Predictive Modelling of Human - Elephant Conflicts in Shimba Hills Ecosystem

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Abstract

Human-elephant conflict (HEC) is a key example of the growing competition between people and wildlife for space and resources in Kenya. To effectively implement mitigation measures, understanding of the underlying factors that determine HEC is required. This study mapped the conflict prone areas in Shimba Hills (SH) Ecosystem. The study used questionnaires, group discussions and available Shimba Hills National Reserve (SHNR) conflict records to gather information on the nature, type and conflict locations (presence data). GIS-based stepwise logistic regression were used to analyze the relationship between the conflict areas and the selected habitat factors including distance to roads, distances to fenced and unfenced areas, distance to water, distance to settlements, slope, elevation and the land cover types. Binary logistic regression was used to determine the presence data of conflict sites and absence data (non-conflict sites). Random points were generated in the study area to represent absence data of conflicts. Results showed that distances to water (β= -0.0012, P=0.000), fence (β= -0.0006, P=0.000), roads (β=0.0005, P=0.016) and settlements (β=0.0002, P=0.037) were significant determinants of HEC. Areas near water, near fence, away from road and settlements were prone to conflicts. The four significant variables were used to generate conflict prone area map. The study successfully identi fied and mapped prone areas for elephant. Such maps are of practical and strategic use to wildlife managers in the SHNR. The study recommended community awareness programs. The programs will educate and involve the community on early detection of HEC and the necessary mitigation measure required.

Keywords***:*** *Human-Elephant Conflict, Predictive Modelling, Shimba Hills Ecosystem*

Introduction

The competition for resources increasingly evokes conflicts wherever humans and wildlife coexist. According to Riley *et al.* (2003), human-elephant interaction becomes a conflict when people experience, perceive and interpret them as producing negative impact. Whereas the conditions for each Human-elephant Conflict (HEC) may be unique, the key driver of such a conflict is co mpetition for space and resources (Balmford *et al.*, 2001). Effective mitigation of human-elephant conflicts require a complete understanding of the problem, its local-specific causes and attempts to solve it, in order to develop effective management strategies for local communities (Sitati *et al.*, 2003). The Shimba Hills (SH) ecosystem in Coastal Kenya, is a site of great concern due to its high biological richness and status as an indigenous homeland. It is a prime example of a location where well-intended management and conservation initiatives have led to even greater conservation dilemmas. Similar to other protected areas in Africa, the limited size of SH cannot adequately sustain its rapidly growing resident elephant population as the extensive browsing behavior is destroying the existing ecosystem and extirpating endemic plant species such as the Cyanometra trees (Kiiru 1995; Kahumbu, 2002). Additionally, elephants have learned to search for food outside of the reserve boundary leading to severe conflic t between elephants within the protected area and farmers living near the Reserve boundary (Kahumbu, 2002; Knickerbocker &Waithaka, 2005). The present situation illustrates the immense challenge of reconciling global biodiversity goals with local residents ‘ concerns for economic development and security. Shimba Hills National Reserve (SHNR) is a typical model of how HEC and subsequent mitigation strategies employed by park managers and conservationists have continued to experience emerging concerns. Local concerns about increases in conflicts with elephants and the haphazard measures adopted when attacks occur in the SH-ecosystem led to this study. The objective was to identify types of conflicts in SH-ecosystem, to identify and map the conflict prone areas.

Materials and Methods

Study Area

The study was carried out in SH ecosystem which comprises of Shimba Hills National Reserve (192 km²), Mwaluganje Elephant Sanctuary (MES) (36 km²), Mkongani North (11 km²) and Mkongani West (14 km²) Forest Reserves making up a total of 253 km^2. It is situated in coastal province, Kwale district. The ecosystem is a remnant coastal rainforest located 35 kilometers south of Mombasa, Kenya between 4°05'-4°21'S and 39°15'-39°30'E . It is composed of a low range of hills which rise to just over 400 meters along the coast of the Indian Ocean. The SH ecosystem is jointly managed by the Kenya Wildlife Service (KWS), Kenya Forest Department (KFD), and the Mwaluganje Elephant Sanctuary Committee (Conservation International, 2007).

The area experiences a humid semi-equatorial climate of an average monthly temperature ranging from 24°C to 28°C and an annual precipitation of 1200mm with long rains between March to June. The vegetation in and around SHNR creates an intricate montage of open grasslands, bushlands, woodlands, and forests. The mosaic of high -canopy forest, grass, deciduous forest and thicket provides ideal habitat for a diverse range of species (Kiiru, 1996). The remnant humid tropical ecosystem contains endemic, threatened, and endangered flora with a total of 1,396 plant species that are endemic to SH and that the forest habitat holds more than half of Kenya's rare tree species. It also habours the endangered Sable antelope (*Hippotragusnigerharris*).

Soil composition of the area is classified as Shimba Grit and Mazeras Sandstone from the Upper Triassic Age (200 million years ago) (Shimba Support Group, 2007). The soil in Kwale has very poor fertility due to excessive leaching, high sand content, and low organic content.

Small-scale agriculture is the most significant source of income in Kwale district, although 92% of the District is categorized as having low agricultural potential (Kahumbu, 2002). The Crops grown here are mainly cassava, maize, sweet potato and pigeon peas and t ree crops such as cashew nut and coconut. The Digo and Duruma, two of the nine subtribes of the Mijikenda group compose the largest populations in Kwale District (Kenyaweb, 2001). Other livelihood activities in the area include; charcoal production and small businesses.

Data Collection

Data collection was done for a period of five months from November 2012 to March 2013. To achieve the objectives, a combination of primary and secondary data collection methods was utilized. The primary data collection method used questionnaires, focused group discussions and observations. Secondary data and GIS techniques were used to gather information on rainfall, landcover, elevation, slopes and conflicts records.

Questionnaires

A total of 11 locations were purposely selected on the bases of (1) a long documented history of human-elephant conflicts (2) villages within the range of 0 to 10 km from the reserve boundary. The 11 locations were stratified into blocks of four regions: North West comprising of Mbuguni and Ngomeni locations; South West having Mkongani, Mwaluphamba and Mwaluvanga; South East having Lukore,Majimboni, and Magawani; and the North East having the Tsimba, Tiwi and Golini (Figure 1). The South East and North East regions were characterized by high populat ions, nearby social facilities that contributed to the settlements being clumped together. The North West and South West regions comprised majorly of rural areas where population was small and scattered.

Respondents to the questionnaire were the general co mmunity in proximity of the Reserve and the staff of KWS and KFS. These groups of respondents were targeted because they were deemed to treasure a wealth of knowledge on the type and nature of conflicts occurring around them. The questionnaire was pre-tested among some group of a population which was not included in the main sample group then necessary corrections were done on the questionnaires. The questionnaires were administered systematically by skipping one or two households depending on the settlemen t pattern of the area. A total of 106 questionnaires were administered.

Focus Group Discussions (FGDs)

Focus Group Discussions (FGDs were used to obtain the conflict sites in the study area as well as complement the information provided on the questionnaires. The FGDs used pre-defined questions to gather information on the human wildlife conflicts around SH-Ecosystem, elephant problem and locating the conflict areas on a baseline map derived from the topographic reference map of the area. Using these conflict areas the actual coordinates of conflict locations were recorded using a handheld Global Positioning System (GPS). The discussions also sought to get the consensus view of group on what can be done to reduce the elephant problem. Selection of participants was based on those who have lived in the area for a minimum period of ten years. The discussions were done by combining two neighbouring locations into one forum; these comprised of Mbuguni-Ngomeni locations, Mkongani-Lukore locations, Mwaluphamba-Mwaluvanga locations, Majimboni-Magawani locations, and Golini-Tsimba-Tiwi locations. The number of participants per discussion group was 10 members. Among them were the officials that were appointed by the community to report on Human wildlife conflict, elderly men and women. Five sessions of group discussions were done. Data collected were collated and integrated in the discussion in a narrative form (Shemweta & Kidegesho, 2000).

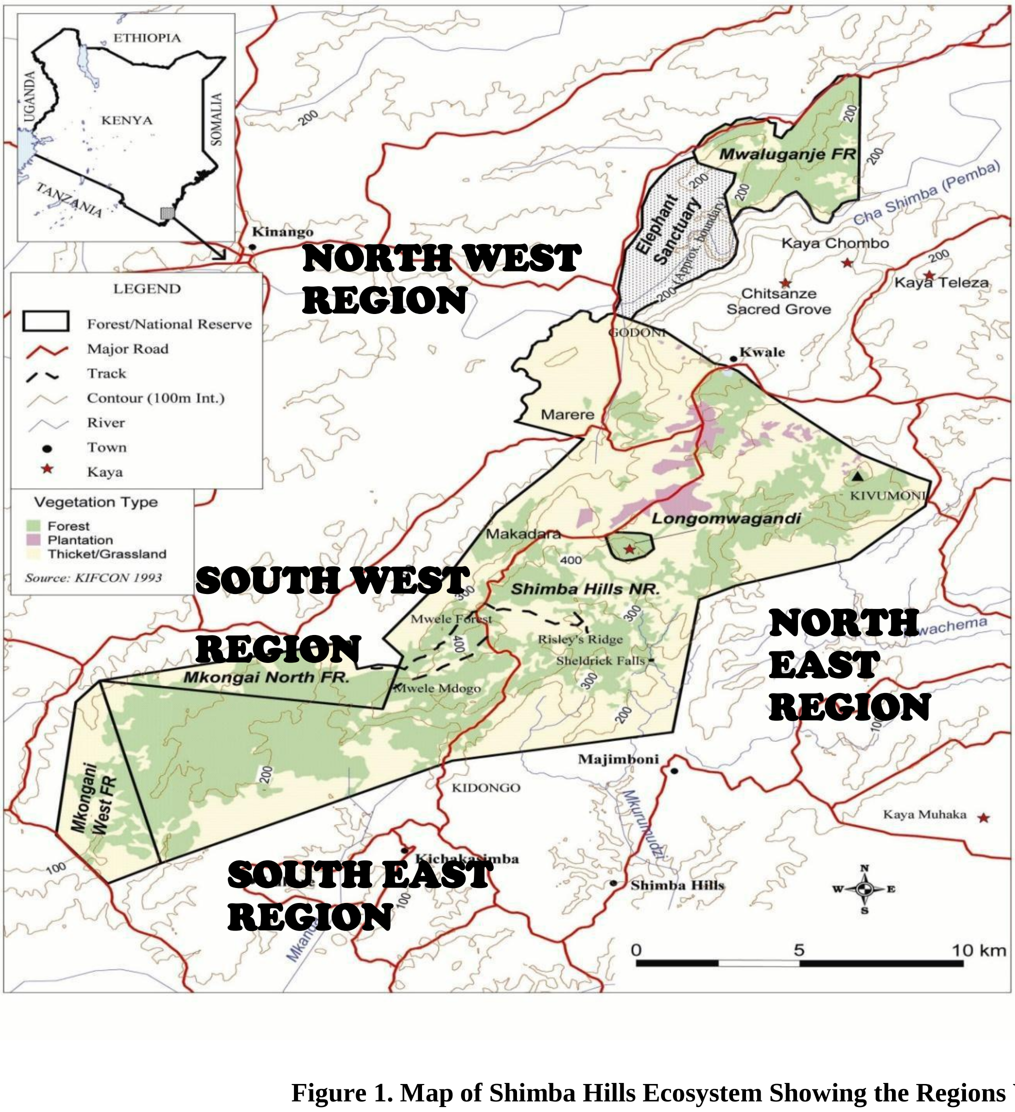

Figure 1. Map of Shimba Hills Ecosystem Showing the Regions Where Data was Collected Map Source: Reuling 2007

GIS Techniques

GIS techniques coupled with secondary data were used to gather data on geographical and environmental variables: elevation, slopes, water, fenced areas, unfenced areas, roads, settlements, landcover, and rainfall. Data for elevation was obtained from Digital Elevation Model (DEM), which wa s downloaded from the Shuttle Radar Topographic Mission website (USGS, 2012). Using ILWIS Academic software (ILWIS, 2009) and the DEM, slope map was prepared in degrees and percentages. Data for water comprised of supplemented water points and the rivers. Data for supplemented water points was obtained by recording their coordinates using a handheld GPS to record their coordinates. Data for rivers were obtained by digitizing them from the scanned topographic map of SHNR.

Shimba Hills National Reserve (SHNR) and Mwaluganje Sanctuary boundaries are fenced with electric fence except in Lukore and Mwaluganje areas. The data for the fenced part of the boundaries were obtained by digitizing scanned maps of Kwale and Msambweni Districts. The coordinates of the two unfenced areas were obtained by recording the two end points in the field using the handheld GPS.

The road network of kwale- Msambweni district consist of tarmacked and murram roads. Both minor and major roads were considered for this study. They were ob tained from the roads department in kwale as shape files. Data for settlements was obtained from the Kwale Youth development database that included the commercial buildings, residential buildings and institutions. The land cover of Kwale district prepared by Reuling (2007) was scanned and digitized to obtain the required land cover types: bush land, forest, woodland, agriculture and town. Rainfall data for the period January 2008 to November 2011 was obtained from the KWS Kwale research records .

A total of 89 conflict locations were recorded in the SH-ecosystem using the handheld GPS to represent the presence points. Absence data when combined with presence data are used in regression based models to predict the relative likelihood of occurrence of conflict s (Pearce & Boyce, 2006). Therefore, an equal number of random points (89 absence points) were randomly generated using the ILWIS 3.3 to represent the absence data points. Apart from the 89 conflict presence points recorded using the GPS, other historical records of 1176 conflicts were obtained from the SHNR records from January 2008 to November 2011. These were useful in relating the frequency of conflict with rainfall and the month of the year.

Data Analysis

The data collected from the questionnaires was entered and coded in excel spreadsheet and analyzed in Statistical Package for Social Sciences (SPSS) version 16. Descriptive statistics in form of percentages, frequencies of counts, tables, bar and pie charts were used for analysis.

In order to relate the habitat factors (independent variables) with conflict locations (response variable) data were analyzed using stepwise logistic regression. The logistic regression was used because it differs with other statistical methods as it is not affected by the ass umptions of variance inequalities across groups and is applicable whenever the dependent variable is binary (Hosmer & Lemeshow, 2000). As recommended by Menard (2010), preliminary analysis of the data was performed to check the assumptions of logistic regression with respect to the selected predictors of the study. Multicollinearity, which is high correlation among predictorsin logistic regression, affects the validity of the statistical tests of the regression coefficients by inflating their standard errors (Garson, 2010). Variance Inflation Factor (VIF) test was done to predict which factor caused multicollinearity problem. Since none of the variables had VIF greater than 10 (Mernard, 2010), all the variables were fit for the logistic regression analysis.

The final best model from stepwise logistic regression was used to prepare a conflict prone areas map in ILWIS package. The following the logistic regression equation (Sokol & Rohlf , 1995) was used:

$$\mathbf{P(X) = Exp(\beta_0 + \beta_1 X_1 + \beta_n X_n)/1+Exp((\beta_0 + \beta_1 X_1 + \beta_n X_n)}$$

Where **P(X)** = probability of occurrence

β_0 =Constant

β_1 = variable 1 intercept

β_n= Variable n intercept.

X_1 = Rastermap of variable 1.

X_n = Raster map of variable n

Results

Types of Human Wildlife Conflicts

The survey showed that many communities around SH ecosystem were dependent on crop farming (38.23%) followed by the mixed farming (36.27%) and trade and professional work (20.59%) (Table1).

The natural resource use by the local communities showed that distance did not matter when obtaining resources (χ^2=0.583,df =2, P=0.11). Chi-square goodness of fit test showed that the utilization of different natural resources was significantly different (χ^2=71.467, df = 7, P=0.001df=7). Firewood

(32.95%) was highly utilized followed by water (18.75%), medicinal plants (17.05%) and charcoal (10.79%). All other uses comprised of only 20.44% (Table 2).

Table 1. Livelihood Activities of Local Community in Shimba Hills Ecosystem

Livelihood Activity	Frequency (n=106)	Percent
Crop Farming	39	36.79
Livestock Keeping	5	4.71
Crop Farming & Livestock keeping (mixed)	37	34.90
Trade	21	19.81

Forms of Conflict

Various forms of conflicts occurring in SH ecosystem ranged from destruction of food stores to human death. The frequency of the various conflicts was significantly different (χ^2 = 132.978, df = 5, P = 0.001). Crop raiding was the major type of conflict (34.8%) experienced in SH ecosystem followed by human threat (29%) (Table 3). A majority of respondents (90.7%) reported that most conflicts in the study area occurred at night. The conflicts that occurred during the day and at all times accounted for 3.7% and 3.6%, respectively. Analysis using the historical (2008-2011) conflicts showed that the highest number of incidents was recorded in July, with a mean of 42.3 incidents per month whereas the lowest recorded incident was in January with 20 incidents per month (Table 4). Human threat was high in March, May and July months whereas crop raiding was at its highest peak.

Table 2: Natural Resources that Communities Obtain from the SHNR

Resources	Frequency (n=106)	Percent
Firewood	58	54.72
Charcoal	19	17.92
Grass	14	13.21
Water	33	31.13
Timber products	14	13.20
Wild fruits	8	7.55

Table 3: Forms of conflict

Forms of Conflict	Frequency (n=106)	Percent
Crop damage	97	91.51
Disease Transmission	29	27.36
Human threat	81	76.42
Damage infrastructure	37	34.91

Table 4. Mean ±SE Monthly Number of HEC Incidents in SH ecosystem (January 2008 to December 2011)

Months	Jan	Feb	Mar*	Apr*	May*	Jun*	Jul	Aug	Sep	Oct*	Nov*	Dec
Mean conflict No.	20	22.67	31	26.25	36.25	26.5	42.25	25	22.25	23	22.75	21
Conflict season rate	Low	High	High	Low	High	Low	High	Low	Low	High	Low	low

*****Shaded region are the rainny months of the year.The rate of conflict was determined by comparing the present month from the previous month.

Relationship of Conflict Sites with the Explanatory Variables

Selection of the Variables

The eight predictor variables tested for significance in explaining conflict sites of the elephant s around SH ecosystem used stepwise logistic regression. The predictor variables were distance to roads, distance to unfenced areas, distance to fenced areas, distance to settlements, and distance to water, slope, land cover (i. e Bush land and forest, woodland, agriculture) and elevation. The final best model had four predictor variables that had significant effect on the conflict occurrence (Table 5). Fence (ß = -0.0006) and water (ß = -0.0012) had a negative effect while settlement (ß =0.0002) and road (ß =0.0005) had positive effect on the probability of conflict occurrence. For the fence, Shorter distances from the SH ecosystem fence experienced more conflicts.

Table 5. Predictor Variables having Significant Effect on the Probability of HEC Occurrence in SH Ecosystem

Variable	B	S.E	Wald	df	P value
roads	.0005	.000	5.790	1	.016
settlement	.0002	.000	4.343	1	.037
Fence	-.0006	.000	33.910	1	.000
Water	-.0012	.000	31.556	1	.000
Constant	4.241	.697	36.984	1	.000

Model Fitness

The final model with the four significant variables had a Nagelkerke R^2 = 65.3%, which indicates that the four predictor variables explains over 65% of the probability of conflict occurrence. The model was also tested using the Hosmer and Lemeshow (H-L) test whereby if the H-L goodness of fit test statistic is greater than 0.05 it implies that the model is fit (Hosmer & Lemeshow, 2000). According to this analysis, H-L was 0.376 implying that there were no difference between the observed and the model predicted values.

Mapping of Human-Elephant Conflict Prone Areas

Figure 3 show a map of potential areas of the probability of occurrence of elephant conflicts in Simba Hills Ecosystem. The map was prepared in ILWIS package using the final model from the logistic regression analysis. The map of the probability of conflict occurrence was divided into 4 classes: low (0 - 0.4); medium (0.4 - 0.7); high (0.7 - 0.9) and very high (0.9 – 1.0) probability. Most of the SH-ecosystem had a very high probability of conflicts (44.6%) followed by high class (30.6%) and medium class (17.2%) with the low class (7.6%) having the smallest percentage. The areas with high probability of conflict are located far away from the reserve boundary.

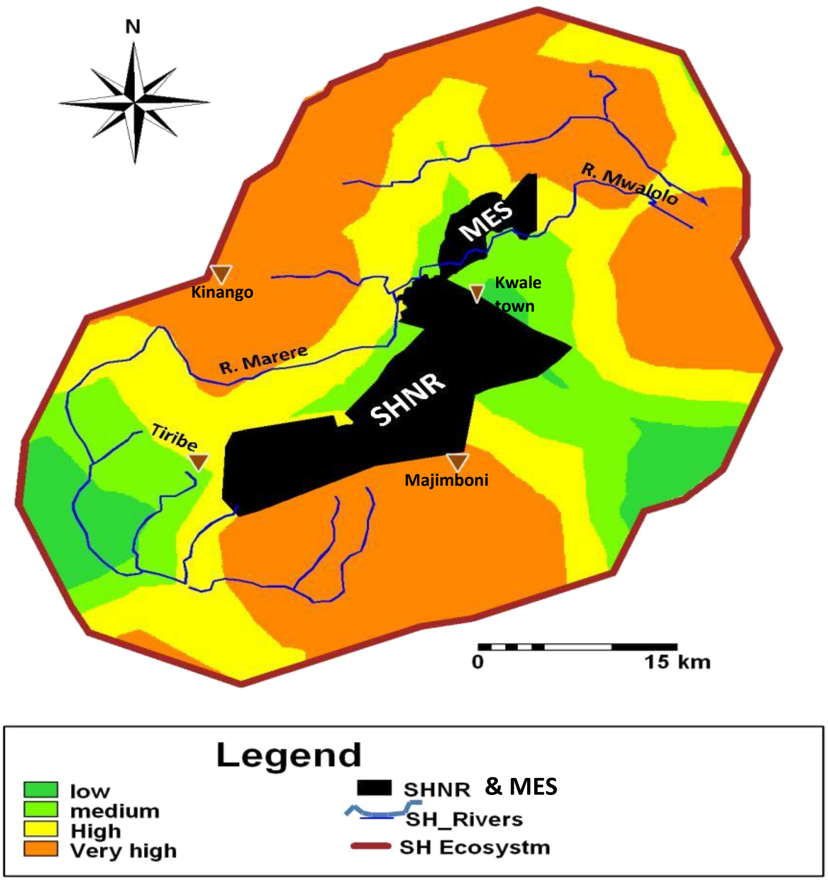

Figure 3. HEC Prone Areas in SHEcosystem

Discussion

Types of Human Wildlife Conflicts

This study indicates that HEC takes place throughout the year with high conflicts experienced in the months of March, May and July. Crop raiding and human threat were the most common types of conflict experienced in SH ecosystem. The peak of crop raiding was in July, which was two months before the harvesting of maize. This may be due to two reasons. First, in many regions in Kenya, maize is harvested when the plant is dried on the field. At this stage the corn cob becomes difficult to chew which increases handling time. Additionally palatability may decrease compared to two months before harvesting when the liquid content of crops is still higher. Parker and Osborn (2001) found a similar trend of crop raiding in Zimbabwe which occurred in the month of March, two months to the harvest.

The highest human threat was experienced in the month of March. Generally, Kwale district experiences water shortage in the months of January, February and early March shortly before the beginning of the rainy season. During this period, the local people travel to obtain water from the waterholes provided by the KWS found at the reserve boundary and hence encounter elephants on their way.

The elephants are causing serious conflicts in SH ecosystem due to their high population of between 400-700 that surpasses their carrying capacity and high density of 1.9 elephants per kilometer (Litoro, 2002). With high elephant numbers, tendencies to search for food elsewhere particularly outside the ecosystem is likely, which would in turn be expected to lead to increased incidences of crop raiding and hence conflict with human beings. In addition, Smith and Kasiki (2000) found that high elephant numbers had the capacity to inflict catastrophic damage during one visit to a field.

Determinants of HEC in SH Ecosystem

Results of the logistic regression analysis revealed that distance to water, roads, settlements, and fence were the most important determinants of HEC in Shimba hills ecosystem. The probability of conflict occurrence was positively related to distance from water. Most conflicts were in areas near water sources. Elephants require drinking water every one or two days (Douglas -Hamilton, 1973). Harris *et al.* (2008) found that the presence of water was a best predictor of elephant presence and if they were close enough to water an elephant seeks areas with high vegetation cover. More conflicts occurred within half a kilometer to about three kilometers away. Similar observations of Short distances to water points were found in Tsavo East national park (Leuthold & Sale, 1973), Serengeti National park in Tanzania (McNaughton, 1990) and Maputo elephant reserve in Mozambique (Boer *et al.*, 2000).

Whilst a vast majority of people living around the SH Reserve are small-scale farmers growing mainly cassava, maize, sweet potato and pigeon peas and tree crops such as cashew nut and coconut, the western side of the ecosystem comprising of Mbuguni and Ngomeni, Mkongani, Mwaluphamba and Mwaluvanga locations were drier than the Eastern side. Farmers in those regions are more vulnerable to crop failure and so, farmers near the water source cultivate crops near water sources where they are raided on by the elephants.

Conflicts occurrence was inversely related to distance from roads. In accordance to natural resource conservation, roads facilitate people movement to areas previously inaccessible. Whereas people move from areas with scarce resources to areas with resource abundance, elephants gene rally prefer areas away from the disturbing effects of roads such as the road kills and poaching (Mukeka, 2010). Elephants in SH ecosystem are driven away from the farms by the rangers using vehicles. Inaccessible road made it difficult for the access to the conflict sites especially at night, making the farms away from the road susceptible for frequent attacks. Sitati *et al.* (2003) found that farms that had been raided frequently were far away from the accessible roads. Barnes *et al*. (1991) found that elephants avoided zones within 7 km of roads because of human disturbance and poaching threat.

Probability of elephant attacks were negatively related to distance from settlements. Avoidance of settlements by the elephants was mainly due to avoidance of human presence and poaching threat (Kyale, 2006). In rural Kwale district, settlements were scattered whereas in the urban area they were clumped together. A study done by Harris *et al.* (2008) found that wherever settlements were found, female elephants with their young stayed 5 km or more away. The communities that had experienced attacks said they were attacked on the months of July while guarding their crops or in March while fetching water and/or firewood at the forest edge. The elephants that managed to go n ear the settlements were few habitual individuals, most probably the bulls.

Probability of conflict occurrence was positively related to distance from reserve fence. However, only the South East region out of the four regions analyzed experienced conflicts near the fence line. This was similar to other studies such as Sam *et al.* (2005) in Bia Conservation Area, Barnes *et al*. (2005) in Kakum Conservation Area, Ghana and Naughton -Treves (1998) in Kibale Forest National Park, Uganda who revealed greater conflicts near the protected areas. The three other regions: North East, North West, and South West found lower levels of human elephant conflicts along the fence. Three reasons could explain this finding. First, there was greater KWS involvement in elephant con trol along the SH ecosystem than further from the reserve. Secondly, farmers along the reserve border spent more time and effort defending their crops than those residing at a greater distance. Finally, probably farmers had abandoned their farms near the fence line. According to the farmers, too much time and expense was required to travel to the KWS main office in Kwale town whereas no tangible benefits were accrued for reporting the damage. A study in TaitaTaveta found significantly lower levels of human elephant conflict in areas bordering national parks (Smith & Kasiki, 2000).

The conflict prone map showed high probability of conflict in the North West and South West regions further away from the fence boundary, this is probably because of the presence of the problem elephants that were translocated to Tsavo East and West national parks. The behaviour of the translocated elephants from SH to Tsavo East (Pinter-Wolloman, 2009) showed that the initially translocated elephants in Tsavo national parks were homing back to SH and some to Malindi. Pinke-Wolloman (2009) found out that some elephants homed back immediately after release, while others waited until the rains before homing.

Conclusion and Recommendation

Conclusion

Four variables viz distance to road, distance to fence, distance to settlement and distance to water were significant predictors of potential conflict areas. It was concluded that the areas far from settlements and road were areas near the electric fence on the South Eastern side i.e Lukore , Majimboni and Magawani. In addition areas near water points were significant predictors of potential prone areas.

Recommendation

There is need to review the existing community awareness and education programmes. The Knowledge about effective local conflict mitigation methods utilized in other areas of high risk can be used to enlighten the local farmers around SH ecosystem. Farmers should be encouraged to work together utilizing various methods of conflict mitigation simultaneously.

The conversion of the solar power to electric power, or increasing the voltage of the solar power, fence repair, and establishing provisions for continued fence maintenance should be foremost on the conservation agenda, along with the replacement of the wooden poles with conc rete posts.

A majority of farmers in Kwale district are dependent on rain fed agriculture. A suggestion on planting the chilli plant was put forward by the KWS management but most farmers were not for it. Other options include bee keeping and cultivation of medicinal plants. A bee keeping project done in Northern Kenya (King *et al.*, 2011) found that beehive fences improved crop production and enhance rural livelihoods through honey sales. Since many communities in Kwale district still depend on medicinal plants from SHNR, an alternative option of cultivating medicinal plants could be used by farmers as their livelihood.

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