LEWA WILDLIFE CONSERVANCY
A UNESCO World Heritage Site inscribed in 2013

BORANA CONSERVANCY

A photograph of Grevy's zebra on the Lewa – Borana landscape

Research and Wildlife Monitoring Report
Q4 2016

Authors:
Mary Mwololo, Timothy Kaaria, Ian Lemaiyan, Edwin Kisio, Saibala Gilisho and Sandy Oduor

Editors:
Geoffrey Chege and Dr Zeke Davidson

ACKNOWLEDGEMENTS

It was yet another productive year for the Research Department of the Lewa - Borana Landscape (LBL), where we successfully continued to monitor wildlife. We are grateful to all the stakeholders who worked with us to ensure that we met our set objectives.

We would like to recognise and appreciate the financial contribution of the Al Ain Zoo, UAE, which supported several of our monitoring activities including the rhino, predators, elephant and selected indicator ungulate species. We also renewed our Memorandum of Understanding with the Zoo, which will run until 2018.

We are grateful to Marwell Wildlife, UK, through Dr Zeke Davidson and the University of Southampton MRes field course for the continued technical support to the department. The MRes programme has supported us by bridging part of our research gaps and providing useful insights on the applied research questions for the management of the landscape. To Wim Giesen and family, thank you for your time and transfer of technical skills during the evaluation of the changes that have occurred on the vegetation in the LBL.

We would also like to appreciate the other numerous organisations who offered their technical, financial and moral support to our research and monitoring activities: the CEOs, Management and Board of Directors in the country as well as the overseas charities of the LBL, The Conservation Committee and the Kenya Wildlife Service (KWS), San Diego Zoo and Smithsonian Institute.

Thank you very much to all of you and we look forward to continuing our engagement.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report provides information on the harmonised research and monitoring activities carried out in the integrated Lewa – Borana Landscape (LBL) in 2016. We are happy to report that most of the programmes including monitoring of the rhino, predators (lion and hyena), critical indicator ungulate species (Grevy's zebra, Plains zebra, giraffe, eland, hartebeest, oryx and buffalo), the annual wildlife counts, evaluating the usage of the migratory gaps/corridors by wildlife and distribution of rainfall were monitored uniformly throughout the landscape. In the year, we held several meetings and undertook joint activities for cross-pollination of knowledge between the Lewa and Borana monitoring teams. These programmes and liaison will continue to be streamlined in 2017 for consistency and uniform data collection.

The landscape continues to utilise intensive cattle grazing in an attempt to improve the range for the benefit of wildlife. While systems have been put in place on the eastern side of the landscape to monitor the impact of such manipulation, these monitoring protocols will be extended to the western side of the landscape for uniformity in coverage. In addition, we will complete correlating data for all the rainfall gauging stations on the western side of the landscape, since only rainfall from one station has been presented in this report.

We would like the reader to note that the List of Figures and Tables are presented at the end of this report.

Rhino monitoring

The rhino in the landscape continued to thrive amidst the challenges facing rhino conservation in the country. The productivity of the black rhino has continued to be monitored after the translocation out of Lewa of 11 and nine animals in 2013 and 2015 respectively. With a 2.5% and 5.7% p.a. growth rate of the black and white rhino respectively in the year, this population stood at 83 black and 74 white rhinos at year end. See Table 3 for the overall performance of black rhino.

Since the removal of the fence line separating Lewa and Borana in 2015, rhino on the Lewa side have slowly been exploring new habitat on the Borana side. We had one black and two white rhino that crossed to the western side of the LBL with high frequency. With an increase in the number of cases of white rhino aggression, it is vital to alleviate the emerging social pressures by physically facilitating their movements to the western side of the LBL by creating safe access routes on the Ngare Ndare River where they can cross. It is also possible to translocate a few individuals and hold them in a large exclusion zone that will be removed after they acclimatise to the area.

Predator monitoring

Monitoring of predators focused on the large carnivores mainly lion and hyena. The lion population recorded a 26% increase and stood at 44 animals at year end. The landscape is utilised by lion at varied levels and this is mainly driven by the availability of prey. The home ranges of different female groups did not overlap. However, the male home ranges overlapped with the female groups.

The hyena clans that were monitored utilised the same areas as the lion. Home ranges of different clans were distinct from each other indicating strong inter-clan avoidance. Spatial data from both species indicated that they also utilised areas outside of the LBL in the community areas. This led to several cases of livestock depredation as shown in Table 10. A number of mitigation measures including setting predator friendly traps to capture the culprits and sending reports to the herders to be vigilant especially when the lion were noted to have exited the landscape, were implemented.

Predation was the main cause for wildlife deaths within the landscape, with the lion contributing to the highest proportion of cases. Prey preference from 2014 to 2016 showed no significant change in prey selectivity. None of the prey species was disproportionately selected by the lion. However, the continued decline of some of the ungulate species like the Grevy's zebra is of concern and even if they were taken according to their availability, they have continued to show a downward trend. To mitigate the continued predation of these species, the LBL has received authorization from KWS to pilot the management of the lion population using non - lethal birth control methods on three females. The results of the scat analysis revealed that wild ungulates were proportionally the most preferred prey compared to domestic prey by lion. The spotted hyena showed a more diverse prey choice than lion.

Ungulate monitoring

Seven ungulate species were monitored in the year. Six of them showed a skewed age ratio with more adults than the juveniles and the young. This is a concern as it translates to low recruitment rates. The growth potential as indicated by the sex ratio and age classes range from low to medium. The majority of these species were preferred prey species by lion but were taken proportionally to what was available.

To understand the connectivity of the landscape, movements of wildlife were monitored using camera traps on the migratory corridors/gaps. Four species of wildlife namely: Grevy's zebra, Plains zebra, giraffe and elephant were the main users of these gaps. There were no seasonal differences in wildlife movements through the gaps, an indication that the landscape is utilised at various levels and times of the year depending on availability of the resources.

Monitoring of fence breaking elephants

Management interventions have been undertaken to de tusk persistent fence breaking elephant with a view of reducing the instances of fence breakages. In as much as this management intervention was undertaken, the fence breaking elephant appeared to recruit other non-de tusked individuals and as a result, instances of breakages persisted. Other elephant resorted to crawling under the upgraded fence lines. However, the overall reconfiguration and upgrading of the fences appeared to greatly reduce instances of fence breakages.

Woody vegetation monitoring

Elephant and giraffe caused significantly higher damage on woody vegetation compared to rhino, eland and impala. High levels of tree damage were recorded on *Acacia nilotica, A. tortilis* and *A. xanthopholea* tree species.

Grassland assessment

There was a significant increase in mean grass biomass from 2011 to 2016. In addition, species diversity showed a significant increase from 2015 to 2016 with *Pennisetum stramineum* being the dominant grass species. From 2011 to 2016, the vegetation cover was high ranging from 80% to >90%. This implies that the grasslands are protected from erosion by either wind or water and direct sunlight, which impacts negatively on the plant roots.

Rangeland management

1,193 head of NRT-Trading (NRT-T) cattle grazed on the eastern side of the LBL in the year. With average ADAs ranging from 25 – 75, 9,309 acres of the Lewa side were grazed representing 29% of the total acres designated for livestock grazing. Long-term monitoring of the ecological changes on the rangeland showed a significant reduction in biomass of grass that that lasted up to nine months post-grazing, after which, the biomass slowly accumulated back. Where re grazing was done, the biomass was much lower than the rest of the non-re grazed areas. The species diversity increased with time and no change in vegetation cover was observed.

Both grazing and mowing produced positive results. However, it is important to consider not only the effects but also the circumstances of application of the management methods, the socio-economic situation, the cost and timing that may affect the suitability of these treatments within the landscape.

Environmental monitoring

During the year, the landscape received an average of 368±44mm of rainfall. This amount was below the long-term mean of 502±181 mm. The low rainfall led to the reduction and poor quality of forage for wildlife. To counter this, some of the critical wildlife species mainly Grevy's zebra and rhino, were monitored for changes in their body condition that could impact negatively on their health.

To understand the hydrology of the LBL, the management is in the process of finalising a partnership with Southwest Research Institute (SWRI) in the USA to build the capacity of the LRD team as well as develop and implement a basic water monitoring protocol in the landscape. This will enable us to continuously assess our hydrological dynamics on both the LBL and the immediate community areas.

CHAPTER 1

1.0 INTRODUCTION

This report presents details of the activities undertaken by the Lewa – Borana Research and Monitoring Department (LBRD) in 2016. The report provides correlation and interpretation on the various programmes that were accomplished. The report also provides recommendations for consideration by the management of the Lewa – Borana landscape (LBL).

One of the objectives of the management of the LBL is to manage the area for wildlife as one by monitoring biodiversity and undertaking harmonised applied research by the LBRD. The information collected by this team is used to make informed management decisions. This objective was achieved through the use of internal capacity to collect data on critical indicator wildlife species including rhino, large carnivores, and selected ungulate species namely, Grevy's zebra (*Equus grevyi)*, Plains zebra (*Equus burchelli)*, giraffe (*Giraffa camelopardalis)*, buffalo (*Syncerus caffer)*, Beisa oryx (*Oryx beisa),* eland (*Taurotragus oryx)* and hartebeest (*Alcelaphus buselaphus*).

The second objective of the management is to augment the department's data by harnessing the expertise and capacity of external conservation, research and academic resources to carry out applied research, aimed at addressing specific management questions. Therefore, during the year, three Masters by Research students (MRes) from the University of Southampton and Marwell Wildlife, UK completed their final reports for their projects undertaken on the landscape. The students focused on the:

1. Assessment of the impact of Lewa's grassland management techniques on wildlife and vegetation;
2. Elephant (*Loxodonta africana*) occupancy, movement and resource use within the Mount Kenya Elephant Corridor; and
3. Resource partitioning between spotted hyenas (*Crocuta crocuta*) and lion (*Panthera leo*).

The reports are available at the following Dropbox link for download:

https://www.dropbox.com/sh/kn3cmkui424yab8/AACcqbUUBHjcS- XjBX5VWPPa?dl=0.

In addition, Wim Giesen and his family assessed the changes in vegetation that have occurred on Lewa from 1962 to 2016. This assessment builds upon earlier work at Lewa by the family in 2006 and Wim in 1979 – 1980. The first draft is under review. The final copy will be circulated in 2017.

CHAPTER 2

2.0 STUDY AREA AND METHODOLOGY

Situated on the northern foothills of Mt. Kenya, the LBL is part of the Laikipia - Samburu ecosystem. This landscape has been described in detail in past reports. For the most recent description, see the LRD Annual Report for 2015.

In summary, the landscape is well connected to the contiguous conservation areas including Mt Kenya National Park/Forest Reserve to the south, the community conservancies of Il Ngwesi, Lekurruki and Leparua, and the Mukogodo Forest Reserve to the north. To the west, the LBL is connected to Ole Naishu and Loldaiga Ranch (Fig. 1). The connection to these conservation areas is through wildlife gaps that allow wildlife to freely exit and re-enter the LBL in search of resources.

The vegetation of the landscape forms a transition from a semi-arid highland to arid lowland ecosystem. Several habitat types are represented including (1) closed canopy forests (*Juniperus procera*, *Olea africana* and *Euclea divinorum*in) in the Ngare Ndare Forest to the south and parts of Mukogodo Forest on the northern boundary; (2) scattered mixed Acacia woodlands (*Acacia xanthophloea*, *A. nilotica*, *A. tortilis, A. drepanolobium* and *A. seyal*); and (3) vast grasslands dominated by *P. stramineum*, *P. mezianum* and *Themeda triandra* in the relatively open areas. There are also numerous riverine forests and swamps with Yellow Fever trees (*A. xanthophloea)* and the so-called "Immense Sedge" (*Cyperus dives)* being the dominant vegetation species. These habitats support diverse and abundant wildlife species including threatened species represented by the black (*Diceros bicornis*) and white rhino (*Ceratotherium simum*), elephant (*Loxodonta africana)*, Grevy's zebra, lion (*Panthera leo*) and cheetah (*Acinonyx jubatus*). The landscape also harbours most of the commonly occurring ungulate species including buffalo, Plain zebra, and eland.

The rainfall in the landscape follows a bimodal distribution pattern averaging 502±181mm p.a. The long and short rains are received from October to December and April to May respectively. Three main perennial rivers bisect the landscape. These are the Lewa, Ngare Sirgoi and Ngare Ndare Rivers (Fig. 1). In addition, the area has numerous man-made dams that support wildlife inhabiting areas that are further away from the perennial rivers.

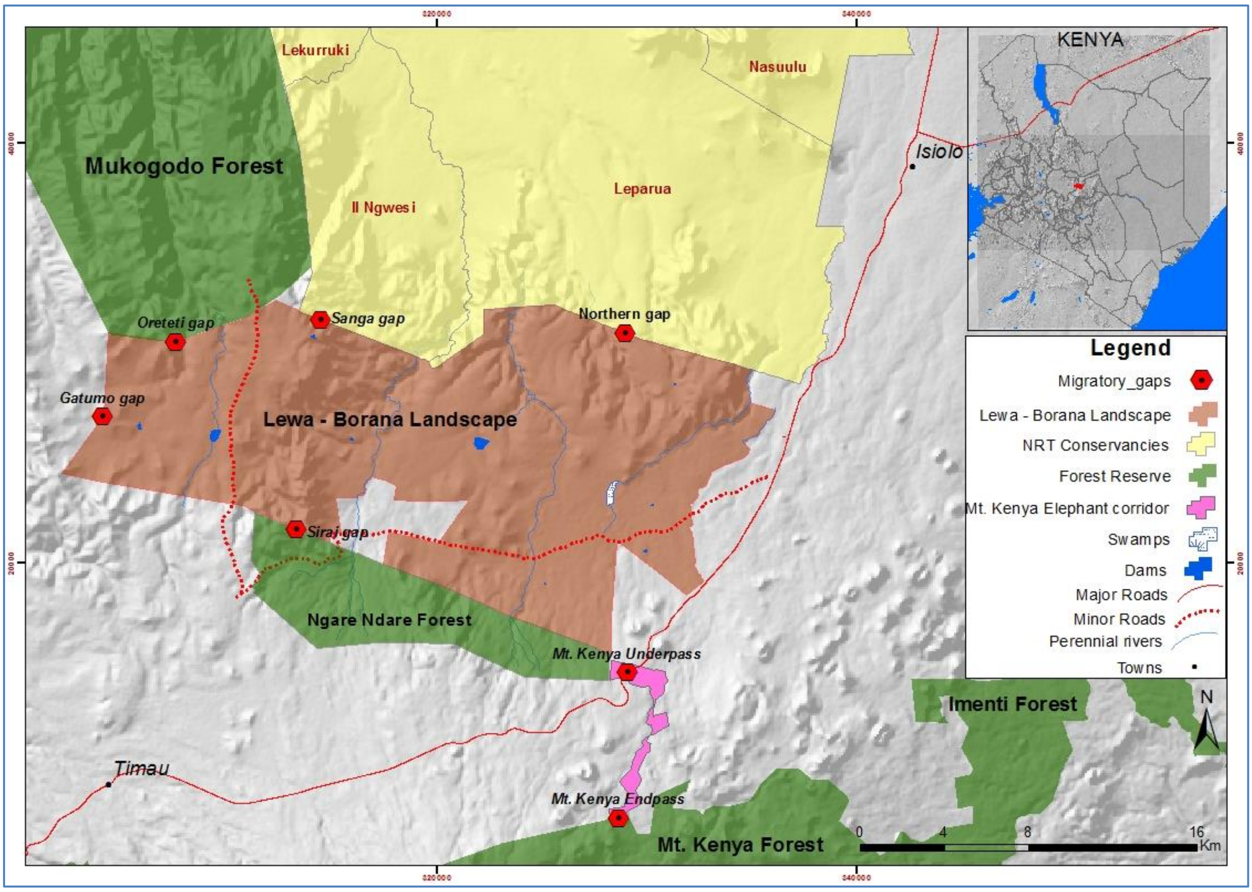


Figure 1: Map showing the location of Lewa – Borana landscape in relation to the adjacent conservation areas

CHAPTER 3

3.0 RHINO MONITORING

3.1 Introduction

The populations of rhino on the LBL continued to thrive during the year amid the challenges that have faced overall rhino conservation efforts in the country. Two of these main challenges have been poaching and lack of adequate habitats that are suitable and secure. While poaching has significantly been reduced from its peak, reached in 2013, generally, since 2009, the country has witnessed a net reduction in the size of land available for rhino conservation. However, during this period, the LBL made significant strides by working with other partners to secure land for this charismatic species. This includes the introduction of a founder population of rhino in Borana Conservancy in 2013 and the establishment of Sera Rhino Sanctuary in 2015, in collaboration with the Northern Rangelands Trust (NRT). The other main threat that affects rhino on the LBL is fighting by dominant bulls. To mitigate these challenges, over time, a number of measures have been put in place to perpetuate rhino growth. These include targeted translocations, removing the fence that divided Lewa and Borana Conservancy to create a larger habitat, as well as working with the Kenya Wildlife Service (KWS) to trim the horns of the aggressive bulls. Despite these challenges, the population of rhino on the LBL performed fairly well as discussed in the sections below.

3.2 Results and discussion

3.2.1 Black rhino population biology

3.2.1.1 Black rhino population performance

In 2016, the population of black rhino increased from 81 to 83 animals. There were six births in the year (Table 1). Four deaths occurred from a range of causes (Table 2). This population is within its estimated ECC of 123 animals (KWS, 2012). We do not anticipate having to undertake any large-scale black rhino removals from the landscape for the next seven years as a result. However, the carrying capacity needs to be re-assessed more regularly. To date, the results of the assessment of the ECC completed in 2016 are awaited.

Table 1: Black rhino births on LBL

No.	Calf name	Dam	Sire[1]	Date of birth
1	No. 6 calf 4	No. 6	Batira	26th Jun. 2016
2	Mama C calf 4	Mama C	Ibong	29th Jul. 2016
3	Linda calf 1	Linda	Batira	18th Aug. 2016
4	No. 18 calf 1	No. 18	Batira	9th Sept. 2016
5	Anna calf 2	Anna	Ndoto	8th Oct. 2016
6	Samia calf 5	Samia	Muturi	17th Oct. 2016

[1]The Sire is determined indirectly through home ranges and association patterns of rhino.

Table 2: Black rhino deaths on LBL

No.	Rhino name	Date of death	Age at death (years)	Cause of death
1	Nicky[2]	5th Aug. 2016	4.2	Clostridium disease
2	Samia calf 5	24th Oct. 2016	10 days	Predation
3	Solio	5th Dec. 2016	41	Old age
4	Anna calf 1	5th Dec. 2016	4.4	Fighting

3.2.1.2 Black rhino biological growth rate

From 2016 onwards, the population in the landscape was amalgamated and hence it has been assessed as one this year. The population recorded an increase of 2.5% p.a. which was rated as "poor to moderate" based on standardised criteria developed to evaluate the performance of rhino (du Toit *et al.,* 2001) (Fig. 2; Table 3).

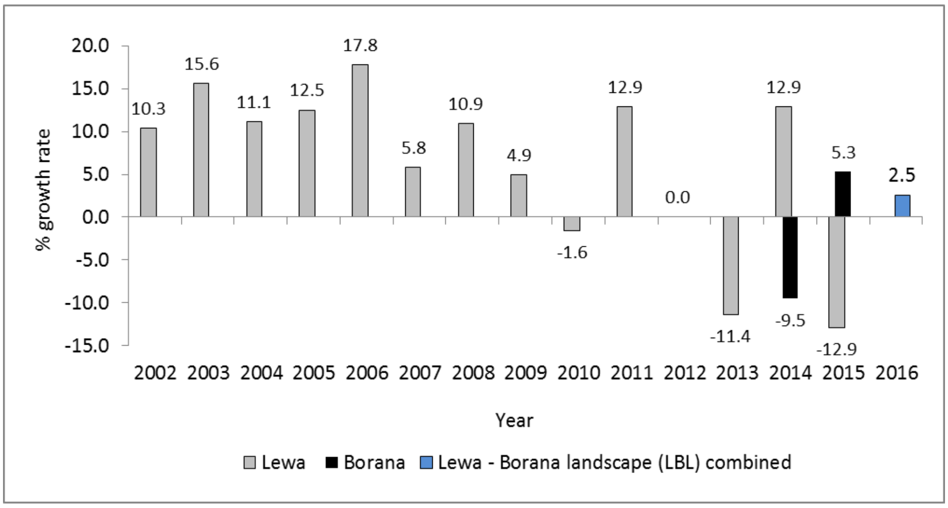


Figure 2: Black rhino annual population increases on the LBL, 2002 – 2016.
Note that rhino were removed from Lewa to Borana and Sera in 2013 and 2015 respectively.

3.2.1.3 Mortality rate

The overall mortality rate reduced from 8.6% in 2015 to 4.9% in 2016. Despite this level of reduction in mortality, this metric was still categorised as "very poor" (Table 3) (see du Toit *et al*., 2001 classification of benchmarks for assessing rhino performance). The four mortality cases recorded in the year resulted from varied causes as shown in Table 2. Supplementary feeding of the older (>30 years) and lactating females was implemented on a case by case basis to support those animals most at risk towards the end of the dry season.

3.2.1.4 Black rhino sex ratio

The proportional age class distribution of calves, sub-adults and adults was 25%, 20% and 55% respectively. The adult male to female sex ratio was 1:1 which was rated as "moderate to good" (du Toit *et al.*, 2001). For large-bodied animals like rhino, the ideal adult female to male sex ratio is >1:1. The proportional age class for calves and sub-adults is relatively high implying that the population has the potential for continuous growth as there are enough young to be recruited into the adult age class.

[2] Nicky is one of the black rhino that was hand-raised from the age of three months. He was suffering from congenital blindness since birth.

3.2.1.5 Black rhino inter-calving interval

The average inter-calving interval (ICI) calculated for 23 breeding females and age at first calving (AFC) was 2.7 and 7.5 years respectively. These two benchmarks were rated as "moderate to good" and "poor to moderate" respectively (Table 3). Five females, namely *Mawingo* (27.7 years), *Waiwai* (21.6 years), *Mama C* (14.6 years), *Mejh* (11.4 years) and *No. 6* (14.5 years) with a mean ICI of 2.3(±1.0), 2.4 (±0.4), 2.5 (±0.4), 2.0 (±0.0) and 2.5 (±0.9) years respectively have been performing well. ICI at this level is expected to continue to be witnessed in future as the rhino population is below the ECC. Appendix 1 shows the average ICI and AFC for the breeding female black rhino on LBL.

Table 3: Summary of LBL's black rhino population performance compared against standard benchmarks (du Toit *et al*., 2001)

Population Indicators	Very Poor	Poor - Moderate	Moderate – Good	Good - Excellent	LBL Performance
Bio. G.R. (%)	<2.5	2.5 - 5	5 - 7.5	>7.5	2.5
Mot. R. (%)	>4	-	-	-	4.9
SR	<1F:1M	<1F:1M	1F:1M	>1F:1M	1F:1M
ICI (years)	>3.5	3 - 3.5	3 - 2.5	<2.5	2.7
%FC	<29	29 - 33	33 – 40	>40	27
AFC (years)	>7.5	7 - 7.5	7 - 6.5	6.5	7.5
%CP	-	<28	=28	>28	25

Key:

Bio. G.R. – Biological growth rate
Mot. R. – mortality rate
SR – Sex ratio
ICI - inter-calving interval
%FC – Percentage of female calving per year
AFC – Age at first calving
%CP – Proportion of calves (<3yrs) in population

3.2.1.6 Black rhino body condition

As recommended in 2015, an assessment of the body condition of 18 relatively old and lactating rhino was undertaken in Q3 to advise on the status of their health. Seven individuals were found to have a body condition ≤3.5 against a potential maximum score of 5 that represents a rhino in good body condition (Adcock & Emslie, 2003). A supplementary feeding programme with *Lucerne* for three females that were judged to be in greatest need was initiated. These females were *Zaria* (28.6 years), *Solio* (41 years) and *Zenetoi* (10.8 years). The uptake of the supplementary feed in all three rhino was minimal.

3.3 White rhino population biology

3.3.1 White rhino population performance

The population of white rhino increased from 70 to 74 animals. There were eight births (Table 4) and four deaths (Table 5). Most of the rhino were concentrated on the eastern side of the landscape. Even though the ECC of white rhino has not been determined, there were several crossing events from Lewa to Borana and vice versa. In order to encourage white rhino to utilise habitat on the western side of the landscape, the management is considering implementing a number of measures to make it easier for other rhino to cross the Ngare Ndare River. If this does not work, consideration is being given to translocate at least three females and one male.

The four animals will then be confined in a temporary large enclosure until they acclimatise. Thereafter, the fencing on this enclosure will be removed.

Table 4: White rhino births on LBL

No.	Calf name	Dam	Sire	Date of birth
1	Tale calf 4	Tale	Ronnie	6th Feb. 2016
2	Natal calf 9	Natal	Imado	21st Mar. 2016
3	Songare calf 11	Songare	Samawati	7th Apr. 2016
4	Lucille calf 1	Lucille	Imado	14th Jun. 2016
5	Wakesho calf 3	Wakesho	Ronnie	26th Jun. 2016
6	Tumbili calf 10	Tumbili	Imado	8th Nov. 2016
7	Jacho calf 3	Jacho	Imado	11th Nov. 2016
8	Jakwai calf 9	Jakwai	Samawati	8th Dec. 2016

Table 5: White rhino deaths on LBL

No.	Rhino name	Date of death	Age at death (years)	Cause of death
1	Lari	17th Jan. 2016	26.8	Fighting
2	Lucille calf 1	27th Jun. 2016	13 days	Predation
3	Tale calf 3	28th Jul. 2016	2.8	Aggression by a dominant male
4	Tumbili calf 9	21st Dec. 2016	2.1	Aggression by a dominant male

3.3.2 White rhino biological growth rate

In the year, the population recorded an increase of 5.7% compared to 8% in 2015. The overall growth rate in the last 14 years averaged 6.7% p.a. Even with these annual increases, the draft White Rhino Management Strategy Plan, 2011, does not put a lot of emphasis on the national growth rate of white rhino until new sites are made available within Kenya and the East African region. However, the Plan recommends maintaining current growth rates through the management of the populations in breeding and non-breeding sites (APLRS & KWS, 2011).

3.3.3 Mortality rate

Mortality was measured at 5.4% in 2016 and attributed mainly to male aggression on calves. Mortality rates >5% have been recorded in previous years, because of various factors ranging from poaching, predation, aggression by dominant males and natural causes.

3.3.4 White rhino sex ratio

The proportional age class distribution of calves, sub-adults and adults was 31%, 20% and 49% respectively. The adult male to female sex ratio stood at 1:1. The sub-adult male to female sex ratio in the population was 2:1. This high number of males is projected to be a problem in the next few years as the sub-adults are recruited into the adult age class where they will exert increased territorial pressure. However, this may be mitigated if some of the sub-adults and adults move over to the western side of the landscape.

3.3.5 White rhino inter-calving interval

The ICI and AFC remained at 2.5 and 7.2 years respectively. These two metrics have been maintained at this level in the past years. Appendix 2 shows the average ICI and AFC for the female white rhino on LBL.

3.4 Spatial ecology

3.4.1 Sighting frequency

The average sighting frequency (SI) for black and white rhino was 1.7 and 1.3 days respectively. These Sis are within the recommended maximum inter-sighting frequency of three days on the LBL. The regular sighting of rhino generates information on the condition and health of the animals with interventions being undertaken in a timely fashion when required.

3.4.2 Rhino home ranges

3.4.2.1 Black rhino ranging areas

Over 92% of the adult black rhino maintained their home ranges in the year. However, there were notable exceptions with two individuals that either shifted or expanded their ranging areas. *Rensuen* (F) (8.8 years) shifted her area of utilization from the eastern side of Ngare Ndare River to the western side (Fig. 3). Similarly, *Mawingu* (F) (27.6 years) has had the most variable home range area of all the adult rhino. Her movements often switch between the northern, central and southern areas of the Lewa property (Fig. 4). Much as black rhino relies heavily on their sense of smell to exploit resources, such movements may be because *Mawingu* is partially blind.

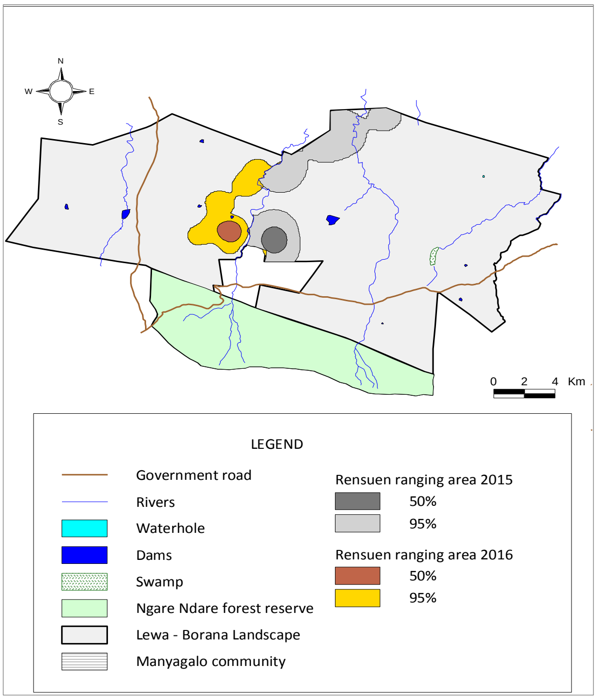


Figure 3: *Rensuen* ranging areas

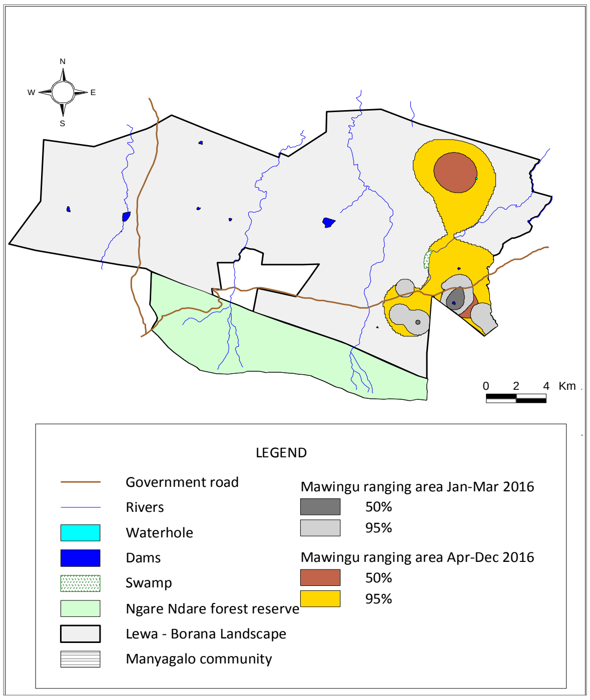


Figure 4: *Mawingu* ranging areas

3.4.2.2 White rhino ranging areas

Four male white rhino: *June* (7.7 years), *Mandela* (8.0 years), *Dominic* (8.7 years) and *Gordon* (8.9 years) showed significant extension in their ranging areas (Fig. 5 - 8). In Q4, *June* and *Mandela* extended their range from the north east to the south east of the landscape. The two males have just graduated into the adult age class and they may be seeking areas to establish their territories. Similarly, *Gordon* (9.0 years) and *Dominic* (8.8 years) moved from the same north eastern section of the landscape into the western side. The two have been utilizing this area since November 2016. They may be exploring new areas to establish their territories as well. Such movements are bound to occur due to the increased social pressure considering that most of the white rhino are concentrated on the central, northern and north-eastern parts of the LBL.

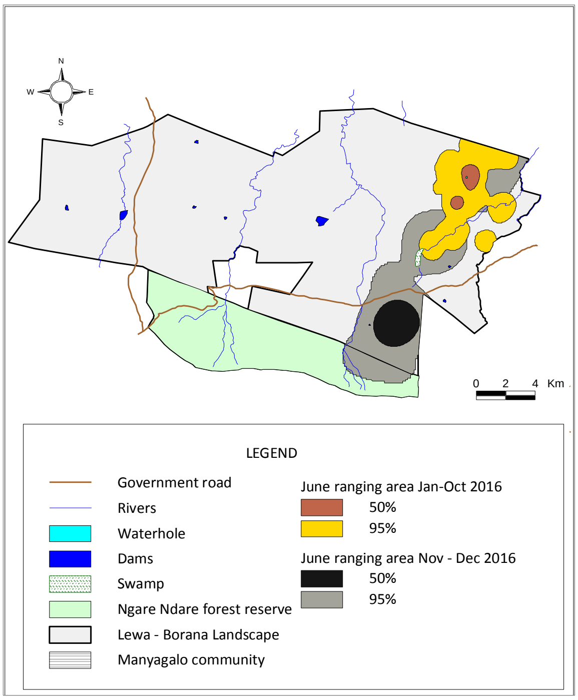


Figure 5: *June* ranging areas

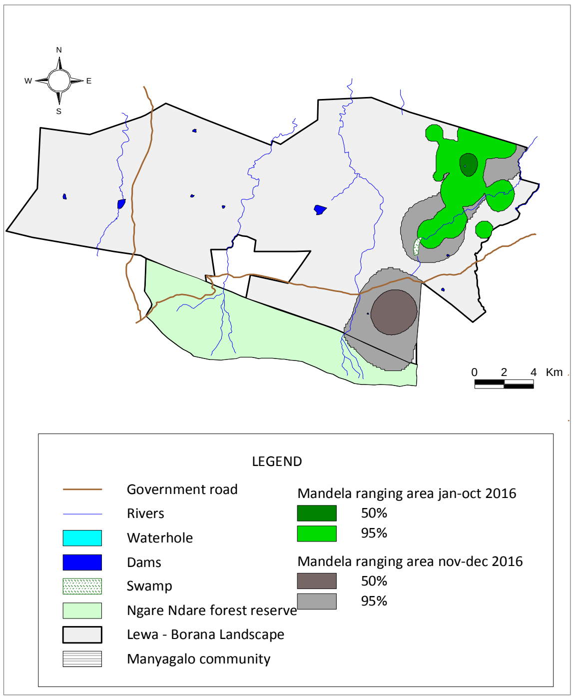


Figure 6: *Mandela* ranging areas

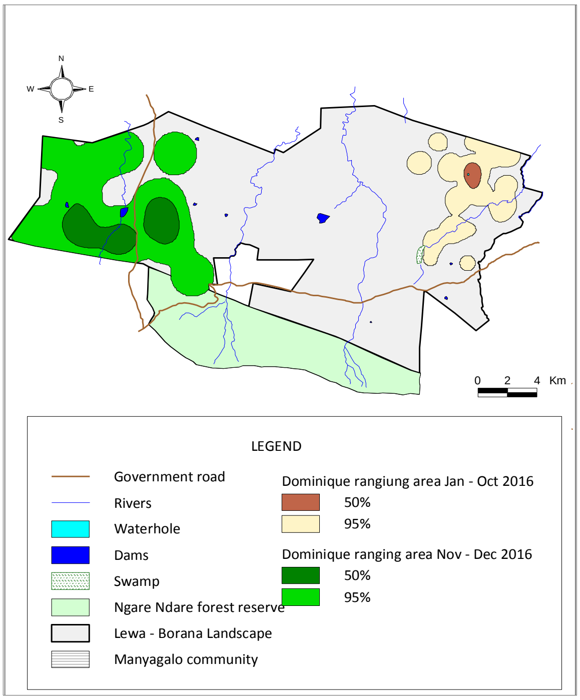


Figure 7: *Dominic* ranging areas

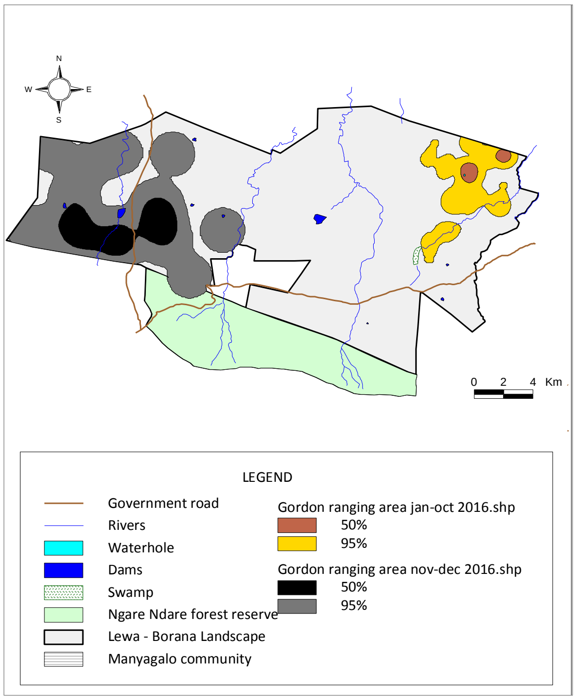


Figure 8: *Gordon* ranging areas

3.5 Conclusion and recommendations

The ECC for white rhino on LBL has not been undertaken. We will actively engage relevant partners to complete this assessment. Since the removal of the fence that divided Lewa and Borana in 2015 creating a larger landscape of 381km^2, a number of rhino have already started moving between the two areas by crossing the Ngare Ndare River. To further facilitate such movements, it would be ideal to implement the proposed crossings on the Ngare Ndare River, by opening at least two new routes that will allow rhino to pass easily. If the rhino do not respond quickly to this intervention, consideration should be given to translocating at least three females and one male to the western side of the LBL and confine them in a temporary large enclosure until they acclimatise in the new area. Thereafter, the fencing on this enclosure should be removed. Suitable candidates for such a translocation are suggested in Table 6.

Table 6: White rhino proposed for translocation

No.	Rhino name	Sex	Age (Years)
1	Songare calf 9	F	5.5
2	Opondo calf 7	F	5.7
3	Lucille	F	6.4
4	Ramadhan calf 1	M	6.2
5	Murembo calf 10	M	6.2

The sub-adult sex ratio of the white rhino is skewed towards males. Signs of negative social pressure will need to be continuously monitored in order to make timely decisions, which may include trimming of the horn of the aggressive males and translocations.

CHAPTER 4

4.0 PREDATOR MONITORING

4.1 Introduction

The LBL supports both large and small-bodied carnivores. In the past, monitoring of these carnivores has focused on the lion and hyena. This is mainly driven by their relative dominance in relation to their abundance and behavioural interactions. One of the main objectives of monitoring the two carnivores is to assess their status, utilisation of the landscape, understanding their impact on prey species as well as their spatial separation and competitive dynamics.

To achieve these objectives, the main activities carried out were collaring, daily tracking, scat collection and analysis, correlation of wildlife mortality through cluster points and camera trapping at the hyena dens.

4.2 Results and discussion

4.2.1 Lion population biology

4.2.1.1Lion population performance

The population of lion rose from 34 animals in 2015 to 44 in 2016. There were several dynamics observed in this population. These included the birth of 12 cubs from 6 lionesses, one immigrant as well as three emigrants. There were no confirmed deaths (Table 7). The one immigrant was a 6-year old male known as *Chalisa* who was the source of several human-carnivore conflict incidents in the community areas north of LBL. He originated from the Buffalo Springs NR, where his last sighting was in 2013. In order to further understand his utilisation of the landscape and mitigate conflicts within the communities, *Chalisa* will be fitted with a GPS collar in collaboration with Ewaso Lions (www.ewasolions.org), Laikipia Landscapes (www.lionlandscapes.org) and Marwell Wildlife (www.marwell.org.uk). The collar will have the capability to send geo-fence alerts[3] of his whereabouts in order to ensure timely action.

The current age and sex structure of the lion are indicated in Table 8. 43% of these animals are sub-adults and cubs that will attain breeding age soon.

Table 7: Performance of lion population on LBL, 2015 – 2016

Year	Births	Deaths	Immigration	Emigration	Total
2015	2	3		2	34
2016	12	0	1	3	44

[3]Geo-fencing is a feature in a software program that uses the global positioning system (GPS) or radio frequency identification (RFID) to define geographical boundaries. Geo-fencing allows an administrator to set up triggers so that when a device enters (or exits) the boundaries defined by the administrator, an alert is issued. Many geo-fencing applications incorporate Google Earth, allowing administrators to define boundaries on top of a satellite view of a specific geographical area. Other applications define boundaries by longitude and latitude or through user-created and Web-based maps (http://whatis.techtarget.com/definition/geofencing).

Table 8: Population structure of lion on LBL

Age class	Male	Female	Not sexed	Total by age
Cubs	3	2	5	10
Sub adults	1	2	7	10
Adults	12	12	0	24
Total by sex	**16**	**16**	**12**	**44**

4.2.2 Hyena population biology

4.2.2.1 Population performance

To enhance monitoring of hyena, six individuals representing different clans were collared and monitored in the year. The photographs of members of the clans were also taken using camera traps placed at their dens. These photographs were used to develop a database of individual hyena identified as per their respective clans.

A total of 99 hyena were identified by year-end (Table 9). It was relatively difficult to determine the sexes given the morphological similarities of males and females (East, 2001). The total population of hyena is likely to be higher considering that some of the dens including that of clan *Borana* have not yet been identified.

Table 9: Population structure of spotted hyena on LBL

Clan name	Adults	Sub-adults	Cubs	Total per clan
Borana	3	0	0	3
Charlie	17	3	8	28
Nala	22	9	5	36
Shamba	3	2	4	9
Utalii	15	3	5	23
Total by age class	**60**	**17**	**22**	**99**

4.3 Spatial ecology

4.3.1 Lion

The home ranges of the three main prides of lion (*Sarah*, *Yas* and *Mole*) and a coalition of three males (*Harry*) overlapped. However, each pride maintained its distinct core area with no interaction with the other prides. Two other lionesses were more solitary (*Dalma* and her 2 cubs, and *Susie),* both utilizing the central and eastern parts of the LBL respectively. *Harry's* coalition utilised the eastern side of the LBL. This was the only group of males that gravitated between the female prides/groups of *Sarah*, *Dalma* and *Susie* (Fig 9). *Yas's* group maintained its area of utilisation on the western side of the landscape.

Monitoring of lion in 2017 will reveal the level of interaction or confrontation between *Harry's* group and *Chalisa*. The latter is new in the landscape and joined *Sarah's* pride since his entry into the LBL in December 2016. Both *Chalisa* and *Sarah's* pride appear to be familiar with each other since no fights have been observed. In addition, *Sarah's* pride used to frequent the northern community conservancy of Leparua, where *Chalisa* is believed to have ranged, having been raised by his natal pride in Buffalo Springs NR (Fig. 9).

4.3.2 Hyena

Six spotted hyena representing different clans were collared in March 2016. However, two individuals, *Nala* and *Ajax* were collared in different areas but ended up being from the same clan. The main objectives of collaring hyena were to: investigate their behavioural ecology, establish prey selectivity and diet overlap with lion, as well as investigate the spatial and temporal separation between the two species.

Throughout the year, the core home ranges of the clans showed no overlap, indicating strong inter-clan avoidance (Fig. 10). Two of these clans extended their home range outside the LBL area and foraged in the community areas (Fig. 10). This led to a number of cases of livestock depredation. To mitigate this, efforts were made to trap and relocate the culprits without success.

4.3.3 Human-carnivore conflict

Conflicts between humans and carnivores appear to be on the increase on the LBL and the contiguous community areas. During the year, there were 41 known incidents of livestock depredation caused by different predators, resulting in the death of 72 head of livestock within the greater landscape (Table 10). Most of the cases were caused by hyena and lion. The spatial distribution of the conflict cases is presented in Fig. 12. A number of mitigation measures including setting predator-friendly traps to capture the culprits, and sending reports to herders (via radio and phone) to be vigilant especially when the lion were noted to have exited the LBL were initiated. To enhance these strategies, in 2017, attempts will be made to geo-fence the collar on *Sarah's* pride and *Chalisa* that mainly frequents the community areas to the north of LBL. Thereafter, these collars will send timely alerts to identified LBL and community members once the collared animal exits the landscape.

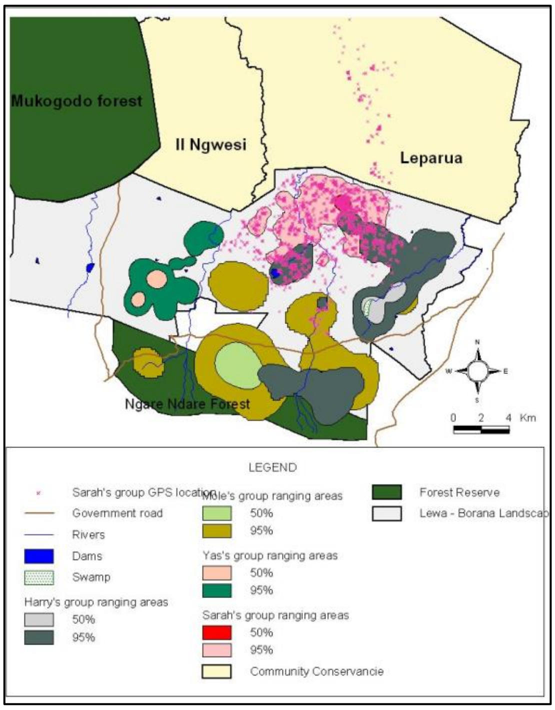


Figure 9: Ranging areas of four prides of lion on LBL

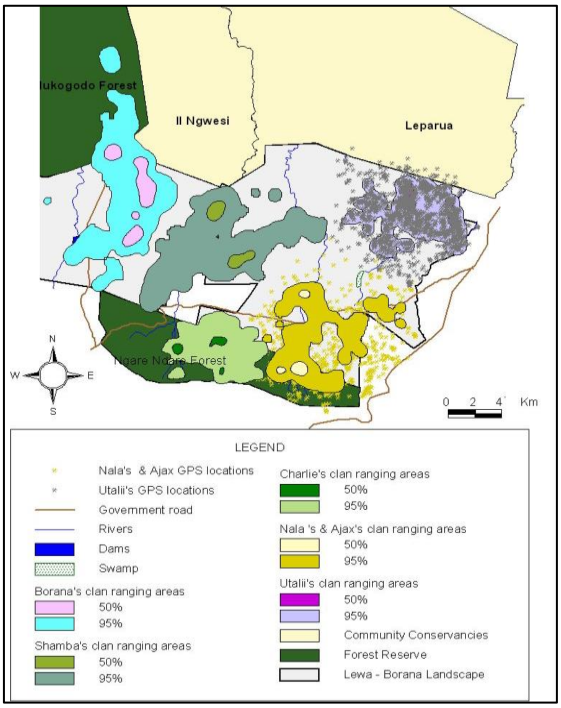


Figure 10: Ranging areas of the five hyena clans on LBL

Table 11: Cases of livestock depredation on LBL

Species	No. of incidents	No. of livestock killed			
		Cattle	Shoats	Camels	Donkey
Lion	23	27	5	1	1
Hyena	8	2	12	0	0
Cheetah	5	0	5	0	0
Wild dog	2	0	14	0	0
Leopard	3	0	5	0	0
Total deaths	**41**	**29**	**41**	**1**	**1**

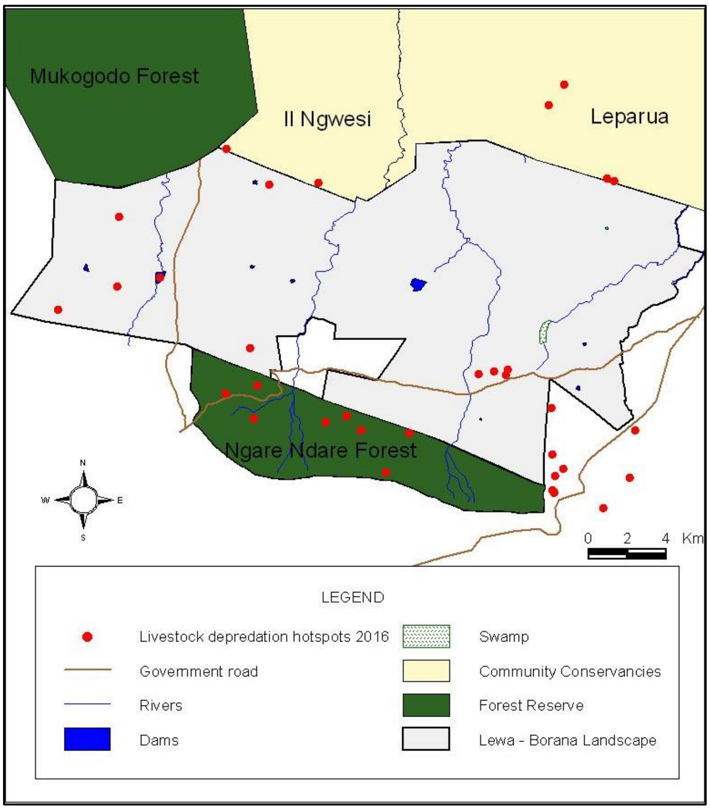


Figure 12: The spatial distribution of livestock depredation on LBL.
Note: The incidents in the Ngare Ndare Forest represent losses of community livestock as this is a communal grazing area.

4.4 Predator-prey interaction

4.4.1 Wildlife mortality

A total of 215 mortality cases of wildlife were recorded in the year. Predation was the main cause of deaths contributing to 79% of the cases. Other causes categorized as natural or unknown and fence entanglement contributed to 20% and 2% respectively. Of all predation cases, the lion was the main predator (76%) followed by cheetah (19%). However, many hyena kills go undetected due to their habit of scattering the carcass, thus making it difficult to find evidence of hyena caused wildlife mortality using the carcass discovery or cluster point method (on collared individuals).

Jacob's Selectivity Index (D) was calculated for each of the identified prey species. Results showed that Giraffe, Plains zebra, Grevy's zebra and eland were selected according to their proportional availability while buffalo, oryx and impala were avoided (Table 11). These species mainly graze in large herds and this strategy provides benefits from many observers by improving detection of the predator through increased vigilance thus avoiding predation (Hamilton, 1971). However, the warthog also appeared to be avoided compared to 2014 and 2015. This scenario will continue to be monitored to determine the actual cause of such avoidance despite warthog being common near water sources that are also areas of high lion activity. Kruskal-Wallis test revealed no significant change in the mean rank of the selectivity index from 2014 to 2016 ($H(2) = 0.24059$, df = 2, p = 0.8867) indicating that the overall prey selection for the three years was similar.

Table 10: Comparison of prey selectivity index from 2014-2016

Species	2014	2015	2016
Plains zebra	0.3	0.2	0.4
Grevy's zebra	0.3	0.3	0.3
Impala	-0.7	-0.6	-0.1
Waterbuck	0.4	0.4	0.1
Eland	0.0	0.4	0.2
Oryx	0.2	-0.6	-0.3
Warthog	0.7	0.7	-0.3
Giraffe	0.4	0.2	0.4
Buffalo	-0.8	-0.5	-0.2

4.5.2 Scat analysis

A total of 183 scat samples were collected and identified as lion (n = 70) and hyena (n = 113). High proportions of Plains zebra (0.36), buffalo (0.15) and giraffe (0.14) were observed in the lion scat (Fig. 13). The high contribution of the buffalo in the scat samples appears to contradict the selectivity index. This phenomenon will continue to be investigated to establish the possible reasons for this difference.

A proportion of cattle hair was also found in lion scat (0.07). This came from a pride of six lion (*Mole's* group) that extended their movement to the Ngare Ndare Forest Reserve (Fig. 9) and that overlapped extensively with livestock herds in the forest.

The spotted hyena showed a diverse choice of prey compared to lion. Among the wild ungulates, the Plains zebra contributed the highest dietary proportion (0.21) followed by impala (0.17). Sheep, goat and cattle were also detected in the diet of hyena (Fig. 14).

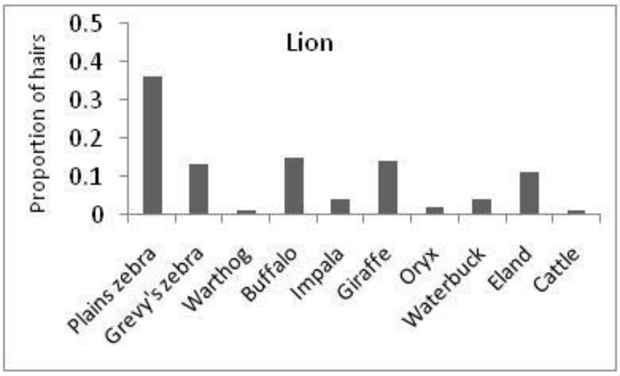


Figure 13: Proportion of prey species hairs found in lion scat

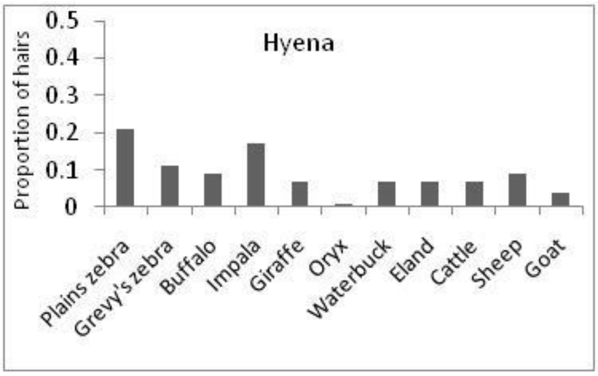


Figure 14: Proportion of prey species hairs found in hyena scat

4.6 Conclusion and recommendations

Leopard and cheetah were both observed in chance encounters during daily field routines. Expanding monitoring effort to these members of the large predator guild will provide a more holistic picture of the large carnivores' ecology. Scat analysis of lion and hyena indicates a negative interaction between livestock and carnivores. With an increase in the number of depredation cases on the landscape, monitoring will be enhanced to ensure timely data collection and intervention in an effort to reduce human – carnivore conflict.

With the current number and trend of lion, and the impact of predation on endangered species, LBL has received authorization from KWS to actively manage this population. This will be achieved through the use of non - lethal birth control methods, aimed at reducing the reproductive success of three females. Monitoring will be undertaken upon implementation of the treatment for approximately three years to understand the efficacy and the effect on the selected individuals. This will act as a trial for implementation in other conservation landscapes, where similar challenges are being experienced.

CHAPTER 5

5.0 UNGULATE MONITORING

5.1 Introduction

The LBL has over 35 species of ungulates. Out of these, the Grevy's zebra, Plains zebra, hartebeest, Beisa oryx, giraffe, eland and buffalo were chosen as indicator species and were monitored to understand their status, performance, utilisation of range, health and condition. The information generated includes both seasonal and annual trends as well as any unexpected variations so that timely management decisions can be made to forestall any emerging threat.

Apart from the Grevy's zebra, hartebeest and buffalo, which were found in specific areas, all the other species of ungulates, were monitored on pre-defined loops. Among others, the metadata collected on each sighting included location, group size, and age and sex structure.

Below, we present a summary of a select number of ungulates that were monitored in the year. For a comprehensive analysis of the performance of these populations, click here to access the report on the LBL Annual Game Count, 2016. However, we also present more details on the Grevy's zebra as a standalone section since this is a species of concern in the landscape.

5.2 Results and discussion

5.2.1 Grevy's zebra

- The age ratio of adult to juvenile/foal was 4:1, the population continues to be adult heavy representing low potential for immediate recovery (Fig. 15). The percentage class of the juveniles and foals is below 30%.
- When the proportion of juveniles and foals approach 30% of the total, populations appear stable and tend to sustain themselves because there are sufficient recruits to replace adults that die (Rubenstein *et al.,* 2016 unpublished).
- Jacob's Index was 0.4 (Table 11).
- The overall population trend has continued to decline over the years in the landscape (apart from 2013 – 2015) (Fig. 16).

5.2.1.1 Births and survival rates of foals

- In 2015, 51 foals were born. 35% (n=18) of these survived to year end. 12 (24%) of these 18 foals were then recruited into the juvenile age class.
- In 2016, 77 foals were born. A significant number of them (68%; n=52) were still alive by year end. This number includes 11 out of the 18 foals that were born in the extremely dry months of July – September.
- The increasing foal survival is encouraging. Should this trend continue we may see an increase in the population size over time.
- The majority of foal mortality cases were in the 0-6-month age class (97% in 2015 and 88% in 2016) indicating the vulnerability of these infants to predation.

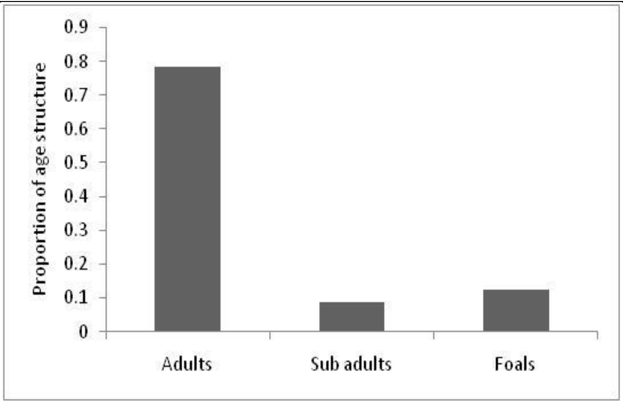


Figure 15: Proportional age structure of Grevy's zebra on LBL

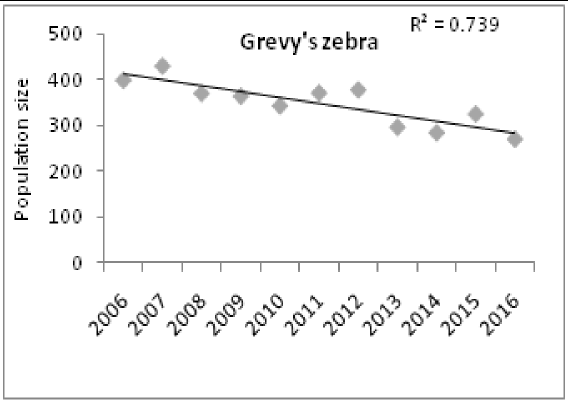


Figure 16: Grevy's zebra population trend on LBL

5.2.1.2 Grevy's zebra foals and lion home range overlap

- The distribution of lactating females was in areas close to water and with short grass.
- These areas had relatively dense vegetation thus reducing visibility.
- However, the areas were also the preferred ranging areas of the lion prides creating a 70% overlap level (Fig. 17).
- With such overlap, predation of foals is inevitable noting that Jacobs Index (D) remained at 0.3 (weak selection) for the last three years (Table 11).

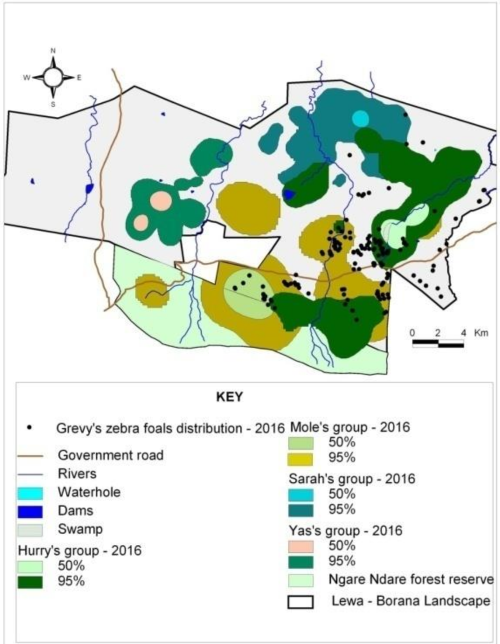


Figure 17: Distribution of Grevy's zebra foals overlaid with lion home ranges in 2016

5.2.2 Plains zebra

- The ratio of adults to the juveniles/foals was 4:1 implying low recruitment rate into the adult age class (Fig. 18).
- However, the male to female sex ratio of the reproductive age class was 1:2.
- This indicates that the population has the potential to remain stable in the medium-term.
- Jacob's Index increased from 0.2 to 0.4 (weak selection) in 2015 and 2016 respectively.

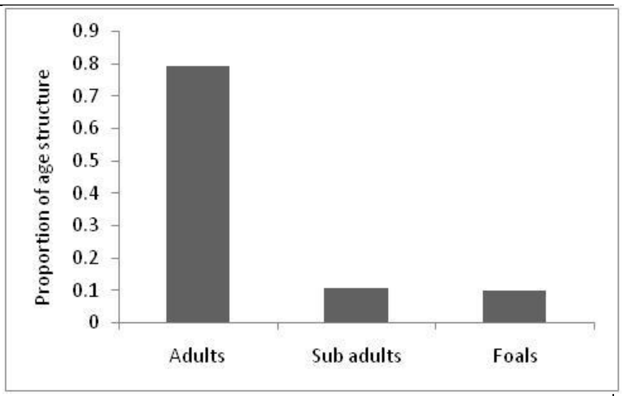
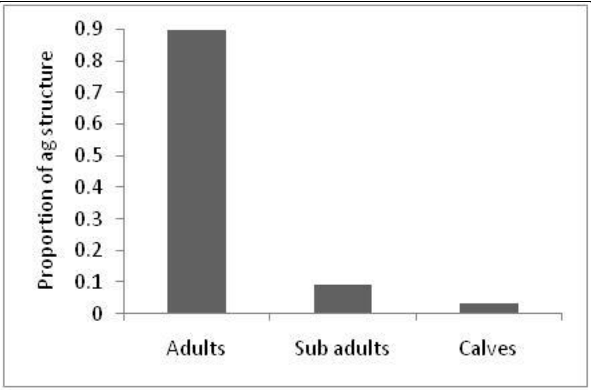
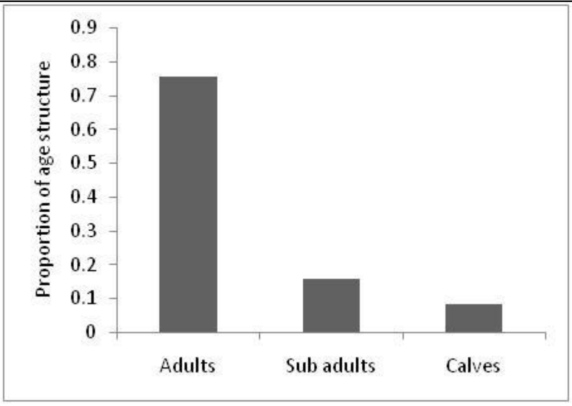


Figure 18: Proportional age structure of Plains zebra on LBL

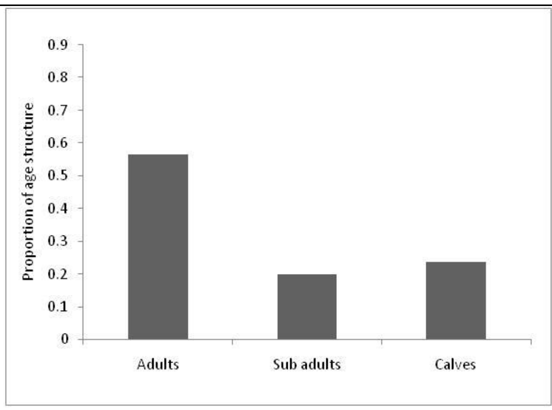
5.2.3 Giraffe

- The ratio of adults to juveniles/calves was 7:1 implying low recruitment rate into the adult age class (Fig. 19). - The adult male to female sex ratio was 1:1.8. - Predation using Jacob's Index increased from 0.2 to 0.4 (weak selection) in 2015 and 2016 respectively. - With an age structure that is significantly skewed towards adults and with continued predation, the population has a low potential to increase in the near future.	 **Figure 19**: Proportional age structure of giraffe on LBL

5.2.4 Eland

- The ratio of adult to juveniles/calves was 3.4:1 (Fig. 20). - The male to female sex ratio for the reproductive age class was 1:3.8 representing high growth potential. - Jacob's Index increased from 0.2 to 0.4 (weak selection) in 2015 and 2016 respectively.	 **Figure 20**: Proportional age structure of eland on LBL

5.2.5 Buffalo

- The age ratio for adult to juveniles/calves was 1:2.2 translating to a high recruitment to adult age class (Fig. 21). - The male to female sex ratio in the reproductive age class was 1:2.6 representing high potential for continued growth. - Jacob's Index shows that buffalo are avoided by lion (-0.2 in 2015 and -0.6 in 2016). - Management will need to monitor carefully to determine at what stage the population is reaching carrying capacity and active reduction measures need to be put in place.	 **Figure 21**: Proportional age structure of buffalo on LBL

5.2.6 Hartebeest

- The population of hartebeest ranged from 35 to 45 individuals.
- In the last two years, the population on the eastern side of the landscape has slowly increased through births. 9 calves were born within this period. However, only two of them survived (5.6% survival rate) by year end.
- The main cause of deaths was predation by cheetah.
- The age ratio of adults to juveniles/calves was 6.2:1 (Fig. 22) representing low recruitment rate.
- The male to female sex ratio in the reproductive age class was 1:2.7.
- The distribution of hartebeest was mainly in the open areas where cattle grazing was intensively undertaken. These areas have reduced biomass and through visual observations, the density of ticks was relatively low compared to non-grazed areas (personal observation).

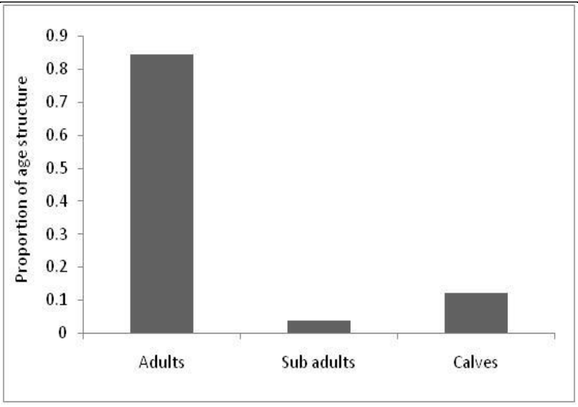


Figure 22: Proportional age and sex structure of hartebeest on LBL

5.2.7 Beisa oryx

- The age ratio of adult to juveniles/calves was 5.2:1 implying low recruitment rate (Fig. 23).
- The male to female sex ratio for the reproductive age class was 1:2 representing medium growth potential
- This species is largely avoided by lion, (D = -0.6). Therefore, this population has a potential to remain stable and continue to grow slowly in the medium term.

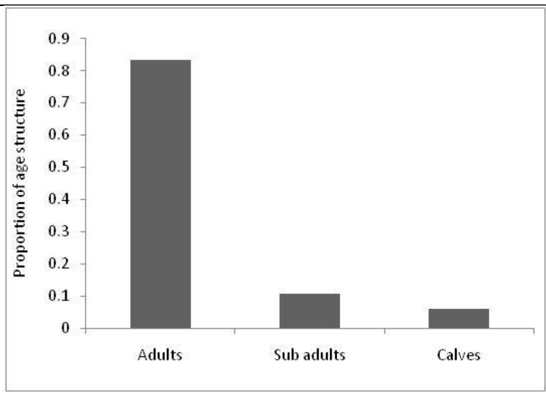


Figure 23: Proportional age structure of Beisa oryx on LBL

5.3 Conclusion and recommendation

Large-bodied wildlife populations are likely to decline if they are relatively adult heavy as is the case with most of the ungulate species surveyed. The declines are attributed to the fact that there will be no sufficient recruits to replace adults that die. If not declining, these populations will have low to medium growth potential. A number of factors including predation have been attributed to the stable or declining nature of the ungulates in general. However, other potential contributors including the overall quality/condition of the rangelands need to be investigated. Some actions that are meant to improve the quality of range either have been implemented or have been recommended, for example, ongoing manipulation of grasslands using cattle to improve their productivity for the benefit of wildlife. To mitigate high predation rates, regulation of the breeding rates of lion will need to be sustained and their efficacy continuously monitored. The first manipulation of the breeding rates of lion is planned for Q1 2017 using non-lethal techniques (see Chapter 4). As research on the hyena population gives a clearer picture in respect of their direct impact on prey species, active management intervention may be required here as well.

It is interesting to note that the selectivity indices for several prey species have changed in 2016. Some have decreased (warthog) and some have increased, including browsers like giraffe and eland, and buffalo whose avoidance is decreasing. Notably, Grevy's zebra have remained consistent at an Index of 0.3. While further monitoring is required to verify these trends, these fluctuations may be indicating the start of a shift in predation pressure between species. We will watch these indicators closely for developing trends.

5.4 Wildlife movement through the corridors

The key drivers to wildlife movements in an area include food, water, cover and mates. Such movements may be within the same or different landscapes. On the LBL, these movements were consistently monitored using camera traps fixed on three sites namely, Mount Kenya End Pass, Mount Kenya Underpass and the Northern gap. Camera traps were also placed on the gaps situated on the western side of the LBL. The consistency of these traps will be enhanced in 2017.

Four species namely: Grevy's zebra, Plains zebra, giraffe and elephant were the main users of the gaps. However, other species like spotted hyena, stripped hyena, lion, wild dog, reedbuck, bushbuck, waterbuck and buffalo occasionally utilised these openings. Further analyses on the usage of these gaps by wildlife was completed for the dry (February, July, August, and September) and wet (April, May, November, and December) seasons from 2014 to 2016.

5.4.1 Results and discussion

- The overall wildlife crossing events from 2014 to 2016 in all the gaps were highly significantly different.
- The northern gap showed a significant reduction in the wildlife crossing events over the years ($\chi^2 = 1815.4$, df = 2, p = 0.0001).
- The Mount Kenya Underpass showed a significant increase in crossing events over the years ($\chi^2 = 688.23$, df = 2, p = 0.0001).
- Crossing events on the Mount Kenya elephant corridor (MKEC end pass) were also highly significant but varied from year to year ($\chi^2 = 2672.3$, df = 2, p = 0.0001) (Fig. 24).
- This implies that corridors are important in the management of metapopulations of wildlife

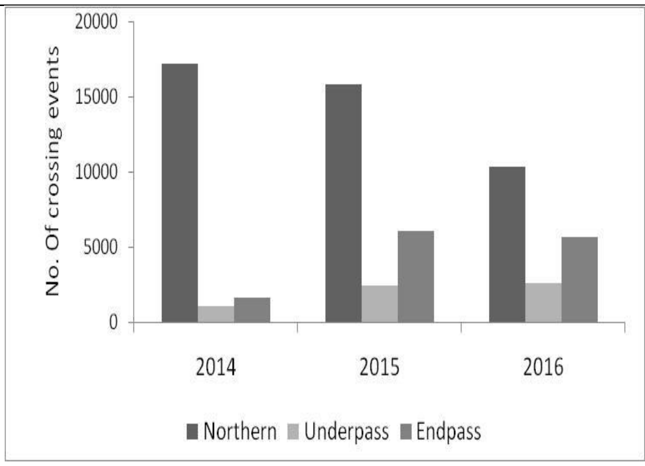


Figure 24: Total crossing events for all observed wildlife species

5.4.1.1 Mount Kenya End Pass

- There were significant differences in all the wildlife crossing events during the wet and dry season in all the three years: 2014 (χ^2 = 14.49, df = 1, p = 0.0001), 2015 (χ^2 = 19.722, df = 1, p = 0.0001) and 2016 (χ^2 = 84.027, df = 1, p = 0.0001) (Fig. 25).
- During the dry and wet season, there was a significant movement towards the Mt. Kenya Forest, dry (χ^2 = 10.662, df = 1, p = 0.0011) and wet, (χ^2 = 5.3821, df = 1, p = 0.0203).
- Elephant movements during the dry season were significantly higher towards the Mount Kenya Forest (χ^2 = 9.965, df = 2, p = 0.007) unlike during the wet season where there was no difference in movements (χ^2 = 0.520, df = 2, p = 0.771) (Fig. 26). This may be due to the availability of resources in the corridor and forest relative to the open rangelands during dry seasons (Sankaran *et al*., 2005).
- In addition, the movements of Plains zebra were significantly higher towards Mount Kenya Forest in both the dry (χ^2 = 9.965, df = 2, p = 0.007and wet (χ^2 = 14.848, df = 2, p = 0.001) seasons (Fig. 26).

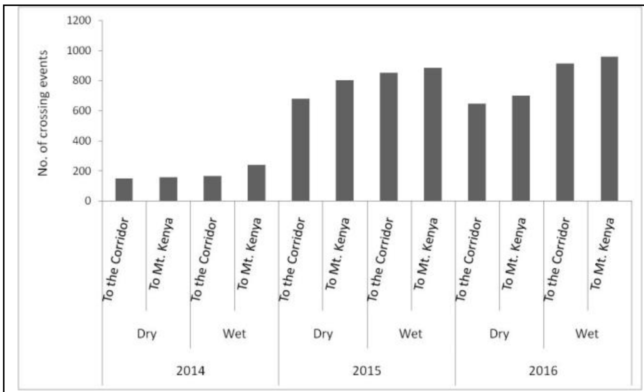


Figure 25: Total crossing events for all observed wildlife species in the dry and wet seasons on the Mount Kenya End Pass

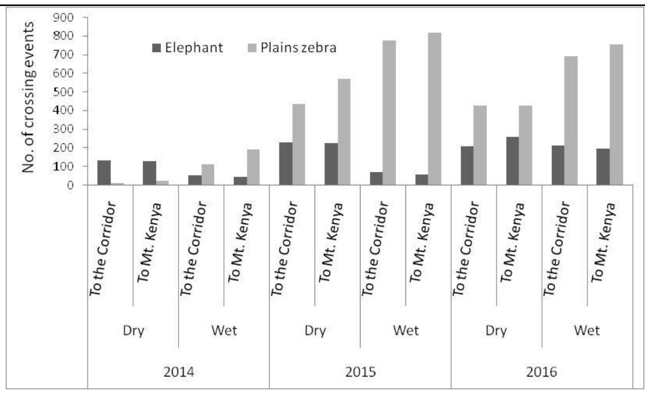


Figure 26: Total crossing events for selected wildlife species in the dry and wet seasons on the Mount Kenya End Pass

5.4.1.2 Mount Kenya Underpass

- There was no significant difference in the number of all wildlife crossing events in the dry season (χ^2 = 2.919, df = 1, p = 0.08754). However, during the wet season, there were significant crossing events towards the Ngare Ndare Forest (χ^2 = 29.653, df = 1, p = 0.0001) (Fig. 27).
- There were increased wildlife movements during the dry season in 2015 (χ^2 = 27.136, df = 1, p = 0.0001) and 2016 (χ^2 = 51.364, df = 1, p = 0.0001). However, in 2014, movements on both the wet and dry seasons were not significant in any direction (χ^2 = 1.1568, df = 1, p = 0.2821).
- The movements of elephant were not skewed to any direction during the wet (χ^2 = 3.417, df = 2, p = 0.181) and dry (χ^2 = 3.725, df = 2, p = 0.155) seasons (Fig. 28) over the years. This is an indication that the Ngare Ndare Forest is an important feeding area for the elephant in both the dry and wet seasons.

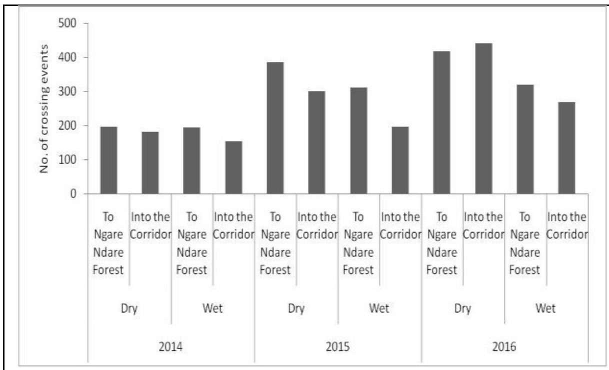


Figure 27: Total crossing events for all observed wildlife species in the dry and wet season on the Mount Kenya Underpass

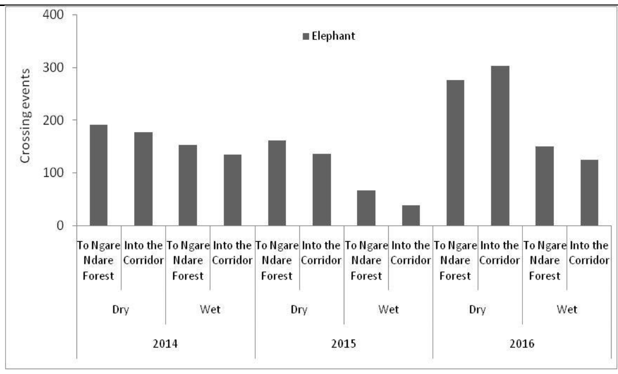


Figure 28: Total crossing events for elephant on species in the dry and wet seasons on the Mount Kenya Underpass

5.4.1.3 Northern gap

- There were significant differences in wildlife crossing events in both the dry and wet season (dry, χ^2 = 4.6051, df = 1, p = 0.03188) and (wet, χ^2 = 44.692, df = 1, p = 0.0001). The wet season had significantly higher movements than the dry season, 2014 (χ^2 = 1550.6, df = 1, p = 0.0001), 2015 (χ^2 = 614.72, df = 1, p = 0.0001) and 2016 (χ^2= 97.64, df = 1, p = 0.0001) (Fig. 29).
- Similarly, to the MKEC, elephant movements were not significant to any direction in both the dry (χ^2 = 1.413, df = 2, p = 0.493) and wet (χ^2 = 4.898, df = 2, p = 0.086) seasons (Fig. 30).
- Grevy's zebra showed significant seasonal movements with more crossing events during the wet (χ^2 = 7.133, df = 2, p = 0.028) compared to the dry season (χ^2 = 0.366, df = 2, p = 0.833). However, the overall exits were similar to the entries (Fig. 30).
- Giraffe did not show significant crossing events during the dry (χ^2 = 0.613, df = 2, p = 0.736) and wet (χ^2 = 4.124, df = 2, p = 0.127) seasons (Fig. 30).
- Plains zebra showed significant movements during the wet season (χ^2 = 36.928, df = 2, p = 0.000) with more crossings towards Leparua Conservancy. However, there were no observed changes in the dry period (χ^2 = 4.489, df = 2, p = 0.106) (Fig. 30).

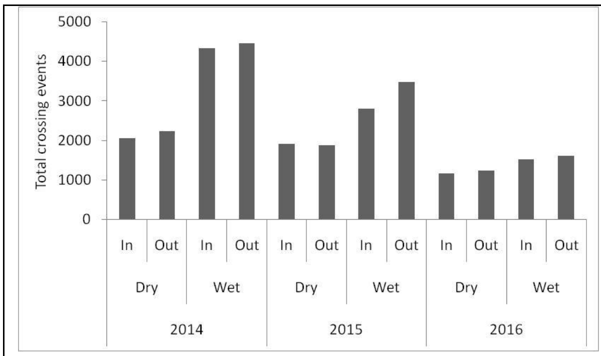


Figure 29: Total crossing events for all observed wildlife species during the dry and wet seasons on the Northern gap

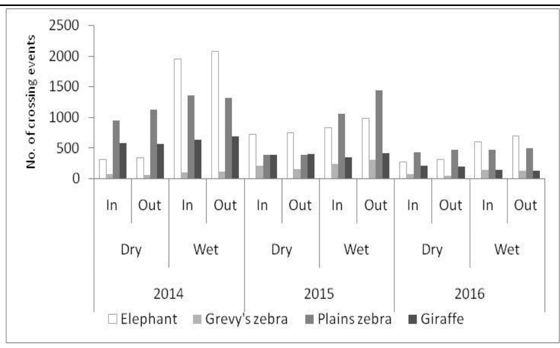


Figure 30: Total crossing events for selected species of wildlife during the dry and wet seasons on the Northern gap

5.5 Conclusion and recommendations

The corridors between LBL and the surrounding areas are an important part of wildlife mobility in the greater landscape. The MKEC appears to have influenced movements generally. Elephant have expanded their range and connectivity both within the corridor and between the areas it connects.

CHAPTER 6

6.0 MONITORING OF ELEPHANTS

6.1 Introduction

The associated problems that elephant have on the habitat are related to the nature of their feeding. This is due to their ability to alter the structure and composition of vegetation (Ben-Shahar, 1998). This effect can lead to reduced browse availability, particularly for critically endangered black rhino. Because of these effects, the presence of small, fenced reserves or exclusion zones may play an important role in the conservation of other browsers (Barnes et al, 1994).

The LBL, being one of the successful sanctuaries for black rhino in Kenya, has established several exclusion zones, which are configured with two strands of electric wires to safeguard browse for rhino. However, these exclusion zones have become the target by elephant that breaks the fences to access the protected browse, especially during the dry seasons. Management interventions including the upgrading of the fences and de-tusking of target candidates with a view of reducing the instance of breakages have been undertaken. However, the problem elephant appear to recruit other non-de tusked elephant and as a result, breakages persisted.

6.2.1 Results and discussion

6.2.1.1. Fence breaking elephant

During this period, it was difficult to establish the most persistent fence breaking elephant as the majority of them were recorded as unknown (Fig. 31). This was attributed to the fact that most of the breakages occurred at night and the elephant responsible would mix with other groups by dawn.

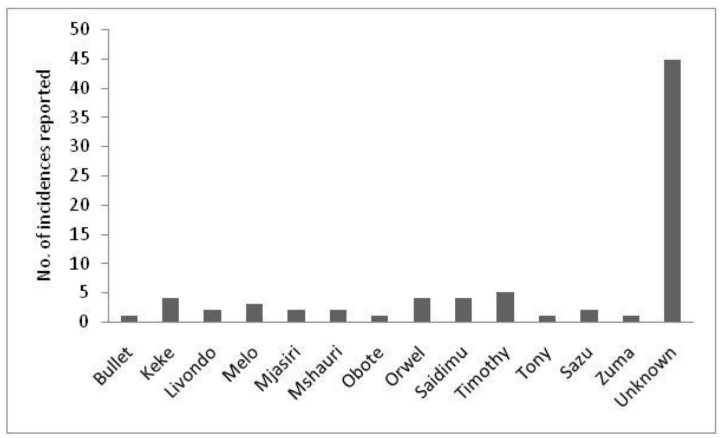


Figure 31*:* Elephant bulls responsible for fence breakages

Despite the fact that detusking persistent fence breakers and upgrading the configuration of exclusion zone fences has been effective management tools to reduce incidents of fence breakages, most detusked bulls appeared to recruit non-detusked bulls to help them in fence breakages (Fig. 33). The average number of companions that accompanied the detusked elephants during fence breaking incidents ranged between 2 to 8 bulls (Fig. 32).

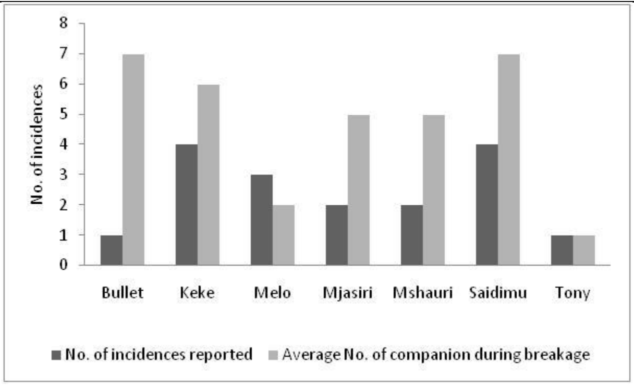


Figure 32: Number of fence breaking incidents reported against the average number of companions among detusked bulls.

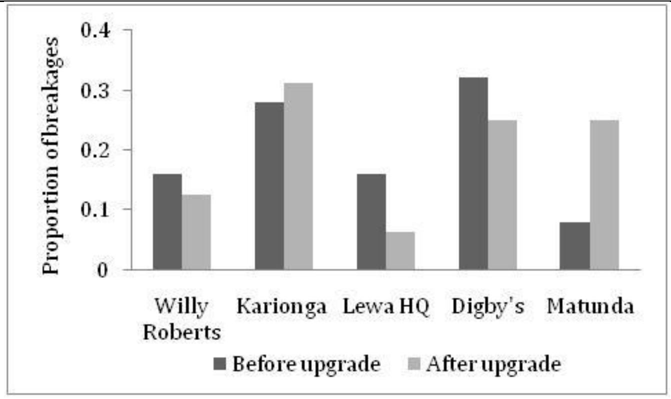


Figure 33: Proportion of fence breakages on upgraded exclusion zones

6.2.1.2 Breakage hotspots

A total of 16 exclusion zones and different sections within the main boundaries were targeted by elephant (Fig. 34).

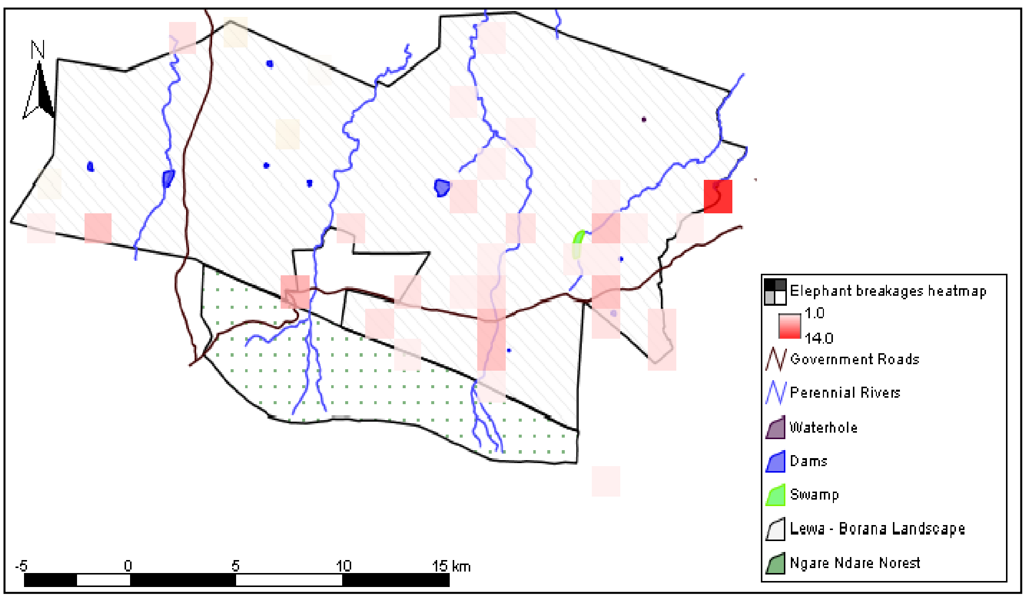


Figure 34: Heat map showing areas prone to breakages

6.2.1.3 Proposed translocation of persistent fence breakers

In a bid to mitigate human-elephant conflict and reduce the costs incurred in maintaining the exclusion zones and the main boundary fence, eight elephants namely *Mjasiri, Mshauri, Keke, Monk, Tyson, Melo, Champion* and *Mukiri* were identified for translocation in 2017. This operation was delayed in 2016 due to the drought situation in Tsavo, where the animals were due to be relocated.

6.3 Conclusion and recommendations

Elephants seem to learn new skills of accessing exclusion zones even with the management of these areas. In regard to this, monitoring efforts need to be intensified to ensure timely data collection and reporting. This will include setting up instant camera traps on hotspot areas to ensure that, photo data is collected in a timely fashion. Management will also look to investigate the use of beehive fences in those areas where elephant consistently challenge the main eastern boundary fence line i.e. adjoin Mutunyi community.

CHAPTER 7

7.0 VEGETATION MONITORING

7.1 Introduction

Vegetation plays an important role in supporting wildlife as a source of food. Different habitats support various wildlife species, and depending on their palatability, they either can be under-utilised or over utilised. Grasslands on the eastern side of the LBL are faced with underutilization as manifested by an accumulation of high grass biomass over a long period of time. Similarly, the woody vegetation undergoes browsing pressure from large herbivores mainly elephant and giraffe. It is, therefore, important to assess the status and condition of these rangelands for timely intervention aimed at maintaining healthy habitats to support wildlife.

7.2 Grassland monitoring

Sampling of grass was completed on 28 sites distributed on four habitat management units (Forest, Hills & Rocky outcrops, Plains and Riverine) occurring on Lewa (Botha, 1999). The data collected was used to estimate grass biomass, species diversity and cover. The results were compared for a period of six years (2011 – 2016).

7.2.1 Results and discussion

There was a significant increase in grass biomass between 2011 and 2016 ($F_{5, 143}$ = 7.286, p = 0.0001) (Fig. 35). Post hoc Tukey test (HSD) indicates that the mean grass biomass in 2011, which was the least contributed to this significant difference (Appendix 3).

There was also a significant difference in the mean grass biomass per management unit ($F_{(3, 145)}$ = 3.503, p = 0.0171) (Fig. 36). A combination of forest and riverine management units contributed to this difference (p = 0.0126409). Similarly, the biomass of grass within the sampling points was significantly different ($F_{(26, 122)}$ = 6.09, p = 0.0001) (Appendix 4).

Rainfall and the levels of utilisation by wildlife species play an important role in plant regrowth that consequently affects grass biomass. The forest management unit is at a higher altitude than the plains unit and receives relatively higher amounts of rainfall that promotes plant growth. The plains unit forms a large proportion of LBL and is dominated by increaser grass species *P. stramenium* and *P. mezianum.* These species are less palatable to grazers and hence underutilized leading to increased biomass.

Species diversity showed a significant change over the period between 2011 to 2016 (*H (2)* =22.523, df = 5, p = 0.00042). It was higher in 2011, 2015 and 2016 than between 2012 and 2014 (Fig. 37). *P. stramenium* was the dominant grass species in all years. With repeat cattle grazing and trampling on the grassland, it is expected that the species diversity will increase in grazed blocks over time (see Section 8.2.1.2).

The vegetation cover was high ranging from 80% to >90% from 2011 to 2016 (Fig. 38). This implies that the LBL's grasslands have a low potential for soil erosion from wind or water. They are also well protected from sunlight, which impacts plant roots negatively (Sebastià et al., 2008).

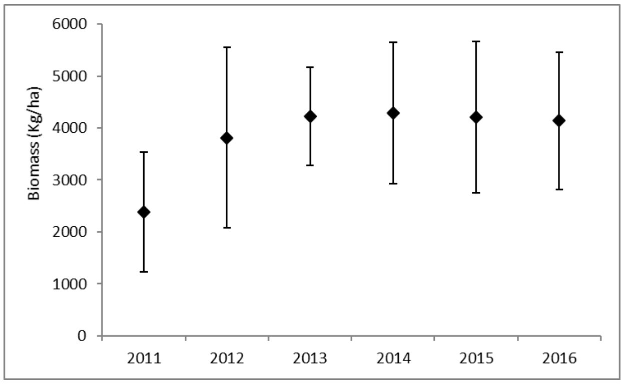


Figure 35: The mean grass biomass, 2011 - 2016

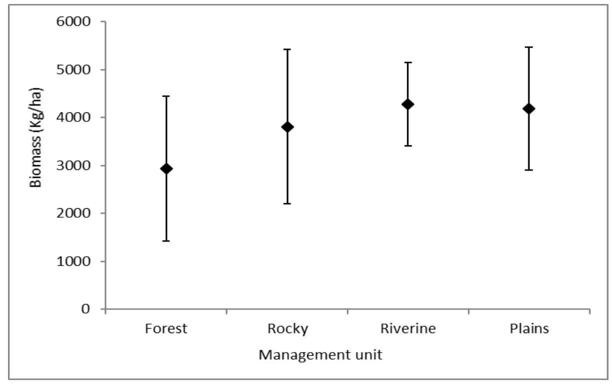


Figure 36: Mean biomass of grass per management unit

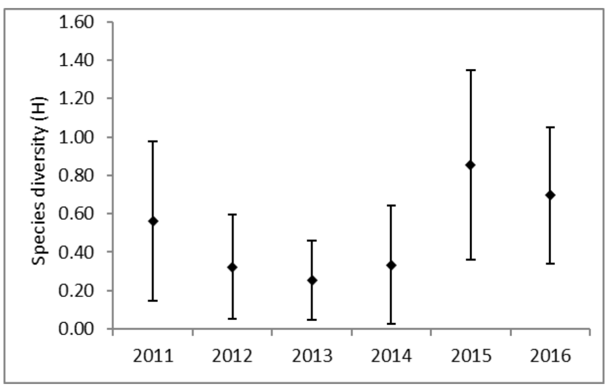


Figure 37: Species diversity, 2011 - 2016

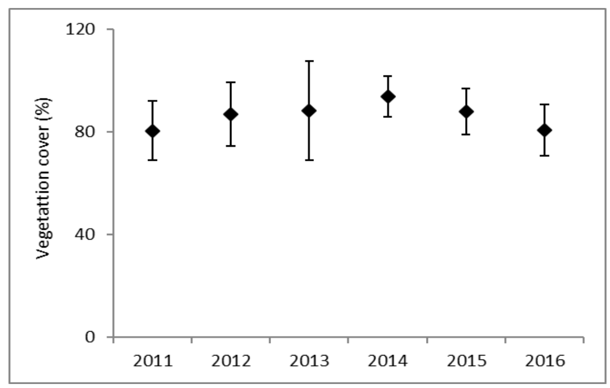


Figure 38: Vegetation cover, 2011 – 2016

7.3 Woody vegetation monitoring

Sampling of the woody vegetation was undertaken in the same fixed-point areas as those for the grass assessment. The main objective was to establish the status of the woody vegetation.

7.3.1 Results and discussion

A total of 20 woody vegetation species were encountered during the study. Most of the trees sampled were damaged with broken branches and trunks or the entire plant was uprooted. The damage occurred mainly from the feeding nature of different wildlife species. There was no significant change in the total number of damaged tree species encountered during the study in 2016 and 2015 (χ^2=2.813, df = 5, p = 0.729). Elephant and giraffe contributed to the highest number of damaged trees compared to rhino, impala and eland (χ^2= 108.78, df = 4, p = 0.0001) (Fig. 39).

No seedling was recorded during sampling. This could be possibly due to: 1) the timing of data collection that is mainly done in the dry month of September when the weather is not favourable for seed germination; and 2) the seedlings could have been browsed before they grew to saplings.

Certain tree species such as *Grewia similis* experienced high damage than others (Fig. 40). This was mainly through feeding by rhino, eland and impala. Elephant damaged *A. seyal, A. drepanolobeum* and *A. tortilis.* All these species (except rhino) are mixed feeders, ingesting both grasses and browse material in varying proportion and their feeding habits can be destructive.

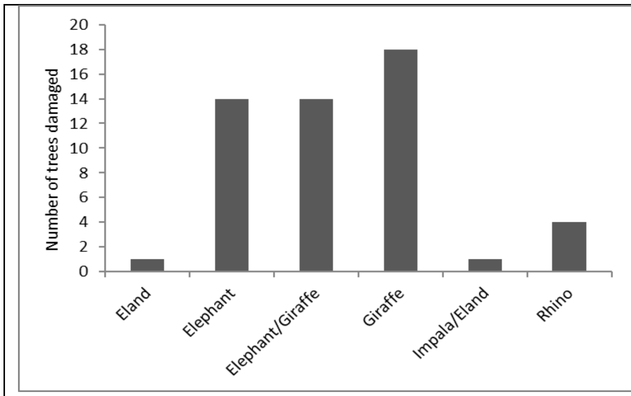


Figure 39: Woody vegetation damage on Lewa by different wildlife species

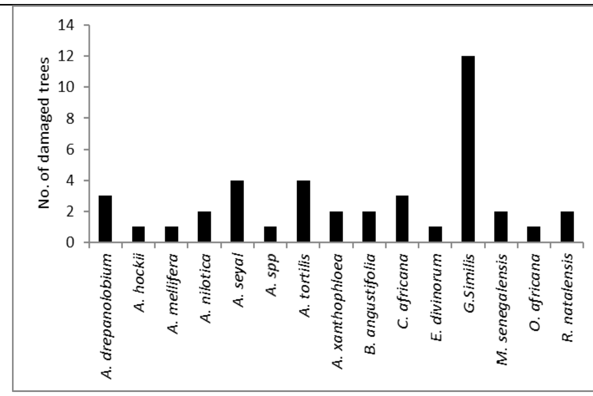


Figure 40: Number of tree species damaged

7.4 Conclusion and recommendation

Establishment of total exclusion zones on fragile habitats such as riverine areas should be considered in future. This will be crucial for reseeding purposes. Monitoring of damaged trees and quantifying those that are lost to other causes such as secondary diseases and insect infestation should also be investigated.

CHAPTER 8

8.0 RANGELAND MANAGEMENT

8.1 Introduction

Rangelands are important as they represent major sources of food for domestic livestock and wildlife. They are also vital ecological resources with environmental benefits such as cycling nutrients. On Lewa, a controlled cattle grazing programme has been applied to improve the condition of the grasslands. This is achieved through the trampling effect, dunging and urination by cattle that add nutrients in the soil that in turn impact on plant growth and composition for the benefit of wildlife.

8.2 Improvement of rangeland using livestock grazing

During the year, a total of 1,193 head of NRT-Trading (NRT-T) cattle grazed on Lewa. These cattle grazed in a controlled system, which involved bunching into herds of 300 (±50) head in a defined paddock.

8.2.1 Results and discussion

8.2.1.1 Grazing blocks

In total, 9,309 acres were grazed representing 29% of the total acres designated for cattle grazing (Appendix 5). The average number of animal days per acre (ADAs) ranged from 25 - 75. This number was determined through an assessment that considered the quantity and quality of the grass, body condition of the animals and the prevailing weather conditions.

8.2.1.2 Ecological benefits

Monitoring changes arising from the intensive livestock grazing is important in evaluating whether the desired management objectives are being attained. Previous assessments have outlined that grazing reduces grass biomass, promoted species diversity and did not impact negatively on vegetation cover. So what is the long-term effect of intensive cattle grazing on LBL's rangeland?

Long-term monitoring of changes in biomass showed that there was a significant reduction in biomass of grass for the first nine months, post-grazing (χ^2=249.061, df = 6, p = 0.000). Thereafter, the biomass slowly accumulated back to almost its original state (Fig. 41). Where re grazing was undertaken, the biomass was significantly lower than the rest of the non-re grazed areas. (t=-11.93, p=0.001).

Grasses go through a fast phase of re-growth after they have been grazed therefore they need to be managed through re grazing to ensure the biomass is kept as low as possible. It is important to take note of 1) frequency, 2) intensity and 3) season of grazing because this will determine how the grass will respond**.** Prolonged and uncontrolled grazing intensity reduces the productivity of the grass over time. Therefore, the frequency of grazing should be carefully balanced with intensity.

Species diversity varied across the landscape: some areas recorded high diversity while it was low in other areas. Overall, there was an increase in grass species diversity after grazing and subsequent re grazing (Fig. 42). High levels of diversity were recorded during the wet season. Rainfall plays an important role in providing the necessary moisture required for seed germination and growth. These results are similar to those reported by Knappet *et al.,* 1999 who demonstrated an increase of 10-31% species diversity on grazed areas. Therefore, grazing is an important tool for maintenance and restoration of species diversity.

Grazing did not show any significant effect on vegetation cover (Fig. 43) (χ^2= 0.645, df = 6, p = 0.996). The rangeland is thus not affected with soil erosion by either wind or water.

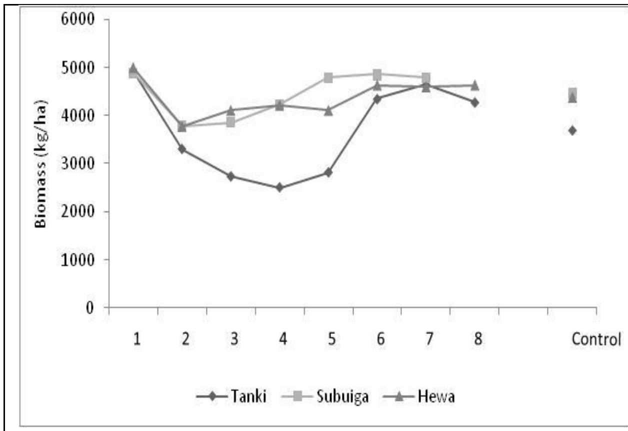


Figure 41: Long-term changes in grass biomass on grazed areas

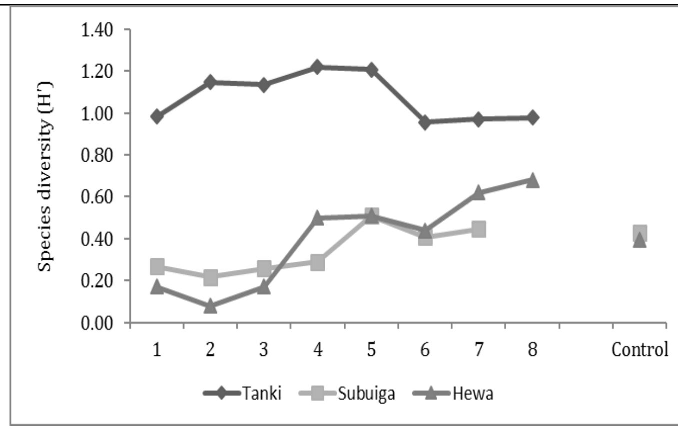


Figure 42: Long-term changes in grass species diversity on grazed areas

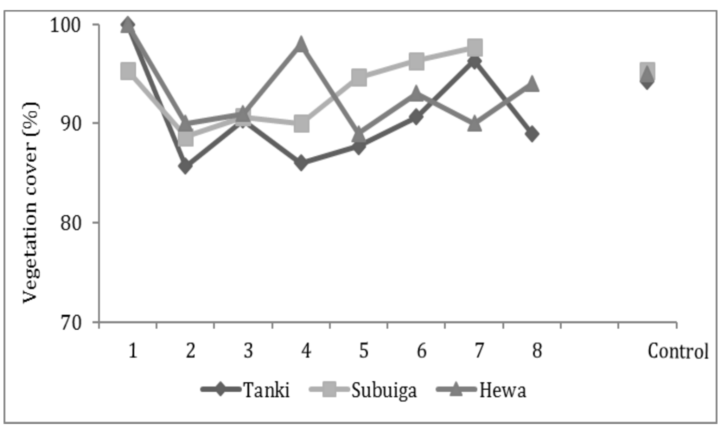


Figure 43: Long-term changes in grass cover on grazed areas

8.3 Improvement of rangeland using mowing

Mowing was undertaken in 2015 on an experimental basis. A total of 570 acres were proposed to be mowed but we managed to mow 70 acres. No mowing was undertaken in 2016.

8.3.1 Results and Discussion

Data presented here compares the long-term effects of "mowing only", "grazing only" and "grazing and then mowing". Both grazing and mowing had similar effects on grass biomass. However, mowing had more positive effects as demonstrated by the "mowing only" and "graze and mow" areas which had significantly reduced grass biomass (t = -10.16, p = 0.000 and t = -21.56, p= 0.000 respectively) compared to "grazing only" areas (t = -2.41, p = 0.052) (Fig. 44).

Estimates on vegetation cover did not significantly change where the three treatments were applied ("graze" t = -0.92, p = 0.394, "graze and mow" t= -2.27 p = 0.064 and "mowing only" t = -1.95, p = 0.099) (Fig. 45).

Species diversity was low on "grazed only" areas compared to "mowing only" and "grazed and mowed" areas (Fig. 46). This is because mowing has a uniform effect by consistently removing biomass in a short time period, which leads to homogenization of vegetation (Lepš, 2014). By providing a uniform disturbance regime, mowing decreases inter- and intra-specific competition for limited resources supporting the co-existence of a numerous species in a given area.

However, with time, grazing promotes higher species diversity due to bare patches caused by trampling especially at boma sites. Therefore, the more the boma sites the more micro sites for seed germination and plant growth are created.

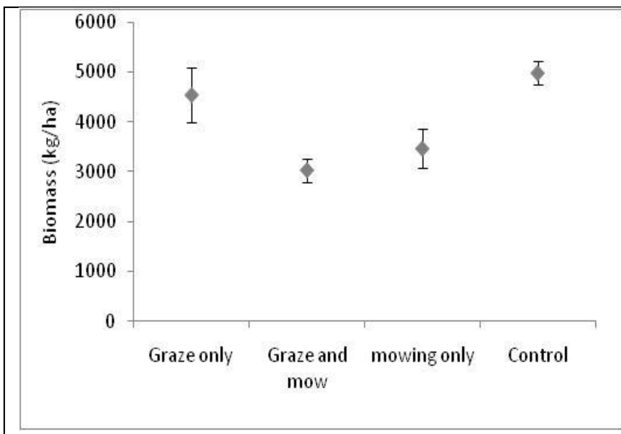


Figure 44: Change in grass biomass on "grazed", "grazed & mowed" and "mowed" areas

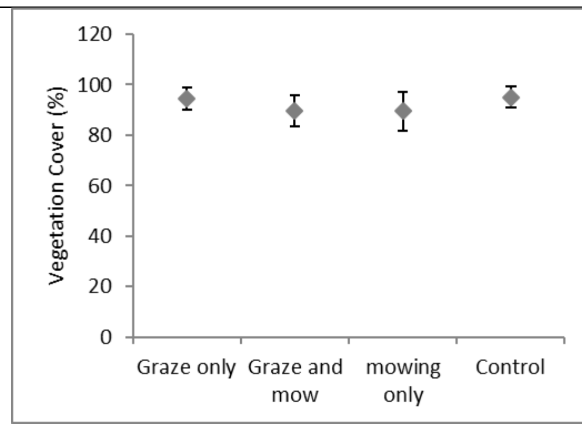


Figure 45: Change in grass cover on "grazed", "grazed and mowed" and "mowed" areas

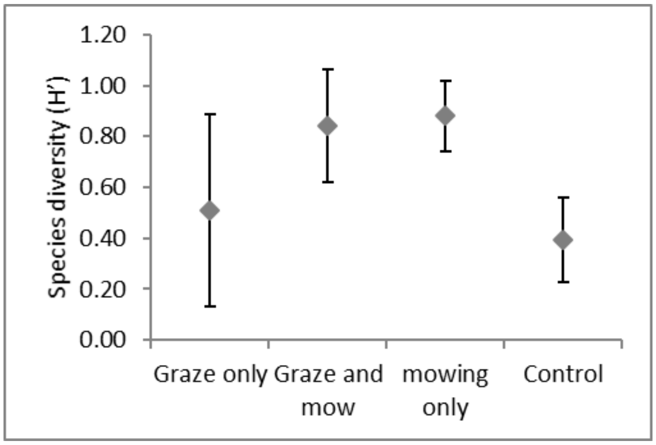


Figure 46: Change in species diversity on "grazed", "grazed and mowed" and "mowed" areas

8.4 Conclusion and Recommendation

The two management options used to manage LBL's rangeland namely, grazing and mowing produce desirable results/effects. However, it is also important to consider not only the effects but also the application and circumstances of the management methods: the socio-economic situation, the cost and time. Mowing can be costly and time consuming.

Re-grazing should be encouraged after every growing season especially in areas with low species diversity. This will serve to reduce the dilution of the positive impacts realised after grazing an area once.

CHAPTER 9

9.0 ENVIRONMENTAL MONITORING

To understand the rainfall pattern as well as the hydrology in the LBL, the amount of rainfall is measured on 13 stations that are distributed across the landscape. However, information on the flow of rivers is done on the Ngare Sirkoi River and has not been extended to all the other rivers in ten landscape. There is also no continuous measurement of other climate data as well as below surface water levels. Our understanding of the hydrological dynamics has therefore been limited. To improve on this shortfall, Terms of References for engagement with potential partners have been developed (Appendix 6). The main objectives of the proposed study will be to:

- Assess the long-term water needs for the ecosystem and wildlife sustainability on the LBL;
- Determine the long-term community water security;
- Implement appropriate measurements of the hydrology for continuous monitoring.

To date, there has been an evolving partnership between the management of LBL and the Southwest Research Institute (SWRI) in the USA who are assisting us to set up a system on basic hydrology monitoring. A planned reconnaissance visit by the SWRI is also being explored. The overall assessment of our hydrology will be guided by the TORs as presented in Appendix 6. The LRD will report on this development as progress is made.

The output of this study will not only be used by the management of LBL, but also other stakeholders including regional WRUAs, County and National governments.

9.1 Rainfall

The LBL received an average rainfall of 368±44 mm in the year with the highest rainfall recorded in November (Fig. 47). The northern part of the landscape received less rainfall compared with the other areas. This was represented by rain gauges in Leparua, Mlima Mbogo, Sambara and Mutunyi areas that received less than 300mm of rainfall in the year (Fig. 48).

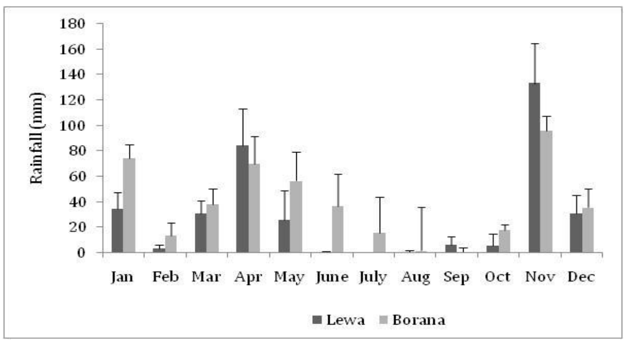


Figure 47: Amount of rainfall received on LBL, 2016

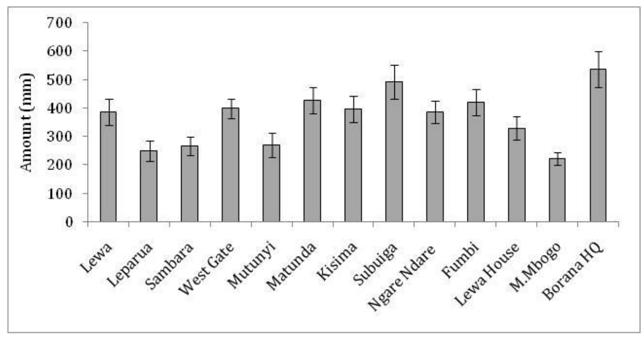


Figure 48: Amount of rainfall received per station on LBL in 2016

9.2 Rivers flow measurements

River flow meter gauges installed at the Ngare Segoi River (Manyagalo Bridge) showed that the height of the river fluctuated from 1.5 – 3.0 cm depending on the season in the year. One of the main problems with this river flow measurement is that the meter gauges do not measure the increased river flows are experienced after a downpour with the recorded height being a one-off at the time of the meter reading. We expect that with our developing partnership with the SWRI, the LRD will develop and implement a basic water monitoring protocol in the landscape that will eliminate some of these identified biases.

10. REFERENCES

1. Adcock, K., Emslie, R.H., (2003). Monitoring African rhino: an AfRSG update of "Sandwith's" training course for field ranger, 5th edition: trainee's guide.
2. Arjun Dheer (2016). Resource partitioning between Spotted Hyena (*Crocuta crocuta*) and Lion (*Panthera leo*). Unpublished.
3. Ben-Shahar, R. (1998). Changes in structure of savanna woodlands in northern Botswana following the impacts of elephants and fire. *Plant Ecology, 136(2), 189-189*.
4. Botha J.O., (1999). A resource management plan for the Lewa Wildlife Conservancy in the Mere District of the central Kenyan highlands. Mac (Wildlife Management) Thesis**.** University of Pretoria, Pretoria
5. Cousens, R., Dytham, C., Law, R., 2008. Dispersal in plants: a population perspective, Oxford University Press, Oxford.
6. Du Toit, R. (2001) Benchmarks for rhino population performance in the wild. In: *Proceedings of a SADC Rhino Management Group (RMG) Workshop on biological management to meet continental and National black rhino conservation goals.* Harare, South African Development Community.
7. East, M. L., & Hofer, H. (2001). Male spotted hyenas (Crocuta crocuta) queue for status in social groups dominated by females. *Behavioural Ecology*, *12*(5), 558-568.
8. Estes, R. (1991). *The behaviour guide to African mammals* (Vol. 64). Berkeley: University of California Press.
9. Kingdon, J. (2015). *The Kingdon field guide to African mammals*. Bloomsbury Publishing.
10. Lepš, J., 2014. Scale- and time-dependent effects of fertilization, mowing and dominant removal on a grassland community during a 15-year experiment. J.Appl. Ecol. 51, 978–987.
11. Lewa Wildlife Conservancy (2015). Post detusking monitoring report of problem elephants. (Unpublished report).
12. MacDonald, D.W. (1983). The ecology of carnivore social behaviour. *Nature* 301: 379–383.
13. Moss, C. J. (2001). The demography of an African elephant (*Loxodonta africana*) population in Amboseli, Kenya. *Journal of Zoology, 255, 145&156*
14. Poschlod, P., Bonn, S., 1998. Changing dispersal processed in the central European landscape since the ice age – an explanation for the actual decrease of plant species richness in different habitats. Acta Bot. Neerlandica 47, 27–44.
15. Prins, H. H. T., &Iason, G. R. (1989). Dangerous lions and nonchalant buffalo. *Behaviour*, *108*(3), 262-296.
16. Rubenstein, D., Stewart, C., Low B.M., Holberg. J., Kahumbu, P., Berger, T.W., Crall, J.& Jason Parham, J. (2016) Great Grevy's Rally: The Need, Methods, Findings, Implications and Next Steps. Unpublished
17. Schaller, G.B. (1972). The Serengeti Lion: a study of predator-prey relations. Chicago: University of Chicago Press.
18. Schmitz, O. J., Hambäck, P. A., & Beckerman, A. P. (2000). Trophic cascades in terrestrial systems: a review of the effects of carnivore removals on plants. *The American Naturalist*, *155*(2), 141-153.

19. Sebastià, M.-T., de Bello, F., Puig, L., Taull, M., 2008. Grazing as a factor structuring grasslands in the Pyrenees. Appl. Veg. Sci. 11, 215–222
20. Stuart, C., & Stuart, T. (2006). *Field guide to the larger mammals of Africa*. Struik Publishers.

LIST OF FIGURES

LIST OF TABLES

APPENDICES

Appendix 1: Breeding performance of black rhino on LBL

BLACK RHINO

																																																Calving Intervals										
No.	**Name**	**Birth date**	**Current age (yrs)**	**Mother**	80	81	82	83	84	**85**	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**Age at 1st calving (yrs)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Mean calving interval/ female**
1	Juniper	28-Jun-88	28.6	Juno																																											7.6	3.2	2.3	2.2	2.3	2.2	2.2	3.7	-			**2.6**
2	Mawingo	1-Jun-89	27.7	Solio Cow																																											**	2.2	2.8	1.7	1.5	1.6	2.4	4.6	1.8			**2.3**
3	Ndito	1-Jan-90	27.1	Solio Cow																																											9.3	3.2	2.2	2.1	2.7	2.8	2.4	-	-			**2.6**
4	Solio	1-Jan-76	41.1	Solio Cow																																											**	3.1	3.5	3.9	3.2	2.1	2.9	2.3	2.4	3.2		**3.0**
5	Sonia	23-Aug-91	25.5	Solio																																											7.1	4.7	2.4	2.4	1.8	2.6	1.8					**2.6**
6	Waiwai	4-Jul-95	21.6	Solio																																											6.8	2.1	2.3	2.0	3.1	2.6	-	-	-			**2.4**
7	Zaria	3-Sep-88	28.9	Solio																																											7.8	2.3	2.1	3.0	2.2	2.3	3.4	2.8	-			**2.6**
8	Nashami	16-Jul-98	18.6	Stumpy																																											7.6	3.4	2.6	2.5	-	-	-	-	-			**2.8**
9	Natumi	26-Sept-98	18.4	Solio																																											6.7	4.4	3.5	-	-	-	-	-	-			**4.0**
10	Samia	9-Oct-98	18.4	Sonia																																											8.2	2.7	2.5	2.6	-	-	-	-	-			**2.6**
11	Seiya	26-Apr-99	17.8	Ndito																																											5.5	2.7	2.8	2.7	2.6	-	-	-	-			**2.7**
12	Zenetoi	15-Dec-05	11.2	Zaria																																											9.3	-										
13	Anna	26-Feb-06	11.0	Oboso																																											6.5	4.0										**4.0**
14	Mama C	22-Jul-02	14.6	Ndito																																											6.8	2.5	2.1	3.0	-	-	-	-	-			**2.5**
15	Winnie	27-Aug-04	12.5	Ndito																																											7.3	2.8	-	-	-	-	-	-	-			**2.8**
16	Juno	19-Jan-06	7.4	Juniper																																											7.0	-										
17	Seneiya	26-Jul-07	6.8	Seiya																																											6.8	-										
18	Kathy	1-Apr-08	7.4	Zaria																																											7.4	-	-	-	-	-	-	-	-			
19	Mejh	08-Jul-05	11.4	Natumi																																											9.0	2.0										**2.0**
20	No. 6	13-Jun-02	14.5	Waiwai																																											7.5	3.5	1.6	2.3								**2.5**
21	No. 9	02-May-07	9.9	Waiwai																																											8.0	-										
22	No.18	23-Jul-09	7.4	N/A																																											7.1	-										
23	Linda	23-Sep-08	8.2	N/A																																											7.9	-										
24																																																										
25																																																										
																																							Mean age at 1st calving =								**7.5**			**Mean inter-calving interval =**								**2.7**

Key
- (green) *Year female born*
- (blue) *Quarter of the year calf born*
- (red) *Future calving based on respective female's last inter-calving interval; and mean inter-calving interval of all females for females with one calf only*
- (cyan) *Future calving based on respective female's mean inter-calving interval*
- (grey) *Expected date of first calving = 7 years)*

** *History unknown*

Appendix 2: Breeding performance of white rhino on LBL

WHITE RHINO

																																																`										**Mean**
No.	**Name**	**Date born**	**Age (yrs)**	**Mother**	80	81	82	83	84	**85**	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**18**	**18**	**18**	**Age at 1st calving (yrs)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**calving interval/ female**
1	Natal	1-Jan-89	28.1	Natal Cow																																											8.1	2.3	2.2	2.2	2.2	2.2	2.4	2.5	2.5			**2.3**
2	Opondo	1-Jan-86	31.1	Natal Cow																																												2.3	2.6	2.5	2.5	2.4	1.5	2.6	1.6			**2.3**
3	Songare	1-Jan-80	37.1	Solio Cow																																												4.0	2.2	4.0	2.0	2.0	2.0	2.1	2.6	2.5		**2.6**
4	Tumbili	1-Jan-86	31.1	Natal Cow																																											8.3	2.2	3.2	3.4	3.6	2.3	1.7	2.0	-			**2.6**
5	Jakwai	1-Jan-87	30.1	Solio Cow																																											9.4	2.2	2.9	1.9	2.1	2.6	3.8	2.6	-			**2.6**
6	Rinta	3-Jun-94	22.7	Ngororika																																											7.7	2.5	2.5	2.6	3.7	2.4	-	-	-			**2.7**
7	Tale	1-Jan-00	17.1	Solio Cow																																											8.3	3.3	2.4	2.2	-	-	-	-	-			**2.6**
8	Titilei	1-Jan-01	16.1	Solio Cow																																												3.4	1.0	-	-	-	-	-	-			**2.2**
9	Schini	12-Nov-02	14.2	Tumbili																																											5.4	1.9	2.8	2.0	-	-	-	-	-			**2.2**
10	Wakesho	3-Jun-03	13.7	Ngororika																																											7.1	3.1	2.6	-	-	-	-	-	-			**2.9**
11	Ramadhan	20-Oct-04	12.3	Murembo																																											6.0	2.6	2.0	-	-	-	-	-	-			**2.3**
12	Jacho	18-Jul-05	11.6	Jakwai																																											11.6	2.8										**2.8**
13	Ngura	25-Oct-06	10.3	Natal																																											6.7	-										
14	Queen (Murembo's 9)	4-May-08	8.8	Murembo																																											6.1											
15	Rosie	21-Aug-08	8.5	Opondo																																											5.5	1.8										**1.8**
16	Naserian (Tumbili's Calf 6)	13-Nov-08	8.2	Tumbili																																											6.0											
17	Lina (Rinta's Calf 4)	12-Aug-09	7.5	Rinta																																											6.3											
18	Lucille	25-Jun-10	6.5	Tumbili																																											5.9											
19																																																										
20																																																										
21																																																										
																																							Mean age at 1st calving =								**7.2**							**Mean inter-calving interval =**			**2.5**

Key
- (green) *Year female born*
- (blue) *Quarter of the year calf born*
- (red) *Future calving based on respective female's last inter-calving interval; and mean inter-calving interval of all females for females with one calf only*
- (cyan) *Future calving based on respective female's mean inter-calving interval*
- (grey) *Expected date of first calving = 7 years)*

** *History unknown*

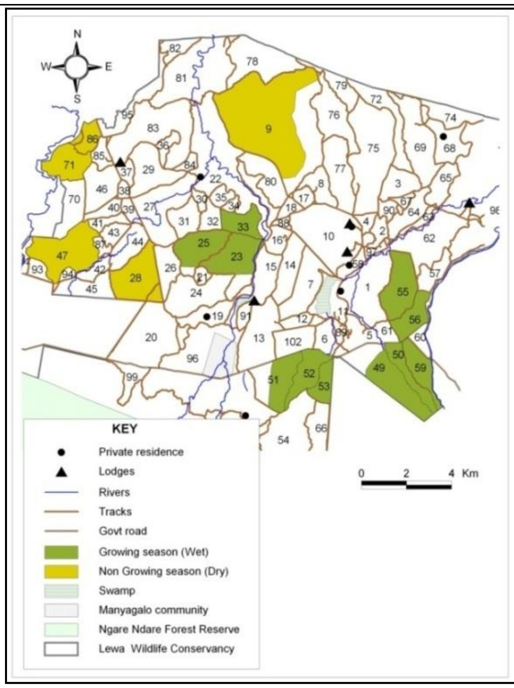
Appendix 3:

Years	P Value
Year 2012-Year 2011	0.0040631
Year 2013-Year 2011	0.0000808
Year 2014-Year 2011	0.0000282
Year 2015-Year 2011	0.0000642
Year 2016-Year 2011	0.0000578

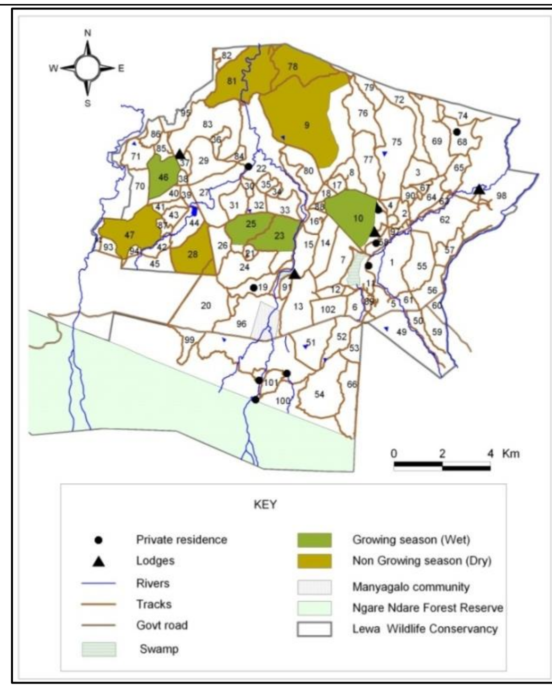
Appendix 4: Monitoring points that contributed to significant biomass change, 2011 – 2016

Management unit	P-Value
Serghoi Plain & SE of Willy's house	0.0000223
Sobuiga& SE of Willy's house	0.0020868
West of Kiboo's Gate & SE of Willy's house	0.0036164
SE of Willy's house & S.W of MlimaTanki	0.0090423
Serghoi Plain & N.E. of Fuzz's house	0.0094590
SE of Willy's house &Morani	0.0208304
N.E. of Fuzz's house &Mtegoyatwiga	0.0343450
SE of Willy's house &Mtegoyatwiga	0.0001652
West of Kiboo's Gate &Mlima Kali	0.0196781
SE of Willy's house &MlimaLoishimi	0.0119451
SE of Willy's house &MlimaNyeusi	0.0028866
MtegoyaTwiga&Mlima Simba	0.0060106
Serghoi Plain &Mlima Simba	0.0014075
Serghoi Plain &Mlima Kali	0.0001820
Sobuiga&Mlima Kali	0.0120579
Kona Mbaya&Dadaboi	0.0013932
Lenjoro&Dadaboi	0.0325999
Mawingu&Dadaboi	0.0000049
Mtegoyatwiga&Dadaboi	0.0079838
Serghoi Plain &Dadaboi	0.0019414
Mawingu& Dam yaMkora	0.0201602
Mawingu&Fumbi	0.0096515
SE of Willy's house &Halvor's plain	0.0236764
Kona Mbaya&Kahawa	0.0251709
Mawingu&Kahawa	0.0001521
Serghoi Plain &Kahawa	0.0330232
SE of Willy's house &Kisima	0.0229526
Mlima Kali & Kona Mbaya	0.0001242
Mlima Simba & Kona Mbaya	0.0010050
N.E. of Fuzz's house & Kona Mbaya	0.0068864
SE of Willy's house & Kona Mbaya	0.0000149
Mlima Kali &Lenjoro	0.0050896
Mlima Simba &Lenjoro	0.0250486
SE of Willy's house &Lenjoro	0.0008034
SE of Willy's house &Matunda	0.0334198
Mlima Kali &Mawingu	0.0000003
Mlima Simba &Mawingu	0.0000034
MlimaWatalii&Mawingu	0.0063860
Mombasa &Mawingu	0.0390308
N.E. of Fuzz's house &Mawingu	0.0000249
Sambara&Mawingu	0.0307196
SE of Willy's house &Mawingu	0.0000000
SE of Willy's house & Meza	0.0106645
MlimaNyeusi&Mlima Kali	0.0161098
MtegoyaTwiga&Mlima Kali	0.0010871
S.W of MlimaTanki&Mlima Kali	0.0438575

Appendix 5 and 6: Map showing grazed blocks in 2016 and blocks projected for grazing in 2017



Appendix 4: Grazing blocks in 2016



Appendix 5: Grazing blocks in 2017

Appendix 6: Key objectives for developing indicators, measurement tools and outputs

Objective	Indicator	Tools	Deliverables
1. Quantify Water resource	1. Rainfall 2. Ground water level 3. River Flow Rates 4. River depth 5. Abstraction	1. Rain Gauges 2. Borehole Water Depth 3. Flow meters 4. Depth Gauges 5. Inputs vs. Outputs	1. Drought security indicators 2. County planning information – abstraction and supply recommendations 3. Water use guidelines for neutral hydrological footprint 4. Report on upstream input sources and threats, and downstream impacts.
2. Map & define underlying geology & geohydrology	1. Subterranean Geology 2. Surface Geology 3. Water resource spatial model	1¤ Geological Survey 2¤ Physical Geographic Survey	1. Hydrological map 2. Geohydrological map 3. Describe the
4. Enhance Monitoring and Evaluation	1. Rainfall 2. Ground water level 3. River Flow Rate & depth 4. Abstraction	Tools that would complement and integrate well with the current database models and hardware being used for data collection are preferred: SMART and Cybertracker.	2. Regular and rigorous data collection 3. Defined SOP's 4. Integrated reporting channels to existing reporting systems.
5. Evaluate and recommend water security improvements	1. Ground Water Level 2. River depth 3. Abstraction rates 4. Dam water retention 5. Dam recharge and emptying rates	1. Managed drainage – Dam, Gully, Gate, Weir and other water flow management construction 2. Borehole assessment and implementation	1. Improvements to stream water intakes to reduce flood damage 2. Increasing exploitation of groundwater by additional boreholes 3. Additional construction of ephemeral flood retention dams 4. Peak river flow diversion, storage & ground infiltration
6. Water Quality Improvements	1. Human water related disease prevalence 2. biohazard detection	1. Human disease diagnostics 2. Water quality/biohazard testing	1. Watershed management improvements to reduce erosion and pollution risk 3. Water demand mgt & environmental health measures at household scale
7. Water resilience strategy	1. Water Resource indicator trends 2. Water Quality trends 3. Tends in water quality impacts (disease)	1. Water M&E Analytics	1. Produce a water resilience strategy 2. Implement water resilience strategy 3. Monitor, evaluate and adapt water resilience strategy