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Conservation, Research and Monitoring

Annual Report 2021

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EXECUTIVE SUMMARY

The population of black and southern white rhinos in the country stood at 897 and 840 respectively as of 31st July 2021. On Lewa-Borana Landscape (LBL), the former stands at 131 and the latter at 116. The year also recorded 17 black and 18 white rhino birth on the landscape. Two black and five white rhinos gave birth to their first calves. We documented 10 rhino battle-fights (7 for white and three for black rhinos), all of which resulted in minor injuries. We adopted a supplementary feeding strategy for eight rhinos (six black and two white) following the dry season body condition evaluation between June and October, targeting the relatively old and lactating rhinos. In addition, we also took photos of all the rhinos for the master ID files. Currently, we have 44 rhinos (23 black and 21 white) as suitable candidates for ear notching.

The lion population on the landscape stood at 57 individuals (39 adults, 4 sub-adults, and 14 cubs), occurring in five prides and two coalitions. They include three adult male immigrants whose origin we have not traced and exclude Bredymark's pride (9 individuals), whom we lost track of, after moving to Mukogodo forest and attacking 13 livestock in the forest. It also excludes two territorial males (Dick and Esau) who moved to Il Ngwesi Group Ranch after the arrival of the three male immigrants.

A minimum of 144 spotted hyenas (134 adults, 4 sub-adults, and 6 cubs) was recorded and our data estimates about 20 individual leopards within the landscape. The planned collaboration with the San Diego Zoo Global (SDZG) leopard project is expected to improve research on leopards in the landscape.

A total of 17 incidences of human-carnivore conflicts were reported, resulting in the deaths of 52 livestock within LBL and the neighbouring communities, mainly caused by lions. An outcome of this conflict is a total of 109 wildlife mortality cases, mainly resulting from predation. From scat analyses to determine the diets of lions and spotted hyenas, we determined that plains zebra and buffalo were the key prey species for the two predators, meaning their diets overlap.

The annual wildlife count indicates an increase in the numbers of most species. Looking at the performance of some of the species, buffalo have attained the recommended 30% threshold of combined juveniles and young. Hartebeest attained this threshold in 2017 and 2019, with little

deviation from the threshold in other years apart from 2016. Eland attained this threshold in 2020 and 2021. The Grevy's zebra, Plains zebra, and Oryx have never attained the 30% mark, but the difference to this mark is minimal. Giraffe recorded the lowest percentage (slightly above 10%) in all years. The growth potential for all ungulates within the LBL ranged from medium to high.

Body condition checks were also done at the end of the long dry spell. Our findings show that buffalo, eland, and hartebeest were the main ungulate species affected by the drought.

Using the national Grevy's zebra database to identify individual Grevy's zebra,142 foals between 2020 and 2021. Using 6 months as a maximum time for re-sighting a foal to be regarded as alive, we noted 85 (59.9%) individuals are surviving and 57 (40.1%) are dead. Of the surviving, 48 (56.5%) have moved to juveniles and adults. This means they are past the vulnerable age brackets of 0-3 months, 3-6 months, and 6-12 months. As the results indicate, 0-3 months and 3-6 months are the most vulnerable age brackets.

Thirteen (13) resident matriarchal family groups, comprising of 188 individuals and 10 lone bulls, were documented on the landscape. 252 fence breaking incidences were documented involving elephants, of which 218 (86%) occurred in the exclusion zone fence lines and 34 (14%) occurred on the main boundary fence line. For the exclusion zones, 110 (51%) incidences involved crawling under the 2-strand fence wires, while 108 (49%) involved snapping the wires and breaking the posts. The most affected exclusion zones were, Lewa HQ, Digby's, Matunda, Kifaru, and Sirikoi. The pilot beehive fence that was installed in 2018 along the Ngare Ndare fence line connecting Ngare Ndare Forest with the Ethi community continues to face bee occupancy challenges, possibly due to unfavourable weather conditions and shifts in rainfall regimes. We continue cleaning the hives and engaging with Save the Elephants (STE) Elephant and Bees (E & B) project as they were the initiators of the project. We have also engaged organized community groups in those villages to manage them, so that they can derive benefits through extracting honey and keeping elephants away from their farms.

Planned cattle grazing improves the quality of rangeland through grazing, trampling, and manure emanating from their excretion. The Northern Rangelands Trust (NRT) Livestock to Market (LTM) programme stalled, leaving the Lewa section of LBL with approximately 100 cattle for the entire year confined in an enclosure under supplementary feeding. However, the Borana section of the LBL maintained 2,500 cattle under a commercial/community program. As a result of dry conditions, Borana Conservancy assisted the surrounding communities by hosting 200 cattle and assisted in securing grazing for another 3,500 cattle at Ole Naishu ranch.

The harmonised bird checklist for LBL now consists of 83 families with 484 species, representing 42% of the 1,149 total species found in Kenya. The photo evidence file stands at 75%. We also did surveys on the Il Ngwesi Group Ranch and recorded 130 different species. The photo evidence here stands at 84% made up of 172 species. The Lewa Wildlife Conservancy was ranked the 4th birding hotspot, while Borana Conservancy was the 5th on the bi-annual Cornell University-led global E-bird, bird count. The National Waterfowl Census survey, led by the National Museums of Kenya (NMK) recorded a total population of 2,426 water birds of 41 species in the landscape. We continue to record a high diversity of waterbirds during our monthly surveys (D = 0.8754). In addition, we continued to monitor the Grey Crowned Crane (GCC) population and nesting, with the greatest number observed in April being 263 birds. The monthly averages for the raptors are estimated at 49±7 individuals.

During the period, 59 individuals of the critically endangered Pancake tortoise (Malacochersus tornieri), being a follow-up survey of 2019 that documented 7 individuals. This is the beginning of more detailed surveys on this species as well as other herptiles, with the view of developing the herpetofauna theme in the department.

To enhance students' critical knowledge to understand the complexities of environmental issues in their surroundings, the Conservation Education Program reached out to 2,060 individuals distributed across 55 groups. The programme encourages them to use natural resources responsibly by making informed decisions and participating in local conservation efforts to protect Kenya's wildlife for current and future generations. The year saw the appointment of the Conservation Education Program Coordinator, Ephantus Mugo, as the International Zoo Educators Representative for Africa, a role he is to hold for 2 years.

Based on the data from the conservation, research, and monitoring activities, the following are some of the main implications for management:

Implications for management

- As the population of unidentifiable rhinos, both black and white, increases on LBL, there is a need to establish an annual ear-notching programme of at least 15 rhinos every year to facilitate identification.
- The Ecological Carrying Capacity (ECC) for white rhinos on LBL has not been established despite the increasing population. In addition, the ECC for black rhinos needs to be reviewed as the existing ones are outdated. This exercise should be framed in a way that will incorporate and allow for other grazers and browsers in the landscape.
- Given the elusive and nocturnal nature of lions on the landscape, we recommend the collaring of six lions (2 males and 4 females) to understand their spatial-temporal trends. Similarly, five spotted hyenas from the five clans should also be collared for the same purpose.
- Grevy's zebra is a species of conservation concern. Monitoring of this species at the individual level remains a priority. The current stripe identity database is bulky; thus the analysis of the images takes a considerable amount of time. We, therefore, need automated software to speed up the analysis for immediate management interventions.
- Human-Elephant Conflict (HEC) is a major conservation concern in communities surrounding protected areas. Plans to constitute a human-wildlife conflict response team are underway. However, this needs to be combined with other mitigation measures such as fence configurations, other techniques, and community education.
- The formation of exclusion zones has proven to be of great importance in encouraging the regeneration and recovery of woody vegetation. We advocate establishing temporary exclusion zones that can be opened once the woody vegetation reaches a height suitable for the majority of browsers.
- The current grazing programme under the Northern Rangelands Trust (NRT) Livestock to Market (LTM) programme has stalled due to challenges brought about by the COVID-19 pandemic and other dynamics in northern Kenya. This programme needs to be reviewed to guarantee long-term results for rangeland health, particularly the grasslands.

- The Grey Crowned Crane (GCC) exhibits local and seasonal migration. This being an endangered water bird, there is a need to invest in satellite tracking to understand their spatial-temporal trends to protect their home ranges.
- There is high bird diversity at Il Ngwesi Conservancy based on the preliminary surveys we have conducted. More bird surveys are needed in collaboration with the National Museums of Kenya to build up the bird checklist for the conservancy.
- Due to the high abundance and diversity of flora and fauna on LBL, we recommend the commencement of the process to designate the landscape as a Key Biodiversity Area (KBA).

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1.0 INTRODUCTION

This report provides details of the research and monitoring activities undertaken on the Lewa-Borana Landscape by the Lewa-Borana Landscape Research and Monitoring Department between January and December 2021. The year received lower rains (253±5) compared to the long-term (1975-2020) averages (510±27mm).

We continue to work with the Centre for Training and Integrated Research in ASAL Development (CETRAD) to create hydromet monitoring procedures that will help us assess the state of this resource in the landscape as part of natural resource planning.. This collaboration saw the installation of the three automated River Gauging Stations (RGSs) on two sites at Ngare Ndare river and one site at Ngare Nyting river. The calibration of the instruments is ongoing which entails taking the speed of water among other parameters at different depths, flow heights, and points on the cross-section of the river. We have also initiated the procurement of two weather stations that are Low Range Wide Area Network (LoRaWAN) enabled and will submit real-time data to the EarthRanger (ER) platform. One of the weather stations will be installed at Lewa Wildlife Conservancy and another one at Borana Wildlife Conservancy. This is the initial stage of the wider rivers and springs monitoring project in the landscape. The entire process will help us quantify this resource and give advisory opinions to the surrounding communities through Water Resources Management Authority (WARMA) and Water Resource Users Associations (WRUAs).

The process of establishing a demand-driven research consortium is almost complete. The consortium will be dubbed Research and Development Centre for Northern Kenya, loosely translated as *'Utafiti na Maendeleo Kaskazini mwa Kenya'* (UMAKA) in Kiswahili. This center will promote long-term monitoring of ecosystem trends, capacity building in evidence-based natural resource management, mobilize resources for ecosystem research and monitoring, and champion demand-driven research that will influence development and policy formulation. The initial partners are local and national training and research institutions namely Meru University of Science and Technology (MUST), Kenyatta University (KU), University of Nairobi (UoN), and National Museums of Kenya (NMK).

We also collaborated with the International Council for Research in Agroforestry (ICRAF) to assess soil and ecosystem health on LBL using the Land Degradation Surveillance Framework (LDSF). The LDSF offers a consistent set of indicators and field protocols to evaluate ecosystem health. The indicators consist of tree, vegetation cover and structure, shrub and grass species diversity, infiltration capacity, current and historic land use, soil characteristics, and land degradation status. This framework can also be used to detect changes over time. Results will be shared once the data is analyzed.

Below are the details of conservation, research and monitoring activities for each thematic area across the landscape during the year 2021.

2.0 RHINO MONITORING

2.1 Introduction

The overall goal of the Black Rhino Action Plan, which runs up to 2021, is to achieve a meta-population of 830 black rhinos in the country (KWS, 2017). The black rhino population stood at 897 as of 31st July 2021, surpassing the target. The southern white rhinos in the country increased from a population of 750 in 2020 to 840 as of 31st July 2021 (KWS, 2021). The process of reviewing the Black Rhino Action Plan for the next five years is underway. Similarly, a process to have the first-ever White Rhino Conservation and Management Action Plan (2021 - 2025) is ongoing and is set to be launched in 2022.

The population of rhinos on the Lewa-Borana Landscape (LBL) increased from 217 (114 black and 103 white) at the end of 2020 to 247 (131 black and 116 white) in 2021. This was after 35 births (17 black and 18 white) were recorded compared to 14 (7 black and 7 white) in 2020. The high number of births were recorded because most rhinos who calved in the peak period of 2017-2019 calved again this year. Seven females also gave birth for the first time. With an average inter-calving interval of 2.5 to 3 years on LBL, we expect the births to reduce in 2022.

2.2 Black rhino population performance

The population of black rhinos on the landscape increased from 114 to 131 after 17 births and 0 deaths were recorded, table 2.1. This represents a biological growth rate of 10.5 % in 2019 - 2021 average 3-year moving window period compared to 9.4% in the 2018 - 2020 period, figure 2.1. These average rates surpass 5% per annum recommended for a well-established rhino sanctuary in the country (KWS, 2017).

Betsy (7.5-year-old) and *Allie* (7.3-year-old) gave birth to their first calves thus increasing the number of breeding females to 33 individuals. Overall, 17 births were recorded against the predicted 19 births in 2021.

Table 2.1: Black rhino births on LBL in 2021

#	Calf name	Date of Birth	Sex	Dam	Sire
1	*Wanjiku Calf 2*	25-Jan-21	F	*Wanjiku*	*Folly?*[i]
2	*Sonia Calf 9*	10-Feb-21	M	*Sonia*	*Ndoto?*
3	*Ndito Calf 9*	13-Feb-21	F	*Ndito*	*Elvis?*
4	*Mama C Calf 6*	5-Mar-21	F	*Mama C*	*Ngiririma?*
5	*Seneiya Calf 3*	1-Jan-21	M	*Seneiya*	*Mutane?*
6	*Allie Calf 1*	9-May-21	F	*Allie*	*Roy?*
7	*Samia 2 Calf 7*	6-May-21	M	*Samia 2*	*Muturi?*
8	*Betsy Calf 1*	14-May-21	M	*Betsy*	*Elvis?*
9	*Anna Calf 4*	8-Jun-21	M	*Anna*	*Ndoto?*
10	*Winnie Calf 4*	1-Aug-21	U	*Winnie*	*Ngiririma?*
11	*Seiya Calf 7*	3-Aug-21	F	*Seiya*	*Sogomo?*
12	*Mejh Calf 5*	29-Aug-21	F	*Mejh*	*Sonny Liston?*
13	*Grace Calf 3*	25-Sep-21	F	*Grace*	*Roy?*
14	*Zaria Calf 10*	8-Oct-21	U	*Zaria*	*Muturi?*
15	*Bahati 2 Calf 2*	12-Nov-21	U	*Bahati 2*	*Lucky?*
16	*Zenetoi Calf 3*	8-Dec-21	U	*Zenetoi*	*Muturi?*
17	*Lucy Calf 3*	8-Dec-21	F	*Lucy*	*Silvester?*

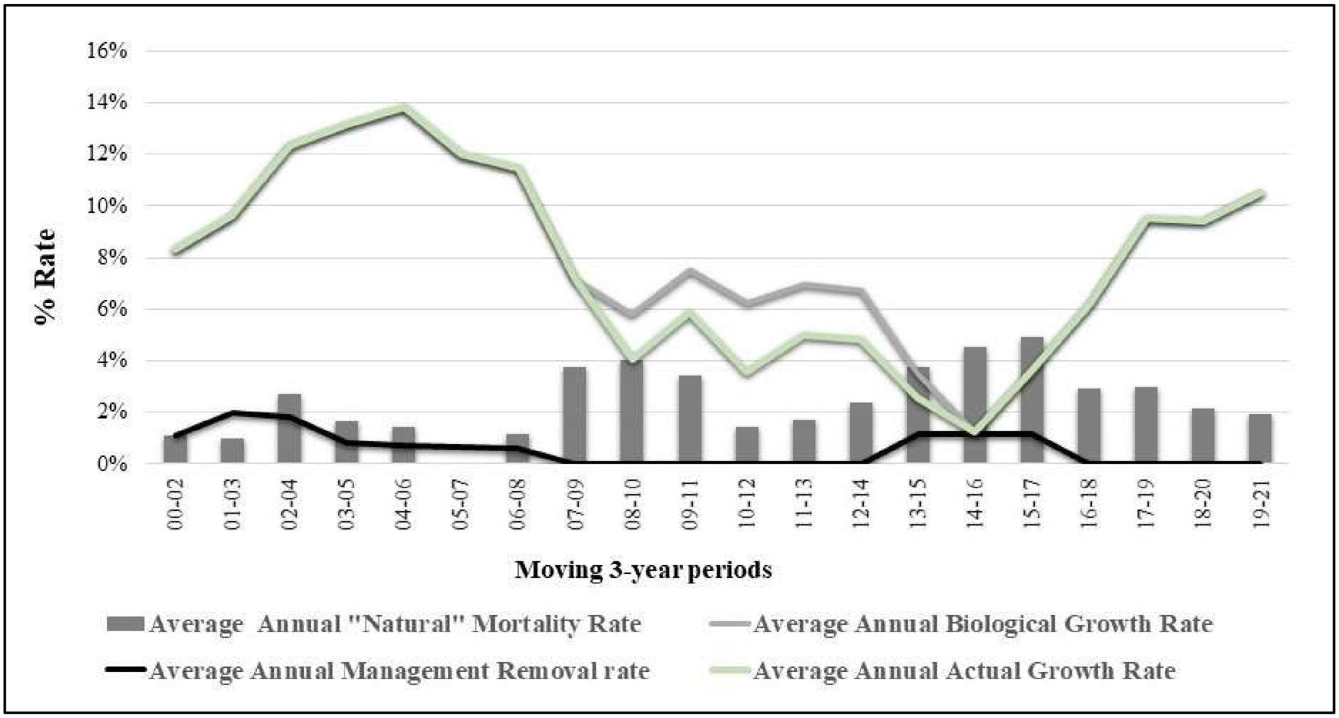

Figure 2.1: Key black rhino population metrics on the LBL, 2000-2021 (**Biological growth rate** - Human-caused deaths, that is, poaching, treated as removals but includes translocations; **Actual growth rate** – Human-caused deaths not treated as removals; **Management removal** – rhinos translocated out)

2.2.1 Performance indicators

Age at first calving (AFC), inter-calving interval (ICI), sex ratios (SR), and yearly percentage of female calving (PFC) are some of the measures of reproductive performance (Okita-Ouma, *et al.*, 2020). LBL black rhino average ICI in the 2019-2021 period was 2.6 years, PFC was 39%, AFC was 7.8 years, and the SR of female to male was 1.2:1. These three benchmarks are rated as good, appendix 1.

52% of calves born were females and 39% were males. The sex of the four calves is still unknown. The sex structure for the entire population consists of 53% females and 44% males. The age structure of the entire population consists of 51% adults, 15% sub-adults and 34% calves, table 2.2. These benchmarks are rated as good (Balfour, *et al.,* 2019).

Table 2.2: Population structure of black rhino on LBL, 2021

Age Class	Male	Female	Unknown	Sub Total	Proportion in population
Calves (0<3.5yrs)	17	23	4	44	**34%**
Sub Adults (3.5<7 yrs) unless calved	10	10	0	20	**15%**
Adults (>7yrs)	30	37	0	67	**51%**
Grand Total	57	70	4	131	**100%**
Proportion in population	**44%**	**53%**	**3%**	**100%**	

2.3 White rhino population performance

The population of white rhinos on the landscape increased from 103 to 116 after 18 births and 4 deaths, table 2.3 and 2.4. This represents a biological growth rate of 11.5% in the 2019 - 2021 average 3-year moving window period compared to 9.9% in the 2018 - 2020 period, figure 2.2.

Barbara (5.2-year-old), *Sanaipei* (7.9-year-old), *Namunyak* (5.9-year-old), *Sidai* (5.5-year-old), and *Moonshot* (6.3-year-old) gave birth to their first calves increasing the number of breeding females to 30 individuals. *Barbara* became the youngest white rhino to calve on LBL at the age of 5.0 years. White rhino female sexual maturity in the wild can be reached as early as 3 years of age, with age at first calving more likely to be 5 to 5.5 years (Patton and Genade, 2017). *Songare* (42-year-old), who is the oldest female rhino on the landscape, gave birth to her thirteenth calf. The 18 births were recorded against the predicted 19 births in 2021.

Table 2.3: White rhino births on LBL in 2021

#	Calf name	Date of Birth	Sex	Dam	Sire
1	*Natal Calf 11*	15-Jan-21	M	*Natal*	*Gordon?*
2	*Wakesho Calf 5*	26-Jan-21	M	*Wakesho*	*Ronnie?*
3	*Djanim*	1-Feb-21	M	*Tumbili*	*Imado?*
4	*Sanaipei Calf 1*	1-Feb-21	M	*Sanaipei*	*Cookie?*
5	*Semenya Calf 2*	15-Mar-21	F	*Semenya*	*June?*
6	*Ramadhan Calf 5*	23-Mar-21	M	*Ramadhan*	*Ruby?*
7	*Babra Calf 1*	28-Mar-21	M	*Babra*	*Ruby?*
8	*Ngura Calf 3*	28-Mar-21	F	*Ngura*	*Imado?*
9	*Queen Calf 4*	3-Apr-21	M	*Queen*	*Muya?*
10	*Naserian Calf 4*	1-Jun-21	M	*Naserian*	*Samawati?*
11	*Namunyak Calf 1*	27-Jun-21	M	*Namunyak*	*June?*
12	*Songare Calf 13*	23-Aug-21	M	*Songare*	*Cookie?*
13	*Titilei Calf 6*	7-Sep-21	M	*Titilei*	*Samawati?*
14	*Jacho Calf 5*	13-Oct-21	F	*Jacho*	*Gordon?*
15	*Sidai Calf 1*	14-Oct-21	U	*Sidai*	*June?*

16	*Moonshot Calf 1*	24-Oct-21	F	*Moonshot*	*Muya?*
17	*Lina Calf 3*	1-Nov-21	U	*Lina*	*Motonto?*
18	*Ruudi Calf 2*	27-Nov-21	U	*Ruudi*	*Obama?*

Table 2.4: White rhino deaths on LBL in 2021

#	**Rhino name**	**Age at death**	**Sex**	**Cause of death**
1	*Robin*	10.6 years	Male	Drowned in water
2	*Schini Calf 6*	2.2 years	Female	Severe injuries
3	*Dominique*	13.2 years	Male	Severe injuries
4	*Sidai Calf 1*	19 days	Unknown	Trampling

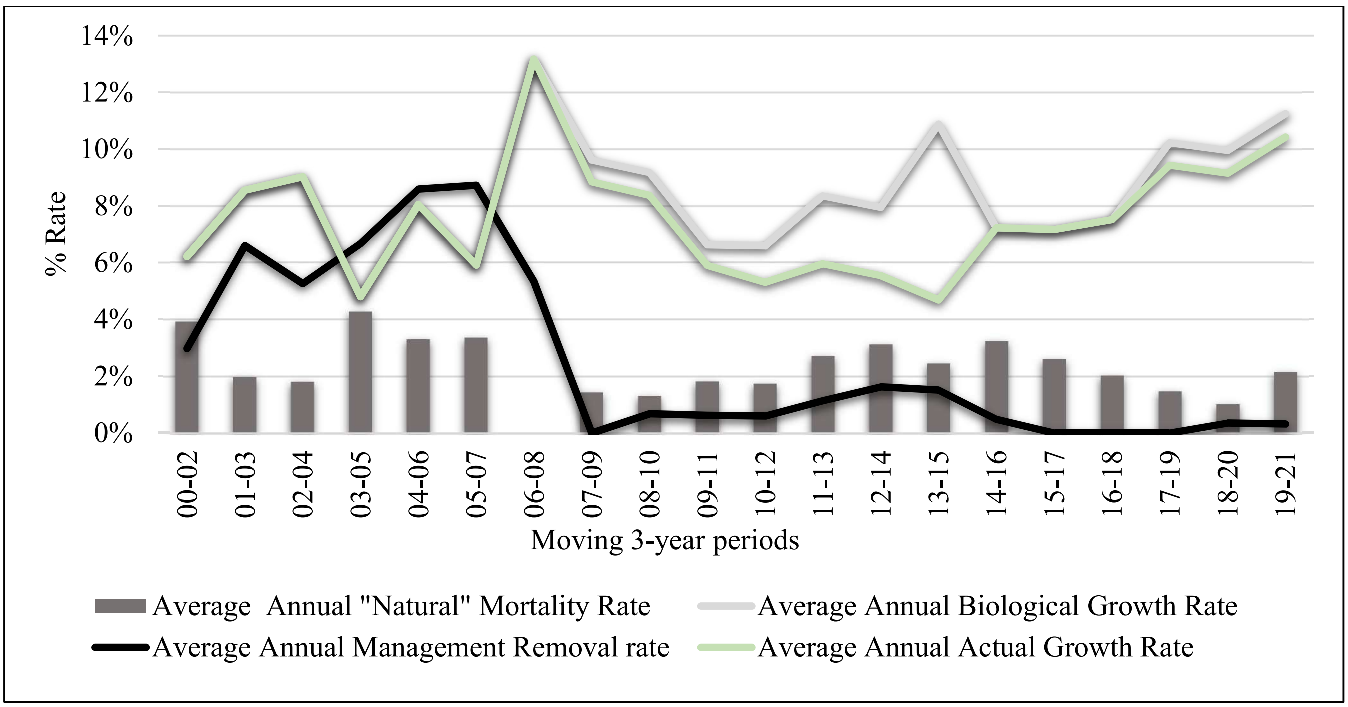

Figure 2.2: Key White rhino population metrics on the LBL, 2000-2021

2.3.1 Performance indicators

LBL white rhino age at first calving (AFC) was 6.1 years, 2.4 years inter-calving interval, 56% of female calving, and 1:1.1 female to male sex ratio. These benchmarks are rated as moderate to good, appendix 1. LBL's white rhino sex structure consists of slightly more males (51.7%) than females (46.6%). 40% of calves born are females and 55% are males. The sex of the two calves is unknown. The age structure of the entire population consists of 51% adults, 15% sub-adults, and 34% calves table 2.5. These benchmarks are rated as moderate (Balfour, *et al.,* 2019).

Table 2.5: Population structure of White rhino on LBL, 2021

Age Class	Male	Female	Unknown	Sub Total	Proportion in population
Calves (0<3.5yrs)	22	16	2	40	**34%**
Sub Adults (3.5<7yrs) unless calved	9	8	0	17	**15%**
Adults (>7 yrs)	29	30	0	59	**51%**
Grand Total	60	54	2	116	**100%**
Proportion in population	**51.7%**	**46.6%**	**1.7%**	**100%**	

2.4 Spatial ecology

2.4.1 Sighting frequency

The average sighting frequency (SF) for each black and white rhino was 2.5±0.08 days and 1.8±0.05 days respectively. This is within the critical sighting frequency of 3 days on the landscape.

2.4.2 Notable shifts in home ranges

Folly, a 19-year-old male black rhino expanded his territory from the northwest side of Lewa to the central part near Lewa headquarters, a territory that was previously occupied by *Ndoto*, figure 2.3. *Ndoto* broke his front horn in 2019 and was pushed to the western side of Lewa. *Mandela*, a 13-year-old male white rhino moved from the Borana side in January 2021 to the northern side of Lewa. He, later on, moved to the edges of Ngare Ndare forest, figure 2.3.

Wire, a 9.7-year-old male white rhino moved from the eastern side of Lewa to Borana during the first quarter of 2021, figure 2.3. He had previously moved to Borana and came back to Lewa in the second quarter of 2020 but currently appears to have established a territory in Borana. *Barry*, a 9.5-year-old male black rhino expanded his territory from the northern side of Lewa to the eastern side of Lewa, figure 2.3. Two male black rhinos, *Antonio* (6.6-year-old) 5 and *Loyau* (6.8-year-old), moved from the Lewa side of the landscape to the Borana side and came back after two weeks.

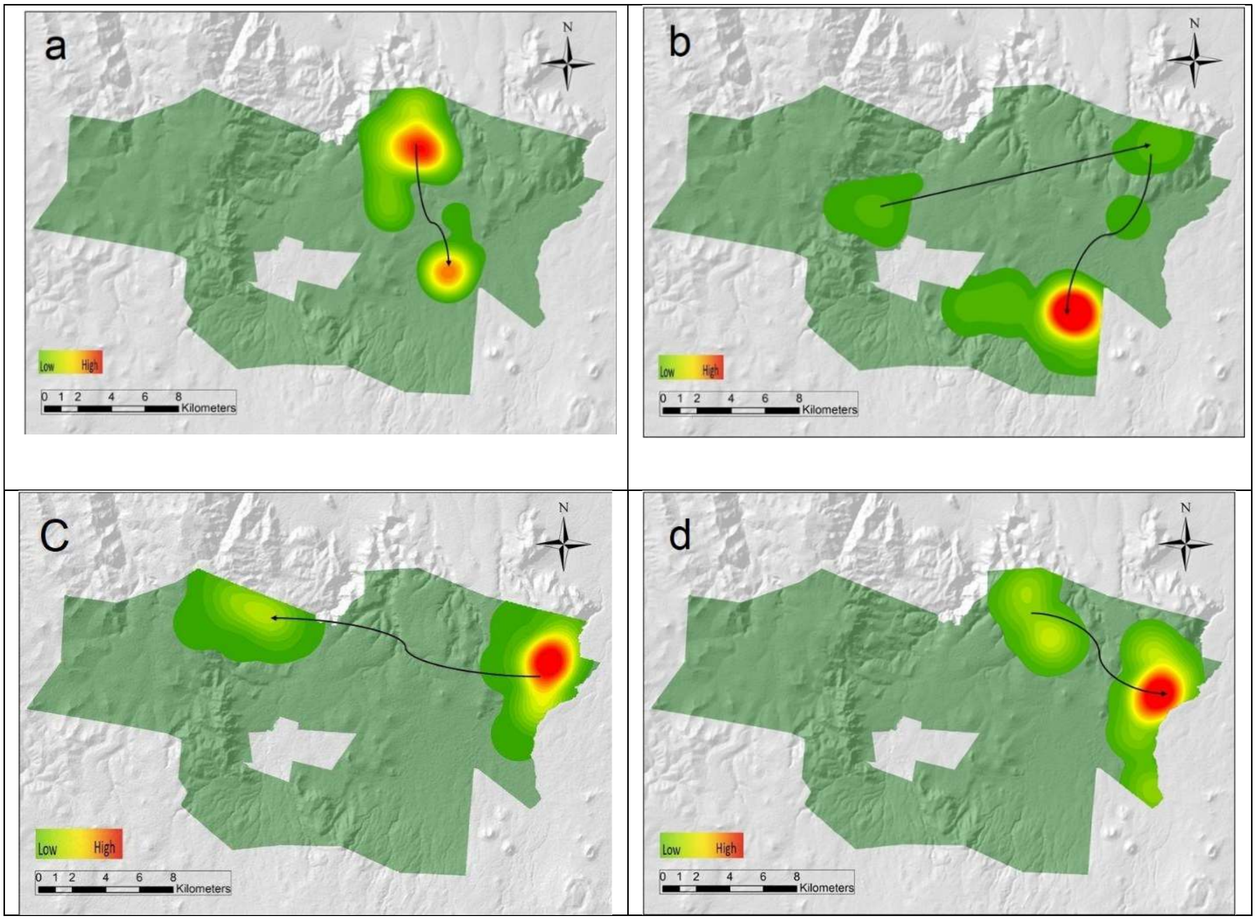

Figure 2.3: Changing home ranges for (a) *Folly,* (b) *Mandela, (c) Wire and (d) Barry*

2.5 Rhino veterinary interventions

Schini's Calf 6, a 2.2-year-old female white rhino, was treated after sustaining injuries on the left hind leg, lower abdomen, and shoulders as a result of being hit, possibly, by *Mia* (15.3-year old male white rhino). A second treatment was done after she sustained similar injuries and it was resolved that she be isolated into a temporary enclosure. The condition worsened and she succumbed to the injuries. The post-mortem report from a Kenya Wildlife Service (KWS) veterinarian indicated that the rhino had a fracture and a complete dislocation of the left hind leg and knee joint, peritonitis due to a penetrating wound on the lower abdomen, torsion and impaction of the large intestine, and dehydration. *Robin* (10.6-year-old male), a white rhino died due to drowning in *Dam ya Wambugu* in the south-eastern section of Lewa. *Namunyak Calf 1*, a 5-month-old male white rhino calf, was treated on 24-Dec-21. He had sustained a severe injury on his left hind leg. He was then transferred to Sheldrick Wildlife Trust for further treatment and care.

Ten rhino fight incidences (7 white and 3 black) were reported this year resulting in minor injuries.

2.6 Rhino body condition assessment

Between June and October 2021, the LBL conducted an annual dry season physical condition assessment of rhinos that were reasonably old and lactating. This assessment followed 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. In July rhinos (4 females and 1 male) whose body condition was seen to have dropped due to deteriorating range conditions were put on supplementary feeding. These rhinos were: *Zaria*, *Sonia*, *Samia 2*, *Anna* and, *Kitui*, (see Table 2.6).

Euphorbia candelabrum, a succulent species of plant and highly preferred and accepted by black rhinos as fodder, was placed strategically for the rhinos to feed on. Once the rhino got used to these sites, lucerne (*Medicago sativa*), there overall health improved. In the month of September three more rhinos (two white and one black) were added to the feeding program. These were: *Tumbili* and *Songare* (all white) and *Nashami* (black), table 2.6. An assessment done towards the end of September before the October-December rains showed improvement of their body condition scores to above 3.0, indicating fair to good body condition.

Toward the end of October and beginning of November, areas around the edges of *Ngare Ndare* forest and the eastern side of Lewa received light showers which slightly improved the condition of the browse. As a result, rhinos under the feeding program that reside in these areas were dropped from the feeding program. These were *Zaria*, *Samia 2*, *Nashami*, *Anna,* and *Tumbili*. The central and western sides of Lewa remained relatively dry. As a result, *Songare*, *Sonia* and, *Kitui*, who inhabit these areas, remained on supplementary feeding in November. The supplementary feeding program was stopped in December when sufficient rains were received.

Table 2.6: Rhinos put on supplementary feeding on LBL, 2021

#	Species	Rhino name	Age(years)	Sex	Date introduced	Reasons for supplementary feeding
1	Black	*Sonia*	30.4	F	Jul-21	Old and lactating
2	Black	*Samia 2*	23.3	F	Jul-21	Old and lactating
3	Black	*Anna*	16	F	Jul-21	Lactating, history of deteriorating body condition in the dry season
4	Black	*Zaria*	33.8	F	Jul-21	Old and lactating

5	Black	*Nashami*	23.5	F	Sep-21	Old and lactating
6	Black	*Kitui*	6.8	M	Jul-21	Orphan, less browse materials in his enclosure due to drought
7	White	*Songare*	42	F	Sep-21	Old and lactating
8	White	*Tumbili*	36	F	Sep-21	Old and lactating

2.7 LBL 2021 Rhino evidence files.

Objective 2.1 under the biological monitoring and management component of Kenya's Black Rhino Action Plan 2017-2021 obliges rhino sites to have at least 99% confirmed rhino population. This is through an up-to-date master ID file including date-stamped photos. The 2021 master ID files for all the LBL rhinos were completed. Photos were obtained from handheld cameras and camera traps that were deployed to capture rhinos in difficult areas like Ngare Ndare forest.

Currently, 50.4% of black rhinos are identifiable through ear notches and other unique features, 25.2% are clean and independent, and 24.4% are calves that can be sighted in association with their mothers. 52% of white rhinos are identifiable, 24% are clean and independent, and 24% are calves that can be sighted in association with their mothers. The identifiable population is below 60% which is required to independently identify rhinos by the monitoring team (KWS, 2017). To date, 44 (21 White and 23 Black) rhinos are suitable candidates for ear notching.

2.8 Conclusion and recommendations

All the rhino monitoring activities scheduled this year were completed except for the annual refresher training for the rangers. This training is scheduled to be conducted in the first quarter of 2022.

As the population of clean rhinos, both black and white, increases on LBL, there is a need to establish an annual ear-notching program to facilitate in identifying the rhinos that are clean. Currently, 444 animals are candidates for ear notching following a remarkable increase in births. Notching of at least 15 individuals per year will help in reducing the number of unidentifiable rhinos.

The Ecological Carrying Capacity (ECC) for white rhinos on LBL has not been undertaken despite the increasing population. There is a need to conduct this exercise so that the maximum number of white rhinos that LBL can support are known. The ECC of black rhinos also needs to be reviewed at a landscape level as the already existing ECC studies are outdated. Previous black rhino ECCs have been conducted separately on the Lewa and Borana conservancies.

3.0 PREDATOR MONITORING

3.1 Introduction

Apex predators such as the s African lion (*Panthera leo*) and Spotted hyena (*Crocuta crocuta*), can influence the composition and density of mesopredators and herbivores (Retief, 2016). Although the Lewa-Borana Landscape (LBL) hosts various large and small carnivores, our emphasis on monitoring has been mainly on the African lion and the Spotted hyena. This is driven by their relative population sizes, competitive dynamics, and their impact on the endangered prey species. They also play a fundamental role in the tourism industry and are ecologically important. These dual functions make them a key functional group needing consistent research and monitoring.

3.2 Population performance

3.2.1 Lion Population

In 2021, we monitored a population of 57 lions (39 adults, 4 sub-adults, and 14 cubs) occurring in five prides and two coalitions, table 3.1. *Bredymark's* pride, consisting of 9 individuals moved to Mukogodo forest towards the mid of the year. The pride attacked the livestock in the Mukogodo forest which coincided with the malfunctioning of the collar. We visited the last GPS location with no sighting, and we assume the pride was killed since none of the individuals has been sighted to date. We also had an addition of three adult males who emerged on the western side of LBL. So far, we have not established their origin. The incomers triggered the exit of two territorial males (*Dick* and *Esau*) to Il Ngwesi Group Ranch.

To obtain the age structure of the population, we classified lions into an adult, sub-adult, and cubs (Pollock, *et al.,* 1989), table 3.1. Adults were any lion aged between 3 to 10 years, sub-adults were those aged between 2 to 3 years, and cubs were all lions less than two years separated into large (1-2 years old) and small cubs (< 1-year-old) (Schaller, 2009). Photographs were also taken during sightings for demographics and identification.

12 lionesses from three different prides namely: *Simone*'s, *Carissa* and *Njaa*'s prides gave birth to a total of 14 cubs within the year. Due to close monitoring, most cubs were usually seen within one to three months after birth. None of the six lionesses on contraceptives gave birth or was even sighted mating.

Table 3.1: Lion population structure on LBL

	Adults		**Sub adults**		**Cubs**			**Total by pride/coalition**
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Unknown**	
Sarah's pride	2	1	0	0	0	0	0	3
Simone's pride	0	5	0	1	2	1	0	9
Dalma's pride	0	2	1	2	0	0	0	5
Carissa's pride	0	2	0	0	0	0	2	4
Njaa's pride	6	14	0	0	0	0	9	29
Ntulele's coalition	4	0	0	0	0	0	0	4
New coalition	3	0	0	0	0	0	0	3
Total by sex	**15**	**24**	**1**	**3**	**2**	**1**	**11**	**57**

3.2.2 Hyena population

By use of the camera traps mounted on each of the clan's communal den, we established a minimum population of 144 spotted hyenas (134 adults, four sub-adults and six cubs). Since the Spotted hyena is majorly nocturnal, collars remain the key tool for monitoring their activities as well as spatial-temporal movements.

While we continue to collect information on scat analysis, understanding the hyena feeding strategies in our landscape is imperative to understanding their uptake from the prey base. This is expected to be a collaborative venture as it will involve building internal capacity.

3.3 Leopard population

This year we began collecting baseline data on leopard abundance on LBL. Since leopards are solitary and elusive animals, a lot of effort is required to document their population. By collating reports from rangers, tour guides, and data from camera traps, we estimate 20 individuals on the landscape, figure3.1. We expect the monitoring to take shape in the yet to come collaboration between our department and San Diego Zoo Global (SDZG) leopard project.

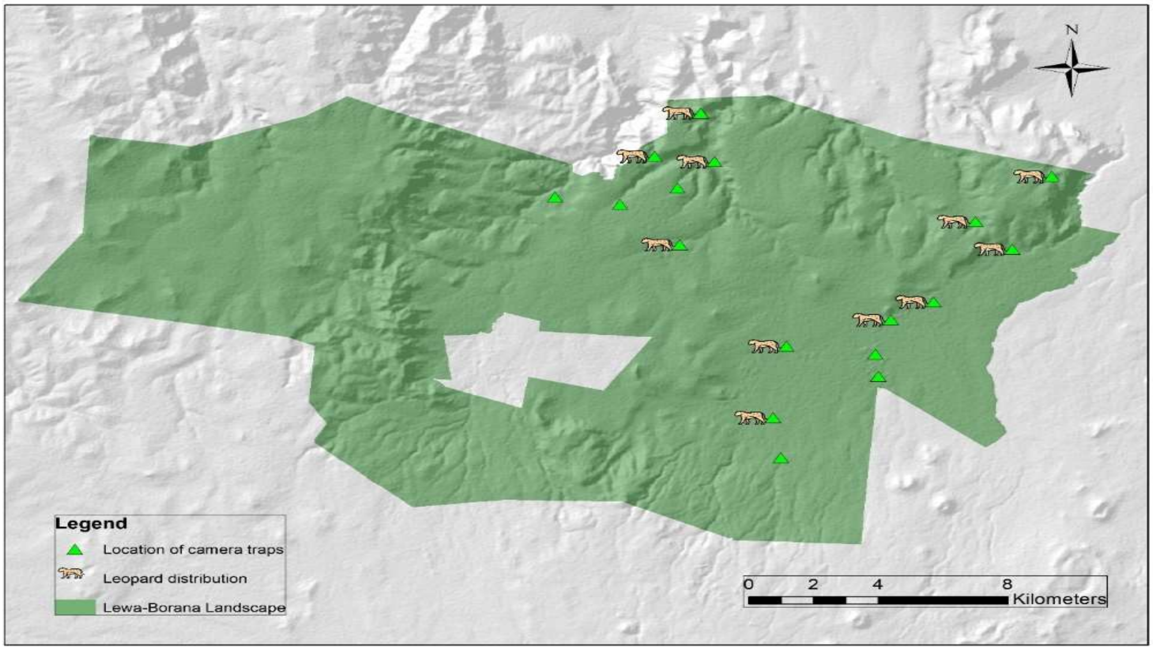

Figure 3.1: Leopards distribution and camera trap locations on LBL

3.4 Spatial ecology

This year, our lion monitoring program relied heavily on lion sightings and footprints observations to enable documentation of their dynamics and spatial-temporal movements as 5 out of 6 telemetric collars malfunctioned. Collar data ensures accurate positioning of the lions which, in turn, ensures potential conflicts with pastoralists are proactively responded to and recommendations are issued to the management.

Lion territories were mapped using sightings data on ArcMap 10.8.0. The territories overlapped, but each pride maintained a specific core area, figures 3.2 a, b, c and d. Lions on the landscape tend to have smaller home ranges which indicate the abundance of prey species. Our observation is consistent with Mosser and Packer, 2009, who documented smaller home ranges when prey was abundant and larger home ranges when prey was scarce.

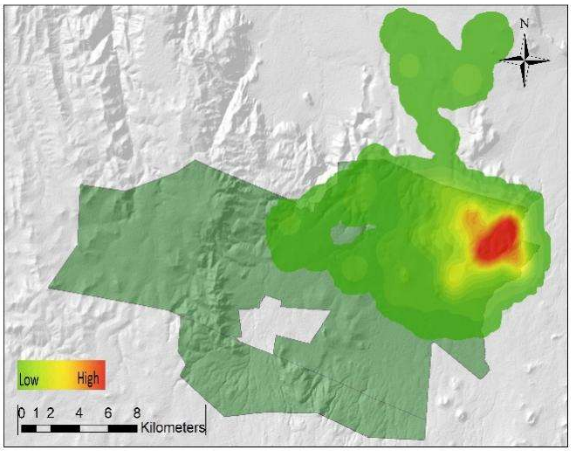

Figure 3.2a: *Sarah's* pride ranging areas,2021

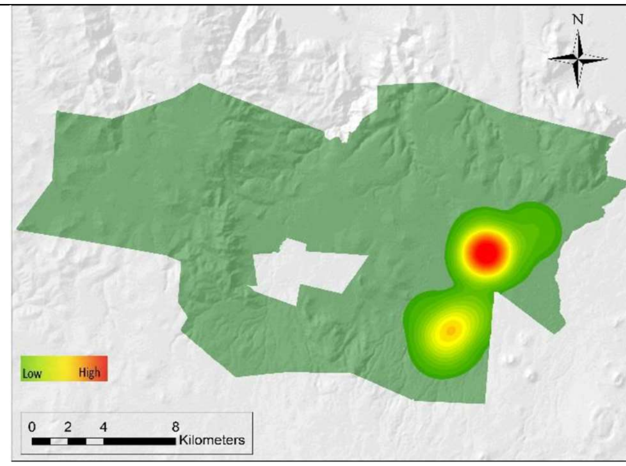

Figure 3.2b: *Dalma's* pride ranging areas, 2021

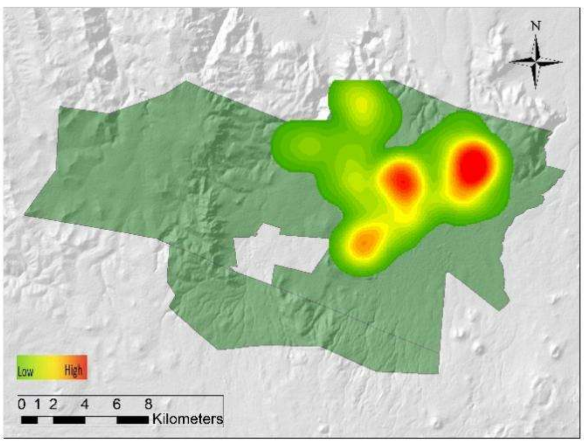

Figure 3.2c: *Simone's* pride ranging areas, 2021

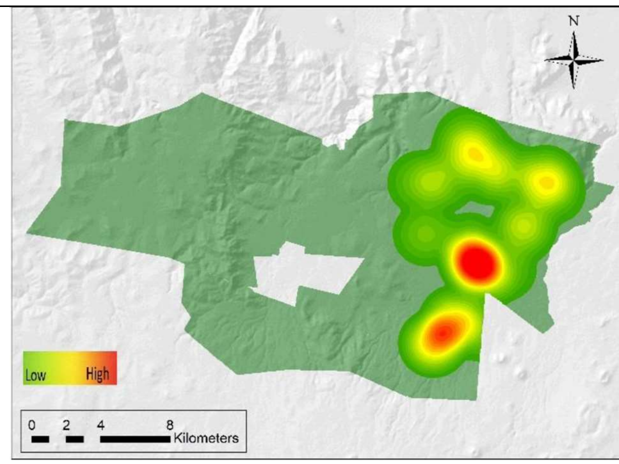

Figure 3.2d: *Ntulele's* coalition ranging areas, 2021

3.5 Human Carnivore conflicts

A total of 17 incidences were reported, resulting in the death of 52 livestock within LBL and the neighbouring communities. Lions were responsible for most of the cases followed by hyenas and leopards, table 3.2.

Table 3.2: Causes of livestock depredation on LBL

Species	Cattle	Shoats	Camels	Total deaths by carnivore
Lion	18	10	2	30
Hyena	0	21	0	21
Leopard	0	1	0	1
Total deaths by livestock	**18**	**32**	**2**	**52**

3.6 Wildlife mortality

Mortality is a fundamental principle of ecology because it affects the s population dynamics of wild ungulates (Scheiner and Willig, 2011). A total of 109 wildlife mortality cases were recorded on LBL, primarily resulting from predation as shown in Figure 3.3.

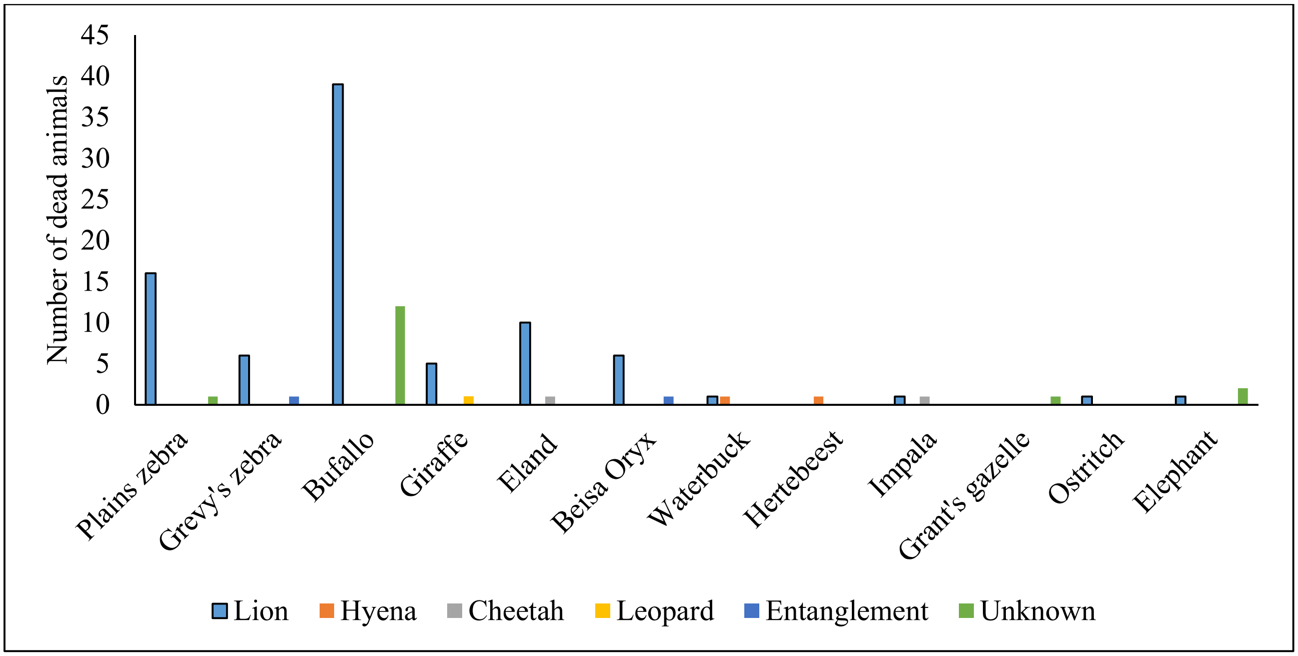

Figure 3. 3: Causes of wildlife deaths on LBL

To assess prey preference and selectivity by lions, Jacob's Selectivity Index (D) was used (Jacob's, 1974).

The index formula is;

D = (r-p)/(r+p-2rp),

where r is the proportion of kills of a particular species of all the kills; p is the proportional availability of that species in the population. Jacob's Index ranges between -1 (highly avoided) and +1 (highly selected).

Giraffe and eland have remained the two species that are mostly preferred by lions for the last five years. Impala, waterbuck, and Beisa oryx were mostly avoided by the lions, see table 3.3.

Table.3.3: Comparison of prey selectivity index from 2021 to 2017

Species	2021	2020	2019	2018	2017
Plains zebra	- 0.1	0.0	0.3	0.2	0.2
Grevy's zebra	0.3	0.0	0.2	- 0.1	0.0
Waterbuck	- 0.1	- 0.2	- 0.5	- 0.2	0.1
Beisa Oryx	0.4	- 0.5	- 0.6	- 0.6	- 0.6
Eland	0.4	0.6	0.5	0.5	0.4
Warthog	- 1.0	- 0.2	0.3	0.6	0.5
Impala	- 0.9	-1.0	-1.0	-1.0	-0.8
Giraffe	0.5	0.7	0.7	0.8	0.4
Buffalo	0.3	- 0.5	0.0	- 0.2	0.0

3.7 Scats analysis

A total of 93 scat samples from lions (n=46) and hyenas (n=47) were collected and analysed for prey hair content. Plains zebra and buffalo remain 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 two predators, figures 3.4a and b. The occurrence of livestock hairs in both lion and hyena scats indicates their interactions with livestock in the conservancy and the neighbouring community areas.

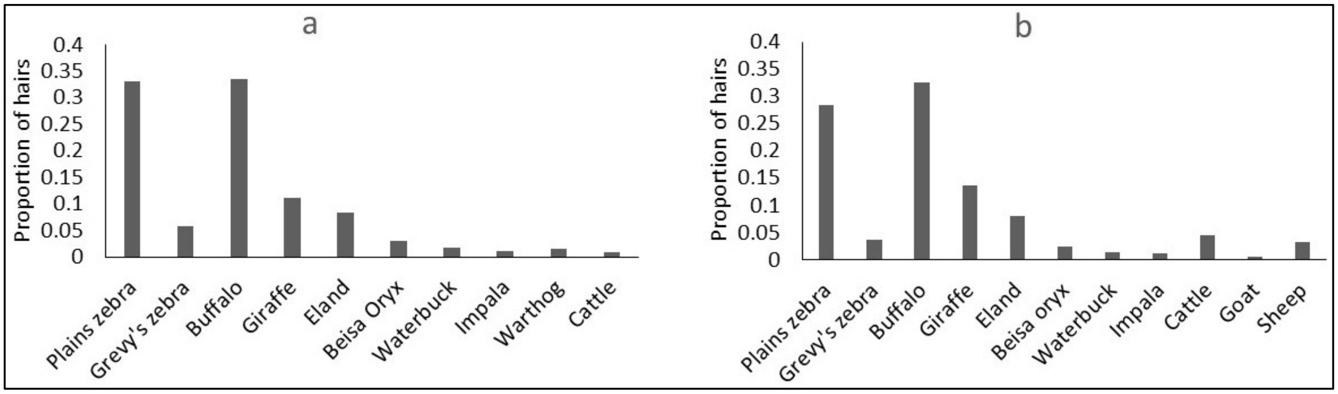

Figure 3.4: (a) Proportion of prey hairs from lion diet; (b) Proportion of prey hairs in hyena diet.

3.8 Conclusion and recommendations

Given the elusive and nocturnal nature of lions on the landscape, we recommend collaring six lions (2 males and 4 females) to understand their spatial-temporal trends and to track their daily activities. Five Spotted hyenas from the five clans should also be collared to study their spaspatial-temporal trends. This should be combined with studying their feeding behaviour since they are the dominant large predator on the landscape and their impact on prey populations is expected to increase.

There is a need to restart the conversation with the spotted hyena experts in the country to set up a comprehensive long-term hyena monitoring program.

While there are already ongoing plans to constitute the human-wildlife conflicts response team to respond proactively and reactively to conflict incidences, there is a need to enlighten local communities on livestock husbandry and farming techniques such as the use of herding dogs and predator-proof bomas since they have been proven to be effective.

The planned collaboration with San Diego Zoo Global (SDZG) leopard project is expected to improve research on leopards on the landscape.

4.0 UNGULATE MONITORING

4.1 Introduction

Seasonal and climatic variations in arid and semi-arid environments influence ungulates dynamics due to spatial variation in forage quality and quantity as well as water (Illius and O'Connor, 2000 and Mduma, *et al.,* 1999). The changes in resource patterns affect the body fat reserves of wild ungulates, movement patterns, as well as age and sex structure (Illius and O'Connor, 2000 and Fryxell 1987). When water and forage are scarce due to inadequate rains, wild ungulates aggregate around water points and in localized vegetation (Chamaillé-Jammes, *et al.,* 2008) damaging vegetation and increasing competition and predation (Landman, *et al.,* 2012).

The Lewa-Borana landscape (LBL), being a semi-arid environment, experiences such changes in vegetation and wildlife population structure. To monitor such parameter changes, we identified Grevy's zebra (*Equus grevyi*), Plains zebra (*Equus quagga*), buffalo (*Syncerus caffer*), Beisa oryx (*Oryx beisa*), hartebeest (*Alcelaphus buselaphus lelwel*), giraffe (*Giraffa camelopardalis*), and eland (*Taurotragus oryx*) to act as indicator species. We also monitored the movement of wildlife through the migratory gaps linking LBL with the contiguous conservancies by use of camera traps.

4.2 Results and discussions

4.2.1 Ungulates performance

The growth potential and the percentage of juveniles and young in a population are the two important parameters that determine the stability of a population based on demographic modelling simulations (Rubenstein*,* 2010). The growth potential is based on the ratio of males to females of the adult age class where 1:1 represents low growth potential, 1:2 represents medium growth potential, and 1:3 and above represents high growth potential. The percentage of juveniles and young combined should approach 30%, which is a set threshold for a stable and self-sustaining population (Rubenstein*,* 2010).

From 2016 to date, buffalo have attained the recommended 30% threshold of combined juveniles and young of the total. Hartebeest attained this threshold in 2017 and 2019, with little deviation from the threshold in other years apart from 2016. Eland attained this threshold in 2020 and 2021. Grevy's zebra, Plains zebra, and oryx have never attained the 30% mark but the difference in this mark is very minimal. Giraffe recorded the lowest percentage (slightly above 10%) in all years of juveniles and young of the total, figure 4.1.

The growth potential for the ungulates ranged from medium to high with hartebeest, eland, Beisa oryx, buffalo, and Plains zebra attaining high growth potentials throughout the years. Grevy's zebra recorded two years of high growth potential while the rest of the years recorded medium growth potential. The giraffe had only two years with medium growth potential while the rest recorded high growth potential, figure 4.2. Based on this data, this is a resilient population that can recover from an ecological disturbance.

The population of hartebeest in the landscape is low. According to the 2021 Game Count Report, we recorded a total of 91 individuals. In 2014 we began monitoring the survival rate of calves of a subset population that had a total of 11 individuals. Up to date, the subset has grown to approximately 47 individuals resulting from births and initial immigrants from Borana Conservancy before the fence separating Lewa and Borana conservancies was completely removed in 2015. From 2014 to date, we have recorded a total of 61 births and 30 deaths, representing a 51 % survival rate for the young ones.

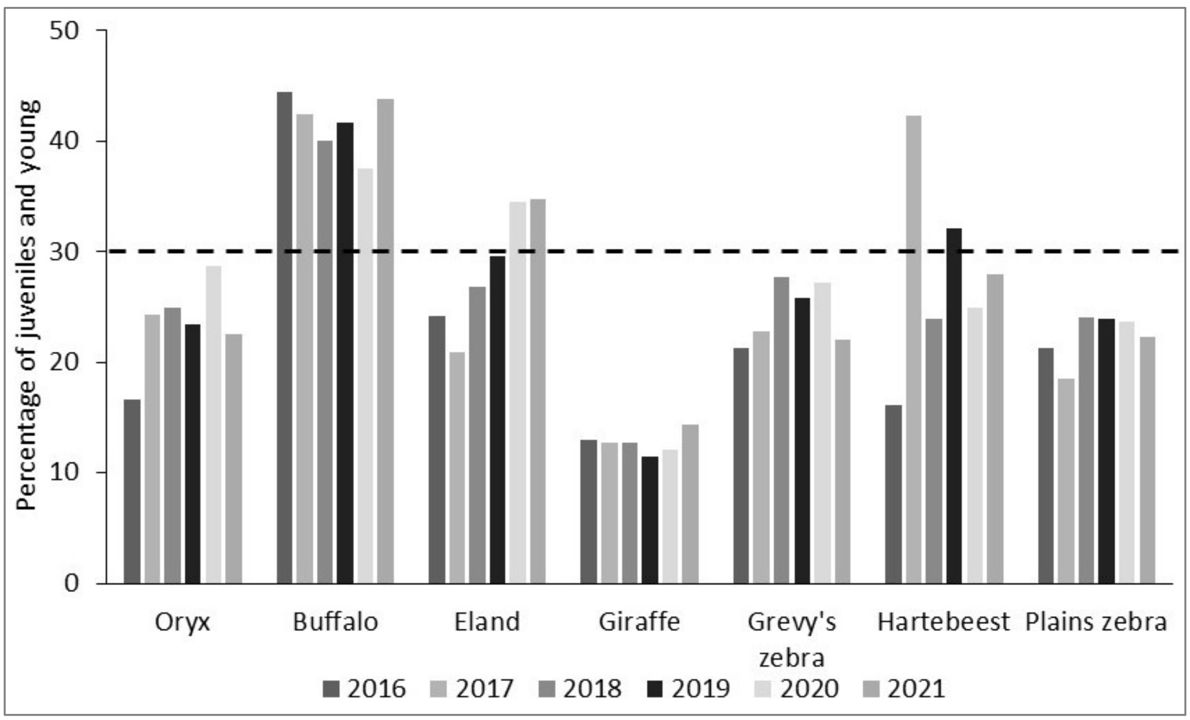

Figure 4.1: Proportion of young and juveniles for ungulate species monitored. The dotted black line indicates the 30% recommended level for stable populations.

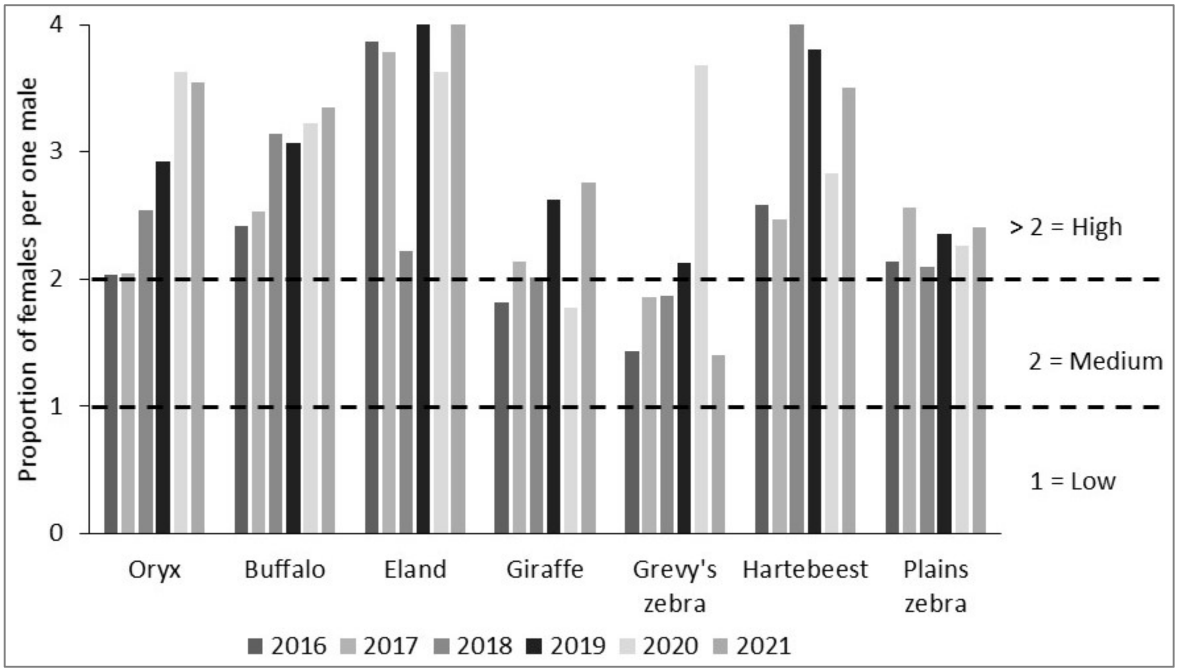

Figure 4.2: Proportion of adult females per one adult male. The black dotted lines indicate levels of various growth potentials, i.e., Low, Medium, and High.

4.2.2 Body condition scores (BCS)

The landscape health and productivity in LBL has mainly relied on rainfall which subsequently influences wildlife performance. With the months of July-November this year being very dry, we carried out the body condition assessment of the indicator species to monitor their response to the prevailing conditions. We used Ezenwa, *et al.,* 2009 criterion to evaluate body condition for buffalo, eland, oryx, hartebeest, and giraffe, table 4.1. For Grevy's zebra and Plains zebra, we used a criterion provided by D. Rubenstein, personal communication, May 12, 2020, figure 4.3.

Buffalo, eland and hartebeest were the main species affected by the drought, table 4.2. The lower body condition scores were mainly for the lactating females and their young ones. The sub-adults and non-lactating individuals were the least affected.

Table 4.1: Description of assessment criteria for individual components of Body Condition Score (BCS) adopted from Ezenwa, *et al.,* 2009.

SCORE	RIBS	SPINE	HIPS	TAIL	COAT
5 (Obese)	Not visible; fatty layer on and between ribs	Spine bones are not visible. Spine sits in slight depression between fatty bulges left and right of spine	Convex, smooth rear, hip bones not visually apparent	Tail base sits in depression surrounded by soft fatty tissue	Glossy coat covering entire body
4	Few ribs visible towards abdomen; ribs can be felt	Spine bones are not visible. Spine feels flat; bone and surrounding tissue are on level	Hip bones can be seen, round smooth appearance and feel	Tail base on a level with surrounding fatty tissue	Thin coat covering entire body; or glossy coat with a few, small bald patches
3	Some ribs are visible the in centre of the ribcage; abdominal ribs feel ridged	Spine palpable as a slightly elevated bony centre-line	Points of hips distinctly visible; bone easy to feel but not protruding	Tail base protrudes slightly; obvious by touch, but not by sight	Some bald patches behind the shoulders or along the flanks
2	Ribs visible throughout; all have ridged feel	Individual spinal vertebrae clearly palpable	Points of hips protrude; flanks are concave	The tail base visibly sticks up from surrounding tissue	Large bald patches throughout torso
1 (Emaciated)	Ribs visible with deep depressions between them; very ridged feel	Vertebrae distinguishable by sight and touch	Hip bones protrude beyond the hip point; emaciated rear	Tissue surrounding tail base forms round hollow defined by pelvis	Majority of body area bald or very sparsely coated

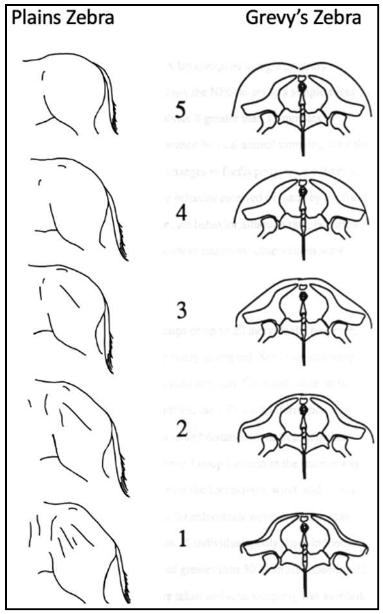

Figure 4.3: Body condition scores assessment criteria for Grevy's zebra and Plains zebra. Grevy's zebra fat lies on the pelvis. As the fat disappears, the pelvic bones poke through. Plains zebra fat is along the spine and as it disappears the skin gets 'flabby' and loose (D. Rubenstein, personal communication, May 12, 2020).

Table 4.2: Species Body Condition Scores (BCS) for November

Body Condition Score (BCS)	Species						
	Buffalo	Beisa Oryx	Eland	Giraffe	Hartebeest	Plain's zebra	Grevy's zebra
5 (Obese)	0	0	0	0	0	0	0
4	97	9	19	17	10	66	221
3.5	79	4	2	0	3	0	24
3	68	4	31	0	3	9	29
2	8	0	0	0	0	0	0
1 (Emaciated)	2	0	0	0	0	0	0

Total By Species sampled	**254**	**17**	**52**	**17**	**16**	**75**	**274**
Totals as per the LBL game count 2021	**2,153**	**239**	**358**	**172**	**91**	**1,561**	**322**
Percentage of the total population sampled	**11.8 %**	**7.1 %**	**14.5 %**	**9.9 %**	**17.6 %**	**4.8 %**	**85.1 %**

Values against the body scores represent individuals of a given species that have that body score.

4.2.3 Grevy's zebra foal performance

We logged the 2020 and 2021 photos of Grevy's zebra into the National Grevy's zebra database for unique stripe identity analyses. The two-year period captured 454 unique individuals in the database of which 142 were foals. Any individual foal not re-sighted within 6 months was assumed dead. Using this criterion, the surviving and the dead individuals were 85 and 57 respectively, which means 59.9% are surviving to date. Out of the surviving 59.9%, 56.5% have moved from being foals to juveniles and adults, meaning they are now past the vulnerable age bracket of 0-3 months, 3-6 months, and 6-12 months, figure 4.4a. The data also indicates that 0-3 months and 3-6 months are the most vulnerable age bracket, figure 4.4b.

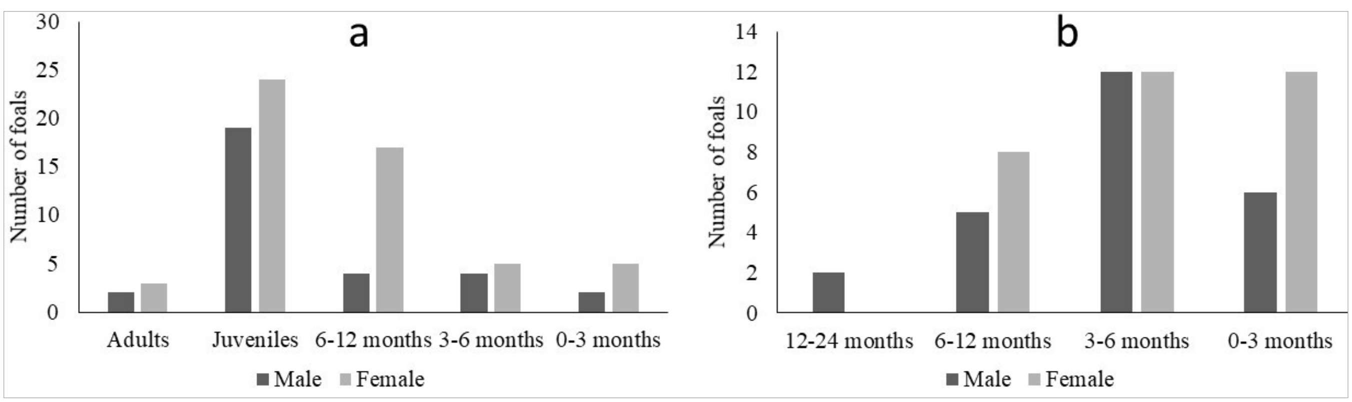

Figure 4.4: a) Age and sex distribution of the surviving foals born in 2020 and 2021; **b)** Age and sex distribution of the dead foals

4.2.4 Annual wildlife count

We completed the annual wildlife count for the LBL in February 2021 where we noted the population of most of the species did not deviate much from the 2020 count. However, some of the species showed a significant increase (Kaaria, *et al.,* 2021, unpublished report). Table 4.1 shows the total population of indicator wild ungulates we've monitored since 2016:

Table 2.1: Game count results for the indicator species from 2016 - 2021

Species	**Year**					
	2016	**2017**	**2018**	**2019**	**2020**	**2021**
Eland	280	192	322	291	245	358
Beisa oryx	179	220	178	227	307	239
Buffalo	1220	1391	1623	1753	2086	2153
Giraffe	273	251	127	167	178	172
Hartebeest	30	62	64	64	93	91
Plains zebra	1262	1236	1228	1484	1599	1561
Grevy's zebra	299	292	308	313	331	322

4.2.5 Movement of wildlife through the migratory gaps

Wildlife corridors are the prime means of securing habitat connectivity. They serve as an important conduit that preserves access to the larger habitat, provide avenues for predation avoidance, reduce inbreeding, and improve genetic viability (Ojwang, *et al.,* 2017).

LBL has been monitoring wildlife movement through designated migratory routes using infra-red camera traps. We analysed the movement patterns for the last nine years and compared the trends between the dry and wet periods. The gaps include the Mount Kenya End pass, Mount Kenya Underpass, New Mount Kenya Underpass and the Northern gap.

4.1.1 Mount Kenya End pass

There was a significant difference in crossing events of all wildlife on the Mt. Kenya End Pass between the dry (22,713) and wet period (23,778) ($\chi 2 = 24.397$, df = 1, p = 0.0001), figure 4.5a. There were more crossing events of elephants towards the corridor leading to Mount Kenya forest (1,952) than into the corridor that leads to Lewa through the NNFR (1,761) during the dry period ($\chi 2 = 9.8252$, df = 1, p = 0.0017) figure 4.5b. During the wet period, there were more crossing events of elephants towards the corridor leading to Lewa through NNFR (1,351) than towards Mt. Kenya forest (1,232) ($\chi 2 = 5.4824$, df = 1, p = 0.0192), figure 4.5b.

The trend indicates a significant increase in crossing events for all wildlife from 2013 to date ($\chi 2 = 16542$, df = 8, p = 0.000), figure 4.1c.

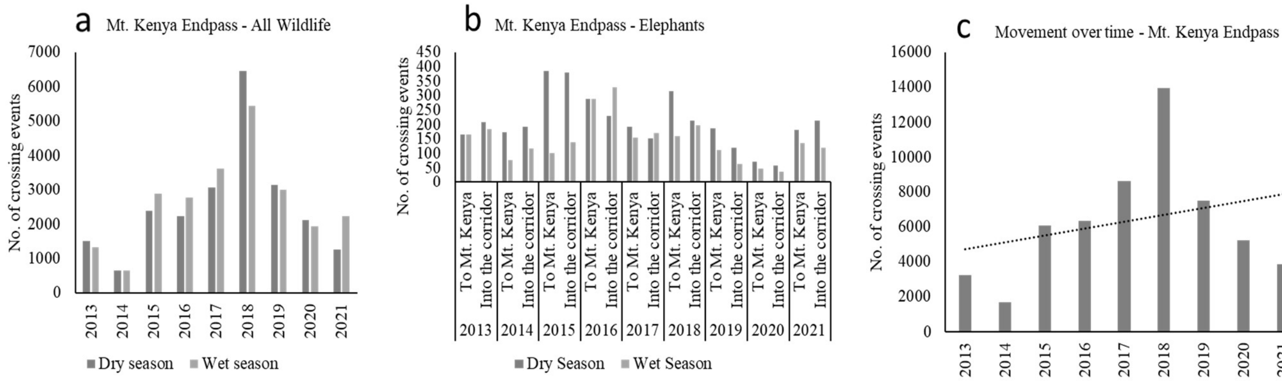

Figure 4.5: a) Seasonal movements of all wildlife species using the gap; **b)** Seasonal movements of elephants; **c)** Trends of all wildlife species using the gap

4.1.2 Mount Kenya Underpass

There was a significant difference in crossing events of all wildlife on the Mount Kenya Underpass gap between the dry (10,341) and wet (7,349) period ($\chi2 = 506.05$, df = 1, p = 0.0001), figure 4.6a. There were more elephant crossing events towards Mount Kenya forest through the corridor (2,695) than towards Lewa through NNFR (2,560) during the dry period (($\chi2 = 3.4681$, df = 1, p = 0.0626), figure 4.6b. During the wet period, there were more elephant crossing events towards Lewa through NNFR (1,698) than towards Mt. Kenya forest through the corridor (1,489) ($\chi2 = 13.706$, df = 1, p = 0.0002), figure 4.6b.

The trend indicates a significant increase in crossing events for all wildlife from 2013 to date (($\chi2 = 2871.9$, df = 8, p = 0.000), figure 4.6c.

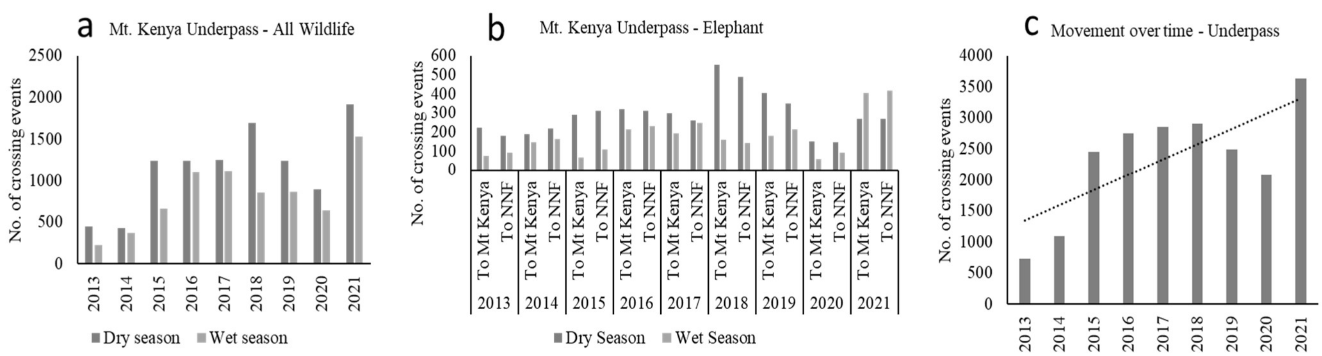

Figure 4.6: a) Seasonal movements of all wildlife species using the gap; **b)** Seasonal movements of elephants; **c)** Trends of all wildlife species using the gap

4.1.3 Northern gap

There was a significant difference in crossing events of all wildlife on the Northern gap between the dry (51,499) and the wet (60,882) period ($\chi2$ = 783.41, df = 1, p = 0.0001), figure 4.7a. There were more crossing events of an elephant during the dry period out of Lewa to the north (9,306) than into Lewa from the north (9,013) ($\chi2$ = 4.6863, df = 1, p = 0.0304) (figure 4.7b). During the wet period, there were more elephant crossing events out of Lewa towards the north (14,562) than into Lewa from the north (11,850) ($\chi2$ = 278.47, df = 1, p < 0.000), figure 4.7b.

The trend indicates a significant decrease in crossing events for all wildlife from 2013 to date ($\chi2$ = 6459.6, df = 8, p = 0.000), figure 4.7c.

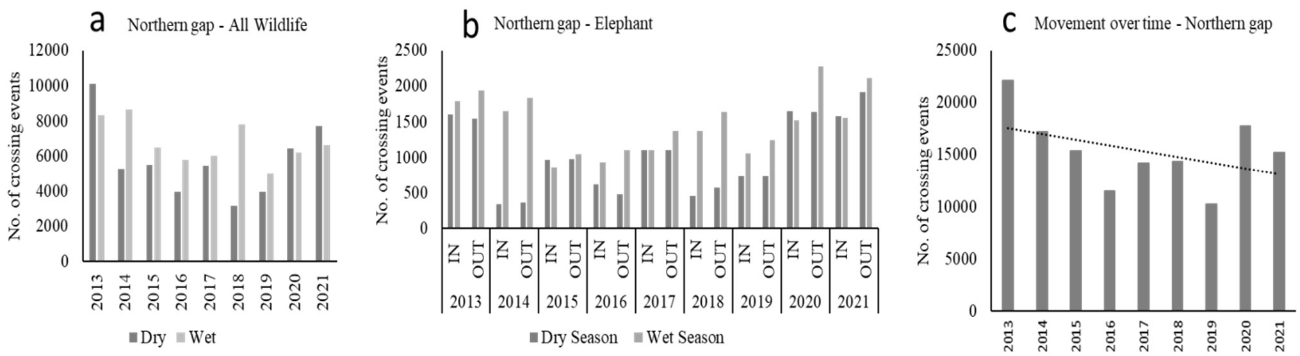

Figure 4.7: a) Seasonal movements of all wildlife species using the gap; **b)** Seasonal movements of elephants; **c)** Trends of all wildlife species using the gap

4.1.4 New Mount Kenya Underpass

The New Mount Kenya Underpass has been in operation for the last 3 years. During this period the gap recorded a total of 1,658 crossing events. There was a significant difference in crossing events on the new Mount Kenya Underpass gap between the dry (517) and wet (772) period ($\chi2$ = 50.446, df = 1, p = 0.0001) as seen in figure 4.4a. There were more elephant crossing events towards Mount Kenya forest through the corridor (227) than towards Mount Kenya underpass (178) during the dry period ($\chi2$ = 5.9284, df = 1, p = 0.0149), figure 4.4b. During the wet period, there were more elephant crossing events towards Mount Kenya underpass (312) than towards Mt. Kenya forest through the corridor (264) ($\chi2$ = 4, df = 1, p = 0.0455), figure 4.4b.

The trend indicates a significant increase in crossing events for all wildlife from 2019 to date ($\chi2$ = 111.61, df = 2, p = 0.000), figure 4.4c.

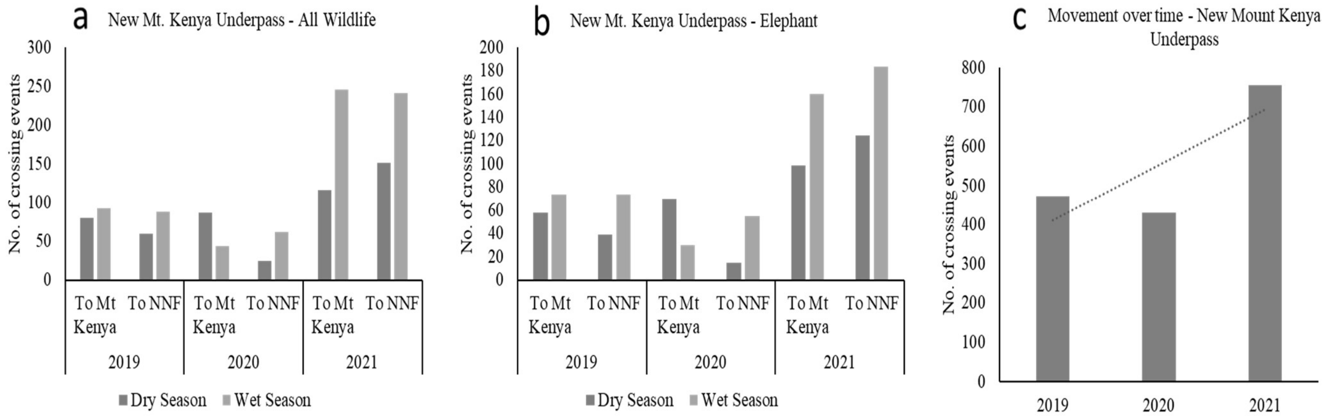

Figure 4.8: a) Seasonal movements of all wildlife species using the gap; **b)** Seasonal movements of elephants; **c)** Trends of all wildlife species using the gap

Rainfall distribution and seasonality principally drives animal migration and dispersal (Bartzke, *et al.,* 2018). In response to localized rainfall patterns, animals may alter their movements in relation to the distances between water and foraging grounds (Bartzke, *et al.,* 2018). This could have contributed to the increased movement of wildlife recorded in the migratory gaps on the landscape.

4.3 Conclusion and recommendations

The general ungulates performance is fairly good. Despite having high growth potential, the giraffe has maintained a low percentage of juveniles and calves.

Grevy's zebra population performance is good. Monitoring this species at the individual level remains one of our priorities. The current database used to process images for unique identity is slow. We, therefore, need automated software to speed up the analyses for immediate management interventions. This, therefore, calls for a continuous engagement with our partners involved in the development of the WILDBOOK software.

5.0 ELEPHANT MONITORING

5.1 Introduction

The African bush elephant (*Loxodonta africana*) is the largest terrestrial mammal that has had a great impact on the forests and rangelands in Africa (Lee and Moss, 1999 and Laws, 1970). The elephant diet consists of a wide variety of grasses, shrubs, herbs, and woody vegetation parts such as trees barks. Their diet is determined by what is available in their habitat in each season. Because of their large size, they require at least 150kgs of forage which makes them impact vegetation structure and composition, especially during the dry season. They expose trees to secondary damage by pests, diseases, and fire through debarking (Pamo and Tchamba, 2001**).** Similar observations have been documented on the Lewa-Borana Landscape (LBL) where elephants have been sighted destroying trees through debarking, uprooting, breaking branches, as well as causing crops and water pipes damage.

On our landscape, we monitor the elephant population demographics, document fence breakage incidences to the adjacent community lands and exclusion zones protected for rhino browse, and identify the individuals causing these damages. This data helps in advising the best management interventions to reduce these conflicts.

5.2 Population demographics and trends in fence breakages

On the landscape, we documented 13 resident matriarchal family groups comprising 188 individuals and 10 lone bulls.

We also documented a total of 252 fence breaking incidences throughout the year. Out of these, 86% (n=218) occurred in the exclusions zone fence line, while 14% (n=34) were in the main boundary fence line. The most affected boundary fence lines were on the southern and western parts of the landscape (*Simon's* gate and *Laga ya fox 3*), figure 5.1.

In the exclusion zones, 51% (n=110) of incidences involved elephants crawling under the 2-strand fence wires, while 49% (n=108) involved elephants snapping the wires and breaking the posts. The most affected exclusion zones were *Lewa HQ, Digby's, Matunda, Kifaru, and Sirikoi*, figure 5.2. These zones hold dense, woody vegetation which may have attracted the elephants. Despite the fence upgrades undertaken on *Lewa HQ, Sirikoi,* and *Digby's* exclusion zones in the past, elephants continued to access these exclusion zones through crawling and snapping the wires. Most of the breakages into these exclusion zones occurred at night and early in the morning making it difficult to identify the exact culprits. We used camera traps at two locations *Ngoroba* and *Simon's gate,* both on the southern part of the landscape, to get photos of the culprits for identification.

The matriarchal family groups namely *Natasha, Sanaipei, Linnet, Carl,* and *Wendy* continued to access the exclusion zones through crawling, with *Natasha* having the highest incidences, figure 5.3.

Out of 10 resident bulls, *Mjasiri, Budi, Odongo, Mugaa,* and *Keke* were mostly responsible for fence breakage incidences, figure 5.4. Even though *Mjasiri, Keke,* and *Tyson* have had their tusks trimmed in the past, they have learned new ways of accessing the fences through snapping wires using their shortened tusks and also stepping on the posts.

Fence breakage incidents and crawling under these exclusion zones increased during the year, which could be attributed to the prolonged dry season which left exclusion zones as the only area with substantial vegetation for elephant forage. The presence of large herds due to the extremely dry conditions in northern Kenya may also have contributed to the increased breakages and crawling into exclusion zones.

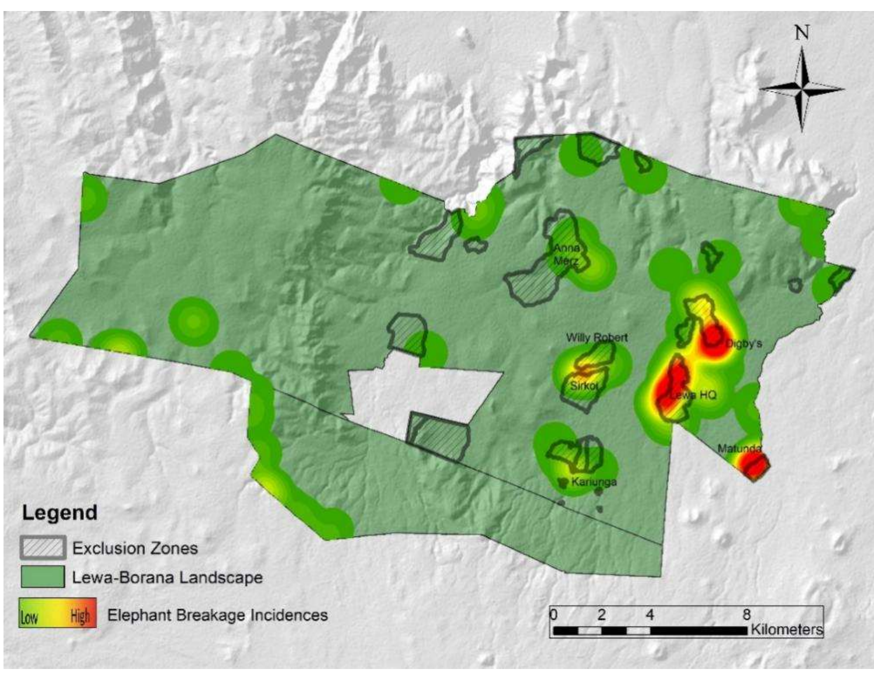

Figure 5.1: Heat map of elephants' breakage incidences on LBL

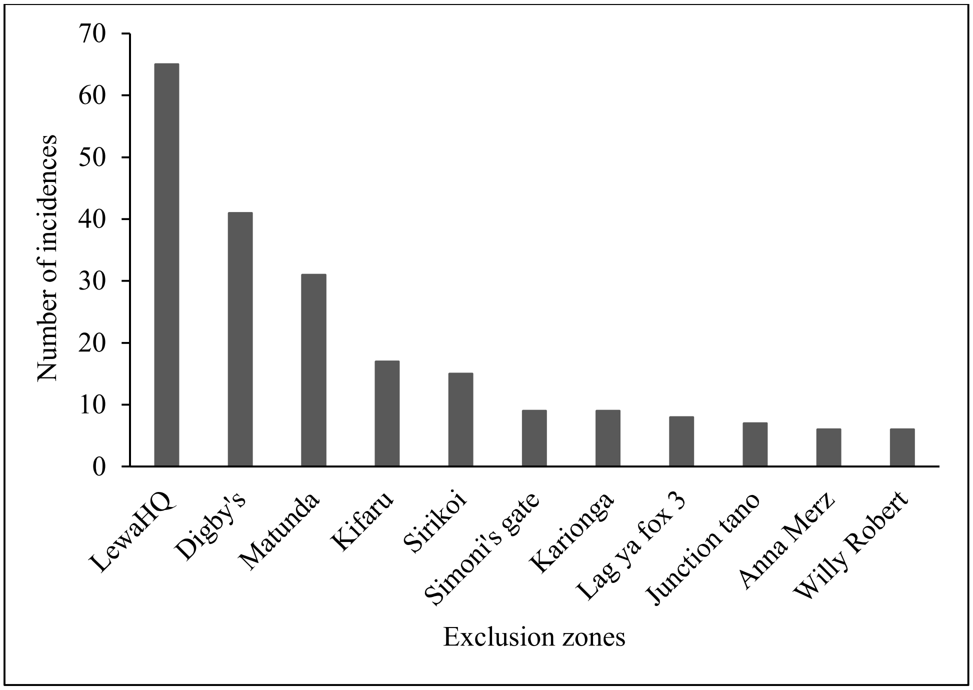

Figure 5.2: Elephant breakages across the top 10 affected exclusion zones

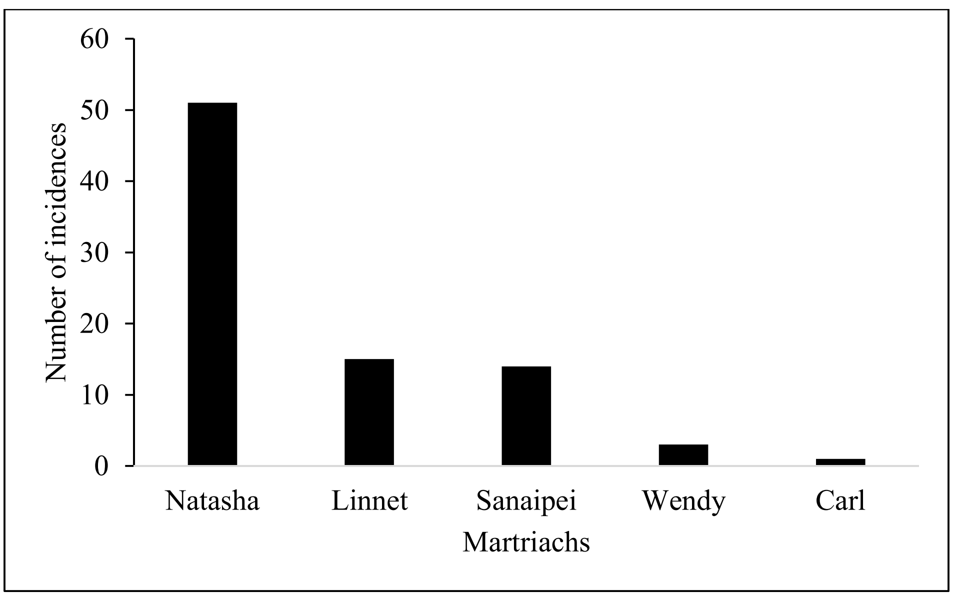

Figure 5.3: Family group incidences of crawling under the exclusion zone wires.

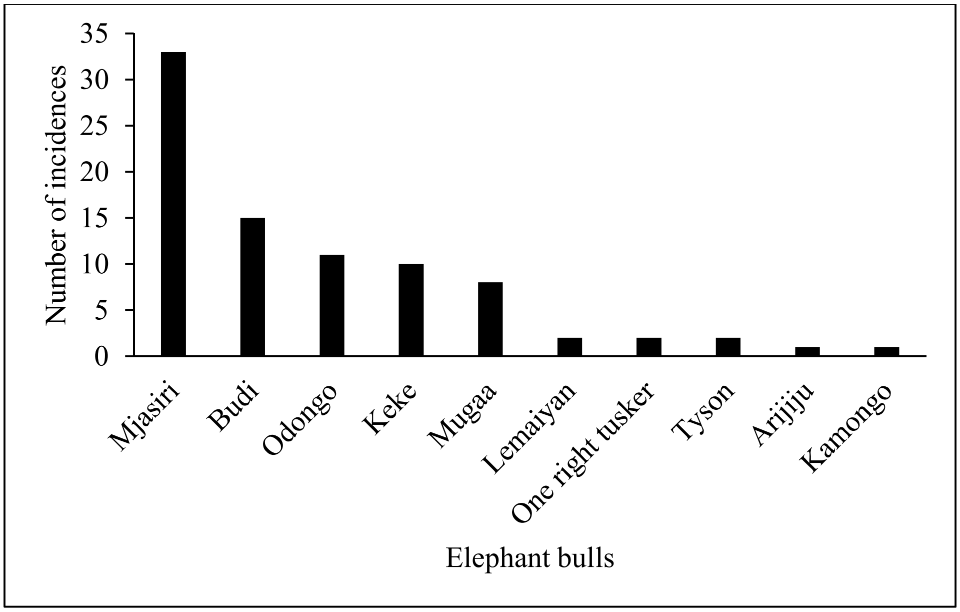

Figure 5.4: Elephant bulls responsible for fence breakages

5.3 Beehive fence

Beehive fencing has been documented as an effective method to mitigate human-elephant conflicts. A fence separating the *Sangala* community adjacent to Tsavo National Park is one example of a successful beehives fence (King, *et al.,* 2017).

In 2018, we collaborated with Save the Elephants (STE), Elephant and Bees (E & B) project to establish a pilot project along the Ngare Ndare fence line connecting Ngare Ndare Forest with the *Ethi* community. To date, the beehives have never been colonized possibly due to unfavorable weather conditions, particularly the shift in the rainfall patterns, which influence the behavior of bees. Other factors that may have triggered the reduction of bees colonizing the hives are direct sunlight on the hives, dust arising from the presence of livestock accessing the gate, and pesticides used to spray crops in the neighboring large-scale farms.

We resolved some of these issues by relocating the fence elsewhere within the same area. Cleaning and waxing of the beehives were undertaken in readiness for full occupancy during the wet season expected in November and December. The brood boxes that were deployed at *Charlie Wheeler's* farm, in the southern part of Lewa, are already colonized by beehives and will be redeployed back once the weather condition improves. Currently, 4 beehives have been occupied at *Charlie Wheeler's* farm and are ready to be deployed to *Simon's* gate in the southern part of the landscape near *Ethi* and *Ngare ndare* villages. The plan is to have these beehives managed by organized community groups in those villages so that they can derive the benefit of extracting honey while keeping elephants away from their farms. Meetings to engage communities are underway.

5.4 Conclusion and recommendations

Human-elephant conflict is a major conservation concern in communities near their ranging areas. Several management strategies for preventing and mitigating conflicts have been developed and are practiced at different scales. We are constituting a human-wildlife response team that will proactively and reactively respond to the conflicts within the conservancy and the neighbouring community lands.

There is need to continue engaging STE E & B project, and the Big Life Foundation (BLF) to ensure the beehives fences are functional and explore other deterrent methods to mitigate human-elephant conflicts in the landscape.

With increased cases of elephants' incidences in *Mutunyi* village, there is need to fundraise to put up a 2-metre short fence with stingers. The aim is to reduce elephant conflicts in the area as well as upgrade the sections of the main fence within LBL that border the communities. *Ngare-Sirikon* community fence in Leparua Conservancy has been funded. Plans are underway to have it put up in the first quarter of 2022.

With the growth of the elephant population in the landscape and the possibility of expanding the monitoring program to include Il Ngwesi Group Ranch, Leparua Conservancy, and the immediate community farms, it is necessary to source a compatible elephant database that will assist in capturing demographic data on all resident and non-resident elephants in the area.

6.0 RANGELAND MONITORING

6.1 Introduction

According to the United Nations Convention to Combat Desertification (UNCCD), nearly 10% - 20% of the arid and semi-arid rangelands have been classified as severely degraded (Diallo, 2008). These rangelands make up 43% of Africa's landmass and support approximately 45% of its population making them fragile (Prăvălie, 2016). Equally, Africa's rangelands are known for their abundant and diverse assemblages of wildlife (Boutton, *et al.,* 1988). This makes their management and restoration important for productivity, sustainability, and ecosystem stability to accumulate enough forage to support wildlife and livestock (Odadi, *et al.,* 2003).

On the Lewa-Borana Landscape, it is important to maintain a healthy ecosystem to be able to support the small and large mega herbivores. Controlled cattle grazing and mowing have been used to manage grasslands to enhance the quality of grass by eliminating unproductive grass through grazing, trampling, and mowing. Grasslands were assessed by documenting grass biomass, diversity, and cover in pre-determined monitoring points.

Woody plants are a major component of the savannah vegetation that determine rangeland condition and biodiversity (Tews and Jeltsch, 2004) and are an important component to consider when making rangeland management decisions. To assess woody vegetation, we took fixed-point photographs and quantitative data by conducting transects on pre-established monitoring points on LBL.

6.2 Grass assessment

The objective of the grass assessment on the landscape is to estimate the grass biomass, diversity, cover, and composition of herbaceous material to provide insight on the range condition and possible management interventions.

6.2.1 Results and discussion

Results indicated a significant decrease in biomass in the year 2021 (3332 Kg/ha) compared to the year 2020 (5361 Kg/ha) ($t = 5.52$, $df = 50$, $p = 0.0001$), figure 6.1. This decrease may be attributed to the late and below-average rainfall in April and May 2021 hindering the growth of annual and perennial grass and other herbaceous plants. Biomass levels across the other years showed a significant difference, probably due to variations in weather regimes particularly rainfall, $F_{(9, 253)} = 9.466$, $p = 0.0001$) as shown in figure 6.1.

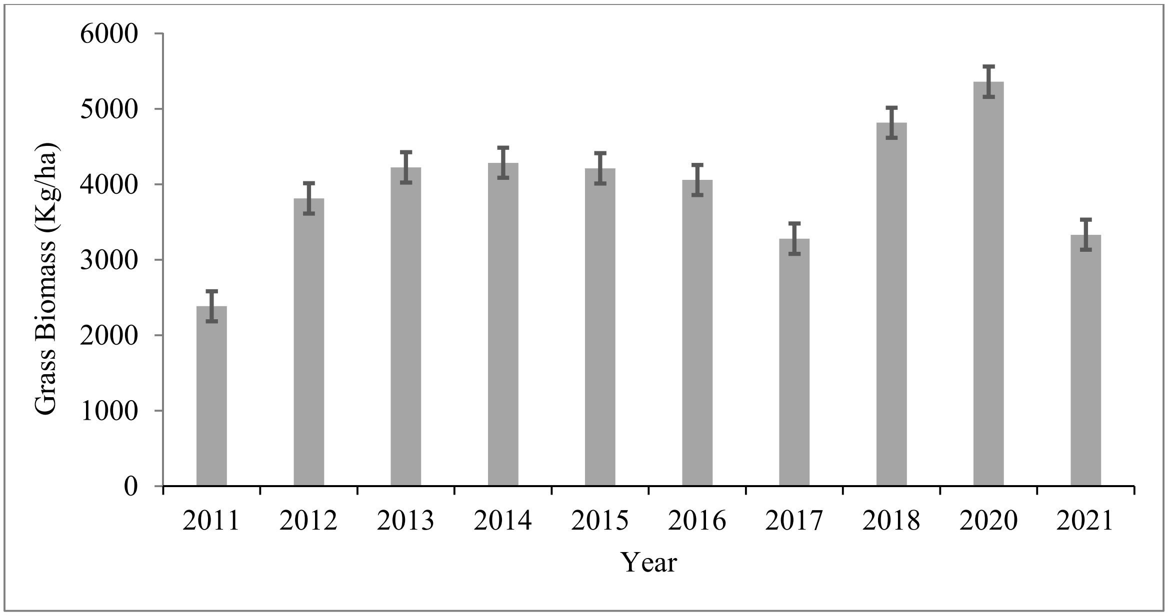

Figure 6.1: Long-term annual fluctuations in average grass biomass across various long-term sampling plots.

We computed species diversity using Shannon-Wiener Diversity Index (*H*) (Omayio, *et al.,* 2019) and tested for statistical significance. There was no significant difference in grass diversity between the year 2021 (0.82) and the year 2020 (0.75) ($t = -5.58$, $df = 42$, $p = 0.5670$), figure 6.2. The sampling sites were dominated by the *Pennisetum stramineum* and *Pennisetum mezianum* which are utilized at a low level by most ungulate species when the grasses are extremely dry.

Species diversity across the other years was significantly different ($F_{(9, 244)} = 10.190$, $p = 0.0001$), figure 6.2. Changing rainfall regimes may affect the response of the vegetation and the ecosystem leading to the differences across the years. Also, the timing of the data collection over the years has been based on time instead of ecosystem state, which could have influenced the species diversity.

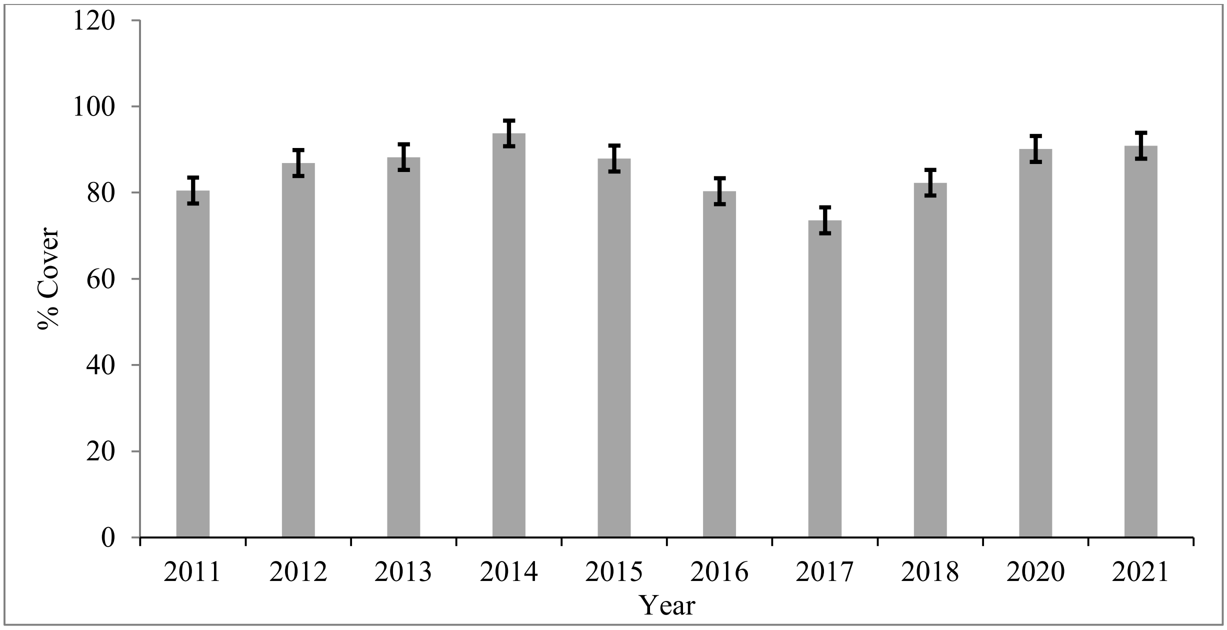

Figure 6.2: Long term annual fluctuations in average species diversity across various long-term sampling plots

There was insignificant change in species cover between the year 2021 (91%) and the year 2020 (90%) ($\chi 2$ = 5.217, df = 26, p = 1.000). Kruskal-Wallis H test indicates a statistically significant in species cover over the other years, *H (9)* = 57.846, p = 0.0001), figure 6.3.

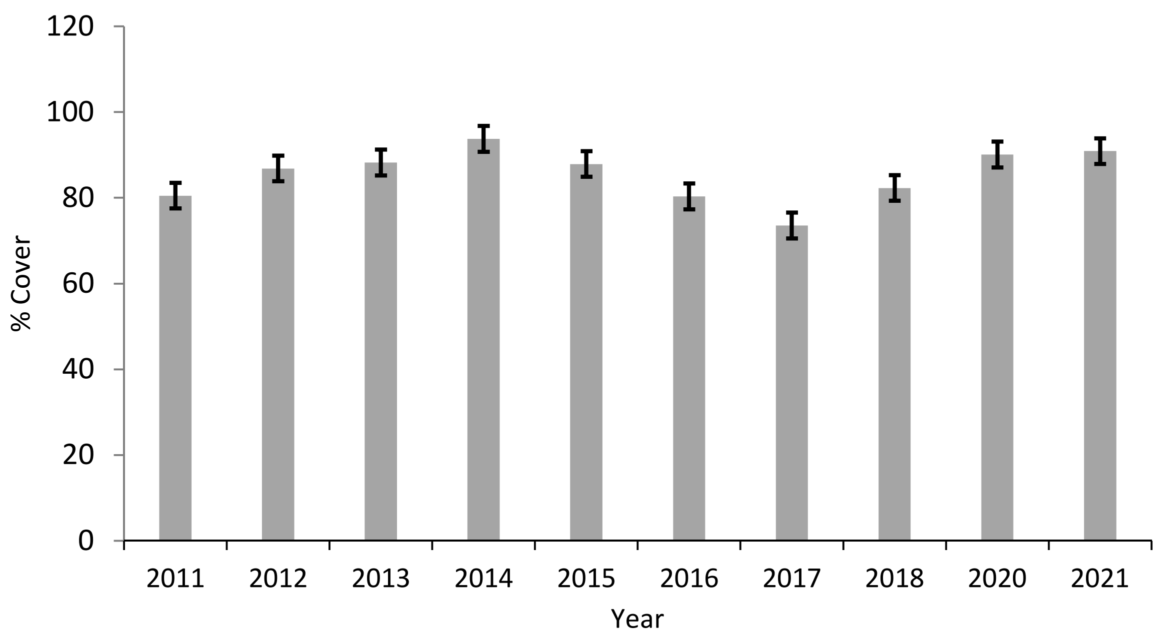

Figure 6.3: Long term annual fluctuations in average plant cover across our various long-term sampling plots.

6.3 Woody vegetation assessment

The assessment was made using visual observations, fixed point blocks, measurements of heights, crown sizes and diameter at breast height. Counts and photography were also used on sampled blocks

6.3.1 Results and discussion

Evidence indicated significant vegetation change due to browsing pressure and weather regimes on the landscape (Giesen, *et al.,* 2017). The elephant and giraffe remain the main wildlife species that damage the woody species, as shown in figure 6.4. Previous studies show that where large numbers of elephants and giraffes are present in a woodland savannah, they exert excessive pressure on the browse, suppressing the growth of trees (Birkett, 2002). There was low recruitment and regeneration of seedlings in the sampling plots possibly due to the presence of a high number of elephants. Heavy browsing and debarking by elephants reduced the growth of the trees thereby increasing their susceptibility to drought and secondary infection.

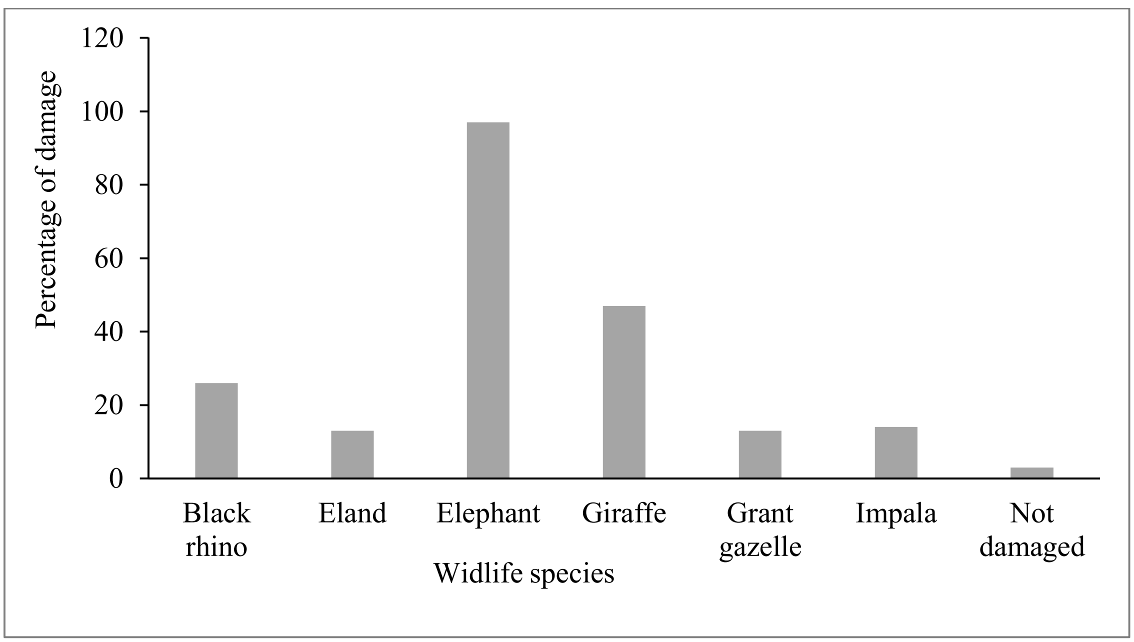

Figure 6.4: Cause of woody vegetation damage by wildlife species

Acacia mellifera, Euclea Divinorum, Acacia drepanolobium, and *Grewia similis* were the most abundant woody species encountered during sampling, which is consistent with findings from previous years. Additionally, *Acacia mellifera, Acacia nilotica, Acacia seyal,* and *Acacia* *drepalobium* exhibited the highest percentage of damage and mortality. Other dominant woody species present in the landscape include *Acacia tortilis, Boscia angustifolia, Lycium europaeum, Rhus natalensis,* and *Acacia nilotica,* figure 6.5.

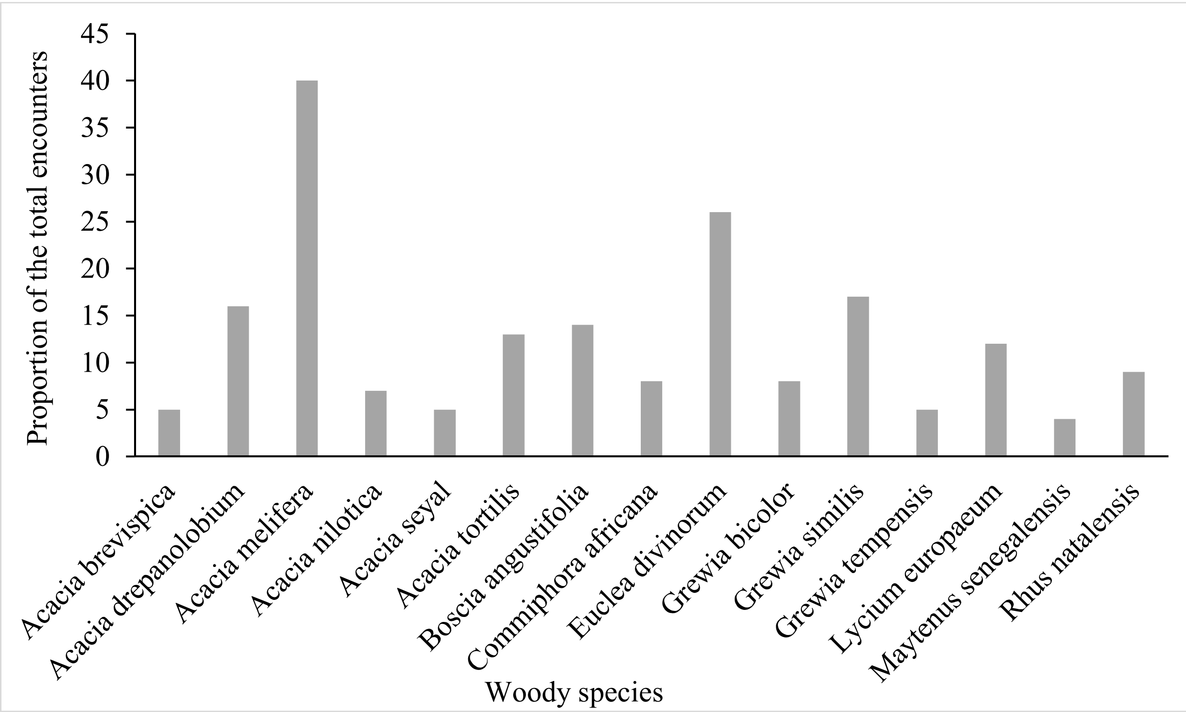

Figure 6.5: Number of damaged individuals encountered in sampling plots

We also analysed the tree height on the two *Acacia xanthophloea* plantation plots at the Lewa HQ initiated in 2018. These plantations were specifically planted to encourage the growth of acacia woodland around the headquarters. Initially, the plantations were fenced to exclude all wildlife species from gaining access and later removed in 2020 as the trees had attained considerable heights. The woody vegetation growth increased significantly in the plantation 1 ($t = 4.5172$, $df = 3$, $p = 0.0203$) and two ($t = 4.3514$, $df = 3$, $p = 0.0224$), figure 6.6a and b. The slight decrease in tree height in 2021 could be attributed to the exposure to the resident giraffes around the Lewa headquarters enclosure after removal of the fence in late 2020 coupled with prolonged dry conditions witnessed in the landscape in 2021.

The new section that formed part of the airstrip exclusion zone after it was extended in 2018 continues to register a significant increase in tree heights across the years in the two plots we monitor (Airstrip plot 1 - $t = 9.8629$, $df = 3$, $p = 0.0022$ and Airstrip plot 2 - $t = 3.9946$, $df = 3$, p

= 0.0281), figure 6.6c and d. This indicates how woody vegetation can quickly recover from the establishment of an exclusion zone.

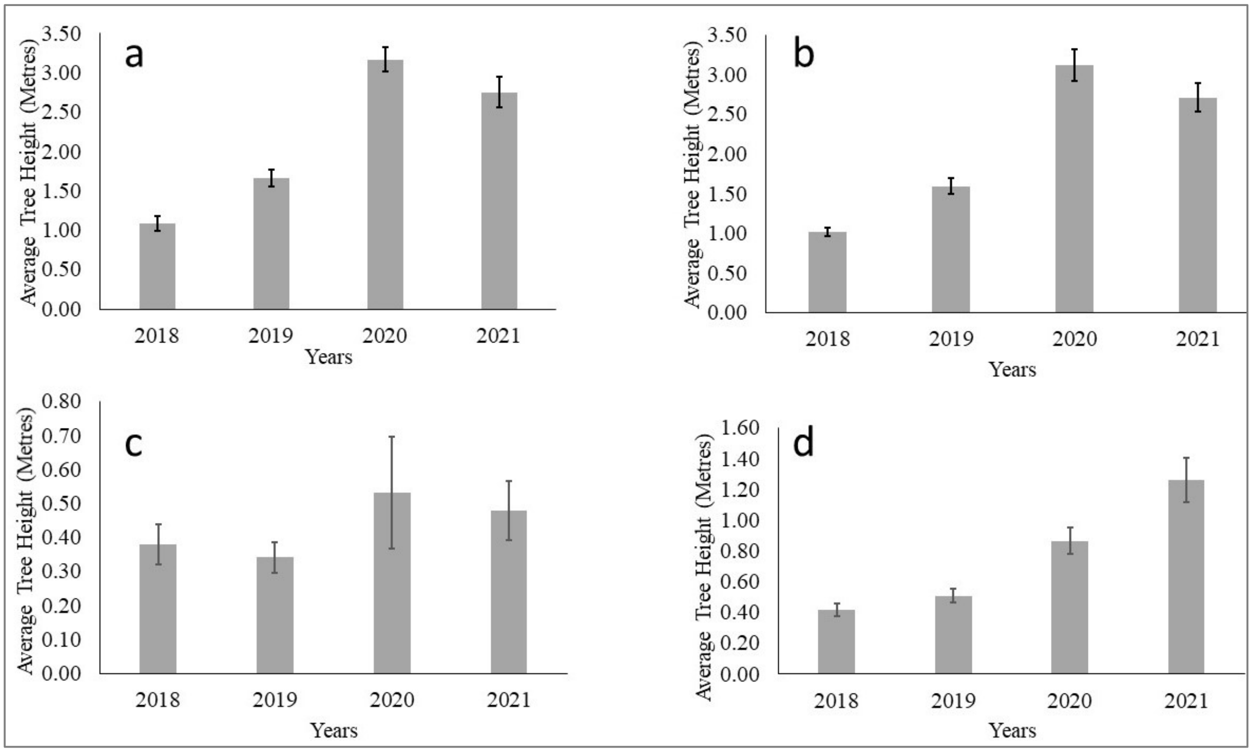

Figure 6.6: **a)** Average tree height in plantation 1; **b)** Average tree height in plantation 2; **c)** Average tree height in Airstrip plot 1; **d)** Average tree height in Airstrip plot 2

6.4 Normalized Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index (NDVI) was used to assess vegetation productivity by quantifying the vegetation greenness. NDVI was calculated as a ratio between the red (R) and near infrared (NIR) values from multispectral satellite imageries. We downloaded free Landsat 8 imagery from the United States Geological Survey (USGS) Earth Explorer platform and produced NDVI maps for January – December 2020 and 2021 using ArcMap 10.8.1. Even though some months had prominent cloud cover obstructing visibility for comparison, the year 2020 was more wet and productive compared to the year 2021. The figure indicates that the wet season month of April was greener than 2021, while the dry season month of September 2021was greener and more abundant than 2021 (see figure 6.7).

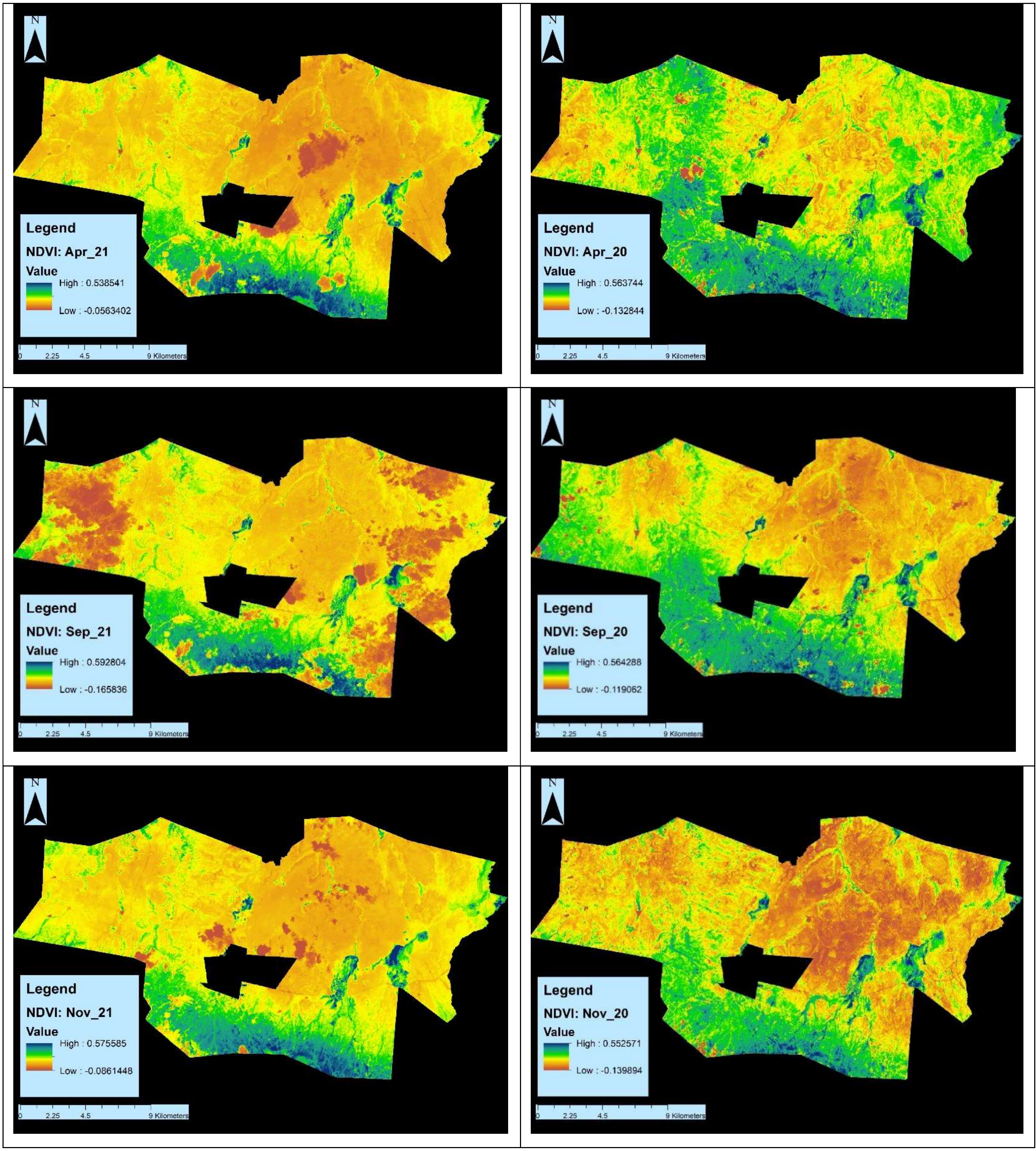

Figure 6.7: Comparison of the dry and wet seasons of 2020 and 2021 NDVI for the Lewa - Borana

6.5 Cattle grazing

The cattle grazing program as a rangeland management tool has been in existence since 2007 and is meant to improve the rangeland condition. Since the outbreak of the COVID-19 pandemic and the dry condition that prevailed, there was a significant reduction of cattle numbers on the landscape. This meant that the Northern Rangelands Trust (NRT) Livestock to Market (LTM) programme was unable to secure enough cattle for the programme, leaving approximately 100 cattle in the entire year on the Lewa section of LBL. These steers were confined in an enclosure under supplemental feeding.

On the Borana section of the LBL, the Borana community Livestock to Market program continued and 32 steers were sold during the period. 201 steers and 22 cull cows remained. Given the exceedingly dry conditions experienced during the year, these heads of cattle were unable to gain adequate weight to be ready for sale. The Borana commercial herd remains relatively static at 2,500 heads. As a result of dry conditions in the landscape, the management of Borana Conservancy assisted in securing grazing for 3,500 community cattle on Ole Naishu ranch and 200 on Borana Conservancy. These communities were largely drawn from the immediate neighbours of Borana Conservancy. This helped mitigate grazing pressure in Mount Kenya, Ngare Ndare, and Mukogodo forests.

6.5.1 Conclusion and recommendations

The exclusion zones on LBL have proven to be of great importance in encouraging the regeneration and recovery of woody vegetation. Since there has been considerable effort targeted towards the establishment of new exclusion zones and maintenance and upgrade of the existing ones, we recommend creating temporary exclusion zones that can be opened up when they attain a certain level of maturity to provide food for other browsers. This will also ensure woody vegetation is within the available height for most of the browsers.

Owing to the change in the operations of the Northern Rangelands Trust (NRT) Livestock to Market (LTM) programme, there is a need to review the grazing program as a rangeland management tool to guarantee long-term results on grassland health. This can be achieved by allowing community cattle from the surrounding *Il Ngwesi*, *Leparua*, *Lekurruki,* and *Makurian* under a controlled program that will serve as a rangeland management tool and will benefit the community cattle. Alternatively, Lewa can buy cattle to improve the range condition.

7.0 AVIFAUNA MONITORING

7.1 Introduction

Birds are the first taxonomic group to be used to build headline indicators of biodiversity due to their worldwide spatial and temporal coverage (Schmeller, *et al.,* 2012). They have been monitored in many countries and their studies are one of the several independent ways of monitoring some aspects of environmental change (Furness and Greenwood, 2013). They play a vital role in controlling pests, seed dispersal, acting as pollinators and forming integral parts of food chains and food webs (Importance of Birds, 2021). Monitoring initiatives are the first provider of long-term data that helps evaluate birds' conservation status and assess their changes in biodiversity (Schmeller, *et al.,* 2012).

The Lewa-Borana Landscape (LBL) provides key habitats that host a diverse avian community. These habitats offer favourable stop-over and wintering sites for large populations of migratory birds from Europe and northern Asia. The LBL also offers a breeding site for raptors and the endangered Grey crowned crane (Kimiti, *et al.,* 2020, Unpublished report). LBL focuses on keeping an updated bird checklist, conducting monthly water birds and raptors surveys, and updating a preliminary checklist of the birds of Il Ngwesi Group Ranch. Through these surveys, we monitor the population dynamics and breeding status of species of conservation concern.

7.2 Lewa - Borana Landscape Birds Checklist

Using the taxonomy, common name, and migration status of the Field Guide to the Birds of East Africa (Stevenson and Fanshawe, 2004), the harmonized LBL birds' checklist consists of 83 families with 484 species, some of which are globally threatened table 7.1. This represents 42% of 1,149 total species found in Kenya (Lepage, 2020). We collaborated with LBL and Ngare Ndare Forest Reserve (NNFR) birder's club to take photos for evidence files for the birds in the landscape. This saw us move from an initial 69% of species with photo evidence to the current 75%. This effort will continue until we have photos of all the species in these contiguous protected areas.

We also participated in the bi-annual Cornell University-led global "eBird" bird count in support of celebrating World Migratory Bird Day. We recorded 210 and 130 species on Lewa and Borana conservancies respectively. Lewa Wildlife Conservancy was ranked the 4th birding hotspot while Borana Conservancy was the 5th on the Kenyan birding hotspot list (eBird, 2021).

Table 7.3: Total bird species on LBL and their IUCN Red List status

IUCN Red List Status	Total No. of Species
Critically Endangered	3
Endangered	6
Vulnerable	3
Near Threatened	7
Least Concern	465
Grand Total	**484**

7.3 Waterbirds Survey

Waterbirds can maintain the diversity of other organisms, control pests, be effective bio-indicators of ecological conditions, and act as sentinels of potential disease outbreaks (Green and Elmberg, 2014). This makes water birds important indicators of ecosystem contamination and deterioration especially in wetland habitats (Rahman and Ismail, 2018).

We participated in the National Waterfowl Census in January, held by the National Museums of Kenya (NMK) and recorded a total population of 2,426 individuals of 41 species. We also conducted monthly waterbird surveys in the landscape and calculated diversity index using [1]Simpson's Diversity Index. We recorded 63 different species and this indicates a high diversity (D = 0.8754) of waterbirds on the landscape.

[1] Simpson's Diversity Index: $D = 1 - \left(\frac{\sum n(n-1)}{N(N-1)}\right)$, where n represents total number of particular species and N represents total number of all species. The index ranges from 0 to 1 where 0 represents no diversity while 1 represents high diversity.

We compared data for the dry (January, February, July, August, September) and wet (March, April, May, October, November) periods to understand when to expect more birds in the landscape. There was a significant difference in waterbirds population between the dry (n = 5,079) and the wet (n=4,243) period ($\chi2 = 74.973$, df = 1, p = 0.001) period, figure 7.1. This may be due to rains being experienced in some months that are regarded as dry and also reduced rains during the wet period.

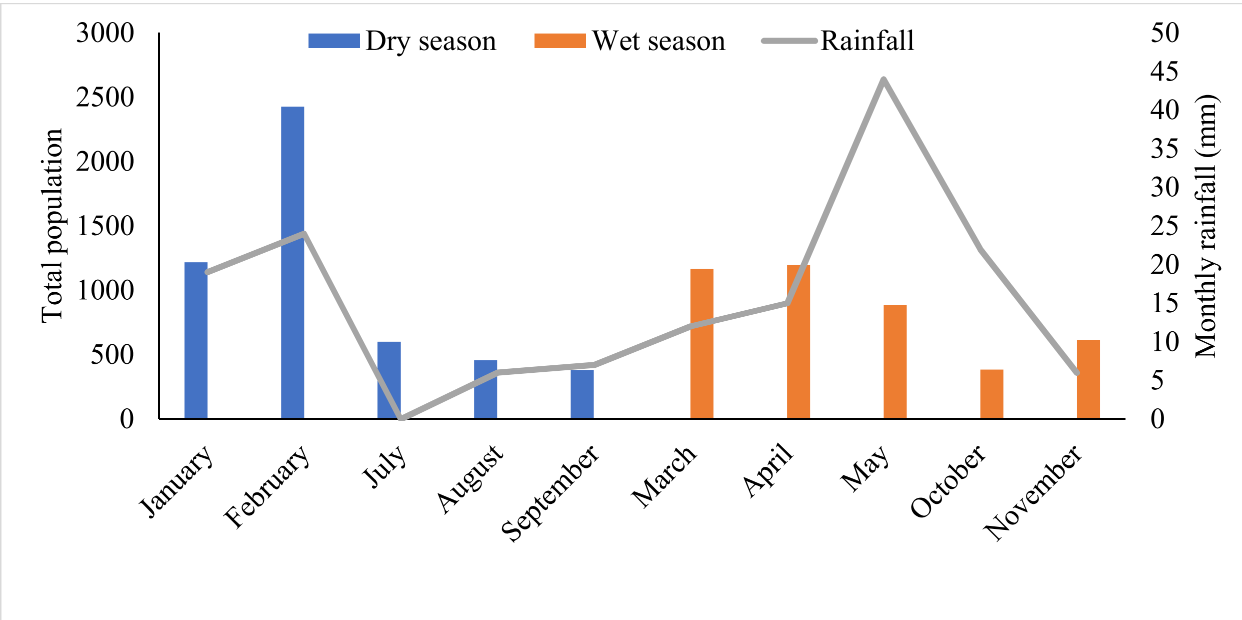

Figure 7.1: Seasonal waterbirds population on LBL

7.3.1 Grey Crowned Crane Surveys

The Grey Crowned Crane (GCC) is classified as endangered by the IUCN Red List of Threatened species (BirdLife, 2021). This is because of a sudden population decline globally primarily due to habitat loss, fragmentation, and degradation (Nsengimana, *et al.,* 2019). GCC is therefore a species of critical conservation concern on our landscape as well as at the national level.

We monitored the population and breeding of GCC across the LBL. The highest individual population counts were recorded in April (263), January (105) and March (98), figure 7.2. The wet period recorded significantly more GCC (392 individuals) compared to the dry period (198 individuals) ($\chi^2 = 63.79$, df = 1, p = 0.0001). GCC make local and seasonal movements in response to food availability, nesting opportunities, and rainfall (Wamiti, *et al.,* 2020). The rainfall distribution was uneven throughout the year and this may have led to the low population records of the GCC on the landscape as well as zero breeding records, figure 7.2.

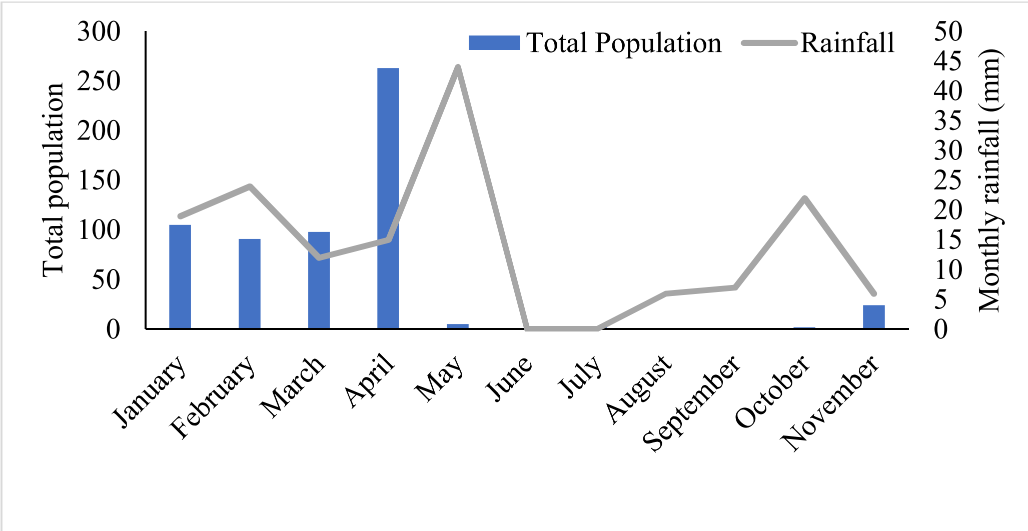

Figure 7.2: Total Grey Crowned Crane population

7.4 Raptors Survey

Raptors serve as environmental sentinels and indicators of habitat quality because of their sensitivity to human disturbance and environmental contamination (Rodríguez-Estrella, *et al.,* 1998). Other than providing ecosystem services, raptors serve as cultural symbols, indicators of biodiversity and environmental health, and structures biological communities (McClure, *et al.,* 2018). It is therefore recommended that raptors 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 averages were 49±7 individuals of 33 species, figure 7.3a. Seven (7) nests were mapped and monitored; one for Bateleur (successful breeding), three for Tawny eagle (two successful breeding, one status is uncertain), two for Martial eagle (both successful breeding) and one for African hawk-eagle (abandoned) figure 7.3b. Diversity was calculated using Simpson's Diversity Index indicating a high diversity of raptors on LBL (D = 0.9157). A Chi-square test shows a significant increase in raptors population from 280 individuals in 2020 to 535 individuals in 2021 (χ^2= 79.785, df = 1, p = 0.0001). This could be attributed to an increase in scavengers feeding on wildlife individuals affected by the prolonged dry season.

Examination of population trends for raptors is a research priority because of their recent population decline making most of them classified as threatened by the International Union for Conservation of Nature (IUCN) (McClure, *et al.,* 2021). LBL has therefore been carrying out a one-year study to estimate the abundance and diversity of raptors on LBL and NNFR and also develop long-term monitoring protocols of raptors on the landscape. We used the distance sampling method and nest surveys to determine abundance and Simpson's Diversity Index to calculate the diversity of raptors on LBL and NNFR. Preliminary results indicate a high diversity (*D* = 0.9157) of raptors and an abundance estimate of 0.0067raptors/ha. This translates to a monthly average of 283±54 raptors on the landscape.

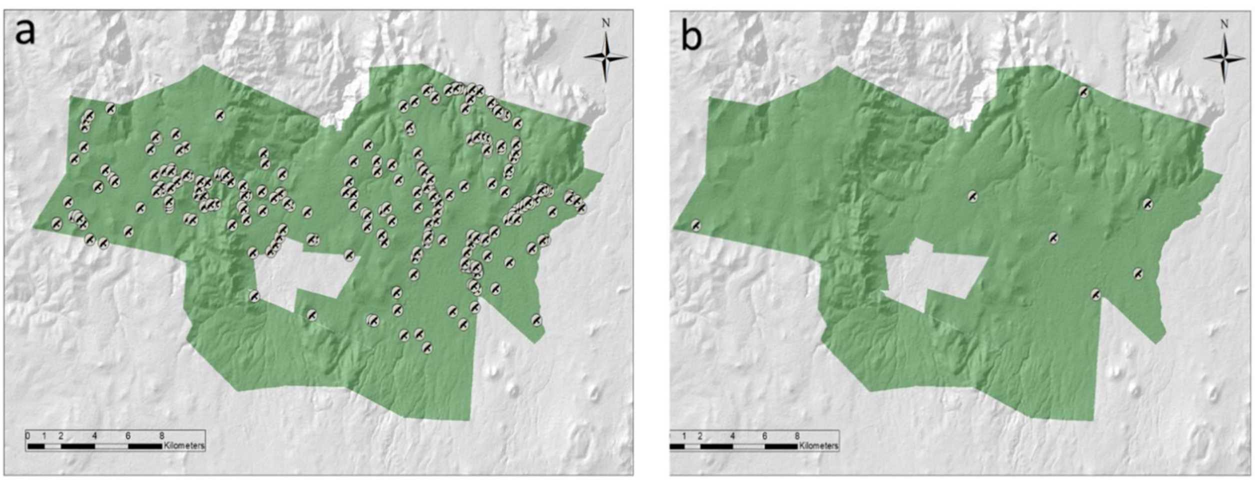

Figure 7.3: a) Raptors distribution on LBL; **b)** Location of nesting raptors on LBL

7.5 Il Ngwesi Bird Survey

Il Ngwesi Group Ranch neighbours Lewa to the northwest and covers an area of 16,500 hectares. The conservancy has less explored diverse avifauna. A two-day initial bird survey in 2020 recorded 112 different species. A repeat of the survey this year recorded a total of 130 different species. This year's survey aimed at estimating the abundance and diversity which is essential to delineate the importance of regional or local landscapes for avian conservation (Yallop, 2003). Diversity was calculated using Simpson's Diversity Index indicating a higher diversity (*D* = 0.9759). The two surveys have led to the establishment of a preliminary checklist for the birds of Il Ngwesi

Group Ranch which has a total of 172 bird species with 84 % photo evidence. Two raptor nests were also identified whose breeding status was uncertain. We recorded 7 Palearctic migrants (Steppe eagle, Pallid harrier, Eurasian roller, Yellow wagtail, Green sandpiper, Wood sandpiper, Red-tailed shrike), 2 critically endangered species, (White-backed vulture, Rüppell's vulture), 1 endangered (Steppe eagle), 2 vulnerable (Somali ostrich, Martial eagle), and 2 near threatened (Pallid harrier, Eurasian roller).

7.6 Conclusion and Recommendations

The avifauna monitoring indicates a high bird diversity on the landscape. LBL wetlands continue to hold a diverse waterbirds species despite poorly distributed rainfall throughout the year. Since the GCC exhibit local and seasonal migration, there is a need to invest in satellite tracking to understand their spatial-temporal trends and protect their home ranges. A few juvenile raptors should also be tracked to help establish their new home ranges and scale up their conservation efforts in the landscape.

The high diversity of avifauna on Il Ngwesi Group Ranch remains to be fully explored. More bird surveys need to be done on the landscape in collaboration with the National Museums of Kenya to build up the bird checklist and document it.

Due to the high abundance and diversity of avifauna on LBL, we recommend the commencement of the process to designate the landscape as a Key Biodiversity Area (KBA).

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

8.0 HYDROMET MONITORING

8.1 Rainfall

Rainfall for 2021 was 253±5mm, lower than 569±8mm received in 2020. Additionally, this was lower than the long term average rainfall of 510±27mm for the last 46 years (1975-2020), figure 8.1a. This year received the lowest rainfall since 1975, figure 8.1b.

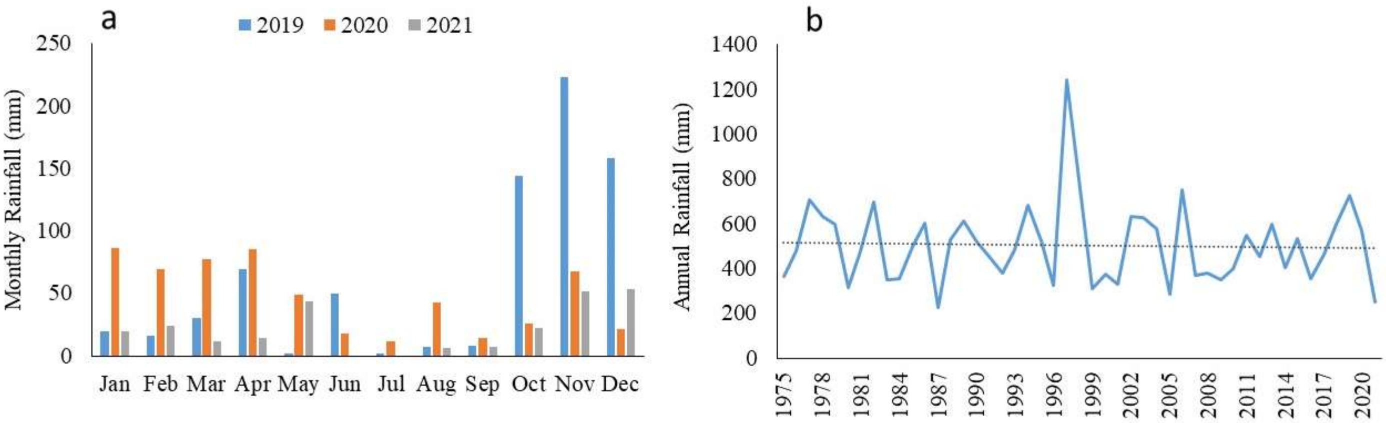

Figure 8.1: Graph showing **a)** Monthly rainfall for 2018 - 2021 and **b)** Annual rainfall for the last 46 years.

8.2 Monitoring the river flows

In collaboration with the Centre for Training and Integrated Research in ASAL Development (CETRAD), we completed the installation of automated river gauging systems (RGSs) in three stations, two at Ngare Ndare river and one at Ngare Nyting river. The systems are expected to quantify the amount of water flows from the rivers before and after abstraction. The automatic data transmission by the systems is complete. We are now working on the rating equations/curves as well as threshold levels (reserve flow, normal flow, and flood flow levels). To quantify the amount of water flowing in a stream or river, one must physically measure the volume (discharge) of water flowing. That volume is usually expressed in cubic meters per second (m^3/s). This is often done using a current meter while standing in the river and measuring the depth and water speed at many places and different gauge heights/stages across the river bank. This helps in establishing a relationship between a stream stage and discharge/flow called a r*ating curve/stage-discharge equations*. We, therefore, need to take readings of the speed of the water at different points, heights, and depths across the river bank to calibrate the instruments. During the year, we recorded the lowest flows due to a prolonged dry period. Once we receive the highest flow, we will be able to complete the calibration process. This is the initial stage of the wider rivers and springs monitoring project in the landscape.

We are also in the process of procuring two automated weather stations that will use the Low Range Wide Area Network (LoRaWAN) to submit real-time data to the EarthRanger (ER) platform.

8.3 Conclusions and recommendations

Knowledge of the underground and surface water flows is necessary for natural resource planning. This entire process will help us quantify this resource and give advisory opinions to the surrounding communities through Water Resources Management Authority (WARMA) and Water Resource Users Association (WRUA).

9.0 HERPETOFAUNA MONITORING

Herpetofauna comprises reptiles and amphibians. Most of these species are widespread with hundreds of new species being discovered every year (Uetz and Hošek, 2015). They are essential components of aquatic and terrestrial ecosystems forming major secondary consumers and essential prey for many tertiary consumers (Böhm, *et al.,* 2013). Despite their widespread, they are among the most threatened vertebrates globally due to habitat loss and degradation, pollution, and climate change (Stuart, *et al.,* 2004).

We started expanding our work on the landscape to include this class of organism initially focusing on the critically endangered Pancake tortoise (*Malacochersus tornieri*) (Mwaya, *et al.,* 2019). As a follow-up of our 2019 survey where we documented 7 individuals, we repeated the survey in 2021 where we documented a total of 59 individuals. We plan to have this survey biannually moving forward.

9.1 Conclusions and recommendations

The critically endangered Pancake tortoise (*Malacochersus tornieri*) is a conservation concern species. Rigorous research on this species is needed. We will document their numbers, establish their spatial distribution, and do a DNA study to understand their genetic relationships.

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13.0 APPENDICES

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.

End Notes

?[i] The dominant male in the territory or the male sighted mating with the female is recorded as the father to the calf. In this case, referred to as "Dam".