Occurrence and Level of Elephant Damage to Farms Adjacent to Mount Kenya Forests: Implications for Conservation

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Abstract

Incidences of elephant's crop raids in Mount Kenya area have escalated in the recent past causing considerable damage to the fragile local economy that is mainly peasant farming. Studies on crop-raiding predisposing factors, nature and extent of the damage in this region are scanty. Thus, this was the aim of this study. Data was obtained from questionnaires and occurrence books at Kenya Wildlife Service between 1997 – 2000. Elephant movements were mapped in relationship to watering points and salt licks. It was found that crop-raiding incidences by elephants were widely spread over the study area (80%, n = 487). Crop damage severity was about 16.8 % of the expected yields. Levels of crop damage were positively correlated to crop occurrence ($r = 0.982$, $P = 0.01$). Thus, damage levels were substantive. Elephant's crop-raids should stop. Fencing off elephant from farmland will solve crop-raiding problems and enhance their conservation.

Keywords: Elephants crop-raiding, human-wildlife conflict, forest fragmentation, conservation area barriers

Introduction

Elephant conservation in Kenya and the world at large is facing myriad of severe challenges that range from human encroachment on elephant habitats and migratory corridors (Lahm 1996), to poaching for ivory and meat (Kamweya and Gakahu, 2008). Overall, the single-most major threat to elephant conservation is the exponential increase in human population leading to encroachment into, and loss of elephants habitats (Spinage, 1994). This has led to restriction of elephants in fragmented range (Caughley, 1976; Cumming *et al.,* 1990). This often results to failure of the fragmented elephant populations to maintain an increase in numbers due to various reasons such as loss of foraging home range (Wilcox and Murphy, 1985; Cumming *et al.,* 1990; Spinage 1994) and genetic drift (Parker, 1990). Inevitably, elephants venture out of these confinements into the surrounding human settlements where they raid crops and cause other forms of damage.

There has been an increase in incidences of elephant raids on people and their property in recent times arousing much attention from both conservationists and wildlife managers in Kenya (Waithaka, 1994; Kamweya, 2002) and elsewhere in Africa (Parker and Osborn, 2001). The damage on farms is quite severe in some areas especially those that border forested protected areas (Waithaka, 1994; Kenya Wildlife Service, 1996; Parker and Osborn, 2001). This damage has serious implications on management and conservation of elephants because it has created and escalated hostility of the adversely affected community towards elephants (Waithaka, 1994; Kamweya, 2002).

Despite the efforts that have been put to mitigate this conflict including erection of high voltage electric fence in some hotspots areas, the results have generally been disappointing, partly due to inherent limitations of the strategies that have been used in the past (Thouless, 1994; Thouless and Sakwa, 1995; WWF, 1997; Hoare, 2001) . Proactive strategies to resolve the conflict would require knowledge of the extent and severity of the damage caused by the problem animals. Anecdote information indicate that wild animals including elephants in Mount Kenya region invade farms and cause much damage to crops, fences and other infrastructure as well as cause death and injury to people and livestock. However, the damage related specifically to elephants is scanty, and mostly addressed only a few areas with heavy elephant damage such as Hombe and Gathiuru, which are located on western slopes of Mount Kenya (Omondi *et al.*, 1998). Despite the reports and concerns raised on need to control elephant incursions on farms and other entities, there is little research done to establish the severity and frequency of elephant infestations in farms. This study examines the role of proximity of elephant habitats to human settlements to discern the severity of damages and losses caused on households by marauding elephants. Elephant movements in Mount Kenya and elsewhere in Africa have been shown to be linked with resources (food, water and mineral licks) availability. This study therefore postulated that the distances between households and these resources encouraged elephants to raid nearby farms during their movement to and from salt licks, foraging and watering points. The study aims to assess the types, extent, severity and frequency of damages caused by elephants in the area adjacent to Mount Kenya Forest.

Materials and Methods

The Study Area

The Mount Kenya Forest Reserve occurs in Central Kenya, about 200 km north of Nairobi (Figure 1). It lies between 0^{o} 25' S and 0^{0} 10 N and 37^{0} 00'E and 37^{0} 45'E. Mount Kenya Forest Reserve (MKFR) covers 200,870 ha and is an area of high agricultural potential of which 16% was under plantation forestry. The area rises from 1,500 m above sea level to 5,199 m at its highest elevation in an area covering the natural forests to the upper zone mostly found within Mount Kenya National Park and plantation forests in the lower zone under MKFR (Rheker, 1992, Njuguna *et al.,* 1999). The rainfall is bimodal and is influenced by its equatorial location on the mountain. The dry season occurs from December to March and the wet season is between June and October (Rheker, 1992). The southeastern slopes are wetter than the other areas. The forests are habitats to many wild plants and animal species some of which are endemic; others are threatened with extinction such as black rhinos, while many others were regarded as agricultural pests by the local community such as elephants and primates (Milner *et al.*, 1993). The land under agro-forestry extends up the mountain to 2375 m above sea level. A fast growing density of human population surrounds the forests (Jaetzold and Schmidt, 1983; Ayiemba, 1991; Central Bureau of Statistics, 2001), of which 92% are peasant farmers growing crops such as coffee, tea, cereals, potatoes, legumes, vegetables and fruits. Livestock and large-scale wheat production are important land use activities particularly in the drier northern foot-slopes of the mountain ecosystem.

This study covered an area of about 900 km^2 of human settlements that adjoined the periphery of the Mount Kenya Forest Reserve in a 2 - 10 Km wide belt, and extended from the town of Nanyuki in the northern part of the study area towards the south and then eastward to the border between Embu and Meru South Districts. This study was conducted between January 1999 and December 2000.

Collection of elephant damage data

Elephant impacts on farms were assessed using structured questionnaires distributed to farmers. The generated information was on; assess relative importance of the elephants as a problem animal species, nature, extent and severity of elephant damage to farms, and factors that influenced severity of elephant damage to farms. Further, records from seven wildlife outposts from records entered in Occurrence Books and other government departments provided data on elephant damage to farms such as type of damage, number of reported incidences for each animal species, date of occurrence, name of the raiding species, and location of incidences of conflict.

The interviews schedules involved use of structured questionnaires and were conducted on 467 respondents (the landowners). The sampling units were the individual households. Sample households were randomly selected from a 2 - 10 Km wide belt covering an area of about 900 km^2 of human settlements lying along the periphery of the

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Mount Kenya Forest Reserve (Figure 1).

The number of households that were included in the scheduled interviews was determined by applying the Fisher *et al.* (1998) model of proportional sample selection, as follows:

$$\mathbf{n} = \frac{Z^2_{\alpha/2} PQR}{D^2} \qquad (1)$$

Where: $Z_{\alpha/2}$ = 1.96 (for 95% level of confidence)

P = proportion of households raided by elephants, assumed as 0.5 where the P was unknown.

Q = proportion of households not raided by elephants, assumed as 0.5 where Q was unknown.

D = the level of confidence required (0.05 for this case).

R = 1 (where there was no replication or comparison)

This model (Equation 1) gave a sample size of 384 households. In addition, sample size was increased by at least 20% of 384 households to account for nonresponse or invalid responses rate that is normally observed when the questionnaire method is used (Kangwana, 1996). This adjustment therefore suggested a sample size of about 467 household for the study area.

These households were selected randomly using a multi-stage sampling procedure that involved dividing the area that stretched around the mountain into eighteen geographical sections, out of which the following eleven were randomly selected using a Table of random numbers: Gakawa, Naro Moru, Waraza, Kabaru, Sagana, Kiamariga, Njatha–ini, Gitunduti, Chehe, Castle and Irangi. This number of sections was sampled to ensure that at least 40 households per section interviewed for statistical testing, taking into account the nonresponse rate. Each was about 5 - 10 km along the forest- human habitations interface. Within each section, the individual households included in the sample were selected by simple random technique where households along randomly selected roads were interviewed. The precise borders between sections were administrative units at location level.

At the beginning of every interview, prospective interviewees were given an explanation about the purpose of the study and cautioned that the interview was only for research. The intention was to dispel any likely tendency by interviewees to mislead about levels of elephant damage in the hope of higher compensation. A pilot survey indicated that some respondents exaggerated the levels of loss and damage from elephants either out of ignorance or by misleading in the expectation of higher compensation. Therefore, this study disregarded estimates of damage that were greater than the expected yields from the cultivated area for the household concerned. Realized crop yields of the previous year and expected yields of crops during the years of study for the respective areas were provided by office of the Ministry of Agriculture and that of Livestock Development. In situations where prices and yields were not available, values for the nearest area were used. In some farms where evidence of damage was discerned even after passage of time, values were verified by making visits to the sites to validate the respondents' estimates. Adjustments were made on all data to accommodate any significant variations between results provided by the interviewees and that obtained from verification sites (Kangwana, 1996).

Evaluation of severity of elephant damage to farms

The data on level of crop damage was used as an appropriate index for measure of severity of elephant damage. This was because it was the most frequently occurring type of damage and that most farmers were able to estimate the amount in contrast to other types such as breakage of fences and water pipes. This index per household per year was computed as below.

$$\text{Crop damage severity index} = \frac{\text{estimated amount of crop damage x 100}}{\text{Expected yield}} \qquad (2)$$

Expected yields were the realized yields in farms that had not been raided by elephants. Data on average realized yields without elephant damage, and their market prices from location to district levels were obtained from the

District Agriculture offices. Data from respondents on yields and damage was counter checked by comparing them with the expected yields from the area of study against data from the local District Agriculture offices (Equation 2). The computed indices were designated into one class of severity of damage (Table 1).

The mean damage, d, for each sampling section was computed according to Equation 3;

$$n = \sum_{i=1}^{n}(f_i \times r_i) \qquad (3)$$

In addition, mean damage, D, for the entire study area was computed as follows (Equation 4):--

$$D = \sum_{i=1}^{n}\frac{(f_i \times r_i)}{h} \qquad (4)$$

Where,

f = number of households in jth sampling section in ith damage class

r_i= ith mid-class damage estimate

n_i = number of households in jth section with damage estimates

r_i = mid-class damage estimate in jth section

i = 1, 2,…, 6th damage class

j = 1, 2,...., 11th section

h = 317 total number of sample households

The difference between the expected yields of crops without elephant damage and the elephant damage-adjusted value of crops were compared and tested for significance.

Standardization of values

Responses on crop yields and damage were presented by farmers in various terms: for instance, 'area' damaged (e.g. 0.5 Ha of maize), 'volume' (e.g. bags of potatoes) or 'mass' (500 Kg of carrots) Ha^{-1} a^{-1} while others in monetary terms. Thus, all the values were standardized into monetary terms (Kenya Shilling: KSH) per unit time or area by calculating the worth of the yields and losses given as per the market prices and costs at the time of production and damage. The mean crop damage Ha^{-1} in the study area was computed from estimates of households according to model below (equation 5);

$$\textbf{Mean crop damage Ha}^{-1} = \sum\frac{(\text{Mean damage to crops Ha}^{-1} \times \text{household}^{-1})}{\text{Number of households}} \qquad (5)$$

Investigation of factors that determine levels of elephant damage to farms

Two groups of factors that were investigated on their influence on the level of damage by elephants included:

i. Character of the households: A questionnaire was conducted with every sample household and gave data on: type and the acreage under each type of crop produced, realized or expected yield of each crop grown per year under study. In addition, for each wild animal species mentioned to have raided the household, its identity, and frequency of raids. The type of damage, date the said raids occurred, and estimates of amount of losses it caused on the household by each wildlife species was sought. Data on frequency of occurrence of various types of crops grown on farms was sought to establish whether elephants had a preference of particular crops to others in the study area. Existence of preference of crops was investigated by testing for goodness of fit between observed frequencies of reported raids and occurrence of crops in farms.

ii. Distances between households (farms) and natural forest, salt licks, watering points (e.g. river), and elephant (movement) migratory routes. Interviewees were asked to give position salt licks, watering point and elephant migration routes that they knew in their vicinity. These information was verified using a geographical positioning system (GPS) was used to give geographical coordinates of location of each sample household, nearby forests, salt licks, water points (e.g. rivers), and migration routes. The coordinates for each of these attributes reported to used by elephants in the area and sampled household provided points which were used to estimate the distances between farms and natural forests, salt licks, water points and migration routes.

Data analysis

The data obtained was analyzed through Kolmogorov-Smirnov test to measure the significance of possible differences in frequencies of various types of elephant damage on farms.

Kruskal-Wallis test measured the significance of the differences between percentage of damage on farms at different sampling sections; Tukey's Post Hoc multiple comparison test considered the significance damage differences between any pair of means of sampling sections; ANOVA analyzed the effects of proximity of crops to possible determinants of severity of damage, while Pearson correlation coefficient r measured the possible associated determinants of severity of damage (distance between farms and natural forests, elephant migration routes, salt licks and watering points, and frequency of occurrence to crops). Chi-square test assessed elephant preference for crops on farms. In all analyses, confidence level was held at 95% and $P < 0.05$ was set for significance.

Results

Relative importance of elephants as a problem animal species

Elephants were the main crop raiding animals (80.4%, Table 2), followed by buffaloes (8.2%, Table 2) and Sykes monkeys (3.6%, Table 2). Crop raiding was the most frequent type of damage caused by elephants and differed significantly from other damage types (Kolmogorov-Smirnov $Z = 1.762$, $P = 0.004$; Figure 2). Where farms were fenced, elephant broke them down to access the crops.

Occasionally, elephants inflicted injury and caused death to both people and livestock. This led to fear of elephants and traumatized the local people with consequent loss of working person-hours that were not determined. Lesser impacts of elephants (miscellaneous) occurred at low frequencies (1.0%) and included scaring of livestock, breakage of buildings and water pipes, all of which. occurred at low frequencies (1.0%).

Extent and severity of elephant damage

Out of the 467 interviewees, 32 exaggerated the amount of crops lost due to elephant damage. These involved those values that exceeded the expected yields under circumstances where elephants had not damaged the crops. In addition, 118 interviewees reported occurrence of elephant raids but failed to estimate the amounts of losses they incurred. Consequently, only data from the rest, 317 (67.9%) out of 467 interviewees were incorporated for analysis of severity of elephant damage on farms (Table 3).

Results indicated that elephant damage was widely distributed within the study area. Generally, the mean level of damage for the various sampling sections was 16.8% ± 4.64. Majority (60.6%; n = 192) of the respondents reported elephant raids on their farms. About 53.0 % (n = 168) households experienced either no damage or less than 5% level of damage from elephants. This contrasted with 28.1% (n =.168) households, which reported between 5% and 30% damage, while 18.9% (n = 168.) of households had exceptionally high (> 30 %) levels of damage.

The mean percentage of damage on farms at different sampling sections was significantly different (Kruskal-Wallis test: H =53.78, df = 10, P = 0.0001). We desired to find out what sections had the significant differences in the levels of damage. Tukey's Post Hoc multiple comparison test considered the null hypothesis that any pair of means of sampling sections were not statistically different (Zar, 1974). The results showed that there were significant differences (P < 0.0001) between the following; 1): three sections (Chehe, Castle and Irangi) and Gakawa; 2) Kabaru and the three sections (Chehe, Castle and Irangi); 3) Njatha-ini and Castle and Irangi. Households in Kabaru, Njatha-ini and Gakawa located in the western and southern slopes of Mount Kenya had relatively high (>26%) levels of damage while others such as Chehe had none or low (<8%: Table 3).

Factors influencing levels of elephant damage to farms

Crop raiding was correlated with the distance between households and some keys resources required by elephants such as salt licks and water points (Table 4). These resources were located beyond the area of sampled households but were valid for inclusion in analysis. This study showed that a higher percent of farms raided by elephants were those closer to natural forests, elephant migratory routes, salt licks and watering points than those that were farther away from these entities (Table 4). However, the severity of damage was not influenced by nearness of the farms to natural forests, migratory routes, salt licks or watering points (Table 5). It was apparent that upon entry of elephants into a farm, the severity of damage they caused on crops was related to the frequency of occurrence of the crops on the farms (r = 0.982, P = 0.01: Table 6). More than eleven different types of crops were grown in the study area. Maize, Irish potatoes and legumes were the most common crops and had the highest incidences of damage while the least damaged were the fruits. Elephants did not show preference for any specific crop to in the farms ($\chi^2_{v=11}$= 7.772; P = 0.05). Results suggests that the more widespread a crop occurred in the study area, the more frequently it was raided by elephants (r = 0.982).

Discussion

There were several large wild animals in Mount Kenya that came into conflict with the local community over the use of land, with elephants being the most offensive animal. The flagship status of elephants in the environment (WWF, 1997) in its apparent omnipresence, insatiability and gigantic disposition was displayed by the unique and relative high levels of damage that was attributed to it compared to the other species. However, Hoare (2001) cautions that incidences involving elephants are more likely to be reported than those of the other species are. If all incidents involving all animals were reported, it was most likely that the relative importance of elephants would be lower than was the case.

Field results showed that it was not practical to quantify the losses incurred from the data provided for all the different types of elephant damage to farms partly due to paucity of information given by the respondents. For instance, most interviewees did not quantify the economic loss they incurred from lost person-hours from work. Furthermore, quantification of injury and deaths caused to people was difficult for lack of vital data on the individuals killed and injured by elephants. Thus, the results obtained from these calculations were indication of severity of damage and not the actual levels of damage, which could be envisaged to have occurred.

The impacts of crop destruction by wild animals are normally devastating especially on families whose livelihoods depend on subsistence crop farming (Waithaka, 1994; Kiiru, 1996; Hoare, 2001). Elephants are herbivores and it is axiomatic that crop raiding was the major type of damage in the agriculturally high potential area of Mount Kenya region. Generally, the amount of damage incurred by households in the study area was about 16% of the expected yield. Results suggested that there was a higher likelihood of farms that were closer to natural forests, migration routes, salt licks and watering points to be raided more by elephants than those that were farther way. However, there was no significant relationship between levels of damage to crops and their proximity to natural forests, migration routes, salt licks or watering points. Njatha-ini and Kabaru sections had outstanding high levels of damage (> 40%) compared to other sections of the study. Elsewhere in Africa, farming has been abandoned owing to repeated attacks by elephants, e.g. in Kwale, Kenya (Kiiru, 1996); Gabon (Lahm, 1996) and Kibale National Park, Uganda (Naughton-Treves, 1997)).

Variation in the number of farms that were raided by elephants were influenced by their closeness to the forests, salt licks watering points and the routes used frequently by elephants to move into and out of the study area. However, the frequency of occurrence of a given crop appeared to have influenced the level of damage where higher frequencies related to higher levels of damage. Although elephants forage on a variety of crops (Spinage, 1994; Lalm, 1996) and showed preference to some crops such as maize, melons, and beans in Mozambique (de Boer and Ntumi, 2001). However, such preference was not established in this study. Rather, a more generalized form of damage was measured, where elephants on encountering crops caused destroyed crops by uprooting, feeding or trampling on them (Kamweya, 2002). A more robust investigation might confirm whether feeding preference among various crops occurs in this region. This information can enable farmers make informed selection of what crops grow to minimize losses.

Generally, sections such as Kabaru, which had higher presence of elephants, compared to other areas experienced greater levels of damage from elephants. This may have been caused by three factors. First, close proximity to the elephants' points of entry and exit between the forests and the western-lying lowlands of Mount Kenya and croplands. The lowlands were mainly ranches and farms with some patches under crop production. Second, the fragments of natural forests in the western slopes of Mount Kenya, which were important elephant habitats, were surrounded by a dense human settlement. From these forests, elephants made frequent attacks to the farms. Third, both irrigation and rain-fed crops were available to elephants throughout the year.

The relatively lower levels of damage at other sections such as Sagana (24.1%) which was located next to Kabaru may be accounted for by the installation of a high voltage electric fence along their entire perimeter in 2000. Ruiri settlement scheme located on northeastern slopes of Mount Kenya is another human-elephant conflict hotspot that was secluded from elephant menace by an electric fence early 1990s. The fenced areas have reported reduced wildlife-human conflicts effectively (Kamweya, 2002). As has been observed in many parts where elephants range, farms in close proximity to elephant habitats suffer more damage than those farther away (Kenya Wildlife Service, 1996); Parker and Osborn, 2001). Elephants have been shown to stay close to forest-human settlement interface for food and refuge (Bhima, 1998) and therefore when they move into the adjacent farms, farmers attempted to keep them away. Although similar observations were made from this study, there was no statistical significance in levels of damage to crops and distribution of elephants in the forest-settlement interface.

The range covered by elephants in the study area was widespread and not restricted to particular sections. Consequently, the impacts of elephants on the land surrounding Mount Kenya forests were also extensive. This extensiveness of the likely sections elephants would attack farms prohibits meaningful patrol for lack of enough personnel and resources. While the overall damage levels were moderately low, those individuals whose farms were attacked by elephants experienced loss and suffering. There were several methods used by KWS in collaboration with the surrounding communities to alleviate the damage problem. These included erection of fences, wooden stockades, brick walls, vegetation barriers, moats and scaring away of the animals but were largely ineffective. Since the serious conflict continue to occur in many other sections within the study area, concerted efforts by several interested parties are presently undertaking proactive fencing programmes to reduce the incidences of damage. The government policy on managing such issues as contained in the Wildlife Management and Conservation Act of 1976 is overly protective of wildlife at the expense of the local community who feel unprotected from wildlife menace. Apart from those few areas where electric fences have been installed in Mount Kenya and elsewhere in Kenya such as Aberdare and Shimba Hills National parks (Waithaka, 1994; Kiiru, 1996), other mitigation efforts are either non-existent or failed to meet peoples' expectations (KWS, 1996; Kamweya and Gakahu, 2008;). Consequently, the local communities comprising including individual ventures especially ranchers and peasant farmers who have pooled their resources are engaged in on-going fencing projects to keep elephants away from farms (Kamweya, pers. observation)

Conservation Implications

Considered in the entirety of the study area, though the damage to the farms by elephants was quite extensive, its level was generally low but with a few hotspots that had serious damage. Results suggested that most people misconceived the amounts of damage elephants had caused to their farms. This damage, whether and when it was actually low or high, together with the deaths and injuries suffered by the local community, were most likely to have influenced their attitudes towards elephants. Well-balanced wildlife conservation policies that recognize local people's needs with proven conflict mitigation measures such as electric fences should be implemented to correct the negative impression that wildlife, especially the elephants are a nuisance to the interests of the communities with whom they share resources. This may not be achieved if the affected communities are burdened with tasks they suppose should be funded by wildlife managers.

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References

Ayiemba, E .H. O. 1991. The ecology of human settlement in Mount Kenya region: A study of population growth consequences on land use. In: Ojany, F. F., Lisigi, W., Rheker, J. R., Taiti, S. W., Wiessmann, U., and Winiger, M. Ed... Proc. *Intl. Workshop Ecol. and socio econ. of Mount Kenya area. Geographical Bernensia*, **Vol.** A8.

Bhima, R. 1998. Elephant status and conflicts with humans on the western bank of Liwonde National Park, Malawi. *Pachyderm*. 25, 74 – 80.

Caughley, G, 1976. The elephant problem: An alternative hypothesis. E. Afr. Wildl. J., 14: 265 - 283.

Central Bureau of Statistics 2001. The 1999 population and housing census. Counting our people for Development. **Vol**.1 Min. Finance and Development. *The Government Printer*, Nairobi.

Cumming, D.H.M., Du Toit, R.F. and Stuart, S.M. 1990. African Elephant and Rhino Survey and Conservation Action Plan. IUCN/SSC African Rhino and Elephant Specialist Group, IUCN, Gland, Switzerland

De Boer, F. and Ntumi, C. 2001. Elephant crop damage and electric fence construction in the Maputo Elephant Reserve, Mozambique. *Pachyderm.* 30, 49 – 56.

Fisher, A. A., Lang, J.S. and Townsend, J.W. 1998. Handbook for family planning operation research design. Population council, Kenya.

Hoare, R. 2001. Management implications of new research on problem elephants. *Pachyderm*. 30, 44 – 48.

Jaetzold, R. and Schmidt, H. 1983. Farm management handbook of Kenya. **Vol**. II. Nairobi.

Kangwana, K. 1996. Assessing the impacts of human-elephants interactions. *African Wildlife Foundation. AWF Technical Handbook* Series 7.

Kamweya, A.M. 2002. Human-elephant interactions and their social-economic impacts in Mount Kenya and its surrounding areas. *Ph.D. Thesis*, Kenyatta University. Nairobi, Kenya.

Kamweya, A. .M and Gakahu, C. G. 2008. Elephant feeding ecology and commercial forestry in Mount Kenya. *East African Journal of Botany.* 1 (2): 125 - 142

Kenya Wildlife Service 1996. Wildlife-human conflict. *Report of the five-person review group* 19 December 1994.

Kiiru, W. 1996. Management options for Shimba Hills elephants after fencing of the reserve. *Pachyderm*.22, 45 – 46.

Lahm, S.A. 1996. A nationwide survey of crop-raiding by elephants and other species in Gabon. *Pachyderm*. 21, 69 – 77.

Milner,J., Litoroh, M. and Gathua, M. 1993. Mammals of Mount Kenya and its forests: a preliminary survey. *Unpubl. NMK/KIFCON/KWS Report*.

Naughton-Treves, L. 1997. Farming the forest edge: Vulnerable places and people around Kibale National Park, Uganda. *Geographical Review*. 87, 27 - 46.

Njuguna, P., Mbegera, M. and Mbithi, D. 1999. Reconnaissance survey of forest blocks west and east of Rift Valley. Permanent Presidential Commission for soil conservation and afforestation, Kenya.

Omondi, P. Waithaka, J. and Bitok, E.K. 1998. Elephant habitat interaction study in Mount Kenya forest. *Unpubl. Report Kenya Wildlife Service*, Nairobi, Kenya.

Parker, C. 1990. Lions, flies, inbreeding and photography. *E. Afr. Wildl. Soc*., 13: 8 – 9.

Parker, G.E. and Osborn, F. V. 2001. Dual-season crop damage by elephants in eastern Zambezi Valley, Zimbabwe. *Pachyderm*, 30: 49 - 56.

Rheker, J.R. 1992. Forest management and timber industry at Mount Kenya. Laikipia-Mount Kenya Reports No. 16. *Laikipia Research Programme LRP. Group for Development and environment. Institute of Geography,* University of Berne, Switzerland.

Spinage, C. 1994. Elephants. *Poyser Natural History*, London. 319 pp.

Thouless, C. R. 1994. Conflict between humans and elephants on private land in Northern Kenya Oryx, 28: 119- 127.

Thouless, C.R. and Sakwa, J. 1995. Elephant fences in northern Kenya. In: (*Eds)*.. A week with elephants: Proceedings on International Seminar on Asian Elephants. (*Eds*).. Daniel, J. C. and Datye, H. *Bombay Natural History Society.*

Waithaka, J.M. 1994.. The ecological role of elephants in restructuring plant and animal communities in different eco-climatic zones in Kenya and their impacts in land use patterns. *Ph.D. Thesis, Kenyatta University*. Nairobi, Kenya.

Wilcox, B.A. and Murphy, D.D. 1985. Conservation Biology. The effects of fragmentation on extinction. *Amer. Nat*., 125 (6).: 879 – 887.

WWF website. 1997. Conserving Africa's elephants. The World Wildlife Fund for nature. Website. Http://www.nwl. Org.Resource Articles/ elephants.html

Zar, J.H 1974. *Biostatistics Analysis*. 2nd Ed. Prentice-Hall, INC., Englewood, N.J.

Notes

Table 1. Elephant damage assessment criteria for Mount Kenya forest in 1999 and 2000

Rank value	Class of damage severity	Mid-class damage estimate (MCDE) for the damage classes are given
1	(Elephant absent) No damage	0
2	0.1 < 2%	1.1
3	>2 - 5%	3.5
4	>5 – 10%	7.5
5	> 10 – 30%	20.0
6	>30 –100%	65.0

Table 2. Levels of farm damage caused by different animal species in Mount Kenya forest between 1999 and 2000

Problem animal species	n	Percent levels of farm damage
Elephant	758	80.4
Buffalo	77	8.2
Sykes monkey	36	3.6
Leopard	21	2.2
Baboon	12	2.1
Vervet monkey	10	1.3
Hyena	10	1.1
Lion	5	0.5
Wild dog	4	0.4
Wild pig	2	0.2
Total	943	100

Table 3. Percent elephant damage estimates in farms per sampling section in the study area between 1999 and 2000. n = number of households with estimate values included in analysis of damage: data in columns 9th and 10th were excluded from analysis of severity of damage. In brackets are frequency of occurrence of households with a given class of elephant damage in various sampling sections is shown. The mid-class value of damage estimate (MCDE) for the damage classes are given.

Sampling section	*n*	*D*	*A*	*B*	*C*	*E*	*F*	*G*	*H*	*I*
Gakawa	38	0.0 (7)	0.0 (0)	0.3 (3)	1.6 (8)	4.2 (8)	20.5 (12)	16	9	26.6
Naro Moru	35	0.0 (15)	0.0 (0)	0.3 (3)	0.6 (3)	2.9 (5)	16.7 (9)	7	11	20.6
Waraza	29	0.0 (15)	0.0 (1)	0.1 (1)	0.5 (2)	3.4 (5)	11.2 (5)	0	6	15.3
Kabaru	13	0.0 (0)	0.0 (0)	0.3 (1)	1.2 (2)	4.6 (3)	35.0 (7)	1	1	41.0
Sagana	15	0.0 (2)	0.1 (2)	0.2 (1)	1.0 (2)	5.3 (4)	17.3 (4)	1	6	24.1
Kiamariga	24	0.0 (7)	0.0 (0)	0.1 (1)	1.6 (5)	7.5 (9)	5.4 (2)	2	8	14.6
Njatha–ini	9	0.0 (1)	0.0 (0)	0.0 (0)	0.8 (1)	4.4 (2)	36.1 (5)	1	4	41.4
Gitunduti	8	0.0 (2)	0.0 (0)	0.9 (2)	0.9 (1)	2.5 (1)	16.3 (2)	0	4	20.6
Chehe	56	0.0 (32)	0.0 (2)	0.4 (6)	0.8 (6)	2.5 (7)	3.5 (3)	2	17	7.2
Castle	46	0.0 (21)	0.2 (10)	0.4 (5)	0.5 (3)	1.7 (4)	4.2 (3)	2	24	7.1
Irangi	44	0.0 (23)	0.1 (4)	0.1 (1)	0.5 (3)	2.3 (5)	11.8 (8)	0	28	14.8
Overall study area	317	0.0 (125)	0.1 (19)	0.3 (24)	0.9 (36)	3.3 (53)	12.3 (60)	32	118	16.8±4.64

n = sample size, D = No damage reported, A = 0.1 to 2% (MCDE of 1.1%), B = 2 to 5% (MCDE of 3.5%), C = 5 to 10% (MCDE of 7.5%), E = 10 to 30% (MCDE of 20%), F = 30 to 100% (MCDE of 65%), G = Exaggerated losses (>100%), H = no loss estimates given, I = Mean percent damage, D

Table 4. Percent of households raided by elephants with increasing distance (in km) from natural forests, elephant migration routes, salt licks and watering points in the study area.

Distance(km) from households	Natural forest	Migration routes	Salt licks	Watering points
0	35.62	33.56	0.68	6.16
1	36.99	14.38	17.12	30.10
2	9.59	6.85	23.97	32.19
3	8.90	10.27	23.97	17.81
4	3.42	4.79	15.75	8.99
5	1.37	2.74	7.53	1.37
6	1.37	9.59	1.37	1.37
7	1.37	5.48	2.05	0.68
8	--	1.37	0.68	0.68
9	0.68	-	-	-
10	-	4.11	2.05	0.68
11	-	0.68	0.68	-
12	0.68	2.74	2.05	-
13	-	0.68	--	-
15	-	2.05	0.68	-
16	-	-	0.68	-
20	-	0.68	0.68	-
Statistics				
R2	0.902	0.673	0.419	0.82
P value	0.002	0.0002	0.01	0.0003

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Table 5. Variation in mean levels of elephant damage to farms in Kenya shillings per hectare per year with increasing distance (km) from natural forests, migration routes of elephants, water points and salt licks in Mount Kenya

Distance	Natural forest	Migration route	Water-points	Salt lick
0	2328.2	2711.2		8097.2
1	1691.0	878.0	2198.7	1922.5
2	2044.5	1666.4	2010.1	2280.1
3	177.3	1812.5	3383.9	1421.3
4	12550.6	4118.3	5636.3	2093.7
5	1175.1	7304.8	354.3	4961.4
6	15905.2	2987.2	3879.9	8097
7	213.5	1890.7	-	10863.7
8	-	-	-	6747.6
10	-	3486.3	-	1005.4
12	-	2436.4	-	2361.7
R2	0.099	0.218	0.116	0.461
df	1,6	3,7	3,2	3,5
F	0.661	0.652	0.087	1.423
P value	0.447	0.607	0.961	0.340

Table 6. Incidences of elephant damage to different crops in the study area, n = 47 households.

Food crop	Frequency of occurrence of crops in the study area	Number of reported incidences of crop raids	Ratio of reported incidences: frequency of occurrence
Maize	132	88	0.67
Potatoes	131	100	0.76
Legumes	104	59	0.57
Cabbages	66	58	0.88
Tea	29	11	0.38
Coffee	20	7	0.35
Wheat	14	9	0.64
Bananas	9	4	0.44
Sugar cane	4	2	0.50
Cassava	3	2	0.66
Fodder	3	2	0.66
Fruits	3	1	0.33

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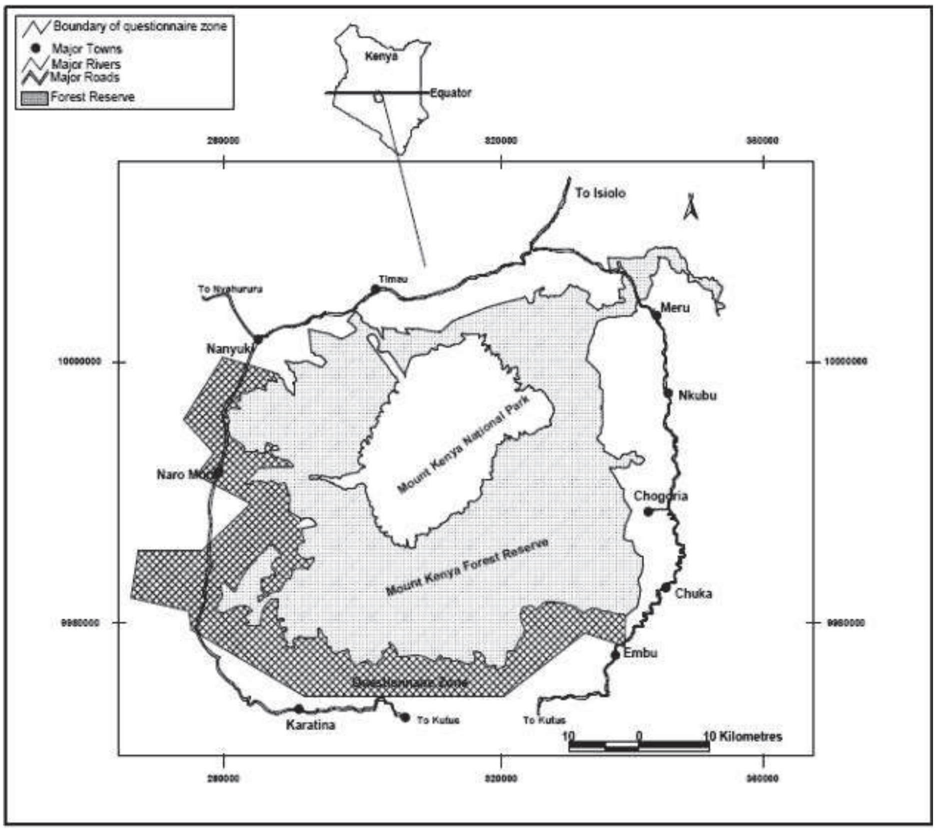

Figure 1. Map showing the location of Mount Kenya Forest Reserve in the study area