LEWA WILDLIFE CONSERVANCY

A UNESCO World Heritage Site inscribed in 2013

BORANA CONSERVANCY

Research and Monitoring

Annual Report 2020

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EXECUTIVE SUMMARY

This report provides a summary of the activities of the Research and Monitoring Department on the Lewa-Borana Landscape (LBL) for the year 2020. This was a challenging year as the world grappled with the effects of the Covid-19 pandemic. With most personnel on Lewa away for various portions of the year, it was a challenge ensuring data collection continuity. Nevertheless, the research team were able to go above and beyond to ensure the continued integrity of our long-term datasets.

The year received mixed rainfall, with the March-May season receiving reasonably high rainfall, while the October-December season received significantly below average rains. The average annual rainfall recorded across the landscape was 569±29mm. This resulted in slightly above average vegetation productivity in the first half of the year, slowing down as the year progressed.

The rhino population was healthy and robust, although annual population growth slowed down as expected given the record-setting births in 2019. Black rhino increased from 109 to 114 individuals, with 7 births and 2 deaths recorded. This represents a biological growth rate of 9.4% in the 2018-2020 average 3-year moving window period compared to 9.5% in the 2017- 2019 period. The population of White rhinos increased from 97 to 103 after 7 births and 0 deaths, representing a growth rate of 9.9%. In the year, the long-term data sets of White rhinos were analyzed in a similar fashion as that of black rhino which has provided better visualization and analysis. Most of the rhinos assessed in 2020 were observed to have a body condition score ≥3.5 which represents a rhino in good body condition, indicating a good year with regards to browse productivity. There is need to continue expanding routine ear-notching programme to enhance accurate rhino reporting and reduce the number of unidentifiable rhino in the population.

The lion population on the Landscape remained robust, with some upheaval within the ecosystem. There were 11 births within the year, with 10 of them surviving as at the end of 2020. Two adult lions (*Defender* and *Suzie*) died due to intraspecific territorial fights while another adult male known as *Loner*, was eliminated under the Problem Animal Control programme after nearly a year of killing cattle at Marania farm. Another adult male, *Omar*, was translocated to Tsavo NP to mitigate livestock depredation. As part of our continued lion population control pilot programme, we received a go ahead from the Kenya Wildlife Service (KWS) to fix contraceptive implants on six lionesses. All were administered in the year. Our Jacob's index assessment of predator-prey preferences on the Landscape showed that giraffe and eland continue to be preferred by

lions, while impala, buffalo, and Beisa oryx were avoided. Other species were predated upon in proportion to their abundance.

Ungulate monitoring on the Landscape showed continued population robustness across most species. All species monitored apart from giraffe indicated an improvement in the percentage of juveniles and young towards the 30% mark for the last four years. Even with medium to high growth potential of giraffe, the number of juveniles and calves in the population remain suppressed. Jacob's selectivity index shows giraffe as the most preferred prey species by lions with an index of 0.7. There are continuing challenges in analysing Grevy's zebra identification data to obtain foals survivorship in real-time due to the lack of fast automated stripe identity database. The use of the current national Grevy's zebra stripe identity database is offline, cumbersome, and shared among partners. This has slowed the process down, allowing us only to analyse 2019 data as at the end of 2020. Engagements with WildMe continue and are being led by the Grevy's Zebra Technical Committee, with some progress made with regards to a general Memorandum of Understanding around development and hosting of the next generation stripe ID database.

Human-elephant conflicts continue to be a major problem within LBL and surrounding community farms particularly during the dry season. There continues to be a need to fully constitute and equip a Human-Wildlife Conflict Response team for proactive and reactive response to all kinds of HWC issues in a timely fashion. As the population of resident elephant in the Landscape increases, there is need to continue expanding the elephant identification database to enhance monitoring in order to understand use of the landscape by elephants.

The disruption in activities occasioned by the onset of the Covid-19 pandemic impacted the timing and duration of our rangeland interventions and assessments, and planned data collection around our mowing and grazing programmes. Nevertheless, our grass assessment results showed a year-on-year increase in grass cover and biomass productivity compared to 2019. This can be attributed to sufficient rainfall across the Landscape during the first half of the year, which likely spurred the continued production of perennial vegetation. From soil analyses we carried out on a selection of sites on the landscape, it was clear that a majority of the soils sampled had relatively low levels of Phosphorus and Nitrogen. We will need to expand these soil assessments to more areas on the Landscape and compare these values across various management systems to understand whether these deficiencies are intrinsic or as a result of legacy management interventions.

Our Avifauna programme continues to expand as we add new protocols and refine existing ones. Efforts continue to update and verify our harmonized birds' list that amalgamates sightings and species records kept by various entities and individuals on the Landscape. The harmonized list now includes 84 families with 467 species, representing over 42% of the 1,122 total species verified in Kenya. To create a photographic evidence file for the bird species on the Landscape and Ngare Ndare Forest Reserve (NNFR), we collaborated with LBL & NNFR Birder's Club to take evidence photos. This saw us move from an initial 55% of species with photo evidence to 69%. This effort will continue until we have the photographic evidence of all species in these contiguous protected areas. Our teams also participated in the Cornell University-led global ebird bird count in support of a campaign to end illegal bird trade. We recorded 184 species on the landscape, ranking us 4th on the Kenyan birding hotspot list. Waterbird and raptor surveys were completed throughout the year, revealing a reduction in raptor sightings between 2019 and 2020. This was attributed to the lack of some Palearctic migrants, primarily the Steppe eagle.

Thanks to a grant by a Foundation in USA, the Research team in collaboration with the Centre For Training and Integrated Research in ASAL Development (CETRAD) carried out a scoping assessment to lay out the groundwork for the first phase of the LBL hydrological monitoring programme. This was followed by a day long Workshop between CETRAD and Lewa Management to iron out general priorities and the overall direction for the next phase of the hydrology programme. Three sites have been selected for construction of River Gauging stations and will be sited on the Ngare Ndare and the Sirkoi Rivers. The second phase of this hydrology project will focus on quantifying and characterizing the spring systems. This will involve isotopic and volumetric assessments so as to understand the origin of spring water, the age of the water and the connection with land use changes upstream. This second phase is being funded through a grant from another Foundation in Europe.

In summary, 2020 was an extremely challenging year with many impacts on our monitoring systems, including postponement of our planned Pancake tortoise survey as well as expansion of the rangeland monitoring programme. However, we were able to continue with most of our programmes without any critical damage to the long-term longitudinal data collection capabilities. Here are some of our salient implications from data collected in 2020.

Implications for management

- There is need to continue with ear notching efforts to reduce the number of clean rhinos on the Landscape, in combination with ensuring regular refresher trainings for the field monitoring teams.
- There is need to continue supporting establishment of new rhino sanctuaries to provide sink populations for the burgeoning rhino population on the Landscape.
- Actualization of the proposed hyena project needs to be explored in 2021, both through increased collar deployment as well as resumption of skills transfer from established long-term hyena projects once logistics are back on track post the Covid-19 pandemic.
- Close monitoring should be intensified on lion prides such as *Sarah* and *Carissa* that extend their ranging areas into the community lands so as to mitigate cases of livestock depredation and other associated human-carnivore conflicts.
- There is need to increase community awareness on best animal husbandry practices, including optimal construction of predator-proof livestock enclosures.
- There may be need 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 HWC 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 the Security and Conservation teams and provide a standard framework around which response protocols, data collection and reporting can be structured.
- There is a need to expand soil and vegetation nutrient assessments across the Landscape and through different seasons to understand the fluxes in forage quality throughout the year and explore how wildlife respond to these cyclical changes.
- There continues to be a need for the LBL to explore opportunities for telemetry studies on select birds on the Landscape, primarily the Grey-crowned crane and the Steppe eagle.

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1.0 INTRODUCTION

The Lewa-Borana Landscape (LBL) Research and Monitoring team had a challenging 2020. Like most parts of the global economy, tourism was not spared the negative impacts of the Covid-19 pandemic. With revenues subdued, the entire of Lewa Wildlife Conservancy was forced into a reduced state of operations. For several months of the year, there was a skeleton staff in the department and field activities were reduced to only essentials. However, despite these challenges, the team was able to ensure that most data collection continued and that there were contingencies to fill in any gaps.

As has been the case in the last few years, the year was relatively mixed in terms of rainfall. The first six months received rainfall slightly above the long-term mean, while the second half of the year experienced below average rainfall. In total, the LBL received an average of 569±29mm of rainfall. 2020 also saw our Avifauna programme coming into its own, with regular monthly surveys, citizen science efforts to build the birds' list, as well as expanding surveys into Il Ngwesi Conservancy. This particular thematic area will continue expanding as our collaborations widen and internal capacity increases.

We received three departmental grants in 2020, all as a result of collaborations between the Research and Monitoring team and Lewa International. Two of these grants were for our hydrology programme, which has allowed us to commence work on surface water monitoring, as Our planned Pancake tortoise survey was postponed indefinitely due to impacts of Covid-19. However, we are currently in discussions with partners to identify contingency plans for a rapid assessment across a larger portion of the Ewaso ecosystem. We will update all stakeholders and partners as new efforts solidify and a replacement plan is developed.

Wildlife populations mostly continued to increase or remained stable, further testament to the continued health of our landscape and its ability to maintain and sustain healthy wildlife populations. Below we go into further detail into highlights from each of our thematic areas across the landscape in 2020.

2.0 RHINO MONITORING

2.1 Introduction

Globally, the two rhino species on Lewa-Borana Landscape (LBL); the eastern black rhino (*Diceros bicornis michaeli*) and the Southern White rhino (*Ceratotherium simum simum*) remain categorized as Critically Endangered and Near Threatened respectively. At the end of 2020, Kenya had 853 and 750 Black and White rhinos (KWS, unpublished) of which 13% and 14% respectively were found on LBL. 14 rhino births (7 Black and 7 White) were recorded in 2020 compared to 32 (17 Black and 15 White) in 2019. This lower rate was expected after the record calving rates experienced in 2019. Rhino monitoring activities continued throughout the year as discussed in the sections below.

2.2 Black rhino population performance

The population of Black rhinos increased from 109 to 114 following 7 births and 2 deaths (Table 2.1 and 2.2). This represents a biological growth rate of 9.4% in the 2018-2020 average 3-year moving window period compared to 9.5% in the 2017-2019 period (Figure 2.1). These averages are above the 5% p.a. rate recommended in the well-established rhino sanctuaries in the Country (KWS, 2017).

Table 2.1 Black rhino births on LBL in 2020

#	Calf name	Date of birth	Sex	Dam	Sire
1	Jackline Calf 1	8-Jan-20	Female	Jackline	Sogomo
2	Nashami Calf 6	16-May-20	Female	Nashami	Elvis
3	Juno 2 Calf 3	20-May-20	Female	Juno 2	Folly
4	Number 17 Calf 2	7-Jul-20	Male	Number 17	Hisa
5	Linda Calf 3	3-Aug-20	Male	Linda	Hisa
6	Kagwiria calf 1	15-Oct-20	Male	Kagwiria	Elvis
7	Calisto Calf 6	13-Dec-2020	Unknown	Calisto	Denny

Table 2.2 Black rhino deaths on LBL in 2020

#	Name	Sex	Date of death	Cause of death	Age at death
1	Delia Calf 1	Male	5-Jan-20	Predation by a lion	24 days
2	Rocky	Male	6-Oct-20	Euthanized after sustaining a complete leg fracture	15 years

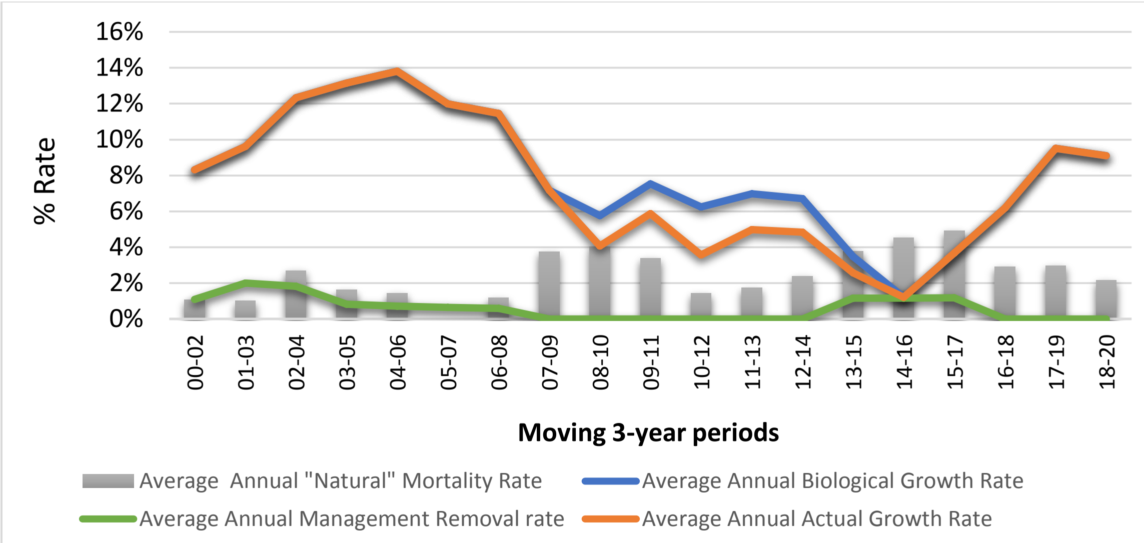

Figure 2.1 Key Black rhino population metrics on LBL, 2000-2020

2.2.1 Population performance indicators

Age at first calving (AFC), inter-calving interval (ICI), sex ratio (SR) and yearly percentage of females calving (PFC) are measures of reproductive performance (Law & Fike, 2018; Du Toit, 2001; Okita-Ouma et al., 2020). Delayed AFC, ICI and skewed SR towards males are indicators of a poorly performing population as they slow down growth. The average ICI in the 2018-2020 period is 2.8 years, PFC is 35% and the SR of females to males is 1.3:1. These three benchmarks are rated as 'good' (Appendix 1). The average AFC in the same period is 8.5 years which is rated as poor. LBL's AFC has been increasing since 2015. Previous studies show that AFC increases with increase in population density (Hrabar & Du Toit, 2005; Du Toit, 2001), and fluctuating quality and quantity of plants (Okita-Ouma et al., 2020). The delayed AFC of Black rhino on LBL adds to the growing body of evidence that the resident population is exhibiting density-dependence effects on biological growth.

The age sex structure is normal, with 50% of calves born being females and 47% males, against a ratio of 54% females and 45% males in the general population. 53% of the population consists of adults, 18% sub-adults and 29% calves (Table 2.3).

Table 2.3 Population structure of Black rhino on LBL in 2020

Age class	Male	Female	Unknown	Sub total	Proportion in population
Calves (0<3.5 yrs)	16	17	1	34	29%
Sub adults (3.5<7 yrs) unless calved	8	12	0	20	18%
Adults (>7yrs)	27	33	0	60	53%
Grand total	51	62	1	114	100%
Proportion in population	45%	54%	1%	100%	

2.3 White rhino population performance

In 2020, the long-term data sets of White rhinos were analyzed in a similar fashion as that of Black rhino which has provided better visualization and analysis (Figure 2.2). The population increased from 97 to 103 following 7 births and 0 deaths (Table 2.5). This represents a biological growth rate of 9.9% in the 2018-2020 average 3-year moving window period compared to 10.2% in the 2017-2019 period (Figure 2.2). One adult male, *Owuan* (21 years) was translocated to Ol Pejeta Conservancy on 24-Nov-2020 to support the Northern White rhino breeding project.

The Landscape's relatively stable grasslands continue to support the growing White rhino population. However, assessment of the ECC needs to be carried out to ensure that the LBL's White rhino population remains healthy. The need for assessment of ECC in all White rhino areas in the County has been identified as one of the greatest priority actions in the first ever White Rhino Action Plan, 2021-2025, currently being drafted (KWS in prep).

Table 2.5 White rhino births on LBL in 2020

#	Calf name	Date of birth	Sex	Dam	Sire
1	Njoki Calf 2	13-Sep-20	Female	Njoki	Cookie
2	Tale Calf 6	19-Sep-20	Male	Tale	Ronnie
3	Lucille Calf 3	29-Sep-20	Male	Lucille	Godon
4	Rinta Calf 8	3-Nov-20	Unknown	Rinta	Samawati
5	Schini Calf 7	10-Nov-20	Male	Schini	Mia
6	Rosie Calf 4	2-Dec-20	Female	Rosie	Owuan
7	Emso's calf 1	29-Dec-20	Female	Emso	Imado

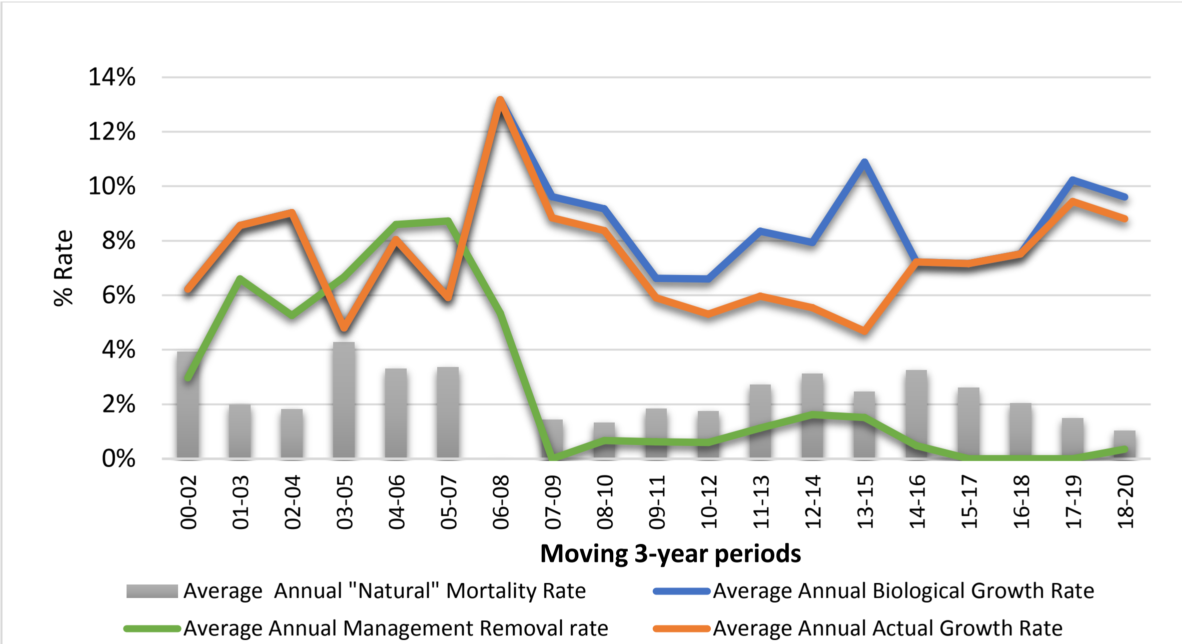

Figure 2.2 Key White rhino population metrics on LBL, 2000-2020

2.3.1 Population performance indicators

The White rhino AFC is 6.3 years, ICI is 2.5 years, PFC is 42% and the sex ratio of females to males is 1:1. These benchmarks are rated as moderate to good (Appendix 1) which indicates the population is performing well. The sex structure consists of slightly more males (50%) than females (49%), with 50% of calves born being females, 46% males and 1% are still unknown. 54% of the population consists of adults, with 19% sub-adults and 27% being calves (Table 2.6). These benchmarks are rated as moderate (Balfour et al., 2019).

Table 2.6 Population structure of White rhino on LBL, 2020

Age class	**Male**	**Female**	Unknown	**Sub total**	**Proportion in population**
Calves (0<3.5 yrs)	13	14	1	28	27%
Sub Adults (3.5<7yrs) unless calved	9	11	0	20	19%
Adults (>7 yrs)	30	25	0	55	54%
Grand total	52	50	1	103	100%
Proportion in population	50%	49%	1%	100%	

2.4 Spatial ecology

2.4.1 Sighting frequency

The average sighting frequency (SF) for Black and White rhino was 1.9±0.02 days and 1.5±0.05 days respectively. This is within the critical sighting frequency of 3 days on the LBL.

2.4.2 Notable shifts in home ranges

The location and size of home ranges are influenced by social interactions (Lent & Fike, 2003), resource (forage and water) availability and breeding activity (Plotz et al. 2016). At the age of 9 years, male black rhino become suitably big, mature and begin to establish territories for themselves (Adcock, 1994). This is what triggered four black rhino males aged between 9 and 11 years to shift their territories. *Barry* (9 years) expanded his territory from the northern part of Lewa to the eastern part, *Barmet* (11 years) moved from the edges of Ngare Ndare Forest Reserve (NNFR) to Borana (Figure 2.3), *Justin* (9.8 years) moved from the northern part of Lewa to Borana and *Sogomo* (9.3 years) expanded his territory from the edges of NNFR to the central part of Lewa. *Subira* (6.6 years), a sub adult female moved from the central part of Lewa to NNFR in January (Figure 2.3). NNFR has adequate browse compared to the central part of Lewa which is generally an open grassland.

Two White rhinos, *Mandela* (11 years) and *Wire* (8.3 years) moved from the Lewa side to Borana but came back in the month of June and October respectively.

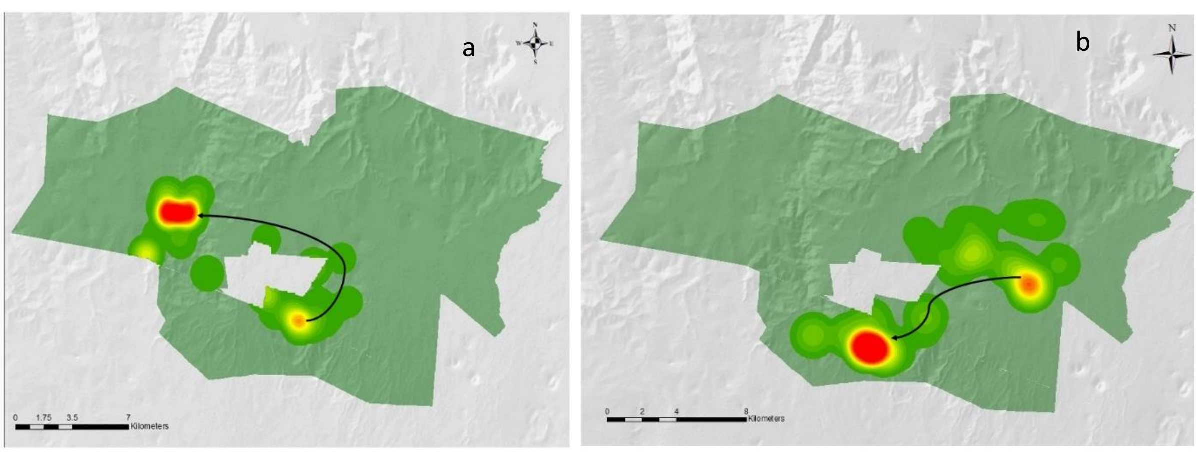

Figure 2.3 Changing home ranges for (a) *Subira* and (b) *Barmet*

2.5 Rhino veterinary interventions

2.5.1 Ear notching exercise

To reduce the number of clean rhinos in the population and ensure that individuals are positively identified by field rangers, an ear notching exercise was conducted in March 2020. This was in line with the overall objective of ensuring that over 60% of individual rhinos can be independently recognized by the rhino monitoring team as outlined in the Black Rhino Action Plan 2017 – 2021. Notching of rhino ears is a common method for distinguishing free-ranging individuals, as the species often lacks unique marks or patterns (Hussek & Hackländer, 2019). Having clearly identifiable rhinos makes monitoring easier, more transparent and in the long run allows quality information to be maintained for decision making (Ouma, 2004). The exercise was jointly carried out by Kenya Wildlife Service and LBL, with a total of 17 rhinos successfully ear notched (Table 2.7).

Table 2.7 Breakdown of rhinos ear-notched on LBL in March 2020

Species	**Lewa side**		**Borana side**		**Total**
	Male	Female	Male	Female	
Black rhino	0	4	1	3	8
White rhino	4	4	0	1	9
Total	**4**	**8**	**1**	**4**	**17**

Currently, 58% of Black rhinos are identifiable through ear notches and other unique features, 15% are clean and independent and 27% are calves that can be sighted in association with their mothers. 61% of White rhinos are identifiable, 17% are clean and independent and 22% are calves that can be sighted in association with their mothers. So far, 21 (11 White and 10 Black) rhinos are suitable candidates for ear notching in 2021. The number of clean rhinos is expected to increase as more calves graduate into adulthood.

2.5.2 Other rhino-related interventions

Dominique, an adult male White rhino aged 12.6 years was treated on 25th March 2020 after sustaining injuries on his left eye and on the perineum. This was after picking up a fight with another adult male *Ronnie* (17.2 years) over territory. *Rocky* (15.2 years), an adult male Black was treated but subsequently euthanized on 6th October 2020 after sustaining a complete fracture on the left front leg.

2.6 Rhino body condition assessment

The annual dry season body condition assessment targeting the relatively old and lactating rhinos was conducted between July and September. The assessment follows the criteria developed by Adcock et al. 2003 where body condition scores range from scale 1-5, with 1 indicating emaciation and 5 indicating obesity. Most of the rhinos were observed to have a body condition score ≥3.5 which represents a rhino in good body condition. This was largely due to the high rainfall received from the last quarter of 2019 to April 2020 which contributed to availability of adequate browse. Two Black rhinos, *Mutane* (40 years) and *Zaria* (32.8 years) had a body condition score of 3.0 (fair to good). This can be attributed to their advanced age. Both animals are the oldest male and female black rhinos on LBL respectively.

2.7 Black rhino mini audit and rhino evidence files

As part of the Rhino Impact Bond Investment Readiness Phase project, a Black rhino mini audit was done in the month of February by the Project Manager of the proposed Bond project. The main purpose was to review all Black rhino evidence files and data sets, identify any errors, determine the quality of evidence, and understand what percentage of the population was been evidenced in 2019. The Audit showed that 88.1% of the rhinos had clear auditable evidence, 6.4% had low quality evidence and 5.5% had insufficient evidence. Improving the quality of evidence provided by camera traps, linking the evidence to records in the KIFARU database, and updating of Master ID files to provide clear details to any Independent Verifier are some of the key recommendations from the Audit. These recommendations were addressed in the 2020 evidence files which are now complete. The Black rhino Master ID files were also updated and the same was replicated to White rhinos.

2.8 White Rhino Action Plan, 2021-2025

The Wildlife and Conservation Management Act of 2013, Schedule 6 details the need to have Action Plans for all endangered species in the Country. The White rhino is one of the listed species. Currently, there is no White Rhino Action Plan in the country and that is why the KWS found it necessary to begin the process of drafting an Action Plan. The consulting team met with stakeholders from LBL and Il Ngwesi on 14-Aug-2020 at Lewa HQ to get their views and proposals that will be incorporated in the Plan. A number of issues were discussed including the ownership, strengths, weaknesses, opportunities and threats to White rhino conservation, objectives, and specific actions including the need for assessment of ECC of White rhinos and other competing grazers, integrating White rhino data into KIFARU database or as a stand-alone database to help with storing and analysing data sets for management uses.

2.9 Rhino monitors refresher training

The annual rhino monitors refresher training was held on 16th and 17th November 2020. The aim of the training was to equip trainees with adequate skills to collect quality data on rhinos. Since 2018, majority of the rhino monitors have changed their job from rhino monitors to gate keepers. In addition, new recruits have been employed thus necessitating the need for training. The course modules recommended by the African Rhino Specialist Group (Adcock et al., 2003) were covered during the training. These modules include conservation background and status, rhino biology and behaviour, patrol and tracking techniques, ageing and sexing of rhino, rhino identification features, rhino body condition assessment, data collection and verification.

2.10 Conclusion and recommendations

Rhino monitoring activities scheduled through to end of the year were successfully completed. Notably, ear notching exercise, Black rhino mini-audit, body condition assessment and the annual refresher training were completed.

Though the identifiable population is almost 60% (KWS, 2017) required to independently identify rhinos by the monitoring team, there is need for continuation of a routine ear-notching programme to enhance accurate rhino reporting.

Since the ECC for white rhinos on LBL has not been studied extensively, there is need to engage experts on the same for the Landscape. This will help avert density related issues and resources competition bearing in mind the increasing population of herbivores such as buffalo in the Landscape.

The Black rhino population has reached the ECC, this can be seen in the increasing age at first calving. To maintain the ECC and encourage the population growth rate, there is need to periodically remove the surplus animals to other suitable rhino range areas in Kenya, as recommended in the LBL Black Rhino Theory of Change 2019. The RIB project is projected to commence in Q4 2021-Q1 2022 which is targeted towards providing such an outlet.

3.0 PREDATOR MONITORING

3.1 Introduction

The Lewa-Borana Landscape supports several large predators namely the lion, leopard, cheetah, and the Spotted hyena. The landscape is also home to a number of medium-sized predators including the Striped hyena, serval cat, caracal, Black-backed jackal, and Side-striped jackal.

During the year, we recorded data on lion and hyena population parameters, their spatial – temporal trends, livestock depredation incidences, predation, and collected their scat for diet determination. These datasets enabled us to determine prey preferences, movement patterns, ranging patterns, areas prone to human-carnivore conflicts, and the identities of lion using the whisker-spot pattern method.

3.2 Population performance

3.2.1 Lion population

The Landscape has a population of 57 lions aggregated into five prides and two male coalitions (Table 3.1). We recorded 11 new births within the year. The cubs were from *Simone* (2 cubs), *Carissa* (3 cubs), *Dalma* (3 cubs), and *Njaa's* pride (3 cubs). Currently, ten cubs born in the course of the year are surviving after *Simone* lost one cub from unknown causes. In addition, one cub born in the previous year from *Njaa*'s pride was trampled by a herd of buffalo on the western part of the Landscape.

Two adult lions (*Defender* and *Suzie*) died due to intraspecific territorial fights while another adult male known as *Loner*, was eliminated under the Problem Animal Control programme after consistently killing cattle at Marania Farm. Subsequently, no livestock depredation incidences were reported in the Farm.

In addition, a four-year-old male known as *Omar* was translocated to Tsavo East National Park after killing 13 livestock within three weeks at Leparua community bordering LBL to the North. Translocation of large carnivores to mitigate human–predator conflict has been proven effective in some instances (Linnell et al., 1997; Fontúrbel & Simonetti, 2011) even though homing behavior and reverting to livestock predation have been reported (Linnell et al., 1997).

As part of the ongoing pilot project to control the high breeding rate of lions, in the year, six lionesses namely *Sarah* (12 yrs), *Simone* (7.9 yrs), *Doris* (4.9 yrs), *Sue* (7.9 yrs), *Fera* (11.9 yrs), and *Njaa* (4.8 yrs) were fixed with reversible contraceptive implants. This method is effective given that *Carissa* and *Simone* who were fixed with similar implants in 2017 were observed to be in oestrus at various points in the year, and subsequently gave birth after the implants expired. The lion population was monitored using traditional tracking techniques such as direct observation, blended with modern methodologies such as the use of GSM satellite collars.

To enhance the lion monitoring programme, three lions namely *Omar* (5 yrs), *Sarah* (12.9 yrs), and *Fera* (11.9 yrs) were collared with GSM/VHF collars.

Table 3.1: Lion population structure on LBL in 2020

	Adults		**Sub adults**		**Cubs**			**Total by pride/coalition**
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Unknown**	
Sarah's pride	2	6	0	0	0	1	0	9
Dalma's pride	0	2	0	0	0	0	3	5
Bredymark's pride	1	3	0	4	0	0	0	8
Carissa's pride	0	4	0	0	0	0	3	7
Njaa's pride	0	6	6	8	0	0	3	23
Ntulele's coalition	4	0	0	0	0	0	0	4
Dick's coalition	1	0	0	0	0	0	0	1
Total by age class	**8**	**21**	**6**	**12**		**1**	**9**	**57**

3.2.2 Hyena population

The hyena population stood at 134 animals, comprising of 84 adults, 45 sub adults, and 5 cubs. Further demographic research that was planned to commence in the year in partnership with Professor Kay Holekamp of the Mara Hyena Project have been significantly delayed due to impacts of Covid-19. A new research framework will be developed once the situation stabilizes.

3.2.3 Pilot project for Leopard monitoring

In collaboration with the Northern Rangelands Trust (NRT), an infra-red camera trap array was fixed at different hotspots across LBL. The survey lasted three months, recording a total of four individual leopards. However, other direct and indirect evidence suggest that there are more than 15 leopards on the Landscape. This is the second survey after another one in 2015 where eight individuals were recorded from the infra-red camera traps. These data will help develop a more comprehensive leopard monitoring programme in collaboration with San Diego Zoo Global (SDZG) global leopard project that has currently been delayed due to the Covid-19 pandemic.

3.3 Spatial ecology

Lion territories were mapped from collar and sightings data using ArcMap 10.6.1. These territories overlapped but each pride maintained a specific core area (Figure 3.1-3.6).

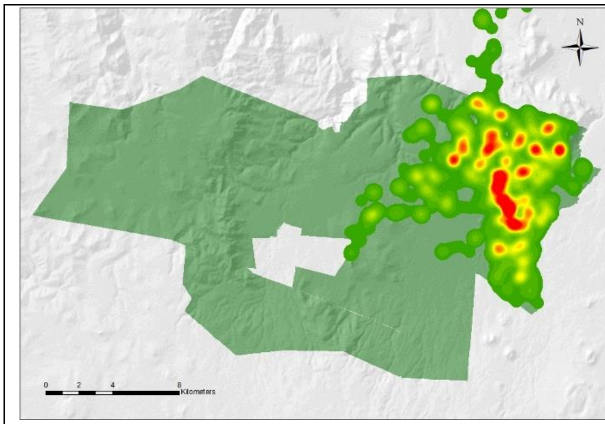

Figure 3.1: *Sarah's* pride ranging areas, 2020

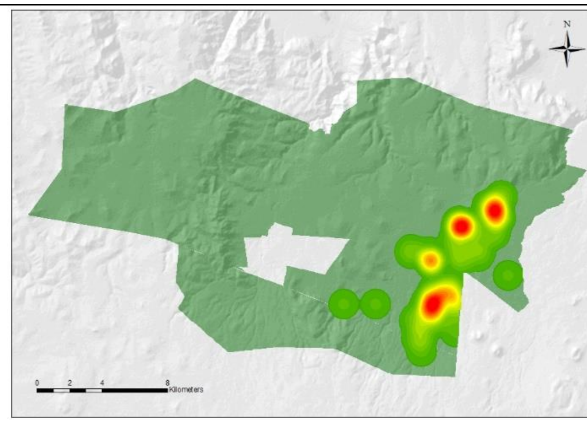

Figure 3.2: *Dalma's* pride ranging areas, 2020

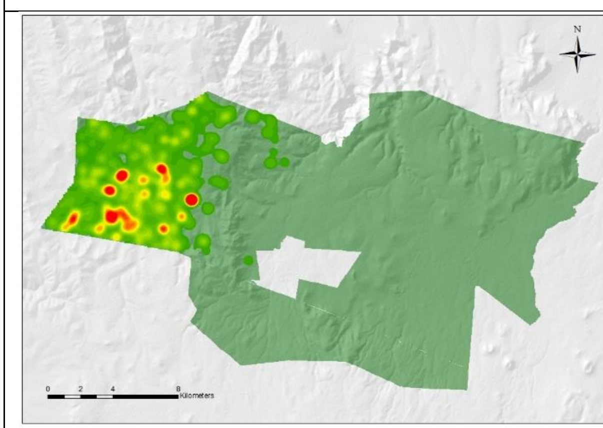

Figure 3.3: *Bredymark's* pride ranging areas, 2020

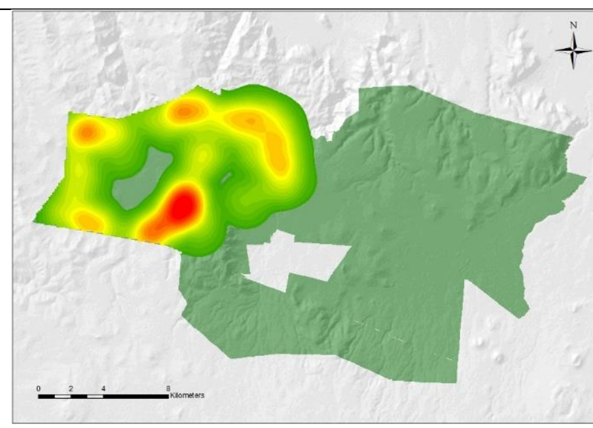

Figure 3.4: *Njaa's* pride ranging areas, 2020

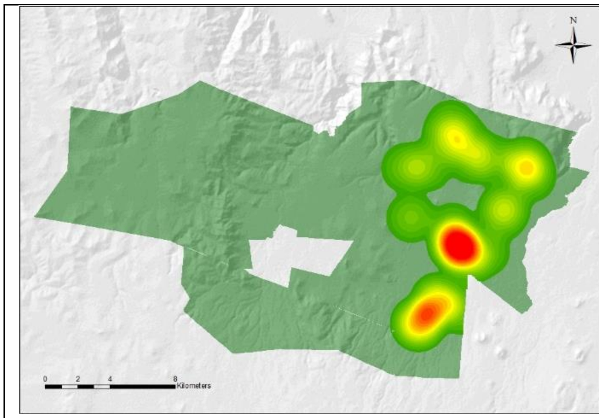	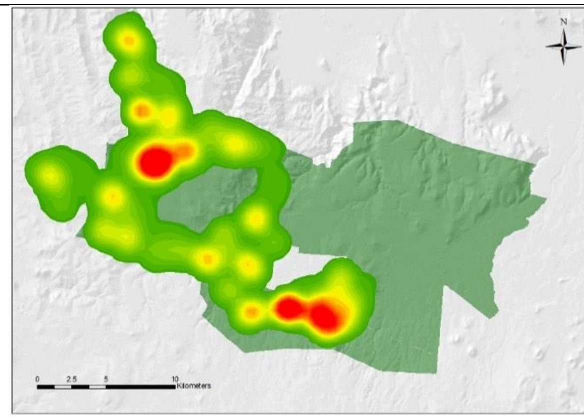
Figure 3.5: *Ntulele's* pride ranging areas, 2020	**Figure 3.6:** *Carissa's* pride ranging areas, 2020

3.4 **The Kenya Wildlife Service (KWS) Lion Survey Workshop**

The Predator Monitoring Officer attended the KWS Lion Survey Workshop held at African Wildlife Foundation (AWF) in Nairobi. The objective of the training was to build capacity on how to estimate lion population using a standardized method known as the Bayesian Spatially Explicit Capture-Recapture model (SECR). We hope to internalize this model and apply it in our lion population estimates.

3.5 Human-carnivore conflicts

Predation on livestock is the main source of conflict between large carnivores and humans (Sillero-Zubiri et al., 2004; Macdonald et al., 2010) leading to losses that have economic impacts (Fleming et al. 2006). Historically, management of large-carnivore populations has been a component of livestock husbandry, and improvements in technology have allowed increasingly effective control methods (Fleming et al., 2006). In some places where large-carnivore populations have been eradicated, traditional husbandry techniques have been abandoned and livestock are allowed to graze over larger areas unsupervised (Linnell et al., 1996).

In 2020, a total of 29 known depredation incidences were reported, resulting in the death of 46 heads of livestock across adjoining community areas. Lion, hyena, leopard and wild dog were responsible for the losses (Table 3.2).

Table 3.2: Causes of livestock depredation on LBL, 2020

Species	Cattle	Shoats	Total by predator
Lion	16	9	25
Hyena	0	13	13
Leopard	0	3	3
Wild dog	0	5	5
Total by livestock type	**16**	**30**	**46**

Of the 46 livestock lost to predators, 54% were by lion, 28% were by the spotted hyena, 11% were by wild dog and 7% were by leopard. Specifically, hyena, leopard and wild dog attacked shoats, whereas lions primarily attacked cattle. 69% of the incidences occurred at night when livestock are in bomas.

3.7 Wildlife mortality

Monitoring of wildlife mortality is important in conservation as the information can be used to determine the status of species and predict trends on their population performance.

A total of 52 mortality cases were recorded in the year. The vast majority of these cases (92%) resulted from predation by lions. Fence entanglement and unknown causes contributed 8% of the cases (Figure 3.7).

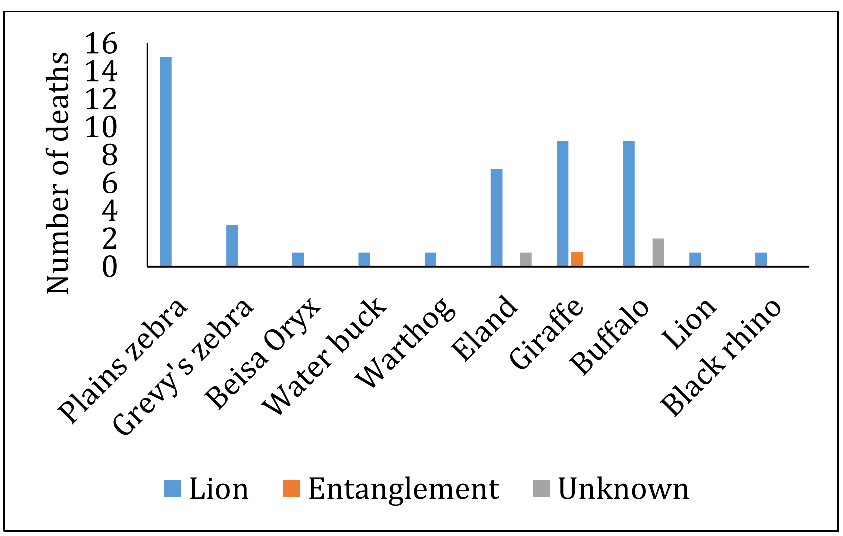

Figure 3. 7: Causes of wildlife deaths on LBL

To determine the selectivity of prey species by lions, 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 giraffe and eland were preferred by lions across the years. Impala, Buffalo, and Beisa oryx were avoided by lion. Other species were taken in accordance to their availability (Table 3.4).

Table 3.4: Comparison of Jacob's index (D) values calculated for nine prey species on LBL, 2014-2020

Species	2014	2015	2016	2017	2018	2019	2020
Plains zebra	0.3	0.2	0.4	0.2	0.2	0.3	0.0
Grevy's Zebra	0.3	0.3	0.3	0.0	- 0.1	0.2	0.0
Waterbuck	0.4	0.4	0.1	0.1	- 0.2	- 0.5	- 0.2
Beisa Oryx	0.2	- 0.6	- 0.3	- 0.6	- 0.6	- 0.6	- 0.5
Eland	0.0	0.4	0.2	0.4	0.5	0.5	0.6
Warthog	0.7	0.7	- 0.3	0.5	0.6	0.3	- 0.2
Impala	-0.7	-0.6	-0.1	-0.8	-1.0	-1.0	-1.0
Giraffe	0.4	0.2	0.4	0.4	0.8	0.7	0.7
Buffalo	-0.8	- 0.5	- 0.2	0.0	- 0.2	0.0	- 0.5

3.7 Scat analysis

A total of 70 scat samples from lions (n=37) and hyenas (n=33) were collected and analyzed for prey hair content. Plains zebra remained the key prey species for the two predators. The proportion of individual species hairs in lion and hyena diets indicates that there continues to be diet overlap between the lion and hyena (Figure 3.8 a & b). The occurrence of livestock hairs in both lion and hyena scats indicates their interaction with livestock in the neighbouring community areas.

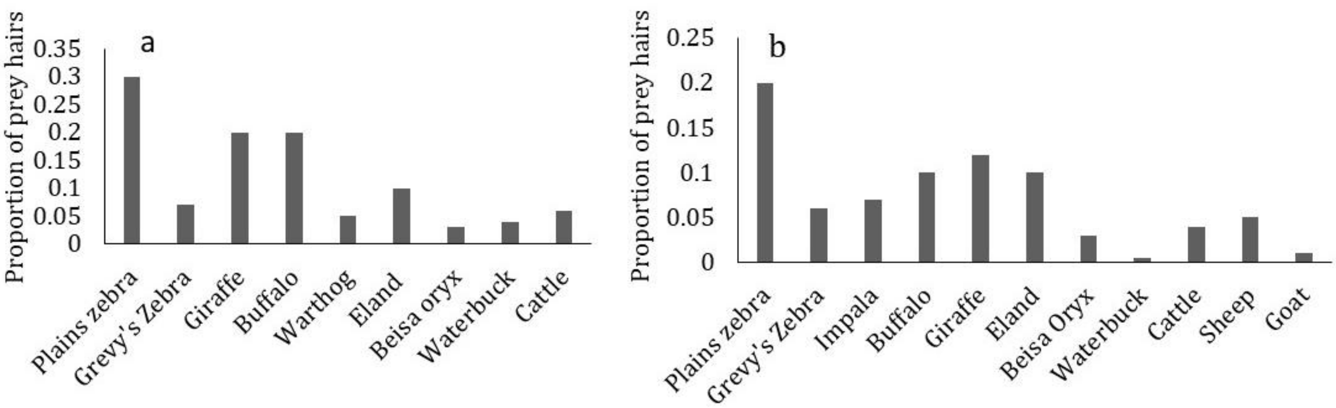

Figure 3.8: Proportion of prey species hairs found in (a) lion and (b) hyena scat

3.8 Conclusions and recommendations

Simone and *Carissa* reverted to their normal breeding cycle after a contraceptive trial that lasted for two years (2017-2018). Given the success of this trial, the implants proved to be self-reversing and can be reliably used to manage lion population in small reserves while preserving pride structure and organization.

Intensive hyena monitoring will be more impactful in terms of our decision-making processes once skills transfer from partners like the Mara Hyena Project is actualized post Covid-19. The proposed leopard monitoring programme under the San Diego Zoo Global Leopard Project was delayed due to Covid-19. This will be prioritized in 2021.

Close monitoring should be intensified on lion prides such as *Sarah* and *Carissa* that extend their ranging areas into the community lands so as to mitigate cases of livestock depredation and other associated human-carnivore conflicts.

The Research and Community Departments will continue raising awareness to the neighbouring communities on the importance of proper livestock husbandry to mitigate livestock losses, especially the use of predator proof bomas.

4.0 UNGULATE MONITORING

4.1 Introduction

To meet conservation goals, ecosystem monitoring has expanded from concentrating effort on endangered species to a more inclusive approach targeting other species to understand ecosystem function and for sustainable biological diversity (Balmford et al., 2005; Western et al., 2009). In addition, monitoring population parameters is important for forecasting, policy formulation, and wildlife population management.

In 2020, we carried out monthly surveys to monitor population dynamics on the key ungulate 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 reticulata*), and eland (*Taurotragus oryx*). We also analyzed data from the motion sensor camera traps placed at the four wildlife migratory gaps namely; the Mount Kenya endpass gap, the Mount Kenya underpass gap, the New Mount Kenya underpass gap, and the Northern gap.

4.2 Results and discussions

4.2.1 Ungulates performance

The performance of ungulates is triggered by their response to ecosystem changes assessed by looking at their growth potential as well as the proportion of foals and juveniles within a certain ungulate species (Rubenstein, 2010; Rubenstein et al., 2018, unpublished report). However, most ungulates are able to overcome major changes in their dynamics due to their ability to store fat reserves and balance energy needs for use during the dry season when forage is scarce (Hempson et al., 2015; Stephenson, *et al.*, 2020; Kohli et al., 2014) preserving their body scores. They also possess capability to recover fat reserves when conditions improve (Adamczewski et al., 1993; Chilliard et al., 1998). In 2020, the LBL received above average rainfall and this could explain there was no detectable drop in body condition scores in ungulates.

All species monitored apart from giraffe indicated an improvement in the percentage of juveniles and young towards 30% mark for the last four years (Figure 4.1). Also, all the species have consistently recorded a growth potential between medium and high (Figure 4.2). These parameters indicate characteristics of stable and growing populations, especially if it exceeds 30% mark (Rubenstein, 2010; Rubenstein et al., 2018, unpublished report). Of continuing concern is the giraffe population that has a growth potential of medium to high but the percentage of juveniles and calves has remained below 15%. This is likely an indication that giraffe are giving birth, but the calves are not surviving, probably due to predation, a theory supported by the relatively high Jacob's index for Giraffe (Table 3.4).

The hartebeest population on the Lewa side of the landscape has grown from 12 individuals to 37 individuals triggered by births and a few immigrants from Borana Conservancy. Since 2014, we have recorded 47 births, of which 22 individuals (47%) have survived. 77% of the surviving individuals have moved out of the vulnerable age bracket (6–12 months).

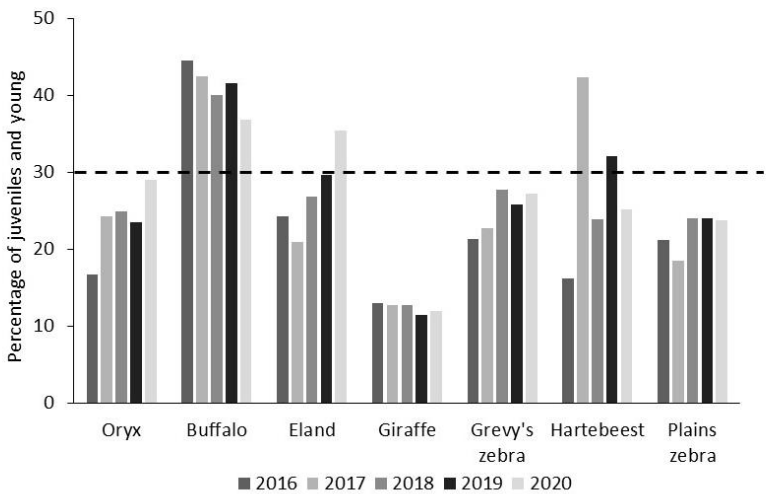

Figure 4.1: Proportion of young and juveniles for ungulate species monitored. The dotted black line indicates the 30% recommended level for stable populations.

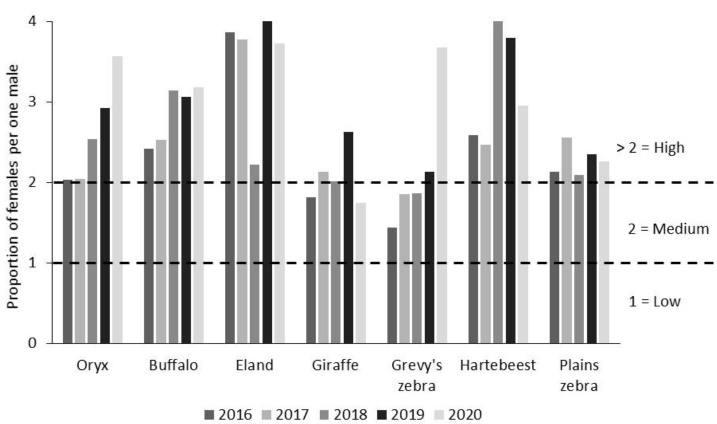

Figure 4.2: Proportion of adult females per 1 adult male. The black dotted lines indicate levels of various growth potential, i.e, Low, Medium and High.

4.2.2 Grevy's zebra survival rates

Amidst many challenges in the development of an automated online stripe identity software (WILDBOOK), we analyzed the photographs of Grevy's zebra using the existing National Grevy's zebra database. The database is offline and shared among collaborating partners in the country thereby slowing the process of identification. So far, we have been able to analyse the 2019 (January to mid-December) data and we present the status of the foals that were born in 2019.

38% (n=195) of all individuals (N=509) encountered in 2019 were foals of which 54% (n=105) were males while 44% (n=90) were females. Out of these, 56% (n=109) were born in 2019 comprising of 58% (n=63) male and 42% (n=46) female. Of the 109 foals born in 2019, 59% (n=64) were surviving while 41% (n=45) were presumed dead by the end of the year. The surviving foals comprised of 53% (n=34) males and 47% (n=30) females while the dead foals comprised of 64% (n=29) males and 36% (16) females. Analyses of this dataset will continue to establish the population dynamics and trends of the foals which are vulnerable to natural factors in their habitats. However, this is entirely dependent on the development of a robust stripe identify database that will ensure timely and consistent data is available**.**

Once we receive the national database again, we will commence analysis of 2020 data, hopefully completing analyses by mid-2021. This slow nature of analyses (while severely compounded by Covid-19 impacts) puts into perspective the need for the Grevy's Zebra Technical Committee (GZTC) members to pool efforts and resources into the completion of the Grevy's Zebra Wildbook. The next version of this completed database will need to be housed in-country, with local IT experts brought into the development fold to ensure local troubleshooting capacity.

4.2.3 Annual wildlife count

The annual wildlife count for the LBL was completed. The findings were that most wildlife species on Lewa are stable or increasing. Concern at the moment is the Reticulated giraffe where the population is decreasing and buffalo which continue to increase significantly (Kaaria et al., 2020, unpublished report). Table 4.1 shows the total population recorded for the species we monitor from 2016 to date.

Table 4.4: Game count results for the indicator species from 2016 - 2020

Species	Year				
	2016	**2017**	**2018**	**2019**	**2020**
Eland	280	192	322	291	245
Beisa oryx	179	220	178	227	307
Buffalo	1220	1391	1623	1753	2086
Giraffe	273	251	127	167	178
Hartebeest	30	62	64	64	93
Plains zebra	1262	1236	1228	1484	1599
Grevy's zebra	299	292	308	313	331

4.2.3 Translocation of Grevy's zebra to Sera Rhino Sanctuary

Kenya's Recovery and Action Plan for Grevy's zebra outlines the need to boost small breeding populations through translocations to ensure their viability and promote population growth (KWS, 2017). The Action Plan also outlines the necessity to train community rangers to ensure proper monitoring of the population.

In collaboration with the Kenya Wildlife Service (KWS) and Northern Rangelands Trust (NRT), we translocated 25 Grevy's zebra (1 male and 24 females) to boost the existing population of approximately 19 individuals in Sera Rhino Sanctuary.

Together with NRT and Grevy's Zebra Trust (GZT), we trained rangers on standard techniques of monitoring the population of Grevy's zebra in-situ. We also developed a comprehensive long-term monitoring protocol to monitor the species to inform population performance so that informed management interventions can be undertaken (Kaaria, T. & Kimiti, 2020, unpublished report).

4.2.4 Movement of wildlife through the migratory gaps

Migratory gaps in perimeter fences creates safe pathways for wildlife to migrate in and out of protected areas which encourages landscape-level connectivity (Dupuis-Desormeaux et al., 2018).

Using infra-red cameras, Lewa monitors four fence-gaps along the migratory corridors across the landscape namely, the Mount Kenya Endpass, Mount Kenya Underpass, New Mount Kenya Underpass, and the Northern gap. We present the trends of gap usage over the period of 8 years as well as compare the crossing events of wildlife during the wet and dry periods. Based on the distribution of rainfall, January, February, July, August, and September generally represent dry period while March, April, May, October and November represent wet period.

4.2.5 Mount Kenya Endpass

There was no significant difference in crossing events of all wildlife on the Mt. Kenya Endpass between the dry (21,467) and wet period (21,542) ($\chi^2 = 0.1308$, df = 1, p = 0.7176) (Figure 4.1a). There were more crossing events of elephant towards the corridor leading to Mount Kenya forest (1,772) than into the corridor that leads to Lewa through the Ngare Ndare Forest Reserve (NNFR) (1,547) during the dry period ($\chi^2 = 15.253$, df = 1, $p < 0.001$) (Figure 4.1b).

During the wet period, there were more crossing events of elephant towards the corridor leading to Lewa through NNFR (1,233) than towards Mt. Kenya Forest (1,098) ($\chi^2 = 7.8185$, df = 1, p = 0.005) (Figure 4.1b). The trend indicates a significant increase in the use of corridor by all wildlife shown by increased crossing events from 2013 to date ($\chi 2 = 15195$, df = 7, p = 0.000) (Figure 4.1c).

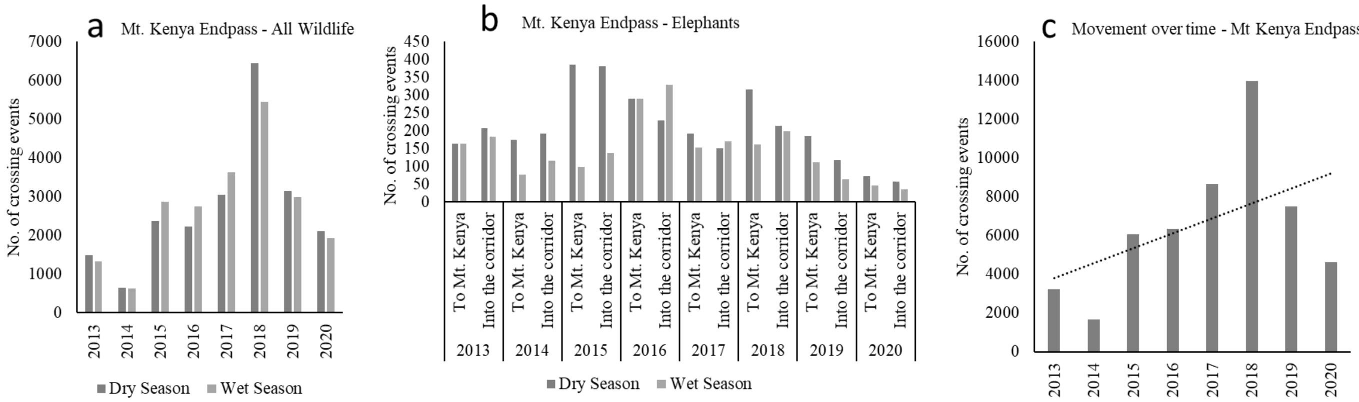

Figure 4.1: a) Seasonal movements of all wildlife species using the gap; **b)** Seasonal movements of elephants; **c)** Trend of all wildlife species using the gap

4.2.6 Mount Kenya Underpass

There was a significant difference in crossing events of all wildlife on the Mount Kenya Underpass gap between the dry (8,425) and wet (5,823) period ($\chi^2 = 475.18$, df = 1, p = 0.000) (Figure 4.2a). There were more elephant crossing events towards Mount Kenya Forest through the corridor (2,467) than towards Lewa through NNFR (2,264) during the dry period ($\chi^2 = 8.7104$, df = 1, p = 0.003; Figure 4.2b). During the wet period there were more elephant crossing events towards Lewa through NNFR (1,283) than towards Mt. Kenya Forest through the corridor (1,087) (χ^2 = 16.209, df = 1, p = 0.0001; Figure 4.2b). The trend indicates a significant increase in crossing events for all wildlife from 2013 to date (χ^2 = 2315.4, df = 7, p = 0.0001; Figure 4.2c).

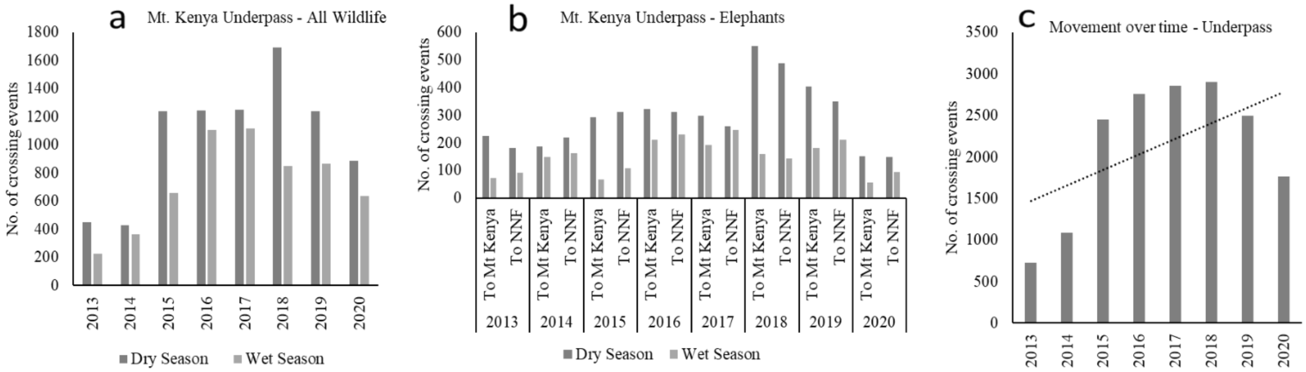

Figure 4.2: a) Seasonal movements of all wildlife species using the gap; **b)** Seasonal movements of elephants; **c)** Trend of all wildlife species using the gap

4.2.7 Northern gap

There was a significant difference in crossing events of all wildlife on the Northern gap between the dry (43,786) and the wet (54,233) period (χ^2 = 1113.5, df = 1, $p < 0.0001$; Figure 4.3a). During the dry period there were more crossing events of elephant into Lewa from the north (7,432) than out of Lewa to the north (7,396) (χ^2 = 0.0874, df = 1, p = 0.768) (Figure 4.3b). During the wet period there were more elephant crossing events out of Lewa towards the north (12,446) than into Lewa from north (10,286) (χ^2 = 205.24, df = 1, $p < 0.0001$; Figure 4.3b).

Unlike other gaps, this corridor indicates a significant reduction in crossing events for all wildlife from 2013 to date (χ^2 = 5918.3, df = 7, p = 0.001; Figure 4.3c).

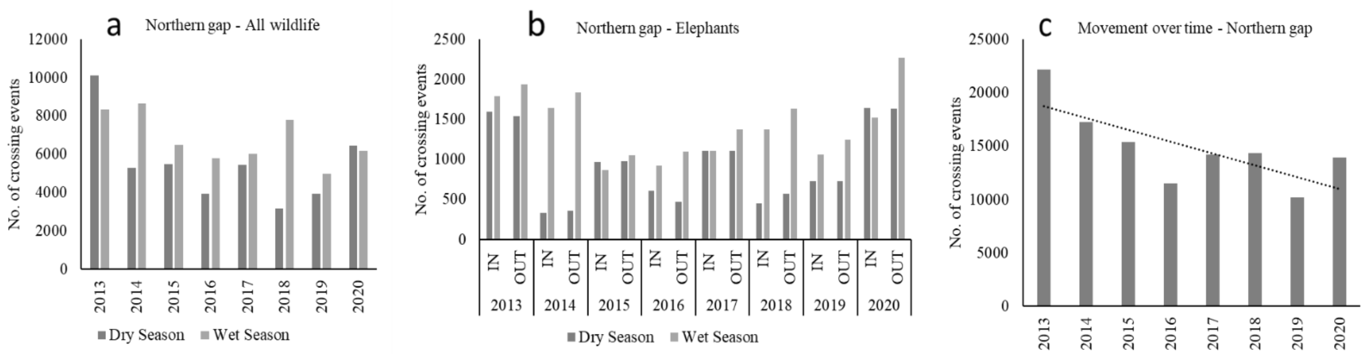

Figure 4.3: a) Seasonal movements of all wildlife species using the gap; **b)** Seasonal movements of elephants; **c)** Trend of all wildlife species using the gap

4.2.8 New Mount Kenya Underpass

The New Mount Kenya Underpass has been in operation for the last 1.5 years. Up to date, the gap has recorded a total of 761 crossing events mostly from elephants which recorded at least 75% of all the crossing events. Other species utilizing the gap include waterbuck (109), reedbuck (35), leopard (9) Spotted hyena (8), bushbuck (21), caracal (2), serval cat (1), and jackal (1). Looking at 3 month window from the time the infra-red camera trap was fixed, the numbers of crossing events have been decreasing (Figure 4.4). However, this is a short time from which to draw conclusions and monitoring will continue for more insights.

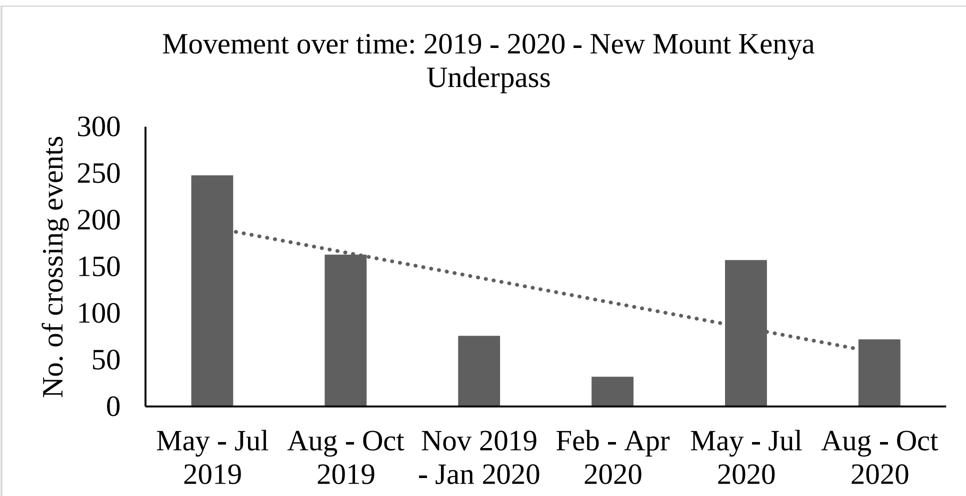

Figure 4.4: Trend of crossing events of all wildlife species using the gap

There is a strong relationship between seasons and movement patterns of wildlife. This is particularly so with elephants where they migrate to higher and lower elevations during the dry and wet periods respectively (Bohrer et al., 2014) as exemplified by our data.

4.3 Conclusion and recommendations

Even with medium to high growth potential of giraffe, the number of juveniles and calves in the population remain suppressed. Jacob's selectivity index shows giraffe as the most preferred prey species for lions, with an index of 0.7. It is recommended to continue manipulating the breeding of lions in order to enhance improvement of the performance of giraffe population.

We continue to face challenges in analysing Grevy's zebra stripe pattern data to obtain foals survivorship in real-time due to the lack of fast automated stripe identity database. Use of the current National Grevy's zebra stripe identity database which is slow, offline, and shared among partners has slowed the process allowing us only to analyse 2019 data. There is need to continue engaging with all the partners involved in the development of WILDBOOK software to hasten its development, which will improve data processing and analyses.

5.0 ELEPHANT MONITORING

5.1 Introduction

Elephants are mega-herbivores that require large tracts of land for their survival. Because of their large body size, they have a huge impact on the environment. Elephant are well known to play an important ecological role through manipulation of vegetation structure and composition (Bohrer *et al*., 2014). They cause change in vegetation structure and composition through their varied seasonal choice of food items, including tree bark. Debarking trees makes them more susceptible to other damage such as fires and diseases which may cause direct mortality (Pamo & Tchamba, 2001; Holdo, 2003**).** Attention in East Africa is invariably drawn to woodland change to open grasslands in the presence of elephants (Buechner & Dawkins, 1961).

In the LBL ecosystem, elephants commonly destroy trees by debarking, uprooting and breaking branches. Additionally, they are commonly documented raiding crops in the surrounding community farms. Monitoring and identification of elephant in the landscape continued with the primary focus being on fence breakers and crop raiders in order to make informed management decisions. Interestingly, following the good rain received in 2020, fence breakage incidents have significantly reduced. Similarly, elephant crawling under the exclusion zone fence wires have also reduced, as there has generally been good forage availability across the landscape, despite 13 matriarchal family groups and 7 large bulls coming back into the Conservancy. There was a gap in data collection over the months of April and May due to the Covid-19 pandemic.

In March, 1 bull and 1 female elephants *(MT Kenya* and *Cointreau)* that use the corridor from Lewa to Mount Kenya were successfully collared in order to monitor their whereabouts and movement and usage of the resources within the landscape. Collaring was jointly carried by KWS, Save The Elephant (STE) and Lewa teams.

5.2 Trends in fence breakages

In total, 89 fence breaking incidences were recorded through to the end of the year. Out of these, 10% (n=9) were recorded on the main boundary fence lines, while 90% (n=80) were on the exclusion zones fence lines (Figure 5.1). The most affected boundary fence line was *Mlima Kali*.

Though a few cases of elephant originating from Lewa were reported breaking this section, most of the incidences recorded were from elephants coming from the LMD/Leparua Conservancy area. Concerted efforts have been made to address this challenge through upgrading of the fenceline and engagement with KWS and community members.

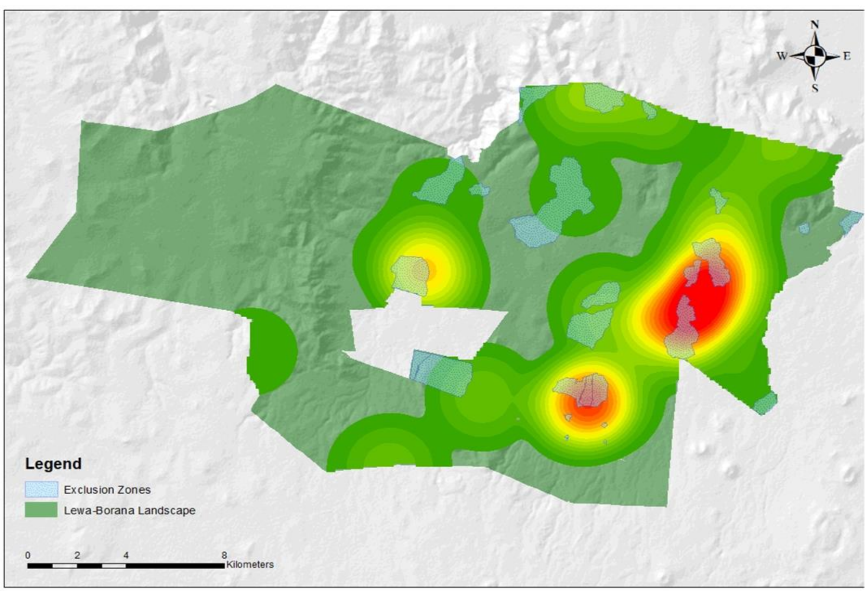

Figure 5.1: Heat map of elephant's breakage incidences on LBL, Jan-Dec 2020

In the exclusion zones, 39% (n=31) of incidences involved elephant crawling under the 2-strand fence wires while 61% (n=49) accessed by snapping the wires. Among the exclusion zones, *Lewa HQ, Karionga, Luai ya Kona Safi, Digby's* were the most hit by elephants (Figure 5.2). These exclusion zones hold large tracts of vegetation which attracted the elephants.

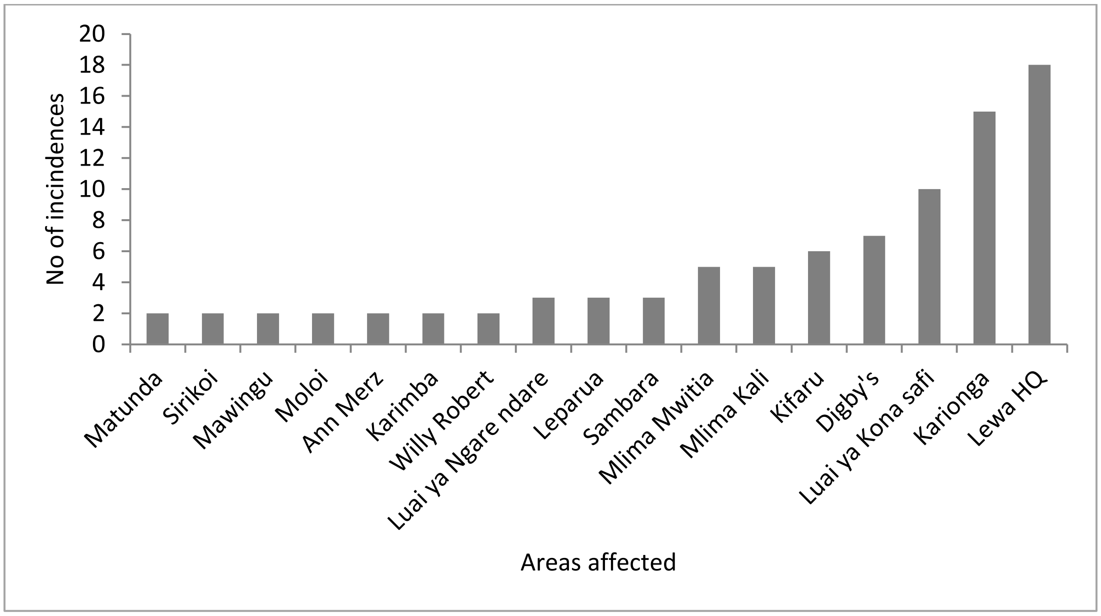

Figure 5.2: Related incidences of breakages across various locations

Mjasiri, Kamongo, Melo, John, Keke, Odongo and *Moreher* were mainly the culprits responsible for the incidences recorded (Figure 5.3). Four of these bulls namely, *Mjasiri, John, Melo,* and *Keke* had their tusks trimmed in 2013. However; they have since learnt new tactics of snapping wires using their shortened tusks, trunks and also by stepping on the posts.

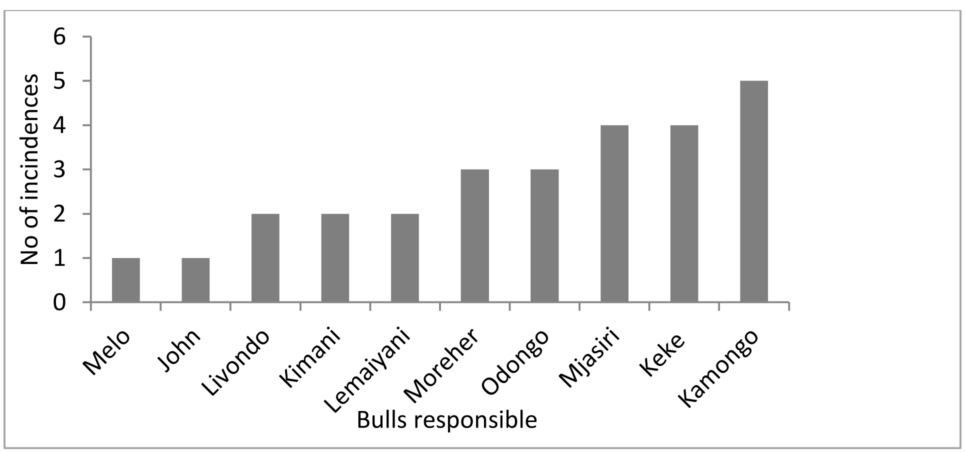

Figure 5.3: Elephant bulls responsible for fence breakages

Most of the matriarchal family groups that continued to access the exclusion zones through crawling were *Sanaipei, Linnet, Carl,* and *Wendy.* Each family group comprised of over 15 individuals (Figure 5.4). Despite the fence upgrades undertaken on *Lewa HQ, Karionga*, and *Digby's* exclusion zones, elephant continued to access these exclusion zones. Since most of the breakages occurred at night and early in the morning, it was difficult to identify the exact culprits. Camera traps were fixed on the hotspot areas in an attempt to get the photographs of these elephant for easy identification.

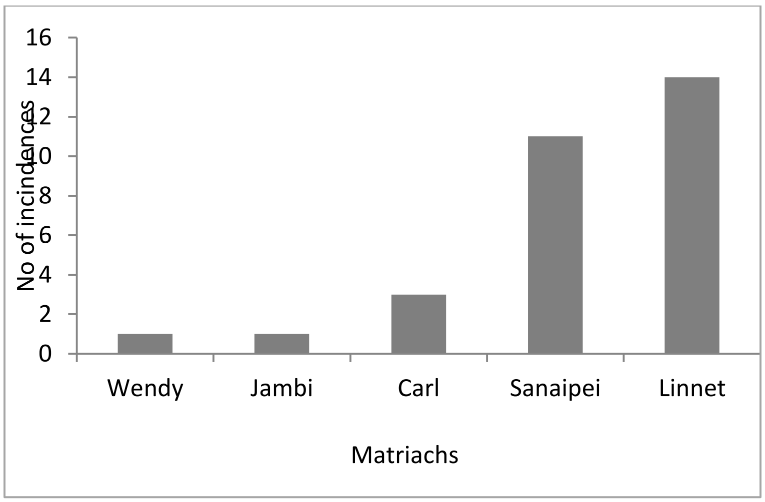

Figure 5.4: Graph showing incidences of the family groups crawling under the exclusion zone wires

Gathering the demography data of individual males and family groups was also undertaken in the year to gain insight onto the use of the landscape by different elephants. To date, 13 matriarchal family groups comprised of 161 individuals and 7 lone elephant bulls have been identified in the landscape. They have been resident since February through to end of October when most of them moved out likely due to good rainfall received in the adjacent areas such as Il Ngwesi and Mukogodo Forest Reserve.

Monitoring and identifying the elephants causing conflicts within and the surrounding community will continue in the coming year in order to provide definitive identification and ensure appropriate management intervention can be undertaken.

5.3 Beehive fence

Beehives fences have been reported to reduce crop-raiding by elephant according to the Elephant and Bees Project (www.savetheelephants.org). Lewa, in collaboration with the

STE Elephant and Bees project and the NNFT partnered and established a pilot project in 2019 in one of the sections that is mostly hit by elephants. A 300-meter long beehive fence was erected at Simon's gate. Unfortunately, most of the hives have never been colonized to date. Nevertheless, there have been no breakages by elephants recorded at this section. Maintenance and monitoring of the hives will continue in the coming year to assess the effectiveness of the beehives. If / when the project is assessed to be effective in deterring elephants from breaking fences, the second phase would be extended to other hotspots within the main boundary.

5.4 Conclusion and recommendations

Human-elephant conflict (HEC) continues to be a major problem within LBL and surrounding community farms particularly during the dry season. This is a result of multiple factors, including increased residency of the elephant population, changing rainfall patterns, as well as changing land use patterns outside protected areas. In an effort to mitigate these conflicts, there is need to constitute and equip a HWC Response team for proactive and reactive response to all kinds of conflicts in a timely fashion. We will also continue exploring the use of deterrent methods to mitigate conflict within Lewa and the neighbouring community areas.

As the population of resident elephant in the landscape increases, there is also need to continue expanding the elephant database to enhance monitoring in order to be able to understand how they use the landscape.

Finally, there is a need to continue strengthening and creating awareness among our immediate community areas on the plight of elephant populations and human / wildlife co-existence.

6.0 RANGELAND MONITORING

6.1 Rangeland management

The disruption in activities occasioned by the onset of the Covid-19 pandemic impacted the timing and duration of our annual rangeland assessments, and planned additions to our monitoring protocol. Nevertheless, we continue to collect relevant data on grass and woody vegetation. Similarly, as part of this process, we have received funding to support with soil and vegetation analyses.

These have been built into an in-depth academic project being carried out by one of our department members, and specific objectives are currently being reviewed and finalized. In general, the current overall goal is to look into the relationship between current and legacy grazing and mowing treatments and soil and forage quality and characteristics. These objectives will be shared with relevant stakeholders as we progress to ensure appropriate input and discussion.

6.2 Grass assessment

Despite the challenges occasioned by the Covid-19 pandemic, we were able to carry out the annual grass assessment at the end of Q2. The main objective of grass assessment is to estimate the standing crop and composition of grassland to identify trends in the condition of vegetation. This information helps to inform management decision-making, especially continued trail of range interventions like grazing and mowing.

6.3 Results and discussion

Our grass assessment results showed a year-on-year increase in grass cover and biomass productivity compared to previous years (Figure 6.1). This can be attributed to sufficient rainfall across the landscape during the year, whose temporal distribution likely spurred the continued production of perennial vegetation, while not leading to large flushes of annuals and ephemeral plants. This would also explain the lower species diversity compared to the large pulses of diversity in 2018 and 2015 in the same plots (Figure 6.2).

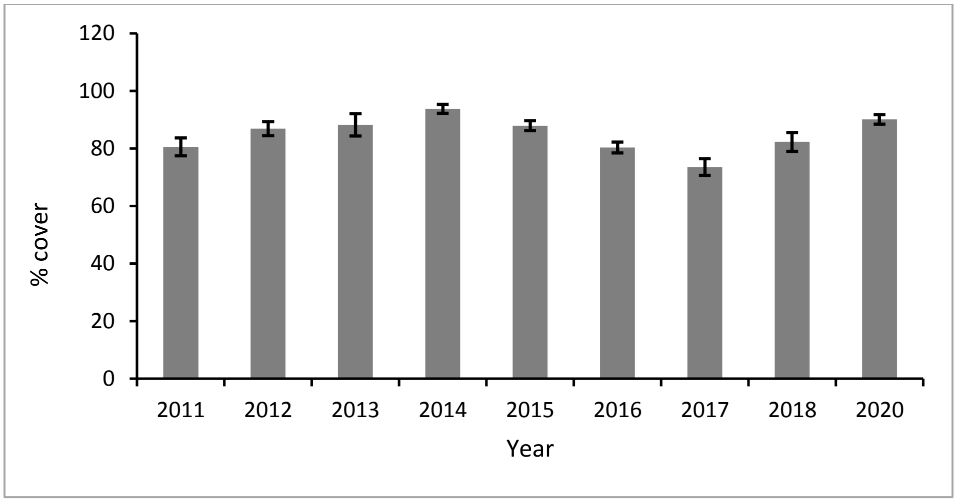

Figure 6.1: Graph showing long term annual fluctuations in average plant cover across our various long-term sampling plots

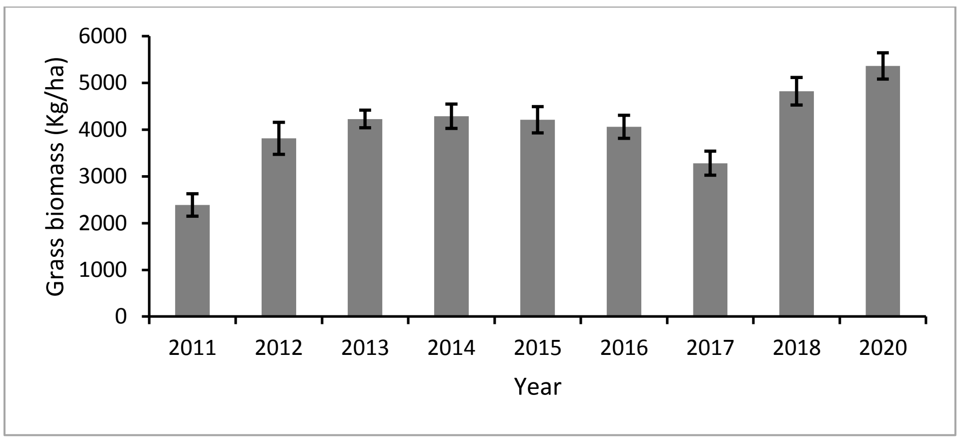

Figure 6.2. Graph showing long term annual fluctuations in average grass biomass across our various long-term sampling plots

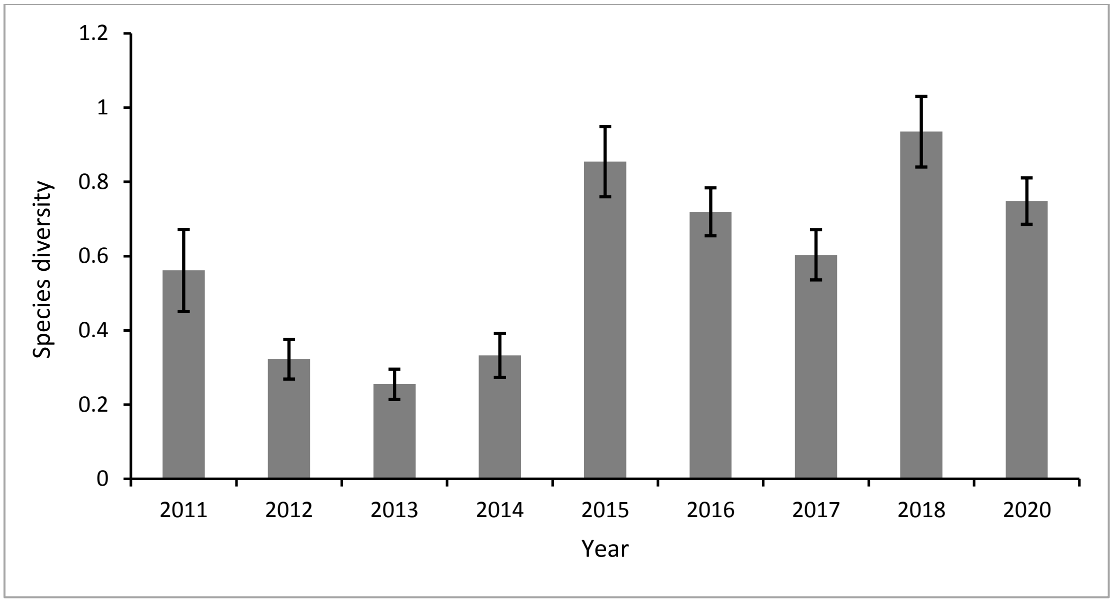

Figure 6.3. Graph showing long term annual fluctuations in average species diversity across our various long-term sampling plots

As is the case in most years, riverine plots exhibited the highest levels of standing biomass and total plant cover. Remarkably, our Riverine plots showed 100% ground cover, showing very little risk of erosion on these fragile ecological units. All sampled plots similarly exhibited high levels of productivity, cover, and diversity.

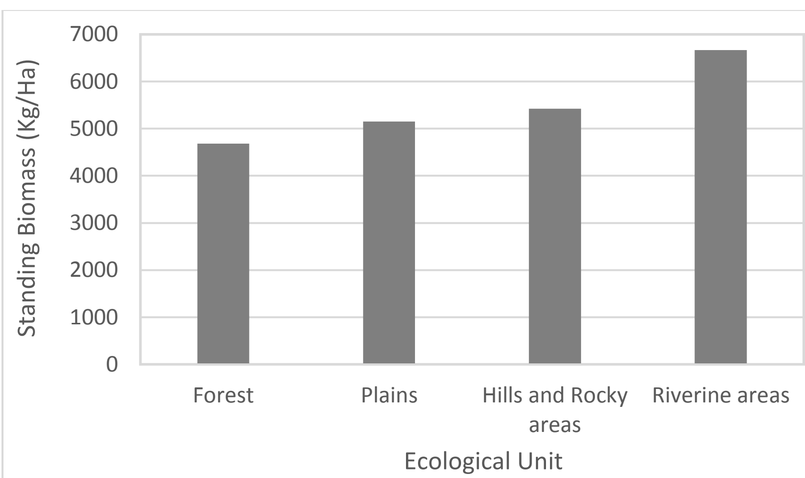

Figure 6.4. Graph showing standing biomass across the different ecological management units on Lewa Wildlife Conservancy

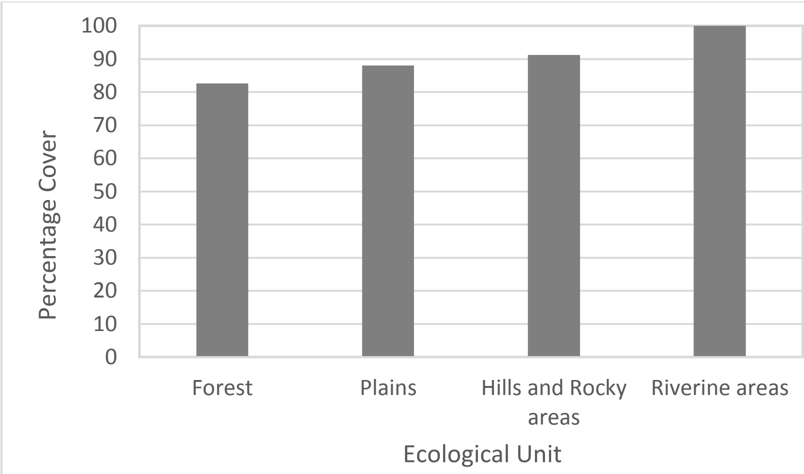

Figure 6.5. Graph showing plant cover across the different ecological management units on Lewa Wildlife Conservancy

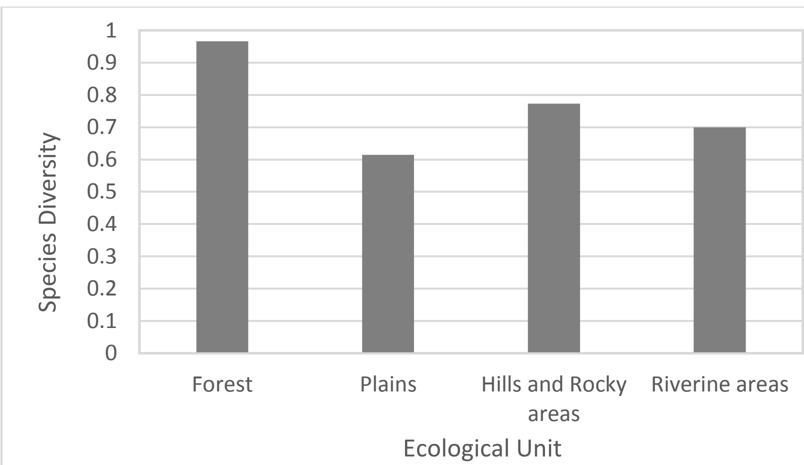

Figure 6.6. Graph showing species diversity across the different ecological management units on Lewa Wildlife Conservancy

6.4 Rangeland interventions

Mowing of grass in June 2020

As reported earlier in 2020, a section of grassland with high biomass and cover was selected for a mowing trial in Q2 2020 (Figure 6.7). The mowing process was timed to happen at the end of the growing season, and the cutter blades were adjusted to ensure a minimum cut height of 8 inches. This latter part proved somewhat difficult to standardize across the entire target plot, and average grass height in places was much lower (Figure 6.8). The total area mowed was 121.4 acres, with 11,527 bales of grass produced, averaging 16kg per bale.

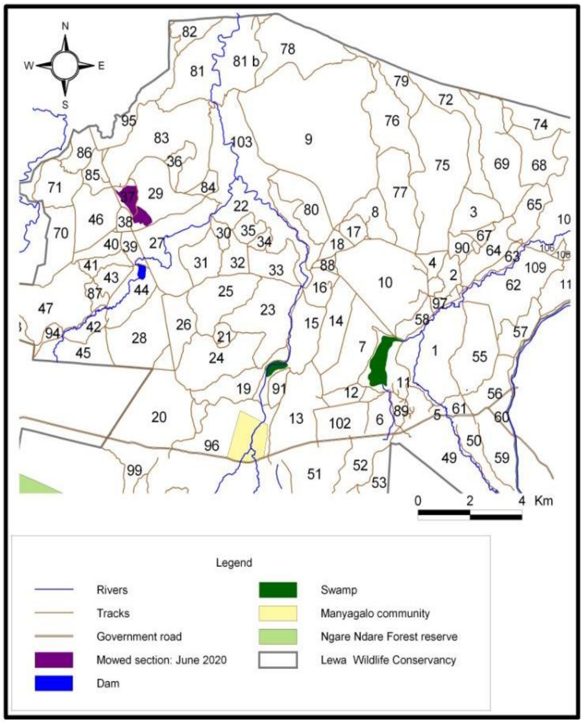

Figure 6.7: Map of Lewa showing mowed sections in June 2020

Figure 6.8. Photographs showing a) mowed and b) unmowed sites near LSC in Jun 2020

A rapid grass assessment was conducted on the above block prior to mowing in order to have baseline understanding on the following parameters: biomass, average grass height, species composition and cover (Table 6.1).

Table 6.1. Baseline results of a snapshot survey on area mowed in June 2020

Biomass (Before mowing)	Average grass height	Average basal gap	Height of grass (After mowing)	Species diversity
5,806 Kg/ha	41.1 cm	28.4 cm	8.8 cm	0.6 (index)

As part of a larger project, we also collected baseline data on soil and vegetation nutrient composition to understand the nutrient quality before and after mowing. Below are some summaries of these nutrient assessments (Table 6.2 and Table 6.3).

Table 6.2. Baseline averages of nutrient compositions for vegetation in mowed areas compared to standard nutrient estimates for cattle (Boutton *et al.* 1988; MSD 2014) and Horses (Tupper 2011).

Plant Nutrient (%)	Lewa Mowed Site	Average Horse requirements (%)	Average Dairy Cow requirements (%)
Crude Protein	7.2	13	5
Sodium	1.16	0.1	0.23
Potassium	0.79	0.42	1.1
Phosphorus	0.12	0.34	0.3

Table 6.3. Baseline averages for select soil nutrients compared to similar soils in Laikipia (Young *et al.* 1995).

Soil Nutrient (%)	Lewa Mowed Site	Averages from KLEE plots (Mpala)
Total Nitrogen	0.1	0.07
Potassium	1.94	1.45
Calcium	1.19	4.5
Magnesium	0.17	2.35
Sodium	1.99	1

While results will take some time to reach significant levels, we collected baseline data from a few plots to give us a general idea of the status of nutrient availability on the sample area. From our preliminary analysis, it is clear that dry season plant nutrient composition is within maintenance requirements for some species while being below requirements for others. This provides some context for wildlife movements across the conservancy and differing spatial use patterns by different species across seasons. This work needs to be scaled up across the conservancy as efforts continue to understand spatial use and decision making by wildlife species on the landscape. Soil nutrient composition was not significantly different from a cognate site on the broader landscape, though data from other management units in the GCA will provide better comparison. We will be conducting repeat grass nutrient data collection at the end of the growing season to ascertain what temporal differences exist if any, as well as ascertain whether there will be an impact of mowing on plant nutrient composition.

Additional rangeland management data was also collected on various sites as part of a Master's project. Analysis of vegetation nutrient composition is ongoing. However, there have been some preliminary findings. Crude protein levels were found to be 7% on average across our sites. Depending on the species and season, crude protein values for rangeland grasses can range from 4-16% on average. Animal requirements can range from 6-13% depending on species, sex, and physiological state. Lewa's grasses are dominated by *Pennisetum stramineum* and *P. mezianum*, which have been shown to have generally medium to low crude protein values. Linsen and Giesen (1983) collected standing crop nutrient data from 6 sites between 1979 and 1980, and found crude protein levels of between 4-7%, meaning our current values are expected for the area. We will replicate our data collection twice more over the next year, in order to establish whether our grazing and mowing interventions had any discernible impact on vegetation nutrient composition in the short-term.

6.5 Woody vegetation

Woody vegetation provide food for large to smaller mammals. They also provide essential habitat structure and provide perches and nest sites for birds (Ogada et al. 2008). On Lewa, woody vegetation assessment has been undertaken to assess the changes in the long term to enable informed management decision making. Fixed-point photography and quantitative assessment were conducted on 28 monitoring sites, distributed across the four management units.

Acacia mellifera, Euclea divinorum and *Grewia similis* were the most abundant woody species encountered during sampling, which is consistent with findings from previous years (Figure 6.9).

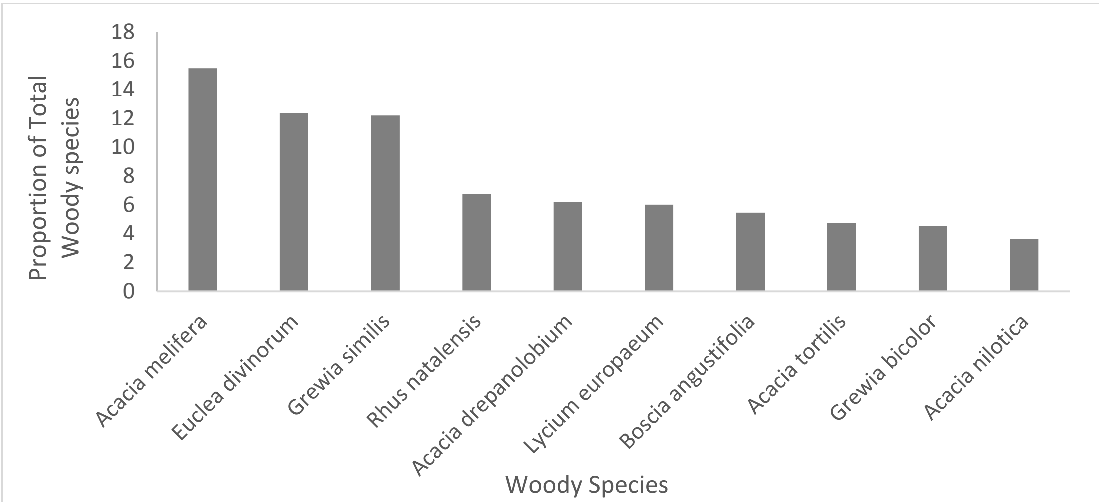

Figure 6.9: Graph showing relative proportion of the top 10 most abundant woody species on our sample plots.

Average tree height was higher than the in 2019, signalling a possible decrease in lateral suppression by elephant and giraffe browsing, therefore allowing the trees to grow vertically. This could also have been because of general wildlife browsing preference towards perennial forbs as a result of the adequate rainfall received in the year.

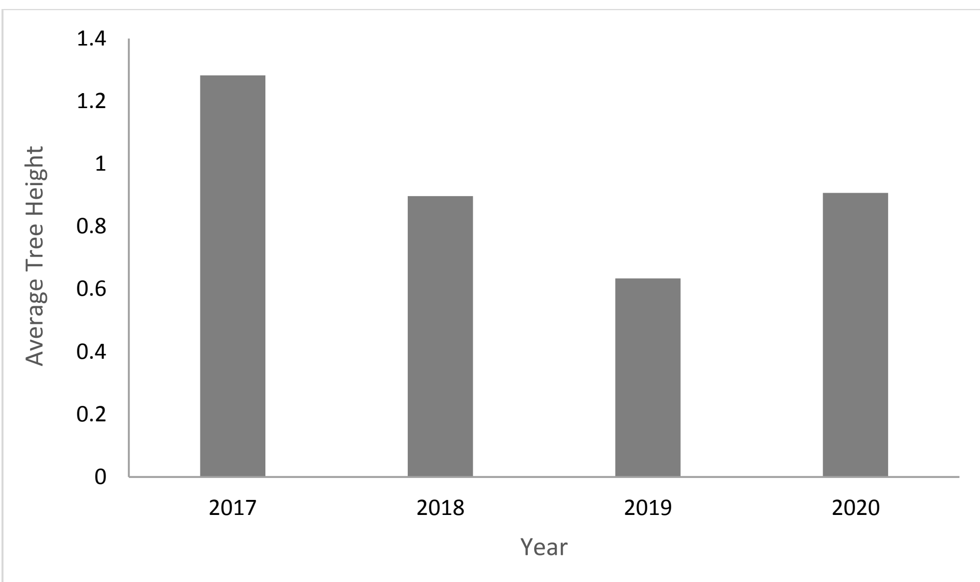

Figure 6.10: Average tree height on our sample plots across the last four years.

As with previous years, *A. mellifera* exhibited the highest amount of animal damage, with 8 of the top 10 most utilized species being from the *Acacia* (*Vachellia*) genus, signifying their nutritional importance on our landscape (Figure 6.11).

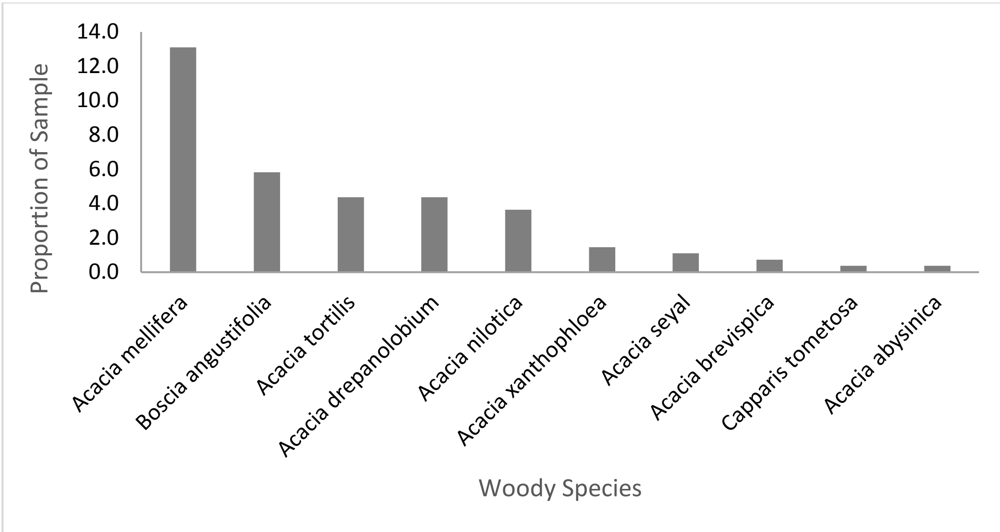

Figure 6.11: Graph showing relative proportion of the top 10 most damaged woody species on our sample plots.

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). Majority of the damage observed was attributed to elephant and giraffe browsing, consistent with previous years' findings (Figure 6.12).

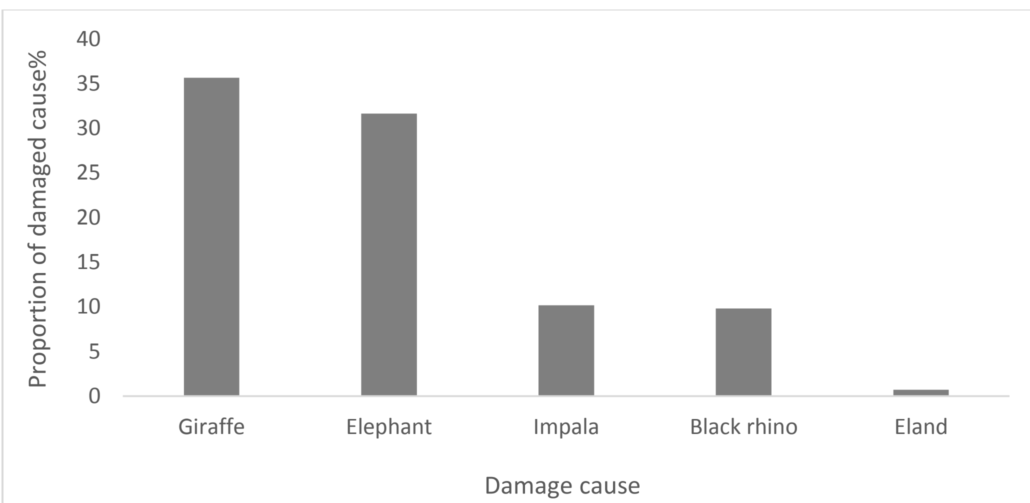

Figure 6.12: Graph showing relative proportion of the top causes of damage on sampled species

On the expanded Lewa Airstrip exclusion zone, sampling plots we set up to capture continuing changes arising from this intervention. The expanded area continued to show immense tree growth, with a nearly 45% increase in tree height in the sampling plots over the last year (Figure 6.13). There was also a year on year increase in tree density, although the magnitude of this increase differed between our two plots, suggesting a gradient in density increase that will need to be examined further (Figure 6.14). This continues to demonstrate the importance and potential efficacy of exclusion zones once the fences are upgraded and maintained.

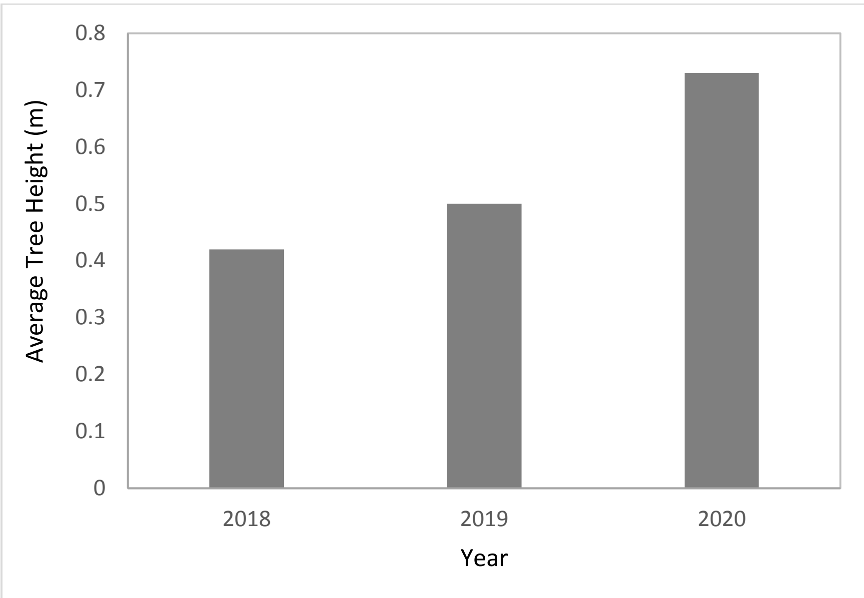

Figure 6.13: Graph showing year on year change in average tree height in the expanded Lewa Airstrip exclusion zone

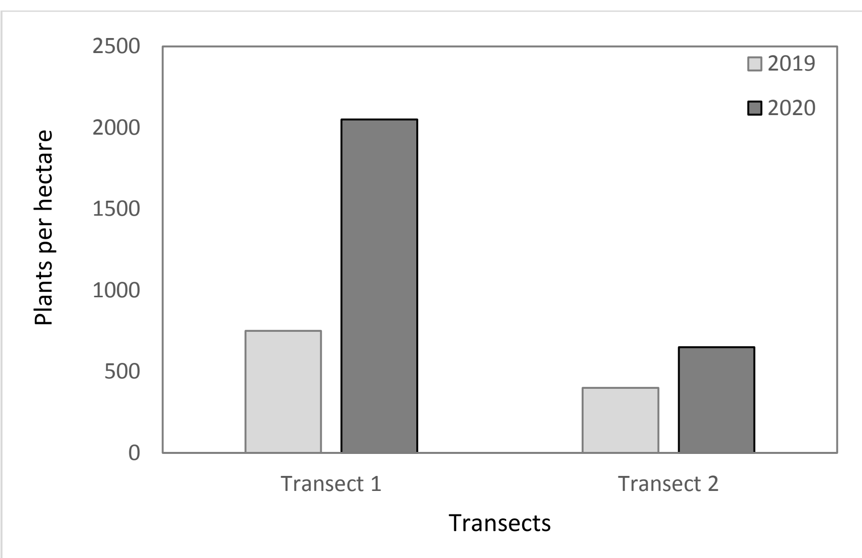

Figure 6.14: Graph showing year on year change in tree density across our two sampling transects in the expanded Lewa Airstrip exclusion zone

6.6 NDVI

We used free sourced satellite data to develop monthly estimates of vegetation productivity using the Normalized Difference Vegetation Index (NDVI). NDVI is used to quantify vegetation greenness and is useful in understanding vegetation density and assessing changes in plant health. NDVI is calculated as a ratio between the red (R) and near infrared (NIR) values from satellite-derived multispectral images. While difficult to make sweeping assessments from individual NDVI maps, the true value of these assessments lies in helping users determine spatio-temporal variations in vegetation condition. For our initial assessment, we used multispectral imagery from the Landsat 8 Satellite, obtained from the USGS Earth Explorer platform. We extracted the relevant image bands and produced composite imagery that was then used to calculate NDVI values (Figure 6.15-6.19). All analyses were carried out in ArcMap 10.8.1.

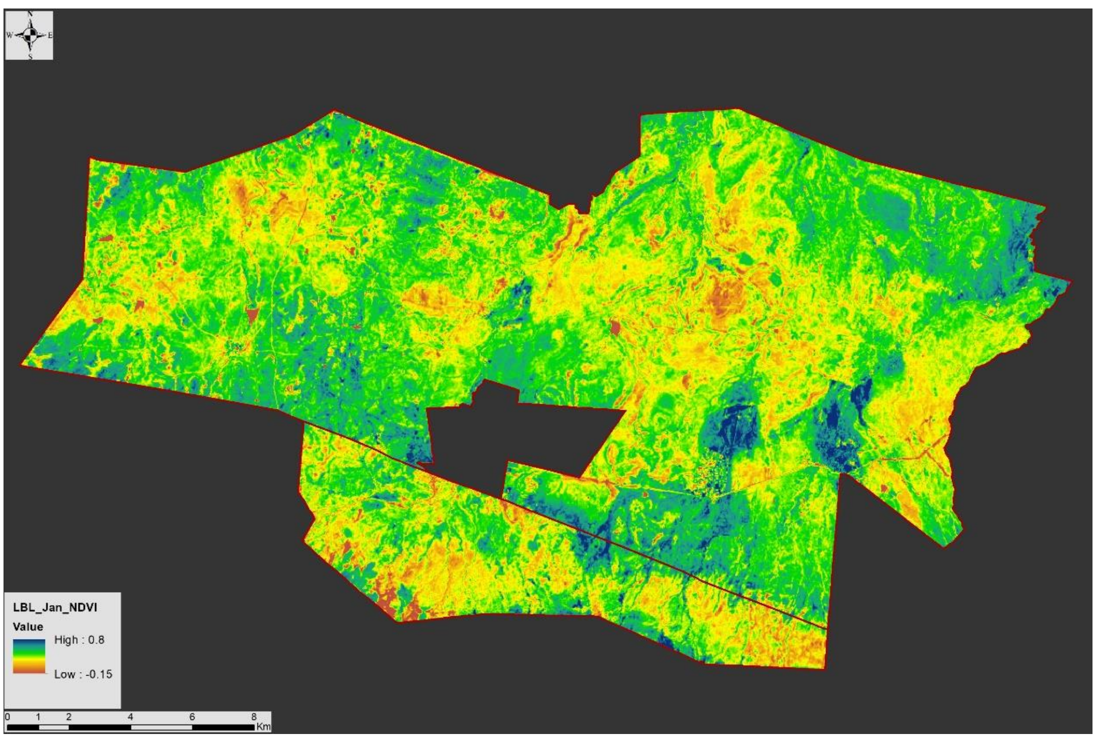

Figure 6.15. NDVI maps for the Lewa-Borana Conservation Landscape in January 2020

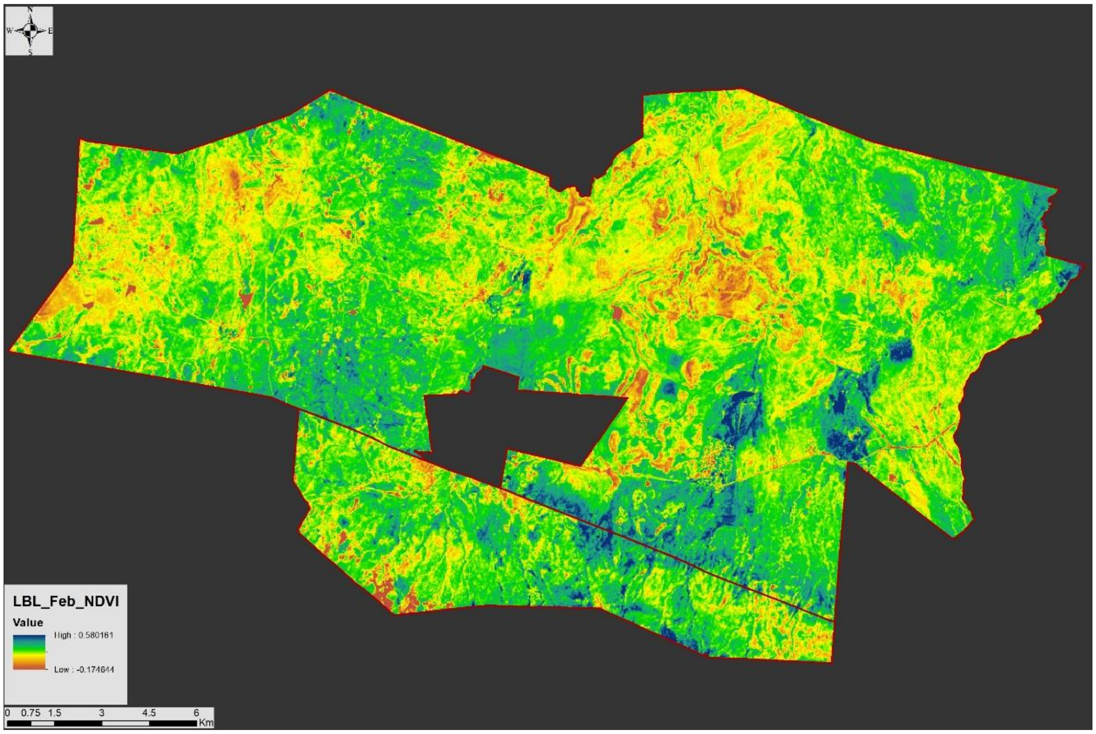

Figure 6.16. NDVI maps for the Lewa-Borana Conservation Landscape in February 2020

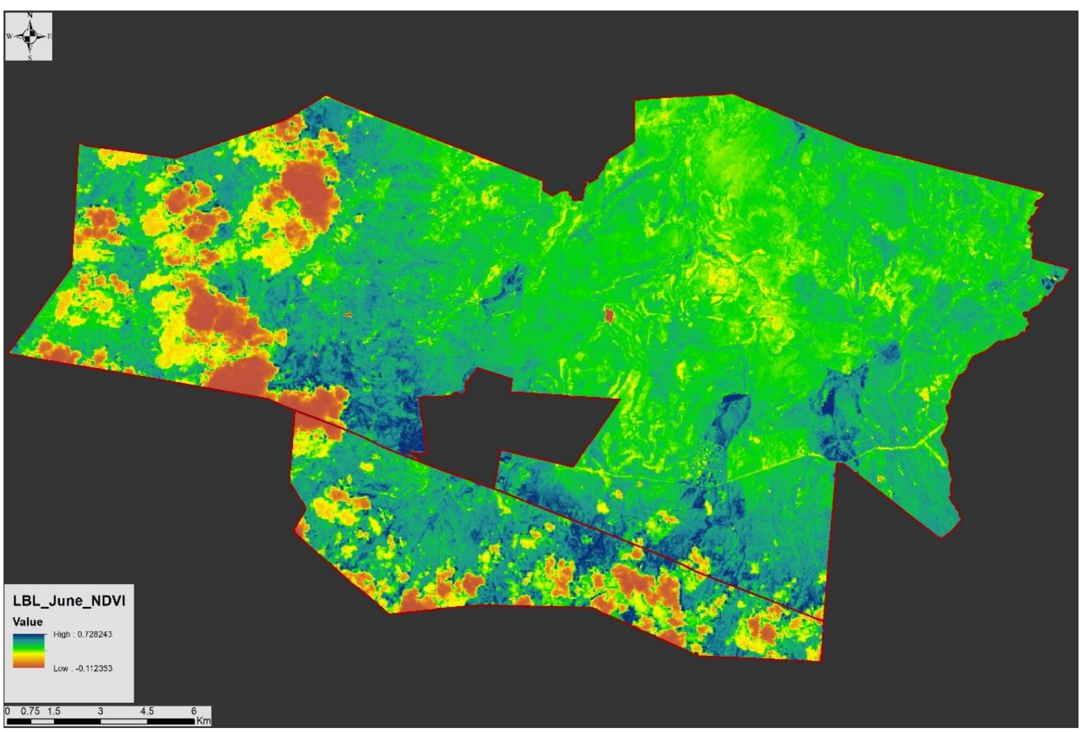

Figure 6.17. NDVI maps for the Lewa-Borana Conservation Landscape in June 2020

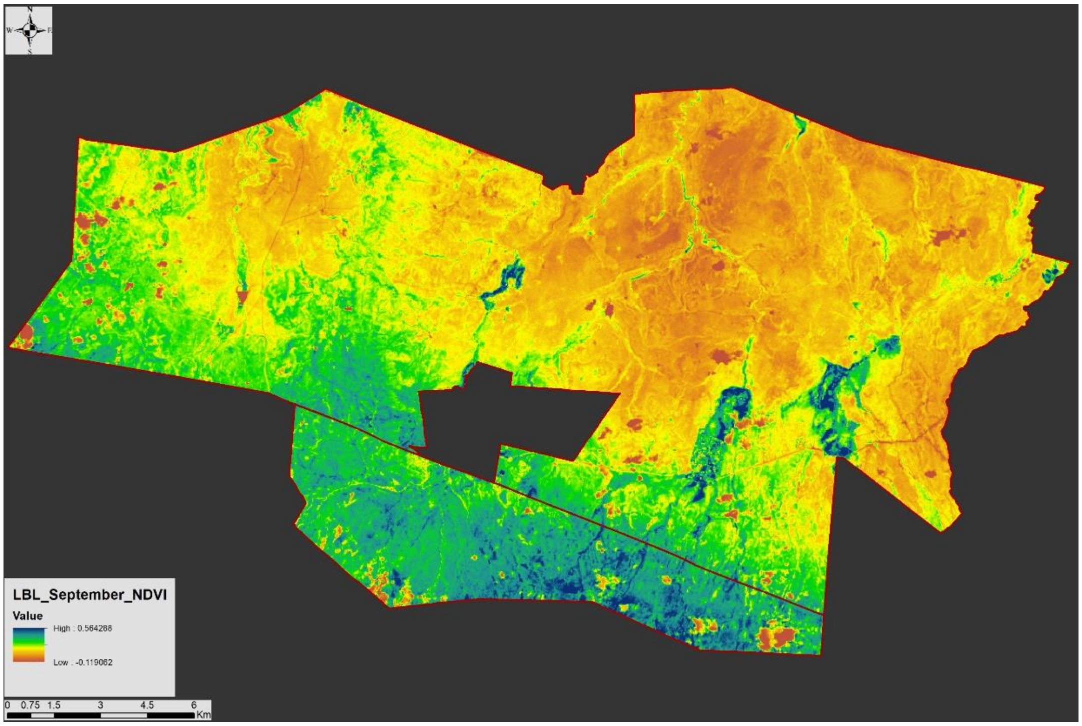

Figure 6.18. NDVI maps for the Lewa-Borana Conservation Landscape in September 2020

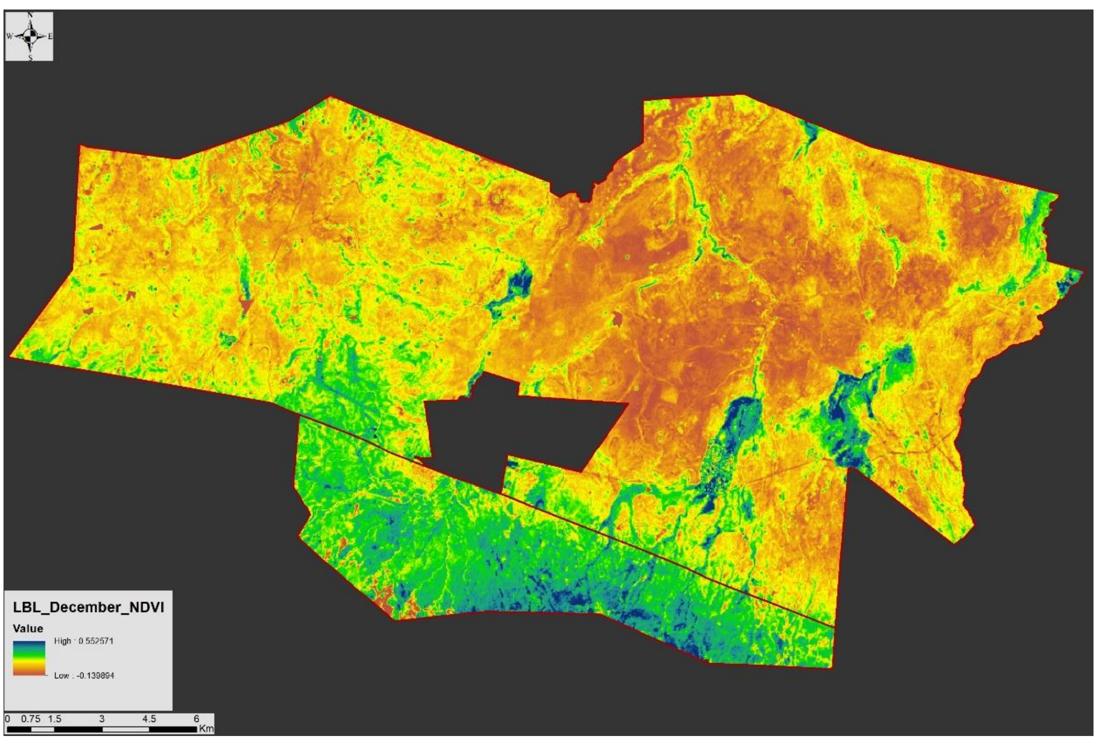

Figure 6.19. NDVI maps for the Lewa-Borana Conservation Landscape in December 2020

In summary, we were able to track response of vegetation to changing rainfall across the year. The first half of the year was relatively wet and therefore relatively productive, even through the normally dry month of June. Ngare Ndare Forest, the Swamp, the Headquarters exclusion zone and riverine areas on the landscape retained vegetation productivity for the majority of the year, even through the very dry months of September and December. The eastern section of the landscape is characterized by lower altitude plains dominated by *P. stramineum* and *P. mezianum*. This would explain why the productivity on this side of the landscape was consistently lower than the higher altitude, higher rainfall sections of Borana and Ngare Ndare Forest. Given how low the productivity on the landscape in general was at the end of December, there is a danger of lowered forage quality and quantity going into 2021 if there are no intermittent showers before the long rains expected in March.

6.7 Grazing

Planned grazing has been heralded as a tool for improving rangeland condition for both wildlife and livestock (Savory, 1999). Its proponents argue that concentrated herds 1) break up compacted soil thereby increasing water infiltration and plant growth, 2) enhance seed burial, laying of litter, and dunging effects, and 3) graze less selectively thereby enhancing growth of palatable species; and that 4) time-controlled grazing rotations, with adequate rest periods, enhance plant recovery from defoliation.

On Lewa, cattle grazing has been practiced since 2007, prior to this, a community livestock grazing programme on Lewa had been initiated *ad hoc*. The sole purpose of this programme is to improve the quality of vegetation by removing old forage and stimulating new growth for the benefit of wildlife.

By the end of Q4, a total of 3,274 head of Northern Rangelands Trust –Trading (NRTT) cattle transited through Lewa after each herd completing the mandatory quarantine period; whilst numbers have been low compared to the recommended 1,500 head of cattle at any given time.

In total, 2,915 acres were utilized through to end of Q4 (Fig. 6.20) with an additional 2,596 projected to be grazed in Q1 & 2 2021. The projection of areas to be grazed in 2021 will be adjusted depending with the rainfall regime and grass quality at the time.

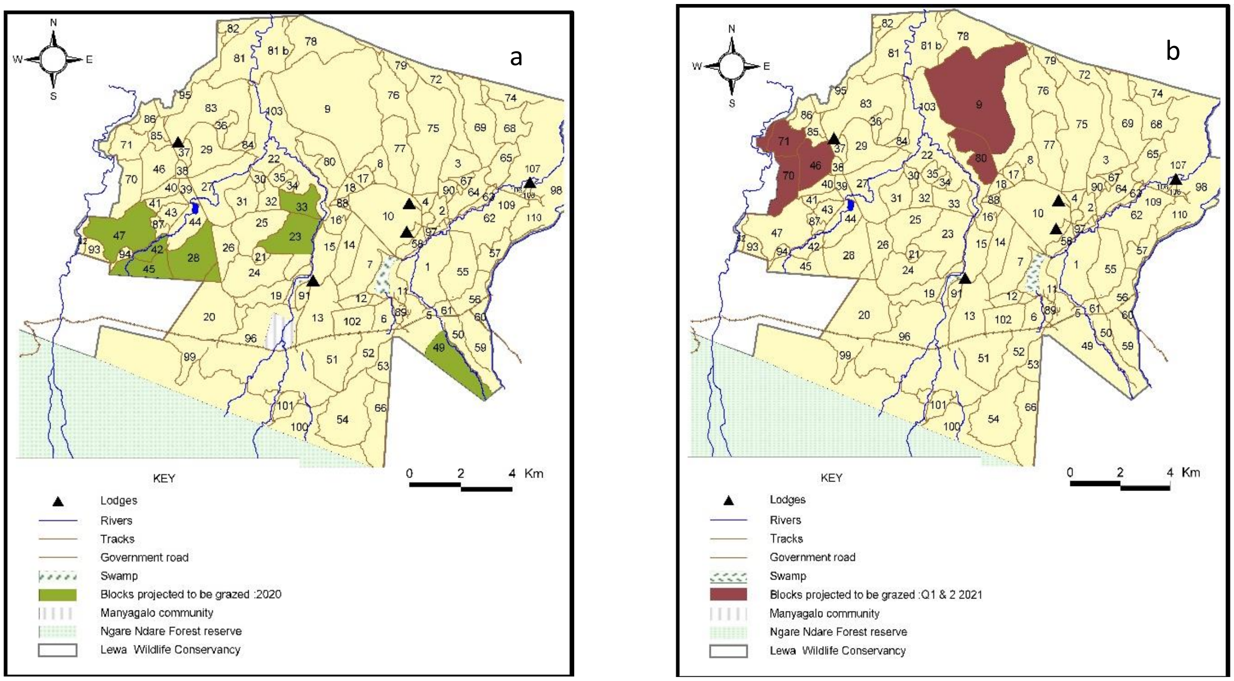

Figure 6.20: Map of Lewa showing a) grazed blocks in 2020 and b) blocks projected to be grazed from Q1– Q2 2021.

6.8 Invasive and encroaching plant species

Reports of expansion of cover for several plant species identified as being potential invasive or having potential to stifle more 'desirable' vegetation have been increasing especially as the rains continued well into Q2 2020. While some of these reports were valid and necessitated action by both the Research and Logistics team, some were also cases of misidentification or were indigenous species that did not demand immediate action. Given the paucity of resources available to the organization at the current time, there is a need to triage these cases, ensuring that the plants are identified correctly, their presence mapped, and the cost-benefit of management assessed. To this end, we encourage the use of the PlantNet App for Lewa to better ensure that the right species is identified, as some are similar looking at first glance, e.g., *Lippia javanica* and *Lantana camara*. The LRD will intensify efforts in 2021 to map these areas seeing increased shifts in vegetation community, map the extent of their spread, gauge the necessity for intervention, and ascertain whether the causes for expansion are man-made or simply natural shifts within the landscape's regular State-and-Transition model. More than ever, this highlights the need to develop rudimentary Ecological site descriptions identifying the range of vegetation communities possible within different parts of the landscape given different weather patterns and management choices.

6.9 Conclusion and recommendation

Given the challenges currently facing the NRTT Livestock programme, there is a need to review that particular engagement and the Lewa Cattle Programme in its entirety. Monitoring of mowed sections will continue to look at long-term impacts, especially around seasonal timing and grass mowing height. Repeat data will be collected at the end of the growing season to allow us to make preliminary assessments.

Collection of data will continue to look into the long-term impacts of cattle grazing on the grassland taking into consideration the fluctuating cattle numbers on Lewa vis-a-vis the increasing population of buffalo on the LBL.

Early warning for invasive species monitoring is critical for timely management and discussion of restoration interventions. Continued use of the PlantNet app for identification and geolocation of plants of concern across our landscape.

7.0 AVIFAUNA MONITORING

7.1 Introduction

Birds fulfill many ecological functions in their habitats. For instance, they are bio-indicators of healthy ecosystems (Gates *et al.,* 2016). Insectivorous birds and raptors regulate disease vectors while scavengers contribute to biomass recycling and reduce levels of disposable wastes (Gatesire *et al.,* 2014). Birds are also important in plant pollination as exemplified by sunbirds. They also act as seed dispersers of fleshy fruit-producing plants as demonstrated by frugivorous birds (Gatesire *et al.,* 2014). Monitoring of birds is essential as it helps evaluate different habitats both qualitatively and quantitatively (Agyei *et al.,* 2017). It also helps in identifying the species and sites of conservation concern.

The main habitats on LBL host a diverse avian community some of which are globally threatened (IUCN Evaluation Report, 2013). It also serves as a stopover and wintering site for large population of over 50 Afrotropical migrants and over 60 Palearctic migrants from Europe and northern Asia. The LBL wetlands are one of the most important breeding sites for the endangered Grey crowned crane and holds more than 50 species of waterbirds (IUCN Evaluation Report, 2013). LBL focuses on keeping an updated bird checklist and conducting monthly waterbirds and raptors surveys.

Through these surveys we monitor the population and breeding status of species of conservation concern.

7.2 Lewa–Borana Landscape Birds Checklist

The harmonized list has 84 families with 467 species, representing over 42% of 1,122 total species found in Kenya (Lepage, 2020). The taxonomy, common name, and migration status follow the Field Guide to the Birds of East Africa (Stevenson & Fanshawe, 2004). To create a photographic evidence file for the bird species in LBL and Ngare Ndare Forest, we collaborated with LBL & NNFR birder's club to take evidence photos. This saw us move from an initial 55% of species with photo evidence to the current 69%. This effort will continue until we have the photos of all species in these contiguous protected areas.

We also participated in the Cornell University-led global ebird bird count in support of a campaign to end illegal bird trade. We recorded 184 species on the landscape, ranking us 4th on the Kenyan birding hotspot list (eBird, 2020).

7.3 Waterbirds Survey

Waterbirds are regarded as important bio-indicators because they exhibit conspicuous and meaningful responses to the changes in wetland habitats. These responses serve as important signs of contamination and deterioration of ecosystem. Waterbirds therefore have been widely used to highlight problems and other risks that may impact the wetland habitats. (Rahman & Ismail, 2018).

We participated in the National Waterfowl Census in January, held by the National Museums of Kenya and recorded a total population of 840 individuals of 30 species (Madindou et al., 2020, unpublished report).

We also conducted monthly waterbird surveys in the landscape and calculated diversity index using Simpson's Diversity Index: $= 1 - \left(\frac{\sum n(n-1)}{N(N-1)}\right)$, where n represents the total number of a particular species and N represents total number of all species. We recorded 54 different species and this indicated a high diversity (D = 0.8091) of waterbirds on the landscape.

We compared data for the dry (January, February, August) and wet (March, October, November) periods to understand when to expect more birds in the landscape. There was no significant difference in waterbird populations between the dry (n=2,666) and the wet (n=2,563) period (χ^2 = (2.0289), df = 1, p = 0.1543), figure 7.1. This was probably due to presence of permanent water sources throughout the year that are largely unaffected by seasonal shifts in rainfall. We will continue designing programmes that will allow us to understand the seasonal use patterns of other guilds of bird species, especially palearctic migrants.

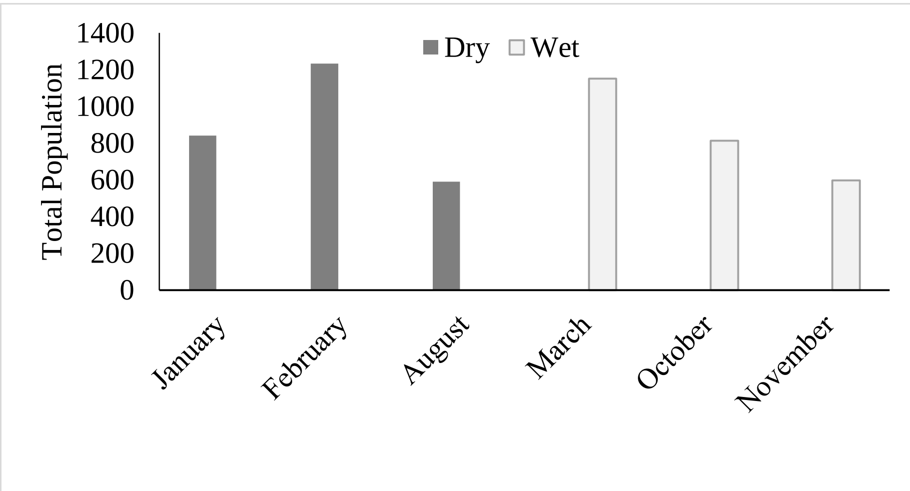

Figure 7.1: Seasonal waterbird population on LBL

7.3.1 Grey Crowned Crane Surveys

The Grey Crowned Crane (GCC) is classified as endangered by IUCN Red List of Threatened species (BirdLife International, 2016a). This is because of a sudden population decline globally primarily due to habitat loss underscoring the importance of its close monitoring (Stabach et al., 2009).

We monitored the population and breeding of GCC across the Lewa - Borana landscape. The highest individual population counts were recorded in October (203), June (112) and September (91), figure 7.2. Eight chicks selected for follow-up monitored fledged successfully. There was a significant difference in the Grey Crowned Crane population between the nominal dry (113) and wet (289) periods (χ^2 = (77.055, df = 1, $p < 0.0001$).

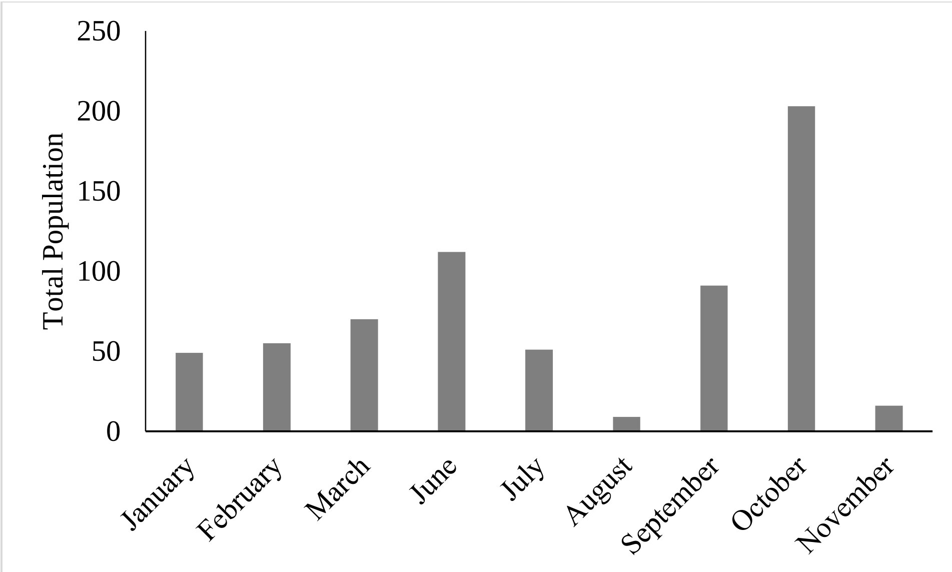

Figure 7.2: Total Grey Crowned Crane population

7.4 Raptors Survey

Raptors have been considered good indicators of habitat quality because of their sensitivity to human disturbance and environmental contamination (Rodríguez-Estrella et al., 1998). Population declines of some raptor species indicate dysfunctional ecosystems because population dynamics of top-order predators often reflect the nature of the ecosystems they inhabit (Rodríguez-Estrella et al., 1998). Thus, it has been recommended that raptors should be included in the management and conservation plans of any region, especially for threatened habitats (Rodríguez-Estrella et al., 1998).

By studying raptor populations through census, we can observe any changes within the population which would suggest deterioration of the habitat quality (Knight, 2010). The monthly monitoring of raptors recorded a total of 280 individual raptors of 37 species, figure 7.3a. 9 nests were mapped and monitored; one for Bateleur (successful breeding), three for Tawny eagle (one active, two successful breeding), two for Martial eagle (one successful breeding, one abandoned), two for African hawk eagle (one active, one abandoned), and one for Secretary bird (abandoned), figure 7.3b. Diversity was calculated using Simpson's Diversity Index indicating a higher diversity of raptors on LBL (D = 0.8913).

A Chi-square test shows a significant decrease in raptors population between 2019 (356) and 2020 (280) (1,933) (χ^2= 9.0818, df = 1, p = 0.002). This could be attributed to zero records of the Steppe eagle *(Aquila nipalensis)* a Palearctic migrant, this year compared to the high population (180) recorded in 2019.

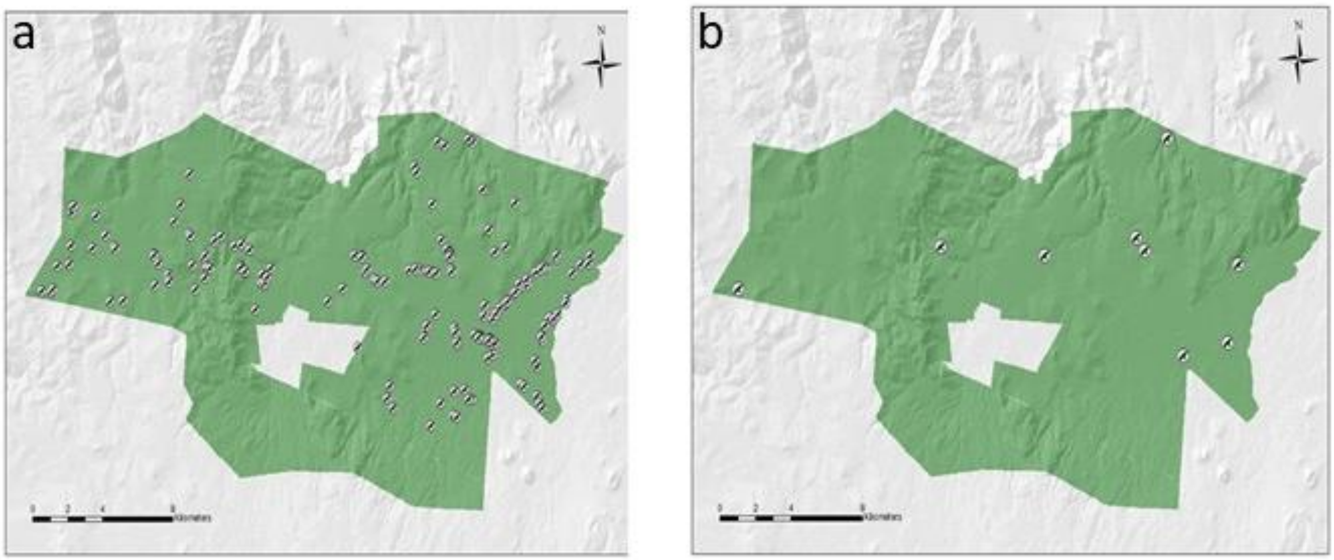

Figure 7.3: a) Raptors distribution on LBL; **b)** Location of nesting raptors on LBL

7.5 Il Ngwesi Bird Survey

Il Ngwesi is a community ranch neighboring Lewa and covers an area of 16,500 hectares. The ranch has less explored diverse avifauna which prompted a two-day bird survey recording a total of 1,303 individuals of 112 different species. This survey aimed at estimating the abundance and establish a preliminary bird checklist for this landscape. Diversity was calculated using Simpson's Diversity Index indicating a higher diversity (D = 0.7864). We recorded 3 Palearctic migrants (Isabelline shrike, Pallid harrier, Montagu's harrier), 2 critically endangered species, (White-backed vulture, Rüppell's vulture) 1 endangered (Grey crowned crane), 2 vulnerable (Somali ostrich, Martial eagle), and 1 near threatened (Pallid harrier).

7.6 Conclusion and Recommendations

The avifauna monitoring indicates a high bird diversity on the landscape. LBL wetlands continue to offer favorable roosting and breeding grounds for the endangered Grey crowned crane (GCC). Since the GCC exhibit local and seasonal migration, there is need to invest in satellite tracking to understand their spatio – temporal trends and protect their home ranges. Satellite tracking of juveniles in raptors will help establish their new home range. Proposals are in development exploring the use of backpack trackers and even Motus tower arrays for such a monitoring strategy.

Information on Somali Ostrich (*Struthio molybdophanes*) in the landscape remain scanty and relies on reports from field rangers. Given that is it currently classified as a vulnerable species, there is need to start a comprehensive monitoring program to assess the population and breeding status on the landscape.

The high diversity of avifauna on Il Ngwesi still remains to be fully explored. We recommend more bird surveys to be done on the landscape to build up the bird checklist and document it.

8.0 HYDROLOGY

Rainfall for 2020 was 569 ± 29mm, lower than the 729 ± 74 mm received in 2019. Additionally, this was slightly higher than the long-term (1975-2019) average rainfall of 509 ± 71mm for the last 45 years, (Figure 8.1). This was mainly as a result of depressed rainfall in the second half of the year, which was exceptionally high in late 2019.

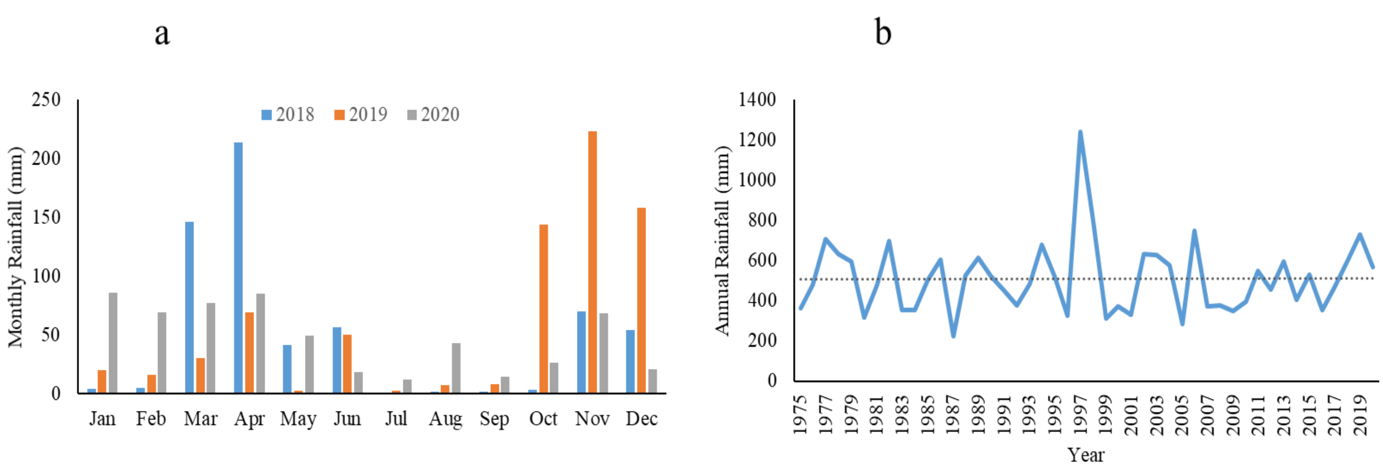

Figure 8.1: Graph showing **a)** Monthly rainfall for 2018 - 2020, and **b)** Annual rainfall for the last 45 years.

8.2 Hydrological monitoring scoping visit and workshop

Following a grant received in 2020, the Lewa Research team in collaboration with the Centre For Training and Integrated Research in ASAL Development (CETRAD) carried out a scoping assessment to lay out the groundwork for the first phase of the LBL hydrological monitoring programme. The objectives of this scoping mission were to identify potential river gauging sites on the Ngare Ndare river and the Sirikoi River, to get a snapshot assessment of Lewa's active springs, and to provide a Bill of Quantities and initial budget for river gauging station construction. This was followed up by a day long workshop between CETRAD and Lewa Management to iron out general priorities and the overall direction for the next phase of the hydrology programme.

8.3 Monitoring Sites

The current plan is to construct three River gauging stations, with construction slated for Q1 2021. These three sites will be sited on the Ngare Ndare River and the Sirikoi River (Figure 8.2). The first site (Ngare Ndare 1 – 37.34737°E, 0.18614°N) will monitor Ngare Ndare River just after it exits the Forest and before reaching Ngare Ndare village. This will help determine the amount of water flowing from the Forest before any abstraction. The second site (Ngare Ndare 2 - 37.35954°E, 0.23038°N) will monitor Ndare Ndare River inside LWC before exiting to Il Ngwesi Community Conservancy. This site will help in estimating the amount of water used in the Ngare Ndare village and therefore will be useful in addressing water use conflicts. The third site (Sirikoi 1 - 37.42494°E, 0.1812°N) will monitor the main Sirikoi River before it joins other nearby springs to drain into the Sirikoi swamp.

During the scoping mission, the team visited four major springs and the Lewa swamp. Two of the springs (next to the Lewa clinic and next to Mike Harrison's plot) seem to be interconnected and had similar electric conductivity of 215µS/cm. However, a visit during the dry season is recommended so as to further assess the level of connectedness. The Lewa Spring had an EC of 196 µS/cm and the source is well protected due to its location within a fenced enclosure.

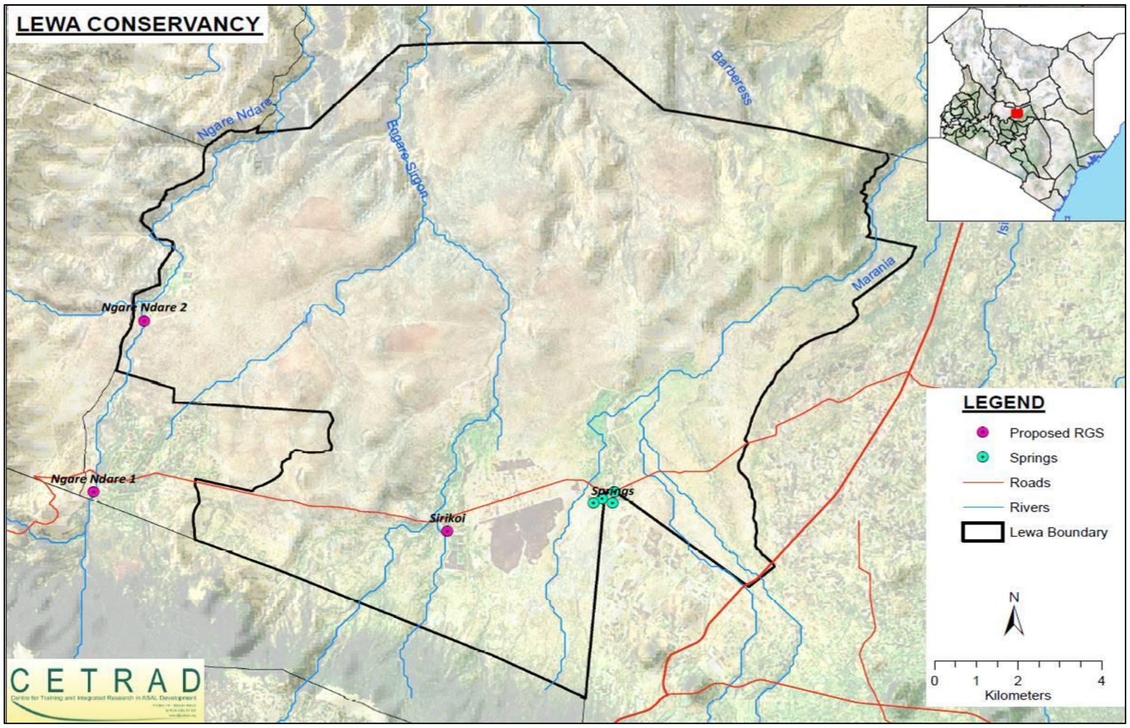

Figure 8.2: Map showing Lewa Wildlife Conservancy (LWC), proposed river gauging sites and major springs

The fourth spring source, just opposite the Lewa Spring, seemed to be very new; there is no clear spring 'eye', rather the water is oozing out of the ground and flowing towards the Lewa Spring drainage system. However, there wasn't much change in vegetation surrounding the 'spring eye'.

From the EC of all the springs measured, it is clear that the water contains low concentration of conductive ions (low EC for a spring water) and is good for domestic use. These conductive ions originate from inorganic materials such as chlorides, alkalis, carbonate, sulphide compounds and dissolved salts underground along 'water movement paths'. The low EC in spring water within the Conservancy indicates that the water has not travelled underground extensively or through many formations long enough to absorb impurities. Therefore, this could be an indication that the spring water is locally generated mostly from the surrounding catchments through sub-surface flow, a catchment area similar to that previously theorized for the Lewa rivers (Green et al 2018).

Figure 8.3: Two interconnected springs on the south eastern side of Lewa HQ. The springs have high discharge of about 200 L/S

The team recommended intensive field campaigns in order to estimate the yield of springs and identify best sites for monitoring as well as mapping the extent of springs. In addition, further investigations are recommended to establish the source of this water and the nature of the springs. The second phase of this hydrology project will focus on quantifying and characterizing these spring systems. This will involve isotopic and volumetric assessments so as to understand the origin of spring water, the age of the water and the connection with land use changes upstream. This second phase will primarily be funded through a grant received from the Prince Albert of Monaco foundation as a result of collaboration with Lewa International.

8.4 Conclusions and recommendations

The relatively adequate amount of rainfall received on the landscape in the year led to reasonable forage quality and quantity, although the reduced rainfall in the latter half of the year meant that primary productivity was not maintained at a high level throughout the year, as attested to by the NDVI images provided in the previous chapter. This would suggest a continued period of fecundity across the ungulate population on the landscape, given the amount of forage available to sustain the nursing animals, particularly the bulk grazers. Upgrading of all manual rain gauges and supplementing with temperature sensors remains a critical intervention of Phase 1 of our Hydrology monitoring programme. For Phase 2, we will focus on initiating a comprehensive Spring monitoring system, starting with discharge quantification and isotopic analyses.

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Appendix 1: Benchmarks for rhino population performance in the wild (Ouma, 2004)

Population performance*	Very poor-Poor	Poor-Moderate	Moderate- Good	Good-Excellent
UnL.G	<2.5%	2.5 – 5.0%	5.0 – 7.5%	>7.0%
Mot.R	>4%	-	-	-
SR	<1F:1M	<1F:1M	1F:1M	>1F:1M[a]
ICI	>3.5 yrs	3.5 – 3.0 yrs	3.0 – 2.5 yrs	<2.5 yrs
%FC	<29%	29 – 33%	33 – 40%	>40%
AFC	>7.5 yrs	7.5 – 7.0 yrs	7.0 – 6.5 yrs	<6.5 yrs
%CP	-	<28%	=28%	-

[a] Good-Excellent in "good habitat"

[b] Calves of age classes A to D.

UnL.G=Underlying growth rate; Mot.R=Mortality rate; SR=Sex ratio; ICI=Average inter-calving interval;

%FC=Percentage of females calving per year; AFC=Age at first calving; and %CP=Proportion of calves (age classes A-D) in the population.

Appendix 2:

Departmental peer reviewed publications for 2020.

Kimiti, D.W., Ganguli, A. C., Herrick, J. E., Karl, J. W., & Bailey, D. W. (**2020**). "A Decision Support System for Incorporating Land Potential Information in the Evaluation of Restoration Outcomes." Ecological Restoration, 38(2), 94-104.

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