Comparison of two dung count methods for estimating elephant numbers at Kakum Conservation Area in southern Ghana

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Abstract

The efficiency of meandering transects—in terms of accuracy, precision and effort required for estimating elephant abundance—was evaluated in the Kakum Conservation Area in Ghana. Four consecutive elephant dung surveys were carried out between February 2000 and February 2002 using meandering transects. The resulting dung density estimates were adjusted by applying a correction factor calculated from matched pairs of meandering transects and standard line transects. The meandering transects required less effort and took 40% less time than line transects and were preferred by the park's staff, but these gains must be balanced against the loss in precision. Elephant densities were estimated from the dung densities with a rainfall model. Empirical and analytical methods were compared for estimating the precision of the elephant estimate. The analytical method returned a more precise estimate for the merged estimate, which was 161 elephants (95% CI from 104 to 249). A genetic survey of the same population by Eggert et al. (2003) using the accumulation method gave a similar estimate of 170 elephants (95% CI from 96 to 270).

Résumé

L'efficacité des transects en serpentin a été évaluée dans la Région de Conservation de Kakum au Ghana pour estimer l'abondance des éléphants en termes d'exactitude, de précision et de l'effort exigé. Quatre études consécutives d'excréments des éléphants ont été réalisées entre février 2000 et février 2002 en utilisant le transect en serpentin. Les estimations résultant de la densité des excréments ont été ajustées en appliquant un facteur de correction calculé à partir des paires de transects en serpentin et des transects linéaires standards. Les transects en serpentin exigeaient moins d'effort et prenaient 40% moins de temps que les transects linéaires et le personnel du parc les préféraient, mais ces gains doivent être équilibrés contre la perte en la précision. On a estimé les densités des éléphants par le biais des densités des excréments avec un modèle des pluies. Les méthodes empiriques et les méthodes analytiques ont été comparées pour estimer la précision de l'estimation des éléphants. La méthode analytique a donné une estimation plus précise pour l'estimation fusionnée qui était de 161 éléphants (95% CI de 104 à 249). Une étude génétique de la même population par Eggert et al. (2003) en utilisant la méthode d'accumulation a donné une estimation semblable de 170 éléphants (95% CI de 96 à 270).

Introduction

Dung surveys are the most commonly used method for evaluating elephant abundance and distribution in West African forests. Dung counts have been shown to give estimates that are as accurate as, and often more precise than, other methods used to count elephants (Barnes 2001, 2002). However, dung counts are expensive in terms of time and man-power and a survey of even a small forest of about 400 km^2 may take longer than a month. In addition, the work is boring and often uncomfortable for the junior staff. Frequent surveys, whether constant monitoring of the same forest or surveys of a series of forests, cause junior staff to lose interest and it then becomes difficult to find enough people to make up the survey teams. The research programme in the Kakum Conservation Area (KCA) intended to undertake regular monitoring activities throughout the forest in order to compare elephant distribution with changes in environmental variables such as fruiting trees and water availability. We therefore needed a method of counting dung-piles that would give estimates of elephant abundance that were both accurate and precise as well as distribution without demoralizing the park staff.

Poaching for small game (antelopes or monkeys) was a major problem in KCA. There was a concern that frequent standard transects would give easy access for poachers into the depths of the forest and provide paths along which they could stalk antelopes and monkeys. Therefore, instead of cutting standard transects, we decided to evaluate the use of a type of informal transect which we called meandering transects. These were a modification of Walsh and White's (1999) 'recce transects'. Meandering transects required minimum cutting and or allowed the survey team to move faster than on line transects and that would not facilitate poaching. Meandering and line transects were then compared. A correction was applied to meandering transects to make their estimates equivalent to those from standard line transects.

However, the correction factor has a variance, and we worried that, when combined with the variance from the meandering estimate, the final estimate of elephant abundance would be less precise than a standard dung count using line transects. In this paper we evaluate the meandering method, discuss the trade-offs and compare its estimate with those by Eggert et al. (2003) that were based on the number of unique genotypes obtained from DNA extracted from elephant dung.

Study area

The Kakum National Park and the adjacent Assin-Attandaso Resource Reserve are remnants of the fragmented Upper Guinean forest block and have been described by Dudley et al. (1992). The two forests were logged until 1989 when they were declared a wildlife reserve. The forest in the National Park was described to be in 'good' condition while that in the Resource Reserve was 'slightly degraded' (Hawthone and Musah 1993). Both forests are now managed as one unit, the KCA, which covers 366 km^2 and lies between latitudes 5°20' and 5°40' N and longitudes 1°15' and 1°30' W in the moist evergreen zone defined by Hall and Swaine (1981). The mean annual rainfall during the 1990s was 1223 mm, with peaks in May–July and October–November.

Elephants were once widespread but were gradually restricted to the Kakum forest as the intensity of human disturbance increased during the 20th century (Barnes et al. 1995). KCA is now completely isolated and lies in the midst of cultivated fields, farm bush and secondary vegetation (Barnes et al. 2003). Elephants use all parts of the KCA.

Materials and methods

Surveys with meandering transects

Four elephant dung surveys were undertaken between 2000 and 2002 using meandering transects that were randomly distributed. All transects in the four surveys were aligned perpendicularly to the major streams. On the meandering transects, the team moved on a compass bearing in a more or less straight line, passing between trees and shrubs, but without using paths and game trails, and always returned to the track-line shown by a GPS device.

The perpendicular distance of each dung-pile (Buckland et al. 1993, 2001) was measured from the transect center line, which was defined as the toe of the navigator's boot. Each dung-pile was placed in the morphological category described by Barnes and Jensen (1987). The survey team of four, led by a compass man and a line cutter, was maintained throughout to ensure consistency. DISTANCE software (Buckland et al. 1993, 2001) was used to estimate dung densities. Thus meandering transects differed from Walsh and White's (1999) 'recce transects' in deviating less from the prescribed bearing, in not following paths or animal tracks, and in measuring the perpendicular distance.

The first two surveys, in the dry (February) and wet (October) seasons of 2000 were based on 25 randomly distributed transects. Each transect was 1.84 km in length, except for one of 1.43 km. Distance along transects was measured with a Keson Roadrunner that had been calibrated in the forest with a topofil or hip chain (a more accurate measurer of distance) to obtain the following conversion factor: each km measured by the Roadrunner was equivalent to 0.92 km by the topofil.

The 2001 and 2002 surveys were arranged differently to allow simultaneous bongo and elephant surveys, with the study area divided into three strata (Boafo 2004). The number of transects was reduced because resources were limited. The data from the first survey (in February 2000) showed that 20 transects gave a reasonable level of precision (CV < 30%), and so the transects were randomly distributed in the proportion of 8:7:5 in the high-, medium- and low-density strata respectively. Each transect was 1.84 km in length except for two that were 1.71 km and 1.47 km.

Comparison of meandering and line transects pairs

Thirty matched pairs of meandering and line transects were randomly distributed in KCA. The purpose was to compare the estimate from each meandering transect with the estimate from its matched line transect. Each transect type was 0.92 km in length. For each pair, the team first walked along a meandering transect. The team then shifted 100 m either to the left or right and then cut a dead straight line transect parallel to the meandering transect. Elephant dung-pile data were collected in the same manner on both. The density of dung-piles from the 30 meandering transects was calculated with DISTANCE. Similarly, the density of dung-piles from the 30 line transects was also calculated.

Bootstrap procedure to correct survey transects

For each survey, the corrected estimate, D, of dung-pile density was calculated by:

$$D = a \times (b/c) \qquad \text{eq. (1)}$$

where a was the dung density estimated from that survey's meandering transects; b was the dung density calculated from the 30 paired line transects; and c was the dung density calculated from the 30 paired meandering transects. The ratio b/c is therefore the correction factor, and D is the estimate of dung-pile density from meandering transects that has been corrected to make it equivalent to an estimate from standard line transects.

The variance of the estimate of D was estimated by bootstrapping (Efron and Tibshirani 1993). Values of a were randomly generated from its mean and variance, and then multiplied or divided by similarly generated values of b and c. This was repeated 1000 times to give 1000 corrected estimates (D) for each survey. Because each estimate comes from the product of two numbers, the estimates will not be normally distributed.

Calculation of elephant densities

A rainfall model based on data from KCA was developed by Barnes et al. (1997) and Barnes and Dunn (2003) to calculate elephant densities from dung counts in West African forests when data on dung decay rates are not available. A model that relates dung density (Y_t) to rainfall two months preceding a survey (Barnes et al. 1997), was bootstrapped with rainfall figures to obtain 1000 independent estimates for a particular survey season.

$$Y_t = 1020.24 - 0.79RAIN_{t-1} - 0.46RAIN_{t-2} \qquad \text{eq. (2)}$$

where Y_t was the dung-pile density if there was one elephant per sq. km and $RAIN_{t-1}$ and $RAIN_{t-2}$ were respectively the total rainfall (mm) in the first and second months preceding the month of the survey. Rainfall data were obtained from six rain gauges installed around the study site.

Since D was the estimated (corrected) dung-pile density in the forest, and Y_t was the dung-pile density expected from an elephant density of one per sq. km, then the elephant density E for the study area is estimated by:

$$E = D / Y_t \qquad \text{eq. (3)}$$

One thousand independent estimates of D were generated from the corrected dung-pile density estimate and its variance. One of those estimates was selected at random and multiplied with a value of $1/Y_t$ randomly selected from the results of the bootstrap above. This gave an estimate of E (eq. 3). This procedure was then repeated 1000 times to give 1000 independent estimates of E.

Table 1. Estimates of uncorrected dung-pile densities

	2000 Dry season	2000 Wet season	2001 Wet season	2002 Dry season
Total transect length (km)	45.59	45.59	36.03	36.03
Max. strip width (m)	10	11	8	7
No. of dung-piles	240	148	180	58
Encounter rate (dung-piles.km^{-1})	5.28	3.25	5.0	1.61
Fitted model	Hazard (+ cosine adj)	Fourier	Fourier	Fourier
Estimated dung density km^{-2} (Y)	592.54	552.71	481.86	331.51
SE(Y)	115.01	118.68	110.15	91.33
%CV(Y)	9.41	21.47	22.86	27.55

Two methods—empirical and analytical—were used to calculate elephant density and its confidence limits from the 1000 independent estimates of *E*. For the empirical method, we ranked the 1000 independent estimates of E for each survey. The median and the 2.5% and 97.5% percentiles were taken as the estimates of elephant density and lower and upper 95% confidence limits respectively (Efron and Tibshirani 1993).

In order to merge the estimates from several surveys to obtain a combined estimate, the 1000 estimates from each survey were pooled. They were then ranked and the median, 2.5% and 97.5% percentiles gave the estimate and confidence limits. The number of elephants was obtained by multiplying the median density by the area of KCA.

For the analytical method, we assumed that the 1000 density values for each survey follow a log-normal distribution. Since the log of the smaller density values would give negative numbers, we converted them to population estimates by multiplying by the area of KCA. Each value was then logged. The mean, variance and confidence limits of elephant numbers were calculated for each survey. These logged values were then back-transformed by taking the antilog to give the estimate of elephant numbers and its CLs.

To obtain a combined estimate from several surveys by the analytical method, the estimates from each survey were merged (Norton-Griffiths 1978) before back-transforming.

Results

The estimates of dung-pile densities from the four meandering transect surveys are shown in Table 1. The encounter rate during the 2002 dry season was less than half the rate of the other three surveys (Table 1). The four surveys differed in the numbers of dung-piles seen per transect (the Kruskal-Wallis one-way analysis of variance by ranks $H = 12.34$, $p < 0.01$). However, there was no difference between the 2000 DS, 2000 WS and 2001 WS surveys ($H = 3.54$, NS). These three, when combined, differed significantly from the 2002 DS survey (the Mann-Whitney test, $z = 2.98$, $p < 0.01$). Non-parametric tests were used for these comparisons because the number of dung-piles per transect was not normally distributed.

When the 30 matched meandering and line transects are compared, more dung-piles were spotted on the meandering transects (Table 2), (the Wilcoxon matched-pairs signed ranks test, $T = 2.4$, $N = 30$, $P < 0.05$). In addition, the effective strip width was narrower on the meandering transects (3.57 ms and 4.05 m respectively for the meandering and line transects). Thus the meandering transects gave a biased estimate of dung-pile density that was 54% greater than that of the line

Table 2. Comparison of dung-pile estimates from 30 paired meandering and line transects

	Meandering	Line
Total transect length (km)	27.6	27.6
Max. strip width (m)	7	8
No. of dung-piles	150	113
Encounter rate (dung-piles.km^{-1})	5.43	4.09
Fitted model	Half-normal (+ hermite adj)	Hazard rate (+ cosine adj)
Estimated dung density.km^{-2} (Y)	750.32	487.54
SE(Y)	141.42	109.1
%CV(Y)	18.85	22.38

transects (Table 2). The corrected dung-pile estimates from the four surveys using meandering transects are shown in Table 3, and the estimated elephant numbers in Table 4.

The median times for cutting meandering and line transects were 1.25 hrs and 1.98 hrs respectively (the Wilcoxon matched-pairs signed ranks test, T=4.30, N=29, $P < 0.0001$).

The corrected estimates of elephant numbers from the three surveys in 2000 and 2001 were similar (Table 4), while those of the 2002 survey were considerably lower. There was a significant difference between the frequency distributions of the elephant densities of the three combined 2000 and 2001 surveys on the one hand and the 2002 survey on the other (the Kolmogorov-Smirnov two-sample test, $D_{max} = 0.34, n_1 = 3000, n_2 = 1000, P < 0.05$). Therefore the three 2000 and 2001 estimates were combined to give an estimate with greater precision (Norton-Griffiths 1978).

The distribution of merged elephant densities from the three surveys in 2000 and 2001 is shown in Figure 1. The median value from Figure 1 gave an empirical estimate of 161 elephants with a 95% confidence interval from 75 to 350. The analytical method gave a more precise estimate, which was 161 elephants with a 95% confidence interval from 104 to 249.

Discussion

Meandering transects returned a biased estimate of dung-pile density that would have given an overestimate of elephant numbers assuming that the standard line transect method provides the most accurate estimate one is likely to obtain from dung counts. But meandering transects required less than two thirds the time needed for line transects and were physically much less demanding. The CV was reasonable—about 20% for the surveys based on 25 transects—and could have been improved by adding further transects. However, correcting the estimates improved the accuracy while greatly reducing the precision, with CVs higher than 35% (Table 3).

Table 3. Corrected dung-pile densities (dung-piles. km^{-2}) and their standard errors

	2000	2000	2001	2002
Density (D)	400.36	378.61	326.21	222.84
SE(D)	148.45	152.13	129.95	95.17
%CV(D)	37.08	40.18	37.08	42.71

Table 4. Estimated elephant numbers and their confidence limits in 2000, 2001 and 2002, including the merged estimate of the three 2000 and 2001 surveys

	Empirical Estimates		Analytical Estimates	
	Median	Confidence Interval	Mean	Confidence Interval
2000 Dry	159	72–317	156	76–321
2000 Wet	153	73–328	154	72–332
2001 Wet	170	81–398	173	78–386
Merged	161	75–350	161	104–249
2002 Dry	84	39–187	85	38–187

For the park manager, the choice is to conduct monitoring surveys with standard straight line transects that are unpopular with the staff but that return estimates that are both accurate and precise, or to adopt meandering transects that can be corrected to give accurate estimates but that are less precise. The less precise method will make it more difficult to detect trends in the Kakum elephant population (Barnes 2002). However, it may be better to adopt the easier field method that gives the less precise estimate and use it frequently rather than the precise method that the staff find too onerous. The staff will also be more willing to use meandering transects for other types of ecological monitoring within the KCA.

The analytical method gave a narrower confidence interval than the empirical method for the merged estimate (Table 4). The retrospective dung decay method described by Laing et al. (2003) will give the best estimates of elephant numbers in forests. In southern Ghana the rainfall model can be used for cases where no dung decay observations were made and rainfall records are available, since the model was developed in the Ghanaian forests (Barnes et al. 1997). In such cases, the analytical method of processing the output from the model will give the most precise estimates when a series of survey outputs are merged.

The 2002 survey returned an estimate that was significantly different from the others. Elephants cannot move elsewhere because KCA is a closed forest. There is less crop raiding during the dry season, so elephants were not in the fields for significant periods. However, shortly before that survey five elephants had been shot in the area where there was a concentration of fruiting trees like *Parinari excelsa* and *Tieghmella hecklii* that attracted many elephants

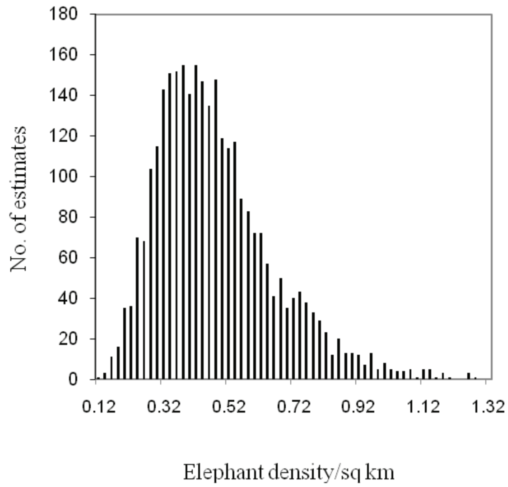

Figure 1. Frequency distribution of 3000 independent estimates of elephant densities comprising 1000 estimates each from the 2000 dry, 2000 wet and 2001 wet season surveys at Kakum Conservation Area.

Table 5. Comparison of elephant estimates from the DNA survey and from dung counts in the present study.

Method	Source	Population estimate	Confidence interval
DNA: Accumulation curve (E_{exp})	Eggert et al. (2003)	170	96–270
DNA: Mark-recapture	Eggert et al. (2003)	225	173–308
Dung counts: merged estimates from 3 surveys in 2000 and 2001	This study	161	104–249
Dung count: 2002 dry season	This study	85	38–187

in the 2000 dry season. The number of dung-piles seen per km of transect at that site in the 2000 dry season was 11.8 compared with 1.09 in 2002. It seems that elephants were avoiding that area in 2002 but in theory they should have been recorded in other transects. A problem with randomly distributed transects, such as these, is that there may be large spaces that are not sampled, and possibly the displaced elephants were using those areas. The probability of missing animals in this way can be avoided by placing more transects and by having a systematic transect design that provides even coverage (Buckland et al. 2001; Hedges and Lawson 2006).

Eggert et al. (2003) used genotyping of DNA from KCA dung samples to estimate the size of the elephant population. With simulated data sets, they showed that two analysis methods gave accurate estimates: i.e. accumulation curve (E_{exp}) and mark-recapture. However, when applied to their field data, the methods gave different results (Table 5). The estimate from the three merged surveys reported here for KCA is close to the E_{exp} estimate.

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