Elephant corridor use and threats in the eastern range of Amboseli elephants, Kenya

Article *in* Pachyderm · January 2011

2 authors:

John Kioko
School for Field Studies

Simon Seno

Elephant corridor use and threats in the eastern range of Amboseli elephants, Kenya

John M. Kioko[1] and Simon Ole Seno[2]*

[1]The School for Field Studies, Center for Wildlife Management Studies, PO Box 27743 – 00506, Nairobi, Kenya

[2]School of Natural Resources Management, Narok University College, PO Box 861 – 20500, Narok, Kenya

* Corresponding author: jkioko@fieldstudies.org

Abstract

Elephant corridors are critical in safeguarding wildlife dispersal areas. Understanding the level of corridor use by elephants and the threats they face is important for prioritizing their conservation. Following cessation of heavy elephant poaching in 1970s and 1980s in the Amboseli area, elephants associated with Amboseli National Park (NP) began to reoccupy their eastern range. However, emerging changes in land use and ownership may be hindering elephant movements and range utilization. The status of three corridors and their use by elephants and other wildlife in the eastern range of Amboseli elephants was assessed. The intensity of daily corridor use by elephants differed among three corridors that were observed in this study. There was a strong relationship between elephant and other wildlife use of the corridors. Elephant corridors were significantly threatened due to constriction by human settlement, agriculture, land subdivision and existence of non-negotiated land tenure. Primarily, these threats have been occasioned by individualization of land. Potential solutions to preserve critical elephant corridors include the initiation of community-based conservation programmes such as conservancies and land lease agreements.

Key words: Amboseli Ecosystem, corridor threat factors, elephant movement

Résumé

Les corridors des éléphants sont essentiels à la sauvegarde de zones de dispersion de la faune. Comprendre le niveau d'utilisation des corridors par les éléphants et les menaces auxquels ils font face est un fait important pour en faire leur conservation une priorité. Après l'arrêt de l'intense braconnage des éléphants des années 1970 et 1980 dans la région d'Amboseli, les éléphants associés au Parc national d'Amboseli ont commencé à réintégrer leur habitat oriental. Toutefois, les changements émergents dans l'utilisation et la propriété foncière peuvent entraver les déplacements des éléphants et l'utilisation de l'habitat. On a évalué l'état de trois corridors et leur utilisation par les éléphants et les autres animaux sauvages dans l'habitat oriental d'Amboseli. L'intensité de l'utilisation quotidienne du corridor par les éléphants diffère entre les trois corridors qu'on a observés dans cette étude. Il y avait une corrélation forte entre l'utilisation des corridors par les éléphants et les autres animaux sauvages. Les corridors des éléphants étaient significativement menacés à cause de la réduction par le peuplement humain, l'agriculture, le lotissement et l'existence de la propriété foncière non négociée. Principalement, ces menaces étaient occasionnées par l'individualisation de la terre. Des solutions potentielles pour préserver les corridors essentiels aux éléphants comprennent l'initiation de programmes de conservation communautaire tels que les conservations et les contrats de location des terres.

Introduction

The viability of protected areas is threatened by loss of wildlife habitat (Newmark, 2008). Habitat loss can be attributed to increasing human population, changes in land use and land ownership. In Kenya, these factors have resulted in a remarkable decline of wildlife populations (Ottichilo et al., 2000). The range of African elephants in East Africa has continually declined due loss of habitat and displacement by humans. In the Amboseli ecosystem, a key elephant range in Kenya (Blanc et al., 2003), agriculture is the major land use in the wetlands and on Mt. Kilimanjaro's slopes (Campbell et al., 2000). Wildlife has relied on the same areas in the dry season and thus crop farming is likely to induce severe conflicts and wildlife displacement.

The evolving land tenure has had broad implications for wildlife conservation. Since the 1960s, the Kenyan government started the processes of setting up group ranches (Kimani & Pichard, 1998), which are livestock production systems where a group of people jointly owned the land title, with membership often based on kinship and traditional land rights (Gok, 1968). The Kajiado district, covering about 1.500 km2, about 72.5% of the land, remained as group ranches until the early 1980s (Gok, 1982). The Loitokitok district – originally part of Kajiado district has land ownership has largely remained as group ranches keeping large tracts of land intact for both wildlife and livestock. The failure of the group ranch system (Munei, 1991; Kimani & Pichard, 1998) and pressures associated with changes in lifestyle among the Maasai has in recent times led to continuing subdivision of their land into individual plots, a process now emerging in Loitokitok district.

These emerging changes in land use and ownership have profound implications for elephant conservation. Elephants move over large areas, between different habitats and at different times (Blanc et al., 2003) in search of free surface water (Jachmann & Croes, 1991) due to segregation and reproductive demands (Stokke & Du Toit, 2002).

Considering that over 80% of the known elephant range in Africa lies outside protected areas (Blanc et al., 2003), it is necessary to ensure that the effects of habitat loss and fragmentation are minimized by promoting habitat connectivity through corridors. Corridors—spaces that facilitate movement—can reduce disjunction of wildlife habitats (Beier and Noss, 1998). Amboseli NP, only about 400 km^2, is relatively small to support large wildlife numbers associated with the park. The Amboseli elephant population (Moss, 2001), now estimated to be about 1,300, seasonally use the Amboseli ecosystem. Their movement is known to extend to the west, to the southwest into Tanzania (Douglas-Hamilton et al., 2005), and to the north into Eselengei and Mailua Group Ranches (KWS & TAWIRI, 2010). Adjacent areas, such as Kimana Wildlife Sanctuary to the east, are critical dry season habitat for elephant and other wildlife (Douglas-Hamilton et al., 2005; Kioko et al., 2006). Agriculture and human structures threaten to curtail the elephant and other wildlife movement. The identification of critical corridors and related management issues is crucial for immediate conservation action. This study explores the status of elephant corridors, relationships between elephant and other wildlife use of corridors and dispersal area, and the nature and level of threats facing elephant corridors in the eastern range of Amboseli elephants.

Study area

Six group ranches and Amboseli NP largely form the Amboseli ecosystem, an area about 5,600 km^2, defined by elephants ranging in both wet and dry seasons. The elephant populations linked with Amboseli, Chyulu, Kilimanjaro and Amboseli NPs are known to use the area (Poole & Reuling, 1987). The eastern range of Amboseli elephants is defined by Kimana, Mbirikani and Kuku Group Ranches and individual plots in the high potential agricultural areas (Fig. 1). Kimana Group Ranch lies adjacent to the park and has been subdivided, with each member receiving 60-acre parcels. The area, like the rest of the Amboseli ecosystem, is semi-arid, where livestock keeping is a main economic activity for the Maasai. Since the 1970s crop farming has developed within swamps and on the lower slopes of Mt Kilimanjaro (Campbell et al., 2000). The Kimana area is now under irrigated farming, which—together with associated human settlement—threatens to isolate Kimana Sanctuary. Three corridors, Mbirikani, Isinet and Empiron corridors and the linking Kimana Santuary, and the wider ecosystem were studied (Fig. 1).

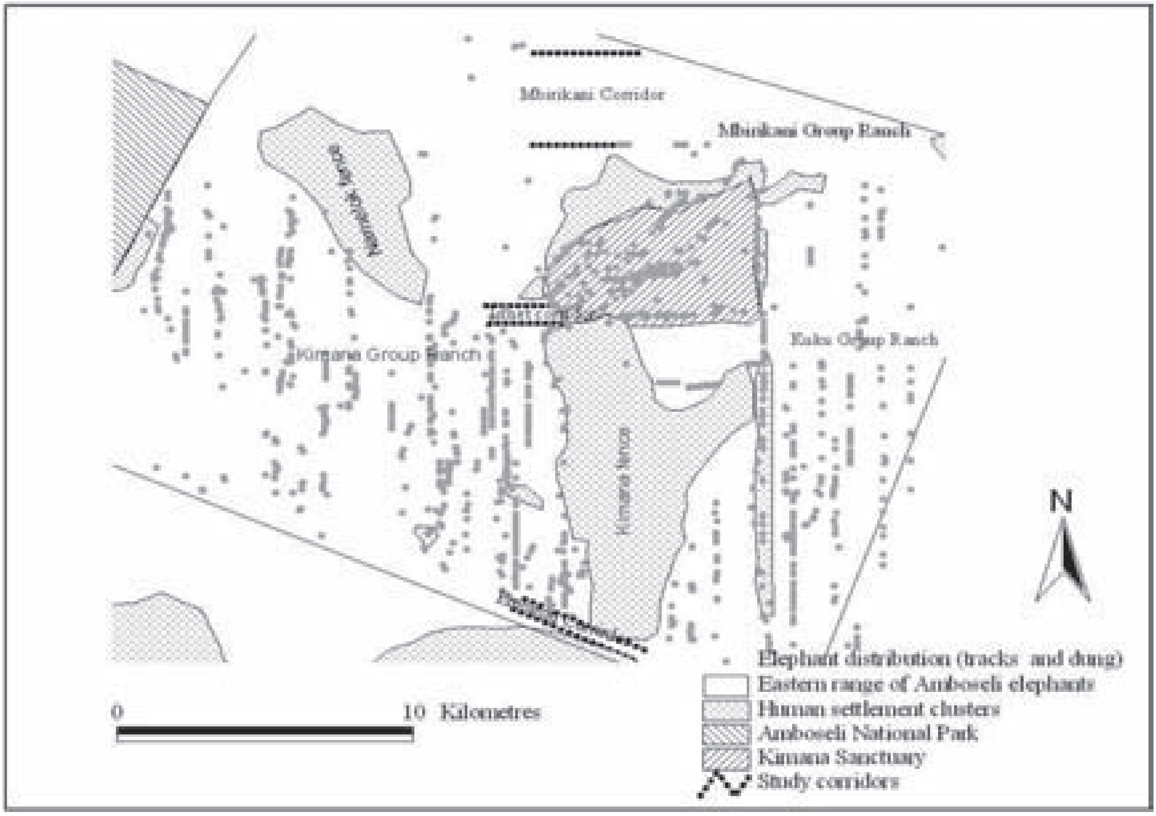

Figure 1. Location of study corridors in the eastern range of Amboseli elephants.

Materials and methods

Elephant use of corridors and dispersal area

To understand how elephants and other wildlife used the corridors and dispersal area, data were collected for a one-year period between November 2007 and November 2008. The spatial-temporal use of the corridors by elephants and other wildlife was monitored daily between 0600–0800 h. After 0800 h, human activity within the corridors heightened and wildlife was observed to avoid the corridors. Transects of variable width (0.5–1 km) within each corridor were monitored on a daily basis for elephant presence (signs and actual sightings). Since elephant use of the corridors was mainly at night, indirect observation was applied in estimating the age of elephants. Measurements (length and width) of hind footprint for clear tracks were taken following the procedure described by Western et al. (1983). In the adjacent dispersal area, elephants were monitored during the wet and dry season by undertaking vehicle and foot counts. For each individual elephant or group, the sex and group type were identified. Data from systematic reconnaissance flights (SRF) (Norton-Griffith, 1978), on elephant use of the area east of Amboseli were obtained from the Department of Regional Centre for Remote Sensing and Survey (DRSRS).

Relationship between elephant and other wildlife use of corridors

To understand how other wildlife species used the corridors and the wider dispersal area, data on type of wildlife species and number were collected.

Nature and level of threats to elephant corridors

Ten threats to the corridors were identified through literature review, discussions with elephant researchers, the local community and field observations. Since the corridors were all along a main road (Emali–Oloitokitok road), a length of 2 km from the centre of each corridor was considered for each corridor. The width of the corridor varied depending on the extent of

Table 1. Description of habitat threats facing elephant corridors in the eastern range of the Amboseli ecosystem

Corridor threat	Question being addressed	Variable of measurement
Human settlement	What is the density of households within the corridors?	Number of homesteads
Encroachment by agriculture	What is the corridor width remaining due to constriction from agricultural activities?	Corridor width
Land subdivision	What proportion of the corridor is under individual ownership?	Proportion of land subdivided
Habitat displacement by human activities	What area of the corridor is taken by human activities?	Area occupied by human structures
Charcoal burning	What is the number of charcoal kilns per km^2?	Number of charcoal kilns
Rangeland degradation	What is the corridor forage potential?	Forage potential (kg/km^2)
Changing landownership	What proportion of landowners within the corridor are non-Maasai people?	Area of corridor owned by non-Maasai?
Urbanization	What area of the corridors is taken by shopping centres or earmarked for market development?	Area occupied
Corridor protection	What area of corridor falls within a negotiated conservation framework?	Area protected
Habitat connectivity	What is the average distance travelled by elephants to their nearest cluster area?	Average distance

corridor constriction. Both the length and width of the corridors were measured using a Geographical Positioning System (GPS) device. The other variables measured to determine corridor threats are explained in Table 1. Additionally, the extent of agriculture and human settlements in the larger dispersal area was mapped using GPS.

Data analysis

The estimates of elephant numbers between 1977 and 2001 were calculated using the Jolly method (Jolly, 1969). The Kruskal–Wallis H test was used to test whether intensity of corridor use by elephants differed among the three corridors. Analysis of Variance (ANOVA) was used to compare mean size of hind tracks of elephants using the corridors and those using the adjacent dispersal area. A post hoc Tukey test was used to determine which sites differed. A similar procedure was used to analyze wildlife biomass data.

Chi-square goodness of fit test was used to compare proportions of hind foot length for different age classes, the number and biomass of large mammal species using the corridors, and Mann-Whitney *U* test used to test if the mean group size of elephants using the Empiron and Isinet corridors was significantly different. Lastly, a Pearson correlation coefficient test was used to determine the strength of the relationship between elephant and other wildlife use of the corridors.

A variable (Table 1) was used within each corridor to evaluate the extent of each threat; the proportion of each threat for all the three corridors was then ranked based on a scale (0-25% = 1, 26-50% = 2, 51-75% = 3 and 76-100% = 4). The mean rank score for each of the corridors was determined by taking the mean score of all corridor risk factors. The mean score for each corridor was considered as

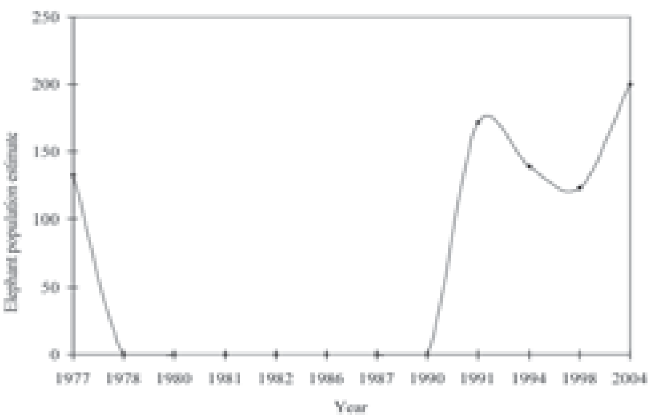

Figure 2. Changes in elephant numbers between 1977 and 2004 within the eastern range of Amboseli elephants. Data for the subsequent years are not available.

the corridor threat index (Cti). In order to determine which corridor was significantly threatened, it was decided that if there was a significant deviation (one-tailed, at type one error, $\alpha = 0.05$) of a corridor mean index from the overall mean score for all the corridors or that the value of corridor deviation from the overall mean was negative, then the threat index was considered high. A similar approach was used to prioritize protected area importance in Kenya (Okello et al., 2005). Area and distance measurements were determined in ArcView GIS (Esri, 2002).

Results

Trends in elephant use of corridors and dispersal area

The trend in elephant numbers between 1977 and 2001 shows that Amboseli elephants' use of the eastern range declined in the 1970s and 1980s (Fig. 2).

Elephant daily presence showed that the intensity of elephant corridor use differed among the three corridors ($H(2) = 10.237$, $p = 0.007$). The Isinet corridor averaged a mean rank of 18.56, compared to 11.56 and 7.38 for Mbirikani and Empiron, respectively. There was a significant difference in the mean size of the hind footprint of elephants using the corridors and those within the dispersal area (F(3)

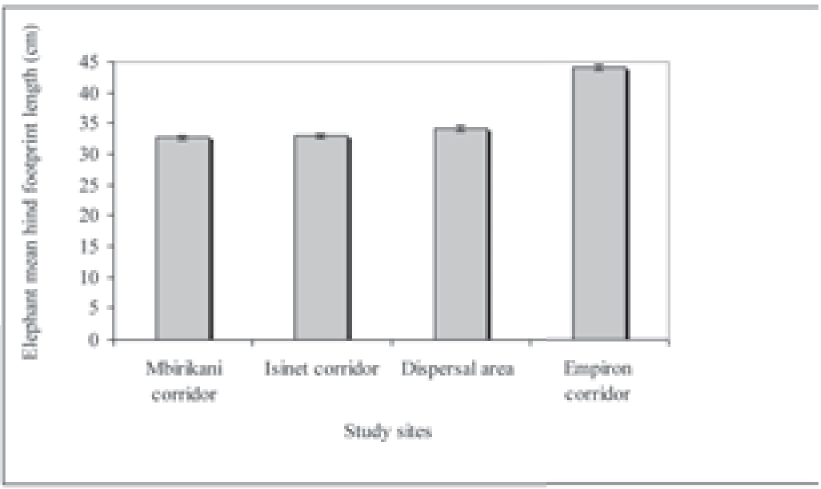

Figure 3. Mean hind footprint length for elephants using corridors and the dispersal area.

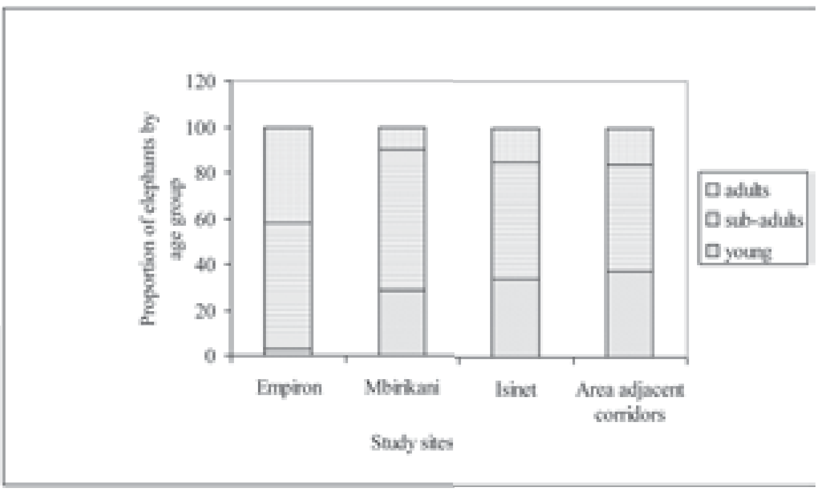

Figure 4. The proportion of young, subadults and adults based on classification of elephant hind footprints.

3536 = 73.410, P<0.001) (Fig. 3). A post hoc Tukey test showed that elephants using Empiron corridor had a higher mean hind footprint size (44.096±.38) compared to elephants using larger dispersal area, and those using Mbirikani (32.68±0.35) and Isinet (32.99±0.34) corridors. The aggregate mean hind footprint length of elephants using the dispersal area (34.08±0.49) was not significantly different from the ones using the Isinet corridor (32.99±0.34).

Large mammal use of corridors and dispersal area

The variety of large mammal species that used the different corridors did not differ significantly (χ^2 = 27.52, df = 2, P = 4.83). Many species however used Isinet corridor, while Empiron corridor was used by a lesser number of species. The number of species that used the corridors did not differ from that for species that used the wider dispersal area (χ^2 = 6.02, df = 3, p = 0.11). Eleven of the 17 species observed within the study area avoided Empiron corridor, while only 2 species avoided Isinet corridor (Table 2).

Table 2. Chi-square goodness of fit test for variation in large mammal (including Maasai ostrich) use of Isinet, Mbirikani and Empiron corridors in January – December 2008

Species	**Isinet corridor**	**Mbirikani corridor**	**Empiron corridor**	**Total**	**χ^2 - value**	**P-value**
Elephant	71	5	28	(104)	64.750	P<0.05
Grant's gazelle	779	363	35	1177	708.731	P<0.05
Maasai giraffe	532	404	34	970	413.699	P<0.05
Impala	567	42	385	994	428.972	P<0.05
Maasai ostrich	12	69	0	81	40.11	_
Thomson's gazelle	886	757	0	1643	10.128	_
Burchell's zebra	1089	0	712	1801	78.917	_
Common wildebeest	1250	788	0	2038	104.732	_
Common waterbuck	2	0	0	2		_
Warthog	42	0	0	42		_
Vervet monkey	21	0	0	21		_
Gerenuk	0	453	0	453		_
Lion	0	*	0	0		_
Spotted hyena	*	1	*	1		_

NB: Only signs cited (*), Test not done (-) as one of the corridor had zero values.

There were significant differences in the proportions of the young (χ^2 = 28.068, df = 3, p<0.001) and the old (χ^2 = 30.01, df = 3, p<0.001), but not the proportion of the subadult elephant population (χ^2 = 2, df = 3, p = 0.572) across the corridors (Fig. 4). The mean group size of elephants in Empiron and Isinet corridors did not differ significantly (U = 813, p = 0.799), and similarly there were no significant differences in the mean among the group of elephants using the dispersal areas and those that used the corridors in the wet and dry seasons (H (4) = 5.04, P = 0.282).

One-way ANOVA comparing large mammal biomass (excluding elephants) in the three corridors shows significant differences (F(2, 18) = 93.99, p< 0.01. Tukey's HSD comparison of large mammal biomass indicates that the mean biomass was significantly different between two of the three corridors. The highest percent of wildlife biomass 58.00% (5,251 kg) was associated with Isinet corridor (χ^2 = 27.52, df = 2, p< 0.01). Consistent with overall monthly wildlife use of the three corridors (Fig. 5),

Table 3. Comparison of threat scores for Isinet, Mbirikani and Empiron corridors

Corridor threat factor ranking	**Isinet**	**Mbirikani**	**Empiron**	**Mean ranks**
Corridor constriction	4	1	4	3.00
Proportion of corridor subdivided	2	1	4	2.33
Habitat destruction (Proportion of charcoal kilns)	1	1	4	2.00
Range degradation (soil erosivity)	2	2	2	2.00
Extent of urbanization	1	1	2	1.33
Rate of change in landownership (non-Maasai homesteads)	1	1	4	2.00
Degree of corridor isolation (distance to the nearest protected area)	1	3	2	2.00
Human settlement (homesteads within corridor)	2	1	4	2.33
Proportion of land under non-negotiated tenure	1	4	4	3.00
Mean ranks	1.67	1.67	3.33	2.22
Corridor threat index (Cti)	**0.52**	**0.52**	**-1.14**	**-0.03**

aggregate means of all the large mammals observed show that there was a strong relationship between elephant and other wildlife use of corridors (r(2) = 0.70, p = 0.05).

There was a significant positive correlation between elephant use of the three corridors and total elephant signs (dung and tracks) during the eight months of this study (r(2) = 0.762, p = 0.028). Elephant use of Isinet corridor was not significantly correlated with wildlife biomass (r(8) = 0.610, p = 0.214, while in Empiron corridor there was a strong positive and significant correlation between elephant and other large mammal use of the corridors (r(8) = 0.714, p = 0.047). In Mbirikani corridor, there was a moderate positive and insignificant correlation between elephant and other large mammal use of the corridor (r(8) = 0.643, p = 0.086).

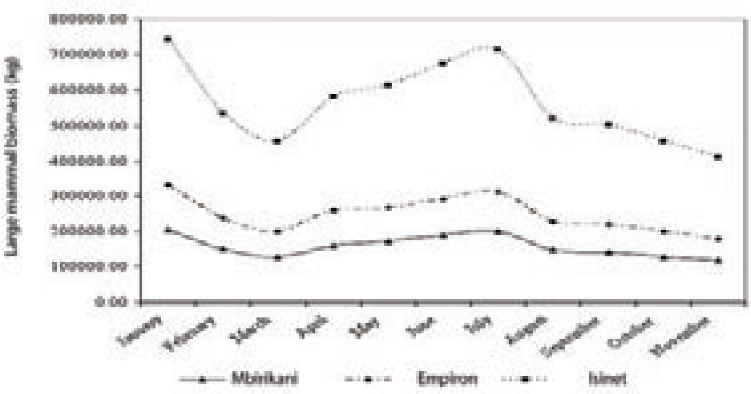

Figure 5. Variation in large mammal biomass (kg) in Mbirikani, Empiron and Isinet corridors.

Nature and level of threats to corridors and dispersal area

The mean threat factor for all the corridor indicators shows that there were significant levels of threats to the corridors (Table 3).

The major threat factors were corridor constriction by agriculture, human settlement, land subdivision and the existence of non-negotiated land tenure to safeguard the land within the corridors. Of the three corridors, Empiron was the most threatened by a range of factors including charcoal burning, change in land ownership from Maasai to non-Maasai, urbanization, existence of non-negotiated land tenure and constriction due to rain-fed and irrigated agriculture.

Human activities (particularly agriculture in association with or independent of human settlement) led to a direct loss of 215.90 km^2 (26.59%) of the eastern range of Amboseli elephants. Several clusters were the centres of these activities with the fenced areas of Kimana and Namelok taking 63.05 km^2 (29.33%) of the area occupied by the human activity clusters.

Discussion

The elephants of Amboseli now partially depend on Amboseli NP, with the larger part of the population seasonally using areas outside the park. It is suggested that with the near elimination of poaching in the 1990s, elephants started to return to their former range (Muruthi et al., 2000). oHowe To the east of Amboseli, due to escalating human developments, elephant movement has been confined to three major corridors. The variation in elephant use of these corridors can be explained by a number of factors. Isinet corridor, which had the highest level of use was adjacent to the swamp in Kimana Sanctuary, while Empiron corridor, the least used, was in an area highly fragmented by human activities. Mbirikani corridor, furthest from the Kimana Sanctuary was intermittently used by elephants even though it had a nominal level of fragmentation compared to the other corridors. This corridor had been isolated by agriculture occurring in the greater part of the Kimana swamp.

The variation in population age structure of elephants using the three corridors could be due to the location of each corridor in relation to Kimana Sanctuary. Empiron corridor had the highest mean hind footprint of elephants of 44 cm, which represents an age group of elephants older than 30 years as per the Amboseli elephant population estimates (Western et al., 1983). The corridor falls between irrigated farmlands and rain-fed farmlands, and most elephant tracks were to or from these farms. It is likely that these were produced by male elephants; females and young may have avoided these areas due to the risks associated with crop-raiding. The three corridors and dispersal areas were used by a similar proportion of subadult elephants of 10–30 years of age. This suggests dominance of male elephants using the corridors and within the dispersal area. Areas such as the Kimana Sanctuary are important concentration areas for bull elephants during the dry season and the point from which they make forays into the adjacent dispersal areas (Kioko et al., 2006)

Elephants are a keystone and flagship species whose conservation is key to the survival of other species. Together with elephants, over 17 large mammal species used the corridors as the only conduits for back and forth access to Kimana Sanctuary and the adjacent dispersal area. The three corridors are in areas very critical to elephant and other wildlife utilization of the Amboseli ecosystem. The lack of significant differences in species richness within the three corridors implies that they are still equally critical to wildlife dispersion. While Mbirikani corridor had the least biomass of large mammals, it was the least affected by human activities and may be more important in the future if the increasing trend in fragmentation and isolation of the other corridors continues.

Although the Amboseli elephants have begun to reoccupy their former range, there is danger of impaired movement and habitat loss. Conservation efforts should focus on ensuring that mechanisms that guarantee land use that is compatible with conservation of the elephant range are encouraged. Conservation lease agreements that specify land use and ownership restrictions could be tested and evaluated. In the Isinet corridor, a land fee of USD 6 per acre per year is being paid directly to the landowner to keep the area open for wildlife (African Wildlife Foundation, 2008). In the Mbirikani corridor, it is suggested that the area could be managed as a conservation area such as a community wildlife sanctuary.

Acknowledgements

This study was funded by United States Fish and Wildlife (Grant No. 0373). Additional financial and logistical support came from School for Field Studies and Moi University, School of Environmental Studies.

References

African Wildlife Foundation (AWF). (2008). *African Heartland News. A newsletter for partners of the African Wildlife Foundation*, Nairobi, Kenya: IUCN.

Beier, P. and Noss, R.F. (1998). 'Do habitat corridors provide connectivity?' *Conservation Biology*.12(6):1241–1252.

Blanc, J.J., Thouless C.R., Hart, J.A., Dublin, H.T. and Barnes, R.F.W. (2003). *An update from the African elephant database*. IUCN/SSC, African Elephant Specialist Group. Gland, Switzerland and Cambridge, UK: IUCN.

Campbell, D.H, Gichohi H.W, Mwangi, E. and Chege L. (2000). 'Land use conflict in Kajiado District, Kenya'. *Land use Policy* 17:337–348.

Douglas-Hamilton, I., Krink T. and Vollrath, F. (2005). 'Movements and corridors of African elephants in relation to protected areas'. *Naturwissenschaften* 92:158-163.

ESRI. (2002). *Using ArcView GIS*. Redlands, CA, USA: Environmental Systems Research Institute.

Government of Kenya (GOK). (1968). *Group (Land) Representatives Act*. Government Printers, Nairobi, Kenya.

Government of Kenya (GOK). (1982). *Minutes on Poka Group Ranch meeting on Subdivision, 21/8/91*. File KAJ/POKA Group Ranch (1)65, Kajiado, Kenya.

Jachmann, H. and Croes, T. (1991). 'Effects of browsing by elephants on the Combretum/ Terminalia woodland at the Nazinga Game Ranch, Burkina Faso, West Africa'. *Biological Conservation* 57:13–24.

Jolly, G.M. (1969). 'Sampling methods for aerial census of wildlife populations'. *East African Agricultural Journal* 34:46–49.

Kimani, K. and Pichard, J. (1998). 'Recent Trends and Implications of Group Ranch Subdivision and Fragmentation in Kajiado District, Kenya'. *The Geographic Journal* 164:202–213.

Kioko, J., Muruthi, P., Omondi, P and Chiyo, P.I. (2008). 'The performance of electric fences as elephant barriers in Amboseli, Kenya'. *South African Journal of Wildlife Research* 38(1):52–58.

Kioko, J., Okello, M. and Muruthi, P. (2006). 'Elephant numbers and distribution in the Tsavo-Amboseli ecosystem, southwestern Kenya'. *Pachyderm* 40:61-68.

Kenya Wildlife Service (KWS) and Tanzania Wildlife Research Institute (TAWIRI). (2010). *Aerial Total Count: Amboseli-West Kilimanjaro Ecosystem, Wet season, March 2010* Kenya: KWS.

Moss, C.J. (2001). 'The demography of an African Elephant (*Loxodonta Africana*) population in Amboseli'. *Journal of Zoology* 255:145–156.

Munei, K. (1991). *Study on the subdivision of group ranches in Kajiado District. Department of Livestock production* Kajiado District, Kenya.

Muruthi, P., Stanley, P.M., Soorae P., Moss, C.J. and Lanjouw. (2000). 'Conservation of large mammals in Africa. What lessons and challenges for the future?' In: A. Entwistle and N. Dustone (eds.) *Priorities for the conservation of mammalian biodiversity: has the pada had its day*? U.K.: Cambridge University Press.

Newmark, W.D. (2008). 'Isolation of African Protected Areas'. *Frontiers in Ecology and the Environment* 6:1–9.

Norton–Griffiths, M. (1978). *Counting Animals. Handbooks on techniques currently used in African wildlife ecology. 2nd Edition*. Nairobi, Kenya: African Wildlife Leadership Foundation.

Okello, M.M., Wishitemi, B.E.I. and Lagat, B. (2005). 'Tourism potential and achievement of protected areas in Kenya: Criteria and prioritization'. *Tourism Analysis* 10:1,083–5,423.

Ottichilo, W.K., Grunblatt J., Said, M.Y. and Wargute, P.W. (2000). 'Wildlife and livestock population trends in the Kenya rangeland'. In: TT. Dolan (ed.) *Wildlife Conservation by Sustainable Use.* pp. 203–219. Boston, USA: Kluwer Academic Publishing.

Poole, J.H. and Reuling, M. (1997). *A survey of elephant and other wildlife of the West Kilimanjaro basin Tanzania*. Unpublished report. African Elephant Specialist Group. Nairobi, Kenya.

Stokke, S. and du Toit, J.T. (2002). 'Sexual segregation in habitat use by elephants in Chobe National Park, Botswana'. *African Journal of Ecology* 40:360–371.

Western, D., Moss, C.J. and Georgiadis, N. (1983). 'Age estimation and population age structure of elephants from footprint dimensions'. *Journal of Wildlife Management* 47:1,192–1,197.