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Raid range selection by elephants around Kakum Conservation Area: Implications for the identification of suitable mitigating measures

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The factors that influenced elephants raiding in some spatial ranges around Kakum Conservation Area (KCA), Ghana were investigated. Crops were the basis for range selection by the elephants and the most commonly raided crops were plantain, cocoa and cassava. However, oil palm (*Elaeis guineensis)* plantations, bushes, crops at seedling and growing stages, or farms with active pepper fence never suffered any raid. It was observed that the presence of pawpaw (*Carica papaya*) and bako (*Tieghemella heckelii)* exposed nearby farms to risk. Since elephants do not raid oil palm plantations around KCA, we recommend that only oil palm groves should border the KCA to mitigate human-elephant conflict around KCA and that the pepper-fence method currently in use could also be effective if its accompanying financial burden is taken away from the farmers and funded by the government.

Key words: Raided zone, oil palm plantation, pepper-fence, human-elephant conflict, protected areas.

INTRODUCTION

West Africa is the only region where a higher proportion of elephant range (about 60%) is found inside designated protected areas than outside. Many of these protected areas, however, are forest reserves, which only afford limited protection (Blanc et al., 2007) but as expanding human populations compete with elephants for habitat (Blanc et al., 2007) and resources (Conover, 2002), the future of forest elephant populations may soon depend entirely on protected areas (Barnes, 1999). The protected range of elephants in Ghana is about 22.8% (Blanc et al., 2007), and elephants in Ghana continue to be under pressure from habitat fragmentation and high human population densities (Barnes, 2002). Shifting cultivation up to the boundaries of protected areas exacerbates the problem of crop raiding by elephants, which is severe wherever elephants occur (Barnes, 2002).

In their position as keystone species that play a major role in stabilizing plant and animal communities (Campos-Arceiz and Blake, 2011; Beaune et al., 2013), or charismatic icons of conservation (Dublin and Hoare, 2004), elephants should enjoy adequate security in protected areas. However, a severe conflict has

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developed between elephants and humans, sometimes leading to serious fatalities on either side (Kiiru, 1995; Nelson et al., 2003; Omondi et al., 2004; Malima et al., 2005; Campfire, 2007; Kioko et al., 2008).

Farmers around protected areas rely on subsistence agriculture as well as cash crops for their food security and livelihoods. However, these crops are also an attractive, accessible, and predictable source of food for elephants (Monney et al., 2010). As a result, elephants may raid crops for food and inflict considerable damage with corresponding impacts on farmer livelihoods. It cannot be overemphasized that wherever agriculturists and elephants (*Loxodonta* spp. and *Elephas maximus*) share the same landscape, conflict develops (Lahm, 1994; Barnes, 1996; Naughton-Treves, 1998; Whyte et al., 1998; Hoare, 1999; Mubalama, 2000; Seneviratne and Rossel, 2001; Sitati et al., 2003; Sukumar, 2003). Ensuring farmers livelihoods and food security through reduction of HEC is an internationally agreed goal (Parker et al., 2007) and conservation managers today are required to tackle this complex issue in collaboration with communities in order to achieve conservation objectives (Parker et al., 2007). If solutions to alleviate crop raids by elephants are not found, persistent raiding of crops may compromise elephant conservation (Chiyo and Cochrane, 2005).

For over a decade, the African Elephant Specialist Group (AfESG) has been actively concerned with trying to help unravel the dynamics of HEC with a view to mitigating the problem (Dublin and Hoare, 2004). It is therefore recognized that a long term solution to elephant crop raids can be devised based on the outcome of proper investigations of the behavioral dynamics and pattern of raids by the elephants (Monney et al., 2010). The farming landscape outside protected area has not been completely unraveled and the actual raid ranges have not been mapped. Mapping and the use of spatial data for forest resource management and planning have been recognized worldwide, especially if they are transformable to readily-analyzed formats. The application of integrated GPS/GIS technology to habitat utilization models has enabled the identification of those areas most at risk from elephant raids (Breininger et al., 1991; 1995; Duncan et al., 1995). A map of this nature is expected to give a clear picture of the elephant raid situation around KCA.

The current problem around KCA is that about 52 communities are located at the fringes of the protected area and farm at its edge sometimes to the immediate boundaries. The farms attract elephants that wander off the reserve (Boafo et al., 2004; Monney et al., 2010), and this coupled with lack of appropriate mechanisms to ward off the elephants have resulted in crop raiding incidences with consequent HEC. Apart from feeding on farm crops, the forest elephant is also noted for uprooting, breaking, trampling and plucking crops without eating them (Monney et al., 2010). The factors that influence raid zone selection by the elephants by mapping the range raided by the animals around the KCA were investigated. This is expected to enable the identification of raid range preferences and rejections by elephants around the KCA. It is hoped that the results will inform the management towards appropriate ways to control raids by the elephants and hence find lasting solutions to HEC.

MATERIALS AND METHODS

Study area

The study was undertaken around the Kakum Conservation Area (KCA), Central Region, Ghana, lying between longitude 1° 30 ' W - 1°51' W and 5° 20 ' N – 5° 40 ' N (Figures 1 and 2) from October, 2011 to September, 2012. The KCA consists of the Kakum National Park (KNP) and the Assin Attandanso Resource Reserve (AARR) and is managed as a national park by the Wildlife Division of Forestry Commission. Towards the end of the 19th century, the Kakum forest was among the various reserves set aside as the "*Celtis-Lophira* hardwood Ghana's Production Resource Reserve"; but the boundaries were not clearly demarcated until 1925. In 1940, the Assin Attandanso forest was added to form a 366 km^2 contiguous block in the moist evergreen forest zone (Hall and Swaine, 1976). Timber exploitation especially of *Khaya ivorensis* (mahogany) escalated from the 1950s until 1989 when the reserve was placed under the then Ghana Wildlife Department (GWD). Over the years, many laws (e.g. 1961 Wild Animals Preservation Act and the Legislative Amendments of 1971) had to be passed to make the existence of the park a reality. The KCA was finally gazetted as a national park and resource reserve by Legislative Instrument 1525 of 1992 under the administrative jurisdiction of the GWD.

The dominant vegetation type is moist forest, with other vegetation types being swamp forest (permanent and periodic) and riverine forest. The canopy coverage is closed or open, with irregular distribution of about 105 species of vascular plants (Wiafe et al., 2010). A small elephant population of about 160 (Dudley et al., 1992; IUCN, 2004) exists within the Kakum Conservation Area among populations of other mammals. KCA is surrounded by agricultural farms and about 52 communities with an estimated total population of 50,000 people. The main source of income of the indigenes is agriculture, supported by logging, hunting, trading, small-scale mining, charcoal burning and domestic animal rearing.

Range mapping

The study area was divided into nine sites, namely Kruwa, Briscoe II, Adiembra, Ahomaho, Aboabo, Afiaso, Antwikwaa, Mfuom and Abrafo (Figures 2 and 3). These sites were named after the nearest fringe communities or staff camps. GPS readings were taken along the boundaries of the ranges raided or visited by elephants, each at about 400 m intervals or less where necessary. GPS readings were also taken at the centre of each nearby community or staff camp. Range around KCA found to have been raided or visited by the elephants were investigated over the study period. Factors that attracted the elephants to the range, the vegetation type and the general habitat features at raided ranges were recorded.

Raid behaviour

A distance of about 50 m from the elephants was maintained to walk behind them to investigate their activities and raid behavior

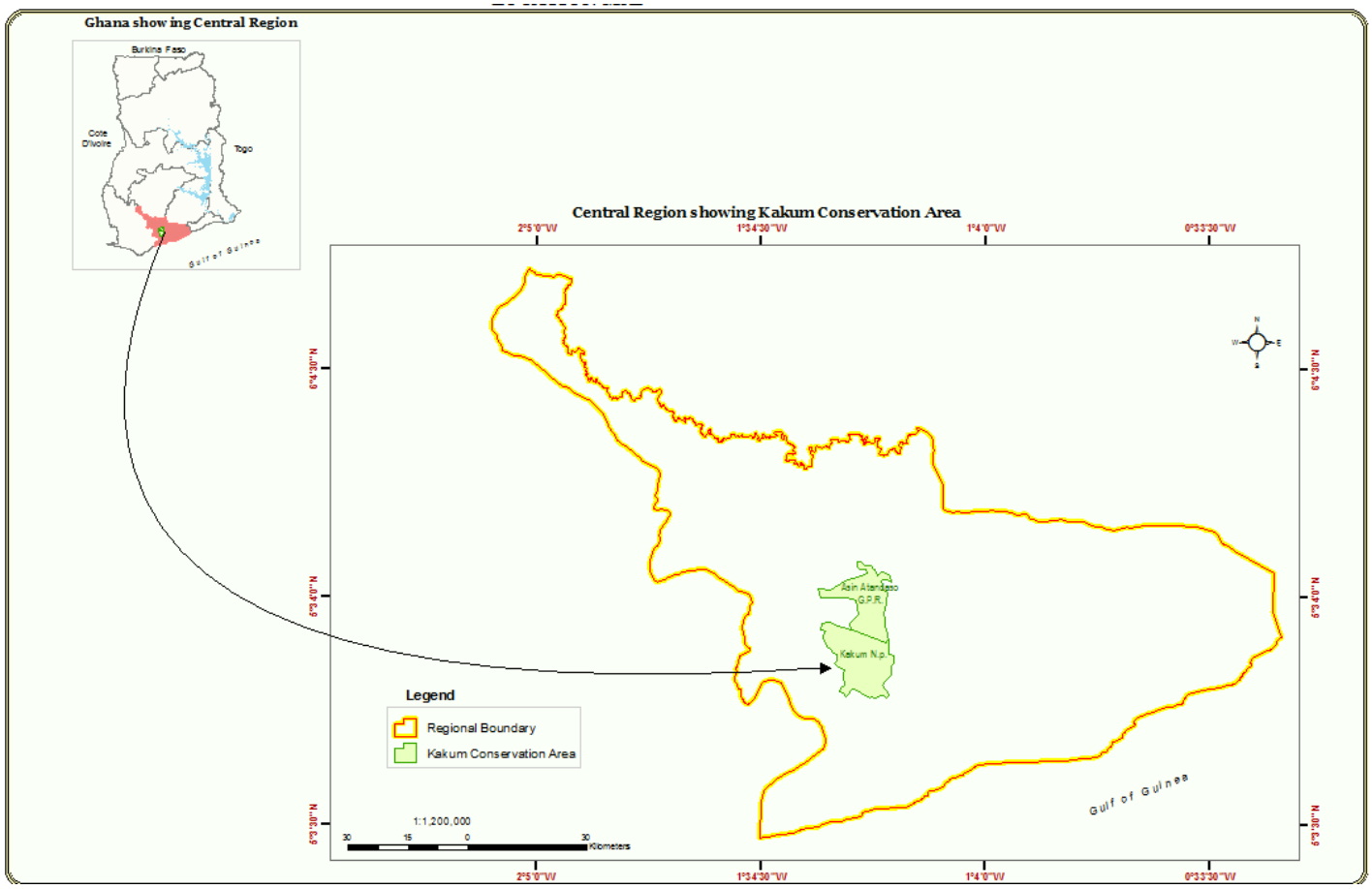

Figure 1. Central Region of Ghana showing the location of KCA.

and determine the herd sizes and raid frequency of herd sizes in such raid ranges.

Seasonal raids

The study period covered both rainy and dry seasons in order to investigate raid occurrences in these two seasons: The two rainy seasons from April to July and from September to November, and the dry seasons from December to March and in August. Data were collected in each season.

Data processing and analysis

GIS (v9.3) remote sensing was used to interpret GPS readings. Spatial data of GPS were downloaded onto a computer, converted to a database file and exported to Arc Map to be projected into a Geographical Coordinate System plotted as individual points and joined together to form maps. All statistical analyses involved the use of Microsoft Excel® software (2007) and PAST (Paleontological Statistics Software Package for Education and Data analysis) software (Hammer et al., 2001). Ordinary least square was used to regress herd size against frequency of raid to evaluate the hypothesis that smaller herd sizes raid more frequently than larger herd sizes or smaller herd sizes raid less frequently than larger herd sizes. Chi-square test was also used to evaluate the hypothesis that raids were more frequent during the dry season than the rainy season.

RESULTS

Range mapping

Sixty-three elephant raid ranges were mapped around KCA during the one-year study and these covered a total land area of 289,447.30 m^2 (Table 1). Afiaso site recorded the highest number of 15 raided ranges covering a total land area of 86,698.40 m^2 representing 30% of the total land area raided, while Briscoe II site recorded the lowest of the two raided ranges covering 1,625.60 m^2 (0.6% of total land area) (Table 1). It was observed that people farmed to the immediate boundaries of the park (Figure 3) as pointed out by previous studies (Barnes et al., 2003; Monney et al., 2010). Crops raided were cocoa (*Theobroma cacao*), cassava (*Manihot esculentus*), plantain (*Musa paradisiaca*), cocoyam (*Xanthosoma* sp.), banana (*Musa*

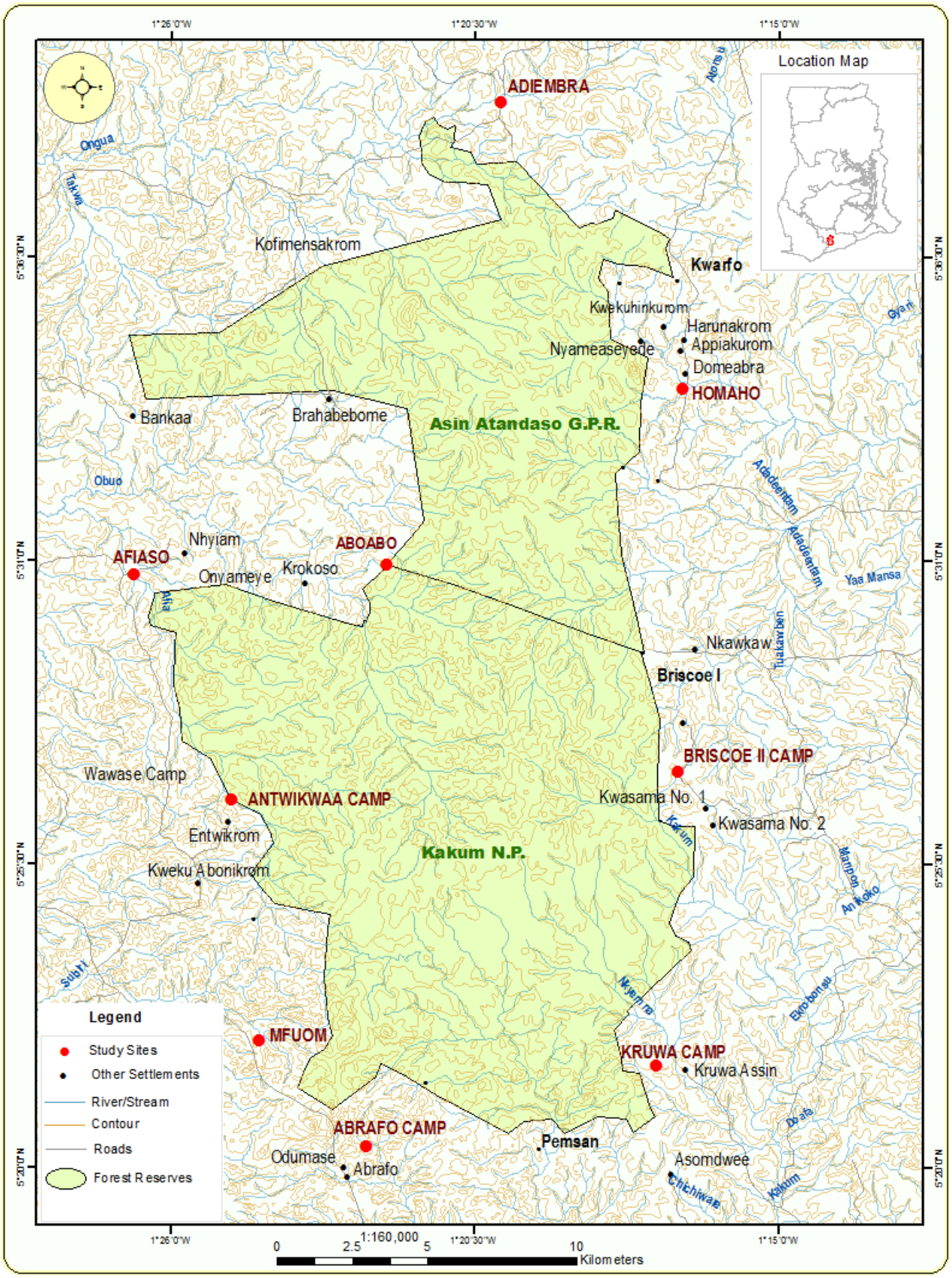

Figure 2. Map of KCA showing surrounding communities.

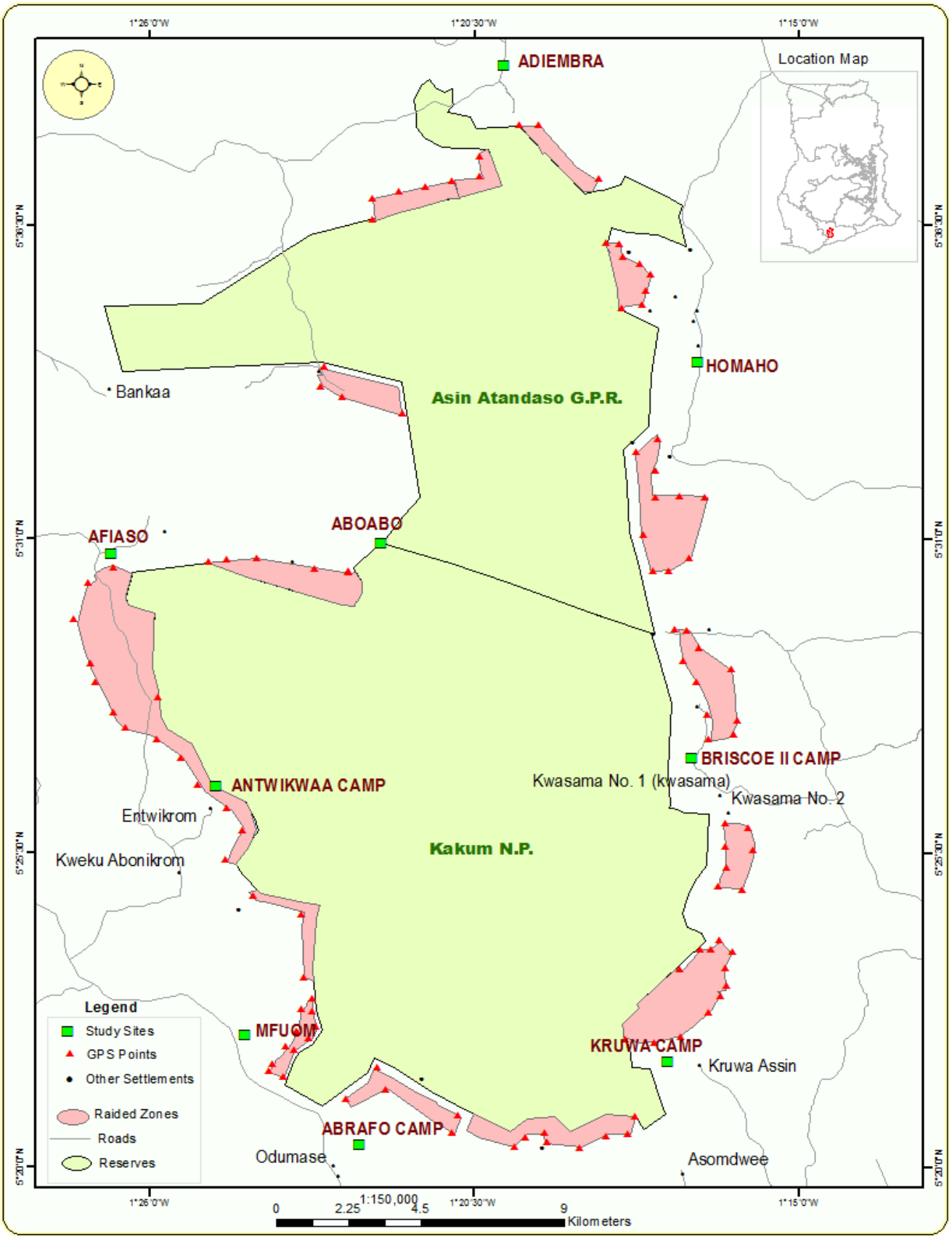

Figure 3. Map of KCA showing raided ranges around it.

Table 1. Activities of elephants in raid ranges in each study site.

Study site	Number of raid ranges	Total area raided (m^2)	Dominant plant/crop	Activities of elephants
Kruwa	7	18,223.20 (6.30%)	Cocoa, cassava, plantain, banana, maize	Eating, breaking, uprooting and trampling
Briscoe II	2	1,625.60 (0.56%)	Cassava, plantain, maize	Eating, breaking, uprooting and trampling
Adiembra	5	16,241.20 (5.61%)	Cocoa, cassava, plantain, maize	Eating, breaking, uprooting, and trampling
Ahomaho	8	39,649.60 (13.70%)	Cocoa and plantain	Eating, breaking and trampling
Aboabo	8	13,004.80 (4.49%)	Cocoa, cassava, plantain,	Eating, uprooting, breaking and trampling
Afiaso	15	86,698.40 (29.95%)	Cocoa, cassava, plantain, maize, cocoyam, yam	Eating, uprooting, breaking and trampling
Antwikwaa	9	17,068.80 (5.90%)	Cocoa, cassava, plantain, yam	Eating, breaking, uprooting, and trampling
Mfuom	5	54,186.5 (18.72%)	Cocoa, cassava, plantain	Eating, uprooting, breaking and trampling
Abrafo	4	43,349.2 (14.98%)	Cocoa, cassava, plantain,	Eating, uprooting, breaking and trampling
Total	63	289,447.3 (100%)		

sapientum), yam (*Dioscorea* sp.) and pawpaw (*Carica papaya*) (Table 1).

Raid behaviour

Though the elephants fed mostly on mature plants, not all raids recorded in this study were accompanied by feeding. There were some examples of raids without consumption at four sites, namely Kruwa, Adiembra, Antwikwaa and Aboabo (Table 3). Some ranges occupied by oil palm (*Elaeis guineensis)* or bushes including *Chromolaena odorata, Securinega virosa, Aspilia africana, Mallotus oppsitifolius and Mimosa pudica,* never suffered any elephant raids (Table 2). There were no records of oil palm raids by the elephants around KCA throughout the study period. It was observed that elephants walked through palm plantations to consume pawpaw plants on 13 occasions (Table 2). Other farms which were also not raided were those in which crops were at the seedling and growing stages or with active pepper fences (fences still smelling of pepper). Farms with inactive pepper fences (no pepper smell) were however raided. Pepper fencing involves soaking rags in a mixture of ground pepper and grease and hanging the rags on fences around each farm. Four farm ranges covering a total land area of 6,268.30 m^2 (Table 2) were never raided by the elephants due to the pepper fences at the boundaries of those farms. The elephants were observed attempting to raid such farms on many occasions but were repelled by the scent of pepper. However, at some sites such as Mfuom (Figure 4) and Abrafo, because pepper scent waned, elephant raids were detected. Visits to farms by the elephants did not always result in crop raiding. For example, four times at Kruwa and two at Mfuom, the elephants walked through farms with only young growing crops such as seedlings without raiding.

We observed that the elephants showed special preference for some plants, notably pawpaw (*Carica papaya)* and bako (*Tieghemella heckelii*). This was evidenced by the frequency at which bako or pawpaw was selected from non-raided ranges after walking past other plants intact except for the obvious trampling as the elephants moved through them. For a mature pawpaw, almost the entire plant is taken as food, while in the case of the bako, only the fruit was of interest to the elephants.

It was observed that elephants raided in herds of two to eight individuals (Table 5) though the field staff used to see herd sizes up to 15. Results of regression analysis indicated a non-significant negative relationship between herd size and frequency of raids with a probability of less than 50% of the raid events ($Y = -0.975x + 9.04$, $r = -.607$, $R^2 = 0.37$, $t = -1.708$, $p = 0.148$). Therefore, the hypothesis that the frequency of raid events is influenced by the size of a herd was rejected.

Seasonal raiding

Raids were recorded in both rainy and dry seasons, even though figures recorded for the rainy season were higher than those in the dry season (Table 4). Chi-square tests however indicated no significant differences ($\chi^2 = 15.48$,

Table 2. Activities of elephants in non-raided ranges in each study site.

Study site	Number of non-raided ranges	Total land area of non-raided ranges (m^2)	Nature of land	Dominant plant/crop	Activities of elephants (no. of times)
Kruwa	6	24,232.30	Bushes, pepper - fenced farm	*Chromolaena odorata,* oil palm	NIL
Briscoe II	5	70,124.40	Abandoned farm	*Securinega virosa*	Consumed pawpaw plants (3x) and bako fruits (3x)
Adiembra	6	18,243.20	Bushes, pepper - fenced farm	*Chromolaena odorata,*	NIL
Homaho	7	43,694.60	Bushes, pepper - fenced farm, belled farm	*Mallotus oppsitifolius, Mimosa pudica*	Consumed pawpaw plants only (2x)
Aboabo	9	47,364.30	Bushes	*Chromolaena odorata,* and oil palm	NIL
Afiaso	10	1,725.60	Bushes	oil palm *Chromolaena odorata,*	Consumed pawpaw plant only (6x)
Antwikwaa	12	20,068.80	Bushes, pepper - fenced farm	*Chromolaena odorata,*	NIL
Mfuom	4	63,186.5	Bushes	*Aspilia africana, Mallotus oppsitifolius*	NIL, consumed pawpaw plants only (2x)
Abrafo	5	51,342.2	Bushes, pepper fenced farm	*Mimosa pudica Securinega virosa,* oil palm	NIL
Total	64	339,981.9			

Table 3. Frequency of raids by elephants at each study site during the study period.

Study site	Frequency of raids by elephants at the various sites observed by our team (and by field staff)			
	Dry season	Total	Rainy season	Total
Kruwa	1 (10)	11	3(16)	19
Briscoe II	0 (2)	2	1 (4)	5
Adiembra	2 (11)	13	5 (12)	17
Ahomaho	2 (13)	15	3 (13)	16
Antwikwaa	1 (0)	1	2(16)	18
Afiaso	3 (3)	6	4 (13)	17
Aboabo	2 (3)	5	4(8)	12
Mfuom	0 (8)	8	0(6)	6
Abrafo	0 (8)	8	4 (5)	9
Total	11 (56)	67	26 (93)	119

df = 8, p = 0.059), and thus the hypothesis that raids were more prevalent in the rainy season than the dry season around KCA was rejected.

DISCUSSION

The results of this study are consistent with the expectation by Monney et al. (2010). For crop raiding to escalate around KCA, indeed,crop raiding by elephants has doubled in less than two years, with 63 raided farms covering a total land area of 289,447.30 m^2 as compared to 33 raids covering 103,496.20 m^2 land area (Monney et al., 2010). This is probably because the elephants became adapted to some deterrent measures that

Figure 4. Inactive pepper-fenced farm.

Table 4. Composition of elephants in raids during the study period.

Herd size recorded	Frequency	Study site(s) and (number of times herds were encountered at site)
1	3	Afiaso (3)
2	10	Afiaso (2), Aboabo (2), Abrafo (2), Kruwa (2), Adiembra (2)
3	9	Kruwa (2), Adiembra (2), Homaho (2), Aboabo (3)
4	8	Homaho (2), Adiembra (2), Afiaso (2), Antikwaa (1), Aboabo (1)
5	3	Briscoe II (1), Antikwaa (1), Adiembra (1)
6	1	Antwikwaa (1)
8	1	Homaho(1)

restrained them previously. For example, it was showed that pepper fencing had been ignored by some of the farmers (Monney et al., 2010; Wiafe and Sam, 2014) and it appeared that the elephants tool advanture from lapses in this deterrent measure and raided when the effect of the pepper had waned (Monney et al., 2010; Wiafe and Sam, 2014).

Field staff confirmed that the elephants could smell the pepper application and stayed far away from the source though no estimates of how far they stay away had been made so far. The implication of this observation is that pepper fencing to protect farms far away from the reserve boundary may be unnecessary and may rather elicit raids by the elephants when the scent of pepper wanes. Also, bako and pawpaw plants were found to trigger crop raiding as the adventure the animals took towards these plants linked them to some nearby farms. Even though this study has inadequate data in the case of the bako tree, this has been confirmed by the field staff. Thus, farmers far away from the park's boundary would be better advised to get rid of pawpaw trees from their farms. In previous studies, plantain, cassava and cocoa farms were found to be the most commonly raided and sources of great risk to farmers around KCA (Barnes et al., 1995; Barnes et al., 2005) and around Bia National Park, Ghana (Sam et al., 2005). Other studies reported banana as the most preferred, for example around the Kibale National Park, Uganda (Naughton-Treves, 1998)

Table 5. Composition of elephants in raids during the study period.

Herd size recorded	Frequency	Length x width of foot print (cm) for herd size	Study site(s) and (number of times encountered at site)	Mode of encounter
1	3	40 x 39	Afiaso (3)	Sight (1), footprint (2)
2	10	50 x 47, 42 x 40	Afiaso (2), Aboabo (2), Abrafo (2), Kruwa (2), Adiembra (2)	Footprint
3	9	50 x 47, 42 x 40, 35 x 32	Kruwa (2), Adiembra (2), Homaho (2), Aboabo (3)	Footprint
4	8	42 x 40, 35 x 32, 36 x 33, 32 x 29	Homaho (2), Adiembra (2), Afiaso (2), Antikwaa (1), Aboabo (1)	Footprint
5	3	51 x 47, 48 x 44, 49 x 47, 42 x 40, 39 x 37	Briscoe II (1), Antikwaa (1), Adiembra (1)	Footprint
6	1	50 x 46, 46 x 43, 35 x 32, 30 x 28, 25 x 22, 21 x 19	Antwikwaa (1)	Sight
8	1	50 x 47, 42 x 40, 49 x 47, 42 x 39, 39 x 36, 35 x 32, 25 x 22, 20 x 18	Homaho(1)	By footprint

and across Gabon (Lahm, 1994).

The elephant is one of the wild species that cause very severe damage to crops and jeopardize entire families' livelihoods. The complex situation currently is that while the feeding behavior of elephants constitutes crop raiding to humans because they cause damage to their crops, this study supports Monney et al. (2010) that the elephants around KCA also raided without feeding. It seems that stringent monitoring of crops by elephants has resulted in the phenomenon of raiding without feeding and that any mechanism used to elude the elephant apart from quitting farming and using the appropriate deterrent method will rather induce the elephants to cause more damage.

Current deterrent methods including pepper fencing, guarding farms in the night and scaring elephants with noise and bells have their own disadvantages which make them ineffective. For example, guarding farms at night involves sacrificing economic ventures during the daytime with compensatory rest. Also, the otherwise most effective deterrent pepper fencing method has not been well patronized due to the cost and effort involved in fencing large farms. Even in the presence of the pepper fence, elephants may still attempt to visit farms looking for lapses in the construction. New ways of the application of pepper as elephant repellent have been tested in Zimbabwe (Le Bel et al., 2010) involving dispensers and projectiles propelling small balls (40–50 mm diameter) filled with either chilli-pepper powder or oil extract but Niskanen (2006), Osborn and Rasmussen (1995), Osborn FV (2002) found lapses in this method. There have been experiments with beehives and elephants elsewhere (Vollrath and Douglas-Hamilton, 2002; King et al., 2009) but this option has not been explored in KCA because it has been proven that bees alone will not stop elephants from raiding crops (Karidozo and Osborn, 2005). Also, electric fences found to be the best solution according to Thouless and Sakwa (1995) have been found to be expensive to maintain (Kioko et al., 2008) while the use of aspirin is traceable in the food web to have adverse consequences on other fauna.

One important finding of this study is that oil palm plantations were never raided at the fringes of the park by the elephants no matter how close the oil palm occurred to the boundary. It has been recommended for management to seek collaboration with farmers and chiefs of fringe communities and with government assent to allow only oil palm plantations around the park as a long term solution to HEC. It is believed that the proximity of the Twifo Oil Palm Plantation (TOPP), about 3.5 km away from the Reserve, will offer a ready market to boost palm oil production in the country, and also offer a more reliable means of income to the communities. This, however, requires great effort initially until the palm seedlings mature to gain immunity from elephant raids. Establishment of oil palm plantations has usually been a controversial issue as forests are sacrificed for them. However, areas around the KCA are already destroyed forest and farmlands, and therefore present a different scenario from the general biodiversity concerns.

In conclusion, this study perceives the problem of farm crop raiding by elephants from KCA as becoming increasingly complex. The mitigating measures used so far offer no lasting solution and HEC continues to escalate. The KCA elephants have evolved to show special preference for a variety of farm crops as food and it seems that they try to access every area possible in their search for food and so preventive measures used should be sustainable. The recommended oil palm plantation, if considered, may offer a more effective

solution than all the previous and currently existing mitigating measures, and others adopted elsewhere, especially combined with the application of pepper-fence method currently used. But the pepper-fence method can be effective if the financial burden is taken away from the farmers.

Conflict of Interests

The author(s) have not declared any conflict on interests.

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