Elephant survey in the Bia Conservation Area, western Ghana

Moses Kofi Sam,[1] Emmanuel Danquah,[2] Samuel K Oppong,[2] Ebenezer Daryl Bosu[3]

[1] Resource Management Support Centre, Forestry Commission, PO Box 1457, Kumasi, Ghana; email: osmo288@yahoo.co.uk
[2] Faculty of Renewable Natural Resources, College of Agriculture and Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana; email: ekadanquah@yahoo.com; edanquah.irnr@knust.edu.gh; kobbyoppong@yahoo.com
[3] A Rocha Ghana, PO Box 3480, Kaneshie, Accra, Ghana; email: darylbosu@yahoo.com

Abstract

In February 2004, a dry-season elephant survey was conducted in the Bia Conservation Area in Western Region of Ghana to determine the distribution and abundance of elephants and the human and ecological variables that affect them. Fifty-two 1-kilometre transects were systematically distributed in three strata (high, medium and low density) based on elephant dung-pile density recorded in an initial reconnaissance. Two estimation models were used to estimate elephant numbers: a rainfall model gave an estimate of 115 (95% CI = [90, 148]) elephants while a steady-state assumption model provided 146 (95% CI = [107, 185]) elephants. Water availability explained a high proportion of the variance in elephant distribution and illegal activity. Other variables assessed, including raphia stand, secondary vegetation, gap length and fruiting trees, did not account significantly for the distribution of elephants.

Résumé

En février 2004, en saison sèche, on a réalisé une étude des éléphants dans l'Aire de Conservation de Bia, dans la Région occidentale du Ghana, pour déterminer la distribution et l'abondance des éléphants ainsi que les variables humaines et écologiques qui les affectent. Cinquante-deux transects d'un km de côté ont été déterminés systématiquement dans trois strates (haute, moyenne et basse) basées sur la densité de crottes d'éléphant relevée lors d'une reconnaissance préalable. Deux modèles d'estimation ont été utilisés pour évaluer le nombre d'éléphants : un modèle « chute de pluie » qui a donné une évaluation de 115 éléphants (IC 95% = [90, 148]), alors qu'un modèle « stationnaire » donnait 146 éléphants (IC 95% = [107, 185]). La disponibilité en eau expliquait en grande partie la variance de la distribution des éléphants et les activités illégales. D'autres variables évaluées, comme la présence de palmier raphia, de végétation secondaire, la longeur de le'space et les arbres en fruits, ne comptent pas significativement dans la distribution des éléphants.

Introduction

Around the turn of the 20th century, elephants were still widely distributed over the Upper Guinea forest zone and were little affected by human settlement (Roth and Douglas-Hamilton 1991) until the 1950s, when intensive development started. Currently, elephants in West Africa are fragmented into 84 separate populations, many of which are small and threatened (Blanc et al. 2003). Twelve of these can be found in Ghana, five of them, including the important Bia population, are forest populations.

The African Elephant Specialist Group through its Small Grants Programme funded by the European Union supported a preliminary investigation into the possibilities of linking this population to others in the Guinean rainforests of western Ghana. This paper is about two of the objectives of the extended study: 1) to determine the distribution and numbers of elephants in the Bia Conservation Area and 2) to investigate the relationship between elephant density and different levels of human activity and ecological factors.

The study also provided an opportunity to test and compare elephant population size estimates derived from two estimation models, a steady-state assumption model (McClanahan 1986), and a rainfall model (Barnes et al. 1997; Barnes and Dunn 2002). The number of elephant dung piles lying on the forest floor is determined by the number of elephants present and the rainfall in the two preceding months (Barnes and Dunn 2002). Hence, the rainfall model uses rainfall data from previous months to estimate the numbers of dung piles that are likely to be on the ground when a survey is conducted and makes no such assumptions as steady states or normality. The steady-state assumption model on the other hand assumes steady state in the forest, such as a steady rate of dung decay. However, because rainfall varies from month to month, and in any one month is unevenly distributed across days, the steady-state assumption is often invalid (Barnes et al. 1997). Because of its appreciable elephant numbers the Bia Conservation Area (BCA) provides the opportunity to test and compare the two estimation techniques (Heffernan and Graham 1999; Sam 2000).

Study area

Located in western Ghana, the Bia Conservation Area (BCA), comprises Bia National Park (Bia NP) in the north and the adjacent Bia Resource Reserve (Bia RR) in the south (fig. 1). Both forests cover an area of 306 km^2 and were managed as a national park before their present classification. In early 1976, pressure from the timber industry compelled the government to downgrade part of the park into a resource reserve to allow controlled logging (PADP 2001). Logging was however stopped in 1997 and both forests classified as the BCA for ecosystem protection, research and recreation.

The BCA was originally part of a larger forest ecosystem for forest elephants known as the Bia Group of Forest Reserves, about 1500 km^2, most of which are non-existent. The Bia elephant range has contracted due to clearance for cocoa cultivation and is now an isolated population on an ecological island of forest with hard boundaries and no transitional zone to farmland (PADP 2001).

The vegetation comprises mainly *Celtis zenkeri* and *Triplochiton scleroxylon* moist semi-deciduous forest, which is transitional towards the more typical rainforest association of *Lophira alata* and *Triplochiton scleroxylon* found in the southern part of Bia RR (Taylor 1960; Hall and Swaine 1976). Rainfall is bimodal, peaking in June and October.

Methods

Reconnaissance survey

In a reconnaissance exercise undertaken in February 2004, the study area was divided into blocks and each block thoroughly searched for elephant dung using meandering transects in a predetermined compass bearing. The idea was to limit excessive cutting of vegetation, which would have had to be done had straight transects been used. Meandering transects also enabled teams to cover much of the forest within a short time.

Based on the dung-density estimates from the reconnaissance survey, the study area was divided into three strata of population density: high, medium and low (fig. 1). The southern half of Bia RR was designated high density; the remaining northern half of Bia RR, medium density; and the whole of Bia NP where no elephant activity was found, low density.

Main survey

The standard line transect method (Barnes 1996a; Buckland et al. 2001) was employed for counting dung piles (Barnes and Jensen 1987) within the study area in February–March 2004.

A grid consisting of squares, each one minute of latitude and longitude, was superimposed on the map of the study area. An initial square was randomly selected and an additional 51 squares were then systematically selected relative to it within the three strata according to the relative dung density found during the reconnaissance (Norton-Griffiths 1978). One-kilometre transects were placed in the middle of the selected grids and oriented northwards as a rule of thumb because of the unavailability of major streams within BCA. Thus 30 transects were distributed in the high-density stratum, 15 in the medium, and 7 in the low.

The perpendicular distance of the dung piles seen on transects was measured from the transect centre line using a tape measure. The distance along transects was measured with a hip chain. Age of dung was gauged using the criteria of Barnes and Jensen (1987).

Two survey teams of four persons each, led by a compass man (team leader) and a line cutter, were maintained throughout the counts to ensure consistency.

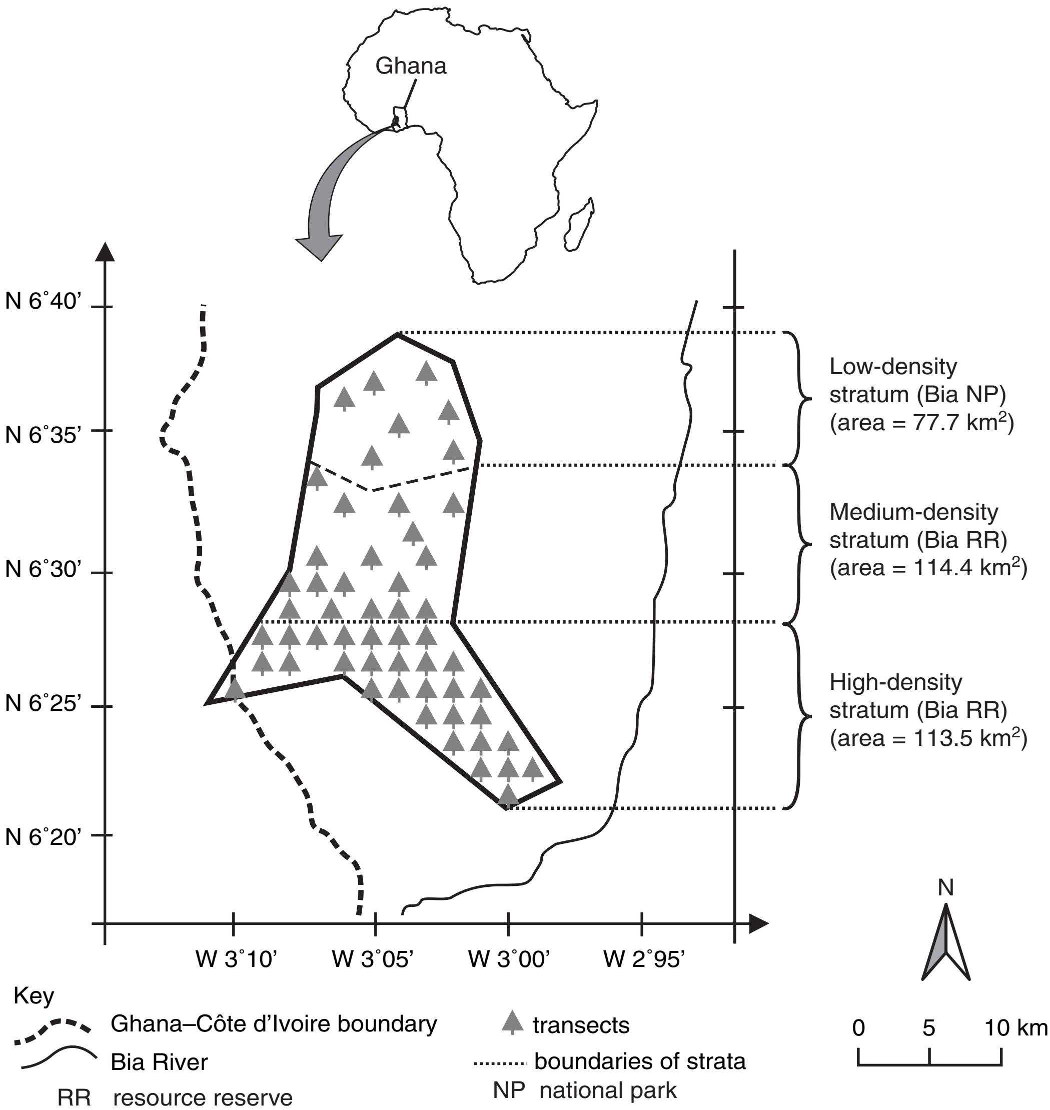

Figure 1. Bia Conservation Area showing transect distribution in the various strata.

Analysis

STEADY-STATE ASSUMPTION MODEL

Assuming a steady state in the forest, the density of elephants (E) can be calculated from three variables (McClanahan 1986; Barnes and Jensen 1987):

$$E = Yr / D \tag{1}$$

where Y is the density of dung piles, r is the decay rate and D is the defecation rate.

However, each of the variables (Y, r, D) is an estimate with its own variance, which will contribute to the variance of E (Barnes 1993):

$$\mathrm{var}\,(E) = \mathrm{var}\,(D) \times [(Yr)^2 / D^4] + [\mathrm{var}\,(Yr) / D^2] \tag{2}$$

where

$$\mathrm{var}\,(Yr) = \mathrm{var}\,(Y) \cdot \mathrm{var}\,(r) + Y^2 \cdot \mathrm{var}\,(r) + r^2 \cdot \mathrm{var}\,(Y) \tag{3}$$

The value of the decay rate, r, of elephant dung in the dry season was obtained from Barnes et al. (1994).

No estimate of defecation rate has been done in BCA; therefore Tchamba's (1992) defecation-rate estimate from Cameroon (*D*) was used. The value of dung-pile density, *Y*, was calculated using the DISTANCE program (Laake et al. 1993).

RAINFALL MODEL

Data on rainfall two months prior to the main line-transect dung survey was collected from four rain gauges mounted around BCA and the mean total rainfall value was calculated for each month. A model that relates dung density (Y_t) to rainfall two months preceding the survey was used to estimate density (Barnes et al. 1997). Thus,

$$Y_t = 1020.24 - 0.79RAIN_{t-1} - 0.46RAIN_{t-2} \quad (4)$$

where Y_t is dung density if there is one elephant per square kilometre and $RAIN_{t-1}$ is the total rainfall (mm) in the first month preceding the month of the survey and $RAIN_{t-2}$ rainfall preceding the second (Barnes and Dunn 2002).

Elephant density (*E*) is represented by

$$E = Y / Y_t \quad (5)$$

where *Y* is dung density from the survey.

The above analyses were done separately for each stratum, after which the separate estimates were merged (Norton-Griffiths 1978).

Factors affecting elephant distribution

On all transects, 10 sampling points were noted, each at every 100-m mark. When the observer arrived at the designated sample point, a GPS fix of the point was taken. The vegetation type (including secondary forest, raphia palm stand, riparian vegetation and other vegetation types, which would then be specified) was noted. Also the canopy condition (presence of gaps in the canopy, length of gaps traversed by transect) was recorded.

Any human-built infrastructure or illegal human signs such as wire snares, empty cartridge cases, poaching camps, cane and wood cuttings encountered on the transects were also recorded. Other human influence such as the construction of trails or points associated with loading or hauling timber products was recorded as logging roads. All fruiting trees and water sources such as streams, rivers, ponds and swamps without raphia palm (may be dry as survey was conducted in the dry season) were also noted.

Regression analyses were used to investigate relationships between dung density and all human and geographical or other natural variables.

Results

Estimate of elephant numbers in the study area

A total of 210 dung piles was spotted: 183 in the high density (6.1 piles per km), 27 in the medium density (1.8 piles per km) and none in the low-density strata. Dung density was significantly higher in the high-density than in the medium-density strata (Mann-Whitney U test: $U = 41.5$, $p < 0.05$). The high-density stratum had a higher density of dung piles, and as expected gave a higher variance (suggesting a highly clumped elephant distribution) than the medium-density stratum (table 1). Using the rainfall model, the estimated number of elephants was 115 (90, 148 at 95% confidence level); with the steady-state assumption model the estimate was 146 (107, 185 at 95% confidence level). The rainfall model gives asymmetrical confidence limits (CLs).

Factors affecting elephant distribution

Most elephant activities were concentrated at the south and south-eastern sections of Bia RR and thinly

Table 1. Estimates of dung density per stratum in the Bia Conservation Area

Stratum	Area (km^2)	Dung-pile density (*Y*)*	Variance*	Number of transects
Low-density	77.7	0	0	7
Medium-density	114.4	305.28	7650	15
High-density	113.5	758.61	10562	30

* Hazard rate model

spread northwards through the central portions with no elephant activity in Bia NP.

Figure 2 indicates that elephant distribution was clumped and significantly influenced ($r^2 = 0.759$, $p < 0.05$) by the number of water sources (ponds and dams).

Elephants were reported hunted but the team could not ascertain the intensity. At Adjuofia, a community in north-eastern Bia NP, for instance, an elephant was reportedly killed less than three months into the study. Yet there was no direct correlation between illegal activity and elephant distribution ($r^2 = 0.413$, NS).

However, there is a threshold dung-pile density (approximately 5 dung piles per km) that affects illegal activity; no illegal activity was found beyond this threshold (fig. 3).

Similarly, no illegal activity was recorded on transects with more than approximately five water sources per kilometre (fig. 4).

Other variables assessed: raphia stand ($r^2 = 0.005$), secondary vegetation ($r^2 = 0.249$), gap length ($r^2 = 0.079$), and fruiting trees per kilometre ($r^2 = 0.009$) did not account significantly to the distribution of elephants.

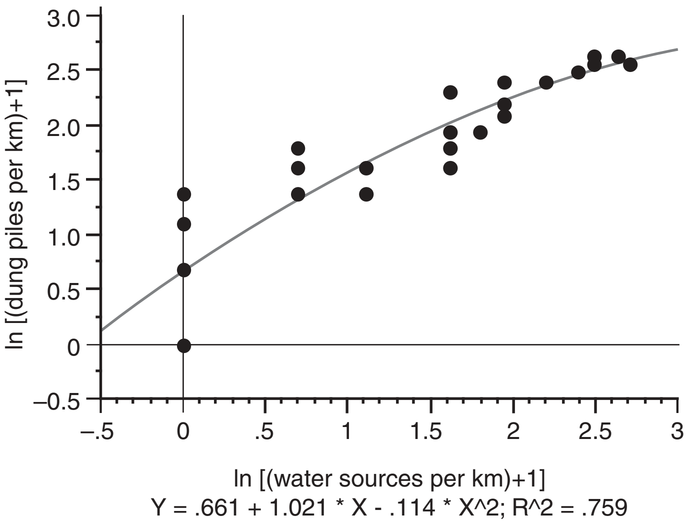

Figure 2. Relationship between water sources and dung-pile density.

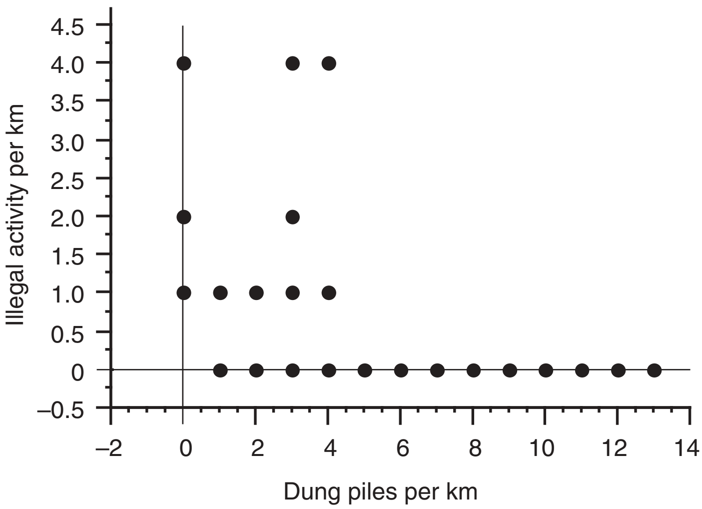

Figure 3. Scatterplot of illegal activity against dung piles per kilometre.

Discussion

Estimate of elephant numbers in the study area

Dung counts relate elephant numbers to a count of dung piles detected along line transects, corrected for variables such as rainfall in the two months before the count, rate of deposition of dung piles, and rate of dung decay (Barnes et al. 1997; Barnes and Dunn 2002). The last factor is usually the most problematic (Laing et al. 2003), and many elephant surveyors have relied on data from other sites. A new alternative approach, referred to as the retrospective model (Laing et al. 2003), employs a more advantageous approach by estimating the mean time to decay of dung piles already present at the time of the survey. We could not use this method because it requires an added dung decay rate experiment, which is not feasible for relatively short-duration investigations like ours. Incidentally, the rainfall model also employs a retrospective approach—that is, it uses the rainfall data from previous months to estimate the numbers of dung piles that are likely to be on the ground when a survey is conducted while making no such assumptions as the steady states or normality. It is more accurate than the steady-state method, which employs a 'prospective' decay rate for analysing data on dung count and hence does not estimate the mean time to decay of dung piles that are present at the time of the

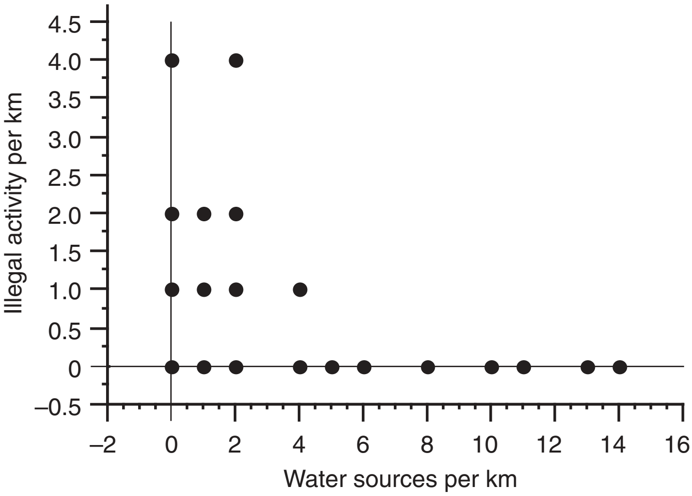

Figure 4. Scatterplot of illegal activity in relation to water sources per kilometre.

survey (Laing et al. 2003). Also, rainfall varies from month to month, and in any one month it is unevenly distributed across days. Thus the steady-state assumption is often invalid (Barnes et al. 1997). This is supported by the fact that the estimate provided by the steady-state assumption model was not conservative but rather higher (21%) than that given by the rainfall model. Conservative estimates of population sizes may be better than overestimates, especially if managers are faced with potentially damaging decisions, such as whether or not they should reduce the size of a population through culling (Eggert et al. 2003). We thus estimate the average density of elephants at BCA at 0.38 per km^2, based on the rainfall model.

In an earlier study based on track identification, Sikes (1975) estimated 52 to 82 elephants in BCA, giving a density of 0.25 per km^2. Martin (1982) followed with an estimate of between 200 to 250 for the Bia forest area, which was previously 1500 km^2 and included BCA, but currently is totally degraded leaving only BCA intact and with elephants. Based on his elephant densities, he provided an estimate of between 89 and 113 elephants (0.29–0.37 per km^2) for BCA. This compared well with an estimated density of 0.33 per sq km (40 to 135 elephants) by Short (1983). More recently, Heffernan and Graham (1999) estimated 138 elephants, comparable to the estimate of 127 elephants provided by Sam (2000) with densities of 0.45 and 0.42 per km^2, respectively. Our present 2004 estimate of 115 elephants (0.38 ele-phants per km^2) also lies well within the CLs of the preceding two estimates, suggesting no evidence for any significant change between the years 2000 and 2004. The estimates up to 2000 suggest an increasing elephant density within BCA over the last quarter century. At the same time, the Bia elephant range has shrunk to about one-fourth of its original size (from 1500 km^2 to 366 km^2), partly as a result of the Sukusuku Forest Reserve and the Bia Tawya Forest Reserve both being illegally and completely converted to farmland (Martin 1982). Hence the increasing elephant density may reflect the same number of elephants in a smaller area.

Factors affecting elephant distribution

Formerly elephants were found in both Bia NP and Bia RR (Short 1981; Martin 1982). Favourable conditions created by logging activities in Bia RR during the early 1980s (de Leede 1994), however, have caused elephants to migrate permanently into its southern portions (Short 1981; Martin 1982). Both Barnes (1996b and de Leede (1994), have also observed this pattern of distribution. However, in the current study, elephants were found to be more widespread than formerly observed. Indeed, there is a medium elephant-density stratum that extends above the more southern high density to the limits of Bia NP, suggesting that after the ban on logging in Bia RR in 1998 elephants have gradually been dispersing towards Bia NP.

Analysis of dung-pile distribution indicated that water sources accounted for a large proportion of this variation in BCA; elephants were spending more time around water sources. Barnes (1996b and Sam (2000) also reported a positive correlation between elephant abundance and number of water sources per kilometre. These pools or water sources, which were more abundant in the south and south-eastern sections of the reserve, were created as part of the logging activities of Mim Timber Company. Their construction of wide and extensive logging and hauling roads (PADP 1998) have blocked many streams, forming several pools and dams along the sides of sections of the roads. Apart from their swampy nature, the areas around these pools were surrounded by thick thorny vegetation, which is difficult to traverse and hence likely to be avoided by hunters (Sam 2000). Therefore, while the pools provided water for the elephants, the vegetation at their banks also gave them protection. Barnes (1996b) further reported significant correlation between dung density and fruiting trees and Sam (2000) between dung density and illegal activity. This study found no such correlation.

Sam (2000) stresses that water availability in the reserve is not a problem because of many artificial pools in the reserve. However, elephants may be avoiding Bia NP due to lack of water in most elephant pools, especially in the dry season, when the present survey was conducted. Besides, the national park was last logged in the 1970s; that is, it has not been recently logged. Consequently, elephant movement and distribution in the dry season may be restricted by water availability more than any other single factor. A deeper understanding into this current movement towards the national park after a long period of absence is worth obtaining.

Mean illegal activity in BCA (0.74 activities per km) was comparable to other Ghanaian forests like the Kakum (0.67) and Ankassa (0.97) Conservation Areas (EBMP 2000; 2001). Similarly, illegal hunting for almost all species of animals occurs there including several killings of elephant (Sam 2000). Although elephants are fully protected in Ghana, the Bia elephant population, like others in the country, is still threatened. The last illegal elephant killing was just three months before this current study. It may be that as many elephants as are recruited are lost annually. Our information suggests that elephants may be killed for ivory rather than out of human–elephant conflict, although the resulting free meat is usually not wasted.

Different levels of illegal human activity within the park did not influence elephant density. The use of wire snares dominated the signs of illegal activity, although hunting with guns poses the greater threat to elephant populations. Poachers may be avoiding watering points, possibly because these areas had the highest concentration of elephants and they may fear encountering herds. These observations suggest that most of the illegal activities seen on the transects may be targeted at small game rather than elephants.

Importance of the Bia population for elephant conservation in West Africa

West African elephants may have diverted from the rest of Africa's elephants more than two million years ago (Eggert et al. 2003) and may constitute a separate taxon. If this becomes confirmed through more extensive genetic sampling, the implications will make securing the long-term survival of the small and fragmented remaining populations of West African elephants challenging indeed (Blanc et al. 2003).

Such a possibility provides a basis for seriously considering the importance of the Bia elephant range for elephant conservation in the subregion. The relatively high elephant density estimate in the present study ranks it high in importance for elephant conservation and for ensuring its long-term survival in the subregion; BCA has the third highest forest elephant density and a relatively well-protected range (Sam 2004). Within Ghana, its importance cannot be overemphasized, especially taking into consideration the number of forest populations available. Such a high concentration of elephants in a relatively small area also has management implications for tourism. Furthermore, the Bia population far exceeds the mean size of 40 elephants set as priority forest populations in West Africa (AfESG 1999). A population of just over 100 elephants is fairly large for today's fragmented forests but still is small, and is less than the viable population size estimated by Sukumar (1993). Hence, arguments for the possibilities of linking this population with the other elephant populations, especially the Goaso population and those in eastern Côte d'Ivoire, is crucial in ensuring the long-term survival of Ghana's elephant population and that of West Africa.

Acknowledgements

We wish to thank the African Elephant Specialist Group (AfESG) through its EU-funded Small Grants Programme and A Rocha Ghana for financing this study. We also wish to acknowledge the contributions of Bright Kumordzi, Frank Tetteh Kumah and other members of the BP 2002 Award Winning Team from Kwame Nkrumah University of Science and Technology for their untiring support of the project. Lastly, we are thankful to the entire staff of the Bia Conservation Area, especially Mr Enoch Amasa Ashie (Senior Wildlife Officer in Charge), Mr Boamah (Senior Wildlife Protection Officer) and Prince Charles Asante (Ranger) for providing staff and other facilities.

References

[AfESG] African Elephant Specialist Group. 1999. Strategy for the conservation of West African elephants. Proceedings of a workshop held in Abidjan, 22–26 February 1999. AfESG, Ouagadougu. Unpublished.

Barnes RFW. 1993. Indirect method for counting elephants in forest. *Pachyderm* 16:24–30.

Barnes RFW. 1996a. Estimating forest elephant abundance by dung counts. In: Kangwana K, ed., *Studying elephants*. AWF Handbook No.7. African Wildlife Foundation, Nairobi.

Barnes RFW. 1996b. Training course in elephant biology for Ghanaian wildlife officers. Report to US Fish & Wildlife Service. 16 + 10 p. Unpublished.

Barnes RFW, Asamoah-Boateng B, Naada Majam J, Agyei-Ohemeng J. 1997. Rainfall and the population dynamics of elephant dung piles in the forests of southern Ghana. *African Journal of Ecology* 35:39–52.

Barnes RFW, Asamoah-Boateng B, Naada Majam J, Agyei-Ohemeng J, Tchamba MN, Ekobo A, Nchanji A. 1994. Improving the accuracy of forest elephant census methods: studies of dung decay rates in Ghana and Cameroun. In: African Elephant Conservation Programme final report, vol. 5. Environment and Development Group, Oxford.

Barnes RFW, Dunn A. 2002. Estimating forest elephant density in Sapo National Park (Liberia) with a rainfall model. *African Journal of Ecology* 40:159–163.

Barnes RFW, Jensen KL. 1987. How to count elephants in forests. *IUCN African Elephant Specialist Group Technical Bulletin* 1:1–6.

Blanc JJ, Thouless CR, Hart JA, Dublin HT, Douglas-Hamilton I, Craig CG, Barnes RFW. 2003. *African elephant status report 2002: an update from the African Elephant Database*. IUCN/SSC African Elephant Specialist Group. IUCN, Gland, Switzerland, and Cambridge, UK. vi + 302 p.

Buckland ST, Anderson DR, Burnham KP, Laake JL, Borchers DL, Thomas L. 2001. *Introduction to distance sampling: estimating abundance of biological populations*. Oxford University Press, Oxford.

de Leede BM. 1994. Feasibility study on the establishment of corridors for forest elephants (*Loxodonta africana cyclotis* Matschie) between forest reserves in western Ghana and eastern Côte d'Ivoire. Ghana Wildlife Department, Accra. 39 p.

[EBMP] Elephant Biology and Management Project. 2000. Dry season elephant census of Kakum Conservation Area. Africa Program, Conservation International, USA. Unpublished.

[EBMP] Elephant Biology and Management Project. 2001. Dry season elephant census of Ankasa Conservation Area. Africa Program, Conservation International, USA. Unpublished.

Eggert LS, Eggert JA, Woodruff DS. 2003. Estimating population sizes for elusive animals: the forest elephants of Kakum National Park, Ghana. *Molecular Ecology* 12:1389–1402.

Hall JB, Swaine MD. 1976. Classification and ecology of closed canopy forest in Ghana. *Journal of Ecology* 64**:**913–951.

Heffernan PJ, Graham NAJ. 1999. University of Newcastle Bia elephant census, Ghana. Report 1. Dept. of Agriculture and Environmental Sciences, University of Newcastle, UK.

Laake JL, Buckland ST, Anderson DR, Burnham KP. 1993. *DISTANCE user's guide* V2.0. Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins, CO.

Laing SE, Buckland ST, Burns RW, Lambie D, Amphlett A. 2003. Methodological insights—dung and nest surveys: estimating decay rates. *Journal of Applied Ecology* 40:1102–1111.

Martin C. 1982. Management plan for the Bia Wildlife Conservation Areas. General part 1 and final report. IUCN/WWF project 1251.

McClanahan TR. 1986. Quick population survey method using faecal droppings and a steady state assumption. *Africa Journal of Ecology* 24**:**37–39.

Norton-Griffiths M. 1978. *Counting animals.* African Wildlife Foundation, Nairobi.

[PADP] Protected Area Development Project. 1998. Small mammals survey of Bia and Ankasa. PADP, Ghana Wildlife Division, Accra.

[PADP] Protected Area Development Project. 2001. Bia Conservation Area Management Plan. Ghana Wildlife Division, Forestry Commission, Accra.

Roth HH, Douglas-Hamilton I. 1991. Distribution and status of elephants in West Africa (1). *Mammalia* 55(4): 489–527.

Sam MK. 2000. The distribution of elephants in relation to crop damage around Bia Conservation Area during the 1999 rainy season. Report for IUCN (World Conservation Union), Gland, Switzerland.

Sam MK. 2004. A preliminary investigation into the possiblities of creating elephant corridors in Guinean forests of western Ghana. Report for IUCN/SSC African Elephant Specialist Goup, Nairobi, Kenya.

Short J. 1981. Diet and feeding of forest elephants, Bia National Park. *Mammalia* 45:177–186.

Short JC. 1983. Density and seasonal movements of the forest elephant (*Loxodonta africana cyclotis* Matschie) in the Bia National Park, Ghana. *African Journal of Ecology* 21:175–184.

Sikes SK. 1975. Report on preliminary elephant population survey in Bia National Park. Ghana Wildlife Department. Unublished.

Sukumar R. 1993. Minimum viable populations for elephant conservation. *Gajah* 11:48–51.

Taylor GJ. 1960. The vegetation zones of Gold Coast. *Bulletin of the Gold Coast Forestry Department* 4:1–12.

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