LEWA WILDLIFE CONSERVANCY
A UNESCO World Heritage Site inscribed in 2013

BORANA CONSERVANCY

Research and Monitoring

Annual Report 2019

Authors:

David Kimiti, Timothy Kaaria, Edwin Kisio, Kenneth Onzere, Eunice Kamau,

Saibala Gilicho, Francis Kobia, and Geoffrey Chege

EXECUTIVE SUMMARY

This report provides a summary of the activities of the Research and Monitoring Department on the Lewa-Borana Landscape (LBL) throughout 2019. The year received mixed rainfall, with the March-May season receiving below average rainfall, while the October-December season received significantly above average rains. The average annual rainfall recorded across the landscape was 729±72 mm. This translated into high vegetation productivity in the last quarter of the year, providing a good base for healthy wildlife populations going into Q1 and Q2 2020. Caution is however advised in case the March-April-May rains in 2020 are below average in response to prolonged rains in Q4 2019.

The rhino population was healthy and robust in 2019 despite some mortalities. 2019 recorded the highest single year births since the establishment of the Landscape as a rhino sanctuary in 1984. Black rhino increased from 97 to 109 individuals, with 17 births and 5 deaths recorded. This translated into a 3-year average growth rate of 9.5% across the 2017-2019 moving window period. White rhino increased to 97 individuals, with 15 births and 5 deaths, representing a growth rate of 11.5%. Two of the White rhino mortalities were as a result of poaching, the first incident of this kind since 2013. Despite sub-par rainfall in the first half of the year, none of the rhino targeted for body condition monitoring exhibited any signs of nutritional stress throughout the year, negating the need for supplementary feeding.

The lion population on the landscape remained robust, with subtle shifts within the population. There was a new entry from outside the landscape, with a dispersing male identified, and since given the moniker *Loner*. This individual has been responsible for livestock depredation on the neighbouring Marania farm, primarily targeting cattle. This male has been identified as a problem animal and targeted for translocation by the Kenya Wildlife Service. The three females included in the contraceptive trial since 2017 have ostensibly reached the end of the shelf life expected from the implant. The next phase of this experimental study will seek to expand the programme to include four additional females, while renewing contraception in two of the pilot candidates and excluding one of them to ascertain reversibility of contraception. Identification of lion across the ecosystem should be greatly improved by the LBLs participation in the Lion Identification Network of Collaborators (LINC) programme. In an effort to further understand our resident hyena population, the department is partnering with Kay Holekamp of the Mara Hyena project to design a study around habituating hyena on the landscape in order to better describe their social and hunting behaviour. In the

meantime, the department is planning to install drop-collars on a representative hyena from each clan to improve our knowledge on their spatial ecology.

Ungulate monitoring on the landscape showed a continued population robustness across most species. Buffalo continued to exhibit high growth potential with young and juveniles making up more than 30% of the population. Eland, oryx, Grevy's zebra, Plains zebra, and hartebeest all achieved rates above 20%, indicating medium to high growth potential in the coming years. Giraffe remain a species of concern, as their proportion of young and juvenile hovered close to 10% for the fourth year running. We therefore expect overall giraffe numbers to decline gradually over the next few years as the population becomes increasingly affected by a lack of recruitment into the adult class. This population could precipitously decline if there was further predation, as well as any unexpected disturbance like severe drought or disease, marking it out for increased monitoring. Grevy's zebra numbers remained steady and the foal population remained robust, but annual individual survivorship could not be accurately determined due to the continued unreliability of existing individual identification platforms.

Following the translocation of seven fence-breaking elephants to Tsavo National Park in 2018, coupled with uneven rainfall patterns across the Greater Ewaso ecosystem, fence breakages reduced significantly in 2019. This was also possibly supplemented by more proactive deterrent methods that included pre-dusk patrols on areas frequently experiencing elephant damage. This latter endeavor further highlights the need for a dedicated Human-Wildlife conflict rapid response team for the landscape. Use of beehives as a deterrent to elephant breakage along the main fence was piloted in 2019. However, due to erratic rainfall and inconsistent beehive colonization, results so far have been inconclusive. Overall, reduced elephant pressure across the landscape has also made it difficult to assign a cause-effect relationship between beehive installation and reduced fence breakage in the piloted section of fence. This pilot project will continue through 2020, with efforts to ensure full hive occupation currently underway.

Uneven rainfall distribution across the first part of 2019 affected vegetation productivity and subsequent wildlife movements between the different portions of the landscape. As rainfall amounts picked up, productivity also increased, leading to high biomass levels at the end of the year compared to the first half of the year, when the annual vegetation assessment is traditionally carried out. While conditions have improved in the entire landscape, the increasing numbers of wild grazing animals underscore the need to carefully assess year to year trends of soil and vegetation health. To this end, the department has partnered with Marwell Wildlife, UK to strengthen the current long-term rangeland monitoring programme. This will be done through more intensive and structured data collection aimed at assessing markers of general rangeland health and identifying legacy effects of management interventions such as the grazing and mowing programmes and historical burning. This collaboration will also be aimed at contextualizing these effects across differing land potentials, characterized by different soil types, topography and climatic conditions. All these data will be collected with the aim of producing a new Rangeland Management Plan for the landscape. In addition, with the help of local partners, Lewa is currently piloting the use of a plant ID software which will immensely increase the quality of species level monitoring and improve the standard of accuracy of research conducted by external partners unfamiliar with local taxonomy and phenology.

The hydrology programme has not had as much traction in 2019 as expected, primarily due to a lack of funding. Despite this, improvements in existing monitoring protocols continue, including standardizing weather reporting across the LBL, and ratifying plans to standardize data collection tools in 2020. As of early February 2020, we have secured $100,000 from the Bently foundation to support the LBL Ecohydrology Monitoring Programme. Additionally, our funding proposal to the Prince Albert of Monaco Foundation is in an advanced stage of consideration, and it is our hope that it will be accepted, allowing us to fully implement our Ecohydrology monitoring programme in partnership with the Centre for Training and integrated Research in ASAL Development (CETRAD) and the Southwest Research Institute (SWRI).

As our continuing engagement with Environmental Systems Research Institute (ESRI) East Africa progressed, we had the opportunity to interact with representatives from ESRI HQ. As a result of this engagement, LBL was included in the GIS for Protected Area Management programme which is continuing. This online resource is meant to provide an easy way to visualize geo-referenced data and allow multiple levels of analysis taking advantage of several datasets provided by ESRI and National Geographic. As part of this process, the department was able to secure a 10-year grant via ESRI for 5 ARCGIS pro licenses and 20 ARCGIS Online user licenses. These licenses will allow increased spatial analysis capacity within LBL and ultimately improve the quality of reporting and recommendation from each thematic area.

Finally, there was much excitement on the landscape after a joint Lewa - National Museums of Kenya (NMK) preliminary survey for pancake tortoise confirmed their continued existence within the landscape, corroborating historical anecdotal and photo evidence. This survey was funded by Lewa Canada, who are currently spearheading efforts to design and carry out a comprehensive survey in Q3 2020 involving multiple local and international stakeholders. The preliminary survey report is available upon request.

Several student studies were carried out or initiated in 2019, and details of these studies are included in the appendix.

Implications for management

- Annual removal strategy to other rhino range areas in Kenya, as recommended in the LBL Black Rhino Theory of Change 2019.
- Rangers training need to be stepped up on rhino identification, especially for new or transferred recruits. This should be supplemented by notching of as many 'clean' animals as feasible in 2020.
- GPS collars need to be deployed on representative lion and hyena individuals, with the opportunity available to standardize frequencies across the landscape and trial drop-collars for easier retrieval.
- Efforts to increase community awareness on appropriate construction of predator-proof livestock enclosures need to be stepped up in collaboration with Lion Landscapes and Ewaso Lions.
- LBL needs to increase investment into Wildbook development as well as exploring possibilities of creating or improving supplementary local stripe ID databases to end current inertia on Grevy's zebra identification and demography.
- A Human-Wildlife Conflict rapid response unit needs to be constituted and equipped to proactively attend to cases of conflict across the LBL. This will reduce intermittent pressure on LBL Security and Conservation teams and provide a standard framework around which response protocols, data collection and reporting can be structured.
- In lieu of constructing new exclusion zones for woody vegetation protection, at significant cost, the LBL strategy should focus on extending existing 'partial exclusion zone' boundaries outward and upgrading derelict fences. Expansion effected in 2019 in the area of the Lewa airstrip, showed materially significant woody vegetation regeneration in a very short space of time, confirming that limiting elephant and giraffe access can have immediate, positive effects on woody vegetation recovery.

- Effort should be put into expanding use of the PlantNet plant ID App to improve plant identification on the Landscape
- LBL should explore opportunities for telemetry studies on select birds on the landscape, primarily the Grey crowned crane and the Steppe eagle.
- Capacity building in Geographic Information Systems and Technology (GIS & T) across the Research team needs to be stepped up in order to take full advantage of our expanding collaboration with ESRI and ESRI East Africa.

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1.0 INTRODUCTION

The Lewa-Borana Landscape (LBL) Research and Monitoring team had a busy but fruitful 2019. As part of our continuing capacity development, a Research Assistant was recruited early in the year. Her focus has been developing Standard Operating Procedures (SOPs) for the new Avifauna thematic area, while at the same time providing support to the Ungulate thematic area and assisting with camera trap data analysis. We also replaced our long serving Rhino Monitoring Officer, and his replacement has picked up seamlessly, allowing data collection and collation to proceed without any issues.

The year was relatively mixed in terms of rainfall, with the first six months receiving below average rainfall, essentially a failure of the March-April-May rains. Rainfall was delayed for the second half of the year on the Lewa section of the landscape, although there were rains on the Borana side. The October-November-December (OND) rains seemed as though they would also fail, before extremely heavy rains were received in November and December. In total, the LBL received an average of 729±72 mm of rainfall, making 2019 the second wettest year since the El Nino season of 1997-1998.

Proposals requesting funding to support LBL's Hydrology programme were shortlisted for consideration by both Prince Albert II of Monaco Foundation and the Bently Foundation in 2019. As of early 2020, we have secured $100,000 from the Bently Foundation to kickstart the critical first phases of our programme. We are hopeful to receive the full funding to carry out this critical work, monitoring both surface and ground water resources as well as related environmental variables.

In the year, we conducted a dry season replicate survey of the feeding behaviour of Black rhino on the Landscape. The final write-up for this survey is still undergoing. Short-term collaborations with university groups continued in the year, with a Columbia University Master of Science Student helping in the project design and collection of data on interactions between three main bulk grazers (buffalo, Plains zebra and White rhino) and their niche separation on the landscape. Results are still under review. Below we look at details for each thematic area.

2.0 RHINO MONITORING

2.1 Introduction

Rhino remain an iconic and threatened species globally and forms one of the cornerstones of the Conservation programme on LBL. In 2019, the population continued to increase and recorded the highest number of births in a single year since the establishment of the Conservancy in 1984 (32 calves; 17 Black and 15 White rhino). This may have resulted from the above average rainfall received in 2018 as well as a settling effect following the large removals done in 2013 and 2015. The population also seems to have synced peak calving every three years coinciding with an average inter-calving interval (ICI) of 2.5-3-years.

There were 10 rhino deaths in 2019 (5 Black and 5 White). With this high number of deaths, the management should continuously focus more on the biological management of this population including managing rhino densities and providing optimum habitat conditions to maintain net growth rates of at least 6% p.a. (KWS 2017). Below are some of the observed major rhino monitoring metrics for 2019.

2.2 Black rhino population performance

With 17 births and 5 deaths (Appendix 1 and 2) recorded, the population of Black rhino increased from 97 to 109 individuals. This represents a biological growth rate of 9.5% in the 2017-2019 average 3-year moving window period compared to 6.2% in the 2016-2018 period (Figure 2.1). On the Lewa side of LBL, the overall biological growth rate was 10% compared to 8% on the Borana side in the 3-year moving window period. These averages are above 6% p.a. rate recommended in the well-established rhino sanctuaries in the Country (KWS 2017).

Four rhinos gave birth to their first calves. These were *Bahati 2* (9.5 years), *Karimi* (7.5 years), *Zainab* (8.2 years) and *Delia* (7.7 years). Overall, 92% of the breeding females calved between 2018 and 2019. Two females are projected to give birth to their first calves in Q1 2020. These are *Kagwiria* (8 years) and *Jackline* (6.9 years).

With an average ICI of 2.5-3 years, such high number of calves born in 2019 will affect birth rates in the 2020-2022 period thus reducing overall annual growth rates for the forthcoming time windows.

The adult male to female sex ratio was 1:1.2. The age structure consists of 51% adults, 17% sub-adults and 32% calves. The sex composition for the calves was 18 females, 15 males and 1 calf of unknown sex (Table 2.1).

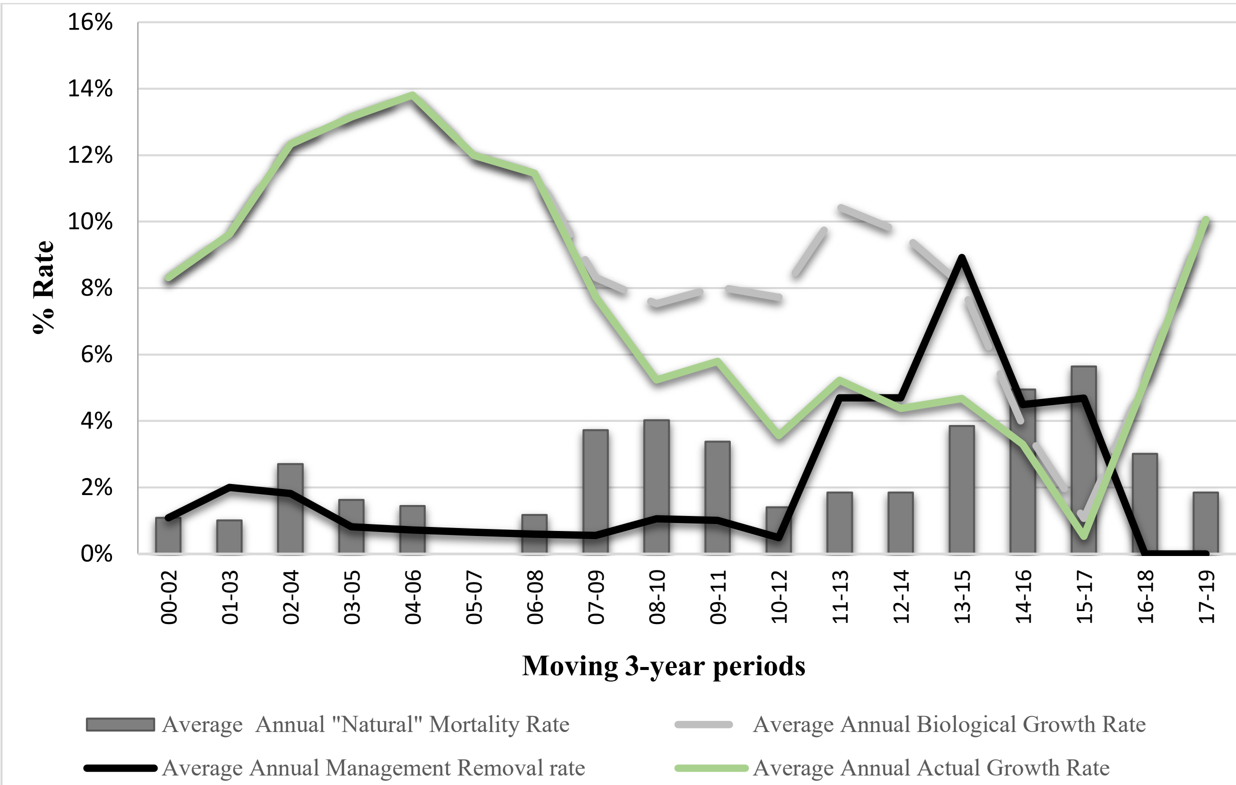


Figure 2.1 Key Black rhino population metrics on the LBL, 2000-2019

Table 2.1 Population structure of Black rhino on LBL, 2019

Age class	Male	Female	Unknown sex	Sub-total	Proportion in population
Calves (<3.5 yrs)	16	18	2	36	33%
Sub-adults (3.5<6yrs) unless calved	8	10	0	18	17%
Adults (>6yrs)	25	30	0	55	50%
Grand total	49	58	2	109	100%
Proportion in population	45%	53%	2%	100%	

2.2.1 Black rhino growth rate and density

Rhino population growth is dependent on density. As a result, increasing population densities can result in a situation where birth rates decline while mortality rates increase (Okita-Ouma et al. 2009). A rhino population left to increase without any density management will reach ecological carrying capacity (ECC) where there is no longer any growth (Balfour et al. 2019). Higher densities may lead to competition for food and longer ICIs. At lower densities, there is sufficient fodder available and cows are able to rapidly regain condition after calving and this enables them to carry their next calf sooner than they would otherwise under dietary stress (Balfour et al. 2019). Longer ICIs reduce the number of calves born each year and therefore result in a reduction in the population growth rate (Nhleko et al. 2017).

The initially estimated ECC of Black rhino on Lewa based on habitat assessment was 70 animals corresponding to a density of 0.28 km^2 (range 0.245 to 0.321 km^2; KWS 2007). However, a closer look at the long-term rhino population performance indicates that this was an underestimate, and that Lewa will likely hit ECC at approximately 97 rhinos. In order to retain a high growth rate in the population, the density will need to be reduced and the rhino would achieve at least 5% growth if stocked at less than 69 rhinos (Figure 2.2; Rhino Impact Investment Theory of Change - RII TOC). Conversely, the Borana rhino population is at the start of its growth rate trajectory, and so it is anticipated that annual growth rates will increase over the coming years. The estimated ECC for Borana based on habitat assessments is 53 rhinos, and the population currently is at 29 rhinos (RII TOC).

On the Lewa population, maintaining productivity >5% p.a. can be achieved through a gradual removal of a total of 29 rhinos over the next five years (RII TOC), ideally to supplement Tsavo West NP populations, and establish a founder population on Il Ngwesi Conservancy. The first removal was set to start in 2020. However, funding from the Rhino Impact Investment Bond was delayed to 2021 meaning that destocking of the Lewa rhinos will be delayed until then.

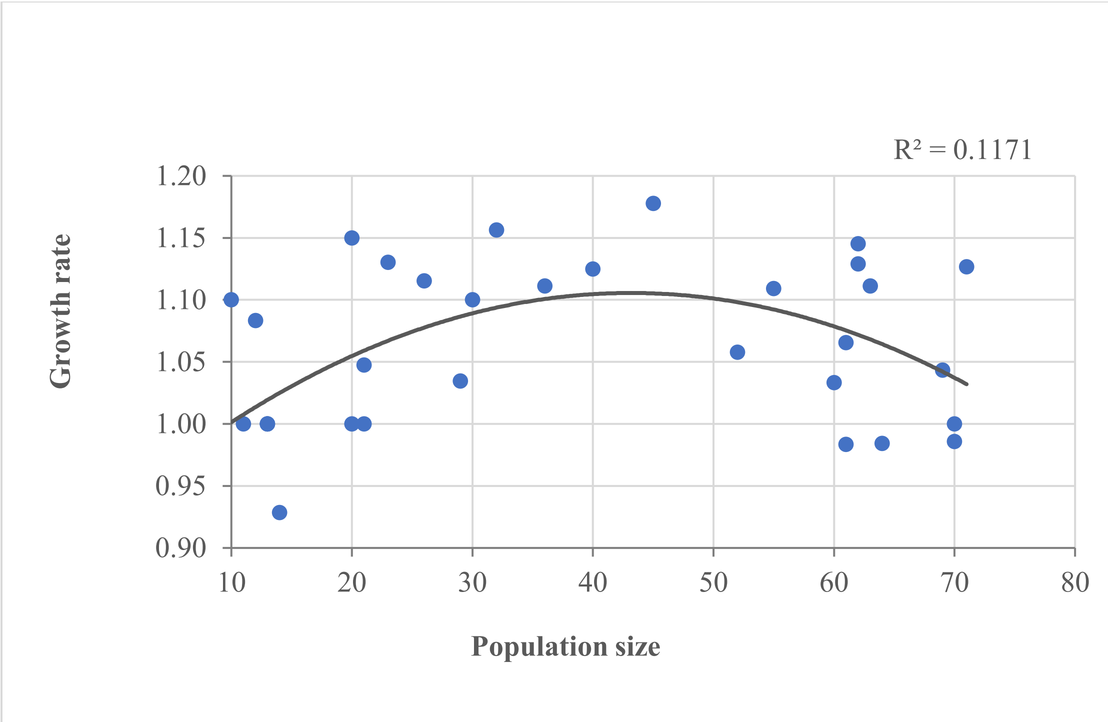


Figure 2.2: Long-term trend of growth rates against population size of the Lewa population of Black rhino

2.3 White rhino population performance

With 15 births and 5 deaths, the population of White rhino increased by 11.5% to 97 individuals (Appendix 3, 4 and Figure 2.3). *Swan* and *Jakwai Calf 9* died from poaching while the rest were natural deaths representing an overall mortality rate of 5.2%. Five females calved for the first time *Rhoda* (8.7 years) *Arot* (6.3 years) *Nduta* (5.7 years) *Semenya* (6.4 years) and *Nashepai* (6.3 years) thus increasing the number of breeding females to 25 individuals (Table 2.2). It is expected that in the next two years, the annual growth rate will reduce since 88% of the breeding females calved in 2018 and 2019.

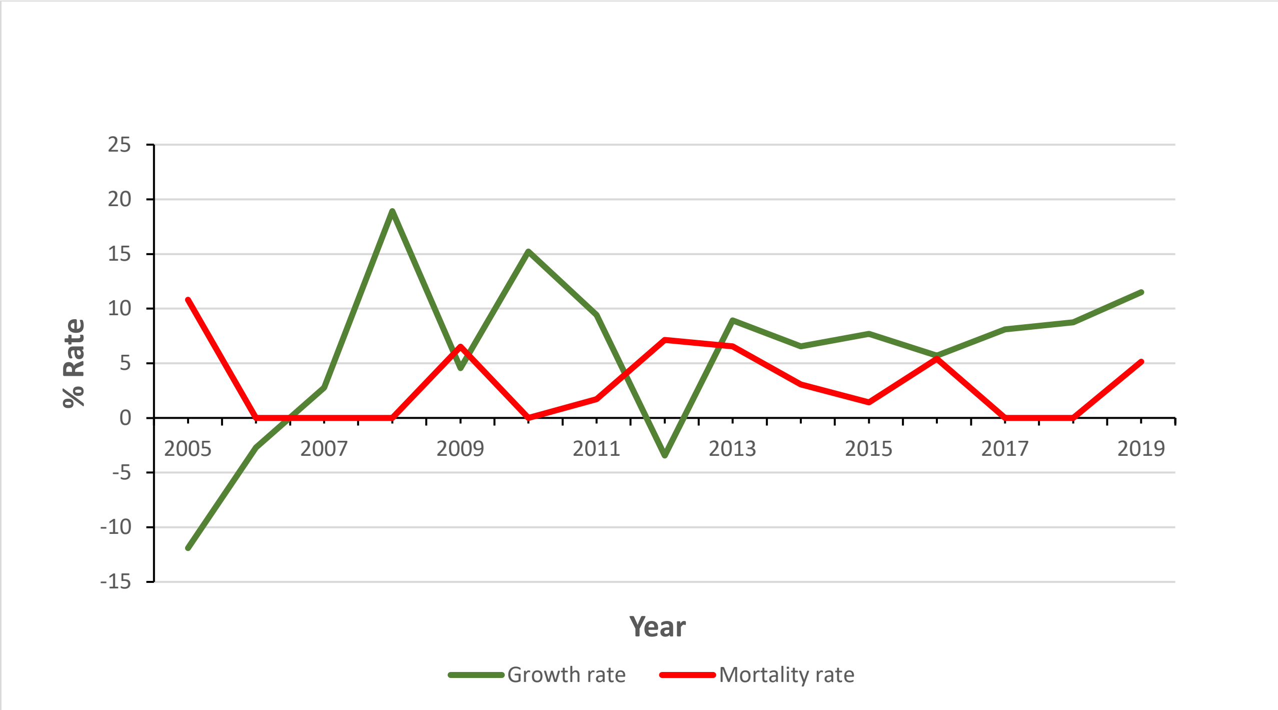


Figure 2.3 White rhino population trend on LBL, 2005-2019

Table 2.2 White rhino age-sex structure

Age Class	**Male**	**Female**	**Unknown**	**Sub-total**	**Proportion in population**
Calves (<3.5yrs)	11	15	2	28	29%
Sub-adults (3.5-6 years) unless calved	8	6	0	14	14%
Adults (>6 yrs)	31	24	0	55	57%
Grand total	50	45	2	97	100%
Proportion in population	52%	46%	2%	100%	

2.4 Spatial ecology

2.4.1 Sighting frequency

The average sighting frequency (SF) for Black and White rhino was 1.9±0.2 days and 1.4±0.1 days respectively. This is within the critical sighting frequency of 3 days in the LBL.

2.4.2 Notable shifts in home ranges.

Peter Holmes (8 years), a male black rhino, spent most of his time on the Borana side after moving from the Lewa side at the beginning of the year. This change in home range might have been triggered by increased pressure from other young adult males including *Sogomo*, *Zoltan* and *Munya* whose ranging areas neighbour that of *Peter Holmes*. *Barmet*, another, 10.5-year-old has been moving from the Lewa to Borana side of LBL on several occasions during the year. *Mutane* (40 years), a male black rhino also ventured deep into the Ngare Ndare Forest area adjoining Kisima village. This was after he spent time on the edges of the Forest when he shifted his home range in 2018. Six White rhinos (*Godon*, *Tulifu*, *Maina*, *Semenya*, *Namunyak* and *Sidai*) have continued to occupy their new territory on the Borana side after shifting in July 2019.

2.5 Rhino veterinary interventions

Opondo (33 years), a female White rhino was treated and later euthanized in January 2019 after she fractured her front leg. *Marti* (13.6 years), a male White rhino was treated on 21st November 2019 following injuries on the right eye sustaining after fighting with an unidentified male.

Sam (3.3 years), a male Black rhino was treated in December after a fight with an unidentified rhino. He died from internal bleeding in the same month.

2.6 Rhino body condition assessment

The annual dry season body condition assessment targeting the relatively old and lactating Black rhino was completed between the months of August and October. Most of the rhinos were observed to have a body condition score ≥3.5 following the higher than average rainfall received in 2018 resulted in availability of abundant browse.

2.7 Rhino Impact Investment project

LBL was one of the seven sites selected in 2018 to pilot the Rhino Impact Investment project a new and innovative model for rhino conservation funding. As part of the Investment Readiness phase, a budget for the Investment Phase was developed based on the RII TOC strategy, and equipment and operational material were purchased and issued to field-based Sector Heads to help in photographing rhino to update individual Master ID files. By the end of 2019, 92% of Black rhino had updated ID photographs.

However, ear notching of seven rhinos was postponed to 2020 following the heavy rainfall received in late 2019.

2.7 Conclusion and recommendations

Many of the rhino monitoring activities and objectives planned in 2019 were completed. The main activities that were not completed include the ear notching exercise of Black rhino that was scheduled to take place in October and postponed twice due to the heavy rains that were experienced. In addition, training on Rhino OMS and purchase of PDA devices as part of the RII Investment Readiness phase were delayed until 2020.

Analysis of long-term Black rhino data with guidance of two members of the AfRSG has continued to produce highly useful outputs. In 2020, we intend to replicate such analysis to the White rhino datasets.

The year recorded the highest number of births since 1984 when the population was introduced. However, 10 deaths were recorded from various causes. Management plans should aim at reducing "natural" deaths so as to continue registering high growth rates. Since the removal of the fence between Lewa and Borana in 2014-2015, the rhino sub-populations in the two areas have not been able to integrate at high rates as expected. Therefore, one of the plans to consider would be translocation of more rhinos onto the Borana side using short term holding to further augment the existing population using Lewa's stock. There should also be an annual removal strategy to other rhino range areas in Kenya, as recommended in the LBL Black Rhino Theory of Change 2019.

The number of 'clean' (rhino without unique distinguishing marks) continue to increase, and it is becoming a challenge for field rangers trying to identify the individual animals. Currently most White rhino calves that have become independent have not been ear notched or have no unique natural ID features. There is need to conduct an ear notching programme on a regular basis to address this challenge and reduce the number of 'clean' animals.

To ensure accurate rhino data is collected, annual ranger training course should be implemented especially for the new recruits. This will enable rangers to correctly identify rhinos, improve on the reporting procedures and have good tracking techniques.

3.0 PREDATOR MONITORING

3.1 Introduction

Today, management of predators plays an important role in conservation due to the intensive management requirements of closed and semi closed protected areas. Apex predators such as African lion (*Panthera leo*) and Spotted hyena (*Crocuta crocuta*), have the ability to influence the composition and density of meso-predators and herbivores (Retief 2016). Knowledge of the status, behaviour, an interactions of apex predators can assist in effective management decisions which will ensure ecosystem functionality.

In 2019, we monitored lion movements and dispersal events, scat collection for both DNA and diet determination, human-carnivore conflicts, collaring, and translocation. Scat collection for diet determination for hyena was also undertaken.

In the year, we hosted Professor Kay Holekamp, a hyena specialist and founder of Maasai Mara Hyena Project to explore potential for collaboration so as to gain more understanding of Spotted hyena ecology. We also co-authored one peer-reviewed scientific paper titled "Borrowing from Peter to pay Paul: managing threatened predators of endangered and declining prey species" which looked at the impact of lions and hyenas on the endangered Grevy's zebra (download the paper here).

3.2 Population performance

3.2.1 Lion population

During the year, we monitored a population of 55 lions (Table 3.1). With 18 cubs born in late 2018 and early 2019, the species is thriving in this landscape. At the beginning of the year, we recorded four male lions (*Ntulele's* coalition) aged 3.5-years, utilizing the eastern side of the LBL after dispersing from their natal pride (*Laragai's* pride) on the western side of the landscape. This dispersal was triggered by the exit of three territorial males namely: *Defender*, *Dick* and *Esau* from the eastern to the western part of the LBL.

A few months later, a new unknown male lion (~3.5-year old), named *Loner*, was sighted on the southeastern part of the landscape. It is suspected that he dispersed to LBL from Laikipia ranches to our west. He has been confined to the periphery of the landscape by *Ntulele's* coalition. He has also been moving into Marania farm that neighbours Mt Kenya Forest and has killed 30 confirmed cattle in the farm from May to December 2019.

Upon the arrival of *Ntulele's* coalition, one sub adult male known as *Omar* from *Dalma's* pride was evicted from his natal pride by the four males and now roams on his own. Sex-biased dispersal is a widespread phenomenon in mammals (Greenwood 1980). Several explanations have been proposed for male-biased dispersals. First, females may gain from philopatry and suffer greater cost from dispersal than males. Second, because intersexual competition for mates is more intense among males than females, males may disperse further than females. Third, males are likely to benefit more than females by gaining access to more mates. In addition, a consequence of sex-biased dispersal is that mating between close relatives is avoided and dispersal has been invoked as an inbreeding prevention mechanism (Cockburn et al. 1985). The Research team continues to monitor all sub-adult males within the population as this could be associated with increased occurrences of human-carnivore conflicts, especially when young males are evicted from their natal prides.

In the first lion contraceptive exercise that commenced in March 2017, a limited number of three lionesses were tested using *Suprelorin* implants as a population control measure. The data showed that the implants were safe and effective since other lionesses within the same age-class produced cubs. The effective length of contraception is estimated at 2.5 years which has already elapsed, and we expect the lionesses to resume their normal breeding cycles. In 2019 we placed a request to Kenya Wildlife Service (KWS) to repeat the implants in two individuals and recruit four new candidates. This request was granted and is expected to commence in 2020, whilst there have been challenges in obtaining the specific contraceptive implants.

Table 3.1: Lion population structure on LBL

	Adults		Sub-adults		Cubs			Total by pride/coalition
	Male	Female	Male	Female	Male	Female	Unknown sex	
Sarah's pride	1	5	2	1	0	0	0	9
Dalma's pride	1	2	0	0	0	0	0	3
Suzie	1	1	0	0	0	0	0	2
Laragai's pride	0	2	0	0	0	0	0	2
Bredymark's pride	0	3	1	0	0	0	3	7
Carissa's pride	0	4	0	0	0	0	0	4
Njaa's pride	0	6	0	0	0	0	15	21
Ntulele's coalition	4	0	0	0	0	0	0	4
Harry's coalition	3	0	0	0	0	0	0	3
Total by age/sex	**10**	**23**	**3**	**1**	**0**	**0**	**18**	**55**

3.2.2 Hyena population

The Spotted hyena population stood at approximately 138 individuals comprising of 84 adults, 50 sub adults, and 4 cubs (Table 3.2). Since the Spotted hyena is majorly nocturnal, collars remain the key tool for monitoring their activities as well as spatial-temporal movements.

Table 3.2: Population structure of the spotted hyena on LBL

	Adults			Sub-adults			Cubs			
Clan name	**M**	**F**	**Unsexed**	**M**	**F**	**Unsexed**	**M**	**F**	**Unsexed**	**Total**
Borana	1	0	2	0	0	0	0	0	0	**3**
Charlie	2	3	16	2	0	16	0	0	0	**39**
Nala	3	3	28	0	0	18	0	0	4	**56**
Shamba	0	2	8	0	0	4	0	0	0	**14**
Utalii	2	5	9	0	0	10	0	0	0	**26**
Total by age/sex	**8**	**13**	**63**	**2**	**0**	**48**	**0**	**0**	**4**	**138**

3.3 Spatial ecology

3.3.1 Lion

The home range size of a lion is largely determined by prey, seasonal changes, and vegetation cover. On LBL, during the dry seasons, the vegetation cover is low, and prey tends to congregate around water points, such as the swamps and along the rivers. These areas have dense vegetation, presenting cover for predators leading to opportunities for predation. The wet season offers wider distribution of food and water for the prey species, making lions move longer distances in search of prey. During the year, the entire of LBL was utilized by the different prides and coalitions of lions as shown in Figure 3.1-3.6.

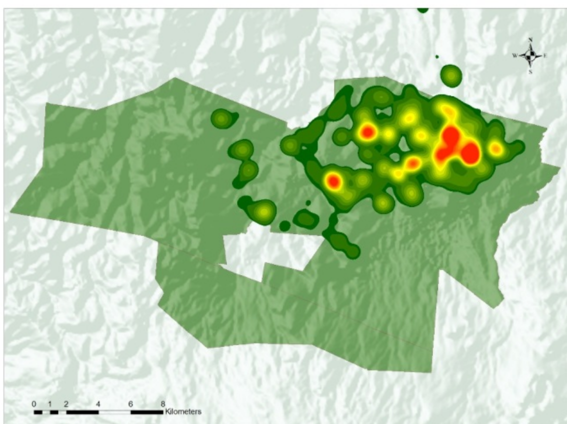


Figure 3.1: *Sarah's* pride ranging areas, 2019

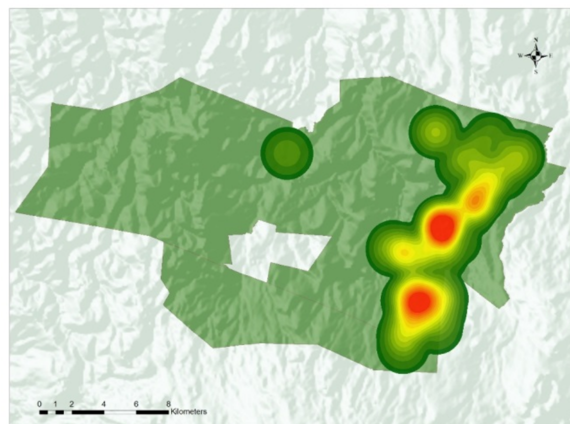


Figure 3.2: *Dalma's* pride ranging areas, 2019

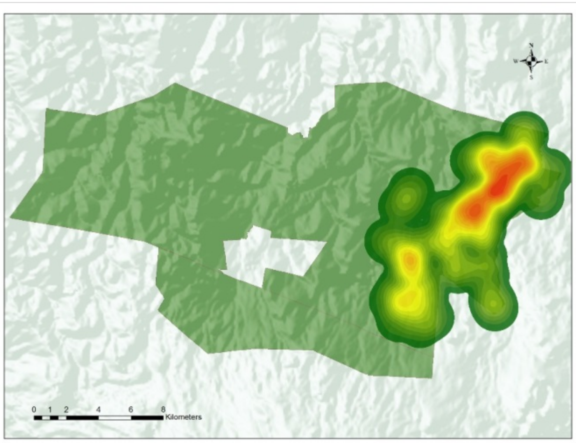


Figure 3.3: *Suzie's* pride ranging areas, 2019

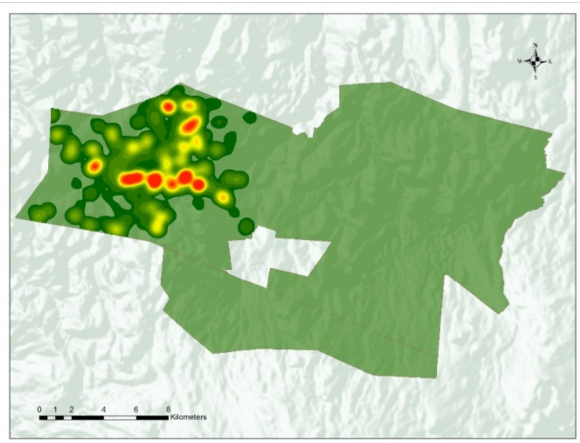
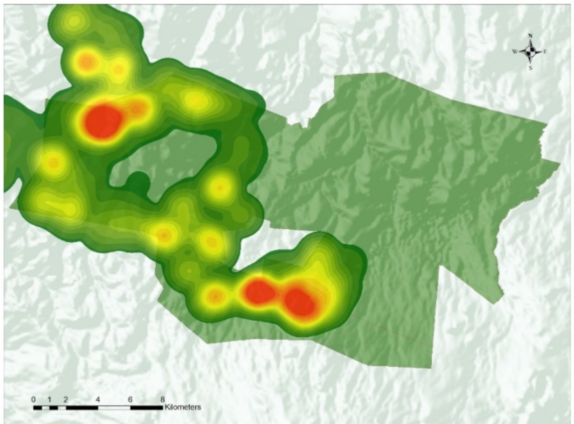


Figure 3.4: *Bredymark's* pride ranging areas, 2019



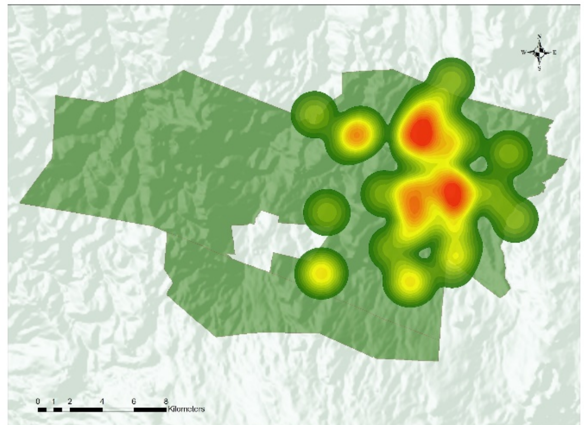


Figure 3.5: *Carissa's* pride ranging areas, 2019 **Figure 3.6:** *Ntulele's* pride ranging areas, 2019

3.4 Human-carnivore conflicts

Across the globe, conservation is increasingly in conflict with other human activities (Wittmer et al. 2006). Although such conflicts can positively influence changes, they are often destructive, costly and not only undermine effective conservation, but also prevent economic development and resource sustainability (Young et al. 2010).

In 2019, a total of 43 incidences of livestock depredation were reported leading to the loss of 74[1] livestock across LBL and the adjoining community areas. Lions were responsible for most of the cases followed by Spotted hyena, leopard, and cheetah (Table 3.3). Such negative interaction between predators and people may antagonize relations and thus require a long-term solution.

Table 3.3: Causes of livestock depredation on LBL

Species	Cattle	Shoats	Total by predator
Lion	9	15	24
Hyena	1	32	33
Leopard	0	16	16
Cheetah	0	1	1
Total by livestock type	10	64	74

[1] This figure excludes the 30 cattle reported to have been killed in Marania farm by a single dispersing lion known as *Loner*.

3.5 Wildlife mortality

Predation constitutes an important feature of the biotic environments of wild ungulates and the effect of these on small reserves can lead to financial implications when direct interventions are needed (Hirst 1969). The availability of mortality data is an important factor in determining the sustainability of predation so as to understand the status of species and predict trends on their population performance.

On LBL, a total of 124 known wildlife mortality cases were recorded during the year as a result of predation by lion, cheetah, leopard, fence entanglement, and unknown causes. Of these cases, 91% were predation by lion while the other causes contributed the remainder.

Six prey species contributed significantly to lion diet. These were buffalo, eland, giraffe, Grevy's zebra, Plains zebra, and Warthog (Figure 3.7).

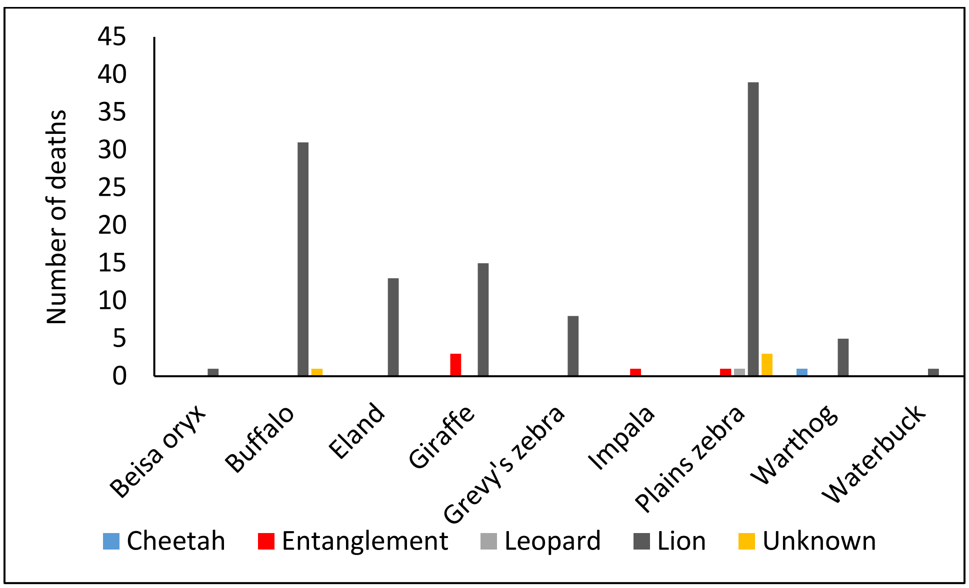


Figure 3.7: Causes of wildlife mortality on LBL, 2019

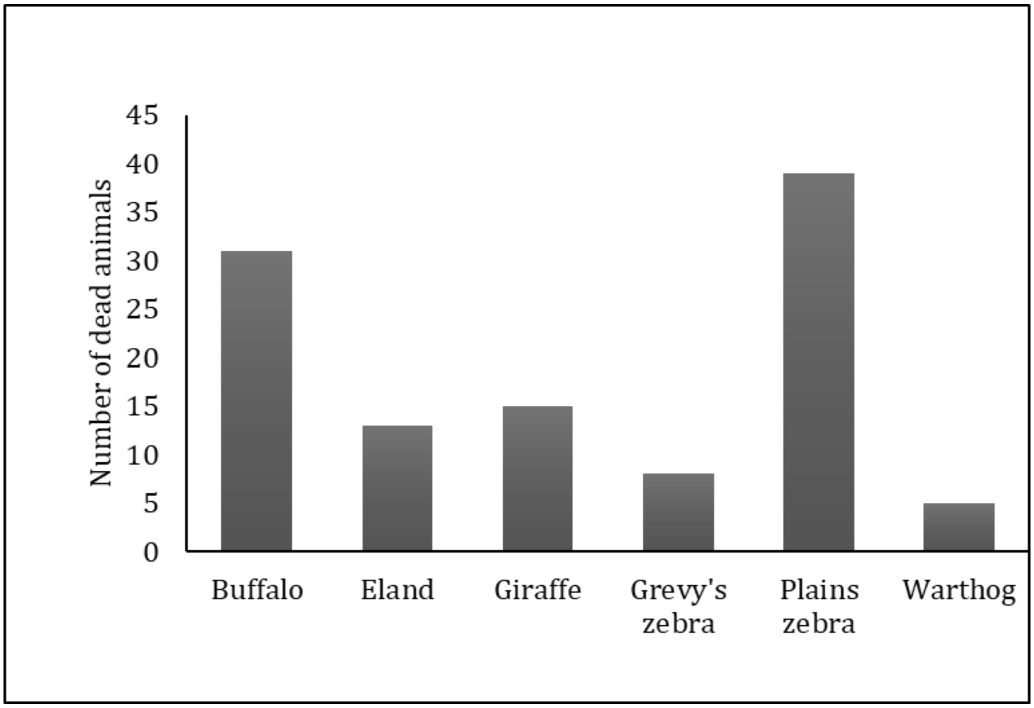


Figure 3.7: Number of wildlife mortality cases per species on LBL

To determine the selectivity of prey species by lion, Jacobs' Selectivity Index (D) was used (Jacobs 1974). The resulting values range from +1 to -1 where +1 indicates maximum preference and -1 indicates maximum avoidance. The analysis showed that apart from giraffe, no other prey species was disproportionally selected implying that feeding by lion may have been influenced by availability and not preference (Table 3.4).

Table 3 4: Jacob's Selectivity Index (D) values calculated for nine prey species on LBL, 2019

Species	**Total population**	**Kills**	**Jacob's Index (D)**
Plains zebra	1,484	39	0.3
Grevy's zebra	313	8	0.2
Waterbuck	180	1	-0.5
Beisa oryx	227	1	- 0.6
Eland	291	13	0.5
Warthog	161	5	0.3
Giraffe	167	15	0.7
Buffalo	1,753	31	0.0

3.6 Scat analysis

Animal diet is influenced by habitat usage, behaviour, morphology and physiology (Hawlena & Perez-Mellado 2009). Understanding predator diet is important because they are able to influence the diversity and abundance of prey species in an ecosystem through predation as well as influencing avoidance behaviour.

A total of 152 scat samples for lion (n=86) and Spotted hyena (n=66) were collected from the kill and cluster point sites, and opportunistically on random tracks. The overall results show that Plains zebra, buffalo, giraffe, and eland formed the main diet for lion and Spotted hyena. Since Spotted hyena are thought to be primarily scavengers, one hypothesis could be that they scavenge on the remains of the large bodied animals predated upon by lion leading to similarities in the proportion of hairs in the scats of the two predators (Figure 3.8).

Only three livestock hairs were found in both lion and hyena scat samples indicating that even though there were 43 recorded cases of livestock depredation in the year, livestock per se do not form a major component of the two predators' diet.

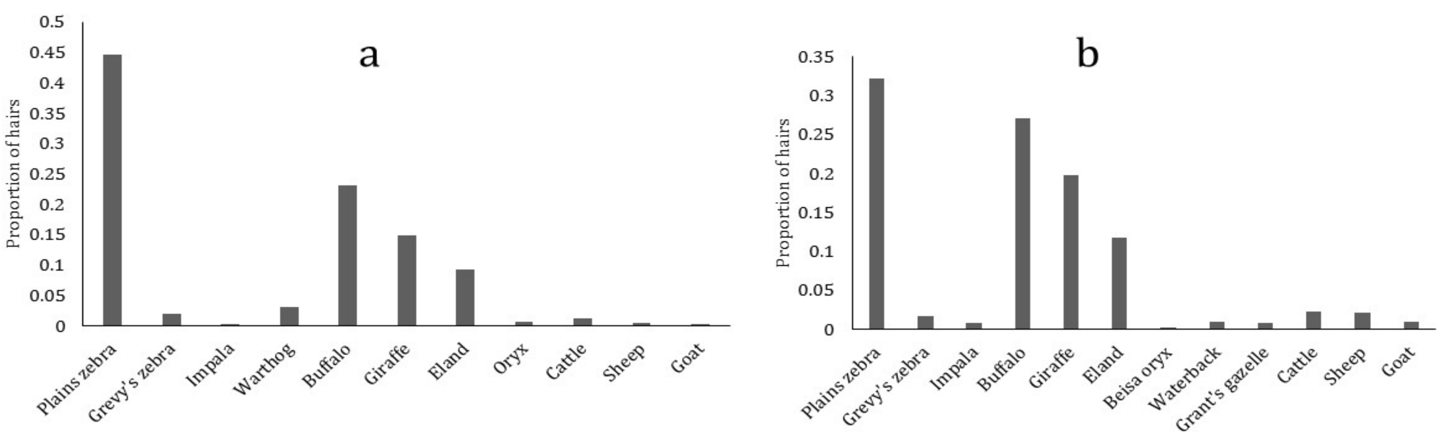


Figure 3.8: Proportion of prey species hairs found in (a) lion and (b) hyena scat

3.7 Conclusion and recommendations

Given the current male lion dynamics on the landscape, we recommend collaring *Omar* and translocating *Loner* so as to understand their spatio-temporal trends, understand their interaction with herbivores and reduce livestock depredation. This should also include replacement of collars of three lionesses namely; *Simone* (8 yrs), *Carissa* (9 yrs), and *Bredymark* (9 yrs), and one male lion known as *Ntulele*.

Four Spotted hyena from the four clans should be re-collared so as to understand their spatio-temporal movements and habitat utilization.

Spotted hyena are the dominant large predator on LBL, and therefore their impact on prey populations would be expected to be greater than any other large predators present. We will therefore continue working with identified experts to understand their feeding behaviour within the landscape.

To further mitigate human-carnivore conflicts, we will engage local communities to enlighten them on livestock husbandry and farming techniques that have been tested and proven to be effective in other areas where livestock keeping and farming takes place in the presence of predators. In addition, for effective mitigation of human–wildlife conflicts, a response team needs to be constituted to ensure all incidences are responded to in a timely basis.

In order to better understand our elusive leopard population, we have initiated a partnership with San Diego Zoo Global and their leopard monitoring project in Northern Kenya. We will be engaging with Dr. Nicholas Pilfold and his team to design and initialize an appropriate leopard monitoring programme for the LBL.

4.0 UNGULATE MONITORING

4.1 Introduction

The population of herbivores in Africa are largely affected by droughts causing mortalities regulating population sizes (Hillman & Hillman 1977). Rainfall has been identified as the most important factor determining food quantity and quality (Mduma et al. 1999) in semi-arid environments. Herbivores concentrate around water points during droughts (Chamaillé-Jammes et al. 2008) increasingly damaging vegetation while simultaneously increasing competition and predation (Landman et al. 2012; Smuts 1978).

The largely savannah LBL supports a varied assemblage of wild ungulates. These species experience changes in population dynamics due to significant seasonal, climatic, and spatial variation in resources within the landscape; a characteristic of semi-arid environments (Illius & O'Connor 2000).

The LBL focuses on identified indicator species namely; Grevy's zebra (*Equus grevyi*), Plains zebra (*Equus quagga*), buffalo (*Syncerus caffer*), Beisa oryx (*Oryx beisa*), hartebeest (*Alcelaphus buselaphus lelwel*), giraffe (*Giraffa camelopardalis*), and eland (*Taurotragus oryx*) to monitor population dynamics such as age-sex structure and body condition. The response of wildlife to these parameters serves as an indicator about the habitat health as well as resilience of other species in the landscape. We also monitor movement of wildlife through the migratory gaps linking Lewa and the contiguous conservancies by use of motion sensor camera traps.

We analysed and compared results for the past four years on population dynamics for the identified ungulates species and seven years for the motion sensor camera trap data.

4.2 Results

For most wild ungulate species, the recommended proportion of young and juvenile animals that would maintain a growing population is generally accepted to be 30%. The LBL's buffalo population attained and surpassed this proportion throughout our study period. Hartebeest attained this threshold in 2017 and 2019 only. Eland, Grevy's zebra, oryx, and Plains zebra shows a move towards this threshold. Giraffe recorded the lowest percent of juveniles and young of the total (Figure 4.1). The growth potential for the ungulates ranged from medium to high (Figure 4.2). This is an indication that these species are thriving well and are able to recover in case of ecological disturbance. The growth potential and percent threshold of young and juveniles are two important parameters in determining stability of population based on demographic modeling simulations (Rubenstein 2010).

The population of hartebeest in LBL is fairly low. The annual wildlife count of 2019 recorded a total of 60 individuals. From 2014, we started recording the number of births and deaths of a subset of the population occurring on the eastern part of the landscape which began with 11 individuals. Up to date, the population has grown to approximately 30 individuals resulting from births and immigration from Borana

Conservancy after the fence was removed in 2014-2015. This represents an increase of 63%. From 2014 to date, we recorded 36 births and 21 deaths while 10 individuals graduated to sub adult and adult age classes, meaning they have moved out of vulnerable age class of 0–12 months. This information indicates an increase of this small population, underscored by the two important parameters discussed above for evaluating population performance.

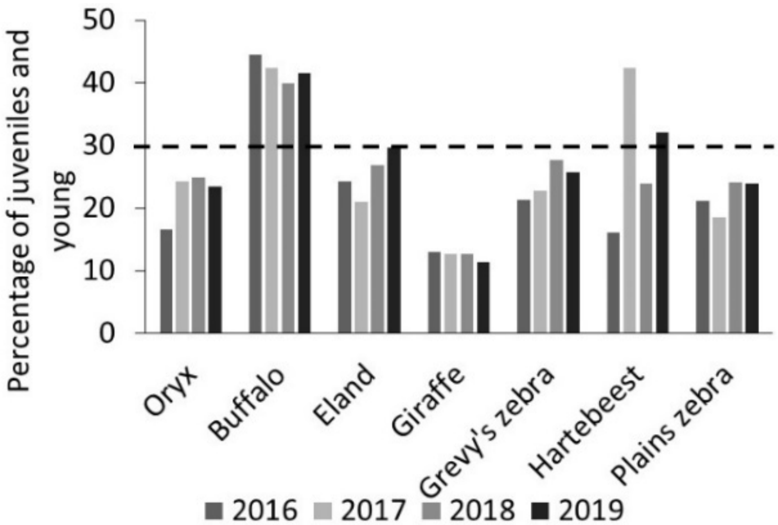


Figure 4.1: Proportion of young and juveniles for specific ungulate species monitored. The dotted black line indicates the 30% mark

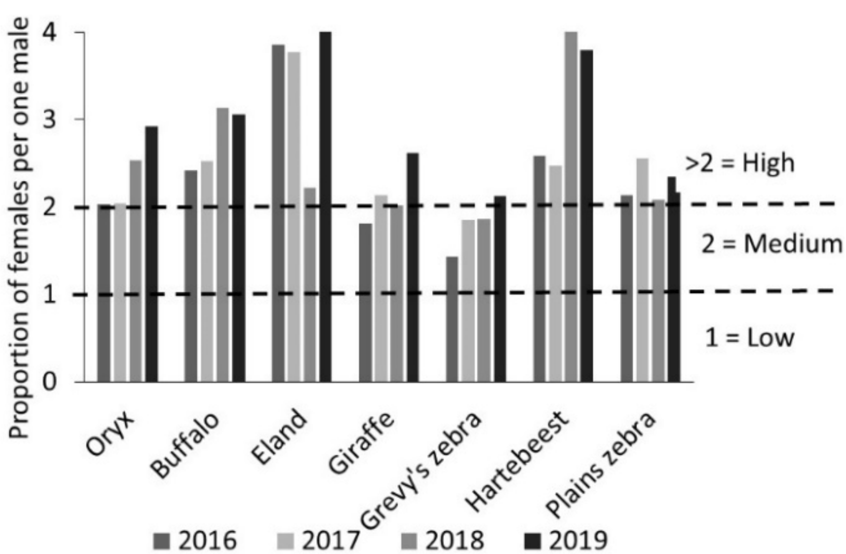


Figure 4.2: Proportion of adult females per 1 adult male for specific ungulates monitored. The black dotted lines indicate levels of various growth potential, i.e., Low, Medium and High

4.3 Assessment of body condition of selected ungulate species

Using criteria developed by Ezenwa et al. 2009, we assessed the body condition of a select subset of ungulates on the landscape. The body condition scores (BCS) recorded a value of 3 and above for the year which indicates resilience of the wild ungulates. Also, adequate rains on the landscape have influenced positive habitat health and wildlife performance.

4.4 Wildlife movement through the migratory corridors

One way of mitigating the negative effects of fragmentation is to improve habitat connectivity (MacDonald 2003). Effective conservation requires connectivity of various habitats for wildlife dispersal to sustain healthy populations (Somers & Hayward 2012).

LBL has been monitoring wildlife crossing events through the designated migratory routes using infra-red camera traps placed at Mount Kenya Endpass gap, Mt Kenya Underpass gap, and the Northern gap. We looked at the differences observed during the dry (January, February, July, August, September) and wet (March, April, May, October, November) periods as well as trends over time from 2013 to date.

Elephants tend to show more movements during the dry than the wet periods. They normally migrate to lower elevations during the wet and to higher elevations during the dry periods (Bohrer et al. 2014). We therefore analysed the crossing events for elephants in all the designated migratory gaps to understand their seasonal movements.

4.4.1 Mount Kenya Endpass gap

There was no significant difference in crossing events on the Mount Kenya Endpass gap between the dry (19,359) and wet (19,562) period ($\chi2 = 1.059$, df = 1, p = 0.304; Figure 4.3a).

There were more crossing events of elephant towards the corridor leading to Mt. Kenya forest (1,701) than into the corridor that leads to Lewa through the Ngare Ndare forest (1,490) during the dry period ($\chi2 = 13.952$, df = 1, $p < 0.001$; Figure 4.3b). During the wet period there were more crossing events of elephant towards the corridor leading to Lewa through Ngare Ndare Forest (1,195) than towards Mt. Kenya forest (1052) ($\chi2 = 9.101$, df = 1, p = 0.003).

The trend indicates a significant increase in crossing events for all wildlife from 2013 to date ($\chi 2 = 14171$, df = 6, $p < 0.0001$; Figure 4.3c).

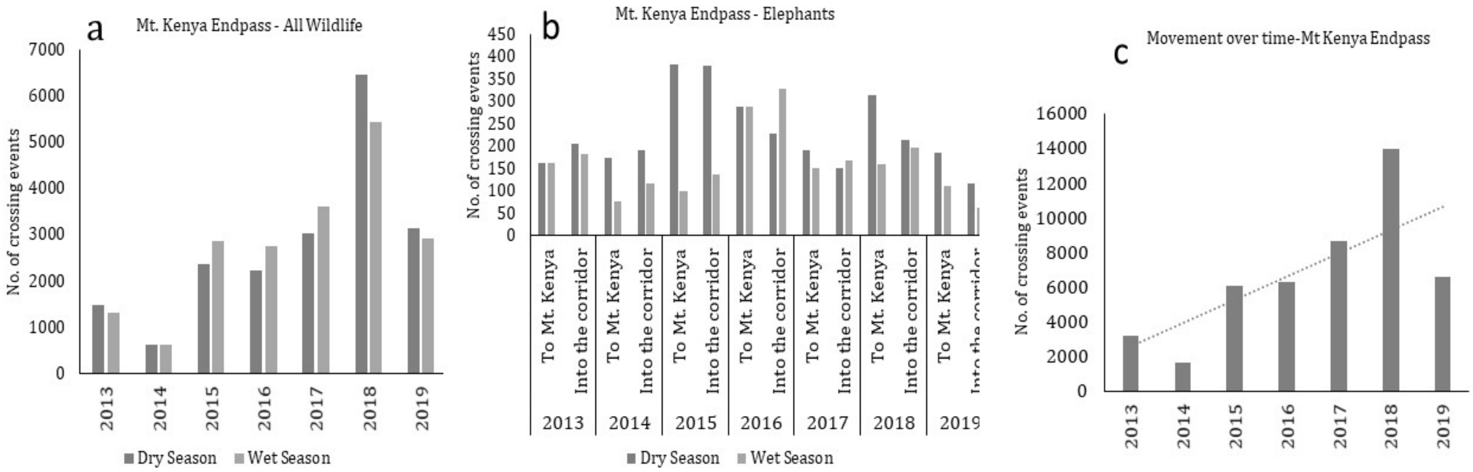


Figure 3.3: a) Seasonal movements of all wildlife species using the gap; b) Seasonal movements of elephants; c) Trends of all wildlife species using the gap

4.4.2 Mount Kenya Underpass gap

There was a significant difference in crossing events on the Mount Kenya Underpass gap between the dry (7,538) and wet (5,174) period ($\chi 2 = 439.62$, df = 1, $p < 0.0001$; Figure 4.4a).

There were more elephant crossing events towards Mt. Kenya forest through the corridor (2,275) than towards Lewa through Ngare Ndare forest (NNF) (2,116) during the dry period ($\chi 2 = 5.7575$, df = 1, $p = 0.016$; Figure 4.2b). During the wet period there were more elephant crossing events towards Lewa through Ngare Ndare forest (NNF) (1,188) than towards Mt. Kenya forest through the corridor (1,031) ($\chi 2 = 5.758$, df = 1, $p = 0.0164$; Figure 4.4b).

The trend indicates a significant increase in crossing events for all wildlife from 2013 to date ($\chi 2 = 2177.6$, df = 6, $p < 0.001$; Figure 4.4c).

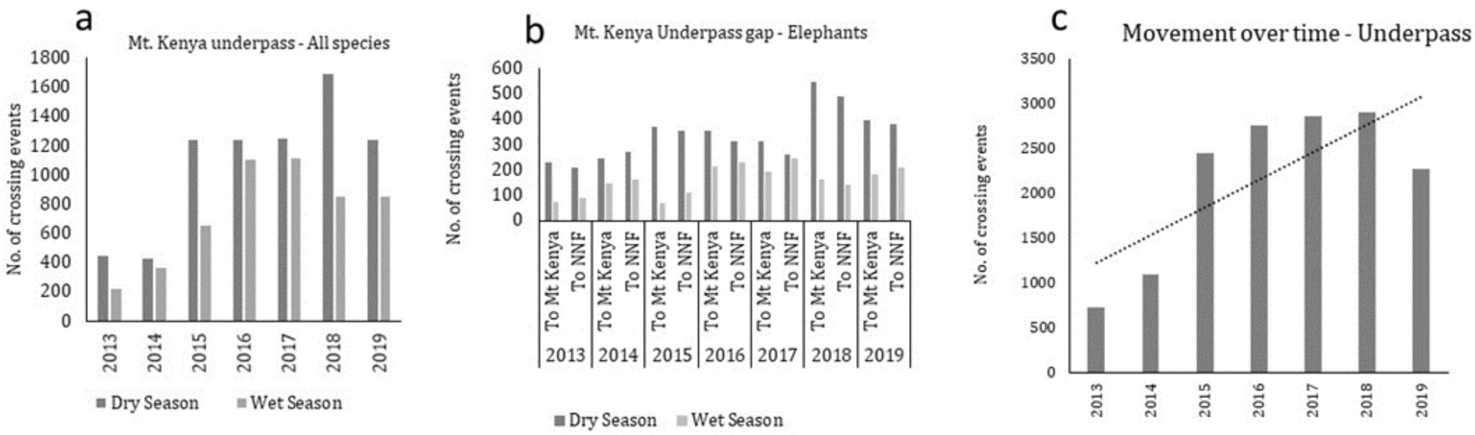


Figure 4.4: a) Seasonal movements of all wildlife species using the gap; **b)** Seasonal movements of elephants; **c)** Trends of all wildlife species using the gap

4.4.3 Northern gap

There was a significant difference in crossing events on the Northern gap between the dry (37,340) period and the wet (48,031) period ($\chi2 = 1338.8$, df = 1, $p < 0.001$; Figure 4.5a). There were more crossing events of elephant during the dry period into Lewa from the north (5,788) than out of Lewa to the north (5,759) ($\chi2 = 0.0728$, df = 1, p = 0.787). During the wet period there were more crossing events out of Lewa towards the north (10,176) than into Lewa from north (8,750) ($\chi2 = 107.44$, df = 1, $p < 0.001$; Figure 4.5b). The trend indicates a significant decrease in crossing events for all wildlife from 2013 to date ($\chi2 = 686.99$, df = 6, $p < 0.001$; Figure 4.5c.

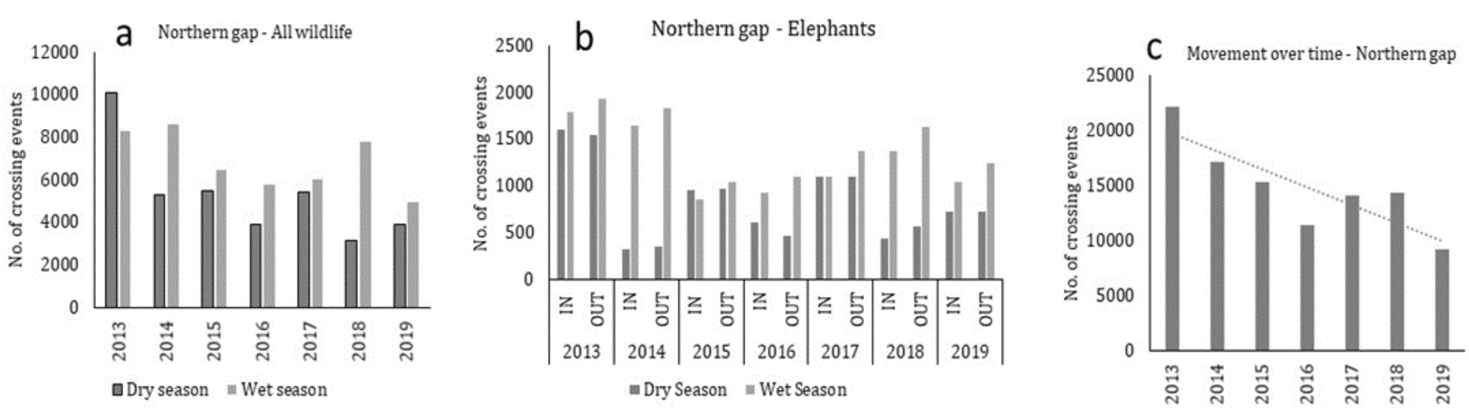


Figure 5.5: a) Seasonal movements of all wildlife species using the gap; **b)** Seasonal movements of elephants; **c)** Trends of all wildlife species using the gap

Apart from the Mount Kenya Endpass gap which shows no significant movements of wildlife during the dry and wet periods, other gaps indicate more frequency in movements during the dry periods. The seasonal movement of elephant indicate migration to lower elevations during the wet periods and to higher elevations during the dry periods.

4.4 Conclusion and recommendations

Individual Grevy's zebra identification software continues to generate important information on the survival rates of foals. There is need to invest in a more automated Grevy's zebra identification software so that information is available in a timely fashion. In this regard, tracking and contributing to the development of the much awaited Wildbook software for stripe identity should continue being a priority. Meanwhile, engagement with the national Grevy's Zebra Technical Committee on alternative Grevy's Zebra Stripe ID database management systems should be scaled up to develop a functional and realistic contingency plan.

5.0 ELEPHANT MONITORING

5.1 Introduction

The associated problems that African elephants have on the habitat are related to the nature of their feeding habits. This is due to their ability to alter the structure and composition of vegetation (Ben-Shahar 1998). This effect can lead to human-elephant conflict, often with catastrophic consequences.

Elephant are also responsible for infrastructure destruction through breaking fences, damaging dam walls, and pulling water piping especially where cultivated land borders protected areas (Thouless & Sakwa 1995).

In the LBL ecosystem, elephants commonly destroy trees by debarking, uprooting, breaking branches, breaking fences and raiding crops in the surrounding community farms. To make informed management decisions, identification and monitoring of elephant in the area continued, with the primary focus being on fence breaking and crop raiders in the neigbouring community areas.

Following the translocation of seven fence-breaking males to Tsavo National Park in 2018, fence breakage incidents reduced significantly. In addition, the introduction of some deterrent methods on a pilot basis in 2019 and timely response by the team to deter the elephants from approaching the fence line may have also contributed to the reduction in breakage incidents. Elephant crawling under the 'partial exclusion zone' fence wires were also significantly reduced as most of the family groups have not returned into the landscape since they migrated out of LBL in December 2018 possibly due to better rainfall distribution in some parts of Laikipia throughout 2019. With more than five incidents each, *One Right Tusker, Moreher, Odongo, Kamongo* and *Champion* were identified as the persistent fence breakers in the various locations (Figure 5.1).

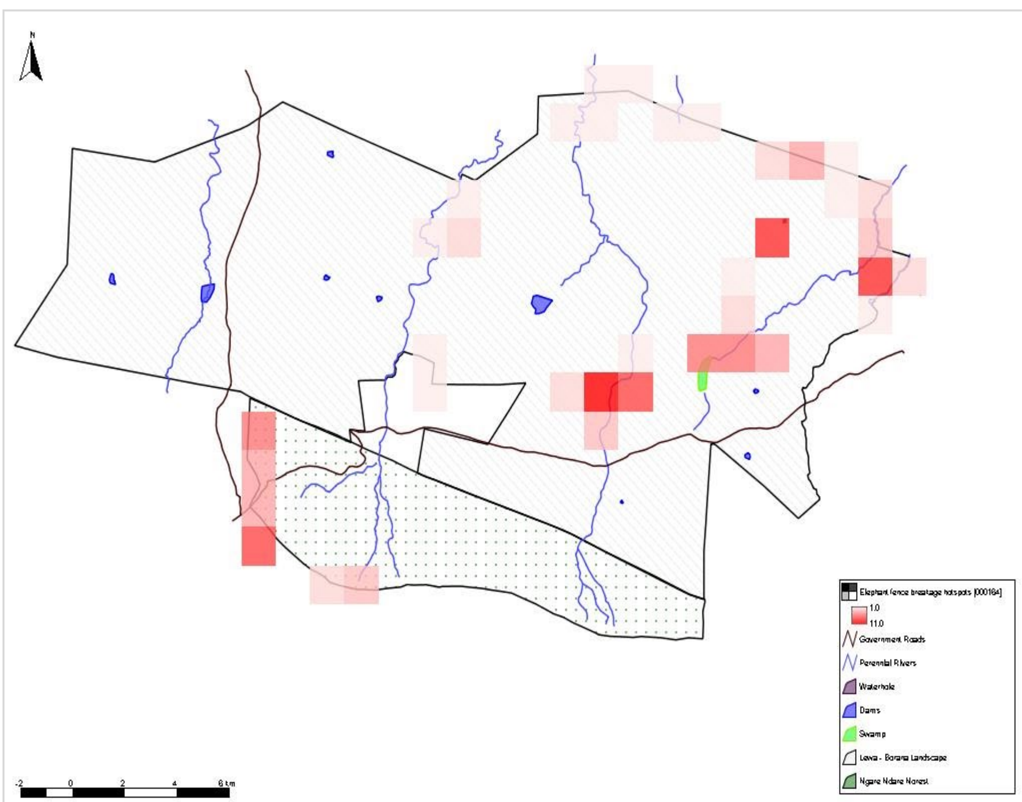


Figure 5.1: Heat map of elephant's breakage incidences on LBL, Jan-Dec 2019

Six bulls namely: *Melo, One-right tusker, Champion, Mjasiri, John*, and *Keke* have had their tusks trimmed in the past. However, they have learnt new tactics of snapping fence wires using their shortened tusks, trunks and also stepping on the posts.

5.2 Trends in fence breakages

In total, 231 fence breaking incidences were recorded. Out of these, 23% (n=53) occurred on the main boundary fence lines, while 77% (n=178) were on the exclusion zones fence lines. The most affected boundary fence lines were; *Simon's Gate, Moloi Gate* and *Mlima Kali* (Figure 5.2). These areas border small scale farmers who grow crops that attract elephants.

In the exclusion zones, 51% (n=91) of incidences involved elephant crawling under the 2-strand fence wires (Figure 5.3), while 49% (n=87) accessed by snapping the wires. Among the exclusion zones, *Kifaru*, *Willy Robert*, *Sirkoi, Sambara* and *Karionga* were the most affected. Despite the fence upgrades undertaken on *Sambara, Willy Robert* and *Sirkoi* exclusion zones, elephant continued to access these exclusion zones through crawling (Figure 5.2). Since most of the breakages into these areas occurred at night and early in the morning, it was difficult to identify the exact culprits. In an attempt to identify these elephant, infra-red camera traps were fixed on the hotspot areas.

Furthermore, the matriarchal family groups continued to access the exclusion zones through crawling. These were: *Sanaipei, Natasha, Mariam,* and *Linnet.* Each family group comprised of over 20 individuals (Figure 5.3). Four adult males namely; *Livondo, Tesh, Kimani* and *Mugaa* have also learned how to crawl under the wires (Figure 5.4). The remaining males and family groups will continue to be monitored in order to provide definitive identity and appropriate management intervention is undertaken.

Gathering the demography of individual males and family groups will be implemented in 2020 to gain insight onto the use of the landscape by different elephants

As a way of mitigating human-elephant conflict incidences using alternative deterrent methods, early in the year, Lewa, the Elephant and Bees project of Save The Elephants (STE), and Ngare Ndare Forest Trust (NNFT) established a pilot project by erecting a 300-meter long beehive fence line. Our pilot project was not successful as colonization of the beehives has been below average probably due to the dry conditions. Further efforts including cleaning and waxing of the hives continued to encourage full colonization. Beehives have been reported to reduce crop-raiding by elephant in the projects being run by Elephant and Bees project (www.savetheelephants.org).

Big Life Foundation offered their pepper/chili gun for two weeks to evaluate its effectiveness in deterring elephant from breaking the fences. It proved difficult to evaluate the effectiveness of the chili gun as the elephant breakages were mainly at night, and by dawn, they would move back to their ranging areas.

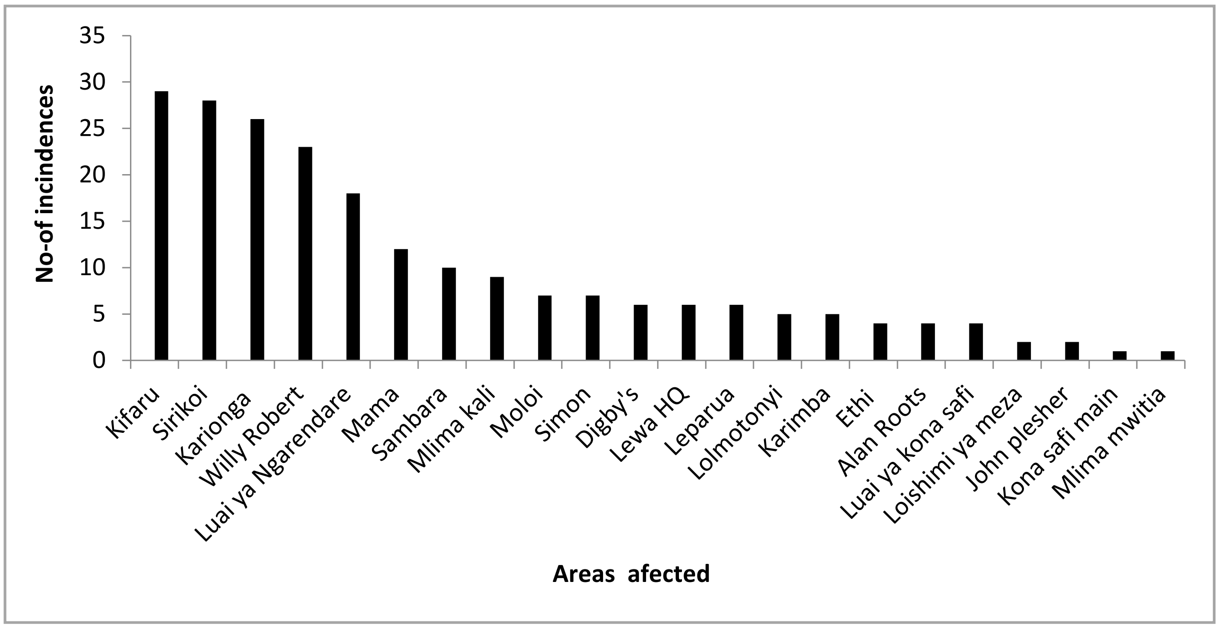


Figure 5.2 Related incidences of fence breakages across various locations

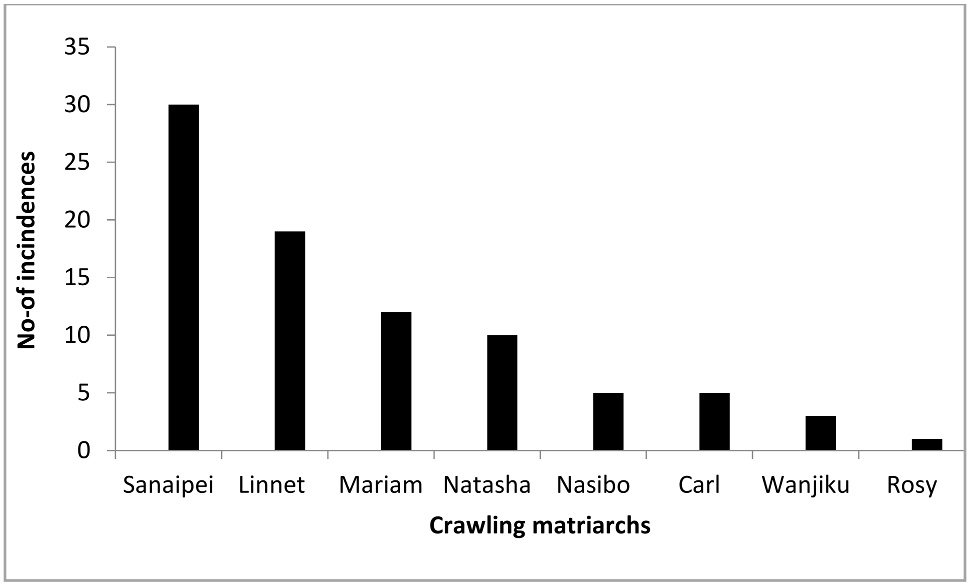


Figure 5.3 Graph showing relative number of incidences for each family group crawling under the exclusion zones wires

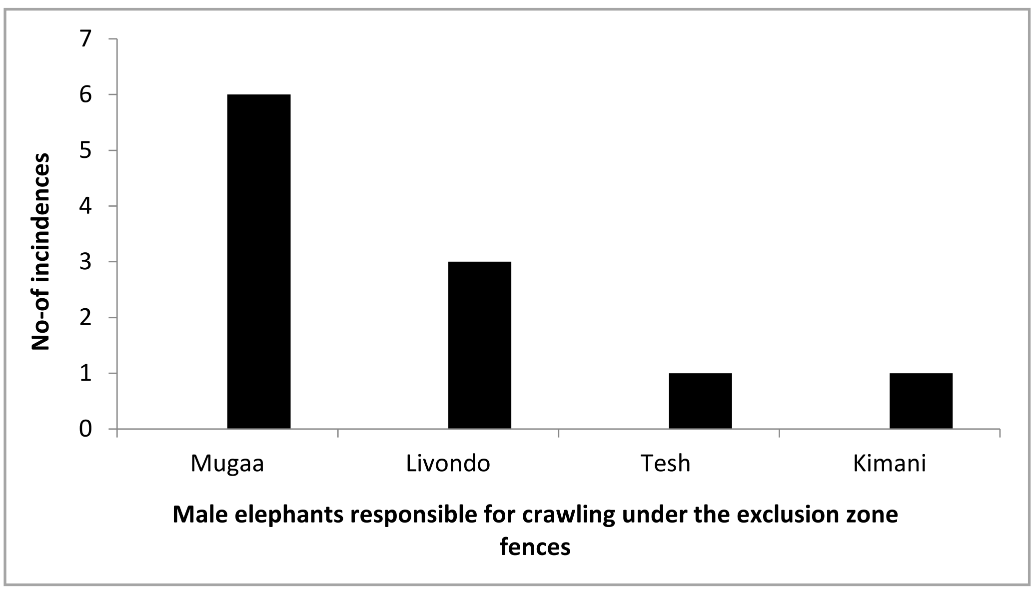


Figure 5.4 Elephant bulls responsible for crawling under the exclusion zones wires

Despite the trimming of tusks of a few male elephants as well as the translocation of seven highly rated fence breaking males in the past, there are still several resident males and new recruits that continue to break fences. These bulls are; *One Right Tusker, Champion, Melo, Kamongo, Odongo and Moreher* (Figure 5.5). Further monitoring will continue to advise the need to trim their tusks or translocate them out of the landscape.

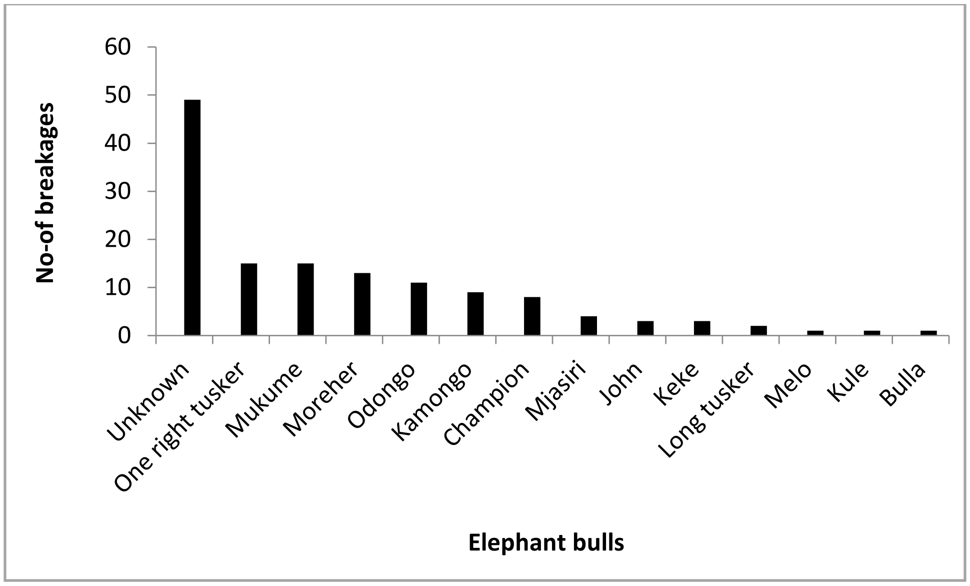


Figure 5.5 Main elephant bulls responsible for fence breakages

5.3 Conclusion and recommendations

Human-elephant conflicts continue to be a major problem within LBL and surrounding community farms particularly during the dry season. In an effort to mitigate these conflicts, there is need to constitute and equip a Human-Wildlife Conflict Response team for proactive and reactive response to all kinds of HWC issues in a timely fashion. We will also continue exploring the use of deterrent methods and strengthen collaboration with partners such as Big Life Foundation and Save The Elephant (STE) to upscale our technical knowhow on mitigating human-elephant conflict.

6.0 RANGELAND MONITORING

6.1 Grazing Management

On Lewa, controlled cattle grazing programme was introduced in 2012 with the main objectives of improving the quality of grassland by eliminating unproductive grass through grazing, trampling and dunging as well as reduce tick densities.

Grazing of NRT-Trading cattle continued on Lewa in 2019. By the end of the reporting period, a total of 361 head of cattle were grazing on blocks 70, 71 and 81b. Other blocks that were grazed across the year were 28, 29, 53, 54, 66, and 93. These blocks had good pasture and accessibility to water. Owing to the prevailing weather conditions during the year, all the animals were kept under supplementation programme to ensure they attained market weight. Across the year, an estimated 3,000 head of NRT – T cattle came through Lewa. However, due to better pasture available in Ol Pejeta, El Karama, and Loisaba Conservancies, cattle numbers at any one time were below the allocated 1,200 head.

In total 5,232 acres were grazed during the year with an additional 4,952 acres projected to be grazed in Q1-2 2020 depending on continued forage availability (Figure 6.1). With exceedingly good rains in October-December, most blocks have physically recovered from previous grazing and the grass has seeded. This is most important for blocks that have had poor rainfall over the last few seasons. Follow-up soil and vegetation nutrient tests will be conducted across all blocks in Q1 2020 to determine the relative health status in different soil types and rainfall regimes.

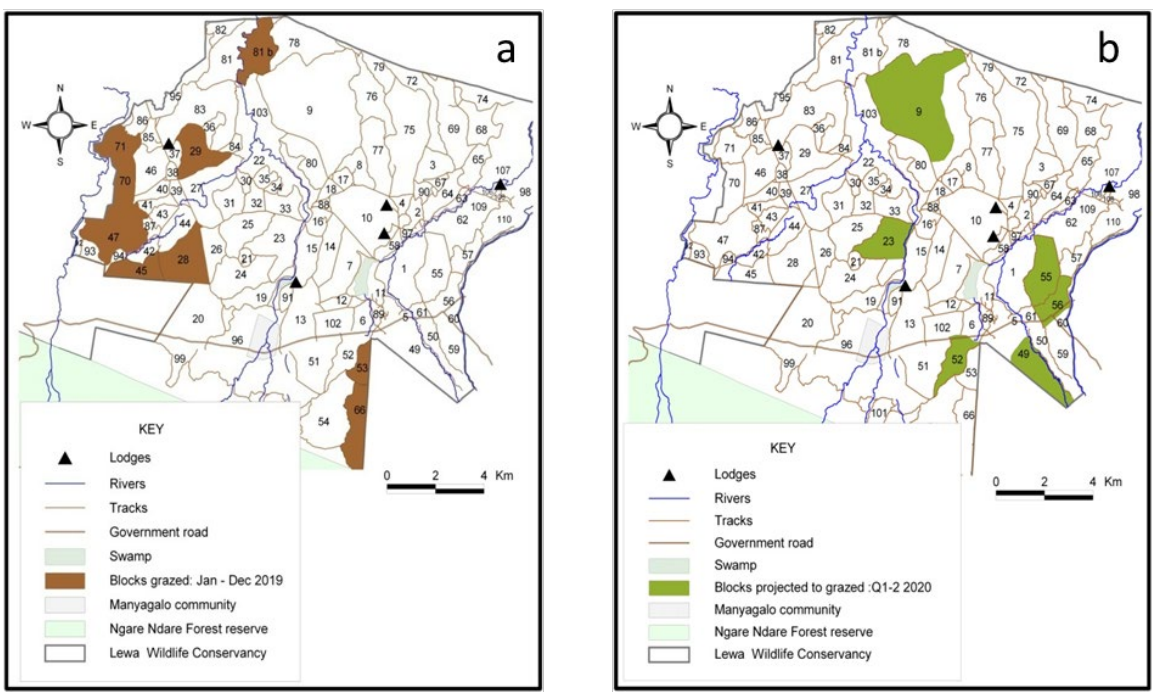


Figure 6.1: Map of Lewa showing a) blocks grazed in 2019 and b) blocks projected for grazing in Q1-2 2020

6.2 Grassland Resources

6.2.1 Grassland Assessment

The major objective of the annual grass assessment on the LBL is to estimate the biomass of grass and composition of herbaceous material in order to provide insight on the range condition and possible management interventions. The Research Department experimented with new ground-based grass assessment techniques, aimed at increasing the rigor of the biomass assessment. This initial assessment was carried out in June, with plans for a further assessment in December. However, the heavy rains experienced on the landscape during the final quarter of the year hampered efforts to complete the second portion of the assessment, which will be completed in Q1 2020.

From the biomass assessment conducted using the new methodology provided by Dr. Peter Goodman of AfRSG, our main findings were that there was a reduction in biomass over the first half of the year, which was expected given the poor March-April-May rainfall season (Figure 6.2).

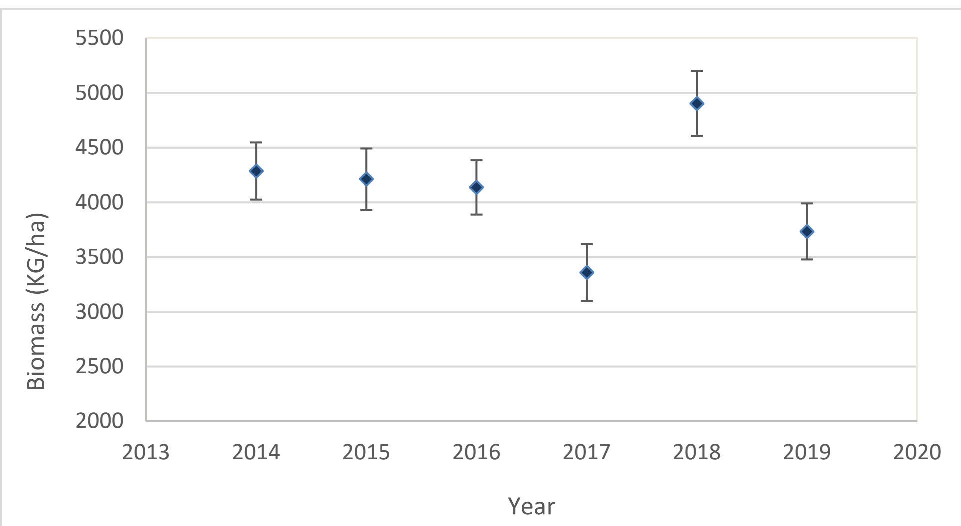


Figure 6.2: Graph showing reduced biomass productivity on Lewa in 2019 compared to 2018

Given that a new methodology was used to collect this dataset, the magnitude of the difference between years, while expected, should nevertheless be treated with caution. With an average biomass of 4,633 kg/ha, the Plains ecological unit had the highest herbaceous standing biomass of the four management units, with the Forest ecological unit having the lowest with 2,933 kg/ha. The low biomass in the forest could be explained by increased utilization by bulk grazers given it serves as a refuge during low production years. This pattern is supported by our satellite image analysis below.

Assessment of the productivity cages set up in late 2018 is currently ongoing, and preliminary results indicate a low influence of clipping height, our stand-in for utilization, on resulting grass height or density (Figure 6.3). However, there was some anecdotal evidence for increased forb prevalence with greater removal percentages. Assessment will continue to look at resulting nutrient and leaf-stem ratios for the different treatment groups.

Figure 6.3. A productivity cage at Mlima Kali, showing similar grass growth at the end of the rainy season, both within treatments, as well as between treatments and the background.

7.2.2 NDVI assessment

We were able to acquire pre-analysed NDVI imagery for the wet season (Mar-April-May) as well as for October-November for both Lewa and Borana through the RCMRD

Rangelands Monitoring platform. From these images, we were able to visually track the erratic pattern of rainfall through 2019. The March-April-May period (MAM) was characterized by below average rainfall, and this was evident in the NDVI Vegetation Condition Index (VCI) analysis, showing poor conditions on the landscape in comparison to historical ranges (Figure 6.4).

Using these NDVI images, we also obtained image-based analysis in the form of the Standardized Anomaly (SA) for the following months, showing how the two areas of the landscape recovered at different rates. From this analysis, we surmised that the Ngare Ndare Forest area was being used heavily by both wildlife and livestock as it is a dry season refuge (Figure 6.5). Over the intermediate June-August period, the Borana section of the landscape received substantial amounts of rainfall, leading to increased herbaceous forage production. The continued lack of rainfall on the Lewa portion of the landscape resulted in lower forage availability, and wildlife distribution became increasingly restricted to Borana and the Forest ecological unit on the south of Lewa (Figure 6.6).

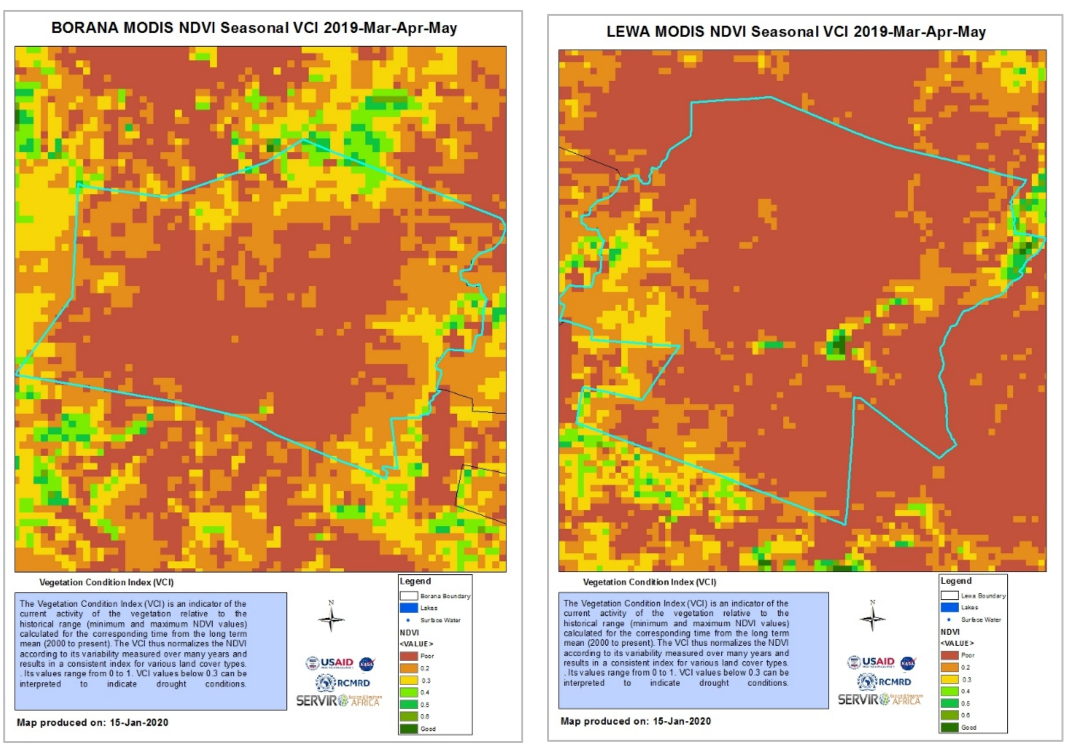


Figure 6.4: NDVI VCI maps of Lewa and Borana showing poor vegetation conditions across the March-April-May rainfall season

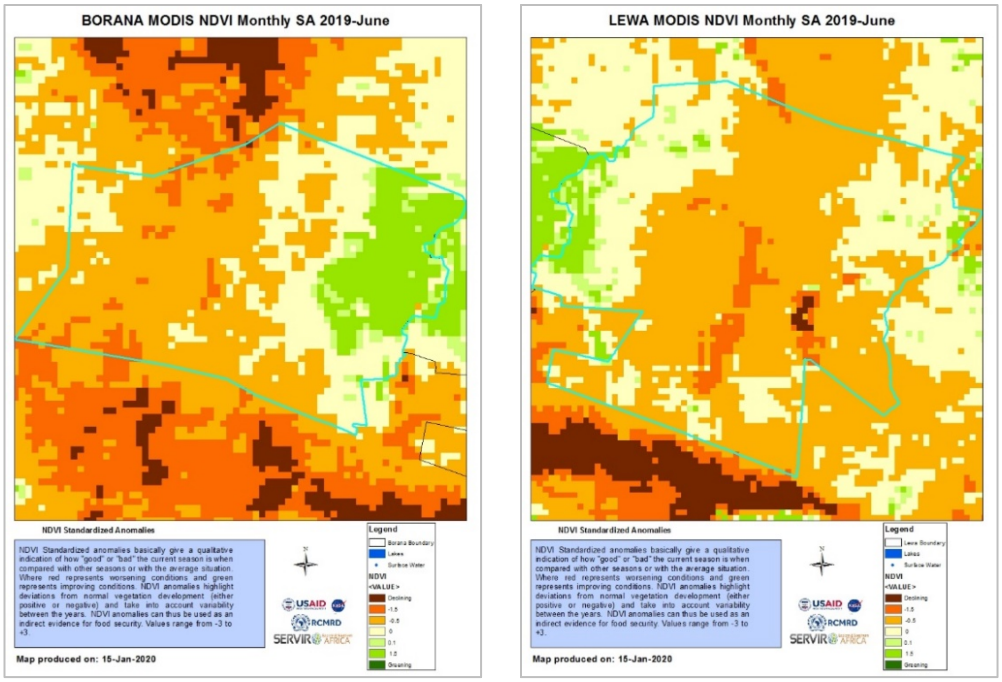


Figure 6.5: NDVI Standardized Anomaly (SA) maps of Lewa and Borana for June showing declining vegetation conditions over most of Lewa and Borana, except along the Ngare Ndare river, on the Western section of Borana and a small portion on the Eastern section of Lewa

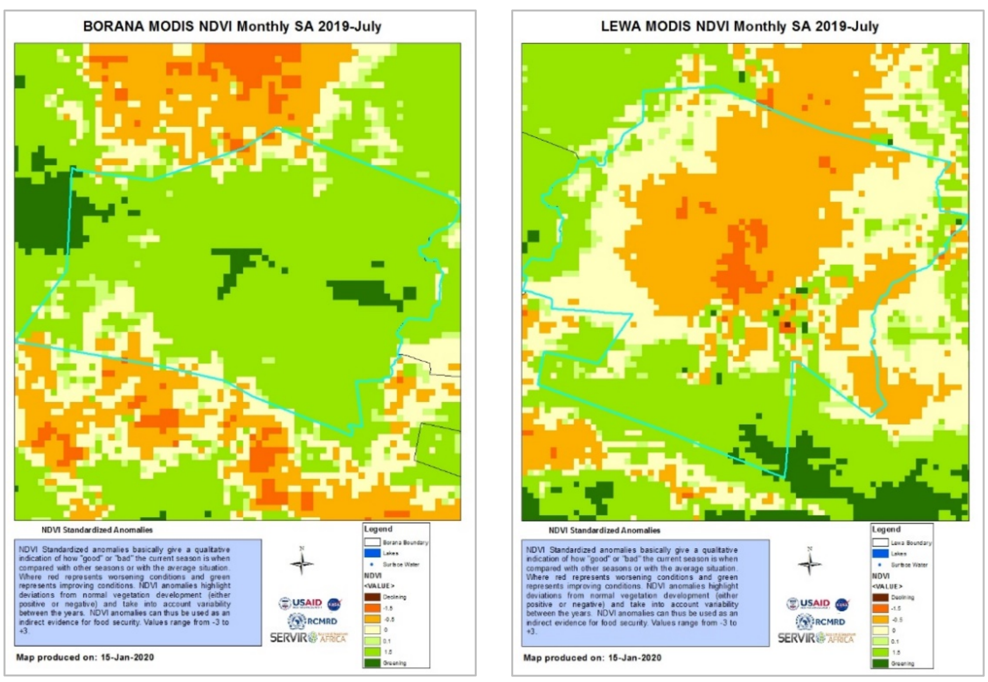


Figure 6.6: NDVI-SA maps of Lewa and Borana showing declining vegetation conditions in July over most of Lewa except along the Ngare Ndare river and close to the forest, where some rainfall was received. Conversely, adequate rainfall led to improving conditions across Borana, leading to a shift in Grevy's Zebra and Rhino utilization patterns on the landscape

The onset of the October-November-December rains was a large boost not only to the productivity of vegetation on the Lewa section of the landscape, but the intense rain storms filled up most of Lewa's dams, allowing a wider distribution of wildlife away from the perennial surface water areas. By the end of December, every section of the landscape was characterized by high vegetation productivity, with most perennial herbaceous species maturing and producing seed heads (Figure 6.7).

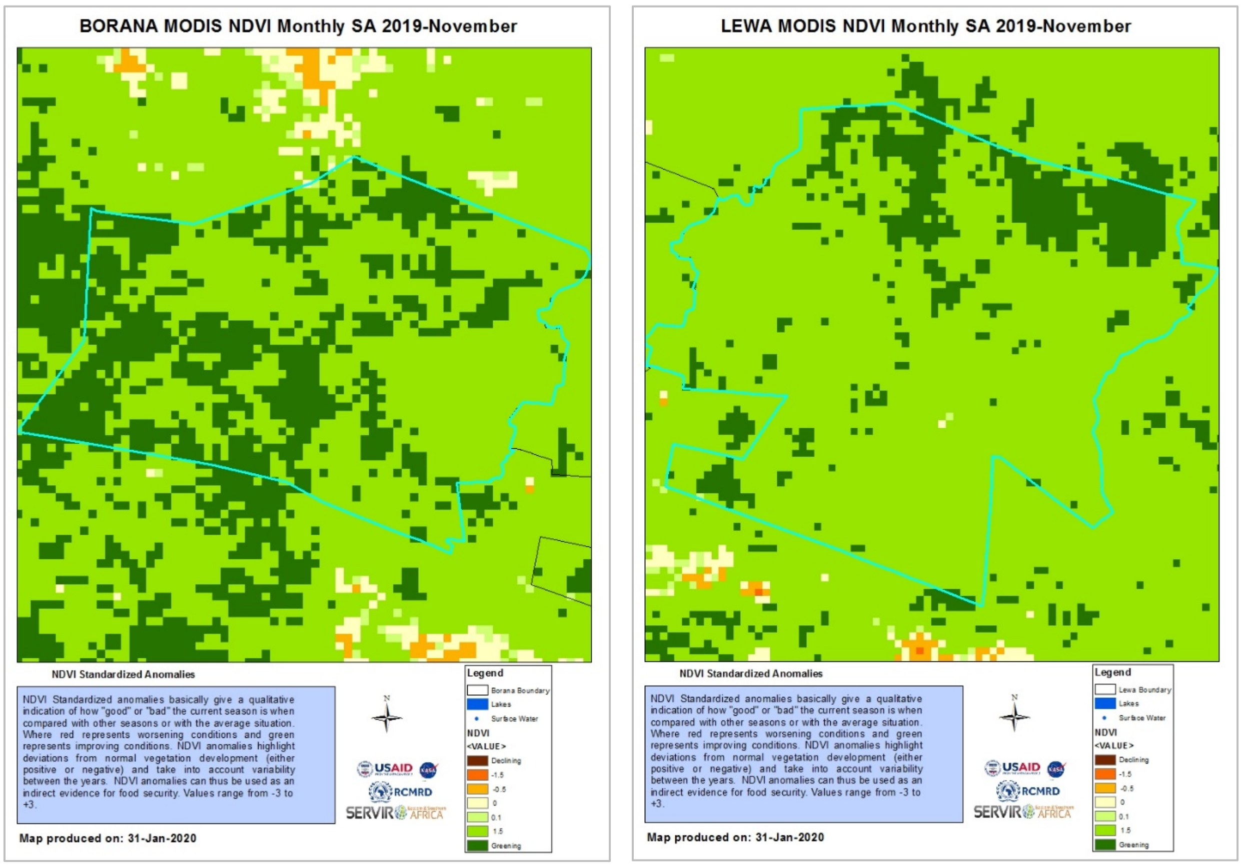


Figure 6.7: NDVI-SA maps of Lewa and Borana showing improving vegetation conditions in November over most of Lewa due to increasing rainfall across the landscape.

6.4 Woody vegetation

Monitoring of vegetation on Lewa has been ongoing since its establishment in 1995. Up to date, the vegetation has undergone significantly changes due to browsing pressure and possibly changes in weather regimes. It is important to document these changes and be able to provide solutions to encourage either natural regeneration or planting.

Fixed-point photography and quantitative woody vegetation sampling were completed on 28 points covering the four management units.

6.4.1 Results and discussion

Result shows that there was an increase in mean canopy diameter from 2018 to 2019 ($t = 3.5918$, $df = 3$, $p = 0.037$). This suggests that the canopy diameter increased nearly in all tree species as a result of browsing on the shoots mainly by giraffe suppressing the vertical growth of the tree thus promoting lateral growth, forming an umbrella shape. *Acacia mellifera, Euclea divinorum* and *Grewia similis* were the most abundant species encountered during sampling, with *A. melifera* and *A. drepanolobium* being the most preferred by elephants. Although *E. divinorum* was abundant, the level of utilization was low (Figure 6.8).

Previous studies show that where elephant and giraffe are present in a woodland savanna in large numbers, they suppress the growth of trees (Birkett 2002). *A. mellifera* experienced the highest amount of browsing damage compared to the other species. Majority of the damage observed was attributed to elephant and giraffe browsing, consistent with previous years findings (Figure 6.9)

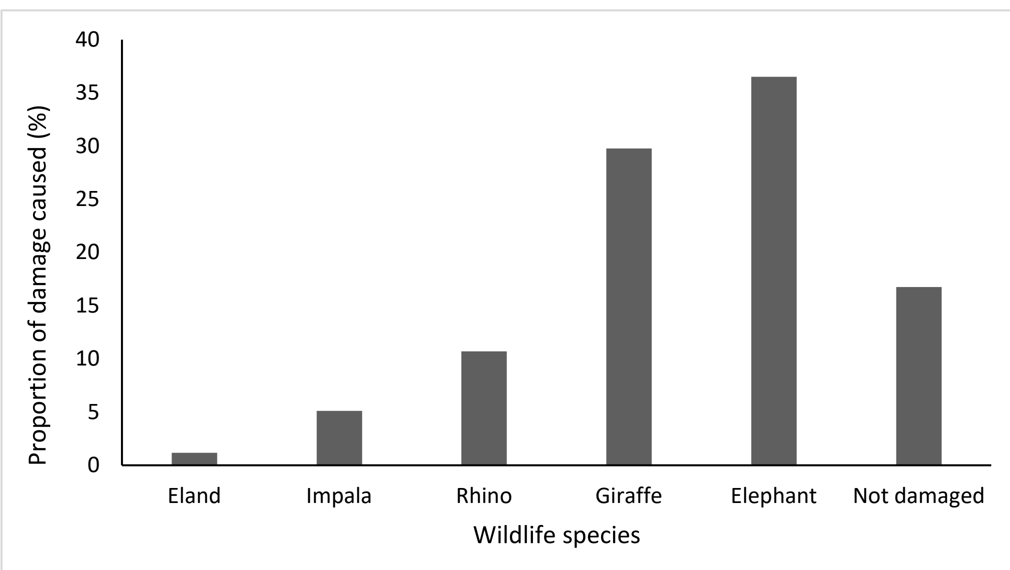


Figure 6.8. Damage incidents attributed to different wildlife species

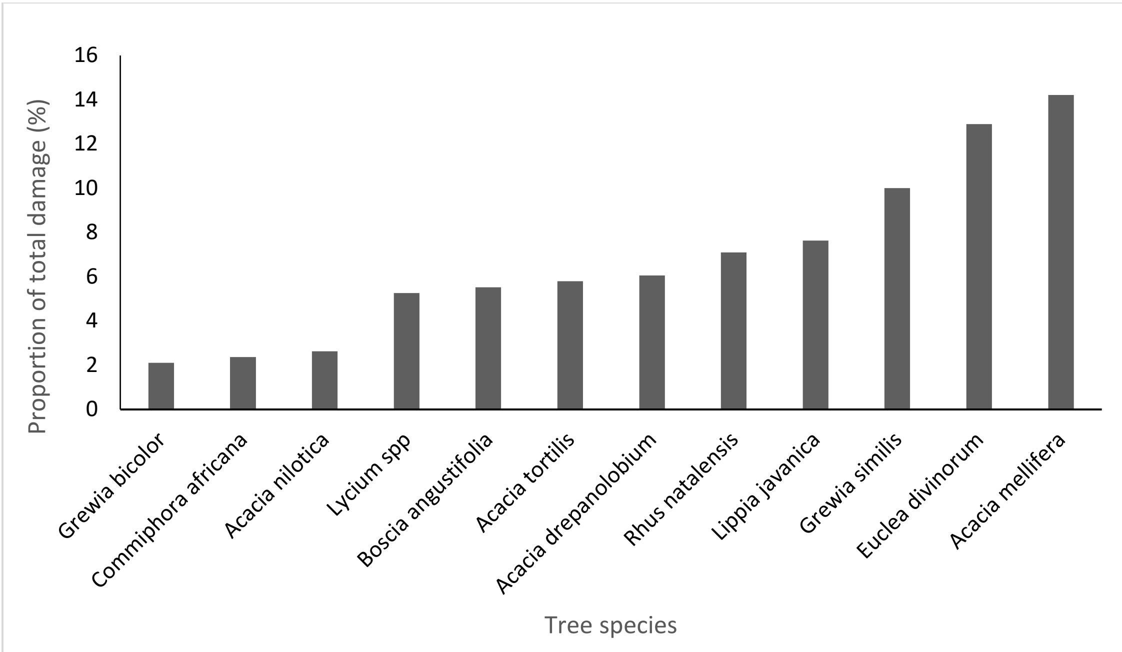


Figure 6.9 Proportion of overall damage by individual tree species

6.5 Exclusion zone extension

In late 2018, the Lewa HQ exclusion zone was extended northward past the Airstrip towards Simba Ridge. A long-term woody vegetation assessment plot was established to allow monitoring of any changes in the species composition, density, and structure. Our pre-assessment in 2018 identified a high seedling density in the plots, suggesting great potential for a change in vegetation structure, and support of findings by Giesen et al. (2017) that there were hotspots of tree seedlings on plains that did not need reseeding. The hypothesis was that in these areas, removal of browsing pressure by large mammals would directly result in increased tree growth without the need for a reseeding programme. This hypothesis has been borne out by a 21% increase in tree height for the airstrip plot, though this difference was not statistically significant yet ($t=-1.480$, $df=12$, $p=0.08$; Figure 6.10, 6.11). Similarly, there was a modest 16% increase in crown diameter, although this was also not statistically significant ($t=-1.054$, $df= 12$, $p=0.156$). We believe the magnitudes of these changes will be increasingly detectable statistically as we accrue more data points, given the extension has only been up for a year. Monitoring will continue on this plot to document further changes in the various vegetation structure metrics of interest.

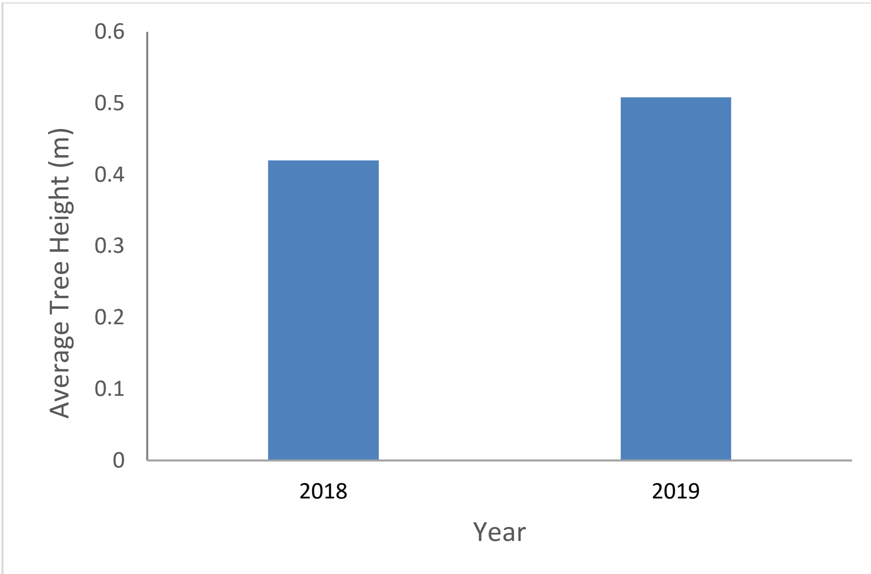


Figure 6.10. Graph of average tree height at Airstrip exclusion plot between 2018 and 2019 showing higher mean tree height in 2019.

Figure 6.11. Image taken at the airstrip exclusion extension after one year of growth. *Acacia drepanolobium* trees beginning to exhibit vertical growth after reduction in suppressive browsing

6.6 PlantNet ID project

Efforts at ecosystem management and provision of timely and useful wildlife and habitat management decisions rely heavily on accurate plant identification in order to properly assess ecosystem changes. The LBL also hosts several student research groups that assist every year in carrying low level monitoring, as well as graduate students that carry out higher level research. Currently, plant identification for these efforts relies on the collective knowledge of a few key individuals, and that model heavily relies on the assumption that these personnel will be available whenever required, and that their plant ID capabilities are infallible.

In part to address some of these issues, David and Susan Brown who are long-term residents on the landscape and help maintain a plant database for Lewa, took lead in exploring existing automated plant ID options. Through their generosity, and with the involvement of Calum and Sophie MacFarlane of Lewa House and the Lewa Research department, an agreement was reached with PlantNet, a European research and citizen science project, part of the Floris'Tic initiative. This platform is a combination of Citizen Science, Machine learning and Crowdsourcing for plant identification. This agreement allowed the creation of a micro-project for Lewa, mainly based on the existing curated plant list and archived images. The aim of the microproject is to allow contributors to take photographs of plants across Lewa, load them onto a mobile phone app, and then select from an auto-generated set of potential matches. As with most machine-learning efforts, the accuracy of the matches will improve as more photos and more users are added onto the database. We hope that this initiative will expand to cover the whole of the LBL and eventually the Greater Ewaso Ecosystem.

Conclusions and recommendations

As the need for better data to manage rangelands on the LBL increases, the Research Department has partnered with Marwell Wildlife to carry out longitudinal studies on the impact of legacy management interventions and changing climatic patterns on the productivity and health of Lewa's ecosystem. Baseline data and initial status assessment will be carried out by two Southampton University MRES students in Q2 2020. These students will be under direct supervision of the Lewa Research Department and will supplement their data with historical data from the department as well as interviews with stakeholders across the landscape. Plant identification, a problematic part of previous student studies, will be supplemented using the PlantNet plant ID microproject for Lewa (Plantnet).

Due to increasing herbivore numbers on the landscape, and an increasing reliance of communities on Lewa's grazing resources during prolonged dry spells and drought conditions, Lewa management has opted to restructure the previously operated community emergency grazing program. This will instead be replaced by a concerted restoration and grazing management programme on Il Ngwesi and Leparua communities aimed at increasing resilience of the landscape and restoring rangeland productivity as well as access to Lewa's grass through the NRT-T livestock grazing programme. This will be carried out in collaboration with NRT and NRT-T and respective Community Conservancies.

Due to the positive results of the exclusion zone extension at the Lewa HQ, it is recommended that the current exclusion zones be expanded outwards as opposed to attempting development of new areas. Not only will this reduce construction costs, it will likely be immediately impactful due to existing seedling density on the outer edges of these exclusion zones.

7.0 AVIFAUNA MONITORING

7.1 Introduction

Birds are often common inhabitants of the ecosystems and they have been considered as biodiversity indicators since they are highly responsive to environmental change (Rajashekara & Venkatesha 2010). Monitoring bird populations is useful in assessing their status, helping to determine conservation priorities, and detecting whether species are responding to management activities (Dunn et al. 2006).

The LBL provides key habitat to many bird species some of which are globally threatened. It is also a centre for some migratory birds, especially Palearctic migrants, and an important wetland and water catchment area that is an attraction and feeding ground to many bird species. We harmonized the many existing bird lists for LBL and produced a single check list which has been vetted by Nature Kenya. The list is currently under review by Don Turner and other renowned ornithologists, both locally and in East Africa. From the list, we selected waterbirds and raptors as the key indicator bird species for monitoring following their conservation status and ecological importance.

7.2 LBL Birds Checklist

The harmonized list has 79 families with 450 species, representing nearly 40% of the 1,105 total species found in Kenya. The list was obtained by compiling various lists produced by the Lewa Research Department, National Museums of Kenya, Peregrine Fund, Borana Conservancy, and Lewa House. The list is categorized into common name, scientific name, order, family, conservation status in accordance to the IUCN Red List of Threatened Species, migration status and sighting status (Table 7.1 & 7.2). The taxonomy, common names and migration status follow the Field Guide to the Birds of East Africa by Terry Stevenson and John Fanshawe (Stevenson & Fanshawe 2014).

In collaboration with internal and external stakeholders, part of the data collection protocol involves photographing the bird species occurring to form the evidence files. 55% of the birds have been successfully photographed to date. From our daily monitoring we updated the list with some species which have never been sighted on LBL before. This includes the Snowy-headed robin chat which is the first ever record of the species east of the Rift Valley.

Table 7.1: LBL birds categorized according to their IUCN Red List status

IUCN Red List Status	Total No. of Species
Critically Endangered	4
Endangered	4
Vulnerable	4
Near Threatened	6
Least Concern	432
Grand Total	**450**

Table 7.2: LBL bird species categorized according to their migration status

Migration Status	Total No. of Species
Palearctic migrant	51
Afrotropical migrant	19
Mixed migrant (Palearctic & Afrotropical)	10
Resident & Afrotropical migrant	4
Resident	366
Grand Total	**450**

7.3 Waterbirds Survey

Waterbirds are an important component of most of the wetland ecosystems as they occupy several trophic levels in the food web of wetland nutrient cycles (Rajashekara & Venkatesha 2010). Activities of waterbirds are considered an indicator of the quality of a wetland ecosystem and form the terminal links in many aquatic food chains, and as a result, they reflect changes originating in several different ecosystem components (Custer & Osborne 1977).

We monitored waterbirds in all the wetlands. Diversity was calculated using Simpson's Diversity Index: $= 1 - \left(\frac{\sum n(n-1)}{N(N-1)}\right)$, where n represents total number of particular species and N represents total number of all waterbird species surveyed. We recorded 54 species and the diversity (D) was 0.8285.

A Chi-square test shows a significant increase in waterbird populations during the wet period (3,406) compared to the dry period (1,933) ($\chi2 = 406.39$, df = 1, $p < 0.001$).

7.3.1 Grey Crowned Crane survey

The Grey Crowned Crane has been recently listed as endangered in the IUCN Red List of Threatened Species due its rapid population decline over the years (BirdLife International 2019). A nation-wide survey conducted in February and March 2019 recorded a total of 7,776 individuals with 95% of them being adults (Bakari et al. 2019).

The LBL recorded a total of 93 individuals during the survey. Considering that these birds make local and seasonal migrations, their population has been fluctuating throughout the year (Figure 7.2). The highest population recorded was 111 individuals comprising of 107 adults and four chicks. We recorded more individuals during the wet season than the dry season ($\chi2 = 119.95$, df = 1, $p < 0.001$; Figure 7.2).

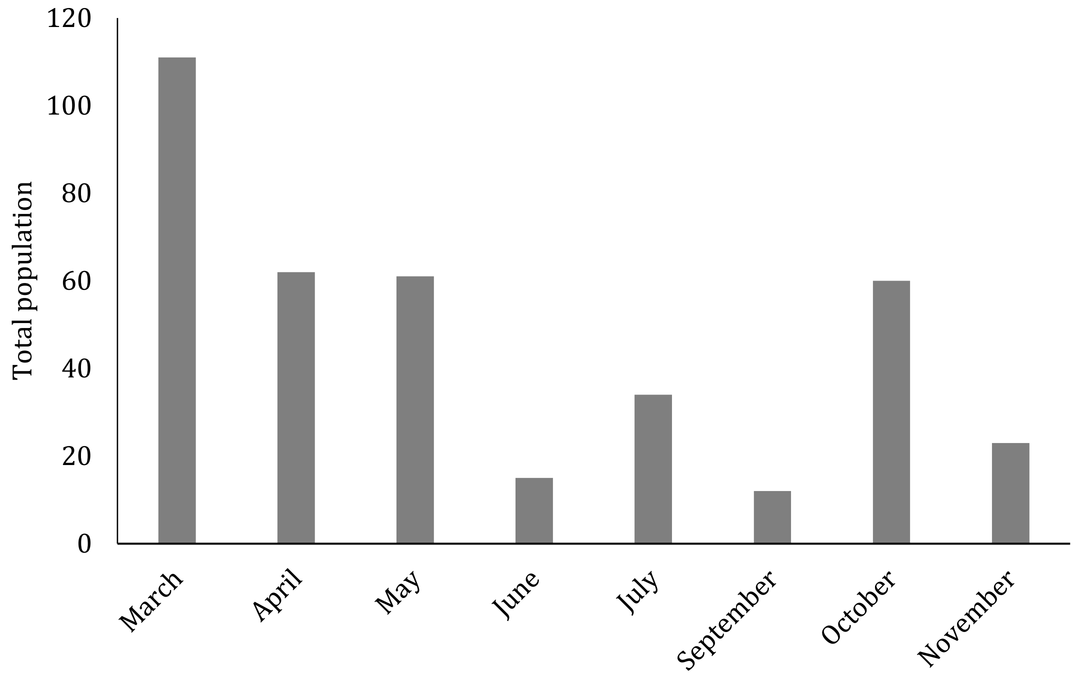


Figure 7.1: Monthly Grey crowned crane population

7.4 Raptors Survey

Raptors tend to be highly sensitive to prey availability, vegetation structure, pollution, and human disturbance, and thus, are good indicators of environmental changes (Keys et al. 2013). A total of 356 individual raptors of 26 species were surveyed including the Ruepell's *(Gyps rueppelli)*, hooded *(Necrosyrtes monachus)*, and African white-backed *(Gyps africanus)* vultures which are Critically Endangered, and Steppe eagle *(Aquila nipalensis)*, Lappet-faced vulture *(Torgos tracheliotos)*, and Egyptian *vulture (Neophron percnopterus)* which are Endangered (Table 7.3). Diversity was calculated using Simpson's Diversity Index, indicating a high diversity (0.8606) of raptors in LBL.

Four of the 9 nests identified and surveyed throughout the year displayed successful breeding. Five nests were still active at the end of the year. The map below shows the distribution of nesting sites of raptors in the landscape (Figure 7.2).

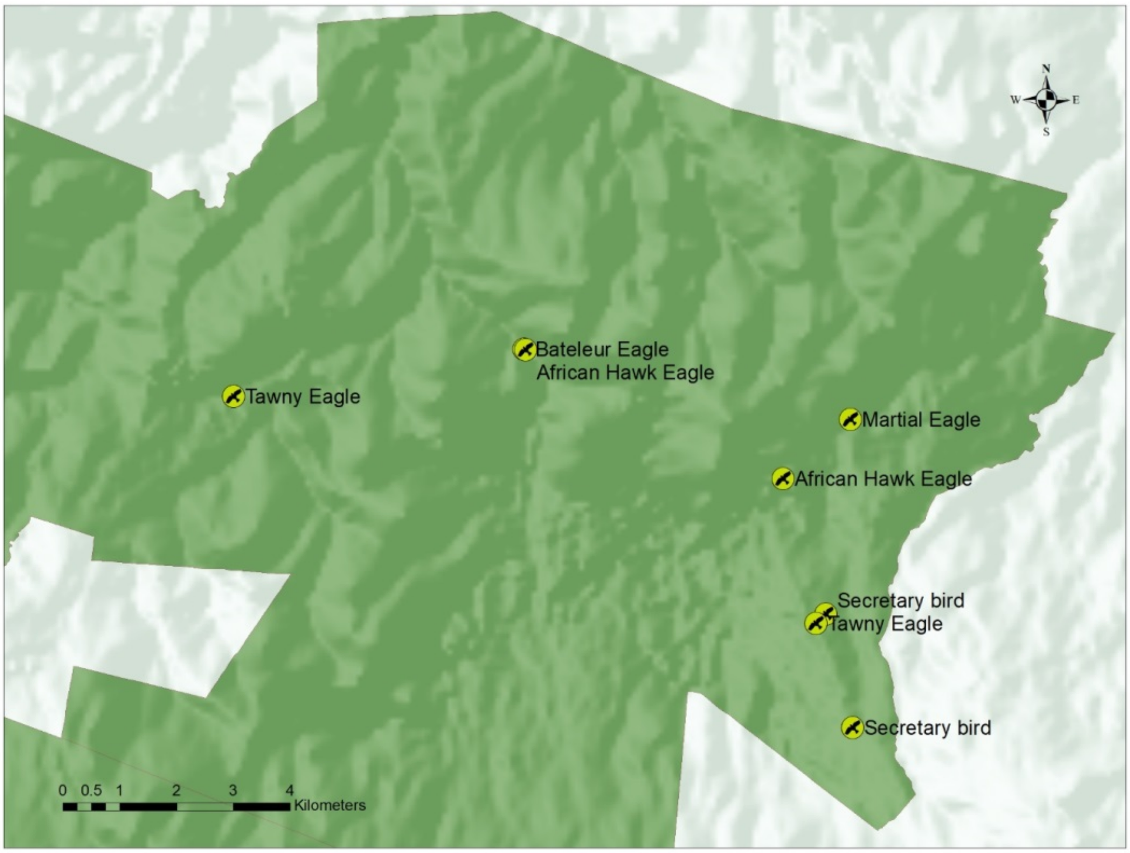


Figure 7.2: Distribution of nesting sites of raptors on LBL

Table 7.3: Total raptors population surveyed on LBL and their conservation status

Species	Count	Conservation Status
African Fish Eagle	3	Least Concern
African Hawk-eagle	11	Least Concern
African Marsh Harrier	4	Least Concern
African Swallow-tailed Kite	3	Least Concern
African White-backed Vulture	16	Critically Endangered
Augur Buzzard	18	Least Concern

Bat Hawk	1	Least Concern
Bateleur Eagle	5	Near Threatened
Black-chested Snake Eagle	3	Least Concern
Brown Snake Eagle	2	Least Concern
Black-shouldered Kite	29	Least Concern
Eastern Chanting-Goshawk	8	Least Concern
Lanner Falcon	2	Least Concern
Greater Kestrel	1	Least Concern
Lappet-faced vulture	7	Endangered
Montagu's Harrier	2	Least Concern
Hooded Vulture	6	Critically Endangered
Long-crested Eagle	7	Least Concern
Martial Eagle	16	Vulnerable
Pallid Harrier	4	Near Threatened
Rupell's Griffon Vulture	49	Critically Endangered
Steppe Eagle	108	Endangered
Secretary Bird	22	Vulnerable
Tawny Eagle	26	Least Concern
Verreaux's Eagle	3	Least Concern
Total	**356**	

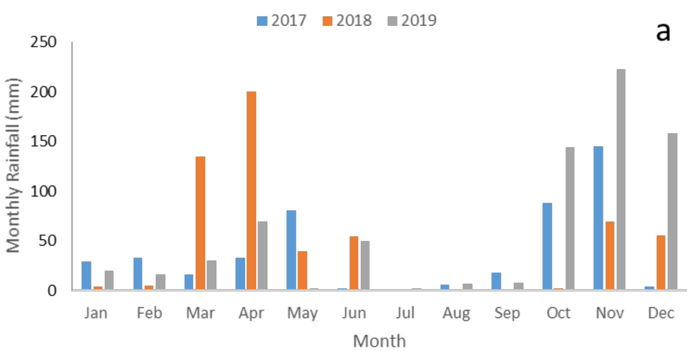
7.5 Conclusion and recommendations

The comprehensive birds' checklist still under review indicates the high diversity of birds on LBL. The addition of five novel species to the list as part of our monitoring efforts shows the potential of more species to be found within the landscape. Further research and monitoring on LBL should be done on species of conservation concern and their status needs to be documented. With a large number of waterbirds residing on the landscape, the annual waterbird counts that are conducted nationally in January and July by National Museums of Kenya should extend the coverage to include LBL.

From the high number of Steppe eagles recorded in 2019 on LBL and in regard to their conservation status, we recommend the species to be considered amongst those selected for satellite telemetry. Partnership with organizations doing research on avifauna is critical for establishment of standard long-term monitoring protocols for the landscape.

8.0 HYDROLOGY

Rainfall for 2019 was 729±72 mm, much higher than the 510±73 mm received in 2018. Additionally, this was also higher than the long-term (1975-2018) average rainfall of 527±72 mm for the last 45 years, (Figure 8.1). This is the fourth wettest year on record since Lewa began keeping rainfall records in 1974. Subsequently, most of the surface dams on Lewa are now full, and the rivers are flowing unencumbered through the landscape.



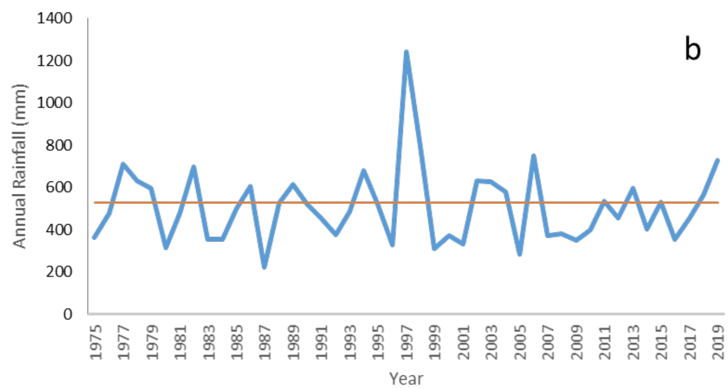


Figure 8.1: Graph showing a) Monthly rainfall for 2017-2019, and b) annual rainfall for the last 44 years with long term average as orange data line

As plans for expanding the Lewa-Borana Eco-hydrological monitoring continue, we have been testing multiple low-cost weather stations for upgrading our hydro-met systems. Given the performance of these cheaper models during high intensity rainfall events, it is our recommendation that the Ambient weather 1001 WS model under testing is not considered for any sensor network upgrades. Simultaneous testing on the Davis Instruments Vantage Vue Pro 2 by Sue Brown at Mlima Mbogo and Calum MacFarlane at Lewa House showed slightly better results, although again, there was concern over accurate recording during heavy storms. Some of these concerns were allayed via troubleshooting through the manufacturer.

As a result of this, the high cost OTT Pluvio² L by OTT Hydromet in use by CETRAD remains the most accurate option for the landscape. While fundraising for these systems continue, a more achievable target for Q1 and Q2 2020 would be to standardize all the manual rain gauges across the LBL to ensure that there are no conversion errors due to differences in units. Additionally, we have instituted standardized reporting times for all rain gauges. Rainfall will henceforth be recorded at 6.00 am and 6.00 pm to prevent double measurement and ensure consistency in recording.

Conclusions and recommendations

As the fundraising phase for a comprehensive ecohydrology programme continues, there is need to update and standardize existing manual rain monitoring systems and complement these with temperature recording systems in selected areas. Baseline work similar to that conducted on Il Ngwesi as part of the RII project should be explored for Lewa and Borana with regards to water quality and distribution.

9.0 ACKNOWLEDGEMENTS

The Lewa Borana Landscape (LBL) Research and Monitoring Department would like to thank all parties who worked with us in 2019. In particular, we acknowledge the management of Lewa and Borana Conservancies, Lewa Canada and Lewa International in general for their continued technical and financial support; Al Ain Zoo, UAE and Zoo Zurich, Switzerland for their continuous financial and technical support of major wildlife monitoring and security programmes; and RII Project for support in upscaling the rhino monitoring programme. In addition, we acknowledge all the other supporters for their technical and financial support to Lewa and Borana to undertake our research and monitoring programmes.

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11.0 APPENDICES

Appendix 1: Black rhino births on LBL in 2019

#	Calf name	Dam	Sire	Date of Birth	Sex
1	Linda Calf 2	Linda	Denny	20-Jan-19	Male
2	Number 9 Calf 2	Number 9	Denny	3-Feb-19	Female
3	Ingo (Lucy Calf 2)	Lucy	Rocky	3-Feb-19	Male
4	Mama C Calf 5	Mama C	Mutane	7-Feb-19	Male
5	Seiya Calf 6	Seiya	Sogomo	11-Feb-19	Male
6	Zenetoi Calf 2	Zenetoi	Ndoto	21-Feb-19	Male
7	Anna Calf 3	Anna	Ndoto	22-Jun-19	Female
8	Mejh Calf 4	Mejh	Sonny Liston	27-Jun-19	Female

9	Number 18 Calf 2	Number 18	Ago	14-Jul-19	Female
10	Bahati 2 Calf 1	Bahati 2	Lucky	16-Jul-19	Female
11	Waiwai Calf 8	Waiwai	Lucky	18-Aug-19	Female
12	Karimi Calf 1	Karimi	Elvis	20-Aug-19	Female
13	Natumi Calf 5	Natumi	Lucky	29-Sep-19	Female
14	Zainab Calf 1	Zainab	Muturi	21-Oct-19	Male
15	Delia Calf 1	Delia	Lucky	12-Dec-19	Male
16	Edwina Calf 2	Edwina	Denny	25-Dec-19	Unknown
17	Rensuen Calf 2	Rensuen	Rocky	26-Dec-19	Unknown

Appendix 2: Black rhino deaths on LBL in 2019

#	**Name**	**Sex**	**Mortality date**	**Cause of death**	**Age at death**
1	Number 5	Male	9-April-2019	Fell off a cliff	35 years
2	Mawingo	Female	28-Jan-2019	Fell off a cliff	34 years
3	Kathy	Female	22-Jul-2019	Birth complications	11 years
4	Linda Calf 2	Male	18-Feb-2019	Predation by hyaenas	28 days
5	Sam	Male	3-Dec-2019	Injury after fight with an unknown bull	3.3 years

Appendix 3: White rhino births on LBL in 2019

#	**Calf name**	**Dam**	**Sire**	**Date of birth**	**Sex**
1	Ramadhan Calf 4	Ramadhan	Samawati	1-Mar-19	Male
2	Lina Calf 2	Lina	Samawati	8-Mar-19	Female
3	Queen Calf 3	Queen	Owuan	9-Mar-19	Male
4	Schini Calf 6	Schini	Samawati	11-Mar-19	Female
5	Rosie Calf 3	Rosie	Marti	26-Mar-19	Female
6	Rhoda Calf 1	Rhoda	Samawati	16-Apr-19	Female
7	Naserian Calf 3	Naserian	Samawati	19-Apr-19	Female
8	Jacho Calf 4	Jacho	Imado	24-Apr-19	Female
9	Songare Calf 12	Songare	Owuan	29-May-19	Male
10	Jakwai Calf 10	Jakwai	Samawati	11-Jun-19	Male
11	Arot Calf 1	Arot	Ronie	2-Jul-19	Female
12	Titilei Calf 5	Titilei	Marti	3-Aug-19	Female
13	Nduta Calf 1	Nduta	Mia	17-Aug-19	Unknown
14	Semenya Calf 1	Semenya	Samawati	1-Sep-19	Female
15	Nashepai Calf 1	Nashepai		28-Dec-19	Unknown

Appendix 4: White rhino deaths on LBL in 2019

#	Name	Sex	Mortality date	Cause of death	Age at death
1	Opondo	F	27-Jan-19	Euthanized after suffering from a leg fracture	33 years
2	Semenya Calf1	F	9-Sep-19	Trampled by the mother	9 days
3	Rosie Calf 3	F	8-Jul-19	Fell in a hole	3 months
4	Swan	M	7-Dec-19	Poaching	5.4 years
5	Jakwai Calf 9	M	7-Dec-19	Poaching	3 years

Appendix 5: Student projects on LBL in 2019

Can Conservation Physiology Improve the Population Management of the Eastern Black Rhino? Nicholas Harvey. University of Manchester. PhD Project.

The Behavioural Ecology of Reproduction and Demography in White Rhinoceros (*Ceratotherium simum*). Sarah Scott. Manchester Metropolitan University. PhD Project.

Spatial Distribution of Two Successful Ungulate Populations at Lewa Wildlife Conservancy as Connected to Rainfall and Grass Species Diversity. Emily Strickland, Columbia University. Undergraduate Thesis.

Seasonal Variation in Browse Availability and Resource Utilisation by the Eastern Black Rhinoceros (*Diceros bicornis michaeli*) on Two Wildlife Conservancies in North-central Kenya. Lara Jackson. Independent. Supplementary data for MSc Project.