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Full Length Research Paper

Human-wildlife conflict in Choke Mountains, Ethiopia

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Human-wildlife conflict is widely known situation where people and wildlife share common resource. This study was conducted to investigate the perceived impact human-wildlife conflict (HWC) in the Choke Mountains, Ethiopia. Data were collected in 2014 and 2015 using semi-structured questionnaires and focus group discussion. Pearson correlation was used to test the relationship between different factors. Majority of respondents (56%) reported the existence of HWC manifested through both crop damage and livestock predation. Anubis baboon, bush pig and porcupine were identified as major crop raiders in the study area. The most prominent sheep predation was caused by common jackal (51.6%). The average crop loss per household per year was 1.56 ± 0.42 quintal. There was a strong negative correlation between the extent of crop damage event and distance of the study area from forest edge ($r = -0.67$, $P < 0.05$). The average sheep loss per household by the common jackal in the last five year was 2.12 ± 0.63. Fire wood collection in the study area is negatively correlated with distance from the natural forest ($r = -0.58$, $P < 0.05$). Encouraging local communities to prepare private grazing land from their own farmland and to keep intact the habitat of wildlife should be done.

Key words: Choke Mountain, crop raiding, forest disturbance, predation.

INTRODUCTION

Human-wildlife conflict (HWC) is a well-known phenomenon throughout sub-Saharan Africa. It can result in negative impact on the livelihoods of local people or their resources, and/or the status of wild animal populations or their habitat and has existed for as long as humans and wild animals have shared the same landscapes and resources (Lamarque et al., 2009).

HWC exists in one form or another all over the world as wildlife requirements encroach on those of human populations and involve several animal species (IUCN, 2005; Lamarque et al., 2009). Human-wildlife conflict is becoming one of the most important threats to the survival of many wildlife species and is an increasingly significant obstacle to the conservation of wildlife (Madden, 2008). It is a serious issue in Africa and other developing areas of the world where rapidly growing human populations and expanding settlements are reducing the areas left for wildlife habitat and increasing the interactions between humans and animals (Blair, 2008; Mwamidi et al., 2012).

The transformation of global landscapes from predominantly wild to anthropogenic over the last centuries has created competition between humans and wildlife for space and other resources and it reached on

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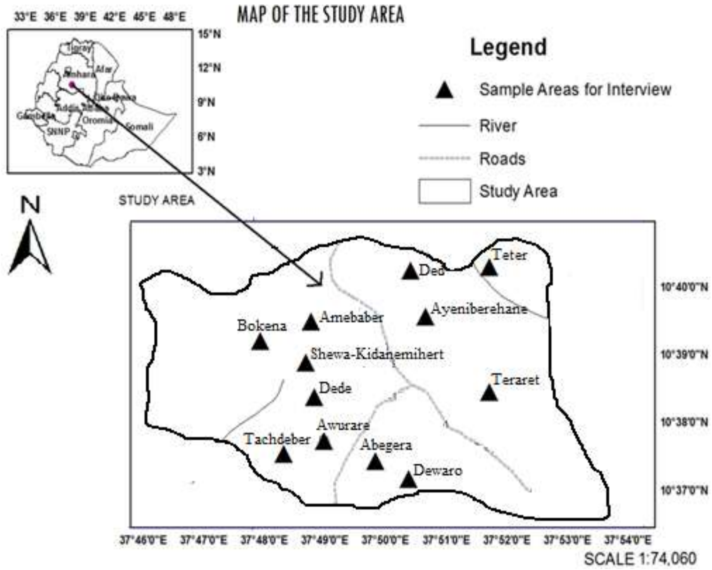

Figure 1. Map of the study area.

unprecedented levels (Kate, 2012). As wildlife habitat becomes more and more fragmented and wildlife gets confined into smaller pockets of suitable habitat, humans and wildlife are increasingly coming into contact and in conflict with each other (Madden, 2008; Lamarque et al., 2009).

Crop damage and livestock predation by wildlife are major source of economic losses (Dickman et al*.,* 2011). Depletion of food supply in the wild forces wildlife to switch to crops and livestock as their food source (Kolowski and Holekamp, 2006). Human population growth and associated increase in rates of resource use, habitat modification and fragmentation is forcing wildlife's to live in increasing proximity to humans (Blair, 2008). The highest intensity of conflicts tends to occur where humans live adjacent to protected areas (Conforti and Azevedo, 2003). When humans live adjacent to larger wildlife habitats and increasingly altered their habitat, conflict between human and wildlife may occur (Michalski et al., 2006).

The major objective of the present study is to investigate the magnitude of human-wildlife conflict in Choke Mountains. This study tried to see wildlife species that are responsible for crop raiding and livestock predation.

MATERIALS AND METHODS

Study area

Choke Mountain is located in East Gojjam Zone of Amhara National Regional State in Central Ethiopia. The mountain range is located on a plateau that rises from a block of meadows and valleys. The central peak is located at 10°42' N and 37°50' E (Fig. 1); the whole mountain area extends over 10°41' to 10°44' N and 37°50' to 37°53' E and covers an area of about 173,443 km^2 (Belay et al., 2013). Its topography is sloppy and mountainous nature, which is sensitive to climatic hazards especially with rainfall variability and intensity. Mean monthly temperature of the area were 17.6°C. In the last ten years the average annual rainfall was 1377.6 mm (ENMSA, 2014).
The Choke Mountains range is harboring a high diversity of plant and animal life. There are 49 bird species are recorded. Furthermore, 16 species of large mammals have been recorded to occur in the area. The major natural habitats in the area are moist moorland, sparsely covered with Giant Lobelia (*Lobelia rhynchopetalum*), lady's mantle (*Alchemilla humania*), Guassa grass (*Festuca spp.*), Red hot poker (*Kniphofia spp.*), St. John's wort (*Hypericum revolutum*), *Helichrysum spp.*, *Arundinaria alpina*, *Erica arborea*, *Euryops pinifolius, Hygenia spp*., *Cordia spp., Ficus spp., Echinopis spp., Acanthus sennii, Erythrina brucei*, and others (CWRDD, 2014) (Figure 1).

Sampling design

Questionnaire survey and focus group discussion were conducted in villages in the Choke Mountains in 2014 to see the perceived magnitude of human-wildlife conflict. A pilot survey was conducted to check the appropriateness of the questionnaire. Out of 24 kebeles, what is that found in and around Choke Mountains range four kebeles namely Abazazh-Weybeyiny, Shewa-Kidanemihert, Sheme and Dangule were selected through stratified random sampling. In the second stage, each village found in the selected kebeles were categorized in to three groups based on their proximity towards the natural forest edge as near (< 1 km), medium(1-5 km) and far (> 5 km), . Following this, one village from each group was randomly selected. Then a total of 12 villages were selected out of four kebeles. Therefore, Awurare, Badema, and Tachdeber villages were selected from Abazazh-Weybeyiny kebele, from Shewa-Kidanemihert kebele Shewa-Kidanemihert, Amibaber and Bokena villages were selected, from Sheme kebele Ayineberehane, Dede and Tetere villages were selected and Abegera, Teraret and Dewaro villages were selected from Dangule kebele at the estimated distance from forest edge near (< 1 km), medium (1-5 km) and far (> 5 km), respectively.

Table 1. Grazing in the forest among different villages.

Villages	N	Grazing inside forest (%)	Grazing outside forest (%)
Abegera	26	76.9	23.1
Amebaber	18	0.0	100
Ayeniberehane	16	37.5	61.5
Awurare	24	91.7	8.3
Badema	18	66	34
Bokena	14	14.3	85.7
Dede	12	0.0	100
Dewaro	16	62.5	37.5
Shiwa-Kidanemihret	26	76.9	23.1
Tachdeber	12	66.7	33.3
Tetere	14	0.0	100
Teraret	20	65	35
Total	216	46.5	53.5

A total of 216 sample household were selected using simple random sampling techniques. Of these 178 were males and the remaining 38 were females. An allocation of the number of sample households to each kebele was proportional to the number of household head living in each selected kebeles. To have complete data, focus group discussions were made with randomly selected 6-10 respondent in selected villages under the guidance of a moderator.

Data analysis

Data were analyzed using descriptive statistics in a form of percentage and frequency was used to analysis socioeconomic profile of the respondents and responses were compared using chi-square test and one-way ANOVA. Pearson Correlation was used to test the relationship between distance of study village from edge of forest and the damage caused.

RESULTS

The community living in Choke Mountains utilized Aba-Jemie forest as grazing land for their livestock and firewood collection. All of the respondents had no private grazing land. Those respondents that were living closer to the forest efficiently use the resources throughout the year. 46.5% of the respondents utilized the forest as a grazing land for their livestock. There was a significant difference ($\chi^2 = 19.95$, df = 11, $P < 0.05$) among villages in using the forest as a grazing land. Most respondents from Awurare (91.7%), Abegera (76.9%) and Shiwa-Kidanemihret (76.9%) utilized the forest. Thus, Awurare utilized the Aba Jemie forest as grazing land most while Dede, Tetere and Amebaber did not use it at all (Table 1). The duration of grazing in the forest was negatively correlated ($r = -0.88$, $P < 0.05$) with distance from the forest.

The respondents used different types of plant species and cow dung as firewood. Some of the plant species were Eucalyptus (*Eucalyptus* spp), St. John wort (*H. revolutum*), Erica (*Erica arborea*), giant lobelia (*L. rhynchopetalum*), and red hot pocker (*Kniphofia* spp). There was a significant difference among villages in terms of firewood collection ($\chi^2 = 92.2$, df =11, $P < 0.001$). Most respondents from Awurare (75%), Abegera (69.2%) and some respondents from Badema (44.4%), Teraret (30%), Tachdeber (16.7%) and few respondents from Dewaro (6.25%) collected firewood from the Aba Gemea Forest (Table 2). Collection of firewood is negatively correlated with distance from the forest ($r = -0.81$, $P < 0.001$) (Table 2).

Most (71%) of the respondents identified five wild animals as problematic that caused crop damage and livestock predation. These were anubis baboon (*Papio anubis*), spotted hyaena (*Crocuta crocuta*), bush pig (*Potamochoerus larvatus*), common jackal (*Canis aures*) and porcupine (*Hystrix cristata*).

Of the respondents, 55.5% of them reported that there were both problem of crop damage and livestock predation to wildlife. Whereas 14.7% of them reported that they faced problem of livestock predation to wildlife. And the remaining, 29.8% did not face any problem caused by wildlife. Result of focus group discussion summarizes that the existence of human-wildlife conflict in all site except Tetere. Respondents were significantly differed in the type of conflict they faced by wildlife in the study area ($\chi^2 = 42.46$, df = 2, $P < 0.05$). 100% and 66.7% respondents from Teter and Dede, respectively reported they did not face any conflict caused by wildlife in the area. Respondents from Awurare (100%), Abegera (100%), Badma (100%), Dewaro (100%), Teraret (76.2%) and Shewa Kidanmeheret (65.4%) were reported the existence of both crop damage and livestock predation particularly sheep (Table 3). Based on the respondents, anubis baboon, bush pig and porcupine caused crop raiding in different degrees. Respondents ranked crop raiding animals according to their level of damage. Porcupine was the most commonly reported crop pest

Table 2. Firewood collection inside and outside of the forests.

Villages	N	Outside the forest (%)	Inside the forest (%)
Abegera	26	30.8	69.2
Amebaber	18	100	0.0
Ayeniberehan	16	100	0.0
Awurare	24	25	75
Badema	18	55.6	44.4
Bokena	14	100	0.0
Dede	12	100	0.0
Dewaro	16	93.8	6.2
Shewa-Kidanemihert	26	100	0.0
Tachdeber	12	83.3	16.7
Teter	14	100	0.0
Teraret	20	70	30
Total	216	79.8	20.2

Table 3. Percentage of respondents who faced conflict due to wildlife.

Villages	Both crop damage and livestock depredation (%)	No conflict at all (%)	Crop damage only (%)	Livestock predation only (%)
Abegera	100	0.0	0.0	0.0
Amebaber	27.8	50	0.0	22.2
Ayenaberehane	31.3	25	0.0	43.7
Awurare	100	0.0	0.0	0.0
Badema	100	0.0	0.0	0.0
Bokena	7.1	64.3	0.0	28.6
Dede	16.7	66.6	0.0	16.7
Dewaro	100	0.0	0.0	0.0
Shewa-Kidanemeheret	65.4	34.6	0.0	0.0
Tach deber	41.6	16.6	0.0	41.8
Tetere	0.0	100	0.0	0.0
Teraret	76.2	0.0	0.0	23.8
Total	55.5	29.8	0.0	14.7

which cause much damage and ranked first.

In the study area, three major types of field crops were grown namely potato, barley and bean in the production season of 2014 in the selected sites. Potato and barley had more size in terms of area coverage on the farmland taken as a sample hence sown in all sites which was 2.5 ha representing 78.4% of the total crop land. Porcupine mainly destroyed potato near maturation stage. Anubis baboon and bush pig were causing damage on crops in all stages from the time of germination to the time of harvest. The average crop loss per household in the year was 1.56 ± 0.42 quintal. There was significant difference on damage event registered by wild animals ($\chi^2 = 97.12$, df = 2, $P < 0.01$).

The result showed that not all crops were equally affected by crop raiders. Most (70.8%) of the respondents claimed that potato was the most vulnerable crop to crop raiders followed by barley (22.2%). Whereas 8% of the respondents reported that bean was the least vulnerable crop to damage caused by wildlife. Most (74%) of the respondents reported that it was increasing (Table 4). All of the respondents from Badema, Abegera, Dewaro and Awurare and 81.3% from Ayeniberehane reported that there was an increase of crop damage by crop raider from time to time. Response on trend of crop damage by crop raiders a mong respondent differed significantly ($\chi^2 = 90.67$, df = 2, $P < 0.05$).

Damage events were significantly differed from site to site ($F_{11\ 205} = 3.6$, $P < 0.05$). There was a significant negative correlation between the extent of crop damage event and distance of the study area from forest edge ($r = -0.67$, $P < 0.05$). As the distance of study village from forest edge decreased damage event registered was high and vice versa. There was also a significant negative

Table 4. Trend of crop damage among villages.

Villages	Trends of crop damage (%)			
	N (216)	Increased %	Decreased %	Unknown %
Abegera	26	100	0.0	0.0
Amebaber	18	66.7	0.0	33.3
Ayeniberehane	16	81.3	0.0	18.7
Awurare	24	100	0.0	0.0
Badema	18	100	0.0	0.0
Bokena	14	42.8	0.0	57.2
Dede	12	33.3	0.0	66.7
Dewaro	16	100	0.0	0
Shewa Kidanemihret	26	80.8	0.0	19.2
Tachdeber	12	83.3	0.0	16.7
Tetere	14	0.0	0.0	100
Teraret	20	100	0.0	0.0
Total	216	74	0	26

Table 5. Correlation of damage event with firewood collection and distance of study site from forest.

Correlation	Firewood collection	Distance from natural forest	Damage event
Firewood collection	1	-0.58	-0.36
Distance from natural forest	-0.58	1	-0.52
Damage event	-0.36	-0.52	1

correlation between livestock predation and distance from the natural forest ($r = -0.93$, $P < 0.05$). Fire wood collection in the study area is negatively correlated with distance from the natural forest ($r = -0.58$, $P < 0.05$) (Table 5). Respondents closer to the natural forest collect firewood more frequently. But there was no correlation between family size and firewood collection ($r = 0.14$, $P > 0.05$).

Majority (70.2%) of the respondents reported that there was damaged livestock by wildlife in the study area while 23% lost their livestock to wildlife. Respondents ranked wildlife which cause livestock predation from the one which causing most damage to the one that cause the least damage. Common jackal was the most commonly reported predator and killed more livestock and ranked first. In focus group discussion also, most respondents reported that there was a strong conflict between local peoples and common jackal. Of the respondent who reported that there was a conflict in their villages about 40.8% of them lost their livestock especially sheep either to common jackal, Anubis baboon or hyena in the last five years. Out of these respondents 51% reported as lost sheep to common jackal alone. In focus group discussion most of the respondents reported that the loss of sheep to common jackal was common to the community. The average sheep loss per household by the common jackal in the last five years was 2.12 ± 0.63. On the other hand, the reported sheep loss to the common jackal differed ($\chi^2 = 68.3$, df =11, $P < 0.001$) among villages. All of the respondents from Tetere reported the absence of predation by wildlife but all of the respondents from Awurare and Badema reported predation by the common jackal (Table 6).

Distance of villages from the forest edge and sheep predation were negatively correlated ($r = -0.96$, $P < 0.05$). Thus, distance from the forest edge was considered as the determinant factor for sheep loss to common jackal. There was also correlation ($r = 0.09$, $P < 0.05$) between predation by the common jackal and the number of sheep per household. Those who had large number of sheep reported greater loss of sheep to the common jackal than those who had less number of sheep.

Response on trend of livestock predation among respondents differed significantly ($\chi^2 = 90.67$, df = 3, $P < 0.001$). About 54.6% of the respondents reported that it is increasing whereas 15.6% of them said it is unknown and finally no one reported that the trend of livestock predation was decreasing (Table 7). In focus group discussion also, the majority of respondents reported that trend of livestock predation by common jackal was increasing.

DISCUSSION

Among the different wild animals, anubis baboon, bush

Table 6. Sheep predation by the common jackal and other wild animals in different villages.

Villages	N	No predation (%)	Predation by common jackal (%)	Predation by other wild animals (%)
Abegera	26	0.0	80.1	19.9
Amebaber	18	50	27.8	22.2
Ayeniberhane	16	25	56.3	18.7
Awurare	24	0.0	100	0.0
Badema	18	0.0	100	0.0
Bokena	14	64.3	0.0	35.7
Dede	12	66.6	16.6	16.6
Dewaro	16	0.0	81.3	18.7
Shewa-Kidanemihert	26	34.6	38.5	26.9
Tachdeber	12	16.6	58.4	25
Teter	14	100	0.0	0.0
Teraret	20	0.0	60	40
Total	216	29.8	51.6	18.6

Table 7. Trend of predation by common jackal.

Villages	N	No predation (%)	Increased (%)	Decreased (%)	Unknown (%)
Abegera	26	0.0	80.8	0.0	19.2
Amebaber	18	50	27.8	0.0	22.2
Ayeniberehane	16	25	56.3	0.0	18.7
Awurare	24	0.0	100	0.0	0.0
Badema	18	0.0	100	0.0	0.0
Bokena	14	64.3	30.3	0.0	5.4
Dede	12	66.6	8.4	0.0	25
Dewaro	16	0.0	81.3	0.0	18.7
Shewa-Kidanmihret	26	34.6	38.5	0.0	26.9
Tachdeber	12	16.6	66.7	0.0	16.7
Teter	14	100	0.0	0.0	0.0
Teraret	20	0.0	65	0.0	35
Total	216	29.8	54.6	0.0	15.6

pig and porcupine caused crop raiding in different degree and respondents ranked crop raiding wild animals from the one which causing most damage to the one that cause the least damage. Aharikundia and Tweheyo (2011) reported that baboons and bush pigs were crop raiders in Uganda. Other reports also explained that worldwide primates and bush pigs were among the species most frequently cited by farmers as notorious crop raiders, capable of causing heavy crop damage; porcupine are also involved (Sillero-Zubiri and Switzer, 2004). Both studies agreed with the present study.

The percentage of crop loss increased as the distance between natural forest edge and the study village decrease. There was negative correlation between crop damage and distance from natural forest ($r = -0.67$, $P < 0.05$). The result was in agreement with finding of Hill (2000) and Fungo (2011) who reported that farms most at risk to losses of crop were near to the forest edge than far from the forest. Whereas disagreed with finding of Gubbi (2012) who reported farmland at a distance of 3.1-5.0 km experienced more conflict than farmland at a distance 0-1.0 km from Nagarahole National Park, India.

Respondents mentioned common jackal, spotted hyena and anubis baboon were the most important predators of livestock. A study in Brazil reported that livestock predation by mammalian carnivore is the most frequent sources of conflict between human and wildlife (Conforti and Azevedo, 2003). However, the conflict with common jackal was serious. From the total predated livestock 73.5% was by common jackal in the last five years. Sheep predation by common jackal was more intense. This result was in agreement with Getachew (2010) who reported that human conflict with jackals was very serious compared to other carnivore predators due to sheep predation. Spotted hyena is another problematic animal for the local community but the loss livestock to spotted hyena as result of carelessness of the owner. Unless the livestock are left on field during night time spotted hyenas do not dare to come close to human settlements and attack livestock.

Among villages sheep predation by common jackals was very significant (P < 0.001). Distance of villages from the forest edge and sheep predation were negatively correlated (r = -0.96, P < 0.05). Distance from the forest edge was considered as the determinant factor for sheep loss to common jackal. The result was in agreement with study in SMNP showed that distance from the park was correlated with sheep loss to the Ethiopian wolf (Mesele et al., 2008). According to the present study, 54.6% of the respondents reported that the trend of livestock predation by common jackal is increasing but no one reported that the trend of livestock predation was decreasing.

The local people had no sufficient private grazing land therefore keep their sheep during the day time away from settlement area in communal grazing fields mainly in the Aba Jemie forest edge. The majority of respondents from Awurare, Abegera and ShewaKidanMihert have serious problem of grazing land and they were using largely the forest for grazing livestock as they close to the forest. Decreasing distance of the villages from the forest increased the frequency of grazing in the forest (r = -0.88, P < 0.05). Similarly as reported by Getachew Simeneh (2010), livestock from nearby villages stay for longer time in Guassa conservation area than villages from far away.

Firewood collection is negatively correlated with distance from the forest (r = -0.58, P < 0.001). Respondents closer to the forest collect firewood frequently from the forest. Thus, most respondents from Awurare (75%) and Abegra (69.2%) collected firewood from natural forest. The result was in agreement with Mesele et al. (2009) reported in SMNP who lived closer to the park collect firewood more frequently than those who lived far from the park.

Conclusion

Conflict between human and wildlife existed since the dawn of humanity and is an increasing concern in all parts of the world particularly in developing nations where peoples depend on agriculture. The present study investigated the prevalence of human-wildlife conflict in Choke Mountains and manifested through crop damage and livestock predation. The cause of human wildlife conflict were wildlife habitat disturbance, increased agricultural land around forest edge, proximity to natural forest, nature of the area hence it is forest area and the contribution of all mentioned causes.

Porcupine was the most commonly reported crop raiders and golden jackal was the most common wildlife causing domestic animals depredation. Crop raiders cause significant loss on farmers' production. Potato was the highest vulnerable crop to damage whereas sheep were the most vulnerable livestock. The trend of crop damage was increasing from time to time. In general,
Most of the biological diversities, ecosystems and functions in Choke Mountains are heavily threatened. A mechanism should be required where both the wildlife and people live without affecting one another.

Conflict of Interests

The authors have not declared any conflict of interests.

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REFERENCES

Aharikundira M, Tweheyo M (2011). Human-wildlife conflict and its implication for conservation around Bwindi, Impenetrable National Park, USDA forest service proceedings RMRS-p-6. pp. 39-44.

Belay S, Benjamin FZ, Mutlu O (2013). Agroecosytem analysis of the Choke Mountain Watersheds, Ethiopa. Sustain. 5:592-616.

Blair A (2008). Human-wildlife conflict in Laikipia north, Kenya: comparing official reports with the experiences of Maasai pastoralists. J. Appl. Ecol. 41:89-112.

Conforti VA, de Azevedo FC (2003). Local perceptions of jaguars (*Panthera onca*) and pumas (*Puma concolor*) in the Iguacu National Park area, south Brazil. Biol. Conserv. 111:215-221.

CWRDD (Choke Watershed Research and Development Directorate), (2014). Debre Markos University, Ethiopia. P 5.

Dickman A, Macdonald E, Macdonald D (2011). A review of financial instruments to pay for predator conservation and encouraging human carnivore coexistence. PNAS. 108:13937-13944.

ENMSA (Ethiopian National Meteorology Service) (2014). Meteorological report of ten years 2003-2013. Ethiopian National Meteorology Agency, Addis Ababa, Ethiopia.

Fungo B (2011). A review crop raiding around protected areas, Kampala, Uganda. Environ. Res. J. 5(2):87-92.

Getachew S (2010). Habitat use and diet of golden jackal (*Canis aureus*) and human-carnivore conflict in Guassa community conservation area, Menz, (MSc Thesis), Unpublished, Addis Abeba University, Ethiopia. pp.57.

Gubbi S (2012). Patterns and correlates of human elephant conflict around a south Indian reserve. Biol. Conserv. 148(1):88-95.

Hill MC (2000). Conflict of interest between people and baboons, crop raiding in Uganda. Int. J. Primatol. 21(2):91-98.

IUCN (2005). Preventing and mitigating human-wildlife conflicts: WPC Recommendation. pp. 139-218.

Kate K (2012). Possible strategies/practices in reducing wild animal (primate) crop raids in unprotected areas in Hoima District, Uganda. P 20.

Kolowski JM, Holekamp KE (2006). Spatial, temporal, and physical characteristics of livestock depredations by large carnivores along a Kenyan reserve border. Biol. Conserv. 128:529-541.

Lamarque F, Anderson J, Fergusson R, Lagrange M, Osei Owusu Y, Bakker L (2009). Human-wildlife conflict in Africa: cause, consequences and management strategies. Conserv. Biol. 17:1512-1520.

Madden F (2008). The growing conflict between humans and wildlife: law and policy as contributing and mitigating factors. J. Int. Wildlife Law Policy 11:189-206.

Mesele Y, Afework B, Zelealem T (2008). Human-Ethiopian wolf conflict in and around the Simien Mountains National Park. Int. J. Ecol. Environ. Sci. 34(2):149-155.

Mesele Y, Afework B, Zelealem T (2009). Human-wildlife conflict in and around the Simien Mountains National Park. Ethiopian J. Sci. 32(1):57-64.

Michalski F, Boulhosa R, Faria A, Peres A (2006). Human-wildlife conflicts in a fragmented Amazonian forest landscape: determinants of large field depredation on livestock. Anim. Conserv. 9:179-188.

Mwamidi D, Nunow A, Mwasi SH (2012). The Use of indigenous knowledge in minimizing human-wildlife conflict: the case of Taita Community, Kenya. Int. J. Curr. Res. 4(2):26-30.

Sillero-Zubiri C, Stwizer D (2004). Management of wild Canids in human dominated landscapes. People and wildlife initiative, wildlife conservation research unit, Oxford University, UK. P 16.

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Home range sizes and space use of African elephants (*Loxodonta africana*) in the Southern Kenya and Northern Tanzania borderland landscape

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The African elephant (*Loxodonta africana*) require vast areas to meet their survival needs such as food, mates, water, resting sites, and look up positions; the area referred to as home range. We collared 9 bull and 3 female elephants using satellite-linked Geographic Positioning System (GPS) collars in February 2013. Their movements were monitored up to April 2016 in the wider Amboseli landscape. We estimated their home ranges using 100% minimum convex polygon (MCP) and 95% Fixed Kernel Density Estimator (KDE) methods. A total of 48,852 GPS points were used representing 77% of the expected GPS points. This study revealed that bulls had a larger total home range size (MCP = 32,110 km²; KDE = 3,170 km² compared to females (MCP = 10,515 km²; KDE = 3,070 km²). The 95% confidence interval of the monthly range (95% KDE) for all elephants was 6,130 to 7,025 km² with the minimum and maximum range being 5,200 and 7,790 km² respectively. Females had smaller home ranges during the dry and wet season (MCP: dry = 2,974 km²; wet = 1,828 km²; KDE: dry = 2,810 km²; wet = 3,070 km²) than bulls (MCP: dry = 3,312 km²; wet = 13,288 km²; KDE: dry = 2,960 km²; wet = 3,720 km²). The variations of the elephant home range could have been influenced by an interaction of factors including rainfall, human disturbances and land use (e.g., farms, settlements, road network, and fences), water availability, bush cover, food availability, and tracking period. The most important areas that had key habitats for elephants were scattered throughout the Kenya/Tanzania borderland. The Amboseli-Tsavo-Magadi-Natron-West Kilimanjaro elephant population roams within specific areas of the landscape. Trans-boundary efforts should be enhanced to ensure sound management of the elephant-habitat-people interface for continued well-being of the elephant population.

Key words: Amboseli ecosystem, elephant, home range, minimum convex polygon, Kenya/Tanzania borderland, kernel density estimator.

INTRODUCTION

The African elephant (*Loxodonta africana*) are mega-herbivores that require large areas for acquisition of the necessary resources for self-sustenance. Ecologists refer to this area as the home range. The initial definition of home range was provided by Burt (1943) as, "the area traversed by individual in the normal activities of food gathering, mating and caring of the young". Mohr (1947) estimates home range using the minimum convex polygon method that completely encloses all data points by connecting the outer locations in such a way as to create a convex polygon. The area under the polygon is used by the animal to satisfy its resource requirements over a specified time (e.g., mates, food, water, escape routes from enemies, resting sites, and look up positions; Delany, 1982; Jewell, 1966).

The concept of animal home range has been discussed in detail by different authors including Osborn (2004), Walter et al. (2011), Odrenj (2011), Douglas-Hamilton et al. (2005), Lyons et al. (2013) and Kie et al. (2016). The authors agree that the size of an animal home range is an exact area whose size depends on the method and parameters used to define and estimate it. Some methods used to estimate home range include: 100% minimum convex polygon (MCP) (Mohr, 1947; Leuthold and Sale 1973; Lindeque and Lindeque, 1991; Thouless, 1996; Whyte, 1996; Getzand Wilmers, 2004; Getz et al., 2007; Foguekem et al., 2007; Ipavec et al., 2007), squared grids (SG) (Douglas-Hamilton et al., 2005), 95% kernel density estimation (KDE; Leggett, 2006; Lyons et al., 2013), and Brownian Bridge Movement Models (BBMM) (Horne et al., 2007; Fischer et al., 2013; Walter et al., 2011). More recent home range estimation methods that combine the simplicity of polygon methods with the robustness of kernel methods have been developed (Lyons et al., 2013). These methods superimpose and then aggregate non-parametric shapes constructed around each point and include Voronoi polygons (Casaer et al., 1999), Delaunay triangles (Downs and Horner, 2009) and Local Convex Hull (LoCoH) approach (Getz and Wilmers, 2004; Getz et al., 2007). These current methods (e.g., LoCoH and BBMM) better estimate animal home range than the old methods e.g., MCP (Kie et al., 2016). However, the current methods have not been used long enough and researchers are still using the old methods to facilitate comparison of home range sizes over time (Kie et al., 2016).

Individual elephants are known to range over vast areas, varying from 10^1 to 10^3 km^2 (Leuthold and Sale, 1973; Lindeque and Lindeque, 1991; Thouless, 1995, 1996; Whyte, 1996; Douglas-Hamilton et al., 2005; Leggett, 2006; Foguekem et al., 2007; Ipavec et al., 2007; Ngene et al., 2009). Table 1 provides a summary of the sizes of African elephants in different ecosystems. Elephant home ranges were small in fenced areas (10 km^2 to about 80 km^2) and large in open areas (90 to about 800 km^2; Douglas-Hamilton et al., 2005; Leggett, 2006; Dolmia et al., 2007; Ngene et al., 2009; Kikoti, 2009). Long distance migrations of over 90 and 400 km in length have been reported from Kenya (Ngene et al., 2009), Mali (Blake et al., 2003) and Namibia (Leggett, 2006; Lindeque and Lindeque, 1991).

Despite the importance of the home range concept, there is no consensus among scientists studying animal movements on how to estimate the home range size of animals (Reinecke et al., 2014). However, in this paper, we estimate the home range of elephant in Amboseli ecosystem using the MCP and KDE methods. Despite its limitations (Powell, 2000; Osborn, 2004), the 100% MCP method was selected to facilitate comparisons of Amboseli elephant home ranges with those of West Kilimanjaro-Loliondo-Natron-Manyara areas in northern Tanzania (Kikoti, 2009). The 95% KDE method will provide a baseline for future comparisons of elephant home ranges in the study area. Although the MCP method estimates a larger home range size than KDE, it has been used for a long time and therefore, it offers an opportunity for comparing elephant home range in different areas (Osborn, 2004; Worton, 1989; Powell, 2000; Lyons et al., 2013; Kie et al., 2016). However, there is need to use another method to accurately estimate the elephant home range and offer an opportunity for future comparisons, especially with the current challenges of land use changes and their implications on elephant ranging patterns in the area. The 95% KDE method is popular (Worton, 1989; Lyons et al., 2013) because it is based on the superposition of Gaussian or compact (e.g., uniform or Epinechnikov) kernels and is more suitable for concave geometries (Lyons et al., 2013). Also, the method can estimate probability contours, and is easy to use due to its implementation in a variety of software packages (Lyons et al., 2013; Laver and Kelly, 2008). Regardless of the methodology used to estimate home range, changes of land use and land tenure systems affect utilization of range by elephants and constrict their home ranges (Doughlas-Hamilton et al., 2005; Gara et al., 2016a, b). The increase in human population and changes in lifestyles have resulted to changes in land use emanating from mushrooming of human infrastructure (e.g., roads, human settlements, fences and crop fields) within elephant ranges (Gara, 2014; Gara et al., 2016a, b). These changes impede wildlife movement and fragment prime elephants habitats (Burn Silver et al., 2008). Understanding elephant home range and space use in fragmentation landscape is critical for conservation and mitigating human-elephant conflicts (Gara et al., 2016a, b). In most savanna ecosystem across Africa landscape fragmentation due to land use and land tenure changes is understood to be a major threat to elephant and other

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Table 1. Size of elephant home range in different ecosystems.

Location	Home range size (km^2)	Country	Reference
Amboseli NP	100-200	Kenya	Douglas-Hamilton et al. (2005)
Shimba Hills	10-80	Kenya	Douglas-Hamilton et al. (2005)
Meru NP	200-300	Kenya	Douglas-Hamilton et al. (2005)
Marsabit	260-910	Kenya	Ngene et al. (2009)
Samburu-Laikipia	100-700	Kenya	Douglas-Hamilton et al. (2005)
West Kilimanjaro-Natron	191-3698	Tanzania	Kikoti (2009)
Krugar NP	129-1255	South Africa	Whyte (1993)
Hwange NP	1038-2981	Zimbabwe	Conybeare (1991)
Waza NP	248-3066	Cameroon	Tchamba et al. (1995)
Queen Elizabeth NP	363-500	Uganda	Abe (1994)
Sengwa	322	Zimbabwe	Osborn (1998)
Lake Manyara NP	10-57	Tanzania	Douglas-Hamilton (1972)
Tsavo East NP	1035-2380	Kenya	Leuthold (1977) and Leuthold and Sale (1973)
Tsavo West NP	294-408	Kenya	Leuthold (1977) and Leuthold and Sale (1973)
Etosha NP and Kaokoveld	5800-8700	Namibia	Lindeque and Lindeque (1991)
Northern Namib desert	1763-2944	Namibia	Viljoen (1989)

NP = National Park.

large mammals' distribution (Groom and Western, 2013). In Kenya, most protected area (parks, reserves and sanctuaries) aimed at *in-situ* conservation of different types of wildlife are bordered by human settlements (Graham et al., 2009). The Amboseli National Park is surrounded by six community ranches that are used by the Maasai agro-pastoralists for livestock grazing and subsistence and commercial crop farming (Hobbs et al., 2008; Gara, 2014).

These ranches act as dispersal areas and migratory corridors for elephants as they endeavor to connect cut off habitats (Burn Silver et al., 2008; Gara, 2014). However, these community ranches have experienced increased landscape fragmentation as a result of sedentarization of the Maasai, intensification of different landuse types and changing land tenure system (Ogutu et al., 2009; Gara et al., 2016a, b).

Landscape fragmentation as a result of sedentarization in the ranches has resulted in the increase of human-elephant conflict. The human-elephant conflicts in the area around Amboseli National Park are intensified by the fact that the elephants spend over 63% of their time outside the Amboseli National Park (Okello and D'Amour, 2008).

This paper maps the home ranges of 12 GPS-collared elephants in the Amboseli ecosystem using the 100% MCP and 95% KDE methods. We estimate the total and seasonal home range of the elephants (all combined, by sex [bull and females], and individual elephant). We also identify core areas utilized by the elephants using the 95% KDE method to discern key habitats important to the elephants as well as identify ranches important for elephant conservation.

MATERIALS AND METHODS

Study area

The Amboselie cosystem is located in Loitoktok Sub-County of Kajiado County. The ecosystem stretches between Mount Kilimanjaro, Chyulu Hills, Tsavo West National Park and the Kenya/Tanzania border. The current study area covers about 3,400 km^2 (Figure 1). Administratively, the Amboseli ecosystem consists of Amboseli National Park and the surrounding six group ranches (KWS, 2014). The six group ranches include: Kimana/Tikondo, Olgulului/Olararashi, Selengei, Mbirikani, Kuku, and Rombo and cover an area of about 506,329 ha (KWS, 2014). In addition, it includes the former 48 individual ranches located on the slope of Kilimanjaro Mountain that are now under rain fed crop farming (KWS, 2014). These ranches were all once connected together and with Amboseli National Park but today, human settlements, farms, fences and road networks are slowly making them more isolated from each other and the park (Kioko and Okello, 2010).

The area falls in the agro-ecological zones V and VI, and is hence classified as arid to semi-arid savanna (Gara, 2014). It is more suitable for pastoralism rather than crop farming and has a high potential for conservation of wildlife and tourism based enterprises. The rainfall shows spatiotemporal variations during the year. Annual rainfall ranges from 500 to 600 mm in the north to 250 to 300 mm in Amboseli National Park (Gara, 2014). The rain falls in two seasons with short rains being experienced from November to January and long rains from March to April. The two rainy seasons are interspersed by two dry periods (February, May, June, July, August, September, October; Altmann et al., 2002; Gara, 2014). Surface water is scarce other than permanent water in swamps and artificial waterholes in the southeast part of the ecosystem (BurnSilver et al., 2008). Temperature varies from 20 to 30°C (Gara, 2014). Elevation ranges from 850 m above sea level to 1350 m above sea level (Gara, 2014). The ecosystem is dominated by the following vegetation types: The broad leaf, dry tropical forests and woodlands on the Kilimanjaro and Chyulu slopes; open grassland, riverine forest, halophytic grass and scrubland in the Amboseli Basin; and, scattered *Commiphora* and *Acacia*

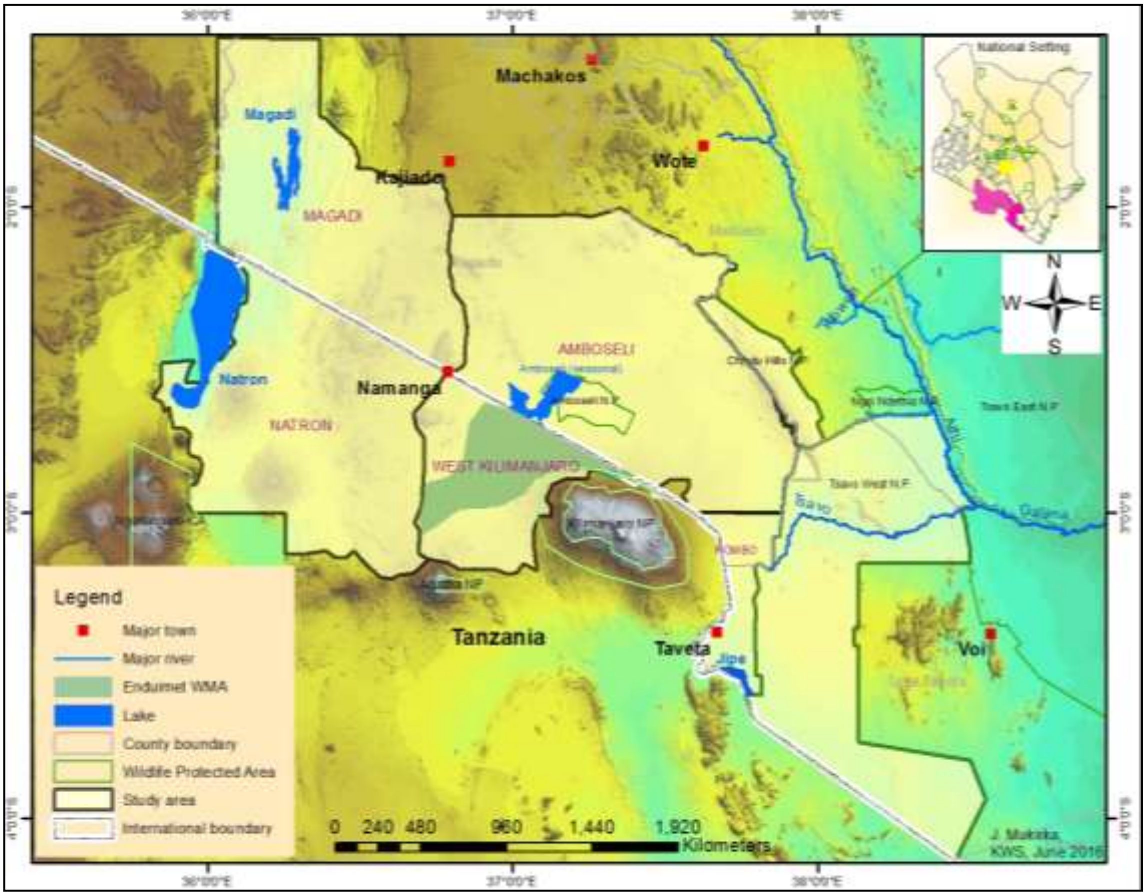

Figure 1. Map of the Amboseli ecosystem that includes the Amboseli National Park, Tsavo West National Park, Chyulu National Park and surrounding areas.

woodlands within the surrounding ranches (Howe et al., 2013; Western, 2007).

Data on elephant locations

Data on the space-use of elephants were collected from 12 elephants (9 bulls and 3 females) collared with satellite-linked GPS collars in 2013 (between: 18th February 2013 and 15th March 2013; and, 2nd December 2013 and 5th December 2013) and 2014 (between 23rd April 2014 and 24th April 2014) by Kenya Wildlife Service (KWS) and the International Fund for Animal Welfare (IFAW). The collars were supplied by African Wildlife Tracking, South Africa and were satellite GPS/VHF model. The collaring operation followed procedures described by Ngene et al. (2013). The collared elephants belonged to different family groups. All the elephants were collared outside Amboseli National Park, with the objective of observing and monitoring their movement patterns outside the park and understanding when the elephants utilize the park. Table 1 provides details of the collared elephants. Figure 2 shows the point data of all the 12 collared elephants.

The collared elephants were immobilized with *Etorphine hydrochloride* (18 mg) administered using a dart gun. The immobilized elephants were then revived using *diprenorphine* (54 mg). The GPS collars were configured to acquire one GPS fix after every four hours. The GPS fixes were acquired in form of geographic coordinates (latitude/longitude) format but were re-projected to Universal Transverse Mercator (UTM) WGS-84 reference system (Zone 37M) using ArcGIS 10.1 (ESRI, 2011).

Before analysis the GPS fixes were checked for any positional irregularities that included checking whether GPS fixes were within acceptable locations within and around study area. All the elephant location data were screened for accuracy following procedures described by Bjørneraas et al. (2010). Dataset that had GPS errors like missing coordinates were removed from the dataset before analysis. The causes of GPS errors are: Temporal malfunction of the GPS collars (Gala, 2014), canopy cover (Jiang et al., 2008; Sager-Fradkin et al., 2007; Heard et al., 2008), topography (terrain and slope; Hebblewhite et al., 2007; Frair et al., 2004) and collar orientation (Sager-Fradkin et al., 2007; Heard et al., 2008; Moen et al., 1996; Frair et al., 2010). The data available for analysis after screening ranged between 58 and 92% (Table 2), which is within acceptable range to characterize wildlife movement patterns and make sound inference (Frair et al., 2010). After GPS tracking data screening a total of 48,852GPS points were used for analysis (Figure 2).

The datasets for each collared elephant were then classified into two seasons including wet(January, March, April, November and December) and dry (February, May, June, July, August, September and October) seasons respectively. The two seasons were selected as the study area falls within the tropical areas, which has only the wet and dry seasons. The seasons were selected based on monthly rainfall data from January 1976 to October 2015 (Figure 3; Altmann and Alberts, 2016). Months with average rainfall of below

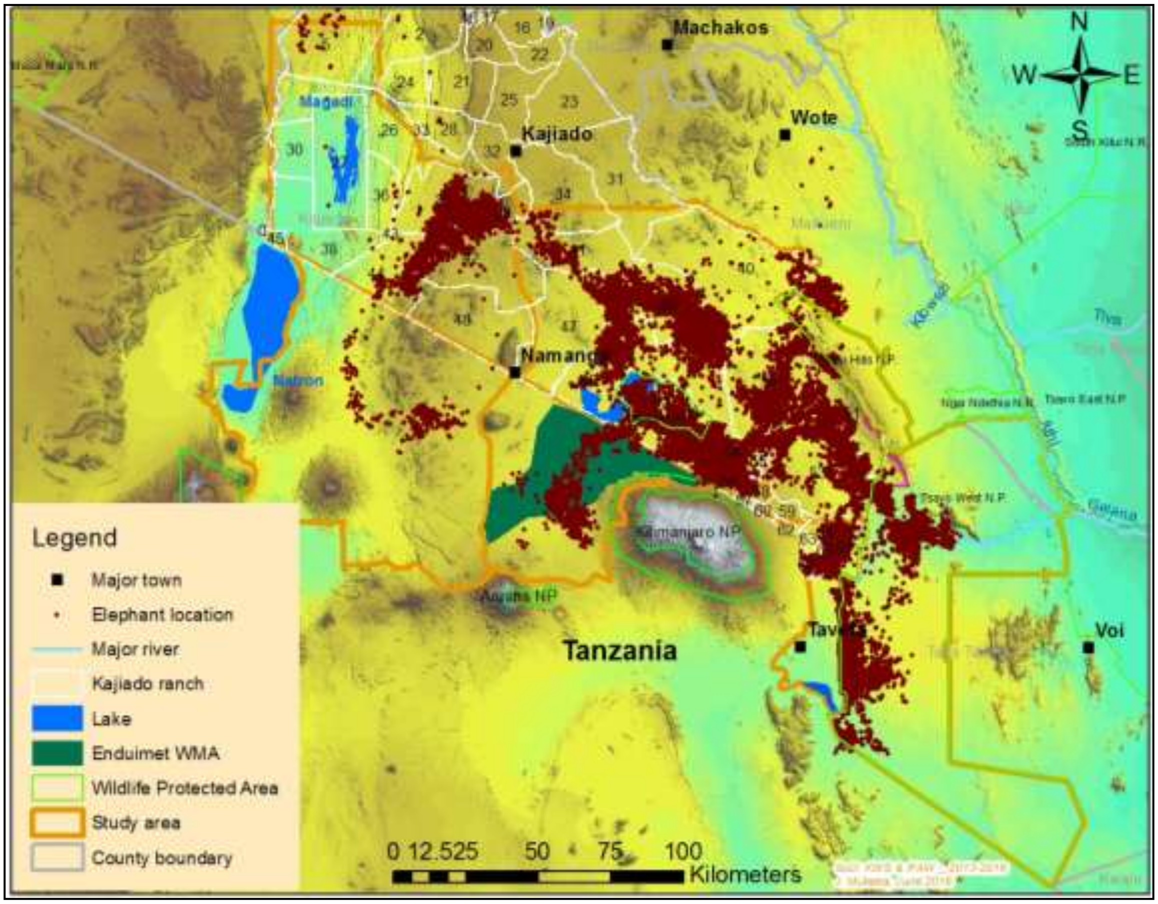

Figure 2. Location of 12 elephants collared in Amboseli ecosystem (2 February 2013 to 16 April 2016).

and above 30 mm were categorized as dry and wet respectively (Altmann and Alberts, 2016; Figure 3). The elephant locations datasets were grouped into these two seasons because previous studies demonstrate that elephant behavior is season dependent (Douglas-Hamilton *et al.*, 2005; Ngene et al., 2010). For example, the speed of elephant movement has been shown to vary from one season to another (Buij et al., 2007; de Beer and van Aarde, 2008; Ngene et al., 2010). Also, Gara (2014) reported that seasonality has a significant effect on the speed of elephant movement and habitat utilization.

Estimation of elephant home range

Home range of the elephant was estimated using the 100% Minimum Convex Polygon (MCP) method (Mohr, 1947) following procedures described by Beyer (2005) and implemented using Hawth's tools as an ARCGIS extension. The Hawth's tools were uploaded to ARCGIS 10 and used to calculate the MCP for each elephant. Based on the number of fixes (Table 2), the range used by all the elephants was estimated. In addition, individual elephant total and seasonal (dry and wet) home ranges were estimated. The MCP was used in different studies ((Leuthold and Sale 1973; Lindeque and Lindeque, 1991; Thouless, 1996; Whyte, 1996; Foguekem et al., 2007; Ipavec et al., 2007; Ngene et al., 2010), including in Tanzania (Kikoti, 2009) allowing comparisons with our study.

Space use by elephants

We established space use by the elephants using the 50 and 95% fixed kernel density estimator (KDE) method (Worton, 1989) implemented with the ARCMET tool (Wall, 2016) under the ARCGIS 10.3 environment (Worton, 1989; Fieberg, 2007; ESRI, 2013). The 95% KDE method quantified the probability density of elephant occurrence in the study area (Worton, 1989; Fieberg, 2007). The KDE was estimated for: all elephants for all seasons; all elephants during the wet and dry seasons; all bull and female elephants; and individual elephants in all seasons. The 50% KDE was used to isolate the core areas utilized by elephants. This is the areas that have the highest probability of being used by the elephants within their home ranges (Worton, 1989; Fieberg, 2007). The 95% and 50% KDE was estimated using a fixed bivariate normal kernel with a choice of ad hoc bandwidth (*h-ad hoc*) smoothing parameter as recommended by Worton (1989) and Schuler et al. (2014). We used the fixed kernel method rather than the adaptive kernel method as fixed kernel estimators are sensitive to multiple areas of concentrated use, and produce less area bias and better surface fit than adaptive kernel estimates (Seaman and Powel, 1996; Seaman at al., 1999).

Data analysis

Datasets for use in parametric tests were tested for normality and homogeneity of variances using the *Shapiro-Wilk Test* (Shapiro et

Table 2. Characteristics of the 12 collared elephants in Amboseli ecosystem including duration of tracking, number of fixes and GPS-fix success rate

No.	EID	Name	Sex	Age (year)	Collar Number or Frequency (freq)	Date of collaring	Date first GPS fix	Date last GPS fix	Days	Expected fixes	Fixes used	% Fixes used
1	KM	Kimana	Bull	26	00580824VTI9E75	19/2/2013	19/2/2013	6/4/2016	1127	6,762	6254	92
2	OSW	Osewan	Bull	30	00580819VTI0A5C	20/2/ 2013	20/2/ 2013	8/7/2016	1218	7308	4646	64
3	ESM	Eselengei	Bull	33	00580810VTI662F	20/2/ 2013	20/2/ 2013	22/2/2015	1082	6,492	3778	58
4	RF	Rombo	Female	15	00580811VTIEA34	14/3/2013	14/3/2013	6/4/2016	11102	6,612	5392	82
5	KUF	Kuku	Female	26	00580813VTIF23E	14/3/2013	14/3/2013	6/4/2016	11102	6,612	6031	91
6	MBM	Mbirikani	Bull	22	00580812VTI6E39	15/3/2013	15/3/2013	8/7/2015	1193	7,158	4278	60
7	ELM	Elerai	Bull	20	126150.620415freq	23/4/2014	23/4/2014	17/12/2015	594	3,564	3285	92
8	EWM	Elengata	Bull	40	124150.310B550freq	3/12/2013	3/12/2013	26/5/2015	533	3,198	2587	81
9	EWM2	Elengata2	Bull	30	125150.600BD5Afreq	3/12/2013	3/12/2013	6/4/2016	843	5,058	4250	84
10	KIM	Kitirua	Bull	22	Not recorded	23/4/2014	23/4/2014	6/4/2016	703	4,218	2933	70
11	MAF	Mailua	Female	25	129150.7906187freq	4/12/2013	4/12/2013	29/7/2014	235	1,410	1247	88
12	MAM	Mailua	Bull	25	128150.770DD82freq	4/12/2013	4/12/2013	6/4/2016	842	5,052	4171	83
Total										**63,444**	**48,852**	**77**

al., 1968; Fowler et al., 1998) with normality and homogeneity of variances being assumed when P> 0.05 (Shapiro et al., 1968). The *Shapiro-Wilk* test is the preferred test of normality because of its good power properties as compared to a wide range of alternative tests (Shapiro et al., 1968). For datasets that were not normally distributed and the variances were heterogeneous, they were Log_{10} transformed to normalize them and ensure homogeneity of variances (Fowler et al., 1998). For datasets that could not attain normality non-parametric test were used. For parametric and non-parametric tests, we then used *T*-test, one-way ANOVA *F*-tests and chi-square goodness of fit test to analyze the data (Fowler et al., 1998) following procedures described by Statsoft (2002). Significant differences were at P ≤0.05 (Fowler et al., 1998).

RESULTS

Annual home range size

The annual range of the 12 elephants as estimated using the 100% MCP and 95% KDE methods was about 37,167 km^2 (Figure 4A) and 5,360 km^2 (Figure 4B) respectively. Bull elephants (n = 9) ranged in an area of about 32,110 km^2 (100% MCP; Figure 5A) and 3,170 km^2 (95% KDE; Figure 5B). The total home range of female elephant (n = 3) was about 10,515 km^2 (100% MCP; Figure 5A), 3,070 km^2 (95% KDE; Figure 5A) respectively. The home range of individual elephants is summarized in Table 3, Figure 6A (MCP method) and Figure 6B (95% KDE method). Female elephants did not range into Tanzania but three bulls (Kitirua, Osewani and Elengata) extended their range from Southern Kenya into the northern parts of Tanzania. The bull named Kimana ranged within the border area of Kenya and Tanzania, with some time being spent in Tanzania (Figure 6B). All the elephants utilized Amboseli National Park but the frequency of use varied among them (Supplementary Table). Rombo, a female elephant, was frequently located in Tsavo West National Park whereas the bull Erelai spent sometime in the same park (Supplementary Table).

The core areas used by all elephants were located in Lengesim and Kimana/Tikodo ranches (Figure 4B). However, individual elephant core areas were located in the following ranches and parks: Mbuko, Lorngosua, Mailua, Lengesim, Amboseli National Park, Kimana/Tokondo, Endonet, Rombo Block II, Kuku, Tsavo West National Park, Chyulu West Game Conservation Area (Figure 6B; Supplementary Table). The 95% confidence interval of the monthly range (95% KDE) for all elephants was 6,130 to 7,025 km^2 with the minimum and maximum range being 5,200 and 7,790 km^2. The monthly range for all elephants varied significantly (t = 279; df = 11; p < 0.05; Figure 7). There was a significant variation of monthly home range with amount of rainfall with smaller home ranges being recorded in dry months than in wet months (t = 12; df = 1; p <

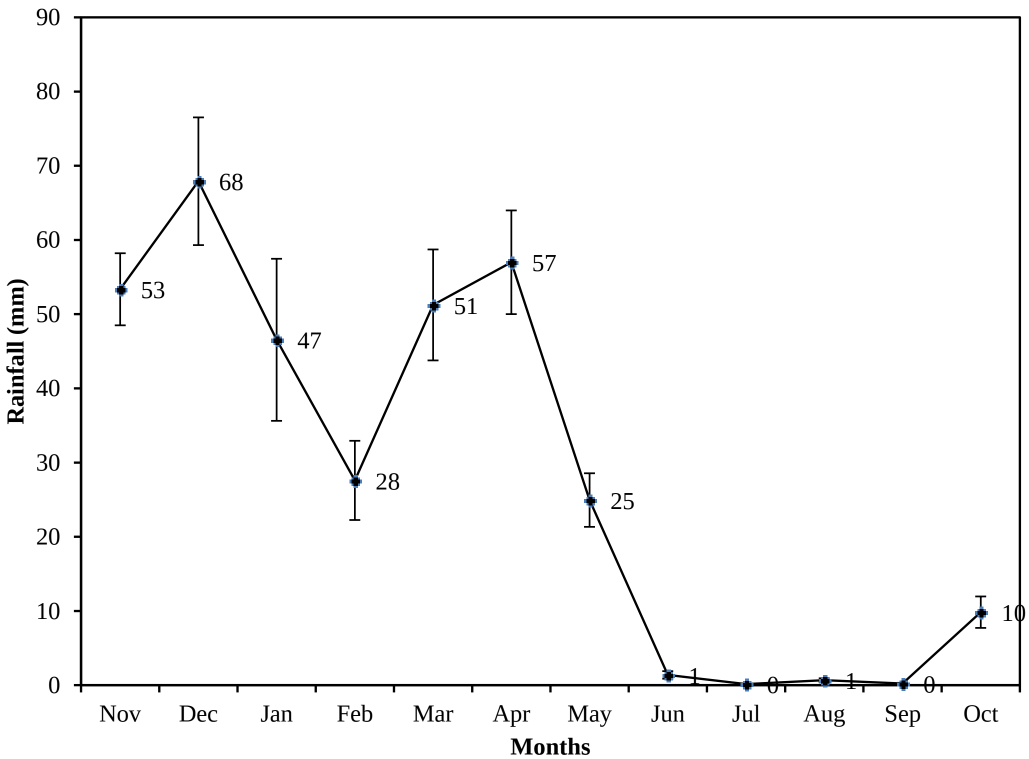

Figure 3. Mean monthly rainfall from January 1976 to October 2015 (Source: Altmann and Alberts, 2016). Months with less than 30mm of rainfall were categorized as dry season whereas those with more than 30 mm of rainfall were categorized as wet season.

0.05; Figure 7). The smallest (5,200 km^2) and largest (7,710 km^2) range were observed in August and April, respectively (Figure 7).

Seasonal home range

The elephants covered a range (100% MCP) of 31,404 and 33,471 km^2 during the dry and wet seasons respectively (Figure 8A). The dry and wet season home range (100% MCP) varied from 932 to 9,034 km^2 and 671 km^2 and 4,954 km^2 respectively (Table 4). There was a significant seasonal variation of elephant home range sizes with smaller home ranges being recorded during the wet season than dry season (dry: X^2 = 16,751; df = 11; p < 0.05; wet: X^2 = 14730.94 df = 11 p < 0.05; Table 3).Some of the elephants showed larger and small home range (100% MCP) during the dry season than the wet season respectively (Table 4). Females had a significantly smaller mean home range (100% MCP: dry = 2,974 km^2; wet = 1,828 km^2) than bulls (100% MCP: dry = 3,312 km^2; wet = 3,288 km^2) during the dry and wet seasons respectively (dry season: t = 645; df = 22; p <0.05; wet season: t = 610; df = 22; p < 0.05).

The elephants ranged (95% KDE) in an area of about 5,448 and 6,129 km^2 during the dry and wet seasons respectively (Figure 8B). Results for 95% KDE showed the home range of females during the dry and wet season as 2,810 and 3,070 km^2 respectively, while that of bulls was 2,960 km^2 (dry season) and 3,720 km^2 (wet season; Figure 9). Table 4 also summarizes home range of individual elephants using the 95% KDE method. The 95% KDE home range sizes vary as those reported for the MCP method. However, the 95% KDE method recorded smaller home ranges than those calculated using the MCP method (Table 4).

DISCUSSION

Our results reveal that individual elephants ranged from 1,839 to 10,016 km^2 (100% MCP) and 290 to 1,226 km^2 (95% KDE; Figure 10). Similar results of large variation of home range area (100% MCP) have been reported in other studies in East Africa (Ngene et al., 2009; Kikoti, 2009). For example, Kikoti (2009) reported that annual range of 21 elephants collared with satellite-linked GPS collars in northern Tanzania varied from 191 to 3,698 km^2 (100% MCP).

In northern Kenya, Thouless (1996) reported that range area (100% MCP) for 20 female elephants varied from 102 to 5,527 km^2. Also, Douglas-Hamilton et al. (2005) reported the home ranges size (100% MCP) for 11 elephants varied from 11 to 5,520 km^2 in

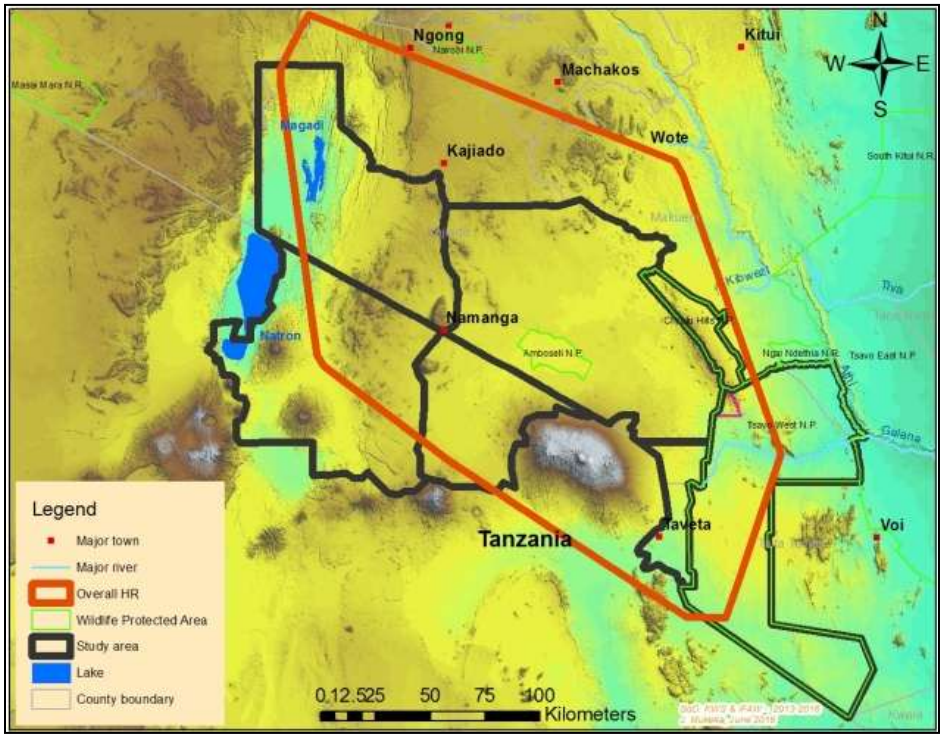

Figure 4A. Total home range (MCP method) of 12 elephants collared in Amboseli ecosystem (2 February 2013 to 16 April 2016). The numbers represent the group ranches in the study area (Supplementary Table

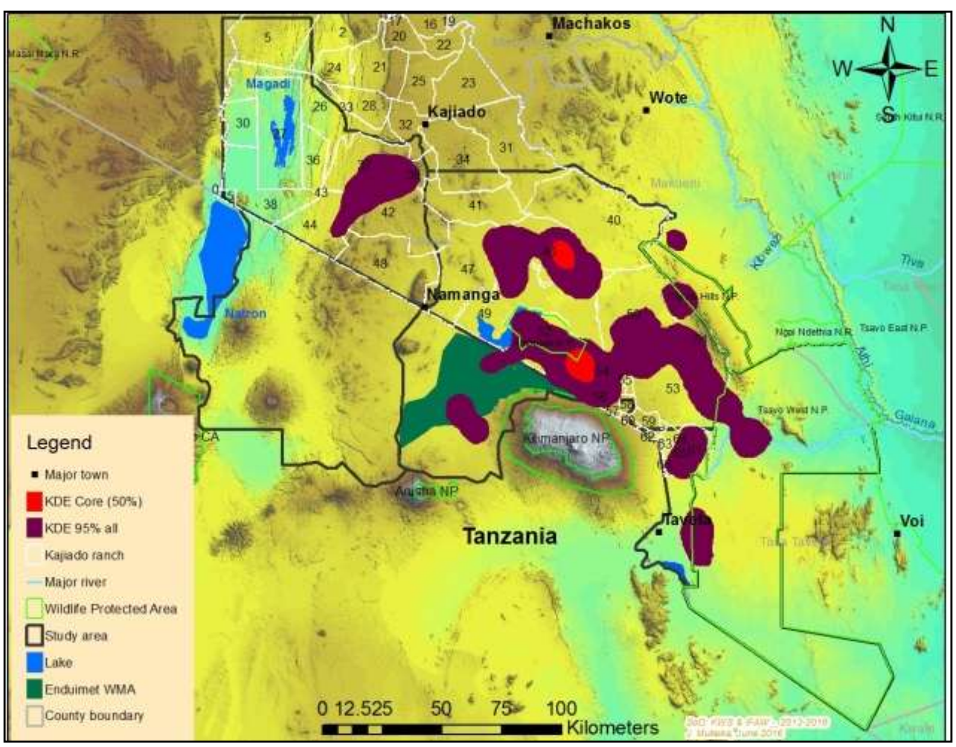

Figure 4B. Total home range (KDE method) of 12 elephants collared in Amboseli ecosystem (2 February 2013 to 16 April 2016). The numbers represent the group ranches in the study area (Supplementary Table).

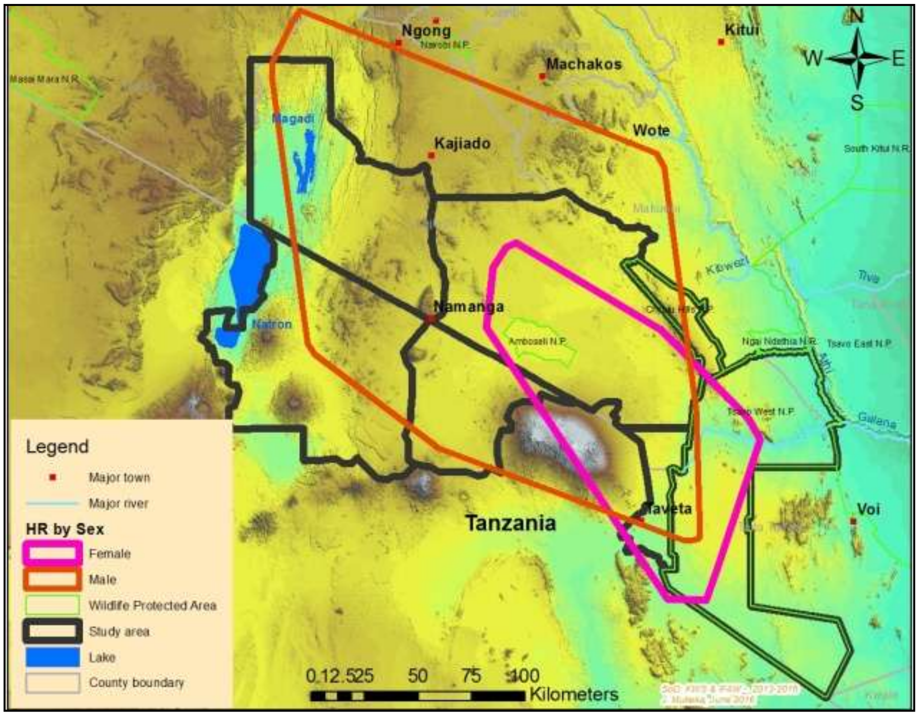

Figure 5A. Total home range (MCP method) of bull (n = 9) and female (n = 3) elephants collared in Amboseli ecosystem (2 February 2013 to 16 April 2016).

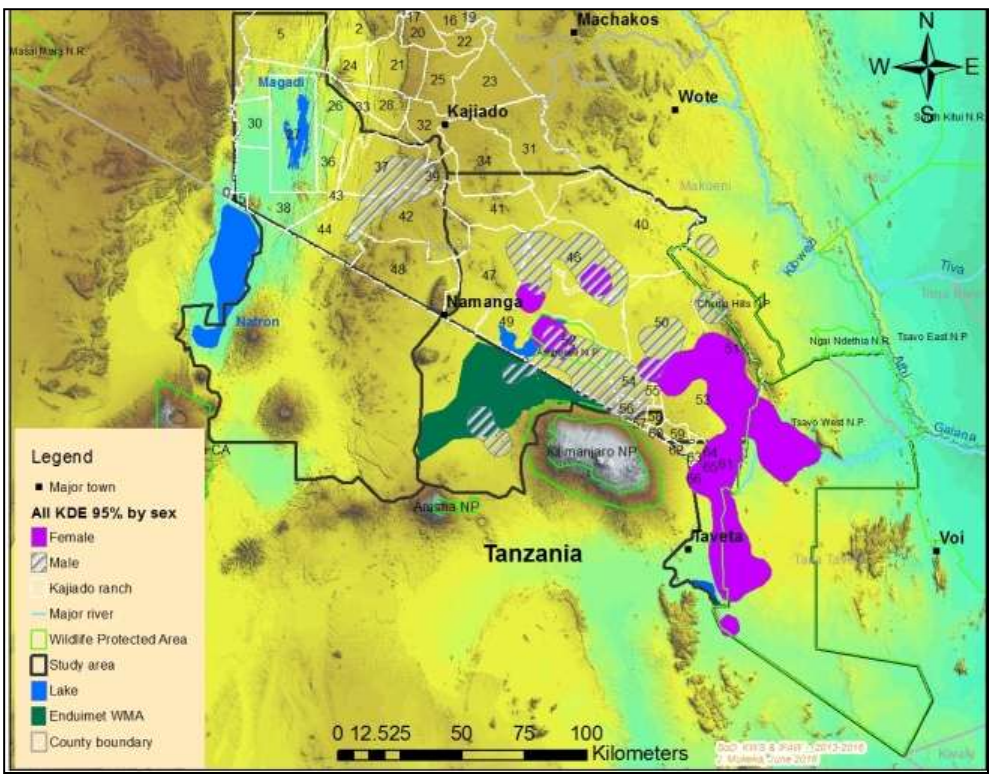

Figure 5B. Total home range (KDE method) of bull (n = 9) and female (n = 3) elephants collared in Amboseli ecosystem (2 February 2013 to 16 April 2016). The numbers represent the group ranches in the study area (Supplementary Table).

Table 3. Total home range (MCP and KD) of 12 elephants collared in Amboseli ecosystem (values for MCP and KDE are in km^2).

EID	Name	Sex	Age (years)	Fixes used	MCP	KDE
KM	Kimana	Bull	26	6254	2,005	290
OSW	Osewan	Bull	30	4646	4,040	769
ESM	Porini	Bull	33	3778	5,449	669
RF	Rombo	Female	15	5392	3,444	1226
KUF	Kuku	Female	26	6031	4,995	749
MBM	Mbirikani	Bull	22	4278	3,314	704
ELM	Elerai	Bull	20	3285	2,602	223
EWM	Elengata	Bull	40	2587	5,143	1073
EWM2	Elengata2	Bull	30	4250	10,016	1162
KIM	Kitirua	Bull	22	2933	2,745	903
MAF	Mailua	Female	25	1247	1,839	606
MAM	Mailua	Bull	25	4171	3,695	208

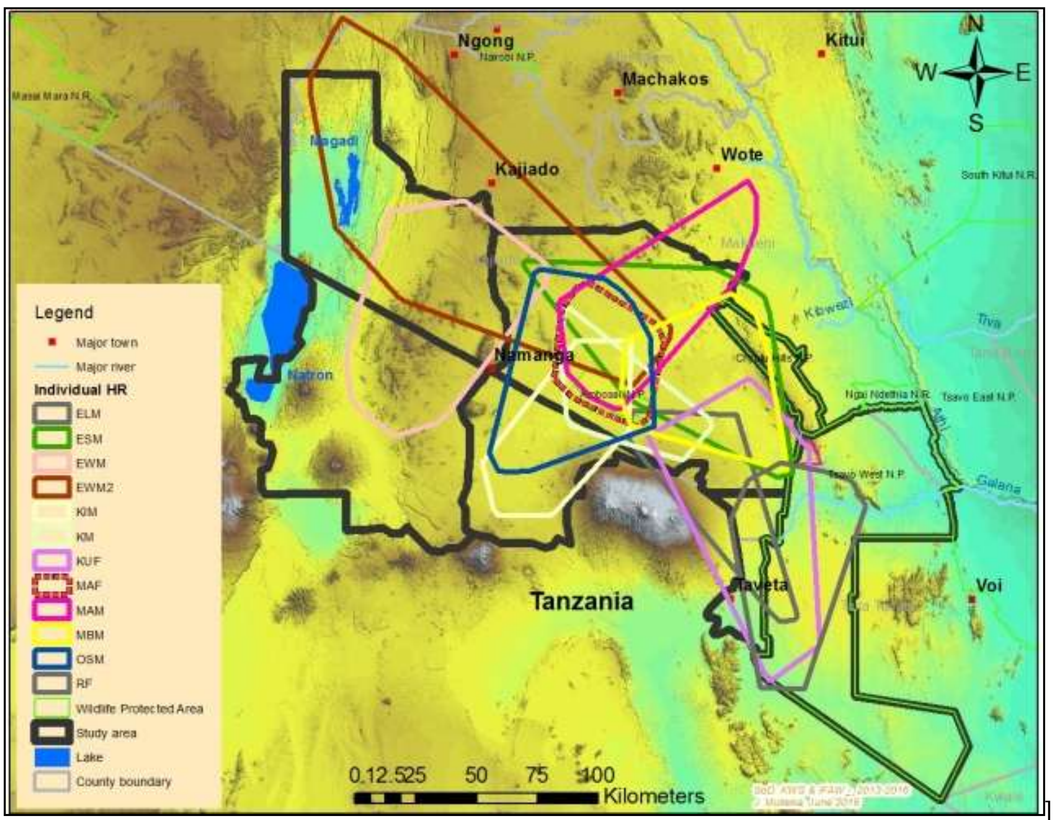

Figure 6A. Home range (MCP method) of individual elephants collared in Amboseli ecosystem (2 February 2013 to 16 April 2016).

southern and central Kenya. The average home range of bulls (100% MCP), was much larger than the range of two bulls (M86: 210 km^2; M169: 140 km^2) collared in Amboseli National Park (Douglas-Hamilton et al., 2005). However, the two bulls were monitored for very short periods (134 and 168 days respectively) compared to this study that monitored the elephants from February 2013 to April 2016. The general implication of these space use patterns is that the elephants require space outside the protected areas within the larger Amboseli ecosystem. It is important to secure the space for elephants outside the protected areas for their continued use and future

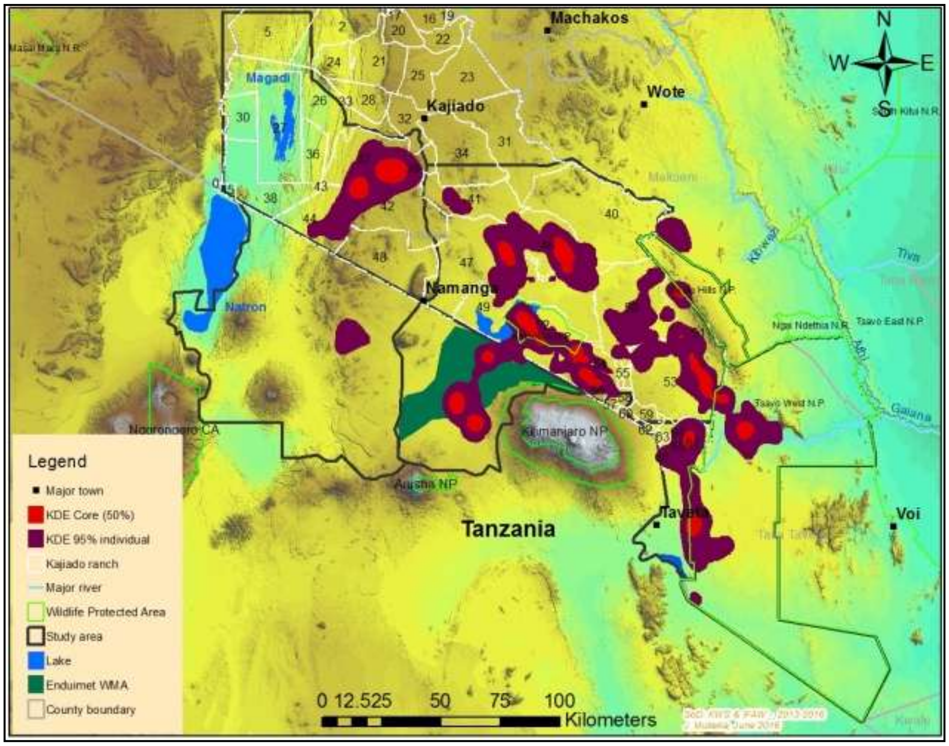

Figure 6B. Home range (KDE method) of individual elephants collared in Amboseli ecosystem (2 February 2013 to 16 April 2016). The numbers represent the group ranches in the study area (Supplementary Table)

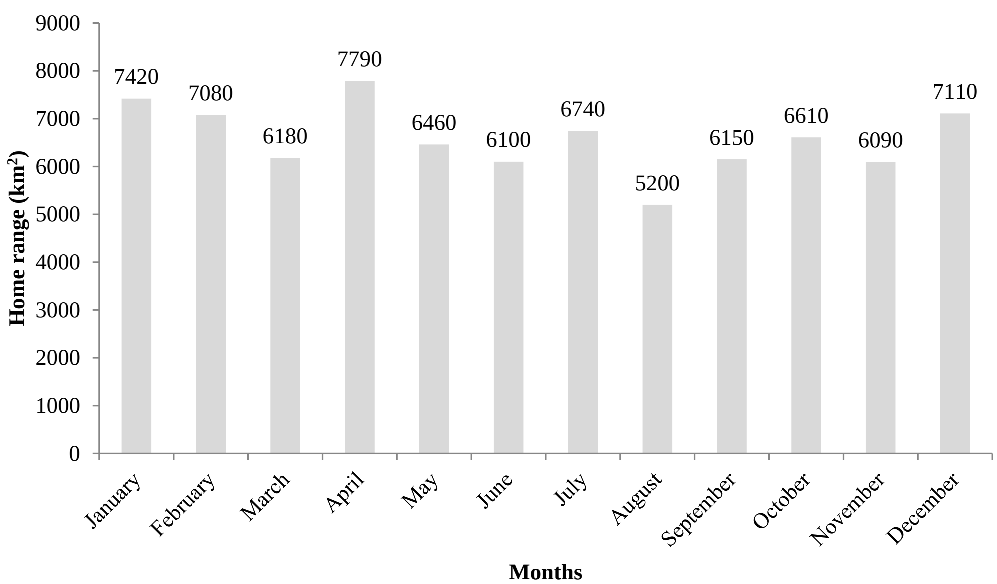

Figure 7. The monthly range (95% KDE) covered by all elephants in Amboseli ecosystem (February 2013 to April 2016).

existence in the ecosystem. This can be achieved by direct purchase of land used by elephants outside the protected areas as well as establishment of successful community and private conservancies on space utilized by elephants outside the protected areas.

Only three females compared to nine bulls were

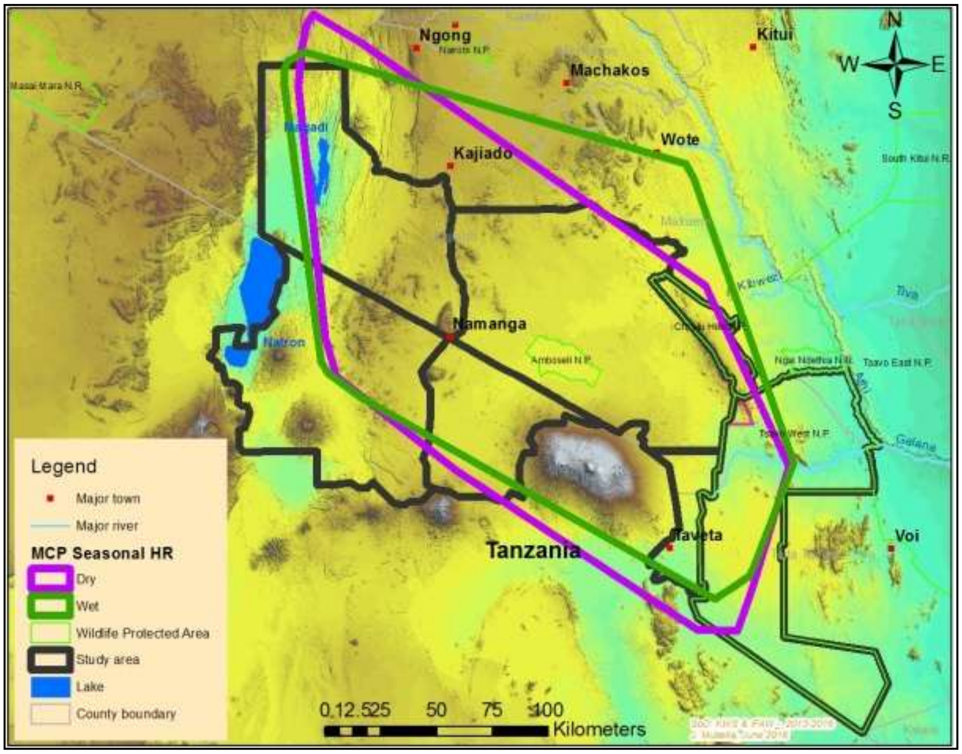

Figure 8A. Seasonal home range (MCP method) of all 12 elephants collared in Amboseli ecosystem (2 February 2013 to 16 April 2016).

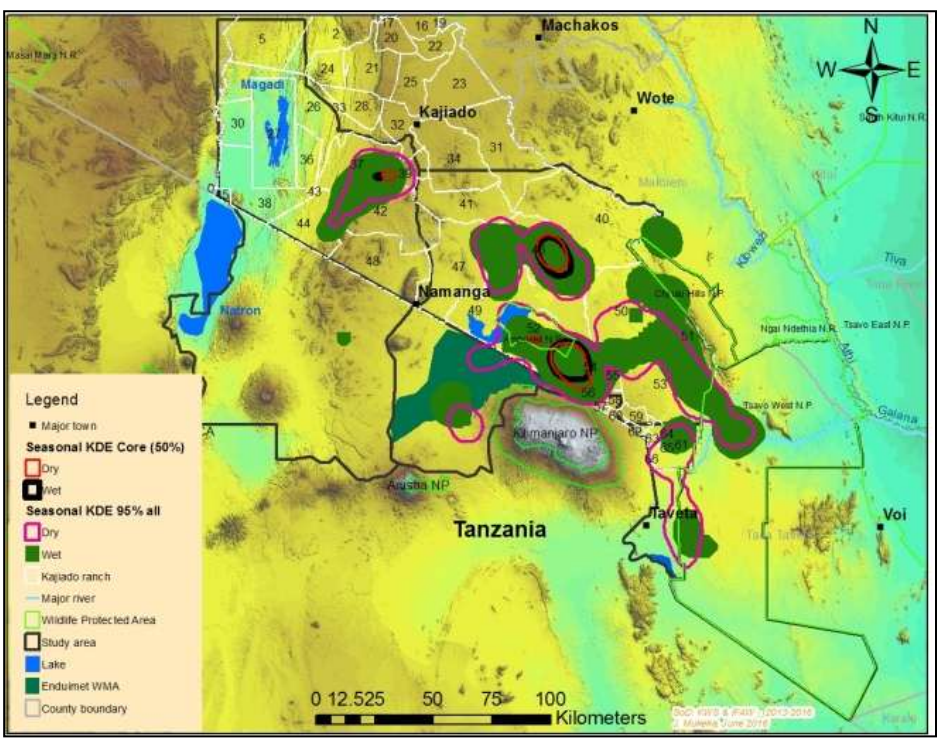

Figure 8B. Seasonal home range (KDE method) of all 12 elephants collared in Amboseli ecosystem (2 February 2013 to 16 April 2016). The numbers represent the group ranches in the study area (Supplementary Table).

Table 4. Seasonal home range (dry and wet) for 12 elephants collared in Amboseli ecosystem

EID	Name	Sex	Age (years)	Dry season (km^2) MCP	Dry season (km^2) KDE	Wet season (km^2) MCP	Wet season (km^2) KDE
KM	Kimana	Bull	26	1,896	256	671	280
OSW	Osewan	Bull	30	1,764	697	3,957	954
ESM	Porini	Bull	33	4,762	925	3,716	1,244
RF	Rombo	Female	15	3,107	791	2,693	495
KUF	Kuku	Female	26	4,882	617	1,013	475
MBM	Mbirikani	Bull	22	2,612	205	2,915	266
ELM	Elerai	Bull	20	2,341	808	770	1,102
EWM	Elengata	Bull	40	3,894	1,247	4,954	1,021
EWM2	Elengata2	Bull	30	9,034	711	7,610	875
KIM	Kitirua	Bull	22	1,994	278	2,201	546
MAF	Mailua	Female	25	932	164	1,777	321
MAM	Mailua	Bull	25	1,515	256	2,796	280

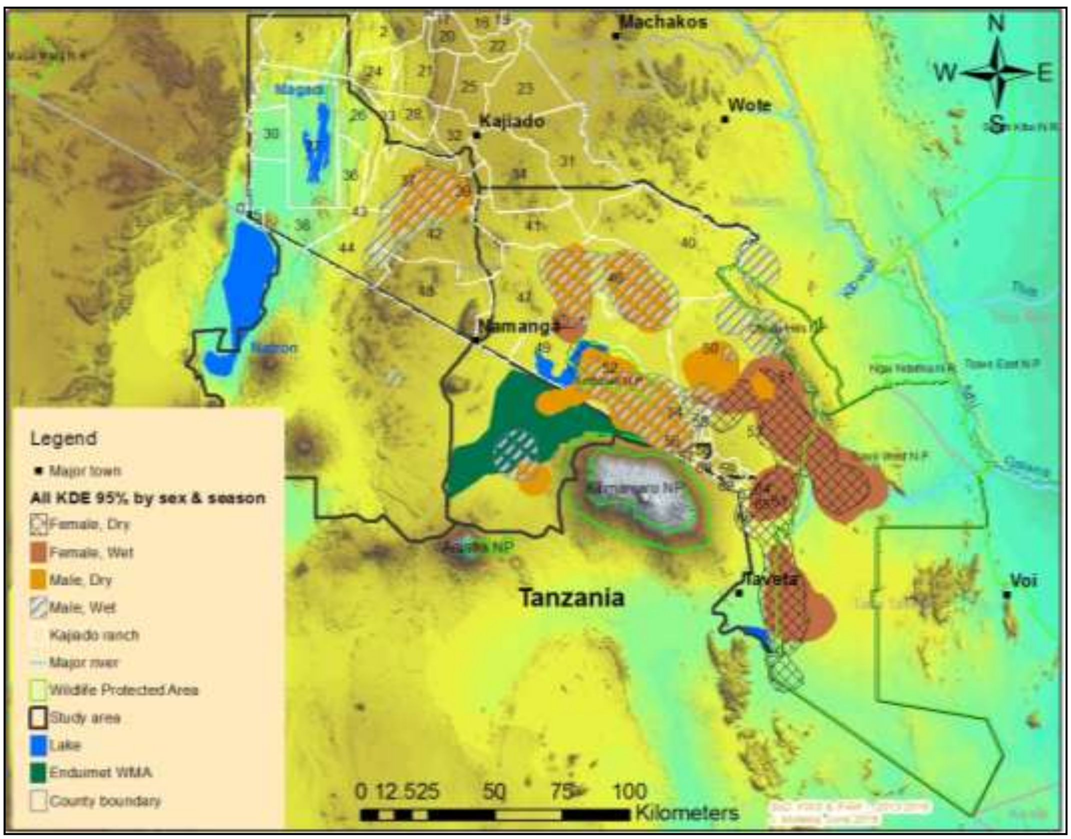

Figure 9. Seasonal home range (95% KDE) of bulls and female elephants collared in Amboseli ecosystem (2 February 2013 to 16 April 2016). The numbers represent the group ranches in the study area (Supplementary Table).

collared during the study. However, our results showed that bulls had a larger total range (100% MCP) than females (bulls range: 2,005 to 10,016 km^2; female range: 1,839 to 4,995 km^2). However, when the 95% KDE was used, females had a larger total range than bulls (bulls: 208 to 1,162 km^2; female: 606 to 1,226 km^2). Similar

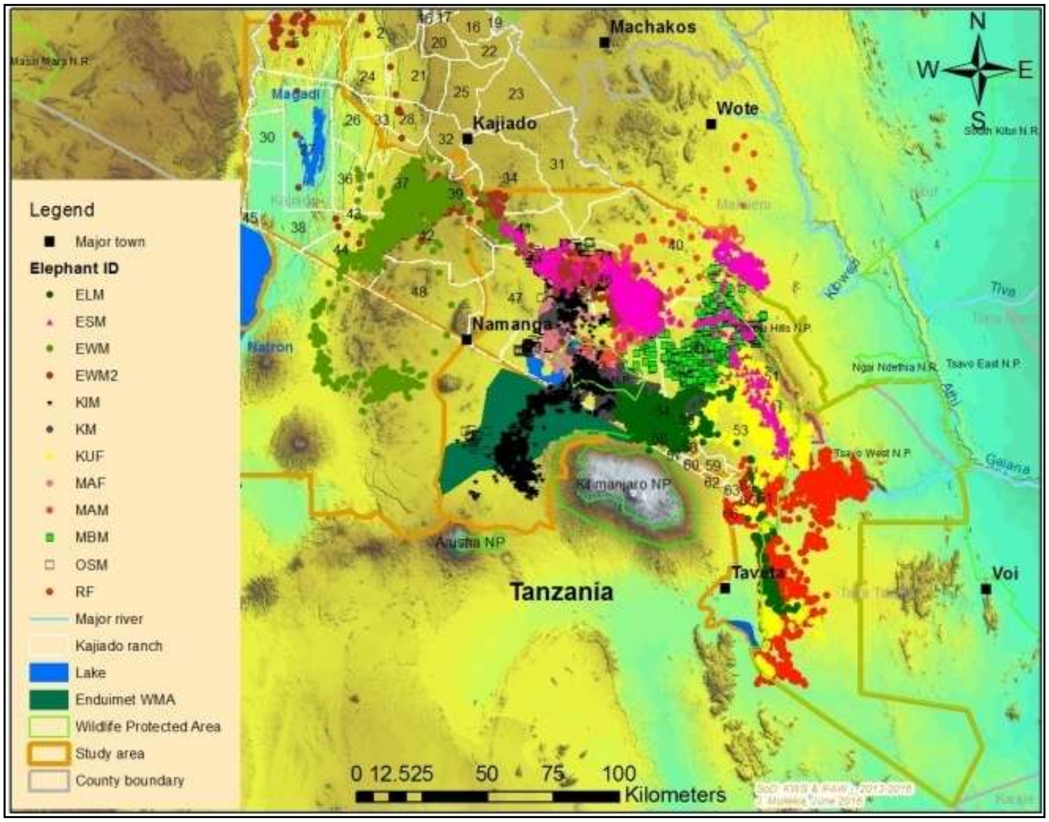

Figure 10A. The areas utilized by the 12 elephants in the borderland (February 2013 to April 2016). Point data of all areas utilized by the elephants. The numbers represent the group ranches in the study area (Supplementary Table).

results (100% MCP) were observed by Kikoti (2009) in Northern Tanzania where bulls had a larger home range than females (bulls: 700 to 3,698 km^2; females (100% MCP): 191 to 2,590 km^2). During the dry and wet seasons, bulls had larger mean home range than females (bulls dry: 3,312 km^2; female dry = 2,974 km^2; bull wet = 3,288 km^2; female wet = 1,828 km^2). Similar observations were made when the 95% KDE was used (bulls dry: 598 km^2; Female dry = 143 km^2; bull wet = 730 km^2; Female wet = 430 km^2). Our results match with similar previous studies on elephant home range (Stokke and du Toit, 2002; Jackson and Erasmus, 2005; Chase, 2007; Kikoti, 2009), which reported the home range sizes (95% fixed kernel) of bulls were larger than that of females. The female herds mostly consist of young elephants that cannot cope with extensive movements, therefore making female elephants to range in smaller areas than bulls (Ngene et al., 2009; Leggett, 2006). However, males consist of bulls of almost the same age and they are able to roam around in larger areas as their movements are not interfered with by young individuals who cannot cope with rigorous movements like females (Douglas-Hamilton et al., 2005; Ngene et al., 2009). It is evident that bulls will therefore require more space than females, a factor critical for them to continue accessing females on estrous at different localities within the larger Amboseli landscape. Efforts to secure space outside the protected areas should be enhanced to ensure it is available to the bull elephants.

Overall, the variations of elephant home range are influenced by an interaction of factors including rainfall, human disturbances (e.g., farms, settlements, fencing, urban development and road network), pressure from poaching, water availability, bush cover, food availability, habitat fragmentation, tracking period, and fencing of parcels of land (Esikuri, 1998; Douglas-Hamilton et al., 2005; Leggett, 2006; Foguekem et al., 2007; Mutima et al., 2009; Kikoti, 2009; Ngene et al., 2009; Gara, 2014). For Amboseli ecosystem, the elephant range has increasingly come under threat due to four factors including: Conversion of rangeland to farmland, increase of settlements, increase of human population, and shift of the Maasai community from nomadic pastoralism and transhumance to sedentary intensive agro-pastoralism (Esikuri, 2009; Okello and Kioko, 2010; Kioko and Okello, 2010). These factors have resulted to fragmentation of elephant range in Amboseli ecosystem as described and discussed in details by Gara (2014) and Gara et al. (2016a,

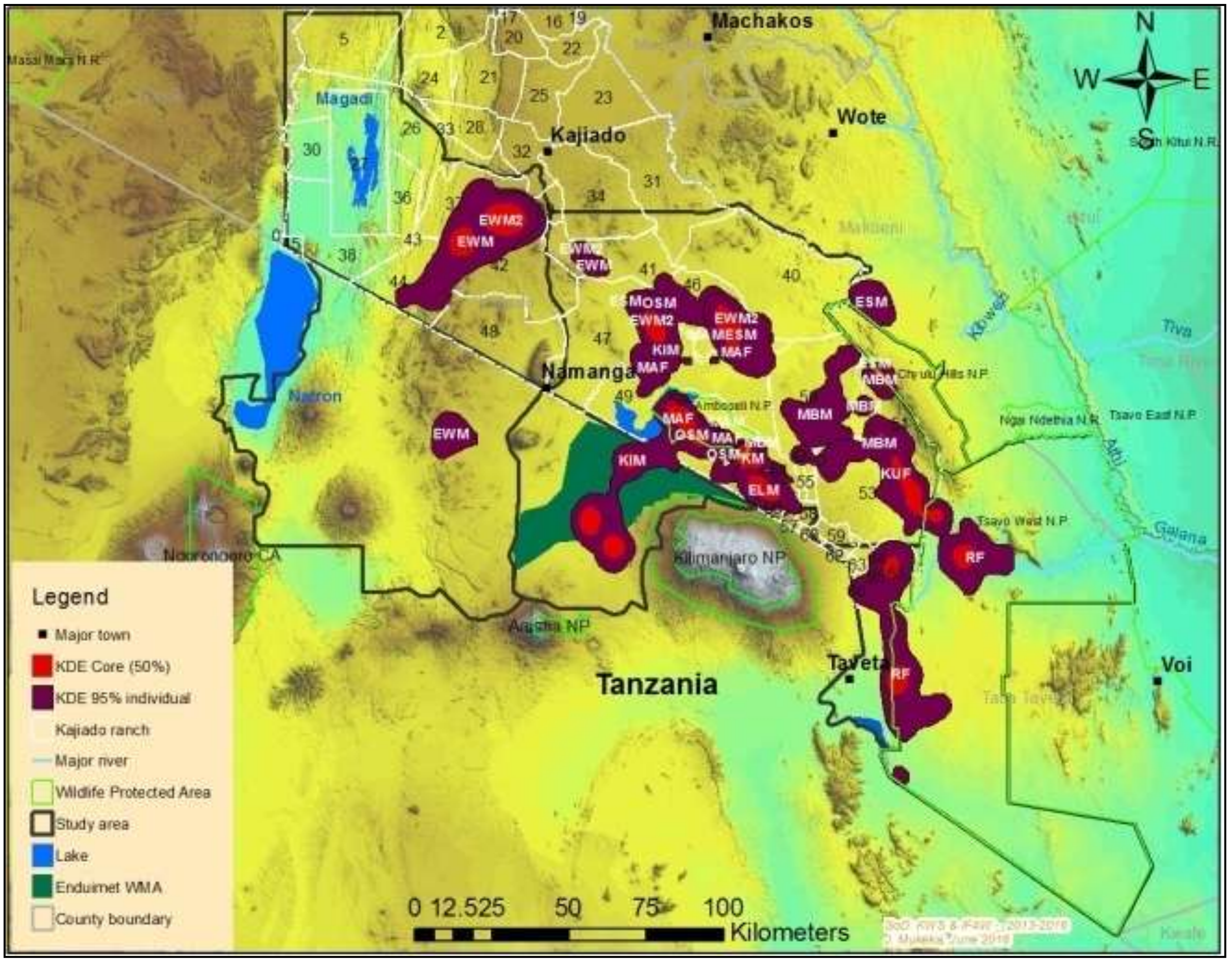

Figure 10B. The areas utilized (95 and 50% KDE) by the 12 elephants in the borderland (February 2013 to April 2016). The white labels are the names of elephants. The numbers represent the group ranches in the study area (Supplementary Table).

b). The fragmentation has resulted to reduction of elephant home range as the elephants only utilize secure habitats (Gara, 2014; Gara et al., 2016a, b). Gara et al. (2016a, b) reported that habitat utilization by elephants in human-dominated landscapes of Amboseli landscape was mostly explained by a combination of landscape fragmentation and vegetation productivity during the dry and transition seasons, than each of the factors alone.

The proof of continued habitat fragmentation in the Amboseli ecosystem has been by many authors including Eskuru (1993), Kioko and Okello (2010) and Nyamasio and Kihima (2014). For example Esikuri (1993) reported over 70% of conversion of rangeland to crop land in Amboseli ecosystem with the trend being on the increase over the years. For example, Eskuru (1993) reported an increase of area under crop farming in Amboseli basin by 273, 461 and 733% for the time periods 1975-1988, 1988-1993, and 1975-1993 respectively. Kioko and Okello (2010) reported an increase of land under irrigated and rain-fed crop farming by 2,217 and 96% between 1976 and 2007. A more recent study by Nyamasio and Kihima (2014) at Kimana Wetland Ecosystem (KWE; 3,349 km^2) reported increase of area under crop farming from about 70 km^2 in 1980 to about 438 km^2 in 2013, which represents a 526% increase in 33 years. During the same period land area under woodlands, wetlands and grassland decreased by 5.35, 69 and 8% respectively. These conversions are a pointer to constriction of elephant home range due to habitat fragmentation (Gara et al., 2016a, b). It is evidenced by avoidance of farmed or heavily settled areas of Kimana, Nguruman, Njukini, and Rombo in larger Amboseli ecosystem (Figure 10A and B; Gara et al., 2016a, b). Settlements and mushrooming of urban centers have ncreased over the past years (Gara et al., 2016a, b). For example, in KWE, which comprises of Entonet division, Central division, Imbirikani Location, and Amboseli National Park, land under settlements and urban areas increased by 682% between 1980 and 2013 (Nyamasio and Kihima, 2014). Human population has also increased in the ecosystem as more people and other communities (especially Changa, Kamba and Kikuyus) move to the area to undertake irrigation and rain fed crop farming (Okello, 2005; Kioko et al., 2006; Okello and Kioko, 2010; Kioko and Okello, 2010). For instance, over the past three decades, KWE has experienced an estimated annual human population growth rate of 4.67 as per the 2009 census, which translates to 84,297 persons and a population density of about 25 persons/km^2 in 2009 (Nyamasio and Kihima, 2014). The human population in KWE is projected to be about 210,789 individuals and a population density of 63 persons/km^{2}by 2030 (Nyamasio and Kihima, 2014). This will further constrict the elephant range within the ecosystem. From the results, the KWE was avoided by the collared elephants during the study period (Figure 10A and B). This is because of settlements and farms therein. The shift of the Maasai community from nomadic pastoralism and transhumance to sedentary intensive agro-pastoralism has increased land fragmentation in Amboseli ecosystem (Kioko and Okello, 2010; Western, 1990). The land fragmentation has been aggravated by the development of infrastructure, demand for more land as the population increases, migration of people from crop farming communities, and sub-division of group ranches as individual members realize the need to own land and use it for other activities like farming and for selling (Kioko et al., 2006; Kioko and Okello, 2010; Gara, 2014; Gara et al., 2016a; Gara et al., 2016b).The above observations reveal massive conversion of Amboseli elephant range to farmlands and settlement areas (Esikuri, 1998; Kioko et al., 2006; Nyamasio and Kihima, 2014; Gara, 2014). The resultant effect is reduced elephant range, increased human-elephant conflicts, increased mortality of elephants and reduced income from farming (Okello, 2005; Okello and Kioko; 2010; Kioko et al., 2006; Kioko and Okello, 2010; Nyamasio and Kihima, 2014; Gara, 2014; Gara et al., 2016a, b). The above explains why elephants avoided the Kimana, Nyukini, Ngurumani, and Rombo area of Amboseli ecosystem as shown in Figure 10a and B.

Conclusion

In this study, we describe the home range of elephants in Amboseli ecosystem using the 100% MCP and 95% KDE. Bulls had larger home ranges than females. The elephant home range was larger during the dry season than wet season. The most important ranches that offer key habitats for elephants include: Lolarashi/Olgulului, Rombo, Mbirikani, Kimana/Tikondo, Endonet, Lengesim, Kaputei south, Kuku, Lorngosua, Mbuko, and ElangataWuas, Torosei, Kimana/Tikondo Small Holdings and Dalalakutuk. The Isilalei ranch was used as a corridor to and from Elengata Wuas, Lorngosua and Torosei ranches. These are priority ranches where efforts to establish community conservancies should be enhanced. Other important areas used by the elephants include Chyulu West Game Management Area (CWGMA) in Kenya and Endimet Wildlife Management Area (EWMA) in Tanzania. Amboseli, Tsavo West and Chyulu National Parks in Kenya as well as parts of the Natron area in Tanzania were also utilized by elephants. The elephant population utilizes the range in both Southern Kenya and Northern Tanzania. Therefore, trans-boundary efforts should be enhanced to ensure sound management of the elephant-habitat-people interface for continued wellbeing of the elephant population and communities living with the elephants in Southern Kenya and Northern Tanzania.

Conflicts of Interests

The authors have not declared any conflict of interests.

REFERENCES

Altmann J, Alberts S, Altmann S, Roy S (2002). Dramatic change in local climate patterns in the Amboseli basin, Kenya. Afr. J. Ecol. 40(3):248-251.

BurnSilver S, Worden J, Boone R (2008). Processes of Fragmentation in the Amboseli Ecosystem, Southern Kajiado District, Kenya. In Galvin K, Reid R, Hobbs RBNT (Eds.), Fragmentation in Semi-Arid and Arid Landscapes: Springer Netherlands. pp. 225-253.

Burt WH (1943). Territoriality and home range concepts as applied to mammals. J. Mammol. 24:346-352.

Casaer JIM, Hermy M, Coppin POL, Verhagen RON (1999). Analyzing space use patterns by Thiessen polygon and triangulated irregular network interpolation: A non-parametric method for processing telemetric animal fixes. Int. J. Geogr. Inform. Sci. 13:499-511.

Douglas-Hamilton I, Krink T, Vollrath F (2005). Movement and corridors of African elephants in relation to protected areas. Naturwissenschaften 92:158-163.

Downs J, Horner M (2009). A Characteristic-Hull Based Method for Home Range Estimation. Transactions in GIS 13:527-537.

Esikuri EE (1998). Spatio-Temporal Effects of Land Use Changes in A Savanna Wildlife Area of Kenya. PhD Thesis, Virginia Polytechnic Institute and State University, Virginia, USA.

ESRI [Environmental Systems Research Institute] (2010). ArcGIS: Arc Map Version 10.3. ESRI, California, USA.

Fieberg J (2007). Kernel density estimators of home range: smoothing and the autocorrelation red herring. Ecology 88(4):1059-1066.

Frair JL, Nielsen SE, Merrill EH, Lele SR, Boyce MS, Munro RHM, Stenhouse GB, Beyer HL (2004). Removing GPS collar bias in habitat selection studies. J. Appl. Ecol. 41:201-212.

Frair JL, Fieberg J, Hebblewhite M, Cagnacci F, DeCesare NJ, Pedrotti L (2010). Resolving issues of imprecise and habitat-biased locations in ecological analyses using GPS telemetry data. Philos. Trans. R. Soc. B: Biol. Sci. 365(1550):2187-2200.

Fowler J, Cohen L, Larvis P (1998). Practical statistics for field biology. John Wiley and Sons. West Sussex, England.

Gara TW, Wang TJ, Skidmore AK, Zengeya FM, Ngene SM, Murwira A, Ndaimani H (2016a). Understanding the effect of landscape fragmentation and vegetation productivity on elephant habitat utilization in Amboseli ecosystem, Kenya: Open access. Afr. J. Ecol.

Gara TW, Wang TJ, Skidmore AK, Ngene SM, Dube T, Sibanda M (2016b). Elephants move faster in small fragments of low productivity in Amboseli ecosystems Kenya. Geocarto International,

Gara TW (2014). Effect of Water Availability, Landscape Fragmentation and Forage Abundance on the Movement and Habitat Utilization of Elephants. MSc Thesis, University of Twente, Faculty of Geo-Information Science and earth Observation (ITC), Enschede,

The Netherlands.
Getz W, Fortmann-Roe S, Cross P, LyonsA, Ryan S, Wilmers C (2009). LoCoH:Non-parameteric Kernel Methods for Constructing Home Ranges and Utilization Distributions. PLoS ONE 2:e207.
Getz WM, Wilmers CC (2004). A local nearest-neighbor convex-hull construction of home ranges and utilization distributions. Ecography 27:489-505.
Graham MD, Douglas-Hamilton I, Adams WM, Lee PC (2009). The movement of African elephants in a human-dominated land-use mosaic. Anim. Conserv. *12*(5):445-455.
Groom, RJD, Western D (2013). Impact of Land Subdivision and Sedentarization on Wildlife in Kenya's Southern Rangelands. Rangeland Ecol. Manage. 66(1):1-9.
Heard DC, Ciarniello LM, Seip DR (2008). Grizzlybear behavior and global positioning system collar fix rates. J. Wildlife Manage*.*72:596-602.
Hebblewhite M, Percy M, Merrill EH (2007). Are all global positioning system collars created equal? Correcting habitat-induced bias using three brands in the Central Canadian Rockies. J. Wildlife Manage*.* 71:2026-2033.
Hobbs NT, Reid R, Galvin K, Ellis J (2008). Fragmentation of Arid and Semi-Arid Ecosystems: Implications for People and Animals. In Galvin K, R Reid RB Hobbs N T (Eds.) Fragmentation in Semi-Arid and Arid Landscapes: Springer Netherlands. pp. 25-44.
Horne JS, Garton EO, Krone SM, Lewis JS (2007). Analyzing Animal Movements Using Brownian Bridges. Ecol. 88:2354-2363.
Howe M, Okello MM, Davis JM (2013). Inter-specific Variation in the Distribution of Ungulates Relative to Human Infrastructure Surrounding Amboseli National Park. Afr. Zool. 48(1):159-166.
Jiang Z, Sugita M, Kitahara M, Takatsuki S, Goto T, Yoshida Y (2008). Effects of habitat feature, antenna position, movement, and fix interval on GPS radio collar performance in Mount Fuji, central Japan. Ecol. Res. 23:581-588.
Kie JG, Matthiopoulos J, Fieberg J, Powel RA, Cagnaccia F, Mitchell MS, Gaillard J, Moorcroft PR (2016).The home range concept: A traditional estimator still relevant with modern telemetry? Phil. Trans. R. Soc. 365:2221-2231.
Kikoti AP (2009). Seasonal home range sizes, trans-boundary movements and conservation of elephants in Northern Tanzania. PhD Thesis, University of Massachusetts, Massachusetts, USA.
Kioko J, Kiringe J, Omondi P (2006).Human–elephant conflict outlook in the Tsavo–Amboseli ecosystem, Kenya. Pachyderm 41:53-60*.*
Kioko J, Okello MM (2010).Land use cover and environmental changes in a semi-arid rangeland, Southern Kenya. J. Geogr. Regional Plann. 3(11):322-326.
Laver PN, Kellyn MJ (2008). A Critical Review of Home Range Studies. J. Wildl. Manage. 72:290-298.
Legget KEA (2006). Home range and seasonal movement of elephants in the Kunene Region, northwestern Namibia. Afr. Zool. 41:17-36.
Lyons JA, Turner WC, Getz WM (2013). Home range plus: a space-time characterization of movement over real landscapes. Mov. Ecol. 1(2):1-14.
Moen R, Pastor J, Cohen Y, Schwartz CC (1996). Effects of moose movement and habitat use on GPScollar performance. J. Wildl. Manage. 60:659-668.
Mohr CO 1(947). Table of equivalent populations of North American small mammals. Am. Midl. Nat. 37:223-449.
Ngene SM, Njumbi S, Ngoru B, Nzisa M, Bitok E, Poghon J, Gombe A, Koech E, Sangawe O, Wambua D, Omondi C, Korir W (2013). Satellite-Linked GPS Collars Deployed on Elephants in Tsavo Ecosystem, Kenya. In: Recent Advances in Satellite Research and Development (Eds. S. Gardiner and K.P. Olsen). Nova Publishers, New York, USA.
Ogutu JO, Piepho HP, Dublin HT, Bhola N, Reid RS (2009). Dynamics of Mara-Serengeti ungulates in relation to land use changes. J. Zool. 278(1):1-14.
Okello MM, D'Amour DE (2008). Agricultural expansion within Kimana electric fences and implications for natural resource conservation around Amboseli National Park, Kenya. J. Arid Environ. 72(12):2179-2192.
Okello MM (2005). Land use changes and human-wildlife conflicts in theAmboseli area, Kenya. Hum. Dimens. Wildl. 10(1):19-28.
Okello MM, Kioko J (2010). Contraction of wildlife dispersal area in Olgulului-Ololorashi Group Ranch around Amboseli National Park,Kenya. Open Conserv. Biol. J*.* 4:28-39.
Osborn FV (2004). The concept of home range in relation to elephants in Africa. Pachyderm 37:37-44.
Powell RA (2000). Animal home ranges and territories and home rangeestimators. Research Techniques in Animal Ecology: Controversies and Consequences (Eds L. Boitani& T.K. Fuller). Columbia University, NewYork. pp. 65-110.
Reinecke H, Leinen L, Thißen I, Meißner M, Herzog S, Schütz S, Kiffner C (2014). Home range size estimates of red deer in Germany: environmental, individual and methodological correlates. Eur. J. Wildl. Res. 60:237-247.
Sager-Fradkin KA, Jenkins KJ, Hoffman RA, Happe PJ, Beecham JJ, Wright RG (2007). Fix success and accuracy of global positioning system collars in oldgrowthtemperate coniferous forests. J. Wildl. Manage*.* 71:1298-1308.
Seaman DE, Powell RA (1996). An evaluation of the accuracy of kernel density estimators for home range analysis. Ecol. 77:2075-2085.
Schuler KL, Schroeder GM, Jenks JA, Kie JG (2014). Ad hoc smoothing parameter performance in kernel estimates of GPS-derived home ranges. Wildl. Biol. 20:259-266.
Stokke S, Du Toit JT (2002). Sexual segregation in habitat use by elephants in ChobeNational Park, Botswana. African J. Ecol. 40:360-371.
Wall J (2016). Movement Ecology for ArcGIS (ArcMet*)* [Online]. Available: www.movementecology.net [Accessed 10th June 2013].
Walter WD, Fischer JW, Baruch-MorDo S, Vercauteren KC (2011). What is the proper method to delineate home range of an animal using today's advanced GPS telemetry systems: the initial step, pp.249-268. In O. Krejcar (ed.), Modern telemetry. InTech, Rijeka, Croatia.
Worton BJ (1989). Kernel Methods for Estimating the Utilization Distribution in Home-Range Studies. Ecol. 70:164-168.

SUPPLEMENTARY MATERIAL

Table 1. List of number and names of Kajiado ranches.

S/N	Ranch name
1	EwuasoKidong
2	EwuasoKidong
3	Embakasi Forest
4	Ngong Scheme 2
5	Suswa
6	Not Named
7	Ngong Scheme 1a
8	Ngong Scheme 3
9	Ngong Scheme 1b
10	Ololua Forest
11	Ngong Town
12	Ngong Scheme 5
13	Ngong Scheme 4
14	Ngong Scheme 4b
15	Olteyani
16	Kitengela Game Conserv. Area
17	Ngong Scheme 6
19	Nairobi National Park
20	OlochoroOnyore
21	Kipeto
22	Olooloitikoishi
23	Kaputei North
24	LoodoAriak
25	Kisaju
26	Oldoinyoke
27	Magadi Concession
28	Kilonito
30	Olkiramatian
31	Kaputei Central
32	Ildamat
33	Lake Kwenia
34	Dalalakutuk
36	Olkeri
37	Erangata-Wuas
38	Shombole
39	Mbuko
40	Kaputei South
41	Osilalei
42	Lorngosua
43	Lake Kabongo
44	Torosei
45	Magadi Concession
46	Lengesim
47	Mailua
48	Meto
49	Lolarashi/Olgulului
50	Mbirikania
51	Chyulu West Game Conservation Area
52	AmboseliNp

Table 1. Contd.

53	Kuku
54	Kimana/Tikondo
55	Kimana/Tikondo Small Holdings
56	Endonet
57	EnkariakRongena
58	Emperon
59	Olkarkar
60	Nkama
61	Rombo B
62	Entarara
63	Rombo A
64	Rombo Block II
65	Rombo Block II
66	Rombo Block III


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