Research Article

Spatial Distribution of Elephants versus Human and Ecological Variables in Western Ghana

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An elephant survey was conducted in the Bia-Goaso Forest Block in western Ghana during the wet season month of November 2012 to determine the distribution of elephants and assess the human and ecological variables that affect them. One hundred and thirty 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. Elephant activity was concentrated in southern and mid-Bia Conservation Area, the southern tip of Bia North Forest Reserve, and eastern Mpameso Forest Reserve towards the adjoining Bia Shelter belt, indicating a clumped distribution. Secondary forest, water availability, poaching activity, and proximity to roads and settlements explained a high proportion of variance in elephant distribution. Given that the Bia-Goaso Forest Block forms an important biogeographic corridor between Ghana and Cote d'Ivoire, more effort should be directed at mitigating the problems such as poaching activity, vehicular traffic, and impacts of settlements that hinder seasonal movements of forest elephants between western Ghana and eastern Cote d'Ivoire.

1. Introduction

Habitat encroachment by humans presents some of the biggest problems confronting modern wildlife conservation [1]. Present human population growth and its attendant increasing demand for space and resources directly affect wildlife habitat quality [2]. The outcomes of habitat encroachment include reduction in wildlife habitat, which sometimes lead to local extinction of some species and human-wildlife conflicts. Many wildlife corridors connecting fragmented habitats are being cleared rapidly for human settlements [3, 4]. Large migratory mammals are especially at risk to this fragmentation. Reference [5] argued that human encroachment leading to wildlife habitat fragmentation may be one of the most serious threats elephants face in Africa.

Because of the variation in ecological and administrative boundaries, large mammals often migrate outside the limits of these protected areas [6]. Consequently, some large mammals, particularly elephants, may stray into adjacent community lands, regardless of the security threats. These contacts with community lands in elephant ranges in Africa and Asia have resulted in increased human-elephant conflicts.

Generally, maturing crops in adjacent farms attract elephants, which can lead to confrontations and the destruction of the whole annual produce of a farmer overnight. Usually, the farmer risks his personal safety in most times. Available records suggest that crop-raiding is common wherever humans live in close proximity to elephants. Within Asia, countries like India [7], Nepal [8], Sumatra [9], and Malaysia [10] have been affected by this problem. Other areas where this problem persists include African countries like Ghana [11, 12], Kenya [13], Mozambique [14], Rwanda [15], Benin [16], and Zimbabwe [17].

Elephant population increase in fragmented habitats that lack existing migratory routes can sometimes lead to significant pressure on local ecological resources which may result in serious destruction of wildlife habitat [18, 19]. This problem has been a grave concern for wildlife managers since the early 1960s because it mostly leads to decimation of woodlands by elephants [20].

Identifying the determinants of elephant dispersal in an area is a necessary requirement for natural resource managers and biologists to appreciate the intricacies between elephants and their environment [1]. Such information is important

FIGURE 1: Study area showing wildlife reserves, forest reserves, and shelterbelts.

for prioritization of areas for elephant population protection and to strengthen the argument for conservation of those critical areas [1]. Conservation strategies that aim at the long-term protection of flagship species like elephant will not only benefit elephants but also safeguard other species within its range [21].

Ongoing studies have explored wildlife distributions versus environmental factors based on time consuming ground and expensive aerial surveys [1]. Nevertheless, a small number of these studies have employed the use of existing geographic information such as satellite images and Global Positioning System (GPS) location data into a Geographic Information Systems (GIS) [1]. This study recorded elephant incidents in spatial subdivisions of one ecosystem in the wet season of 2012. The analysis is concerned with investigating associations with possible ecological and human explanatory variables: vegetation type, altitude, poaching activity, logging activity, water sources, fruiting trees and proximity to forest edge, roads, international boundary, Wildlife Division (WD)/Forestry Service Division (FSD) guard post, and human settlement. Regression analyses were used to investigate which of the possible explanatory variables influence elephant distribution in the Bia-Goaso Forest Block (BGFB).

2. Materials and Methods

2.1. Study Area. The study was undertaken in the forest zone of western Ghana in the Bia-Goaso Forest Block (BGFB). The BGFB comprises the Bia Conservation Area (Bia National Park and Bia Resource Reserve) and an extensive network of 9 forest reserves (Figure 1), south of Sunyani and to the west of the Tano River to the Ghana-Cote d'Ivoire border. The natural land cover corresponds to the tropical moist

FIGURE 2: Study area showing distribution of strata.

forest of the Guinea-Congolian forest vegetation. At the north, the vegetation is dry semideciduous; however, more southwards, the vegetation changes to the moist deciduous vegetation type [22]. Key commercial species of these forests are *Triplochiton scleroxylon*, *Entandrophragma utile*, and *E. cylindrium* with the climbing palms *Ancistrophyllum secundiflorum* and *Calamus deerratus* being characteristic of swampy areas. The mean elevation is 200–550 m, with generally undulating topography. Mean annual rainfall is 680–1450 mm/year, characterized by a bimodal wet season from March to July and September to November and a major dry season from December to February.

2.2. Reconnaissance (Recce) Survey. A one-week reconnaissance (recce) exercise was undertaken in the study area in October 2012 to assess relative densities of elephant signs (dung and tracks). A team spent each recce day per reserve following paths and trails on predetermined bearings and recorded elephant signs as to when possible. Distance was calculated with a *Global Positioning System* (GPS). Notes on illegal activities such as wood cutting, grazing, and poaching were also recorded. The period also provided the team with the opportunity to predict logistical problems and test operational procedures.

2.3. Stratification and Transect Layout. Based on dung densities recorded in the recce, the BGFB was stratified into 3 strata, namely, low (1–4 dung piles per km), medium (5–8 dung piles per km), and high (9–12 dung piles per km) density strata (Figure 2). The high density stratum constituted the

southern half of the Bia RR. The medium density stratum consisted of the remaining northern half of the Bia RR, the eastern portion of the Mpameso FR (about 6 km along the Bia River), and Bia Shelterbelt. The low density stratum covered the Bia NP, the remaining western portions of Mpameso FR, and the rest of the forest reserves in the study area.

In a grid consisting of cells, each one-minute of latitude or longitude was placed over a map of the study area using the MAPINFO software package. The intersections of the lines formed the likely start points for each transect. In all 130 transects of length one kilometre each was distributed within the various strata based on the respective dung densities recorded in the recce survey [23, 24]. This gave 70 transects in the low, 30 transects in the medium, and 30 transects in the high density stratum. Transect orientation was perpendicular to the main drainage lines of the area. Since the main River Bia flows from north to south, our transects ran from east to west.

2.4. Field Survey. An elephant dung count survey using the line transect method [23, 25, 26] was conducted in the study area in the wet season (November 2012). Three survey teams of three persons each and led by a compass man (team leader) were maintained throughout the counts to ensure consistency in data collection procedures. Straight transects were maintained throughout the survey.

The starting point of each transect was reached by navigating with a compass and a GPS. Once on the transect, only those dung seen from the transect centre-line were recorded. The compass man sighted on a stake held by a line cutter. Once the stake was correctly aligned, all walked in a straight line towards the line cutter, scrutinising the undergrowth on either side for elephant dung. The length of transects was measured with a GPS.

The following notes were made each time a dung was recorded: the distance along the transect, measured by the GPS, and the perpendicular distance from the dung to the transect centre-line, measured with a tape-measure. The stages of dung decay were classified based on the *MIKE S System* [27]. Other notes were made along the transect, particularly of ecological and human factors that might explain the distribution of large mammals: length of secondary forest (disturbed vegetation), altitude, water sources (ponds, rivers, and streams), fruiting trees, and signs of poaching and logging activity. Using GIS, the distance between each transect and the nearest forest edge, major road, international (Cote d'Ivoire) boundary, WD/FSD guard post, and human settlement was measured. Major roads were classified as roads linking any two villages, usually with a minimum of 10 vehicles plying along the road per hour.

2.5. Data Analysis

2.5.1. Elephant Distribution. All transects where elephant dung was recorded were noted and their coordinates were marked using a Global Positioning System (GPS). The coordinates were digitized into a Geographic Information System (GIS; ArcView Spatial Analyst, version 9.0; Environmental Systems Research Institute, Redlands, CA, USA) and processed into an overall elephant distribution map.

FIGURE 3: Distribution of elephant dung piles for the study period.

2.5.2. Factors Influencing Elephant Distribution. All variables were statistically treated before analysis. Regression analyses were used to investigate relationships between the elephant dung data and variables recorded on transects to determine which factors influence elephant distribution in the BGFB. In this case the statistics package StatView 5.0.1 was used.

3. Results

3.1. Elephant Distribution. Most elephant activities were concentrated at the south and south-eastern sections of the Bia Resource Reserve (Bia RR) and thinly spread northwards into the Bia National Park (Bia NP). In the Goaso range, elephant activities were only in the south-eastern tip of the Bia North FR and eastern Mpameso FR towards the adjoining Bia Shelterbelt. There was no activity of elephants in the rest of the forest reserves (Figure 3).

The distribution of elephant dung piles recorded during the main field survey followed closed the distribution observed during the recce, except that, in the main field survey, a few very old elephant activities were also recorded in the southern tip of the Bia North FR. Judging from the proximity of Bia Conservation Area to Bia North FR (under 2 km), it is possible that some elephants might have migrated from the Bia Conservation Area into the Bia North FR at the time of the survey (Figure 3). The results suggest that the BGFB elephant range may be partitioned into two main populations: Bia conservation area population and the Mpameso-Bia SB population (hereby referred to as Goaso population).

TABLE 1: Regression coefficients (r_s) between dung per km and a suite of human or ecological variables recorded on transects in the wet season.

Description of variable	r_s	P
Length of secondary forest (km)	0.878	<0.01
Number of water sources per km	0.837	<0.01
Distance to nearest road (km)	0.815	<0.01
Distance to the nearest human settlement (km)	0.783	<0.01
Number of poaching activities per km	-0.698	<0.05
Number of fruiting trees per km	0.304	>0.05 NS
Number of logging activities	0.226	>0.05 NS
Distance to reserve boundary line (km)	-0.218	>0.05 NS
Distance to the international boundary (km)	-0.144	>0.05 NS
Distance to the nearest WD/FSD guard post (km)	0.127	>0.05 NS
Altitude (m)	-0.093	>0.05 NS

3.2. *Factors Influencing Elephant Distribution.* Secondary forest (disturbed vegetation) ($r = 0.878$, $P < 0.01$), water availability ($r = 0.837$, $P < 0.01$), distance to nearest major roads ($r = 0.815$, $P < 0.01$), distance to nearest human settlements ($r = 0.783$, $P < 0.01$), and poaching activity ($r = -0.698$, $P < 0.05$) had the most significant effects on the distribution of elephants in the BGFB (Table 1).

The number of fruiting trees ($r = 0.304$, $P > 0.05$), logging activity ($r = 0.226$, $P > 0.05$), altitude ($r = -0.093$, $P > 0.05$), and distance to the reserve boundary line ($r = -0.218$, $P > 0.05$), the Ivorian border ($r = -0.144$, $P > 0.05$), or WD/FSD guard post ($r = 0.127$, $P > 0.05$) did not influence elephant distribution significantly in the BGFB.

3.2.1. *Water Availability and Secondary Forest (Disturbed Vegetation).* The regression models indicated that presence of water and secondary vegetation may be the strongest predictors of elephant assemblage in the BGFB. Elephant dung density generally increased steadily with increasing number of water sources per km (Figure 4) and length of disturbed forest vegetation (Figure 5). Highest numbers of elephant dung piles were recorded at higher intensities of water sources and secondary forest where tree cover is relatively low.

3.2.2. *Proximity to Major Roads and Human Settlements.* Generally, elephant density also increased steadily with increasing distance from major roads (Figure 6) and human settlements (Figure 7). Very low elephant dung piles were recorded close to these human variables.

3.2.3. *Poaching Activity.* The regression model that described elephant distribution with respect to poaching activity in the BGFB indicated an inverse relationship (Figure 8). Lowest elephant dung densities were recorded in areas of high poaching activity.

FIGURE 4: Relationship between dung pile density and water sources.

FIGURE 5: Relationship between dung pile density and length of secondary forest.

FIGURE 6: Relationship between dung pile density and distance to nearest major roads.

FIGURE 7: Relationship between dung pile density and distance to nearest human settlements.

FIGURE 8: Relationship between dung pile density and poaching activity.

Elephants were reported hunted but the intensity could not be ascertained during the study. Nevertheless, four hundred and fifty-five (455) signs of poaching activity were encountered in the survey. Eighty-one (81) poaching activities were recorded in the Bia range (encounter rate = 0.68 per km), 183 in the Mpameso range (encounter rate = 1.73 per km), and 191 (encounter rate = 1.71 per km) in the forests south of Goaso.

Poaching activities in the study area consisted mostly of use of wire snares for large rodents and ungulates (84%, $n = 455$). Finding of empty cartridges cases (9%), discarded carbide from poacher headlamps (4%), and poacher camps (3%) also indicated the occurrence of poaching. Twelve (12) gunshots were heard in the night during the entire survey. Illegal activities per km was significantly higher in the Goaso block of reserves than in the Bia CA (Mann-Whitney U test: $U = 4175$, $P < 0.01$).

4. Discussion

4.1. Distribution of Elephants. Formerly, elephants were found in both the Bia NP and the Bia RR [28, 29]. However, since timber companies started logging in Bia RR in the early 80s [30] elephants migrated from the Bia NP and moved downwards into the south-eastern portions of the Bia RR [30, 31]. References [28, 29] attributed the absence of elephants in the Bia NP as a temporal reaction to different and more palatable secondary vegetation conditions created by logging within the Bia RR. Even though the survey confirmed elephant concentrations in southern Bia RR, elephants were found to be more widespread than previously thought. The study showed a medium elephant density stratum, which extended above the southern high density to the limits of the Bia NP and a low elephant density in the Bia NP [32]. Thus, the question that needs to be asked and investigated is why elephants seem to be gradually moving back into the Bia NP after a long period of absence. There is every indication that, close to two decades of the stoppage of logging in the southern portion of the BRR, the vegetation is maturing and becoming like elsewhere in the conservation area, so making elephants spread out the more. Hence, the current widespread distribution of elephants may be in response to the increased occurrence of maturing fruiting trees in other areas of the park [31, 33].

4.2. Factors within Reserves. Analysis of dung pile distribution indicated that secondary forests and water sources accounted for a large proportion of variation in elephant distribution in the BGFB. References [31, 32] also reported a positive correlation between elephant abundance and number of water sources per km. Secondary forests and pools or water sources, which were more abundant in the south and south-eastern sections of the reserve, were created as a result of the logging activities of Mim Timber Company. In the construction of their logging and hauling roads which were larger than those specified in Ghana's Logging Manual [32], many streams have been blocked forming several pools along the sides of sections of the roads. Also the original primary forests were converted to highly disturbed secondary forests as a result of the logging actions. Apart from their degraded and swampy nature, the areas around these pools are surrounded by very thick thorny vegetation which is very difficult to traverse and hence likely to be avoided by hunters [32]. Therefore whilst the pools and associated vegetation provided water and food, respectively, for the elephants, the highly disturbed nature of the vegetation at their banks also gave protection to the elephants, by warding off poachers. Elephants' low use of the northern sections of the Bia Conservation Area, particularly the Bia NP, may be more pronounced, especially in the dry season when most rivers dry up. Also as the Bia NP has not been logged for over three decades there are limited man-induced pools or succulent secondary vegetation, making it a less preferred area. Consequently, it seems that water availability may feature strongly in influencing elephant movements and distribution, particularly in the dry season.

The vegetation in the Goaso area is primarily secondary forest; hence water availability may be the most important

determinant of elephant assemblages. Similarly, [30] has observed the lack of water to be the main reason for elephants moving out of the forests in the Goaso area. The distribution of elephants along rivers in the dry season is also well documented in the Goaso area [32, 34]. The authors show that scarcity of water in an area and elephants' need for water becomes the central theme for determining elephant distribution. At the Mpameso-Bia Shelterbelt area, the main Bia River may be serving as a major source of water for most of its elephants; dung density per km was inversely related to distance from the Bia River. Elephant distribution during the survey was concentrated in the eastern section of the reserve along the Bia River where a few elephant ponds were observed to contain water. It is possible that most of the elephants residing in this area might have migrated to live close to the River Bia due to scarcity of water in other parts.

Poaching activity within the BGFB was found to influence elephant distribution. Even though there was a difference in the level of illegal activity between Bia RR and the Mpameso-Bia SB area, the use of wire snares dominated the signs of illegal activity in comparison to hunting with guns. Hunting with guns possesses a greater threat to the elephant population than wire snares. These observations imply that most of the illegal activity seen on the transects were those of small game poachers and were not targeted at elephants. No poacher was encountered even though three gunshots were heard during the day whilst 12 gunshots were heard in the night during the entire study period. Poachers may have been active in the night than daytime. Information from wildlife guards also suggested that poachers avoided swampy vegetation possibly because these areas had the highest concentration of elephants and they feared encountering them.

Elephants were reported hunted but the team could not ascertain the intensity. Park rangers expressed fears and concern about an alleged presence of a group of poachers lurking in the vicinity of the reserve but there was no evidence to suggest that they operated in the park. Historical evidence indicated that, in 1999, there were at least four official elephant-poaching cases in BCA alone [33]. At Adwuofia (a native community at north-eastern edge of Bia NP), an elephant was also reportedly killed in 2004. Considering the small number of elephants in the BGFB (223 elephants), their long-term viability will depend on earning the goodwill of community members.

References [29, 31] further reported significant correlations between dung density and variables such as fruiting tree. However, this study found no such correlation. In the BGFB, elephants are known to feed on a wide variety of plant species including fruits of *Tieghemella heckelii*, *Balanites wilsoniana*, *Panda oleosa*, and *Parinari excelsa* [29]. It is possible that as the logging in the south-eastern portion of the reserve has ceased since about two decades before the study, that area no longer has the highest concentration of available fruiting trees; hence elephants are gradually dispersing to other areas of the reserve.

4.3. Factors outside Reserves. Roads and human settlements had significant negative impacts on elephants, in which elephant showed strong road and settlement avoidance in

the off-reserve areas, presumably as a result of increased hunting activity near roads and human settlements [35]. This is very important since information on the effect of roads on elephant movement between reserves is vital in determining gene flow between reserves. The question is "Could the relatively narrow (usually < 40 m wide) roads act as a movement barrier to elephants?" Off-reserve roads that separate reserves can significantly reduce local movements between reserves and alter the behaviour of elephants [36]. Roads could be far more difficult obstacles to strictly arboreal species, including various primate species. Moreover, the inhibitory effects of roads on movements of larger animals will undoubtedly be on the ascendancy as human activities and local hunting pressure rise [37] and as road width increases [35]. Across Gabon, roads appear to have negative, large-scale impacts on the abundance of forest elephants [38], putty-nosed monkeys [39], duikers, and other antelope [40].

Eighty percent (80%) of the reserves constituting the low density stratum form a contiguous block and are aligned in a north-south manner. This block of forests lies parallel to and within 8 km of the main Bibiani-Dormaa Ahenkro road and hence can be easily and quickly assessed by poachers from the road. Some major commercial towns and district capitals, which are linked by the road and consequently, very close (not more than 8 km) to these reserves, are Bibiani, Goaso, Mim, and Dormaa Ahenkro.

Moreover, because these are only forest reserves and not protected by strict wildlife laws, they are vulnerable to professional elephant poachers from the major towns. A lot of forest products including bush meat are carted along this road to various destinations. This could also be the reason for the striking difference in the intensity of illegal activities between the Bia range and the Goaso range because Bia is well protected by armed wildlife guards as against the Goaso range that has only a few unarmed forest guards. Highly exploited bush meat species include ungulates, particularly Maxwell's Duiker (*Cephalophus maxwelli*) and Bushbuck (*Tragelaphus scriptus*), and large rodents like Grasscutter (*Thryonomys swinderianus*).

4.3.1. Future of the Bia-Goaso Forest Block Corridor. Given its stable social conditions and relatively intact forest cover, Ghana is likely to play a crucial role in forest conservation initiatives in West Africa. Within Ghana, the general vicinity of the Bia-Goaso Forest Block is very important from a regional perspective because it forms a biogeographic link between Ghana and Cote d'Ivoire. The BGFB has been proposed as a transfrontier elephant corridor to facilitate seasonal movements of forest elephants and other large wildlife species between western Ghana and eastern Cote d'Ivoire [41]. In this regional context, the future management of the BGFB is extremely important.

Competing Interests

The author declares that there is no conflict of interests regarding the publication of this paper.

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