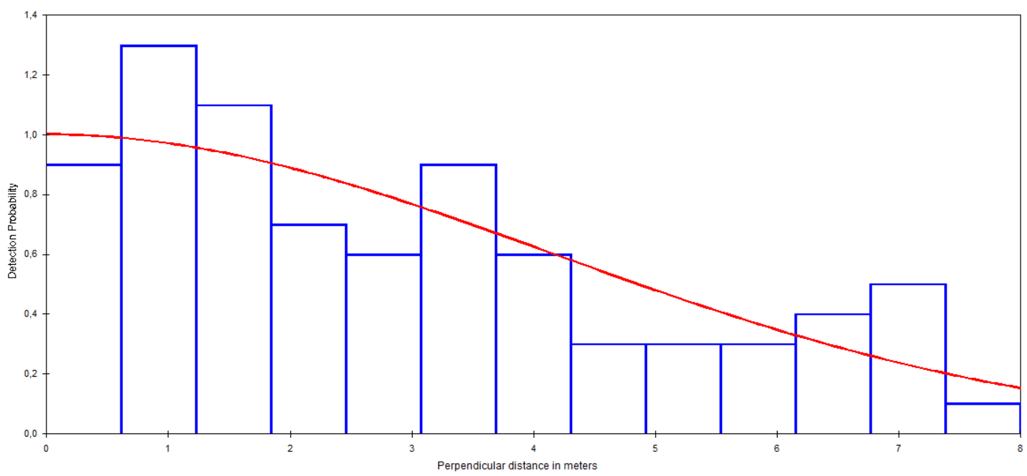
Model 2
Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))
Cosine adjustments of order(s) : 2
Results:
Convergence was achieved with   9 function evaluations.
Final Ln(likelihood) value = -156.55627
Akaike information criterion =   317.11255
Bayesian information criterion =   321.87659
AICc =   317.26840
Final parameter values: 4.2272049   0.18181815

Likelihood ratio test between models 1 and 2
Likelihood ratio test value   =   1.3093
Probability of a greater value =   0.252526
*** Model 1 selected over model 2 based on minimum AIC

Detection Fct/Global/Parameter Estimates

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95 Percent Confidence Interval	
A(1)	4.132	0.5065			
f(0)	0.20386	0.18730E-01	9.19	0.16985	0.24467
p	0.61317	0.56338E-01	9.19	0.51089	0.73594
ESW	4.9054	0.45070	9.19	4.0871	5.8875

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	0.615	9	10.00	0.100
2	0.615	1.23	13	9.78	1.060
3	1.23	1.85	11	9.36	0.289
4	1.85	2.46	7	8.76	0.352
5	2.46	3.08	6	8.01	0.506
6	3.08	3.69	9	7.17	0.465
7	3.69	4.31	6	6.28	0.013
8	4.31	4.92	3	5.38	1.053
9	4.92	5.54	3	4.51	0.504
10	5.54	6.15	3	3.69	0.130
11	6.15	6.77	4	2.96	0.366
12	6.77	7.38	5	2.32	3.096
13	7.38	8.00	1	1.78	0.341

Total Chi-square value = 8.2731 Degrees of Freedom = 11.00

Probability of a greater chi-square value, P = 0.68865

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	0.615	9	10.00	0.100
2	0.615	1.23	13	9.78	1.060
3	1.23	1.85	11	9.36	0.289
4	1.85	2.46	7	8.76	0.352
5	2.46	3.08	6	8.01	0.506
6	3.08	3.69	9	7.17	0.465
7	3.69	4.31	6	6.28	0.013
8	4.31	4.92	3	5.38	1.053
9	4.92	5.54	3	4.51	0.504
10	5.54	6.15	3	3.69	0.130
11	6.15	6.77	4	2.96	0.366
12	6.77	8.00	6	4.10	0.882

Total Chi-square value = 5.7182 Degrees of Freedom = 10.00

Probability of a greater chi-square value, P = 0.83836

Density Estimates/Global

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
D	144.27	50.031	34.68	73.597	282.82
N	0.25652E+06	88955.	34.68	0.13086E+06	0.50285E+06

Measurement Units

Density: Numbers/Sq. kilometers
ESW: meters

Component Percentages of Var(D)

Detection probability : 7.0
Encounter rate : 93.0

Estimation Summary - Encounter rates

	Estimate	%CV	df	95% Confidence Interval	
n	80.000				
k	57.000				
L	56.520				
n/L	1.4154	33.44	56.00	0.73730	2.7172
Left	0.0000				
Width	8.0000				

Estimation Summary - Detection probability

	Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine					
m	1.0000				
LnL	-157.21				
AIC	316.42				
AICc	316.47				
BIC	318.80				
Chi-p	0.83836				
f(0)	0.20386	9.19	79.00	0.16985	0.24467
p	0.61317	9.19	79.00	0.51089	0.73594
ESW	4.9054	9.19	79.00	4.0871	5.8875

Estimation Summary – Density & Abundance

Estimate %CV df 95% Confidence Interval

Half-normal/Cosine

D	144.27	34.68	64.51	73.597	282.82
N	0.25652E+06	34.68	64.51	0.13086E+06	0.50285E+06

ANNEX: ESTIMATE OF ELEPHANT DENSITY FROM THE DISTANCE PROGRAMME: HN+COSINE + MULTIPLIERS + BOOTSTRAPPING

Estimation Options Listing

Parameter Estimation Specification

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

Distances:

Analysis based on exact distances
Width specified as: 8.000000

Estimators:

Estimator 1
Key: Half-normal
Adjustments - Function : Cosines
- 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	.17293E-01	.12117E-02	Inf
Dung Prod rate	.50582E-01	.24421E-02	Inf

Variances:

Bootstrap variance/confidence intervals for density. Random number seed = 60889875.
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:

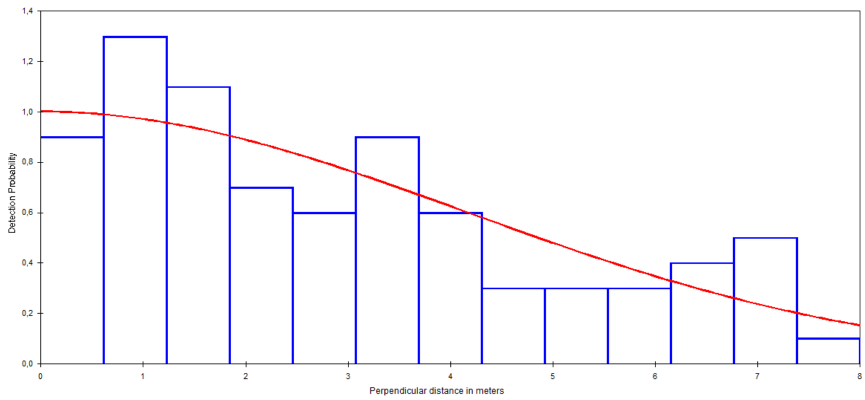
Cut points chosen by program

Effort : 56.52000
samples : 57
Width : 8.000000
observations: 80

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)	4.160	0.5446			
f(0)	0.20284	0.19771E-01	9.75	0.16715	0.24616
p	0.61624	0.60066E-01	9.75	0.50780	0.74785
ESW	4.9299	0.48053	9.75	4.0624	5.9828

Detection Fct/Global/Plot: Detection Probability 3



Perpendicular distance in meters

Detection Fct/Global/Chi-sq GOF Test

Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	0.615	9	9.94	0.090
2	0.615	1.23	13	9.73	1.100
3	1.23	1.85	11	9.39	0.277
4	1.85	2.46	7	8.65	0.315
5	2.46	3.08	6	8.06	0.525
6	3.08	3.69	9	7.11	0.504
7	3.69	4.31	6	6.34	0.018
8	4.31	4.92	3	5.35	1.033
9	4.92	5.54	3	4.57	0.538
10	5.54	6.15	3	3.69	0.130
11	6.15	6.77	5	3.02	1.303
12	6.77	7.38	4	2.33	1.187

13	7.38	8.00	1	1.83	0.374

Total Chi-square value = 7.3934 Degrees of Freedom = 11.00

Probability of a greater chi-square value, P = 0.76639

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	0.615	9	9.94	0.090
2	0.615	1.23	13	9.73	1.100
3	1.23	1.85	11	9.39	0.277
4	1.85	2.46	7	8.65	0.315
5	2.46	3.08	6	8.06	0.525
6	3.08	3.69	9	7.11	0.504
7	3.69	4.31	6	6.34	0.018
8	4.31	4.92	3	5.35	1.033
9	4.92	5.54	3	4.57	0.538
10	5.54	6.15	3	3.69	0.130
11	6.15	6.77	5	3.02	1.303
12	6.77	8.00	5	4.16	0.169

Total Chi-square value = 6.0009 Degrees of Freedom = 10.00

Probability of a greater chi-square value, P = 0.81518

Density Estimates/Global

Point Parameter	Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
D	0.12557	0.45021E-01	35.85	0.62793E-01	0.25109
N	223.00	79.956	35.85	112.00	446.00

Measurement Units

Density: Numbers/Sq. kilometres
ESW: meters

Component Percentages of Var(D)

Detection probability : 7.4
Encounter rate : 87.0
Dung Disap time : 3.8

Dung Prod rate : 1.8

Estimation Summary - Encounter rates

	Estimate	%CV	df	95% Confidence Interval	
n	80.000				
k	57.000				
L	56.520				
n/L	1.4154	33.44	56.00	0.73730	2.7172
Left	0.0000				
Width	8.0000				

Estimation Summary - Detection probability

	Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine					
m	1.0000				
LnL	-196.31				
AIC	394.61				
AICc	394.67				
BIC	397.00				
Chi-p	0.81518				
f(0)	0.20284	9.75	79.00	0.16715	0.24616
p	0.61624	9.75	79.00	0.50780	0.74785
ESW	4.9299	9.75	79.00	4.0624	5.9828

Estimation Summary – Density &Abundance

	Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine					
D	0.12557	35.85	73.65	0.62793E-01	0.25109
N	223.00	35.85	73.65	112.00	446.00

Bootstrap Summary- encounter rate

	Estimate	%CV	#	df	95% Confidence Interval	
Half-normal/Cosine						
n/L	1.4311	31.27	999	56.00	0.77620	2.6387
					0.70175	2.3860

Bootstrap Summary- Detection probability

	Estimate	%CV	#	df	95% Confidence Interval	
Half-normal/Cosine						
f(0)	0.22178	15.67	999	79.00	0.16266	0.30238
					0.16337	0.29366

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

Bootstrap Summary- Density &Abundance

```
                 Estimate    %CV   #    df     95% Confidence Interval
                ------------------------------------------------------
 Half-normal/Cosine
           D     0.14092     38.84  999    73.65 0.66771E-01   0.29739
                                                0.55724E-01   0.26225
 Half-normal/Cosine
           N      250.55     38.84  999    73.65  119.00        529.00
                                   99.000       466.00
```

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 : RESULTS OF DUNG DECAY RATE ESTIMATION BY GENSTAT

GenStat Release 7.22 DE (PC/Windows) 03 June 2010 11:05:54
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GenStat Discovery Edition 3
GenStat Procedure Library Release PL15.2

```
  1  %CD 'F:/'
  2  "Data taken from File: \
 -3  C:/Users/uicn/Desktop/Cote D'ivoire/Tai NP Survey/Tai survey data analyses/Tai Dung_Decay DATABASE.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\Cote D'ivoire\Tai NP Survey\Tai survey data analyses\Tai Dung_Decay DATABASE.xls
on: 3-Jun-2010 11:10:39

taken from sheet ""Taidungdecaydat"", cells C2:D87

```
  11  DELETE [redefine=yes] DAYS,STATE
  12  UNITS [NVALUES=*]
  13  VARIATE [nvalues=86] DAYS
  14  READ DAYS
    Identifier   Minimum      Mean   Maximum    Values   Missing
         DAYS     38.00     96.53     145.0        86         0

  20  VARIATE [nvalues=86] STATE
  21  READ STATE

   Identifier   Minimum      Mean   Maximum    Values   Missing
        STATE    0.0000    0.2326     1.000        86         0    Skew

  25
  26  "   Calculates mean decay time & s.e & c.v for retrospective dung/nest decay survey
data."
  27  "   Data should consist of two variables:   DAYS  = age in days"
  28  "                                           STATE = 0 if decayed, = 1 otherwise"
  29  "   First read in data from spreadsheet (or otherwise) and then execute the following
commands."
  30  "   To do this, do ctrl-W to submit the commands in this window."
  31  "   Fit logistic regression model to STATE on DAYS"
  32  MODEL [DISTRIBUTION=binomial; LINK=logit; DISPERSION=1] STATE;
NBINOMIAL=1
  33  FIT [PRINT=model,summary,esti; FPROB=yes; TPROB=yes] DAYS

33...............................................................................
```

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

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

*** Summary of analysis ***

	d.f.	deviance	mean deviance	deviance ratio	approx chi pr
Regression	1	63.82	63.8160	63.82	<.001
Residual	84	29.47	0.3508		
Total	85	93.28	1.0975		

* 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 0.43
        are consistently larger  than observed values
        and fitted values in the range 0.90 to 0.91
        are consistently smaller than observed values
* MESSAGE: The error variance does not appear to be constant:
        large responses are more variable than small responses
* MESSAGE: The following units have high leverage:
      Unit     Response    Leverage
        58        0.00       0.064
        59        0.00       0.064
        60        0.00       0.064
        61        0.00       0.064
        62        0.00       0.060
        63        1.00       0.060
        64        0.00       0.060
        65        0.00       0.060
        66        1.00       0.060
        67        1.00       0.060
        68        1.00       0.060
        69        1.00       0.060
        70        1.00       0.060


*** Estimates of parameters ***

                                           antilog of
              estimate        s.e.     t(*)  t pr.   estimate
Constant            6.71        2.00      3.35  <.001      821.4
DAYS             -0.1162      0.0353     -3.29  0.001     0.8903
* MESSAGE: s.e.s are based on dispersion parameter with value 1
```

```

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

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

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

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

mean_decay	se_mean	cv_mean
57.8278	4.0519	0.0701

The mean decay rate per day=0.01729