Amboseli-West Kilimanjaro Large Carnivore Census Report 2012

AFRICAN WILDLIFE FOUNDATION

KENYA WILDLIFE SERVICE

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Executive summary

Increasing concerns about the recent decline and disappearance of large carnivores in the world has called attention to conservationists and wildlife management institutions to collect information to be used in action plans for management and conservation of large carnivores. Reliable estimates of population density and composition are crucial for planning of strategies for long-term conservation prospects of carnivore populations.

The objectives of this census were i) to provide information on the status and spatial distribution of large carnivores throughout the Amboseli-West Kilimanjaro cross-border ecosystem (AWKE), ii) to validate the perception by community that high human-carnivore conflicts were due to high numbers of large carnivores in the ecosystem, iii) to harmonize reported estimates of large carnivores across the AWKE by various studies in the region, iv) To determine demographics and composition of the large carnivore species in the ecosystem including lion, hyena, cheetah, leopard, jackal and wild dog.

Population estimation was based on call-back methodology modified to allow for the use of samples and determining probability distribution pattern of carnivores using Maximum entropy modeling of species geographic distribution. This technique of combining call-backs and Maxent modeling has a great potential to be used to assess carnivore population estimates over large landscapes in African rangelands.

Seventy three (73) call-in stations were created and used in data collection. Three species of carnivores (African lions, spotted hyenas and black-backed jackals) responded to call-backs. The population estimates were 104±13 African lions, 377±40 spotted hyenas and about 191±26 black-backed jackals. In addition, questionnaire surveys indicated that wild dog, leopard and cheetah to be found in the ecosystem although these carnivores are found at low densities.

Human-carnivore conflict is a major challenge for conservation of large carnivores in Amboseli-West Kilimanjaro Ecosystem (AWKE). Poor husbandry strategies employed by pastoralist such as the use of young boys as herders, poorly reinforced enclosures for livestock security contribute to high levels of livestock predation. More concerted efforts especially those integrating direct conflict mitigation approaches (such as the use of strong barriers to prevent livestock predation) and indirect approaches (such as those that focus on community engagement, like compensation) are needed to foster carnivore conservation.

Despite having a large expanse of land in the AWKE, only a small proportion of the habitat was identified as being suitable for carnivore species. In conservation terms, this underscores the need for concerted effort to secure suitable habitats based on species distribution. Currently

habitat loss in the AWKE is fraught by increasing changes in land uses and the sub-division of rangelands into small plots. For long-term conservation prospects of large carnivores, maintaining large contiguous land should a priority by conservationists.

Table of contents

1.0. Introduction

Increasing concerns about the status and distribution of large carnivores in the world have called attention to conservationists and wildlife management institutions to collect information for management and conservation actions to be taken to improve conservation prospects for large carnivores. In wildlife management and conservation, reliable population size estimates are crucial for planning of strategies for long-term conservation of carnivore populations. Several direct and indirect methods have been developed to estimate the abundance of larger carnivores (Bertram, 1979; Gros, Kelly & Caro, 1996; Mills, 1997; Gese, 2001; Wilson & Delahay, 2001). Among these methods, the direct assessment of carnivore numbers is particularly difficult, expensive and time-consuming. Therefore, several indirect census techniques have been proposed, which have proved to be cost-effective, repeatable and objective (e.g. Van Dyke, Brocke & Shaw, 1986; Van Sickle & Lindzey, 1991; Smallwood & Fitzhugh, 1993, 1995; Beier & Cunningham, 1996; Stander, 1998; Grigione et al., 1999; Lewison, Fitzhugh & Galentine, 2001). The selection of a method to use in the estimation of carnivore numbers in each situation should thus be based on the objectives, the targeted species, and size of area. In addition, type of habitat to be surveyed, the amount of money, and time available are important considerations in the selection of a method to be used (Mills, 1997; Wilson & Delahay, 2001).

More recently, lure surveys, using playback sounds, have been used to model population sizes (e.g. Mills et al., 2001; Ogutu, Bhola & Reid, 2005) and have produced reliable results compared with known population sizes (Ogutu & Dublin, 1998). This method incorporates response probability and range, which are modeled with an independent experiment (Mills et al., 2001). Recent studies (Christian et al, 2008) indicate that luring efficiency did not seem to be influenced by night-time or moon-phase and the tested assumptions of the probability based model seem to largely meet carnivore behavior, suggesting that this method is adequate for estimating population sizes of a range of species of carnivores.

The objectives of this census were i) to provide information on the status and spatial distribution of large carnivores throughout the Amboseli-West Kilimanjaro cross-border ecosystem (AWKE), ii) to validate the perception by community that high human-carnivore conflicts were due to high number of large carnivores in the ecosystem, iii) to harmonize reported estimates of large carnivores across the AWKE by various studies in the region, iv) To determine demographics and composition of the large carnivore species in the ecosystem including lion, hyena, cheetah, leopard, jackal and wild dog.

Livestock predation by hyena has been a major concern for consolation programs especially in the Amboseli side. A census to determine the abundance of hyenas was therefore important so as to form a basis for appropriate management decision. Apart from this, human-carnivore conflict mitigation initiatives are not uniform across the two countries. The census was therefore aimed at providing information that can be a basis for mitigation measures. Overall the census provides the baseline information on the estimates of large carnivores in the area and this can now be used in the evaluation of conflict mitigation measures.

Because of the multidisciplinary nature of large carnivore conservation and management, this census collected both ecological as well as the socio-ecological data related to human-carnivore interactions. This report presents results of the ecological studies including information on estimated population densities and distribution of large carnivores. Information from questionnaire surveys conducted with the local communities to understand human-carnivore conflicts, attitudes and challenges for carnivore conservation is also presented and discussed.

2.0 Study Area

The Amboseli-west Kilimanjaro ecosystem straddles the border of Kenya and Tanzania. On the Kenyan side, the ecosystem covers an area of approximately 5,700 Km² stretching between Mt. Kilimanjaro, Chyulu Hills, Tsavo West National Park and the Kenya/Tanzania border. The area is generally arid to semi-arid with a very small variation in its agro-ecological zones and is more suitable for pastoralism rather than cultivation with a high potential for conservation of wildlife and tourism enterprises. Administratively, the Amboseli ecosystem consists of Amboseli National Park and the surrounding six group ranches. The six group ranches namely; Kimana/Tikondo, Olgulului/Olararashi (Norht, East West and South), Selengei, Mbirikani, Kuku, and Rombo cover an area of about 506,329 hectares in Kajiado County (Fig. 1). It also includes the former 48 individual ranches located at the foot slope of Kilimanjaro that are now under crop production, mainly rain fed agriculture.

On the Tanzanian side, the Amboseli-west kilimanjaro ecosystem comprise of Enduimet Wildlife Management Area (EWMA) and the surrounding communities in nearby villages. The Enduimet Wildlife Management Area constitutes the core area for conservation and management of natural resources, and covers about 128,179 hectares (Fig. 1) excluding village lands. The Enduimet Authorized Association (EAA) is responsible for management of the EWMA. The EAA is formed by eight villages from Enduimet Division namely Sinya, Tingatinga, Ngereiyani (TingaTinga Ward), and Elerai, Ol Molog, Lerangwa, Kitendeni, and Irkaswa (Ol Molog Ward). EAA implemented the first Resource Zone Management Plan (RZMP) between 2005 and 2010.
The Enduimet Wildlife Management Area (EWMA) lies in the Longido district near the Tanzania-Kenya border. It serves as an important trans-national migratory route and dispersal area for

many fauna including the African elephant, lions and other ungulates. It remains the only corridor that connects Tanzanian West Kilimanjaro ecosystem to the Kenyan Amboseli-Tsavo system.

Enduimet Division has a population of approximately 17,000 people with a total of 2,615 households in Ol Molog Ward and 1,060 households in Tingatinga wards. The dominant ethnic group is the Ilkisongo Maasai but on the more heavily cultivated lands, the area also includes a large number of WaArusha, WaChagga, WaPare and WaMeru ethnic groups. Land use is dominated by pastoralism, although most people in Enduimet practice agro-pastoralism.

Fig. 1. Map showing the Amboseli-west Kilimanjaro cross-border ecosystem including Amboseli NP and the surrounding group ranches and Enduimet Wildlife Management Area.

2.1. Flora and Fauna

Amboseli-west Kilimanjaro ecosystem is predominantly semi-arid climate. Nevertheless, water springs associated with Mt. Kilimanjaro emanate at the basin of the ecosystem and give rise to several swamps which are critical to maintaining wildlife in the ecosystem. The high primary productivity of the swamps is able to sustain a vast array of wildlife species in a semi-arid environment and contributes to the high biodiversity and tourism value of the ecosystem. The ecosystem has an elephant population of about 1400 individuals. Elephants have been a major driving force in the ecology of the AWKE and are closely associated with habitat changes in

Amboseli National Park. Although AWKE experience a semi arid environment, it supports a wide range of ungulates, which in turn support carnivores such as lion, leopard, cheetah, hyena, jackals, civets, and serval cats.

Amboseli National Park is one of the 60 Important Bird Areas (IBA's) in Kenya and thus it is recognized as globally significant for bird conservation. The ecosystem has a rich birdlife, with over 400 species recorded, of which 40 are birds of prey. It has globally threatened bird species (e.g. Lesser Kestrel), restricted-range birds that are found only in a very small area such as the Taveta golden weaver, bird species that live only in a particular vegetation type such as the Grosbeak weaver and regionally threatened bird species such as Martial eagles

The AWKE falls under the Chyulu/Kilimanjaro volcanic natural region which is an Acacia dominated dry woodland savannah. This vegetation type supports the pastoralist lifestyle of the local Maasai and a wide array of savannah wildlife species.

The EWMA and the surrounding areas also experience a semi-arid climate with low rain fall as a result of the rain shadow effect from Mount Kilimanjaro. The region has a short rain season from November to December and a long rain season from March to May, with the driest months from August to October. The vegetation comprises of mixed Acacia bush and woodlands dominated by *Acacia Commiphora, A tortilis* and *Sporobulus* short grass plains.

3.0. Material and methods

3.1 Study Design

Three methods were used to obtain information for this study: 1) direct count of the large carnivores by the use of play back systems, 2) interviews with communities using structured questionnaires and 3) by the use of individual identification and radio telemetry. The third method was only used for lions and the study team obtained this data from an on-going PhD research project in the Amboseli Area. The first method largely targeted hyenas and jackals while the second was important in determining the sighting frequency of all large carnivores by the community as well as determining presence and absence of these species in the ecosystem.

3.1.1 Play back experiments

3.1.1.0 Identification of sampling points for placement of call-in stations.

Because the study areas encompass protected as well as semi-protected community areas such as group ranches and wildlife management area (WMA), strata were created according to level of human-carnivore conflict, and group ranch divisions including the WMA as a division. Human-carnivore conflict zones were created by use of data acquired through the predator consolation schemes and conflict monitoring records. The study area was stratified into 5km^2 grids of high and low conflict. This was achieved by performing a spatial join of the grids and the conflict incidences using ESRI ARC GIS 9.3. High and low conflict grids were defined by the number of incidences per grid, where high was above 3 incidences and low was below this threshold (Fig. 2). To ensure adequate coverage of the study area, a minimum of 25% sampling effort was targeted for each zone (Ogutu and Dublin 1998). Using Hawths analysis sampling tools, sample points were randomly generated ensuring that the following conditions were met; (1) that the minimum distance between calling stations was equal to or more than five kilometers, (2) no calling station was within two kilometers from human settlements. Prior to the survey, locations of known hyena dens were identified and mapped in partnership with the communities. This information was used to guide the placement of call-in stations to ensure that known den sites especially for hyenas were properly surveyed.

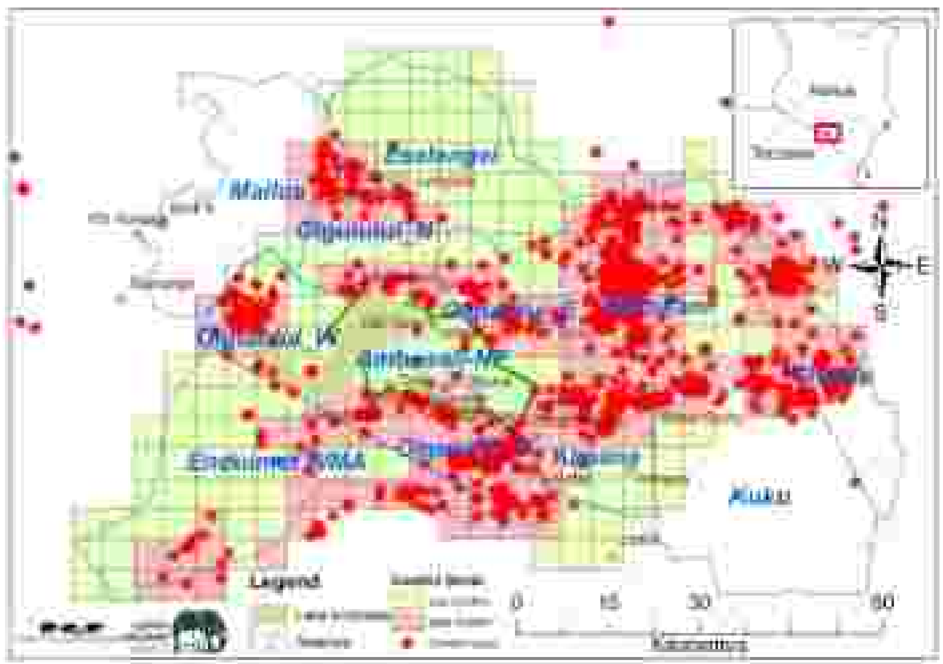

Fig. 2: Stratification and identification of grids for placing call-in stations for carnivore surveys

3.1.1.1 Call-in play backs

At each call-in station, vocalizations were used to attract carnivores by playing a mix of lion roars, hyenas mobbing lions at a kill, buffalo calf in distress and pig squeals. A loud speaker was used to broadcast vocalizations at a volume of 110-120 db at each call-in station for 30 minutes then turned at 180^{o} angle and the same sequence of vocalization played and recording done for another 30 minutes. The call-in were done at each station either very early in the morning 600-800hrs and/or in the evening 1800-1900hrs. Where possible call-in were conducted at night 2000-2200hrs when spotlights were used to scan for responding carnivores. Vocalizations at each call-in station were broadcast in three bouts of five minutes each interspaced with five minutes breaks of silence. During playback vocalizations the station was searched using binoculars or spotlights for responding predators and recorded as they arrived at the station. Information recorded at each call-in station included time of each broadcast, species of each responding predator, number of individuals and age-sex classes of responding predators (Appendix 1). At each call-in station pictures of vegetation were taken facing four directions (E-W, N-S) (Fig. 3.)

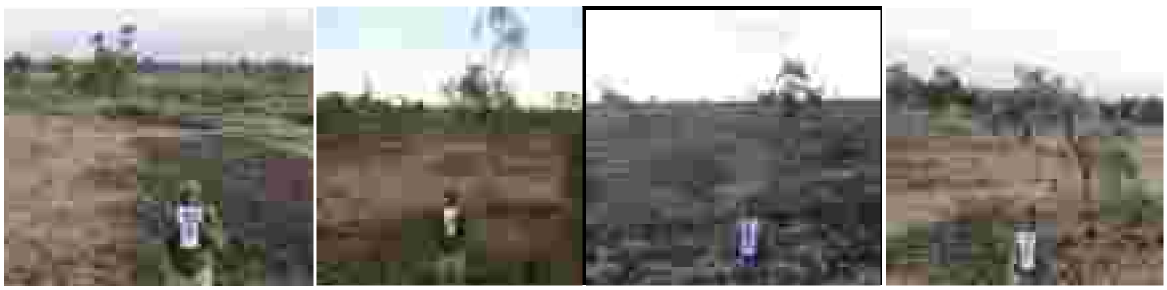

Fig.3. Four pictures taken to depict the vegetation types at each call-in station

3.1.1.2 Calibration of the Play back systems

Prior to executing the call back experiments, the instruments were calibrated for distance to which the carnivore would respond to the sounds (Mills etal 2001). Upon finding one or more hyenas, a vehicle with one observer stayed with the group, while an observer in a second vehicle drove a distance of 5Kms and played the recording by broadcasting from the roof of the second vehicle. The first vehicle noted the behavior of the hyenas and the distance between the two vehicles was reduced until when the animal under study responded to the broadcast. This distance was then used as the maximum distance at which broadcasts from our instruments is audible. On average the animal responded at a distance of about 5Kms windward and 2 kms against the wind. We used an average of 2.5 Kms as the distance for our equipment. We also attempted to calibrate the probability of approach of the various carnivores, however due to time and resources constraints, not sufficient repetition/animals were found to give a reliable estimate. Consequently in order to estimate population size we used probability figures from studies conducted in similar habitats.

3.1.2 Questionnaire surveys and interviews

Questionnaire survey was used to gather information both from households as well as from herders in the grazing fields. The issues captured were; presence/absence of carnivore species and the distribution based on sighting frequency of different carnivore species in any one location; the level and impact of human-carnivore conflicts in the ecosystem and the strategies used by livestock keepers to reduce livestock losses due to predation and lastly the attitude of locals towards carnivore conservation.

3.1.2.0 Sampling Procedure for questionnaire survey

The group ranches included in this survey were Olgulului Ololorashi, Eselengei, Mbirikani, Kimana, Mailua and Olgulului Trust. Nine villages (Olmolog, Kitendeni, Irkaswa, Elerai, Tingatinga, Sinya, Ngereyani, Lelangwa and Kamwanga village) forming Enduimet WMA were also included in the study. Since the study areas covers protected as well as semi-protected community areas such as group ranches and wildlife management area (WMA), zones were created according to the level of protection and human activities. A total of 227 households (121 from Kenya and 106 from Tanzania) and 86 herders (46 from Kenya and 40 from Tanzania) participated in the survey. Each of the respondents participated only once.

3.2 Data Collection, Monitoring and Supervision

3.2.1 Questionnaire survey

The questionnaire was subjected to pretest with a population experiencing the same challenges and intervention. Prior clearance was sought from the local provincial administration. After selecting the areas and establishing times when selected respondents are present, trained research assistants (RAs) visited homes to explain the study to the individuals. The RAs read the informed consent and eligibility criteria aloud and individuals who consented then completed the questionnaire. However, those unable to read or write were assisted by the RAs. Data was collected on household bio-demographic characteristics, socio-economic/ livelihood activities and threats, issues relating to conservation, community perceptions and tourism, and human-wildlife conflicts. The AWF M&E staff in collaboration with field supervisor oversaw the data collection and logistics exercise to ensure that RAs arrived at the selected areas on time; they appropriately obtained informed consent, maintained confidentiality, and provided information on the study's eligibility criteria. The complete questionnaires were then taken to the AWF offices for data entry and storage.

3.2.2 Individual identification and radio telemetry from long-term studies

Information from long-term lion study was used primarily to determine the abundance and distribution of lions in the study area for comparison with estimates obtained using call backs and modeling. Individual identification was deemed most appropriate for the lions since it is noted that lions at times do not respond well to the call backs. Distribution information on lions was obtained from 9 lions that were collared from 2009. This ongoing study under KWS-Leiden project has developed a system for identifying individual lions using whisker spot patterns and other identifiable features and has generated a lion pictorial database from which information from continuous monitoring has led to the identification of most lions and therefore provide reliable population estimates.

3.3 Data Analysis

A combination of methods was used for data analysis. Data obtained from questionnaire survey were entered into an excel spreadsheet, coded and analyzed using descriptive statistics in excel and Statistical Package for Social Sciences (SPSS).

Spatial data obtained from call-in stations and radio telemetry was analyzed using spatial tools in ArcGIS 9.3 software. Overlay analyses were used to depict spatial relationships between various variables such as carnivore distribution and human settlement patterns. Spatial statistics were employed to study the observed carnivore distribution pattern. Average neighbor analysis were first undertaken to determine whether the observed pattern of carnivore distribution was random, dispersed or clustered. Kernel densities were used to determine the spatial density distribution of the carnivores. Point distances and near analyses were used to investigate the relationship between the observed distribution of carnivores and distances to various environmental variables.

3.3.0. Population Estimation

Population size for lions were estimated using two methods; known individuals from ongoing monitoring and call-in stations. The first method was applicable in Amboseli National Park and immediate surrounding group ranches of Olgulului, Eselenkei and Mbirikani. For the areas that were beyond coverage of the regular monitoring, call-in stations were used to obtain population estimates. Call-in stations were the only method used for estimation of Hyena and Jackal population. Play back was the only method used for estimation of Hyena and Jackal population.

We modified the conventional method of call-in estimation (Ogutu et al 1998; Mills et al 2001) to accommodate our use of suitability habitat index rather than assuming uniform distribution of carnivores in the study area which had been the case in previous studies. This modification entailed the use of Maximum entropy modeling approach to determine suitable habitat and probability distribution of the carnivores. Maximum entropy modeling of Species Geographic Distributions (Philips et al 2006) uses Maxent software to identify landscape features likely to support specific species of carnivores. It uses observed species distribution or presence data and a set of environmental variables to model species habitat suitability in a GIS environment. Output from the model is a spatial representation of the most suitable habitat for the species and indicates the most probable areas to find a species. We employed this approach in order to factor heterogeneity in distribution of the carnivores since our call-in stations were only a sample of the study area. Due to patchy distribution of carnivores, it was not appropriate to extrapolate the population estimate using density and the size of the area alone.

In estimating the population size of the carnivores, we used a probability of response (Mills et al 2001) (the proportion of animals that respond to the call in stations) of 0.27 for lions (Whitman et al 2006) and 0.67 for spotted hyenas (Dloniak, 2006) from studies conducted in similar habitats. We did not find in literature any such response probability for black backed jackal hence we used an arbitrary figure of 0.70 assuming that jackals have a higher response probability closely matching that of spotted hyenas due to their strict opportunistic scavenging behavior.

4.0 Results

4.1 Questionnaire survey

4.1.1. Characteristics of respondents

The background characteristics of respondents included household sizes, gender, age and occupation. Questionnaire results revealed that households comprised an average of five people. There was variation in household sizes in terms of age group distribution of members in the Amboseli and Enduimet side as shown in Table 1. Households in Amboseli had relatively higher number of people per household compared to the Enduimet side. A similar trend can also be observed in the distribution of different age groups of household members.

Table 1: Number of people in the household

Group of people	Amboseli		Enduimet	
Gender	**Sum**	**Average**	**Sum**	**Average**
Male adult	719	5.9	505	4.8
Male youths	481	4.0	273	2.6
Male children	958	7.9	495	4.7
Female adults	846	7.0	566	5.3
Female youths	444	3.7	261	2.5
Female children	875	7.2	451	4.3

Figure 4 shows the gender distribution of both the household respondents and the herders. Majority of respondents were male accounting for 59.5% of household respondents and 92.9% of herders respectively. Given the higher proportion of male herders it suggests that herding in these communities is majorly a male affair.

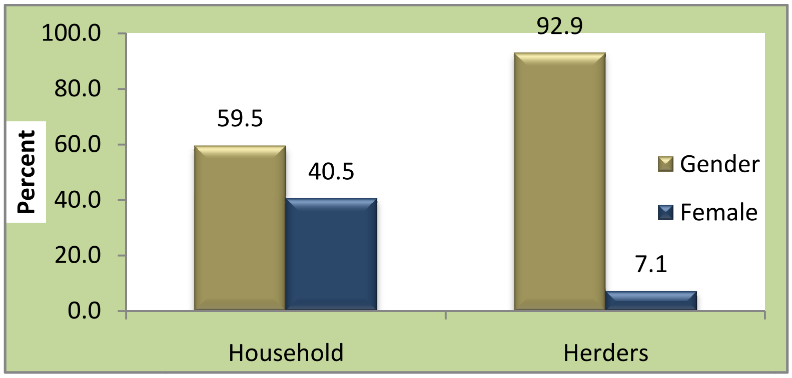

Fig. 4. Gender of respondents in questionnaire survey

4.1.2. Occupation of respondents

Pastoralism was identified as the predominant occupation in the Amboseli-west Kilimanjaro ecosystem: more than half (50.6%) of respondents were identified as pastoralists followed by agro-pastoralists at 47.0%. Other occupations account for less than 3% (see Figure 5).

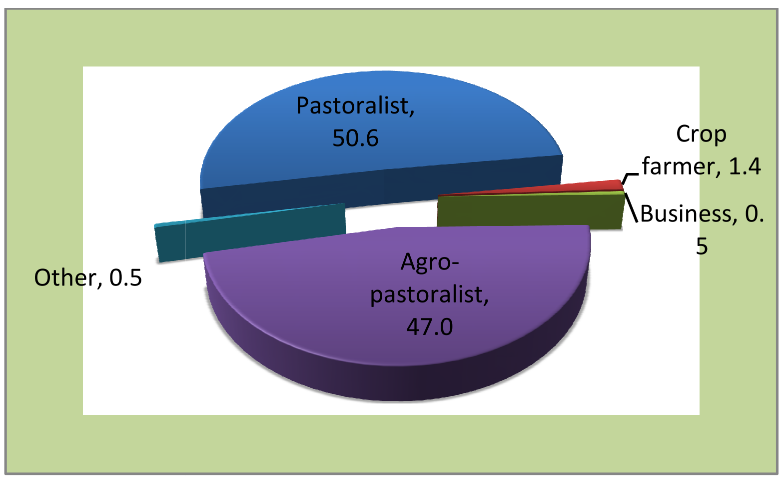

Fig.5. Occupation of respondents who participated in questionnaire survey in the Amboseli-west Kilimanjaro ecosystem

4.1.3. Carnivore sightings from questionnaire survey

The frequency of sighting of carnivores both in wet and dry season is shown in Table 2. The sighting frequency was categorized into daily, weekly, monthly and yearly. In both seasons lions were mostly seen weekly; hyenas mostly seen daily; leopards seen monthly, cheetahs were seen daily; wild dogs seen yearly while jackals were mostly seen daily. However, it was noted that there were variations in the frequency of sighting of the carnivores for wet and dry season. The spotted hyena is the most frequently sighted carnivore species in both seasons, followed by black-backed jackal, and lions and cheetah. Wild dogs and leopards are the rarest carnivores in the ecosystem. But, the overall trend indicates only a slight variation in the frequency of carnivore sightings for wet and dry season.

Table 2: Percentage sighting frequency of carnivores as indicated by respondents

	Wet Season				Dry Season			
	Daily	**Weekly**	**Monthly**	**Yearly**	**Daily**	**Weekly**	**Monthly**	**Yearly**
Lion	25.1	32.2	21.1	10.1	19.6	27.9	24.0	12.3
Hyena	82.5	9.4	4.7	2.8	79.5	10.0	7.0	2.5
Leopard	23.3	20.0	23.9	12.8	21.7	16.9	24.1	14.5
Cheetah	27.6	20.1	22.4	15.5	28.1	20.3	21.6	16.3
Wild dog	2.1	2.1	13.4	20.6	4.1	5.4	12.2	16.2
Jackal	74.2	8.2	7.2	4.1	75.4	8.0	6.3	3.4

4.2. Carnivore response to playbacks

A total of 73 playbacks were conducted in the entire study area between the 14th and 25th February 2012. Three species of carnivores responded to the call backs including spotted hyenas (*Crocuta crocuta*), black-backed jackals (*Canis mesomelas*) and the African lion (*Panthera leo*). The number of responding animals varied between calling stations ranging from 0-26 animals. In one station in Enduimet area 18 hyenas, 3 jackals and 5 lions responded. Generally hyenas responded the most followed by black backed jackals and finally the lions. No other species of the large carnivores responded to the call backs.

In Amboseli area, 44 playbacks were conducted with a total of 161 spotted hyenas, 49 black-backed Jackals and 13 lions responding to playbacks. The age-sex composition of the 161 responding hyenas were 7(4.35%) adult females, 6(3.73%) adult males, 146 (90.68%) unsexed adults and 2(1.24%) unsexed sub-adults. For lions, there were 8(61.54%) adult females, 3(23.08%) adult males and 2(15.38%) unsexed sub adults, while black backed jackal comprised of 2(4.08%) adult males, 2(4.08%) adult females and 45(91.84%) were unsexed adults (Table 3).

In the Enduimet, 29 playbacks were conducted with a total of 97 spotted hyenas, 43 black-backed jackals and 9 lions responding to playbacks. The composition of the 9 responding lions were 2 (22%) adult males, 2 (22%) adult females, 2 unsexed adult lions, and 3 (33%) cubs. Spotted hyenas comprised of 8 (8.25%) adult males, 4 (4.12%) adult females, 75 (77.32%) unsexed adult hyenas and 10 (10.31%) unsexed sub-adult hyenas. Black-backed jackal comprised of 5(11.63%) adult males, 2(5.26%) adult females and a single sub-adult male (Table 3). In all the three species that responded, it was not possible to obtain the sex for majority of individuals (Table 3).

Table 3. Age-sex composition (numbers) of carnivores responding to playbacks in the Amboseli-west Kilimanjaro cross border ecosystem

		SPECIES NAME		
AREA	**Age-sex**	**HYENA**	**JACKAL**	**LION**
AMBOSELI	Adult female	7	2	8
	Adult male	6	2	3
	Unsexed adult	146	45	0
	Unsexed sub-adult	2	0	2
AMBOSELI Total		**161**	**49**	**13**
ENDUIMET	Adult female	4	2	2
	Adult male	8	5	2
	Sub-adult male	0	1	0
	Unsexed adult	75	35	2
	Unsexed cub	0	0	3
	Unsexed sub-adult	10	0	0
ENDUIME Total		**97**	**43**	**9**
Grand Total		**258**	**92**	**22**

4.3 Estimates of carnivore population size

Based on the 29 call in stations and the assumption that each broadcast vocalization covered an average of 2.5km radii (Ogutu & Dublin 1998), approximately 529km^2 was sampled during playbacks in the Enduimet area, while in the Amboseli side 803km^2 was sampled during playbacks in 44 call-in stations. These provided the basis of the observed carnivores used in Maxent modeling. Table 4 presents modeled and un-modeled population size estimates for lions, hyenas and jackals. Un-modeled population estimates assumes that carnivore species are evenly distributed across the entire area, while modeled estimates are based on species specific habitat suitability index which assumes that carnivores are not evenly distributed across the landscape but only occur in certain suitable habitats. The suitable habitat is calculated based on probability of carnivore occurrence using Maxent modeling. Figure 6 show the suitability probability distribution for hyenas, jackal and lions in the ecosystem.

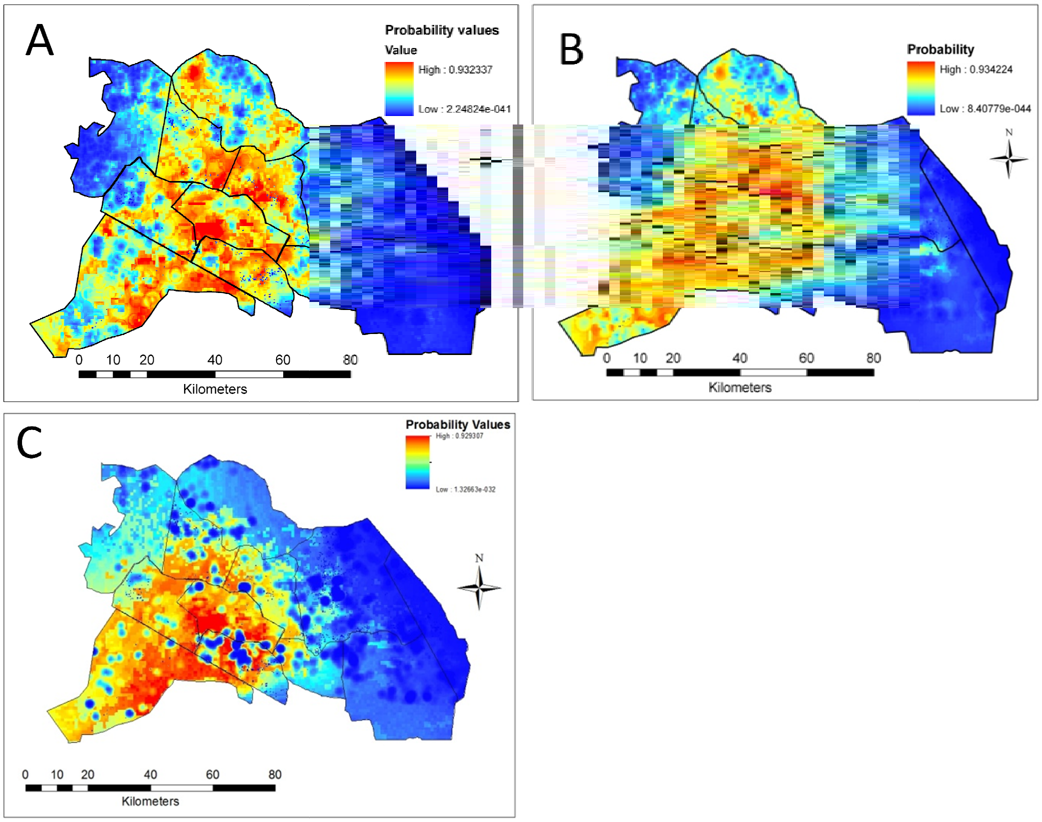

Fig. 6. Modeled distribution of (A) Hyena, (B) Jackals and (C) lions based on Maximum entropy modeling (Maxent) averaged over 30 runs. Cells with a probability value of equal or greater than 0.8 were considered as suitable for the carnivores and were used in the estimation of population size.

The modeled estimates indicate that only about 1.42% of the total area in Amboseli is suitable for lions with an estimated 76±18 lions (density 0.221±0.055 lions/sqkm), while in Enduimet 3.01% of the total area is suitable for lions with 28±4 lions (density of 0.229±0.036 lions/sqkm). For hyenas, 8.12% of the area in Amboseli is suitable for hyenas with estimated population size of 271±37 hyenas (density 0.304±0.042 hyenas/sqkm) while in the Enduimet 18.64% of the area is suitable for hyenas with estimated population size of 106±23 hyenas (density 0.309±0.068 hyenas/sqkm). The estimated jackal population size of 115±13 jackals (density 0.131±0.015 jackals/sqkm) was obtained in Amboseli with 9.78% of the area being suitable for jackals while in the Enduimet 25.30% of the area is suitable for jackals with an estimated 76±20 jackals (density 0.199±0.052 jackals/sqkm).

Results indicated in Table 4 suggest that the un-modeled population estimates tend to be higher than the modeled population, suggesting a potential for overestimating the actual population size. However, the magnitude of overestimation varies for different species of carnivores.

Table 4 Density and population estimates for species responding to Play backs. Population estimates have been corrected using probability of approach (Dloniak, S, M 2006) of 0.57 for hyenas, 0.26 for lions and 1 for Black backed jackals. Density all include all call-in stations even where no carnivore responded. Density presence includes only call-in stations where at least one individual animal responded to call back. All densities are per km^2.

Species	Study Area	Density-All	Density-Presence	Area (KM^2)	Modeled Suitable Area (KM^2)	Population Estimate- un modeled	Modeled Population Estimate
Lion	Amboseli (n= 44)	0.015±0.009	0.221±0.055	6259.9	89	362± 216	76 ± 18
	Enduimet (n= 29)	0.015±0.011	0.229±0.036	1049.8	31.6	64± 45	28 ± 4
	All (n= 73)	0.015±0.007	0.224±0.029	7309.7	120.6	426± 194	104 ± 13
Hyena	Amboseli (n= 44)	0.186±0.034	0.304±0.042	6259.9	508	2048 ± 374	271 ± 37
	Enduimet (n= 29)	0.170±0.046	0.309±0.068	1049.8	195.6	314± 86	106 ± 23
	All (n= 73)	0.180±0.027	0.306±0.035	7309.7	703.6	2363± 350	377 ± 40
Jackal*	Amboseli (n= 44)	0.057±0.012	0.131±0.015	6259.9	612	507± 105	115± 13
	Enduimet (n= 29)	0.076±0.026	0.199±0.052	1049.8	265.56	113± 39	76± 20
	All (n= 73)	0.0642±0.012	0.156±0.021	7309.7	877.56	670± 130	191± 26

4.4 Spatial distribution of carnivores

Figure 7 depicts the spatial distribution of the three species of carnivores that responded to playbacks. Spotted hyena was the most widely distributed species. At least one spotted hyena responded in 16 (55.172%) call-in stations. On average (6 ± 2.265SE, range 1-18) spotted hyenas responded in each station. Black-backed jackal responded in 11 (37.931%) call-in stations with average of (3.91 ± 1.799SE, range 1-10) jackals per station. Lions responded in only 2 (6.896%) of call-in stations, suggesting that lions might be rarer species in the ecosystem compared to spotted hyenas and black-backed jackal.

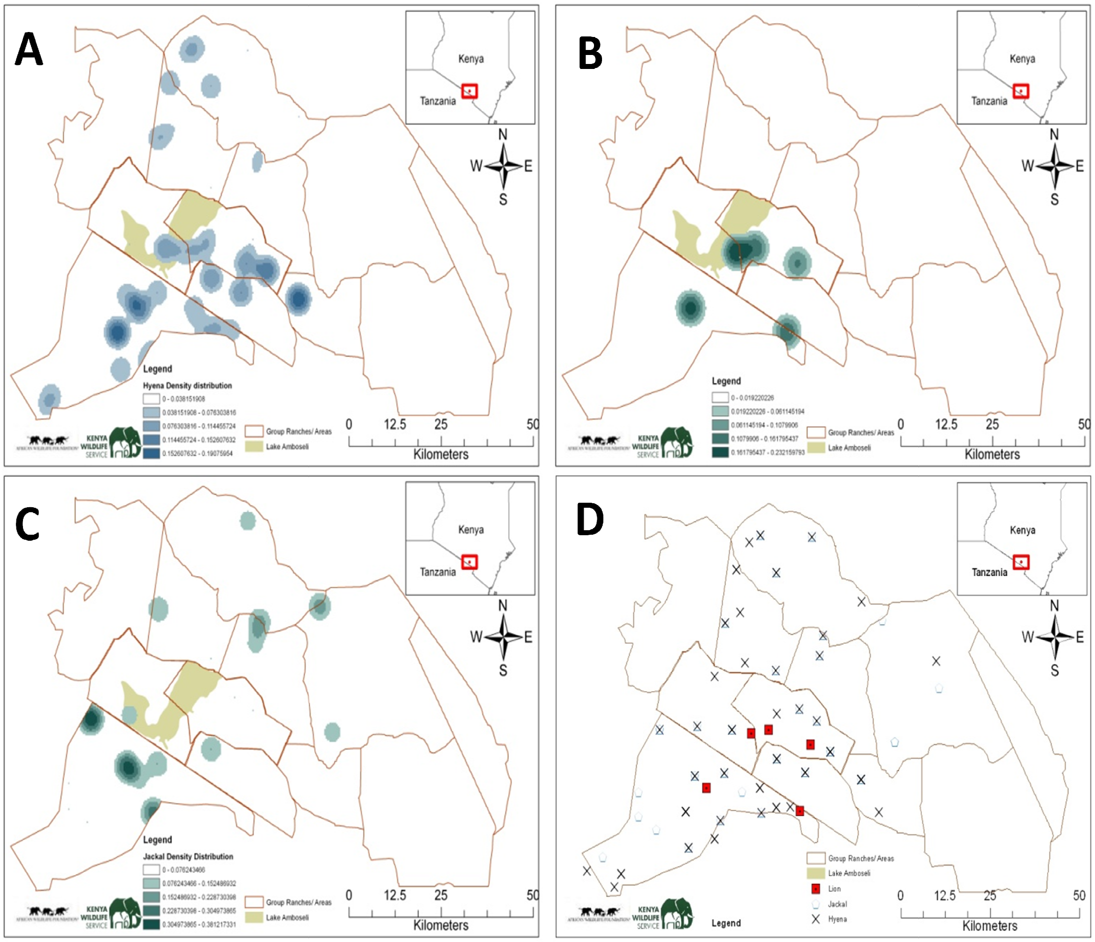

Fig.7. Kernel density distribution of A) spotted hyena, B) black-backed jackal and C) the African lion in the Amboseli-West Kilimanjaro area based on playbacks conducted. Figure D shows the species distribution according to the call-in stations for all three species combined in the entire study area

When the species distribution was aggregated (i.e. all the three carnivore species combined), average nearest neighbor analysis showed that the overall distribution pattern was clustered (Z score = -11.092, P<0.001; Table 5). On disaggregation of the species, average Neighbor analysis showed that both lions (Z score = -6.085, P<0.001 and hyenas (Z score = -9.761, P<0.001) had a clustered pattern of distribution. In contrast however Jackals (Z score = -1.276, P=0.201; Table 5) had a distribution pattern that did not significantly differ from complete spatial random. This indicates that jackals were more evenly distributed than spotted hyenas and lions.

Table 5. Nearest neighbor analysis showing spatial distribution of spotted hyenas, jackals and lions in the AWKE

Species/Environmental layer	Aggregate all carnivores (lion, hyena, jackal)	Lion	Jackal	Hyena
Observed mean Distance	811.382065	1009.728	6257.286	2057.006
Expected Mean distance	3749.282	12340.398	7027.793	4749.821
Nearest Neighbor ratio	0.216	0.082	0.890	0.433
Z- score	-11.092	-6.085	-1.276	-9.761
P value	0.0000001	0.000001	0.202	0.00001

Using information from the long-term lion population monitoring in the Amboseli, the distribution and movement pattern of lions for dry and wet season months indicate that lions utilize the Amboseli NP as the core home range and utilizing the surrounding areas for short excursions Fig. 8 consistent with results from nearest neighbor analysis. The lion movement pattern also underscores the importance of areas outside Amboseli NP for the long-term lion conservation strategies in the ecosystem.

Fig.8. Distribution and movement pattern of lions in the Amboseli-West Kili ecosystem during Nov-Dec 2011 and Jan. 2012.

4.5 Relationship between modeled carnivore distribution and environmental variables

The influence of various environmental variables on carnivore distribution varied between carnivores. In general, vegetation cover, distance from abandoned bomas and distance to water sources showed the greatest influence on the distribution of spotted hyena, lion and black-backed jackal. For example, vegetation cover contributed 40.1% of the influence on spotted hyena distribution, 48.1% of black-backed jackals' distribution, and 18.1% of lion's distribution. Three vegetation classes (open grasslands with sparse shrubs, open grasslands and sparse grasslands) had the greatest contribution indicating that both carnivores were more likely to be found in these types of habitat. Abandoned bomas contributed 25% of the influence on spotted hyenas distribution, 21.1% of black-backed jackal distribution and 27.7% of lions' distribution Fig 9a-c.

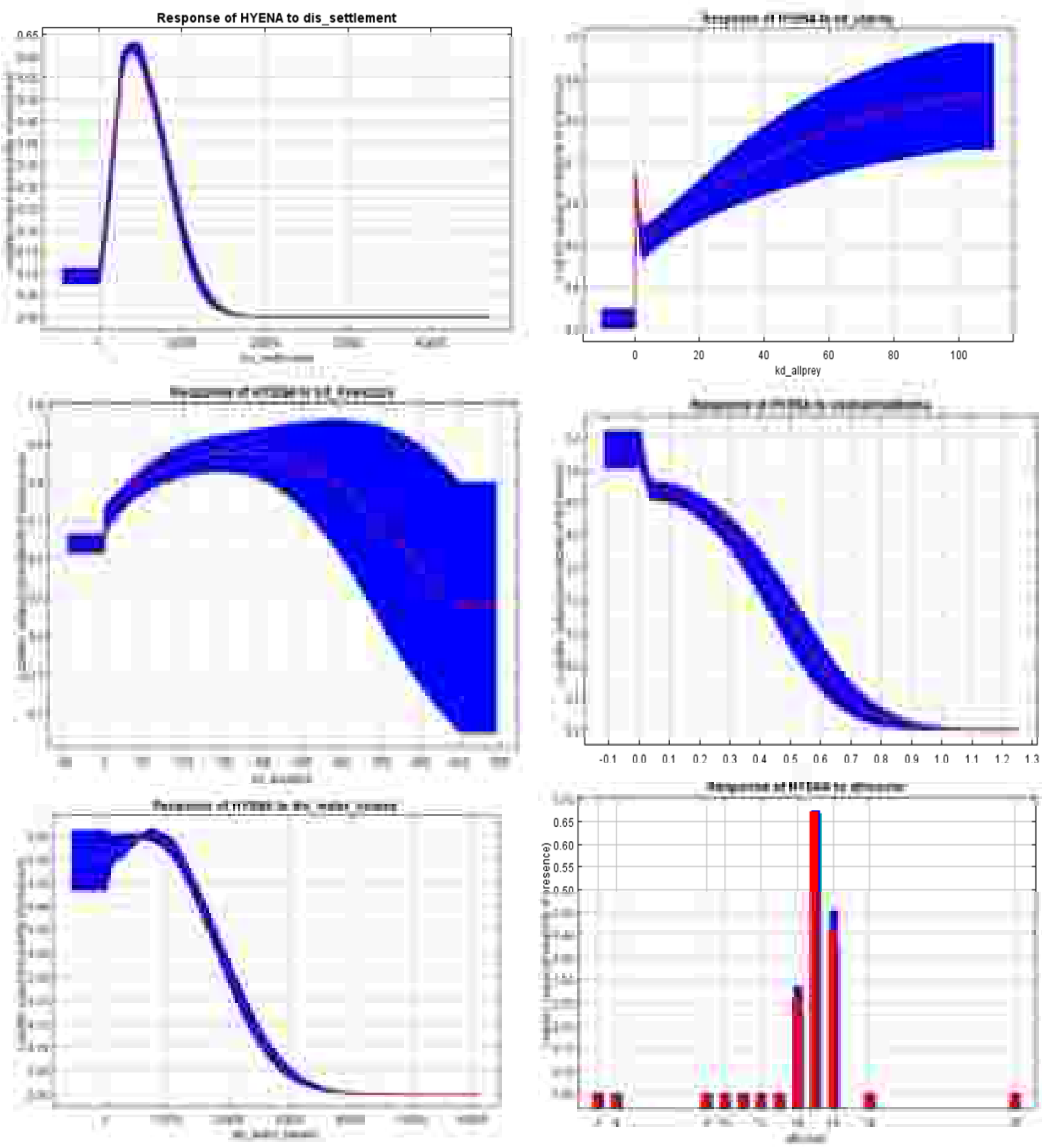

Figure 9a. Relationships between modeled spotted hyena distribution and various environmental variables as generated by Maxent software. The blue region around the red line indicates variation from the mean represented by the red line. Appendix 2A show the percentage contribution of each environmental variable used in the model.

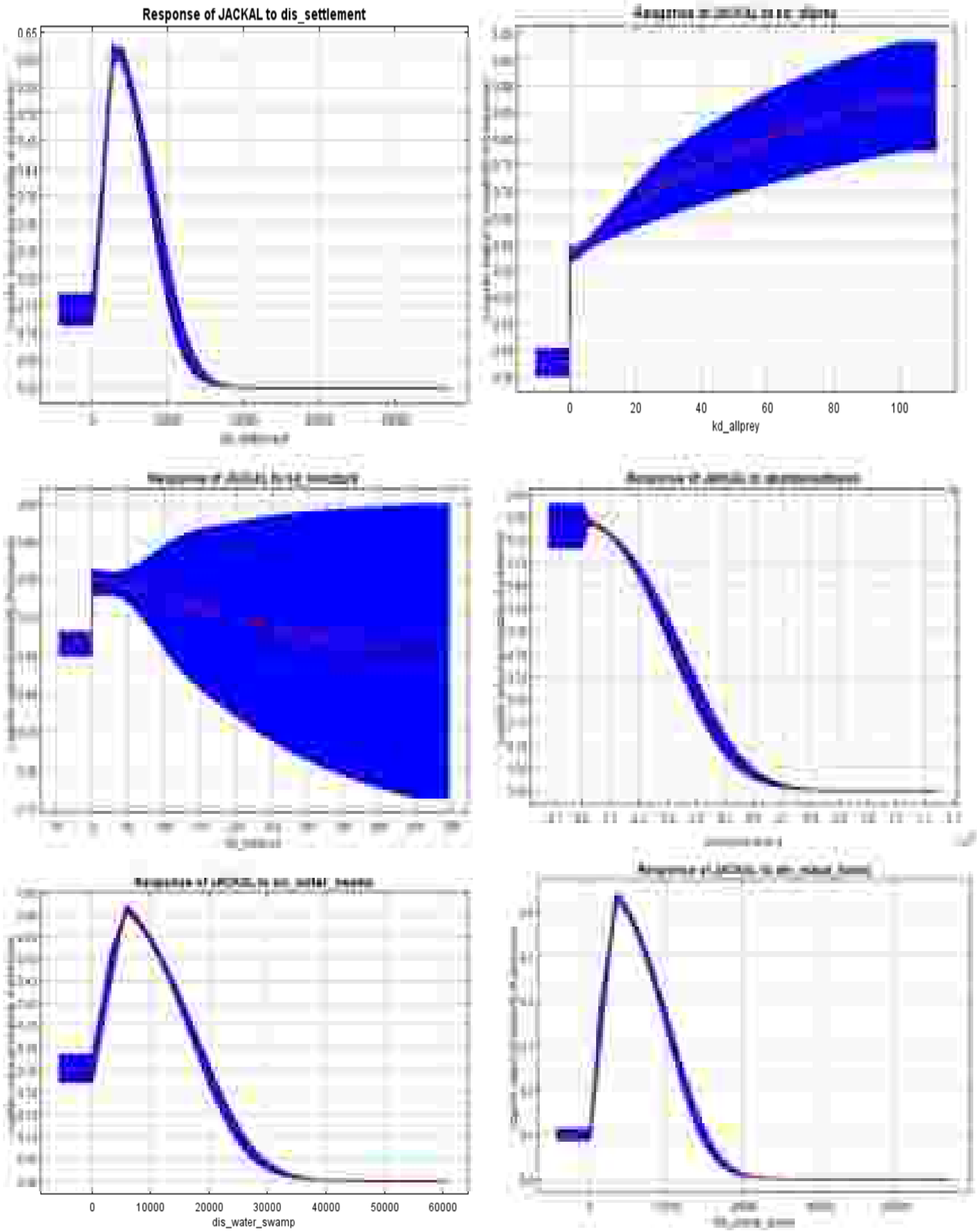

Figure 9b. Relationships between modeled black-backed jackal distribution and various environmental variables as generated by Maxent software. The blue region around the red line indicates variation from the mean represented by the red line. Appendix 2B show the percentage contribution of each environmental variable used in the model.

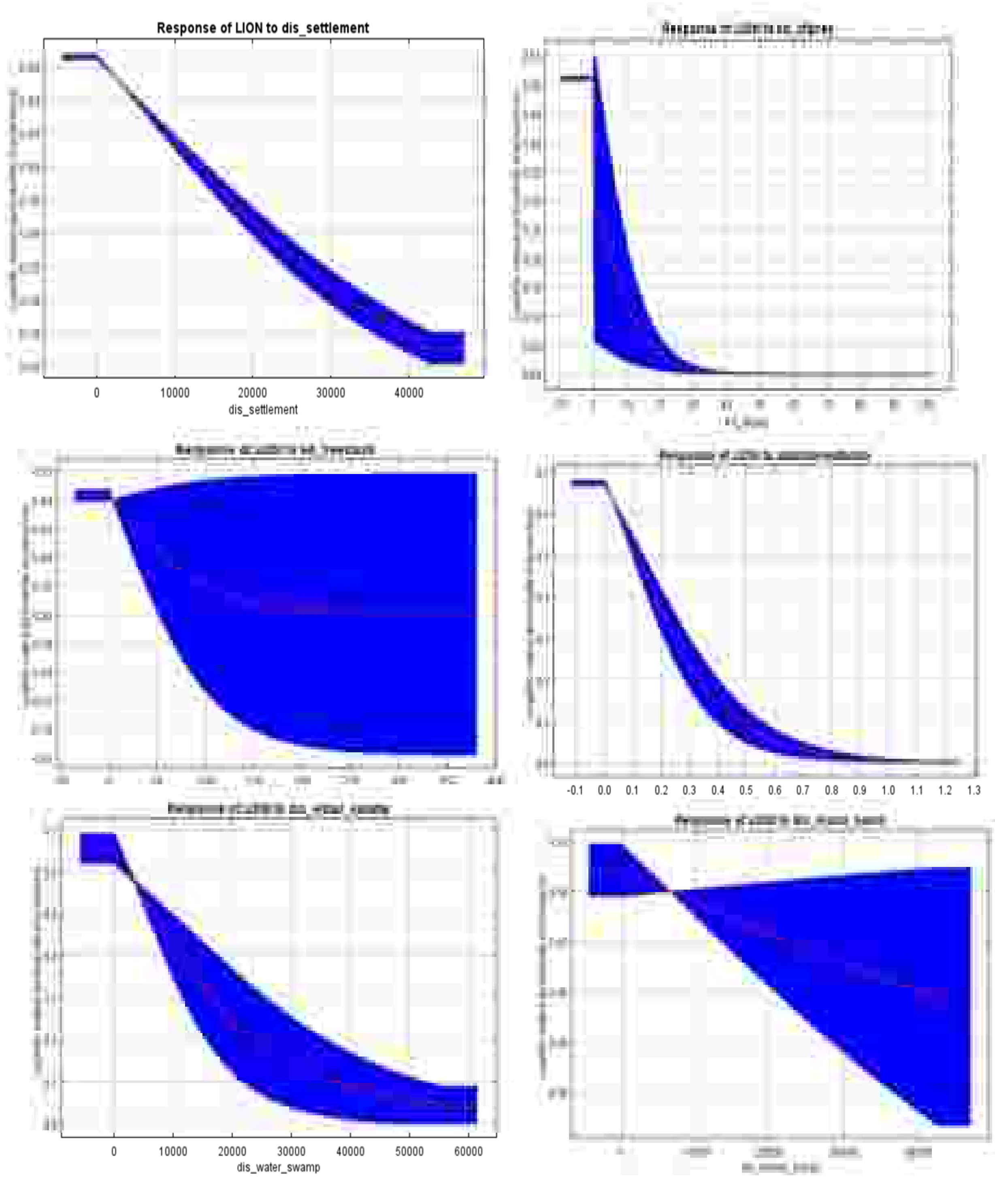

Figure 9C. Relationships between modeled African lion distribution and various environmental variables as generated by Maxent software. The blue region around the red line indicates variation from the mean represented by the red line. Appendix 2C show the percentage contribution of each environmental variable used in the model.

The distance from human settlement to where spotted hyenas and jackals were likely to be found showed a belly curved relationship. The optimum distance where they were likely to be present was 5km from human settlement. The probability of presence increased with increasing distance from settlements (bomas, mabati houses, churches, centers etc) up to about 5km then decreased with increasing distance, indicating that these carnivores are likely to be distributed not too close and not too far from settlements (Figure 9a&b). However, the presence of lions on the other hand showed an inverse linear relationship with settlements (Figure 9c). For all the three carnivores results showed that abandoned bomas was a major contributor to their distribution pattern. Highest probabilities of presence of all carnivores were within abandoned bomas and this probability decreased in somewhat sigmoid pattern with increasing distance (Figure 9a-c).

Density of wild prey (zebra, wildebeest, kongoni, impala etc) had the most influence on the distribution of lions. While wild prey density contributed 15.1% of the influence on lion distribution, it only contributed marginally to both spotted hyena (3.6%) and black-backed jackal (0.8%) distribution pattern. Interestingly though the relationship between density of wild prey and probability of presence of both hyena and jackals were linearly positive with probabilities of the presence increasing with increasing prey density. This however seemed to be reversed when it came to lions.

5.0 Discussion

Human-carnivore conflict is a major concern for conservation of large carnivores in Amboseli-West Kilimanjaro Ecosystem (AWKE). This has given rise to a number of initiatives aimed at preventing, mitigating and/or compensating the communities for predation related loses with the eventual goal of promoting the conservation of large carnivores. However, conflict mitigation initiatives aimed at reducing conflict related mortality to large carnivores has been with varying degrees the success (e.g. Maclennan et al 2009), thus more concerted efforts especially those integrating direct conflict mitigation approaches (such as the use of strong barriers to prevent livestock predation) and indirect approaches (such as those that focus on community engagement, like compensation) are needed to foster large carnivore conservation in the AWKE. Some husbandry strategies employed by pastoralist such as the use of young boys as herders, poorly reinforced enclosures for livestock security are contributing to increased livestock depredation by large carnivores.

High livestock depredation has created a perception by the community that there is very high number of large carnivores in the AWKE especially the spotted hyenas. Hyena poses the biggest problem to livestock owners. Lions which normally attack cattle are the second problem animal following hyenas. Overall predation of livestock has increased in recent years across all types of livestock although shoats have experienced the highest predation caused by hyenas. Nonetheless, this study established that the highest number of livestock losses occur during drought periods. Thus early warning systems about impending droughts could play a great role in reducing losses to livestock owners by allowing them to take appropriate actions before drought.

The estimated density of spotted hyenas was 0.306hyenas/km^2 in the entire ecosystem. It is difficult at this point to conclude whether this is extremely high density of hyenas to justify community perception of high livestock predation due to high predator density. But, during this survey it was observed that most hyenas are found at a medium distance of 5km from human settlements. Hyenas have ability to commute over long distances for foraging (Kruuk, 1972, Hofer & East 1993b), it is possible that hyenas travel during nighttime and attack livestock in nearby settlement. A similar situation has been reported in the Maasai steppe in northern Tanzania (Kissui, 2008). The increase in livestock predation in the AWKE could be attributed to two factors: the behavior of the predators being able to commute over long distances to human settlement and the poor husbandry techniques used by livestock keepers to protect their livestock herds.

The lack of information on carnivore abundance and distribution is one of the challenges in conservation of large carnivores in African range lands. Despite there being several studies, research groups and conservation organizations working in and around the AWKE, there have never been a common reference point on the status of large carnivore populations in the AWKE. This study presents the first ever cross-border (between Kenya and Tanzania) survey of large carnivores--an endeavor to create baseline reference information on status of large carnivore populations in the AWKE. It can play a crucial role in harmonizing reported estimates by various studies as well as in determining demographics and composition of the large carnivore species. Based on modeled results, the number of lions in AWKE was estimated to be between 91-117 individual lions. The number of hyenas was estimated to be 337-417, and about 93-145 black-backed jackals. These estimates should be treated as baseline information to be used for comparison with future estimates. In the wake of rapid changes in land uses within the AWKE, it will be imperative to conduct follow-up surveys to establish a trend in the carnivore populations in the ecosystem.

This study combined the traditional play back technique and Maxent modeling (Philips et al 2006) to obtain abundance estimation and distribution of large carnivores. Limitation in resources and time necessitated such combination of techniques in order to arrive at the best possible population estimates from a sample survey. In most traditional play back studies (Mills et al 2001; Dloniak 2006; Whitman et al 2006), the call-in stations are usually placed in such a way that they cover large proportion of the study area. In such studies it would be plausible to estimate population based on density and study area alone. In our case however, the call-in stations only covered about 25% of the study area. Under this situation extrapolating the sample density to the entire study area would have provided grossly inaccurate estimates of carnivore numbers because it would be based on simplistic assumption of homogeneity in the carnivore distribution. To improve population estimates, a modeling approach (Maximum entropy) aimed at determining the likely pattern of non-homogenous carnivore distribution pattern was employed.

Maximum entropy modeling (Maxent) models species habitat suitability using presence/absence data. We used carnivore presence data based on call-in stations and modeled probability distribution to obtain modeled population estimates. For comparison purpose we have presented both modeled and traditional un-modeled population estimates in Table 4. Based on known population estimates of lions from long-term studies in Amboseli, our results of the modeled lion population estimates closely match estimates from the long-term study in Amboseli. This suggests that the combined approach of play backs and Maxent modeling has a potential to provide reliable carnivore population estimates over large landscapes using presence data. We would however like to caution that our population estimates should be considered as adult population estimates as there were very few young animals that responded to the call backs.

The carnivore species were spatially clustered. This conforms to the assumption of non-homogenous distribution of natural resources needed by the animals. Some environmental variables such as human settlement, density of wild prey greatly influenced the observed pattern of carnivore distribution. For example the relationship between distribution of the carnivores and human settlement pattern showed a belly-like pattern (Fig. 9a) indicating that some carnivores especially spotted hyenas preferred to keep a certain distance from human settlements. This may be due to the need by hyenas to optimize need for cover and proximity to a source of food in human settlement. Despite having a large expanse of land in the AWKE, only a small proportion of the habitat was identified as being suitable for carnivore species. In conservation terms, this underscores the need for concerted effort to secure suitable habitats based on species distribution. Currently habitat loss in the AWKE is exacerbated by increasing changes in land uses and the sub-division of rangelands into small plots. For long-term conservation prospects of large carnivores, maintaining large contiguous land should a priority by conservationists.

The approach used in estimating carnivore populations in this study clearly provides a promising alternative to the pressing need of obtaining carnivore population densities and abundances in various ecosystems. But, more testing and calibration of this approach using known carnivore population would provide more reliability for wide use in conservation of large carnivores in African rangelands.

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8.0 Appendices

Appendix 1

AMBOSELI HYENA SURVEY
CALLING STATION OBSERVATIONS

Name Data Recorder: ______________ Date: ______________
Observation Time: Start ________ Finish ________ Team left ________
Calling Station Grid No: ________

Location:
GPS: ______ Habitat: ________ Weather / Wind Conditions: ____________
Broadcast 1: 1 – 30 min
Vocalization: ___________
Time Start: _________ Time Stop: _________
Remarks:
……
……

Species Observed	**Number (Responding[1])**	**Cub / Sub-adult / Adult**	**Male / Female**
Lion **[1]**	( )	/ /	/
Hyena **[2]**	( )	/ /	/
Leopard **[3]**	( )	/ /	/
Cheetah **[4]**	( )	/ /	/
Wild dog **[5]**	( )	/ /	/
Other	( )	/ /	/

Other: ____________

Turn 180 Degrees
Broadcast 2: 31 - 60 min
Vocalization: _________
Time Start: ________ Time Stop: _________
Remarks:
……
……

Species Observed	**Number (Responding)**	**Cub / Sub-adult / Adult**	**Male / Female**
Lion **[1]**	( )	/ /	/
Hyena **[2]**	( )	/ /	/
Leopard **[3]**	( )	/ /	/
Cheetah **[4]**	( )	/ /	/
Wild dog **[5]**	( )	/ /	/
Other	( )	/ /	/

Other: ____________

[1] "only predators that approached a station" Ogutu & Dublin (1998)

Appendix 2

A: Contribution of environmental variables on the distribution of spotted hyenas

Variable	Percent contribution	Permutation importance
Vegetation cover	40.1	4.9
Distance to Abandoned boma	25	23.7
Distance to water	7.4	25.8
Distance to maasai boma	6.7	1.7
Distance to settlement	4.1	10.8
Precipitation of coldest quarter	4	2.7
Kernel density livestock	0.8	0.1
Kernel density all prey	3.6	1
Isothermality	2.2	3.7
Precipitation Seasonality	1.7	16.4
Kernel Density livestock	1.5	2.2
Precipitation of Wettest Month	1.5	2.2
Annual precipitation	0.8	2.5

B: Contribution of environmental variables on the distribution of black-backed jackal

Variable	Percent contribution	Permutation importance
Vegetation cover	48.1	3.8
Distance to abandoned boma	21.5	43.9
Distance to water	5.3	5.6
Precipitation of coldest quarter	4.7	3
Isothermality	4.4	3
Distance to maasai boma	3.8	3
Distance to settlement	3.6	4.9
Minimum temperature of coldest month	2.1	14
Kernel density livestock	1.8	2.6
Kernel density all prey	0.8	0.3
Precipitation of driest month	0.8	0
Kernel density conflict	0.8	0.1
Precipitation of wettest month	0.5	2.5

C: Contribution of environmental variables on the distribution of African lion

Variable	Percent contribution	Permutation importance
Distance from abandoned boma	27.7	10
Vegetation cover	18.1	2.2
Kernel density of all prey	15.1	58.5
Distance from water	11	11.1
Precipitation seasonality	10.3	5.5
Maximum temperature of warmest month	6.2	0.2
Mean diurnal range	3.6	1.7
Kernel density livestock	0.3	0
Precipitation of driest month	2.8	1.3
Precipitation of warmest quarter	2.5	2.9
Distance from maasai boma	1.3	6.3
Kernel density conflict	0.4	0
Minimum temperature	0.4	0
Precipitation of coldest quarter	0	0.2
Distance from settlement	0	0