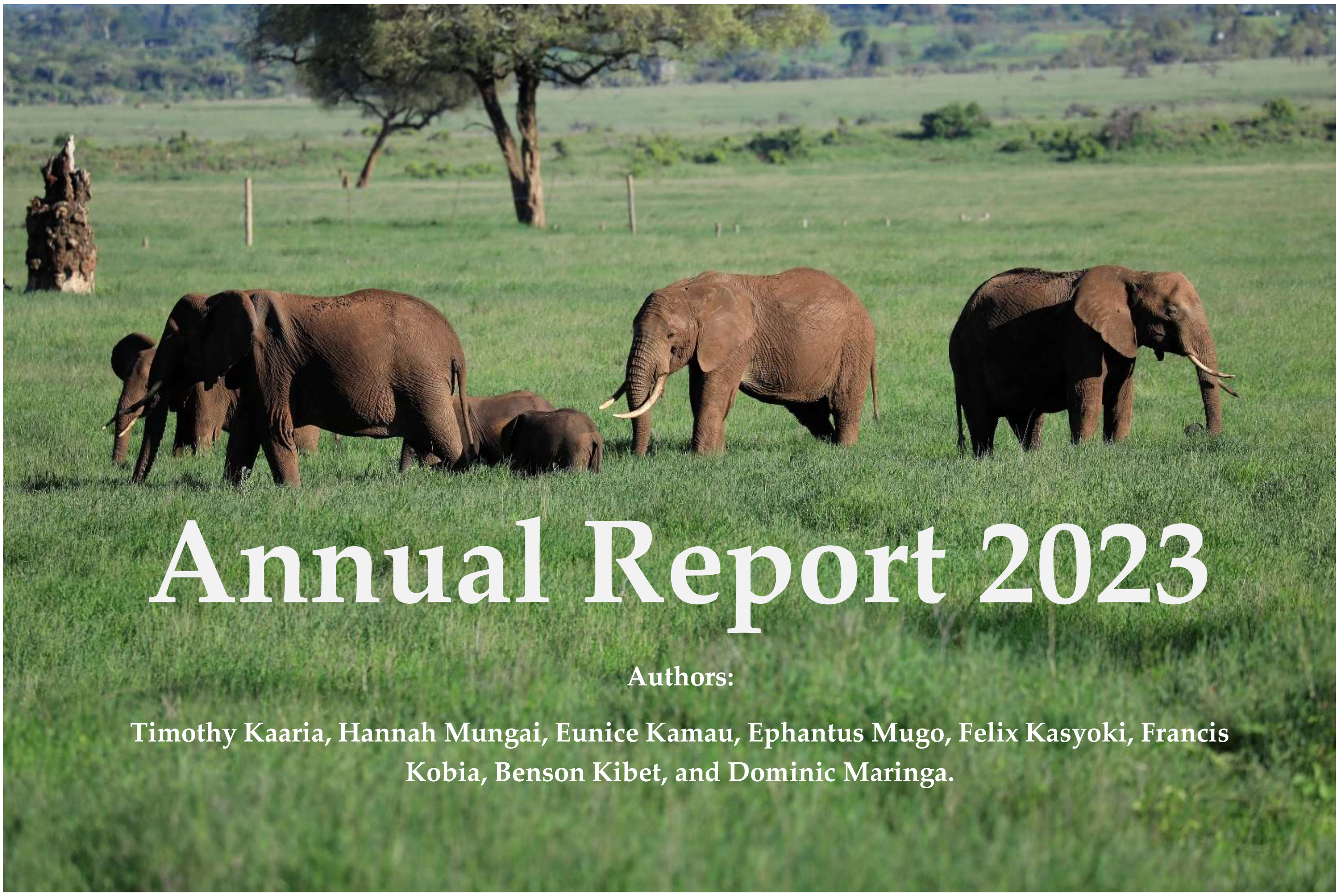
LEWA WILDLIFE CONSERVANCY
A UNESCO World Heritage Site inscribed in 2013

BORANA CONSERVANCY



Annual Report 2023

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EXECUTIVE SUMMARY

In 2023, the Lewa – Borana landscape (LBL) experienced a substantial climatic shift, marked by a remarkable increase in rainfall to 672mm, surpassing the previous year's 183mm and exceeding the long-term average. This climatic variation had cascading effects on the ecosystem, influencing wildlife populations and vegetation dynamics. Rhino populations showed nuanced changes, with a decrease in Black rhinos from 133 to 132 and an increase in White rhinos from 122 to 128. Reproductive metrics for both species demonstrated satisfactory growth rates and moderate to good values for Age at First Calving (AFC) and Average Inter-calving Interval (ICI). Technology, including Iridium/GPS collars and infra-red camera traps, played a crucial role in monitoring elusive species, revealing insights into predator populations, with lions identified as a leading cause of wildlife mortality. The landscape's semi-arid nature led to significant fluctuations in vegetation and wildlife populations, highlighted by a decline in buffalo and eland populations, potentially linked to prolonged drought conditions for the last few years. Despite minimal early-year rainfall, species exhibited robust body condition scores, signalling resilience in resource-limited environments. Elephant population dynamics and fence breakages were closely monitored, revealing a surge in occurrences, particularly in exclusion zones, with certain resident bulls identified as persistent fence breakers. The rich biodiversity, including 492 bird species, showcased the landscape's importance, with the LBL securing recognition as Kenya's premier birding hotspot. Herpetofauna conservation efforts focused on critically endangered Pancake tortoises and terrapins, with collaboration from key organizations and community engagement. Ecosystem rehabilitation initiatives, including enclosures and exclusion zones, were expanded to track changes in plant diversity and cover, emphasizing the impact of weather patterns on rangeland conditions. The comprehensive findings underscore the interconnectedness of climate, wildlife, and habitat health, emphasizing the need for sustained monitoring and adaptive management strategies in the LBL.

Implications for Management

The implications for management arising from the current findings encompass several critical areas. The observed fights among black and white rhinos, coupled with an apparent increase in males in white rhino populations, raise concerns about potentially surpassing the Ecological Carrying Capacity (ECC). Urgent action is recommended to expedite an ECC assessment for accurate population management. The search for an effective Grevy's zebra stripe identity software continues with several stakeholders involved in the landscape, recognizing that the current gap poses a great challenge to population estimates which necessitates immediate efforts to complete WILDBOOK, an AI-based software for unique identification from photographic images. Essential for monitoring elusive animals like lions and hyenas, applying collars to hyena clans is crucial for understanding their impacts on prey species and gaining insights into spatial-temporal movements and social behaviours. Given the significant decline in buffalo and eland populations, proactive drought preparedness plans are essential to mitigate the impact and conserve these populations, along with other species in the landscape. Recognizing the vital role of elephants, acquiring a compatible elephant database is crucial for effective data management, enabling the capture of demographic information for resident and non-resident elephants in the LBL. The observed increase in the raptor population calls for post-fledging monitoring to establish home ranges and enhance conservation efforts, with GPS and GSM backpack transmitters on critically endangered vultures providing essential data for understanding their ecology. Successful mitigation efforts against invasive species underscore the importance of proactive control measures, with ongoing monitoring and documentation using EarthRanger and mapping software guiding effective management. The sustainability of the Lewa swamp, crucial for biodiversity and local communities, requires continuous evaluation of its condition and productivity through dedicated monitoring efforts. This also calls for robust collaboration with other stakeholders, individuals and institutions in the landscape like the Natural State for carrying out synergized research and bringing out informed decisions on the swamp ecosystem. Finally, to improve the accuracy of rainfall data, continuous deployment of automated precipitation sensors is recommended for real-time monitoring, ensuring timely and precise collection of rainfall information. These proactive measures are crucial for effective conservation and management of the LBL landscape.

1.0 INTRODUCTION

The Conservation and Wildlife Research Department at Lewa Wildlife Conservancy is committed to promoting a healthy, sustainable, and secure ecosystem, aligning with the goals outlined in our strategic plan. The department engages in an ecosystem-based approach, systematically monitoring both habitat and wildlife to gain comprehensive insights for effective management of the Lewa – Borana landscape (LBL). This involves wildlife surveys to track population trends and assess performance indicators, water resource monitoring to understand water reserves in the landscape, and extensive vegetation monitoring to evaluate the rangeland's condition. These measures contribute to informed decision-making and adaptive management practices. To address species of key conservation concern, the department collaborates with Kenya Wildlife Service (KWS) veterinarians, executing targeted veterinary interventions designed to enhance the survival chances of vulnerable species within the ecosystem. In addition to ecosystem research, the department actively engages in conservation education initiatives through the Conservation Education Program (CEP), reaching organized groups, including school-going children and students. This educational outreach aims to raise awareness and instil a sense of responsibility toward conservation in the younger generation. In the subsequent sections, we present comprehensive outputs from various thematic areas within the Research and Monitoring (R&M) section, detailing activities conducted by the veterinary unit and the CEP.

2.0 RESEARCH AND MONITORING SECTION

This section outlines the various activities undertaken in monitoring the well-being and status of rhinos, predators, ungulates, elephants, rangelands, avifauna, herpetofauna, and hydrometeorology. The monitoring encompasses a comprehensive approach to gathering relevant data and insights into the dynamics and conditions of these ecological components. By conducting systematic observations and assessments, the aim is to enhance our understanding of animals and their ecosystem and contribute to effective conservation and management strategies for the diverse species and environmental factors.

2.1 Rhino Monitoring

2.1.1 Introduction

The rhino population in Kenya has experienced exponential growth since the late 1980s. Specifically, the population of black rhinos in Kenya has increased from less than 400 animals to the current count of 1040 animals by the end of 2023 (KWS, 2023). The recovery of these two species (black and white rhinos) is guided by the Species Recovery and Action Plans that clearly outline the steps to be taken in their management (KWS, 2022; Khayale et al., 2021).

Within the LBL, we manage a population of 132 Black rhinos and 128 White rhinos, diligently monitoring a range of population metrics daily.

2.1.2 Black rhino population performance

The Black rhino population decreased from 133 to 132 following 3 births and 4 deaths. This dropped the average biological growth rate to 5% for the 2021-2023 three-year period, compared to the 6.6% rate observed in the 2020-2022 period. However, this was still within the recommended national rate of 5.0% (KWS, 2022). The figures below show the general performance of the black rhino on LBL:

Table 2.1.1: Black rhino births on LBL in 2023

#	Calf name	Date of **Birth**	Sex	Dam	Sire
1	*Waiwai calf 9*	01-Jan-23	F	*Waiwai*	*Lucky*
2	*Moomoo calf 3*	13-Mar-23	U	*Moomoo*	*Walib*
3	*Calisto calf 7*	27-May-23	F	*Calisto*	*Roy*

Table 2.1.2: Black rhino deaths on LBL in 2023

#	Rhino name	Age at death	Sex	Date	Cause of death
1	*Senewa calf 2*	1 month	U	18-Jan-23	Unknown
2	*Annitah*	6.4 years	F	5-Mar-23	Euthanized back injuries
4	*Moomoo calf 3*	2 days	U	15	Predation by Hyaena
5	*Kipchoge*	5.8 years	M	20-Mar-23	Predation by lion

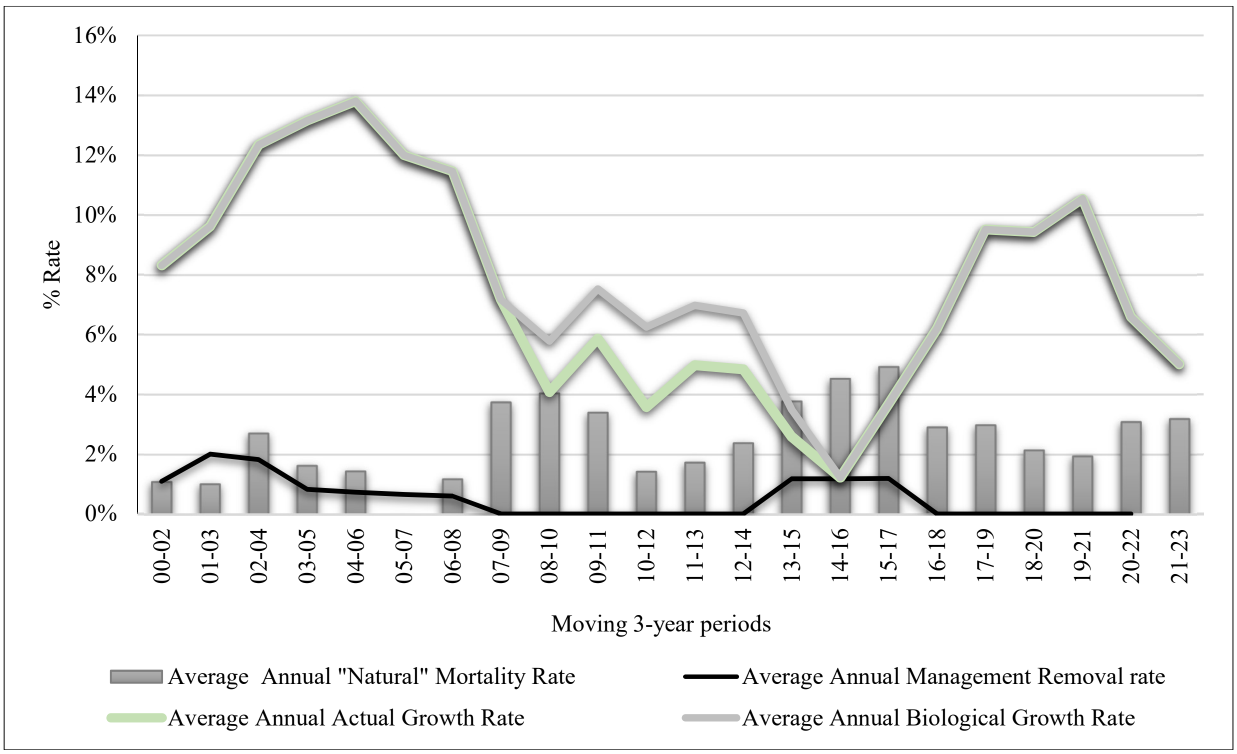


Figure 2.1.1: Key Black rhino population metrics on the LBL, 2020-2023

2.1.2 Black rhino Performance indicators

Metrics such as Age at First Calving (AFC), Average Inter-Calving Interval (ICI), the Sex Ratio of Female to Male (SR), and the Yearly Percentage of Female Calving (PFC) serve as indicators of the reproductive performance of black rhinos (Ouma, 2004). The reproductive performance of black rhinos for the period 2021 to 2023 is summarized as follows: the average ICI was 2.7 years (Moderate - Good), PFC was 27% (Very poor - Poor), AFC was 7.6 years (Very poor - Poor), and the SR was 1.2:1 (Moderate - Good) as also shown in Appendix 1.

The current population structure of black rhinos shows that 23% of the population consists of calves, 24% are sub-adults, and 53% are adults as shown in the table below:

Table 2.1.3: Population structure of Black rhino on LBL, 2023

Age Class	Male	Female	Unknown	Sub Total	Proportion in population
Calves (0<3.5yrs)	12	18	0	30	23%
Sub Adults (3.5<7 yrs.) unless calved	16	16	0	32	24%
Adults (>7yrs)	30	40	0	70	53%
Grand Total	58	74	0	132	100%
Proportion in population	44%	53%	0%	100%	

2.1.3 White rhino population performance

The white rhino population rose from 122 to 128 due to 10 births and 4 deaths. Despite the numerical increase, this led to a decrease in the average biological growth rate for the 2021-2023 three-year period to 7.8%, compared to the 8.6% rate recorded in the 2020-2022 period. However, this was above the recommended national growth rate of at least 5.0% (Khayale et al., 2021). The tables below show the performance of white rhinos in 2023:

Table 2.1.4: White rhino births on LBL in 2023

#	Calf name	Date of **Birth**	Sex	Dam	Sire
1	*Safari Calf 1_2023*	05-Jan-23	M	*Safari (9.1-year-old)*	*Motonto*
2	*Nduta Calf 2_2023*	18-Apr-23	F	*Nduta (9.8-year-old)*	*Mia*
3	*Rosie Calf 5_2023*	13-May-23	M	*Rosie (15.4-year-old)*	*Muya*
4	*Lucille Calf 4_2023*	17-May-23	M	*Lucille (13.5-year-old)*	*Gordon-65*
5	*Queen Calf 5_2023*	31-May-23	U	*Queen (15.7-year-old)*	*Muya*
6	*Namunyak Calf 2_2023*	07-Jun-23	F	*Namunyak (7.9-year-old)*	*June*
7	*Ramadhan Calf 6_2023*	12-Jun-23	M	*Ramadhan (19.2-year-old)*	*Ruby*
8	*Naserian Calf 5_2023*	20-Jun-23	M	*Naserian (15.2-year-old)*	*Hatari*

9	*Sidai Calf 2_2023*	11-Sep-23	M	*Sidai (7.5-year-old)*	*Maina*
10	*Semenya Calf 3_2023*	24-Sep-23	M	*Semenya (10.4-year-old)*	*June*

Table 2.1.5: White rhino deaths on LBL in 2023

#	Rhino name	Age at death	Sex	Cause of death
1	*Chandara*	12 years	M	Territorial fights/fell off the cliff
2	*Sue*	11 years	M	Euthanized back injuries/fights
3	*Nabei*	4 years	F	Hit by a bull
4	*Lucille Calf 3*	3 years	M	Twisted colon

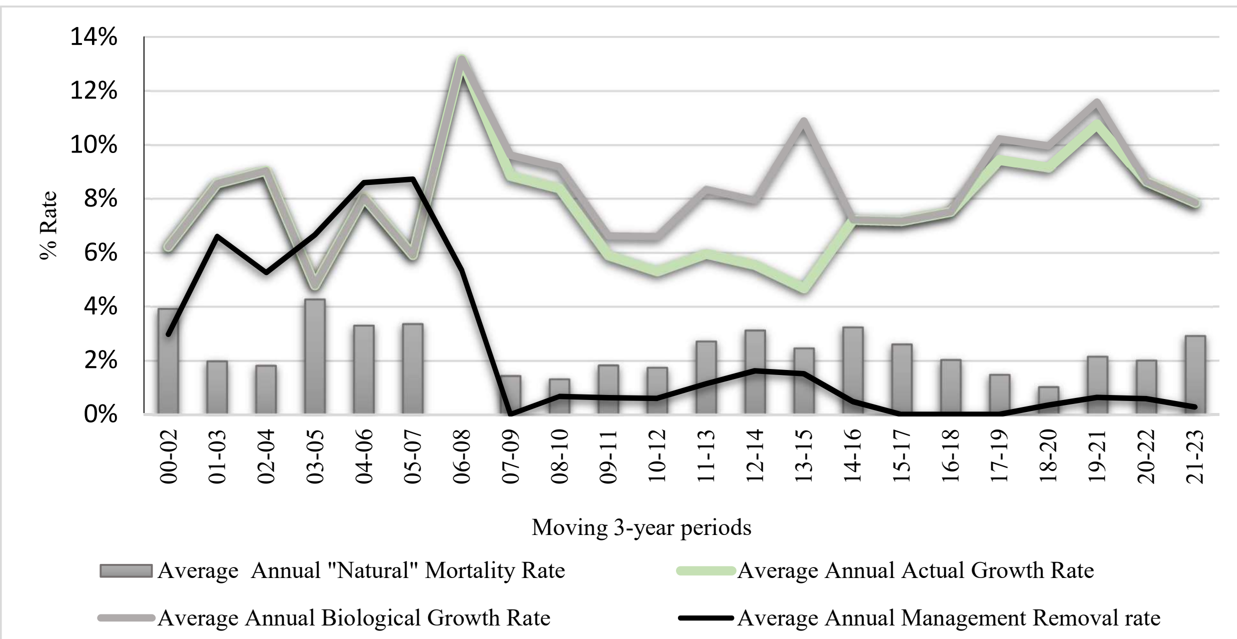


Figure 2.1.2: Key White rhino population metrics on the LBL, 2021-2023

2.1.4 White rhino Performance indicators

The Age at First Calving (AFC) for white rhinos is 6.7 years (Moderate – Good), while the Average Inter-calving Interval (ICI) stands at 2.6 years (Moderate – Good). The Yearly Percentage of Female Calving (PFC) is 42% (Good – Excellent), and the Sex Ratio of Female to Male (SR) is 1:1.1 (Poor - Moderate) also shown in Appendix 1. The age-sex structure of LBL's white rhino population shows a slightly higher proportion of males (54%) compared to females (45%). Among this population, 51% are adults, 19% are sub-adults, and 30% are calves as shown in the table below:

Table 2.1.6: Population structure of White rhino on LBL, 2023

Age Class	Male	Female	Unknown	Sub Total	Proportion in population
Calves (0<3.5yrs)	25	13	1	39	30%
Sub Adults (3.5<7yrs) unless calved	12	12	0	24	19%
Adults (>7 yrs.)	32	33	0	65	51%
Grand Total	69	58	1	117	100%
Proportion in population	54%	45%	1%	100%	

2.1.5 Sighting frequency

The average sighting frequency (SF) for Black rhinos was 2.3±1.1 days, and for White rhinos, it was 1.5±0.6 days. These sighting frequencies fall within the critical range of 3 days on the LBL.

2.1.6 LBL Rhino identities

Effective biological management of rhinos necessitates dependable and efficient field monitoring for making well-informed meta-population management decisions (KWS, 2022). This requires an individual identity-based approach to gather precise data, facilitated by ear notches or other distinctive body features on the rhinos. Ear notching is applied on calves that have separated from their mothers and lack other conspicuous body features for identification, commonly referred to as 'clean rhinos’.

In the current year, we collaborated with the KWS to undertake ear-notching of 42 rhinos (20 black and 22 white). Out of these, six were equipped with LoRaWAN transmitters which are tracked on the EarthRanger (ER) platform.

Presently, 61% of Black rhinos and 63% of White rhinos are distinguishable through ear notches and other distinctive features, surpassing the recommended threshold of 60% (KWS, 2022). However, there are 36 rhinos (11 White and 25 Black) that are considered suitable candidates for the next ear notching. The table below shows the distribution of notched rhinos on LBL:

Table 2.1.7: Break down of rhinos successfully ear-notched

Species	Lewa		Borana		Total
	Male	**Female**	**Male**	**Female**	
Black rhino	6	5	5	4	20
White rhino	11	10	1	0	22
Total	17	15	6	4	42

2.1.7 Rhino interventions

Among the various deaths documented in tables 2.1.2 and 2.1.6 above, postmortems were conducted to ascertain the causes of death for five rhinos (2 black and 3 white). *Annitah* succumbed to injuries and had to be euthanized, *Kipchoge* perished due to lion predation, *Sue* was euthanized after breaking its limb from a fall, *Nabei* suffered fatal internal injuries from being struck by a male rhino, and *Lucille Calf 3* succumbed to twisted colon.

2.1.8 Rhino Fight Incidences

Intra-specific competition arises when a specific individual faces limitations in available resources. These competitions among individuals of the same species may result in territorial conflicts, some of which can be life-threatening. Table 2.1.8 provides a record of rhino confrontations observed in the landscape:

Table 2.1.8: Rhino fights on the LBL

#	Date of incidences	Rhinos involved	Sex	Age Class	Rhino species
1	24-Apr-23	*Mandela/Tulivu*	Male	Adults	White
2	6-Apr-23	*Sogomo/Ndoto*	Male	Adults	Black
3	20-Jul-23	*Lacky/Barry*	Male	Adults	Black
4	23-Aug-23	*Koome/Wire*	Male	Adults	White
5	25-Aug-23	*Sue/Chandaria*	Male	Adults	White
6	18-Sep-23	*Sue/Chandara*	Male	Adults	White
7	20-Sep-23	*Schini/Mia*	Female/Male	Adults	White
8	2-Oct-23	*Ruby/Riziki*	Male	Adults	White
9	3-Oct-23	*Imado/Nasa*	Male	Adults	White
10	28-Oct-23	*Elvis/Ngiririma*	Male	Adults	Black
11	29-Oct-23	*Hatari*	Male	Adults	White

2.1.9 Conclusion and Recommendations

The notching of 42 rhinos has significantly enhanced the identification of individuals in the population, thereby improving ranger reporting and field identification. Those yet to be notched are likely to increase due to the high reproduction and recruitment rate in the landscape. Therefore, we recommend conducting the exercise at least every 2 years to maintain the recommended identification threshold.

Photographic evidence plays a crucial role in the research and monitoring of iconic species like rhinos. We propose assigning a handheld camera to each patrol block in the landscape and providing training to rangers on capturing photos for various purposes. This approach will ensure the timely availability of auditable master files for individuals and facilitate body condition assessments. Additionally, equipping rangers with personal digital assistants (PDAs) to input data directly in the field will ensure the provision of timely and accurate information for decision-making.

The occurrences of rhino fights and related incidents in the year suggest that black rhinos might have surpassed the Ecological Carrying Capacity (ECC). This can only be ascertained by carrying out an ECC review. Nevertheless, in landscapes with a high growth rate, regular removal through translocations is recommended to manage such ecological dynamics effectively.

2.2 Predator Monitoring

2.2.1 Introduction

Predator monitoring is crucial in unravelling the intricate dynamics between predators and their prey within an ecosystem. To enhance the precision and efficiency of our monitoring efforts, we have embraced the use of technologies such as Iridium/Global Positioning System (GPS) collars, Global System for Mobile Communications (GSM) trackers, infra-red camera traps, and EarthRanger (ER) platform. These have enabled the collection, analysis and timely sharing of important information on predator-prey dynamics for decision-making.

2.2.2. Lion Population

We monitored a population of 60 lions (36 adults, 9 sub-adults, and 15 cubs) occurring in four prides and three male coalitions. There were also 7 cubs from this population that died during the year as a result of infanticides as shown in the table below:

Table 2.2.1: Lion population structure on LBL

Pride/Coalition	**Adults**		**Sub adults**		**Un-sexed Cubs**	**Total by Prides & Coalitions**
	Males	**Females**	**Males**	**Females**		
Sarah's pride	1	6	2	2	6	17
Dalma's pride	0	2	1	2	2	7
Carissa's pride	0	1	2	0	0	3
Winter's pride	0	13	0	0	7	20
Ntulele's coalition	4	0	0	0	0	4
Cat-tail's coalition	6	0	0	0	0	6
Three male coalition	3	0	0	0	0	3
Total by sex	**14**	**22**	**5**	**4**	**15**	**60**

2.2.2 (i) Lion Collaring

Partnering with KWS we deployed two Iridium/GPS collars and one GSM collar on three lions within the LBL to better understand their spatial-temporal patterns. This brought the number of collared lions in the landscape to four as shown below:

Table 2.2.2: Collars deployed within the landscape

Date fixed	Name	Sex	Current Age	Collar Status	Collar ID	Frequency
9-Aug-23	*Abijah*	F	6-years	Active	IRI2023-5501	151.143
5-Sep-23	*Kiara*	M	6-years	Active	IRI2023-5500	151.123
23-Jun-20	S*arah*	F	15-years	Active	GSM2014-1664	149.184
30-May-23	*Carissa*	F	9-years	Inactive	SPO40064	N/A

2.2.2. (ii) Lioness Contraception

To regulate the lion population and to check their impacts on key prey species like the endangered Grevy's zebra, we implanted contraceptives in three new individuals (*Abijah, Winter,* and *Anita*) and replaced them for *Carissa* that had already expired. *Simone, Carissa and Doris* resumed their normal breeding cycle after their implants expired hence giving birth to two cubs. The implants have proved to be reversible and can be reliable in managing lion populations.

2.2.3 Spatial ecology

Animal home ranges, like those of lions, are determined by prey abundance and water availability (Powell, 2000; Tumenta et al., 2013). Lions in the LBL area have smaller home ranges, reflecting prey abundance (Figure 2.2.1 a-d). While some overlap occurs, prides maintain distinct core areas. Sarah's pride extends into the Leparua community area, while others stay within the landscape. Initially, Ntulele's and Cat-tail's coalitions roamed Lewa but later shifted, with Ntulele's group moving to Borana. This shift may be due to Cat-tail's coalition expanding its range into Lewa's southern part, as shown below:

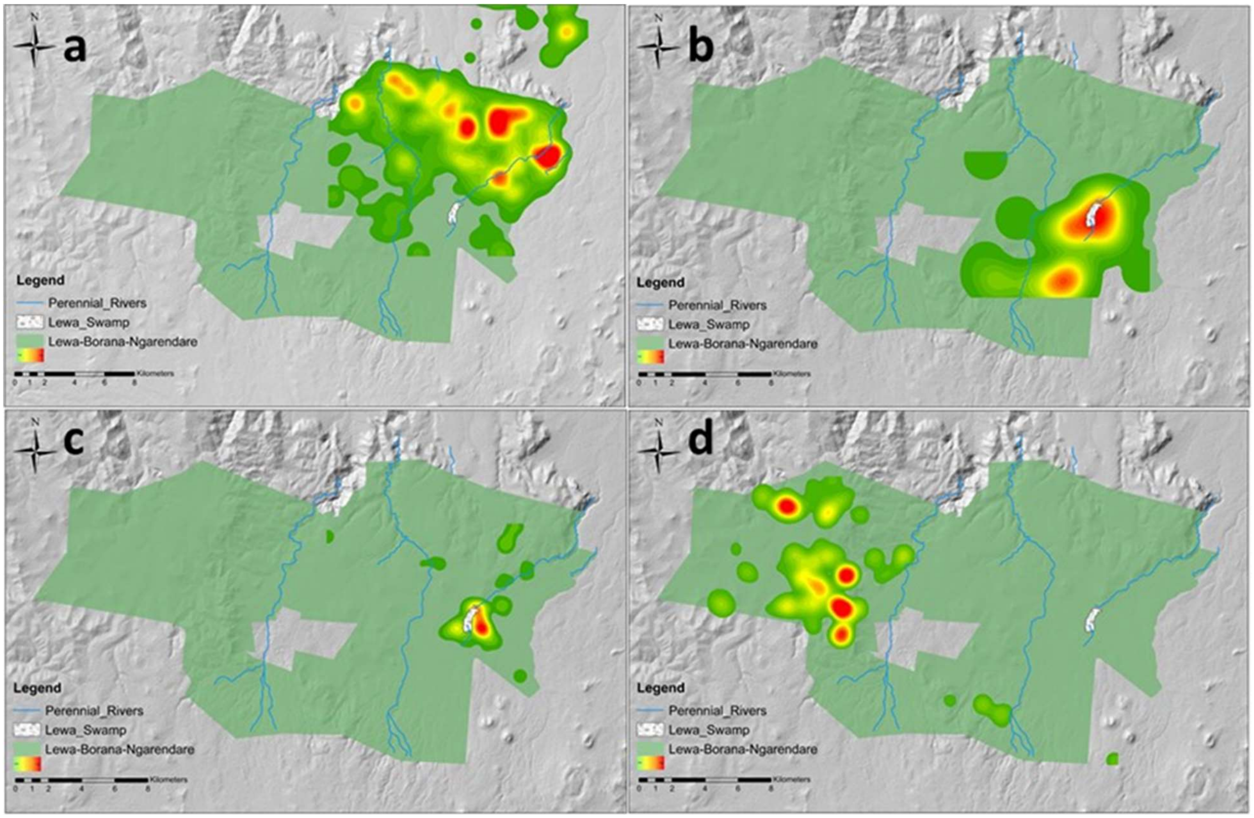


Figure 2.2.1: Predator home ranges; **a)** *Sarah's* pride; **b)** *Dalma's* pride; **c)** *Cat-tail's* coalition; **d)** *Ntulele's* coalition

2.2.4 Wildlife Mortality

Within the landscape, we documented a total of 78 wildlife mortality cases, with predation being the predominant cause. Lions were identified as the primary contributors accounting for 83.3% of the recorded deaths. Other causes classified as natural, entanglement and euthanasia, all together constituted 16.7% of the cases. Most of these mortalities were reported on the central part of the landscape as shown in the figures below:

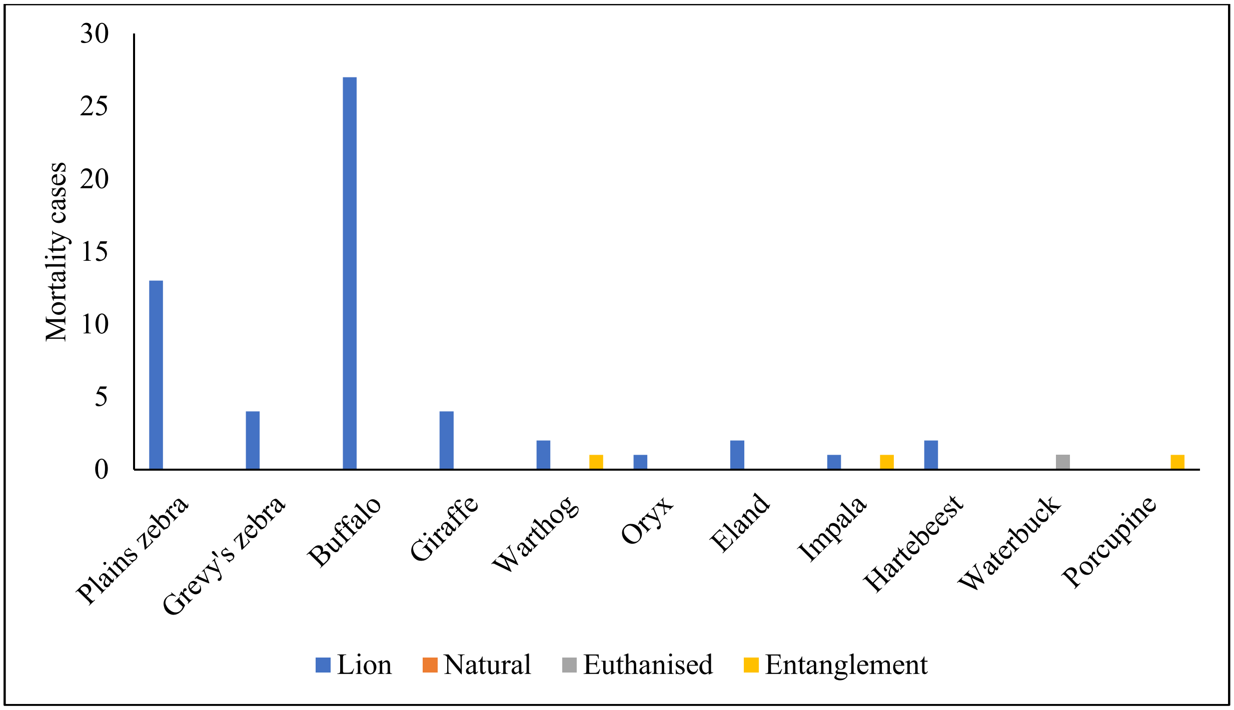


Figure 2.2.2: Causes of wildlife mortality on LBL

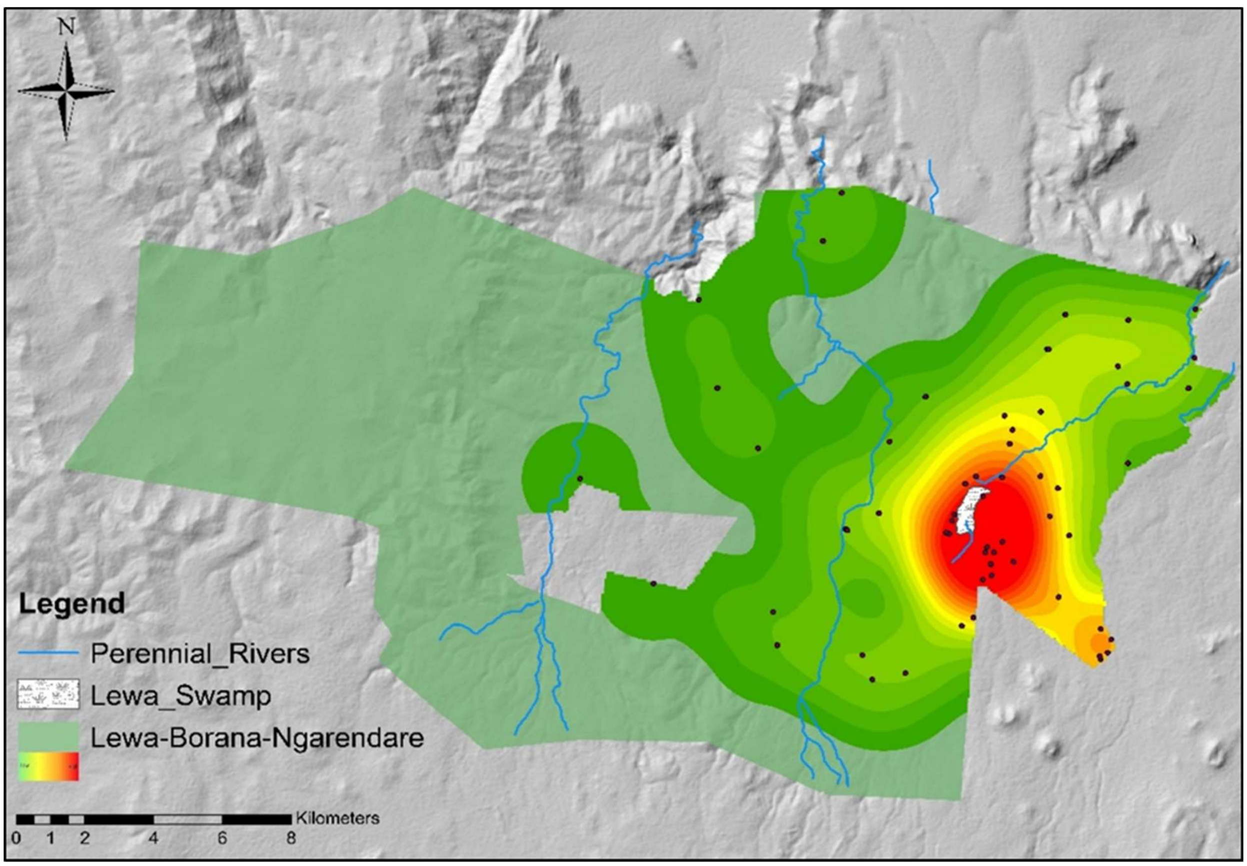


Figure 2.2.3: Location of mortality cases in the landscape

We used the Jacobs Selectivity Index (D) to assess the prey preference by lions (Jacobs,1974) and out of the nine prey species analyzed, the lion showed an avoidance for waterbuck and impala and a preference for buffalo as shown below:

Table 2.2.4: Jacob's Index (D) values calculated for seven prey species on LBL, 2019 -2023

Species	**2023**	**2022**	**2021**	**2020**	**2019**
Plains Zebra	-0.2	-0.5	-0.1	0	0.3
Grevy's zebra	0.1	-0.4	0.3	0	0.2
Waterbuck	-1.0	-0.4	-0.1	-0.2	-0.5
Beisa Oryx	-0.5	-0.6	0.4	-0.5	-0.6
Eland	-0.1	0.5	0.4	0.6	0.5
Warthog	0.1	-1	-1	-0.2	0.3
Impala	-0.9	-0.9	-0.9	-1	0.1
Giraffe	0.5	-0.2	0.5	0	0.7
Buffalo	0.7	0.7	0.3	-0.5	0

2.2.5 Human Carnivore Conflicts

Livestock depredation has adverse effects on conservation efforts and the well-being of surrounding communities, impacting both the effectiveness of conservation initiatives and the sustainability of resources in community development (Young et al., 2010). A total of 17 incidents were reported, leading to the death of 42 livestock within the Lewa-Borana Landscape (LBL) and neighbouring communities. Lions accounted for the majority of cases, contributing to 46.5%, followed by hyenas at 30.2%, and leopards at 23.3% (Table 2.2.5). These incidents were predominantly concentrated in the western and southern parts of the landscape.

Table 2.2.5: Livestock depredation on LBL

Species	**Cattle**	**goats**	**Sheep**	**Total Death by Predator**
Lion	4	15	1	**20**
Hyenas	1	10	2	**13**
Leopard	0	8	1	**9**
Total death by Livestock	**5**	**33**	**4**	**42**

2.2.6 Scats analysis

Prey hair ingested by predators normally passes through their digestive system undamaged and can be collected in the form of scat. We normally collect the scat and extract, clean, mount and observe it under the light microscope (*400X Magnification*), and compare the resultant hairs to the existing reference hairs to discern the prey species involved. A total of 35 scat samples from lions (*n=27*) and hyenas (*n=8*) were collected and analyzed for prey hair content. Overall, the data indicated that the primary prey species preferred by lions and spotted hyenas were Plains zebra, buffalo and Grevy's zebra. Given that hyenas are predominantly scavengers, they may feed on the carcasses of large animals that lions have killed as they do not fully consume their kill, which can explain the slight similarity observed between the proportion of hairs of the two predators as seen in the figure below:

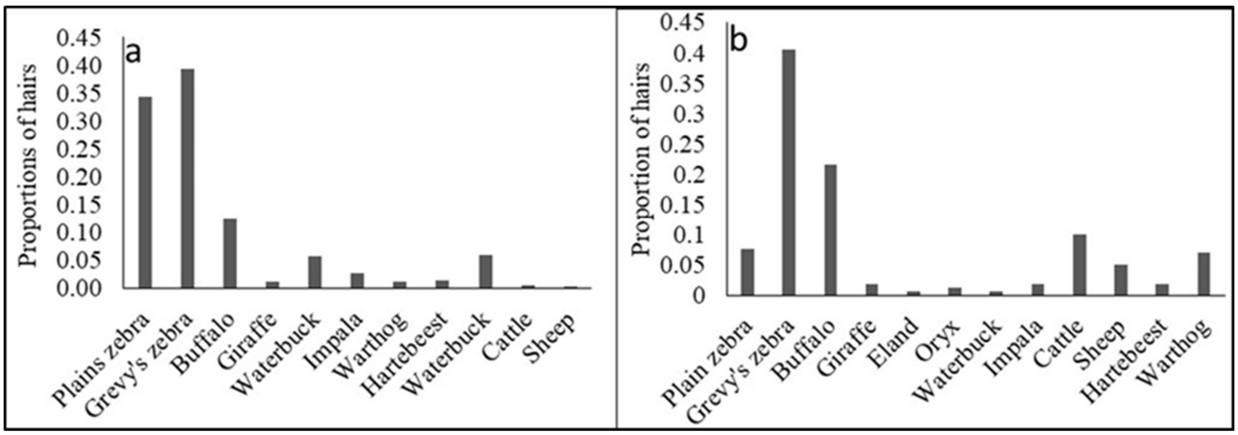


Figure 2.2.4. The proportion of prey species hairs found in **(a)** Hyena, **(b)** Lion Scat

2.2.7 Conclusion and Recommendations

Lionesses with expired implants reverted to their natural breeding cycle, indicating the reversibility of the process, a valuable aspect of managing the lion population.

Collars play a crucial role as indispensable tools in monitoring elusive animals such as lions and hyenas. A more thorough monitoring strategy by use of collars for the two species is essential for the LBL. We also recommend prompt reporting of mortality cases especially on the western side of the landscape and this can be enhanced through proactive patrols, the use of the Earthranger platform and effective data collection. We propose raising awareness in the neighbouring communities regarding the use of predator-proof bomas in the mitigation of human–carnivore conflicts.

2.3 Ungulate Monitoring

2.3.1 Introduction

Fluctuations in seasonal and climatic conditions within arid and semi-arid environments play a pivotal role in shaping the dynamics of ungulates. This influence stems from the spatial variability in both the quality and quantity of forage, coupled with water availability (Illius and O'Connor, 2000; Mduma et al., 1999). The variations in resource distribution have far-reaching consequences, impacting the wild ungulates' body fat reserves, movement patterns, and age-sex composition (Illius and O'Connor, 2000).

The LBL undergoes significant shifts in vegetation and wildlife population structure due to its semi-arid conditions coupled with the climatic and seasonal variations of resources. In our efforts to monitor these dynamic parameters, we have selected 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*) as indicator species. Additionally, we used camera traps to capture the movement of wildlife through migratory gaps that connect LBL with adjacent conservancies. By doing this we gain valuable insights into the responses of the region's fauna to the ever-changing environmental conditions.

2.3.2 Age – sex structure of ungulates

The stability of a population, as determined by demographic modelling simulations (Rubenstein, 2010), hinges on two crucial parameters: growth potential and the proportion of juveniles and young individuals. Growth potential is assessed by the male-to-female ratio within the adult age class. A ratio of 1:1 signifies low growth potential, 1:2 indicates medium growth potential, and 1:3 or higher signifies high growth potential. Additionally, for a population to be deemed stable and self-sustaining, the combined percentage of juveniles and young individuals should approach 30% (Rubenstein, 2010).

Buffalo and Eland consistently met the 30% threshold, except for this year due to the prolonged drought. Grevy's zebra, Plains zebra, oryx, and hartebeest narrowly missed it, with Plains zebra achieving it in 2022 and hartebeest falling below 20% this year. Giraffes had the lowest percentage, attributed to a low number of juveniles and calves in the surveys. The surveyed ungulates showed medium to high growth potential, indicating resilience in resource-limited environments.

The hartebeest population remained low, with the 2023 game count reporting 100 individuals on LBL. Initially, only 14 were recorded on Lewa's side in 2014, but by 2023, it expanded to around 39 individuals, driven by natural births and immigrants from Borana Conservancy before the fence's removal in 2015. Between 2014 and 2023, 77 births and 41 deaths were recorded on Lewa's side, reflecting a 47% survival rate for younger hartebeestsThe figures below show the trends of young and juvenile and the ratio of male to female in the Ungulates population:

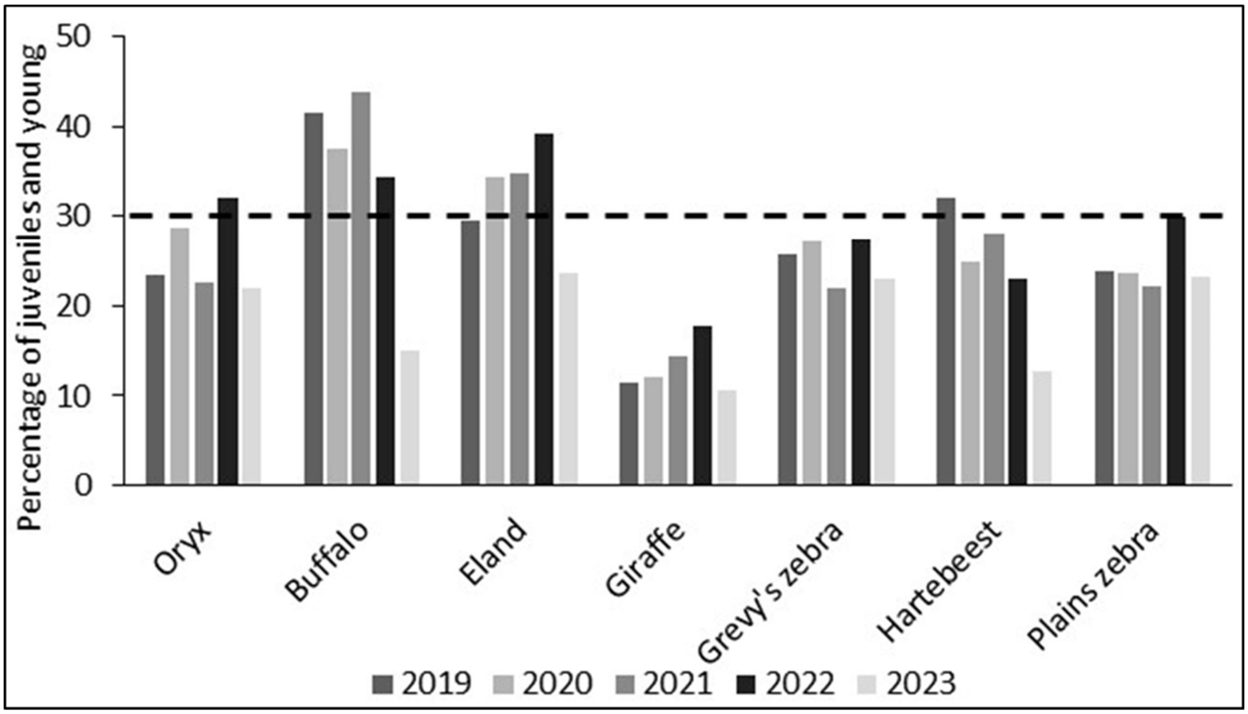


Figure 2.3.1: Proportion of young and juveniles for ungulate species monitored. The dotted black line indicates the 30% recommended level for stable populations.

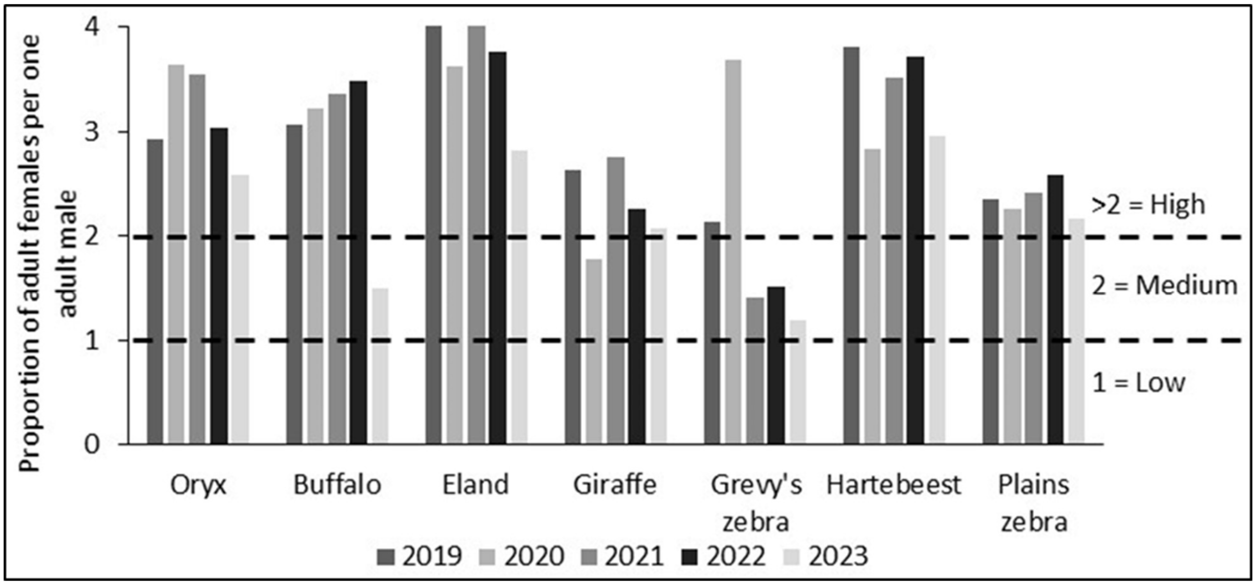


Figure 2.3.2: Proportion of adult females per one adult male for ungulate species monitored.

2.3.3 Grevy's Zebra Foal Survival Rates

We utilized the National Grevy's zebra database to examine photographs of Grevy's zebras, focusing on identifying unique individual foals. In the current year, 48 newly born foals were documented. Among them, 35 were re-photographed within four months before the end of the year, with 11 surpassing this timeframe. The distribution of these foals across different age and sex categories is detailed in Table 2.3.1.

Table 2.3.1: Age and sex distribution of Grevy's zebra foals

Sex	Age category			
	(0-3) months	(3-6) months	(6-12) months	**Total by sex**
Male	5	5	7	17
Female	16	11	4	31
Total by sex	21	16	11	**48**

2.3.4 Grevy's zebra collaring and movements

In the second quarter of 2022, a rise in the population of Grevy's zebra was observed on the Borana side of the landscape, likely influenced by increased rainfall in the area. Subsequently, in the last quarter, rains were evenly distributed across LBL, prompting a significant portion of the observed zebra population to migrate back to the Lewa side. This pattern has persisted into the current year, establishing the Borana section as a refuge for the zebras during adverse conditions. The substantial return of the zebras to Lewa when conditions improved suggested a preference for lower-altitude areas by these animals. The figure below shows the trends of the Grevy's zebra on the eastern (Lewa) and the western (Borana) sides of the landscape in the year:

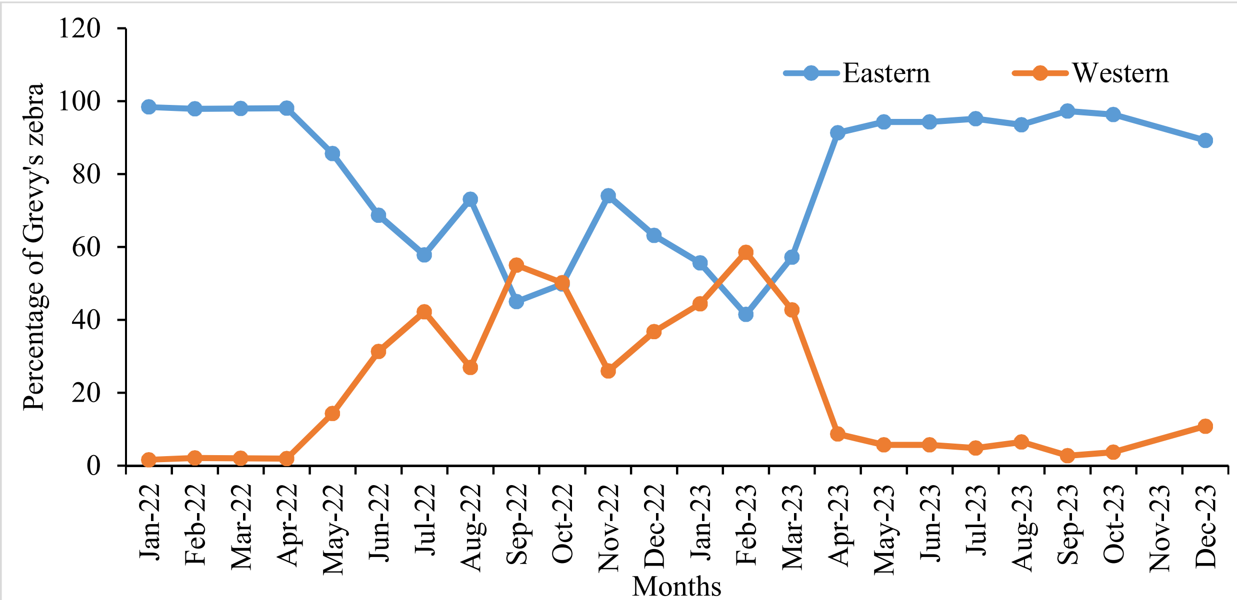


Figure 2.3.3: Grevy's zebra population trends (expressed as a percentage) on LBL, 2023

This movement prompted us to instore Iridium collars on three individuals to track their movements which predominantly occurred within the confines of the two landscape sections. Nevertheless, two individuals that went to Borana, displayed proximity to the western and southern western migratory gaps, suggesting a potential to venture beyond the defined landscape boundaries as shown in the figure below:

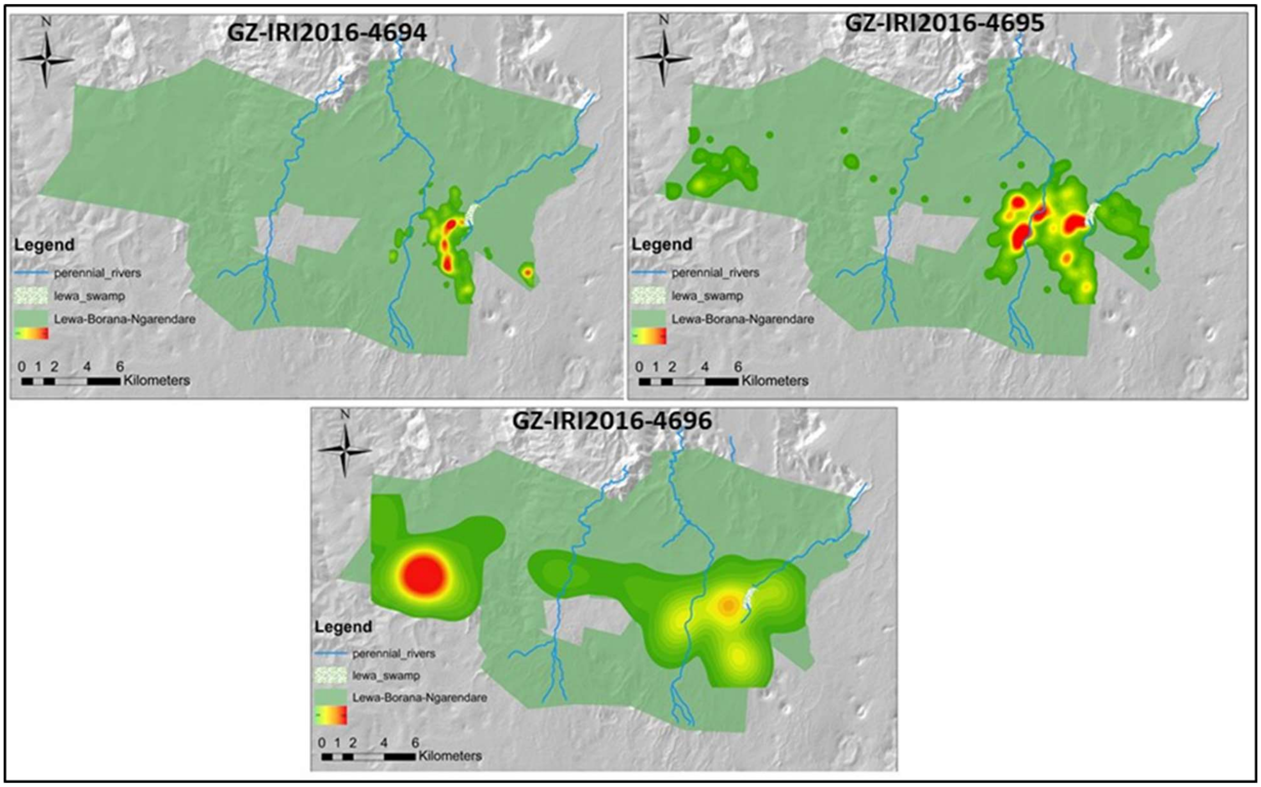


Figure 2.3.4: Movements of the collared Grevy's zebra in the landscape

2.3.5 Annual wildlife count

The annual wildlife census for 2023 was conducted revealing a significant decline in the buffalo and eland populations compared to previous years as shown in the table below:

Table 2.3.2: Game count results for the indicator species from 2016 – 2023

Species	Year							
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Eland	280	192	322	291	245	358	331	245
Beisa oryx	179	220	178	227	307	239	247	285
Buffalo	1220	1391	1623	1753	2086	2153	1901	715
Giraffe	273	251	127	167	178	172	119	138
Hartebeest	30	62	64	64	93	91	92	100
Plains zebra	1262	1236	1228	1484	1599	1561	1557	1731
Grevy's zebra	299	292	308	313	331	322	310	359

2.3.6 Body Condition Scores (BCS)

Precipitation stands as a crucial determinant of rangeland productivity, which in turn influences forage availability, thereby impacting the fat reserves and behavioural ecology of wildlife

(Hempson et al., 2015; Stephenson et al., 2020). Despite experiencing low rainfall in 2022 (183mm), resulting in enhanced drought, a notable proportion of species continued to exhibit a BCS higher than 3.0. Plains zebra, Grevy's zebra, and giraffe predominantly registered a BCS of 4.0, while Beisa oryx, eland, and hartebeest recorded a BCS of 3.5. Approximately half of the buffalo population maintained a BCS of 3.0, and nearly the entire population did not surpass a BCS of 3.5 as shown in the table below:

Table 2.3.3: Species BCS

BCS	**Species**						
	Buffalo	**Beisa Oryx**	**Eland**	**Giraffe**	**Hartebeest**	**Plains zebra**	**Grevy's zebra**
5 (Obese)	0	0	0	0	0	0	0
4	2	13	20	75	25	89	82
3.5	49	70	72	25	67	9	15
3	45	17	8	0	8	2	3
2.5	4	0	0	0	0	0	0
1 (Emaciated)	0	0	0	0	0	0	0

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

2.3.7 Wildlife Movement through the Migratory Corridors

Wildlife corridors serve as passage routes for animals between habitats, enabling access to larger habitats, and aiding in predation avoidance while minimizing inbreeding, thereby enhancing the genetic viability of wildlife species (Ojwang et al., 2017).

The LBL has been monitoring wildlife movement through designated migratory routes using infrared camera traps. These routes include the Mt. Kenya Endpass, Mt. Kenya Underpass, Marania Underpass, and the Northern Gap. We analyzed the movement patterns for the past year and compared the trends between the dry months (January, February, June, July, August, September) and wet months (March, April, May, October, November, December). Additionally, we compared the movement trends over the last 11 years.

2.3.7.(i) Mt. Kenya Endpass

There was no significant difference in crossing events of all wildlife over the past year at the Mt. Kenya Endpass between the dry (3,108) and wet period (3,209) ($\chi^2 = 1.615$, df = 1, p = 0.204). In the same year, there were more crossing events of elephants into the Mount Kenya forest (152) than towards the Marania underpass (144) during the dry period, although this difference was not significant ($\chi^2 = 0.216$, df = 1, p = 0.642) (Figure 2.3.5a). During the wet period, there were more crossing events of elephants down the corridor towards the Marania underpass (145) than towards Mt. Kenya forest (45) ($\chi^2 = 52.632$, df = 1, p = 0.001) (Figure 2.3.5a).

Compared to the past 11 years, the trend indicates a significant increase in crossing events for all wildlife ($\chi^2 = 17282$, df = 10, p = 0.001) as shown below:

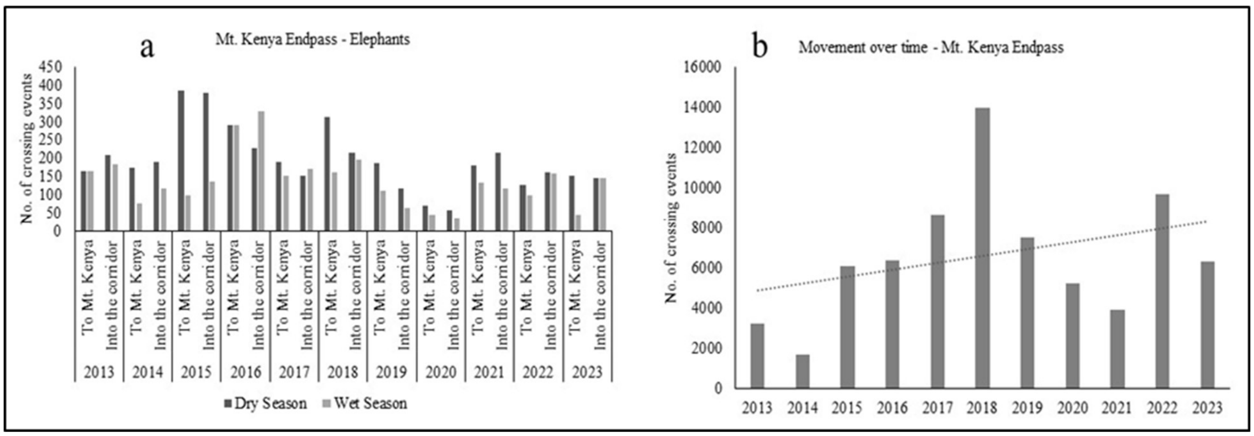


Figure 2.3.5: a) Seasonal movements of elephants; **b)** Trends of all wildlife species using the gap

2.3.7.(ii) Marania Underpass

There was a significant difference in crossing events of all wildlife over the past year at the Marania underpass between the dry (578) and wet period (324) ($\chi 2 = 71.525$, df = 1, p = 0.001). In the same year, there were more elephant crossing events towards Mount Kenya forest through the underpass (242) than down the corridor towards Mt Kenya underpass (149) during the dry period ($\chi^2 = 22.12$, df = 1, p = 0.001) (Figure 2.3.6a). However, during the wet period, there were more elephant crossing events down towards the Mt Kenya underpass (130) than up to Mt. Kenya forest through the underpass (42) ($\chi^2 = 45.023$, df = 1, p = 0.001) (Figure 2.3.6a).

Comparing the past 5 years, the trend indicates a significant increase in crossing events for all wildlife for the past 5 years ($\chi2$ = 529.64, df = 4, p = 0.001) as shown below:

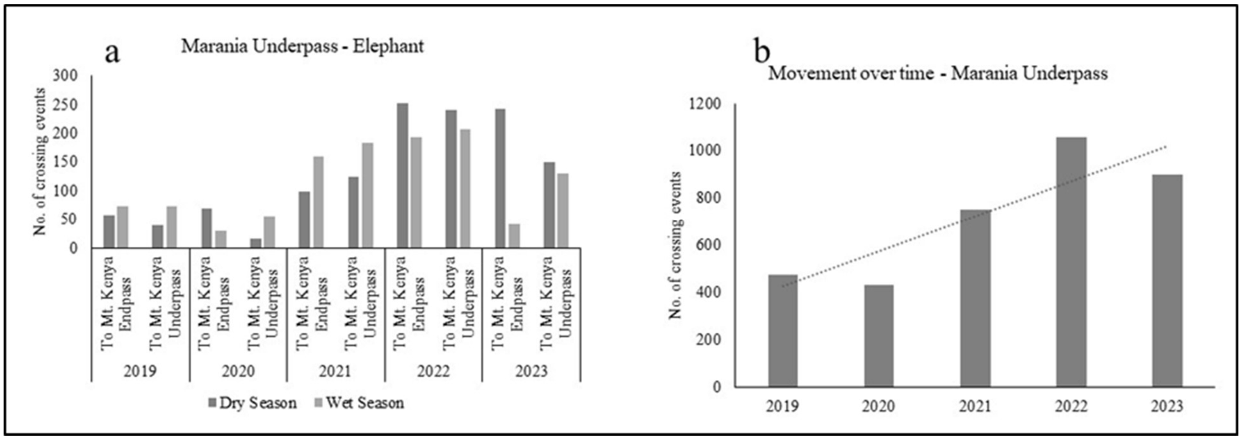


Figure 2.3.6: a) Seasonal movements of elephants; **b)** Trends of all wildlife species using the gap

2.3.7.(iii) Mt. Kenya Underpass

There was a significant difference in crossing events of all wildlife over the past year at the Mount Kenya Underpass between the dry (1,653) and wet period (2,260) (χ^2 = 94.16, df = 1, p = 0.001). Elephants had more crossing events towards Mt. Kenya forest (332) than down towards Lewa through NNFR (272) during the dry period (χ^2 = 5.96, df = 1, p = 0.015) (Figure 2.3.7a). During the wet period, there were more crossing events of elephants down towards Lewa through NNFR (180) than towards Marania underpass through the corridor (152) (χ^2 = 2.361, df = 1, p = 0.124) (Figure 2.3.7a).

Comparing the use of this pass for all wildlife in the last 11 years, the trend indicates a significant increase in crossing events (χ^2 = 5829.9, df = 10, p = 0.001) as shown in the figure below:

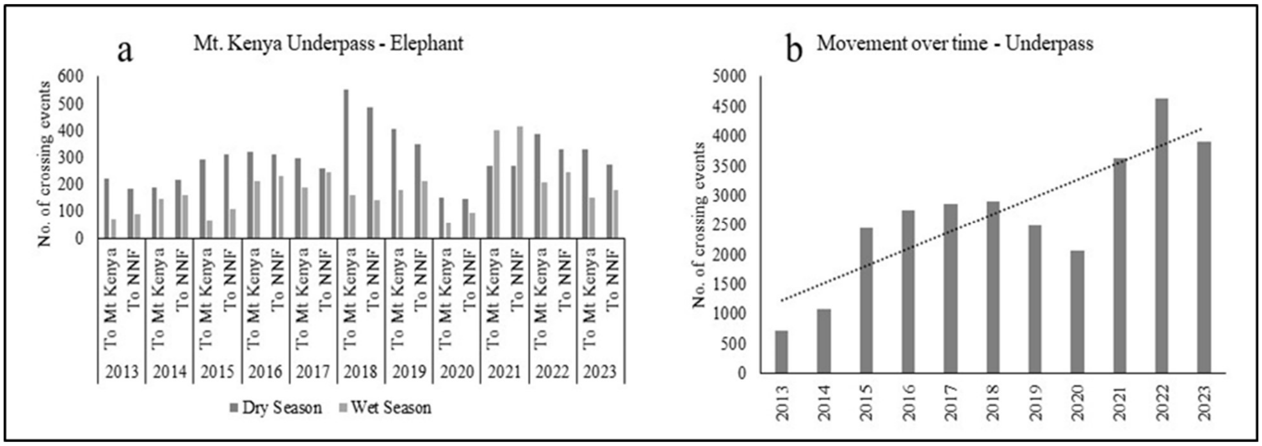


Figure 2.3.7: a) Seasonal movements of elephants; **b)** Trends of all wildlife species using the gap

2.3.7(iv) Northern gap

There was a significant difference in crossing events of all wildlife over the past year at the Northern gap between the dry (9,806) and wet period (7,938) ($\chi2 = 196.65$, df = 1, p = 0.001). Elephants had more crossing events into Lewa (1,903) than out of Lewa (1,823) during the dry period ($\chi2 = 1.718$, df = 1, p = 0.19)) (Figure 2.3.8a). During the wet period, there were more elephant crossing events out of Lewa towards the north (1,999) than vice versa (1,587) ($\chi2 = 2.361$, df = 1, p = 0.124) (Figure 2.3.8a).

Comparing the trend of wildlife usage of this corridor for the last 11 years, it indicates a significant increase in crossing events for all wildlife ($\chi2 = 4555$, df = 9, p = 0.001) as shown below:

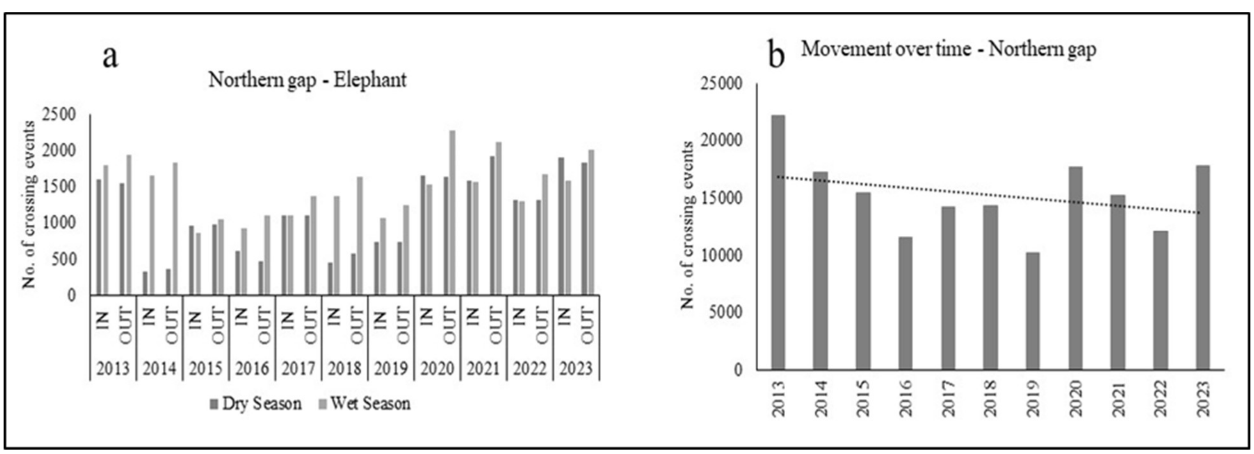


Figure 2.3.8: a) Seasonal movements of elephants; **b)** Trends of all wildlife species using the gap

2.3.8 Conclusion and Recommendations

The resilience exhibited by numerous species, as reflected in the BCS surpassing 3.0 despite minimal rainfall early in the year underscores the adaptability of wildlife in environments with limited resources. However, the observed decline in buffalo and eland populations, potentially linked to prolonged drought conditions in the preceding year, highlights the need for proactive targeted conservation interventions to support these species during periods of environmental stress. Drought preparedness plans may be considered to mitigate the impact on these vulnerable populations. Animals especially elephants respond quickly to changes in forage and water availability, moving to higher elevations when forage decreases in lower areas and vice versa (Bohrer et al., 2014). LBL wildlife migratory gaps have continued to serve as passage routes for wildlife species in response to rainfall distribution in the landscape, therefore is a need to continue maintaining and monitoring their usage by various species.

2.4 Elephant Monitoring

2.4.1 Introduction

The African savanna elephants (Loxodonta africana) in Kenya encounter significant challenges in their dispersal due to escalating anthropogenic activities. Although there has been a decrease in poaching, competition for water and food persists (Sach et al., 2019; Thouless, 1995). Given their need to traverse extensive areas in search of sustenance, conflicts with local communities often arise (King et al., 2011). These interactions foster negative perceptions, with communities advocating for a reduction in elephant numbers. Effectively managing human-elephant conflict (HEC) is paramount for both conservation efforts and fostering community acceptance of protected areas (PAs). Despite Kenya's increasing elephant population since the 1990s, the overlapping of elephant dispersal areas with human settlements has exacerbated human-wildlife conflicts, as also observed in LBL (King et al., 2011)

2.4.2 Population dynamics and fence breakages

Throughout the year, we monitored 6 residential Matriarchal family groups (*Sanaipei* (15), *Saba* (14), *Cointreau* (27), *Namaqua* (30), *Naisula* (27), and *Drachmae* (28), and 19 lone bulls.

A total of 463 elephant fence breakages and 33 crawling incidences were recorded during the year. Compared to 2022, the breakages were significantly lower (243) while the crawling incidences remained almost the same (34). Out of the 463 fence breakage incidences, 80% (n=386) occurred in the exclusions zones, while 20% (n=77) were in the main boundary fence line. The most affected exclusion zones were, *Digby's, Lewa HQ, Junction Tano, and Lewa Safari camp.* Most of these areas were the only ones left with dense woody vegetation during the drought period which may have attracted the elephants as shown below:

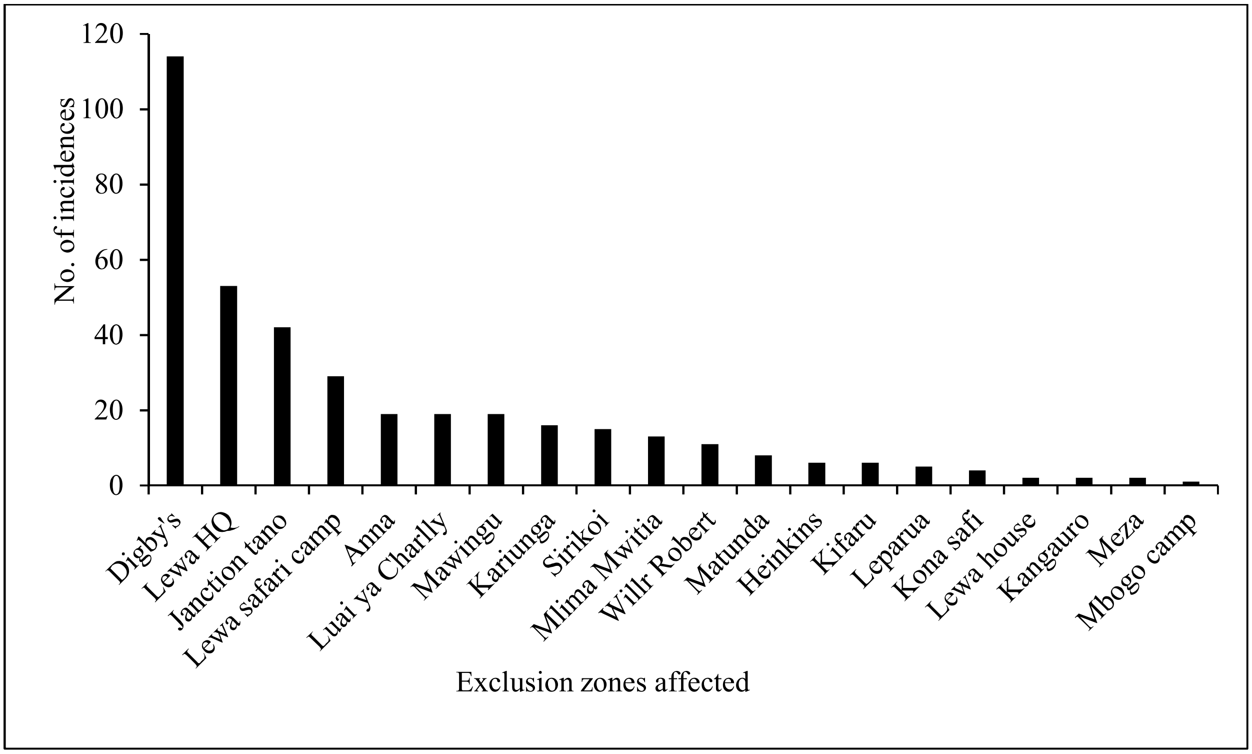


Figure 2.4.1: related incidences of breakages across various locations on the exclusion zones

All 33 crawling incidences occurred in the exclusion zone fences. The primary matriarchal groups involved in these crawling incidents were *Mugumo* (11), *Linnet* (9), *Sanaipei* (15), and Rosy (15). *Mugaa* was the only bull crawling under the exclusion zone fences. The figure below shows the number of fence-crawling incidences per group or individuals as recorded in the year:

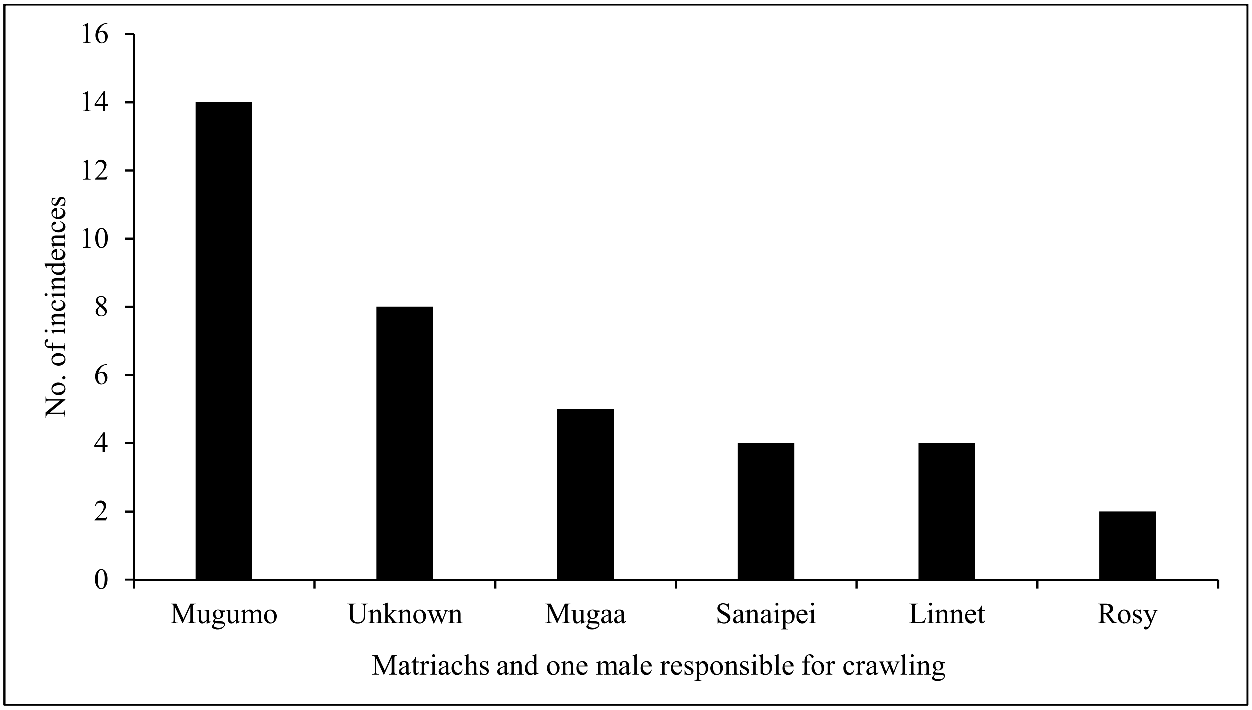


Figure 2.4.2: Graph showing incidences of the male and family groups responsible for crawling under the exclusion zone wires

Compared to previous years, the crawling incidences under the 2-strand wires have reduced as most of the family groups have moved out of the landscape due to the dry conditions. Individuals like *Cointreau* and *Drachmae* went to Mt. Kenya through the southern corridor, while *Kendi's* family group went through the western side of the landscape. The matriarchal family groups namely *Sanaipei, Rosy,* and *Linnet* remained largely in the landscape and continued to access the exclusion zones through crawling.

The most affected boundary fence lines were the western and southern parts of the landscape as shown below:

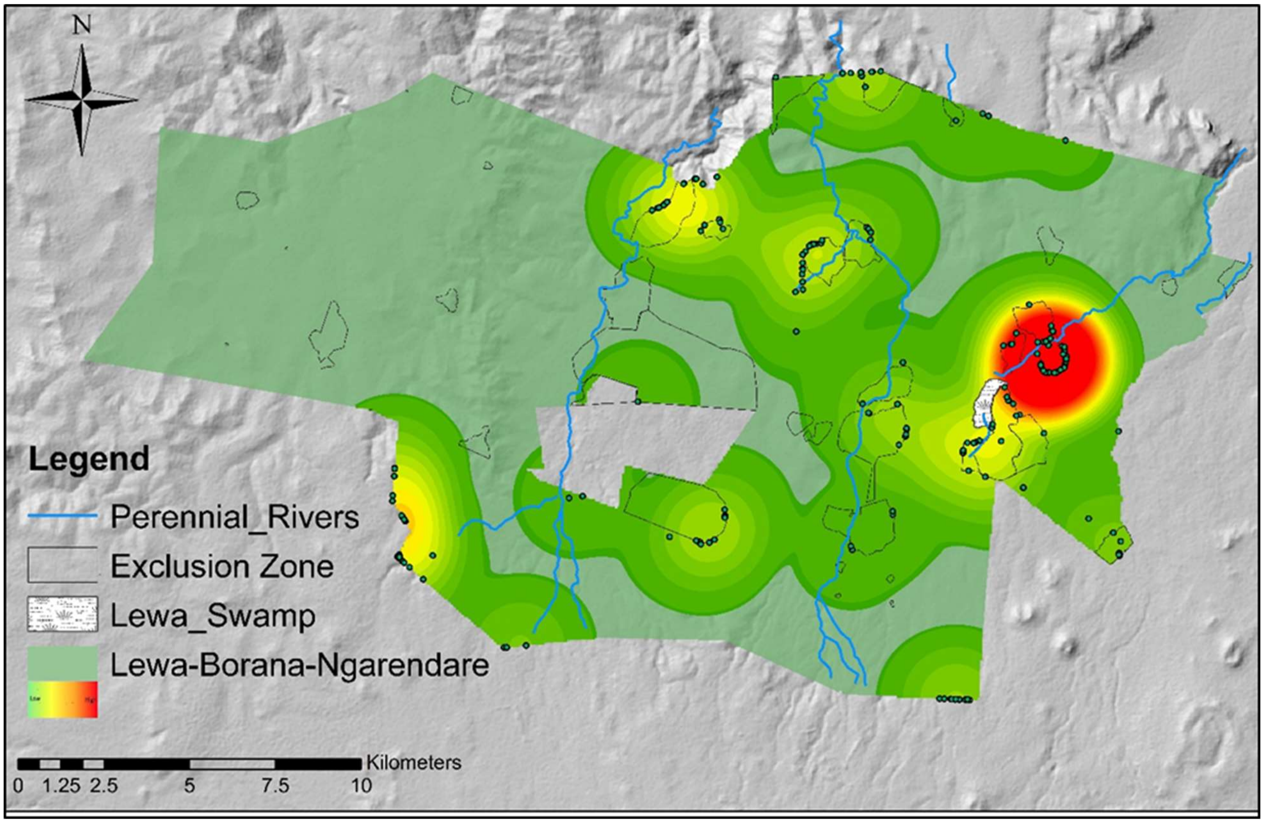


Figure 2.4.3: Heat map showing elephant's breakage incidences on LBL, 2023

The data collected throughout the year also showed the most affected boundary fence lines and breaking hotspots as below:

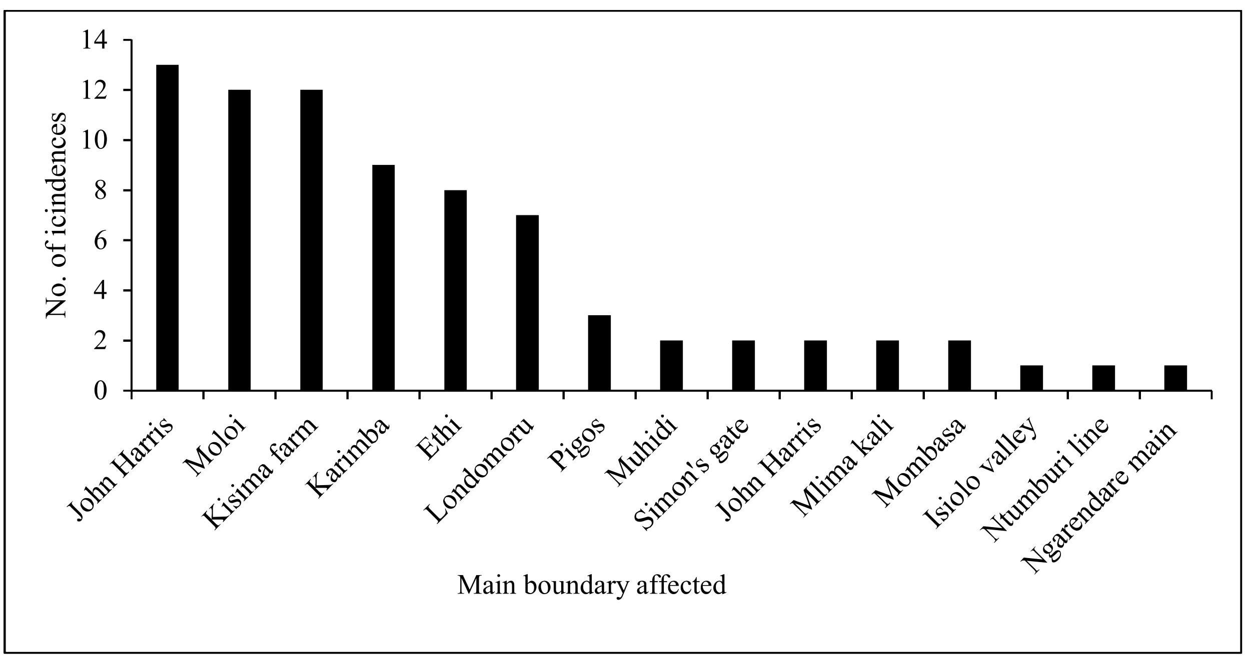


Figure 2.4.4: Graph showing the incidences of hotspots on the main boundary fence line

Out of 19 resident bulls, *One Right Tusker, Sahara, Mjasiri, Tyson, Mukume,* and *Odongo* were identified as the persistent fence breakers both on the main boundary and exclusion zone fence lines on the landscape (Figure 2.4.5). Even though *Mjasiri, Tyson, Monk, Keke, and Melo* have had their tusks trimmed in the past, they have learned new ways of breaking the fences through snapping wires using their shortened tusks, and trunks to pullout the post and stepping on the posts.

2.4.3 Conclusion and Recommendations

The Human-Wildlife Conflicts Response Team (HWCRT) has played a crucial role in addressing HEC challenges. However, to enhance its effectiveness, additional manpower is needed.

Given the increasing incidents of HEC around Ethi and Karimba villages, upgrading the existing fence lines to predator-proof status equipped with butterfly stingers is urgently required. Moreover, incorporating new technologies such as Google Nest and drones for proactive elephant monitoring and surveillance is essential.

To improve data management, sourcing a compatible elephant database is crucial. This will facilitate efficient demographic information for both resident and non-resident elephants in the LBL.

2.5 Avifauna Monitoring

2.5.1 Introduction

Birds in general are important for numerous ecosystem services that sustain human life (Sekercioglu et al., 2016). Some of these services include pest control, seed dispersal, pollination, nutrient cycling, soil formation, and ecotourism (Deng and Yimam, 2020). They are threatened by various environmental and human factors (Tabur and Ayvaz, 2010). Many countries have been monitoring birds to acquire long-term data that enable evaluation of their conservation efforts (Sekercioglu et al., 2016; Schmeller et al., 2012).

LBL has diverse habitats that host different avian communities. These habitats offer a favourable stop-over and wintering site for large populations of migratory birds from Europe and northern Asia. It also offers roosting, breeding, and foraging areas for resident birds. We focus on keeping an updated bird checklist, conducting monthly waterbirds and raptors surveys, and updating the checklist of our contiguous areas like the neighbouring Il Ngwesi Community Conservancy. Through the surveys, we can monitor the population dynamics and breeding status of species of conservation concern.

2.5.2 LBL Birds' checklist

The LBL birds' checklist stands at 83 families comprising 492 species with some of them in the IUCN Red List as she summarized in the table below:

Table 2.5.1: 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	473
Grand Total	**492**

This represents over 43% of the 1,152 total species found in Kenya (Lepage, 2023). We collaborated with the local birder's club to take photographs for evidence files of the bird species in the landscape. Currently, the evidence files stand at 79%.

We also participated in the bi-annual global e-bird count in celebrating World's Migratory Birds' Day. The first count in May recorded 176 and 89 species on Lewa and Borana Conservancies respectively. The Lewa and Borana Wildlife Conservancies were ranked the 3rd and 11th birding hotspots on the Kenyan birding hotspot list respectively (eBird, 2023a). The second count in October recorded 201 and 165 species on both respectively.

2.5.3 Waterbirds survey

Studies have shown that waterbirds are key bioindicators of wetlands conditions on both local and regional spatial scales (Amat and Green, 2010). We monitor waterbirds to provide information for early warnings of changes that could negatively affect the wildlife species or ecosystems (Amat and Green, 2010).

The monthly survey recorded an average of 1,249±262 individuals of 57 distinct species. November had the highest count of 3,627 individuals of 25 species while October had the lowest count of 670 individuals of 31 species. [1]Simpson's Diversity Index was 0.8057, indicating a high diversity of waterbirds on LBL (Okpiliya, 2012). We compared the dry and wet months data and the results indicate that wet months (n=7,773) had more bird species compared to dry months (n=7,217) ($\chi^2 = 20.623$, df = 1, p = 0.001) as shown in the figure below:

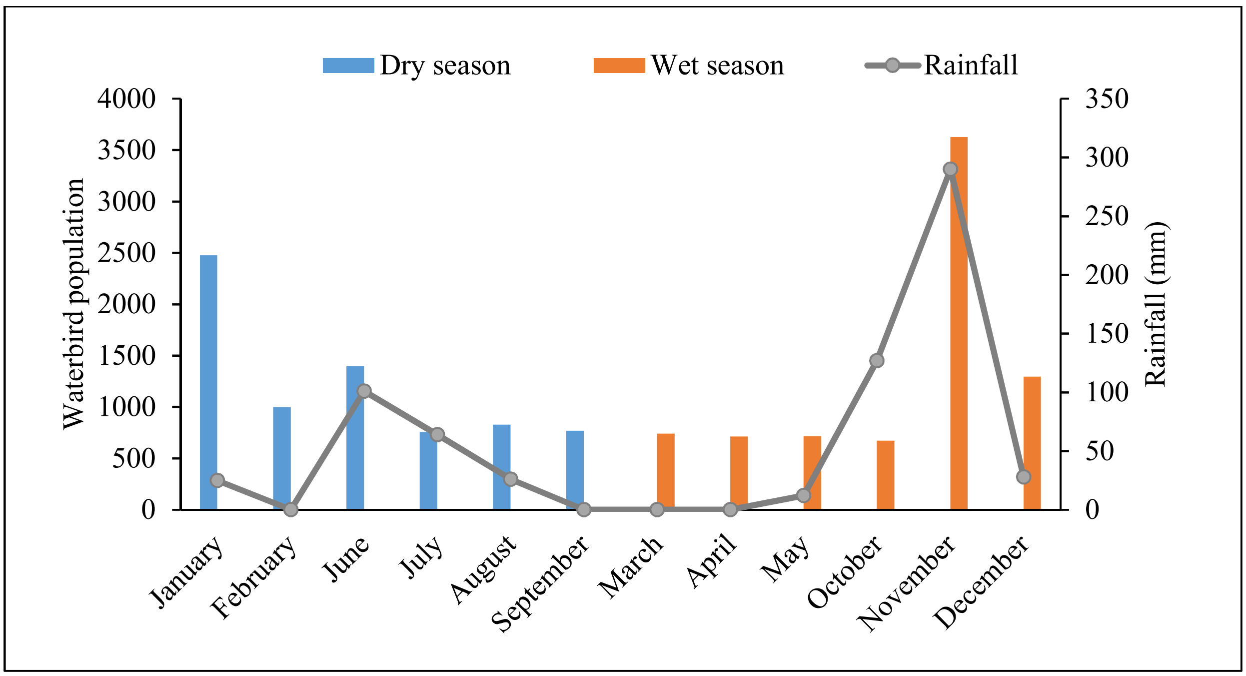


Figure 2.5.1: Seasonal waterbird population on LBL

We also participated in the National Waterfowl Census led by the National Museums of Kenya (NMK) in January and recorded a total of 2,476 individuals of 30 different species of waterbirds.

[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.

The national censuses aim to monitor the numerical trends of waterbird populations, describing changes in numbers and distribution of the populations, and providing information to assist in their protection and management (Wetlands International, 2010).

2.5.4 Grey Crowned Crane Surveys

The Grey Crowned Crane (GCC) is classified as Endangered in the IUCN Red List of Threatened Species (IUCN, 2023). The population has been decreasing globally which is attributed to habitat loss, fragmentation, hunting and removal of eggs from the wild for food (IUCN, 2023). GCC is therefore a species of critical conservation concern on LBL as well as at the National level.

The monthly GCC survey conducted recorded an average of 41±7 individuals. The highest individual population count was recorded in June (86), January (78), and February (68) as shown below:

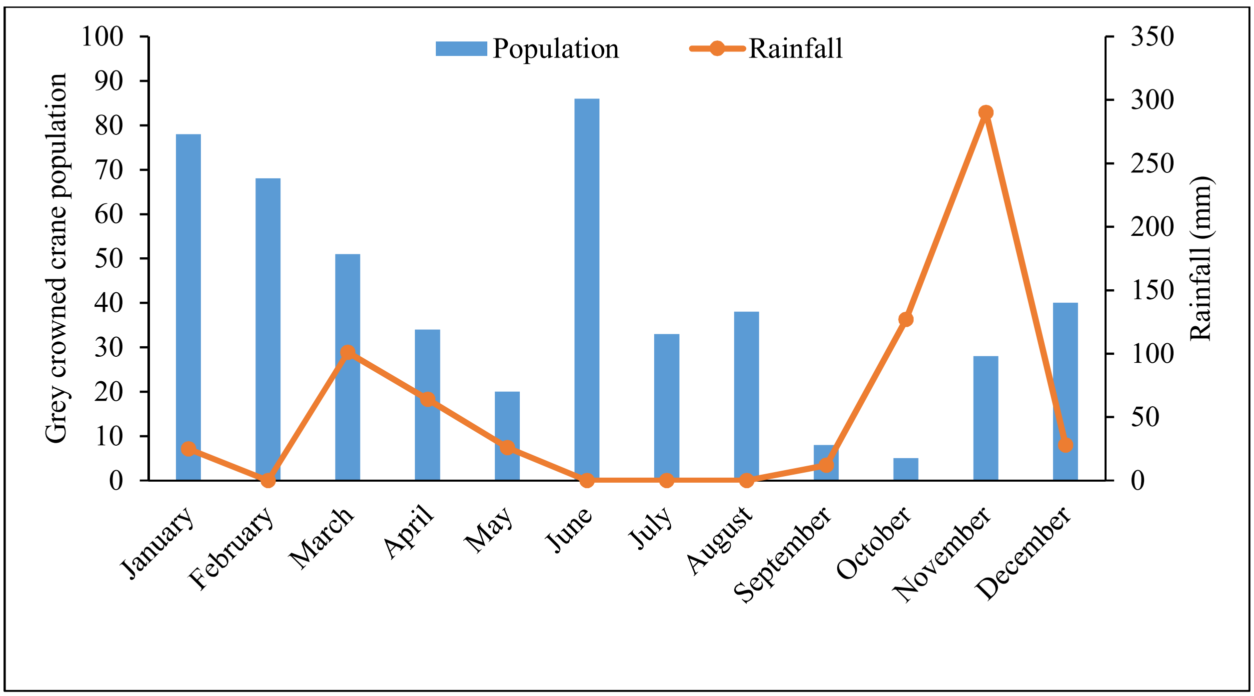


Figure 2.5.2: Total Grey Crowned Crane population

A total of 6 chicks were recorded during the period. The dry period had a significantly higher number (311 individuals) compared to the wet period (178 individuals) ($\chi^2 = 36.174$, df = 1, p = 0.001). GCC makes local and seasonal movements in response to rainfall, food availability, and nesting opportunities (Wamiti et al., 2020). Access to water might have been attributed to the high GCC count during the dry months as most flocks were recorded around the dams.

2.5.5 Raptors survey

Raptors serve as vital indicator species, playing a crucial ecological role in controlling populations of rodents and other small mammals (HawkWatch International, 2023). However, they face global threats from human activities, with populations of several species, such as vultures, experiencing rapid declines (McClure et al., 2018). The primary objective of monitoring raptors is to identify species that may require conservation action and to detect changes within populations indicative of habitat quality deterioration (Hardey et al., 2009; Knight, 2010).

The monthly raptor survey conducted on LBL recorded an average of 88±33 individuals belonging to 31 species. Notably, the months of July (406), August (209), and November (105) exhibited the highest individual counts, while May (15), September (17), and October (17) recorded the lowest counts as shown in Figure 2.5.3:

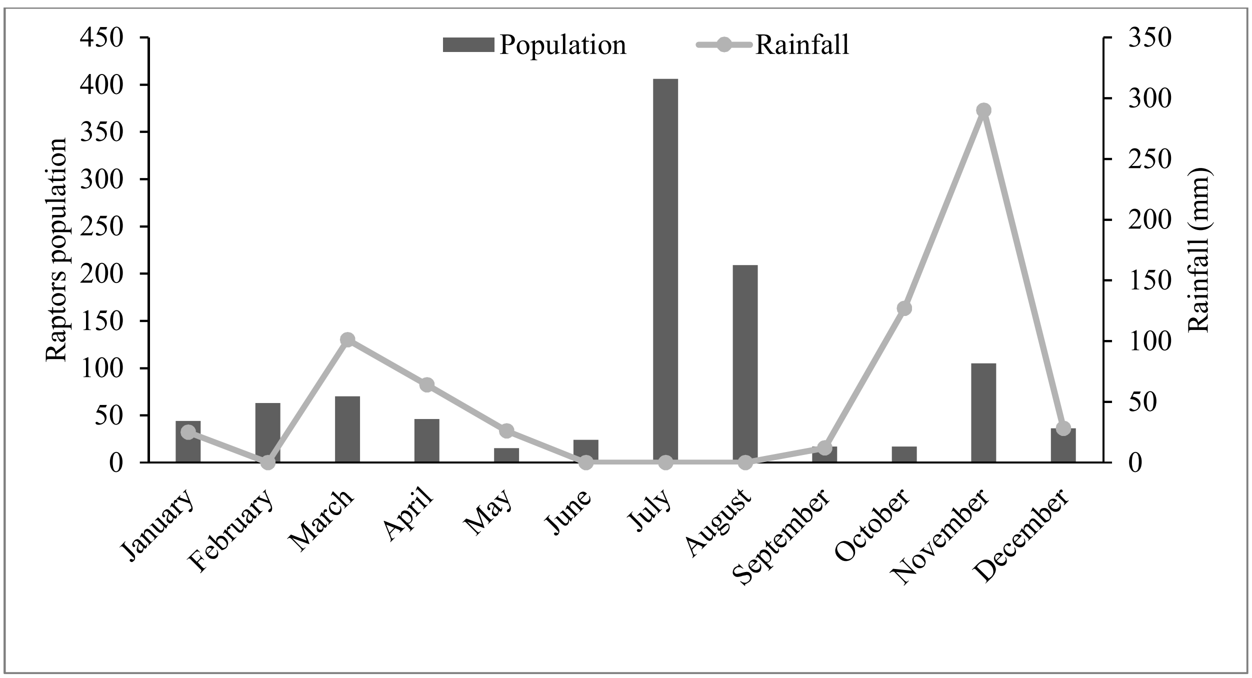


Figure 2.5.3: Monthly raptor population

Diversity was calculated using Simpson's Index which indicated a higher diversity of raptors on LBL (D = 0.8126). The raptor count of 763 individuals during the dry period was significantly higher than the 289 recorded during the wet period (χ^2 = 213.57, df = 1, p = 0.0001). There has been a significant increase in the raptor population on LBL for the last five years (χ^2 = 862.24, df = 4, p = 0.001) as shown in the figure below:

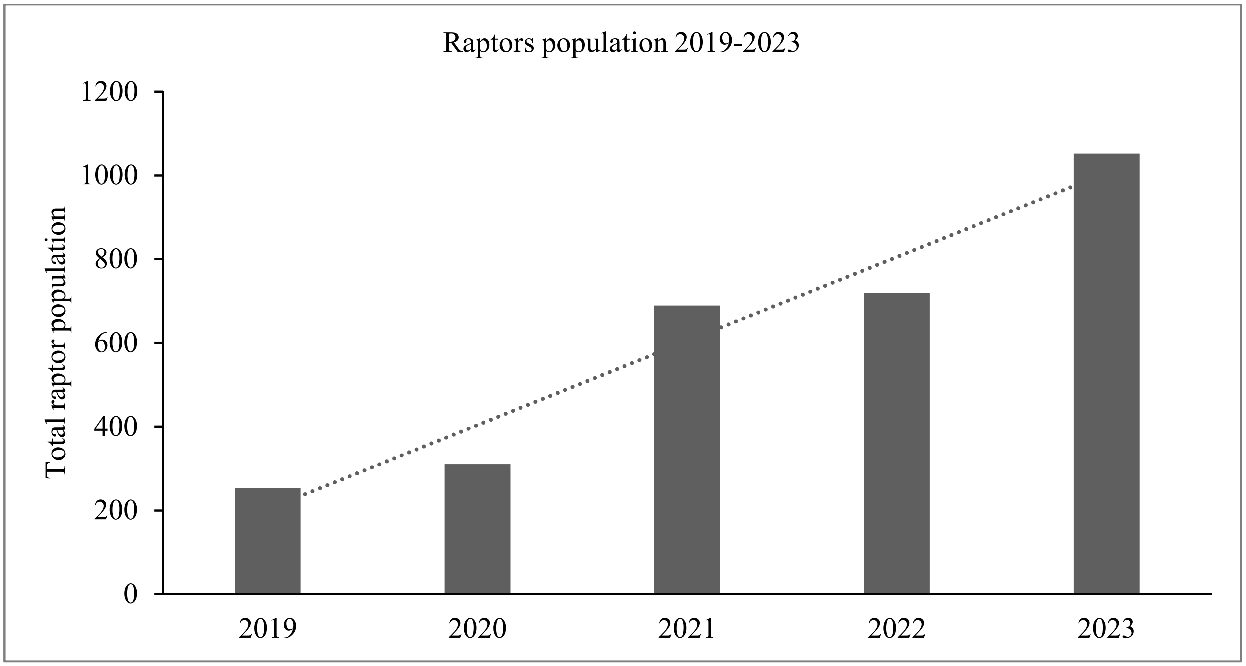


Figure 2.5.4: LBL Raptors population trend for the last five years

The increase can be attributed to the rise in wildlife mortalities due to prolonged episodes of drought. We mapped their distribution and monitored active nests which included 3 for Tawny Eagle (all recording successful fledging), 2 for Martial Eagle (successful breeding), 1 for Bateleur (successful breeding) and 1 for Secretary bird (status uncertain) as shown in the figures below:

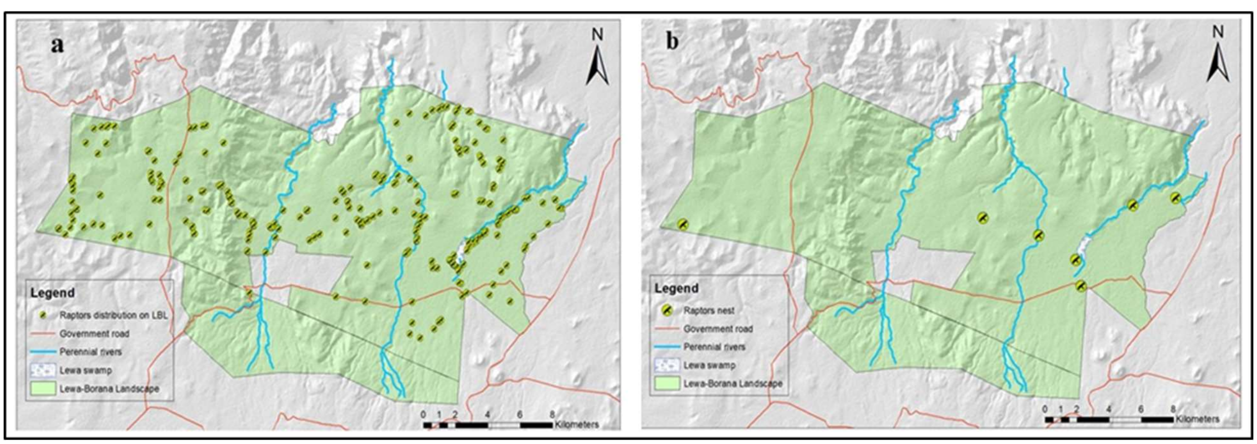


Figure 2.5.5: a) Raptors distribution on LBL; **b)** Location of nesting raptors on LBL

2.5.6 Il Ngwesi Bird Survey

The surveys conducted at Il Ngwesi Community Conservancy are aimed at updating the checklist of the birds in the conservancy and the contiguous areas. We surveyed for the wet season and recorded 120 different bird species. An active nest for Tawny eagle with one chick and an active roosting site for vultures were identified. The preliminary checklist for Il Ngwesi Conservancy stands at 235 species with 90% photo evidence. We expect an increase in the species numbers as we conduct more surveys in the conservancy.

2.5.7 Conclusion and Recommendations

Avifauna surveys have indicated a huge diversity on LBL. There is a notable increase in waterbirds and raptors as well as the raptors' nesting activities and breeding success. We recommend the use of satellite monitoring of the endangered GCC to understand their spatio-temporal movements and seasonal feeding grounds.

We also recommend post-fledging monitoring of raptors to establish their home range and scale up raptor conservation efforts on the landscape. We also recommend fitting GPS and GSM backpack transmitters on selected groups of critically endangered vultures to determine their home ranges, foraging areas, breeding sites, roosting sites, and threats facing their conservation in the landscape information will help understand the raptors' ecology and inform targeted conservation measures.

Regular surveys of birds at Il Ngwesi Community Conservancy should continue to keep an updated bird checklist for the conservancy. The surveys will also help in identifying the roosting and breeding sites of raptors at Il Ngwesi.

2.6 Herpetofauna Monitoring

2.6.1 Introduction

Herpetofauna on LBL encompasses several reptile and amphibian species. This group includes snakes, lizards, turtles, frogs, toads, and salamanders. They are also globally recognised as 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 distribution, they are among the most threatened vertebrates globally due to the pet trade, habitat loss and degradation, pollution, and climate change (Tolley et al., 2016).

2.6.2 Pancake tortoises (*Malacochersus tornieri*) and terrapins (*Pelomedusa neumanni*)

We began surveying in 2019 and initially documented seven Pancake tortoises (PT) and terrapins (TR) confirming their presence on LBL. The discovery of the Pancake tortoise on LBL and being a critically endangered species (Mwaya et al., 2019) prompted the need for a comprehensive survey. We partnered with the National Museums of Kenya (NMK), Kenya Wildlife Service (KWS), Lewa Wildlife Conservancy (LWC), Northern Rangelands Trust (NRT), and Turtle Survival Alliance (TSA) to undertake a comprehensive survey on LBL and extend to the contiguous areas within the NRT landscape. The survey aimed to identify the potential sites for effective population management and protection within the region. For the last three years, the survey has found the following numbers and distribution of these species as shown in Table 2.6.1:

Table 2.6.1: Population dynamics and distribution of Pancakee tortoises and terrapins

Area	PT A M	PT A F	PT SA M	PT SA F	PT HA UNK	PT Total by Area	PT RP	PT MO	TR A M	TR A F	TR SA M	TR SA F	TR HA UNK	TR Total by Area	TR Recap	TR MO
LBL	30	31	6	2	6	75	19	2	6	6	3	1	33	49	3	3
Leparua	14	30	1	0	0	45	6	0	0	0	0	0	0	0	0	0
Lekurruki	20	27	0	1	4	52	3	0	0	0	0	0	0	0	0	0
Nasuulu	8	15	1	2	4	30	0	0	0	0	0	0	0	0	0	0
Kalama	7	14	1	0	1	23	3	1	0	0	0	0	0	0	0	0
Il-Ngwesi	6	6	0	3	5	20	0	0	0	0	0	0	0	0	0	0
Leparua(outside)	14	17	2	2	2	37	0	0	0	0	0	0	0	0	0	0
Westgate	2	3	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Total by Category	**101**	**143**	**11**	**10**	**22**	**287**	**31**	**3**	**6**	**6**	**3**	**1**	**33**	**49**	**3**	**3**

Key: Pancake tortoises (PT); Terrapins (TR); Male (M); Female (F); Sex unknown (UNK); Hatchling (HA); Sub adult (SA); Adult (A); Mortalities (MO), Recaptures (RP).

Overall, this multi-faceted approach integrates scientific research, community engagement, and capacity building to promote the conservation of Pancake tortoises and their ecosystems within the LBL and the neighbouring conservancies. So far, the following achievements and knowledge transfers have been made:

2.6.2 (i) Identification Methods: Various methods such as scute notching, PIT tagging, and painting were used for individual recognition of Pancake tortoises. This allows researchers and conservationists to track and monitor the movements and populations of these tortoises over time.

2.6.2 (ii) Biological Data Collection: Data on various biological parameters including weight, straight carapace length (SCL), straight plastron length (SPL), body width, and depth were collected. This information is crucial for understanding the health and demographics of the tortoise populations.

2.6.2 (iii) Genetic Research: Cloacal swabs were collected for potential genetic research in the future. Genetic studies can provide insights into the genetic diversity, population structure, and evolutionary history of Pancake tortoises, which are essential for effective conservation management.

2.6.2 (iii) Awareness Forums: Awareness forums were conducted within the NRT community conservancies to educate local communities about the threats facing Pancake tortoises, including declining populations and habitat destruction. These forums also aimed to promote conservation efforts and foster community involvement in protecting the species and its habitats.

2.6.2 (iv) Ranger Training: Four rangers per conservancy were trained extensively in search, retrieval, recording, and marking systems for Pancake tortoises. This training equips the rangers with the skills and knowledge needed to collect data on population size, range, and dispersal patterns within their respective conservancies. By involving local rangers in monitoring efforts, the conservation initiative enhances community participation and stewardship of Pancake tortoises and their habitats.

2.6.3 Conclusion and Recommendation

Herpetofauna awareness in the contiguous areas of LBL played a crucial role in understanding and protecting this unique species, especially within the surrounding community conservancies. Educating the communities on the importance of pancake tortoise conservation was undeniably instrumental in fostering a sense of responsibility for their habitats, ultimately contributing to their long-term preservation.

We strongly recommend providing rangers with appropriate equipment such as Global Positioning System (GPS) devices, spotlights, and a tortoise marking system, to enable their effective monitoring within their natural habitat. This will facilitate accurate recording of the population sizes and distribution patterns, thereby offering valuable insights into the species' ecology and conservation needs.

2.7 Rangeland Monitoring

Rangelands, which cover nearly half of the landmass, support wildlife and livestock, in addition to providing other ecological benefits. Rangeland management practices are crucial, as they are sensitive to human activities. Excessive grazing and invasive species pose considerable threats to rangelands; therefore, their monitoring is key to implementing sound management interventions where and when necessary. Rangelands are subject to degradation, soil erosion, and biodiversity loss when negative factors such as climate change, human activities, or wildlife activities are not well monitored and mitigated (Mashizi et al., 2020). The LBL has been monitoring various aspects of rangelands to ensure that sound data is available to guide management decisions.

2.7.1 Grass assessment

Grass assessment was done on the 34 pre-determined monitoring plots within the four management units (F – Forest, RV – Riverine, R – Rocky, and P – Plains) during the year. We collected data on grass biomass, species diversity, and cover. The grass biomass was estimated by dropping a calibrated 1.5kg disc pasture meter (DPM) and recording the mean settling height (in Cm) of the disc. The mean height was converted to biomass estimates (in Kg/Ha) using a modelled regression equation developed by Botha, 1999. Additionally, grass and forbs species composition were determined using a pin hit placed at a 1-meter interval along a 100m transect.

Results indicate a statistical significance ($F_{(1, 406)} = 5.598$, $p = 0.0184$) in mean biomass across the years 2011-2023 (Figure 2.7.1). The overall drop in biomass is attributable to the low and erratic rains in the past.

Notably, there has been a significant increase in mean biomass in 2023 (3875 kg/ha) compared to the previous year 2022 (2840 kg/ha) ($t = -5.0082$, $df = 59.651$, p-value = 0.005). This increase in biomass correlates with the substantial rainfall of 189mm received by midyear, which may have triggered the growth of annual and perennial grasses and herbaceous plants. Increases may be recorded in the coming year because of the heavy rains received in the fourth quarter of the year.

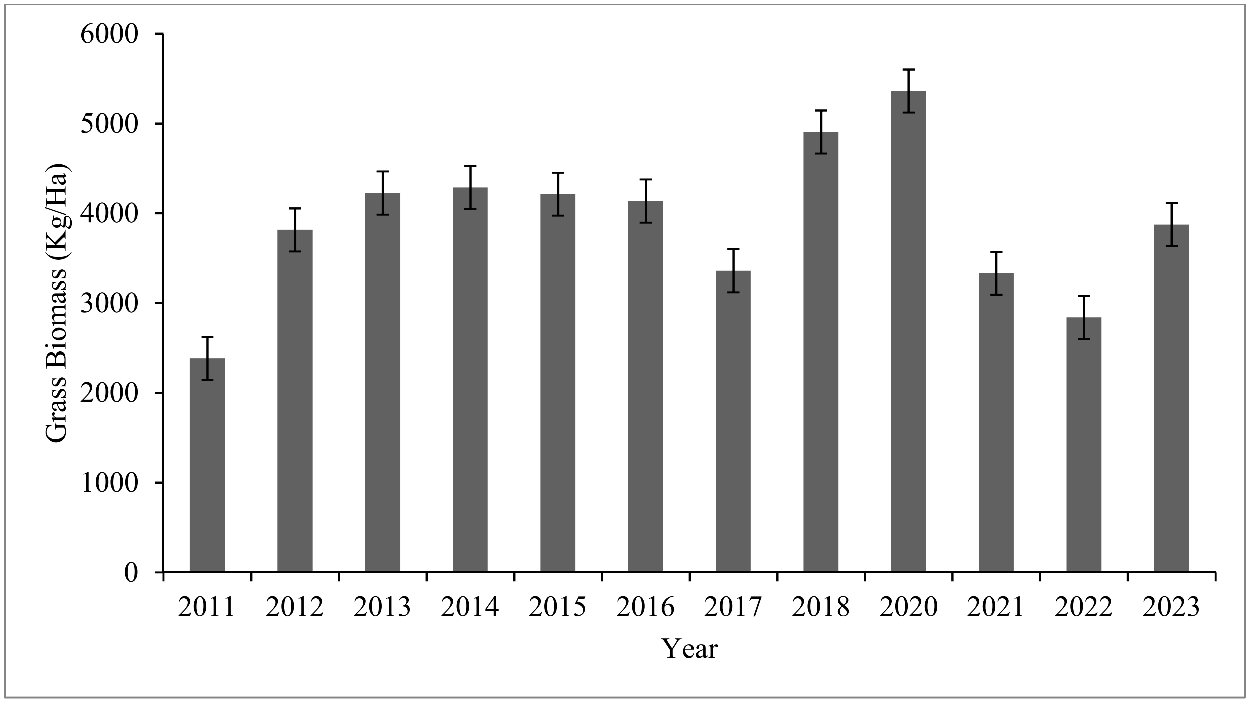


Figure 2.7.1: Long-term annual fluctuations in average grass biomass across the years

There was a significant variation in species diversity across the years 2011 – 2023 ($F_{(1, 406)} = 92.42$, $p = 0.0001$) (Figure 2.7.2). Species diversity is highly influenced by rainfall which might have triggered the recent increase. There was also a significant difference in species diversity between the year 2022 (0.53) and 2023 (1.52) ($t = -7.8393$, $df = 50.406$, $p=0.005$). The current year had slightly higher diversity due to higher rainfall, compared to the last two years in the same period.

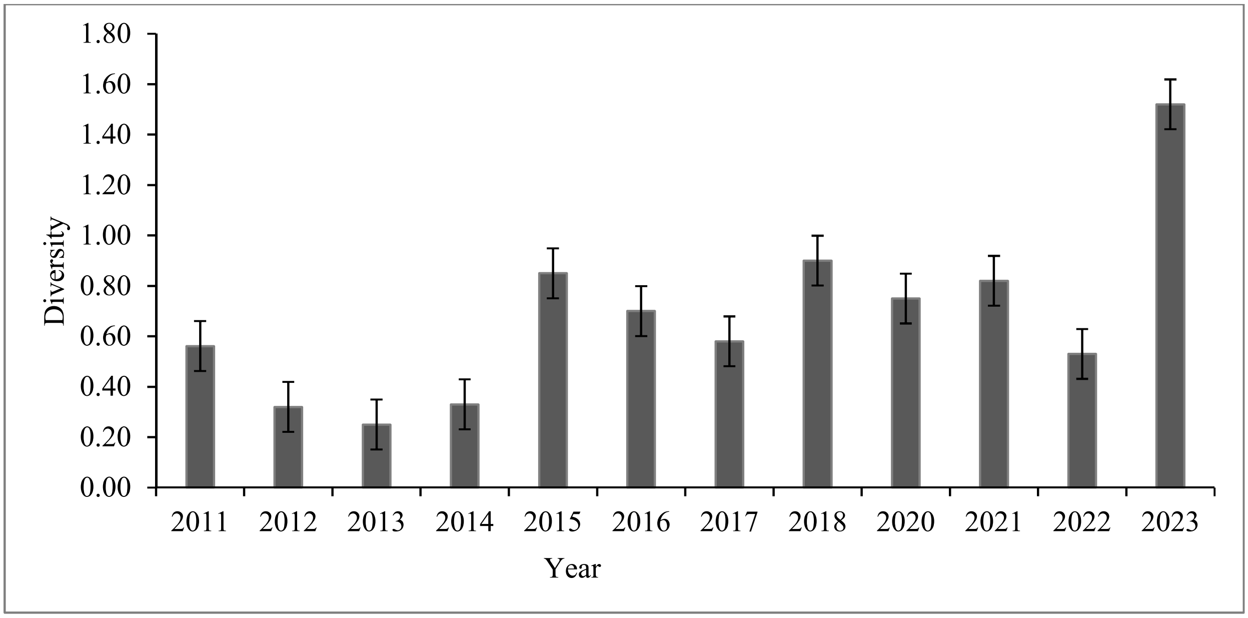


Figure 2.7.2: Annual fluctuations in average species diversity across various long-term sampling plots

Kruskal-Wallis H test indicates a statistically significant difference in grass cover over the other years, ($\chi2$ = 64.531, df = 11, p-value =0.001). There was an insignificant change in grass cover between the year 2022 (63%) and the year 2023 (60%) (t= 0.67709, df = 58, p = 0.501). Rainfall might have played a critical role in the overall decline in grass cover especially for the last two years when rainfall was significantly lower than the long-term mean by the time the data was collected as shown in the figure below:

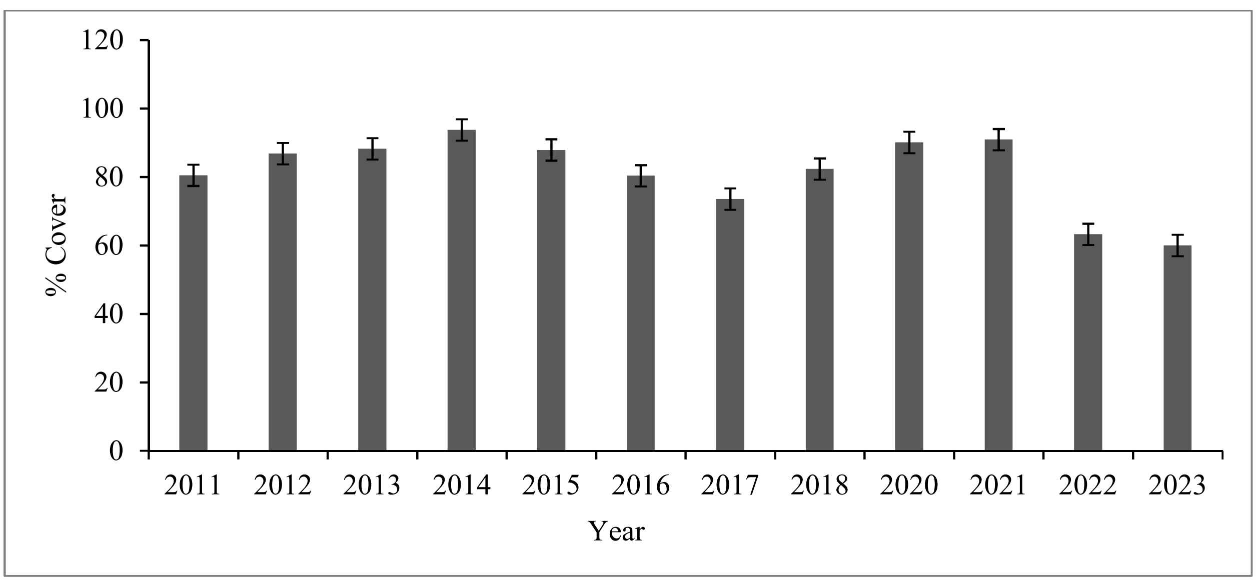


Figure 2.7.3: Long-term annual fluctuations in average plant cover across the sampling plots

2.7.3 Woody vegetation

Most wildlife on the landscape depends on the woody vegetation for shelter, forage, shade and breeding sites. Woody vegetation also contributes to ecosystem health, creating essential microhabitats for biodiversity (Mashapa et al., 2021). Continuous monitoring since 1995 reveals dynamic changes most likely influenced by browsing pressure and weather shifts. Documenting these changes in the landscape over time is vital for developing a woody vegetation recovery plan.

We conducted quantitative sampling of woody vegetation on 34 designated monitoring plots covering the four management units (F – Forest, RV – Riverine, R – Rocky, and P – Plains). The results showed remarkable changes in vegetation composition due to browsing pressure and past weather regimes on the landscape. Elephants were identified as the primary wildlife species causing substantial damage to the vegetation, as depicted in Figure 2.7.4:

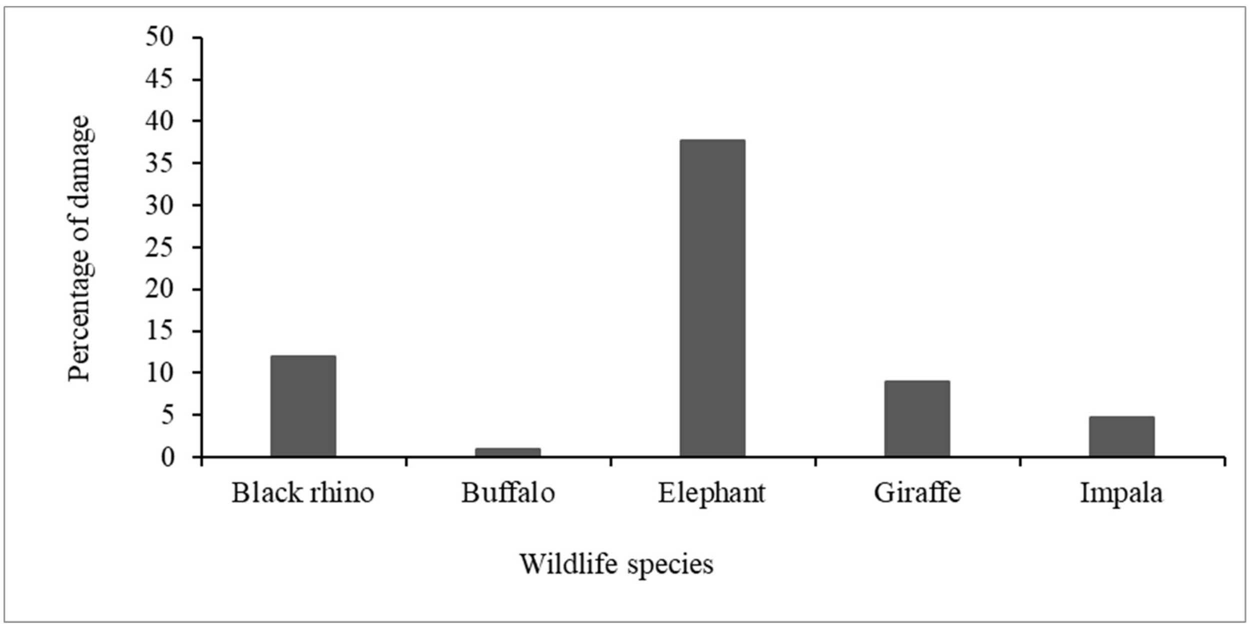
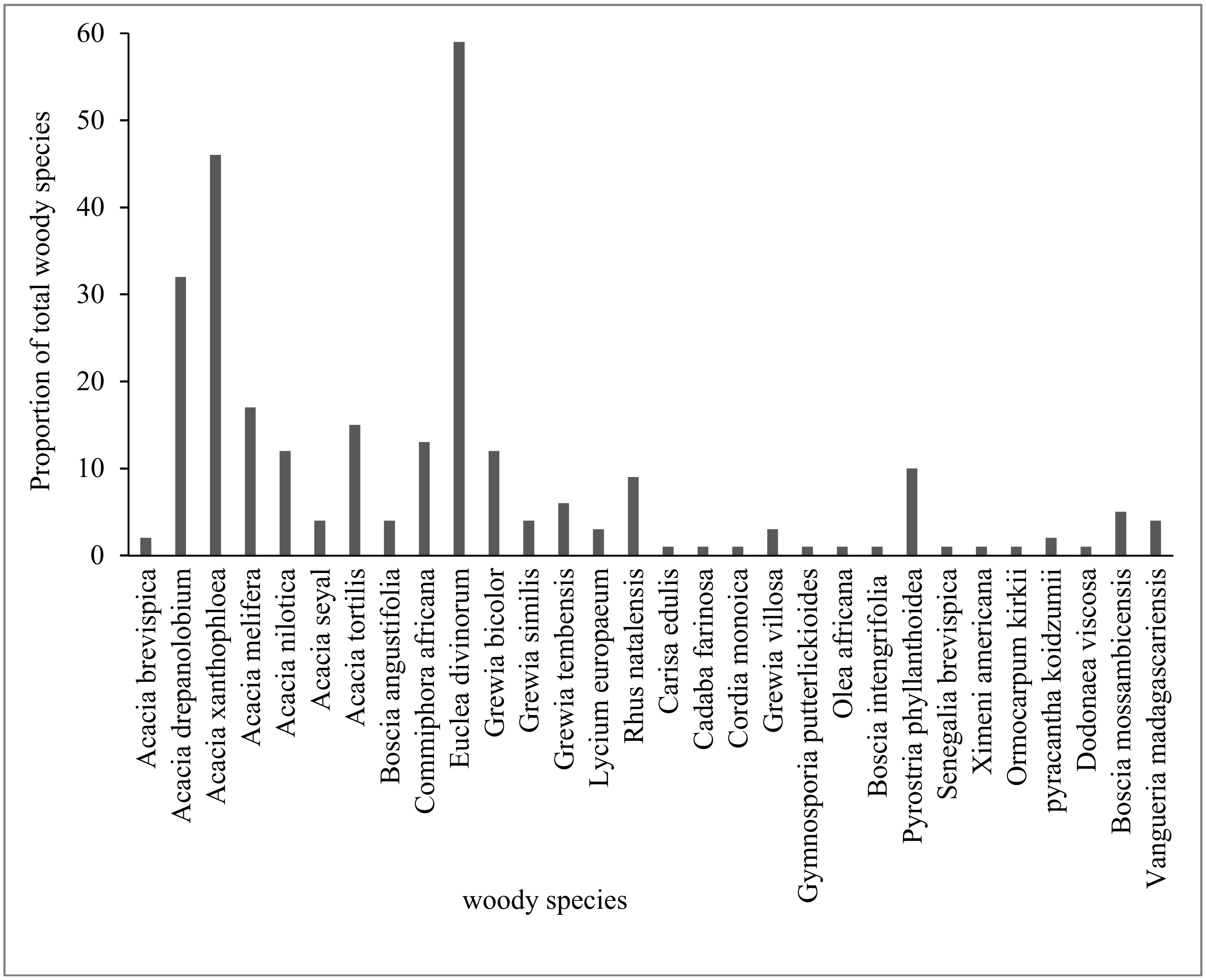


Figure 2.7.4: Cause of woody vegetation damage by wildlife species

Acacia mellifera, Acacia xanthophloea, Acacia drepanolobium, and *Euclea divinorum* were the most abundant species encountered during sampling, with *A. drepanolobium*, *A. xanthophloea*, and *E. divinorum* experiencing the highest percentage of damage perhaps due to their dominance in the landscape as shown in the figure below:



Fi**gure 2.7.5:** Proportion of damaged individuals encountered in sampling plots

Intense browsing and debarking by elephants have reduced tree growth, thereby increasing their susceptibility to drought and secondary infections (Qolli, 2011). We have recorded an increase in tree height in the landscape since 2019 ($\chi2 = 602300$, df = 1, p=0.001) (Figure 2.7.6). This might be attributed to the marked increase in regeneration inside the exclusion zones as seen below:

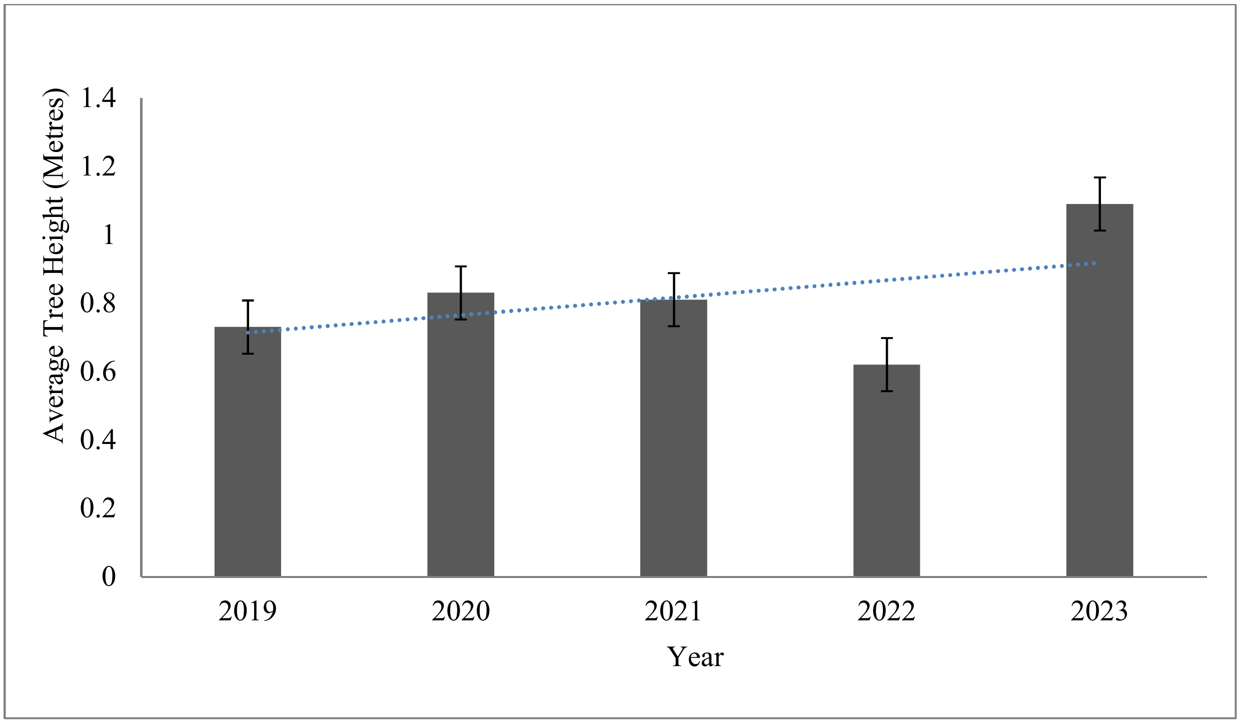


Figure 2.7.6: Average tree height on the landscape in the sampling plots

2.7.4 Results from Normalized Difference Vegetation Index (NDVI)

The NDVI is a widely used metric for quantifying the health and density of vegetation using satellite imagery data. It measures the difference between near-infrared light (NIR), which vegetation strongly reflects, and red (R) light which vegetation absorbs (Lemenkova, 2015). The NDVI ranges between -1 and +1. The higher the NDVI value, the denser and healthier the vegetation. We downloaded Landsat 8 imageries from the United States Geological Survey (USGS) Earth Explorer platform and produced NDVI maps using ArcMap 10.8.2 to compare the level of greenness between 2023 and 2022. Even though some months had prominent cloud cover obstructing visibility for comparison, the year 2023 was more productive compared to the year 2022, which can be attributed to the high rainfall received from the middle of 2023 as seen in Figure 2.7.7:

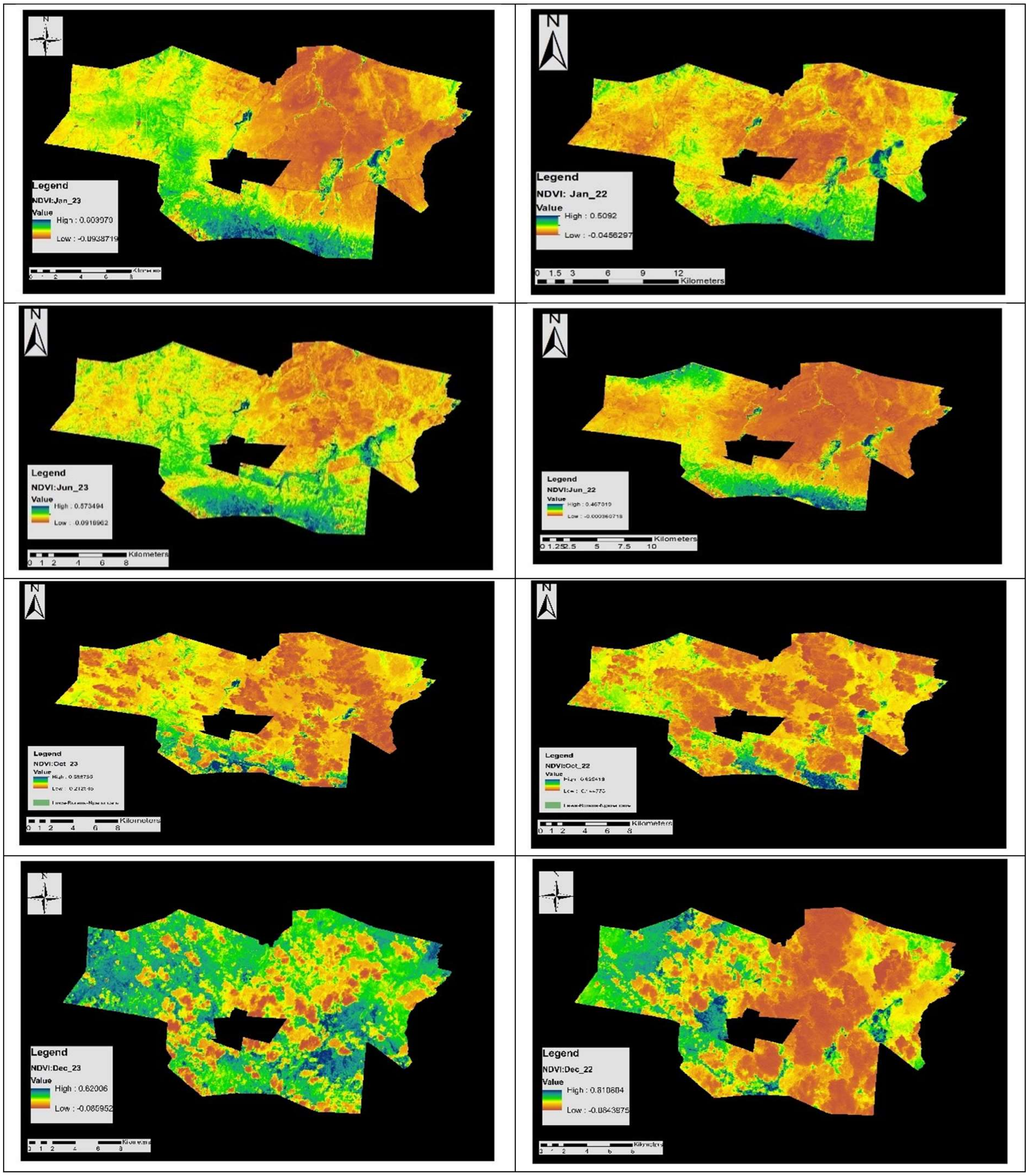


Figure 2.7.7: Comparison of NDVI for the Lewa - Borana Landscape in the years 2022 and 2023

2.7.5 Exclusion zones

Over time, changes in weather, mainly rainfall, and browsing pressure from herbivores cause major changes in vegetation components. To facilitate ecosystem rehabilitation, enhance biodiversity, and promote vegetation regeneration, we have fenced off 42 enclosures within the LBL.

Out of the 42 this year, we have extended the *Kangauru* and *Sirikoi* zones. We collected initial baseline data to observe changes in plant species diversity and cover. In the coming seasons, we will continue monitoring these exclusion zones to assess the progress of vegetation recovery. Figure 2.7.8a-d shows some positive responses of vegetation to enclosures established in 2018. Airstrip plot 2 was accessed by wildlife suppressing tree growth.

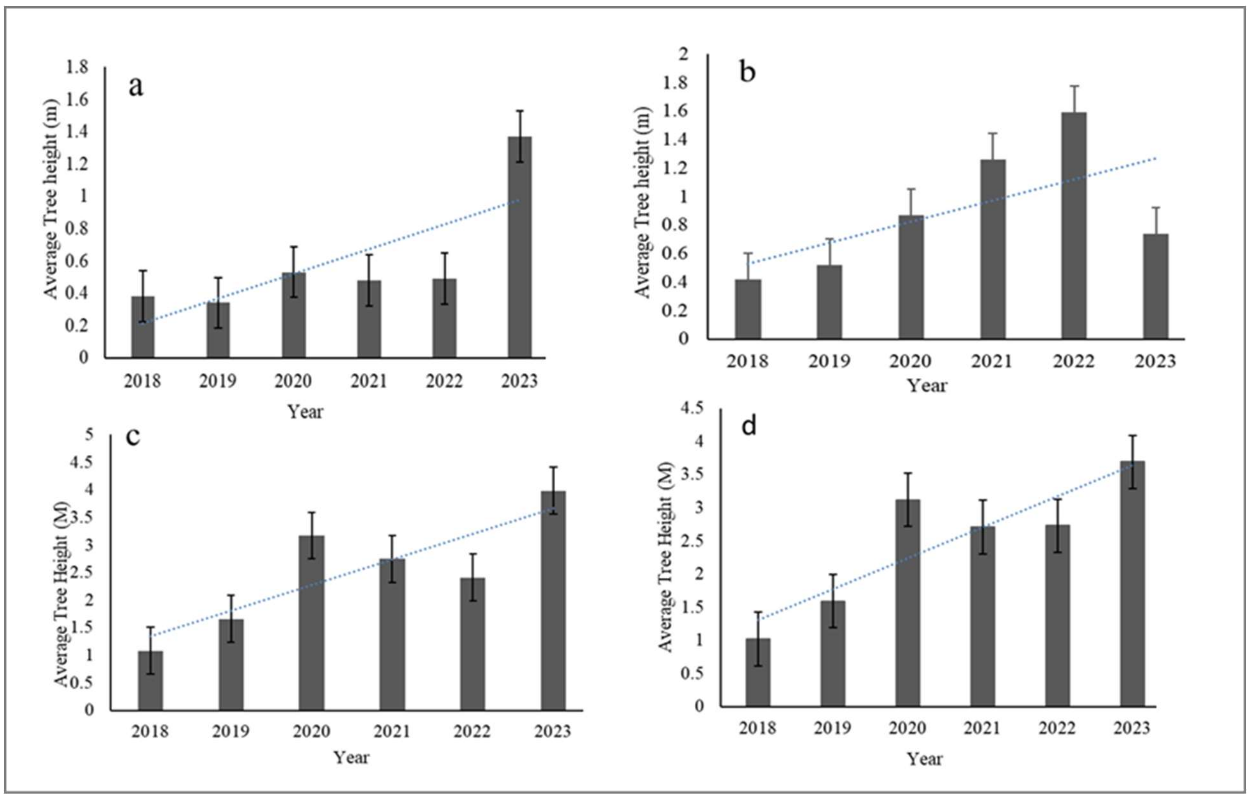


Figure 2.7.8: a) Average tree height in Airstrip plot 1**; b)** Average tree height in Airstrip plot 2**; c)** Average tree height in plantation plot 1**; d)** Average tree height in plantation plot 2

2.7.6 Removal of invasive and alien plant species

Alien plant species are those introduced to an environment outside their native range where they exhibit aggressive growth patterns, enabling them to outcompete and negatively impact the local flora. When these plants become invasive, they can disrupt local ecosystems by displacing native species, altering habitat structures, and affecting ecosystem processes (Bartz et al., 2019).

Although relatively limited and predominantly confined to disturbed areas, we have observed the presence of invasive species, including two cactus species (*Opuntia exaltata* and *O. vulgaris*), two thorn apple species (*Datura stramonium* and *D. ferox*), *Prosopis juliflora*, *Argemone mexicana*, and *Lantana camara*. Among the documented species, we successfully prevented the spread of *D.stramonium*, *A. mexicana*, and *D. ferox* through uprooting and burying. Moving forward, we shall monitor the trend of each of the species and apply the necessary control measures while utilising EarthRanger (ER), GIS and other applicable software for effective monitoring and management. The figure below shows the sites where these species were identified and removed:

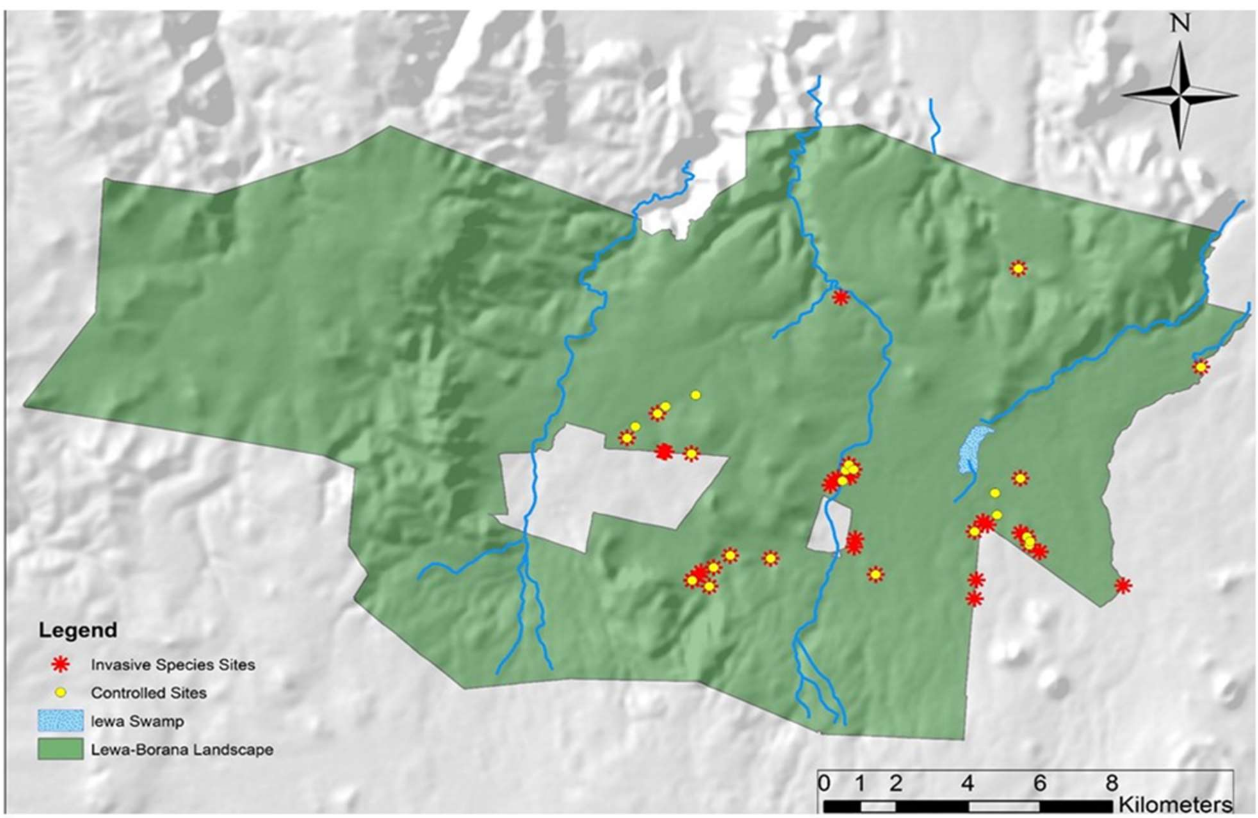


Figure 2.7.8: Spread and eradication of invasive/alien species

2.7.7 Lewa Swamp Monitoring

The Lewa swamp has served as a sustainable source of sedge for roofing the Conservancy houses. To ensure the responsible use of this resource, we initiated a monitoring program to assess the rate of recovery following the harvest. In the last quarter, a total of 168,700 bundles were harvested, with each bundle consisting of 50 sedge stems within the designated block, as detailed in Figure 2.7.9.

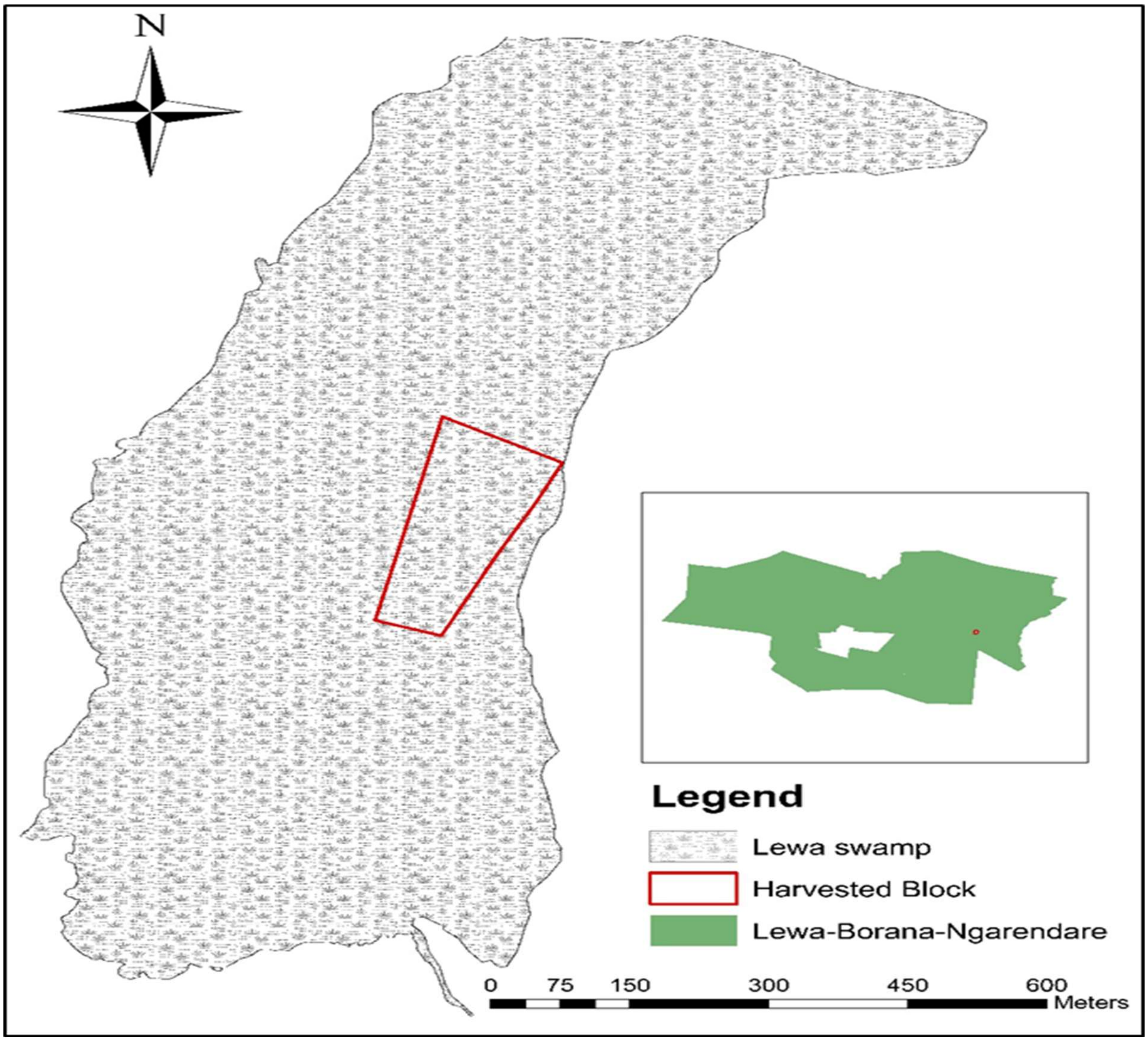


Figure 2.7.9: Sedge grass harvesting block on the Lewa swamp

During the harvesting period, we randomly selected two plots within the block to investigate the growth rate of sedge and assess the long-term impacts of sedge harvesting on the functionality and health of the swamp. In each of the two plots, we sampled 10 stalks of sedge grass that were cut. Measurements were taken from the ground to the remaining tip of the growing sword and repeated after three weeks.

After three weeks, the average height of the growing sword had increased by 75±25 centimetres in these plots. It's important to note that these measurements were conducted during the dry season, and additional data will be collected during the wet season to better understand potential differences in the rate of growth.

2.7.7 Recommendations

We recommend concerted efforts in monitoring, documenting and removing alien/invasive species especially the eradication of *D. stramonium*, *A. mexicana*, and *D. ferox* and others in the landscape.

There is a need to continue constantly monitoring the established enclosures in the landscape in terms of growth, habitat changes, animal usage and plant diversity with time and align these with weather/climatic trends in the landscape. We also recommend the acquisition and use of high-resolution imagery to effectively gauge biodiversity changes in time within the exclusion zones and compare them with the other areas.

The grass assessment in the LBL revealed significant fluctuations in biomass, species diversity, and cover over the years. These fluctuations emphasise the need for continuous monitoring and adaptive rangeland management practices to mitigate the potential threats of degradation, soil erosion, and biodiversity loss in these vital ecosystems.

The Lewa swamp holds significant value within the landscape. To ensure its sustainability, it is imperative to persist in collecting and evaluating data about the trends of the swamp and also assess the productivity of the springs feeding it.

2.8 Hydrology and Weather Monitoring

2.8.1 Rainfall

Rainfall for 2023 was 672±24mm significantly higher than 183±3mm received in 2022 and 253±5mm received in 2021 (Figure 2.8.1a). Additionally, this was higher than the long-term average rainfall of 498±27mm for the last 48 years (1975-2022) (Figure 2.8.1b).

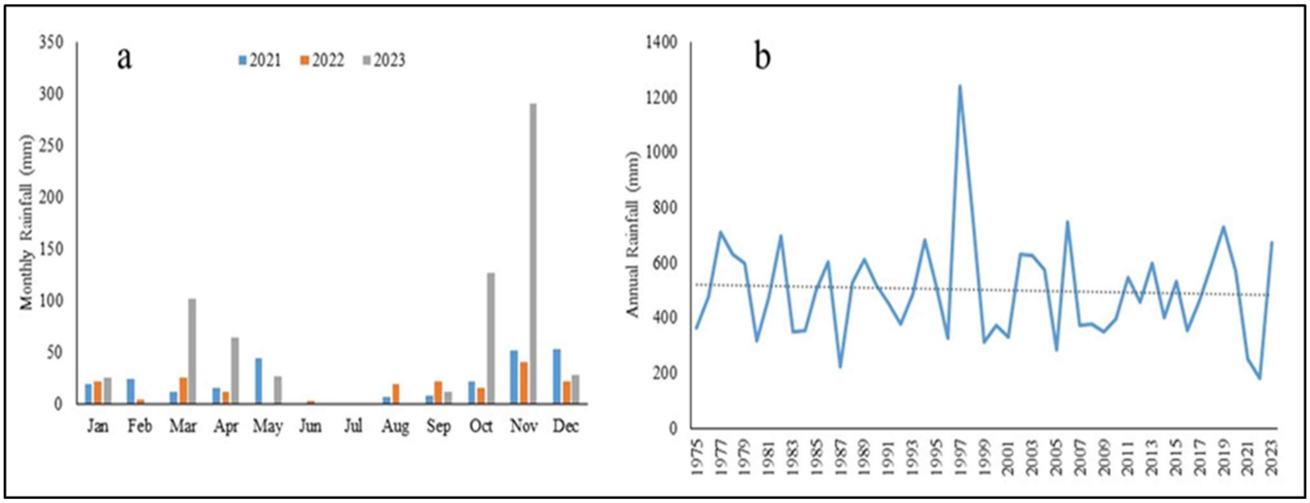


Figure 2.8.1: Graph showing **a)** Monthly rainfall for 2021 - 2023, and **b)** Annual rainfall for the last 48 years

2.8.2 Springs monitoring

We monitored the flow rates of the Ngare Ndare and Ngare Nyting rivers using automated River Gauging Systems (RGSs). The data collected from the three RGSs has been computed to generate the rating curves/stage-discharge equations. We collaborated with the Centre for Training and Integrated Research in ASAL Development (CETRAD) to carry out the calibration work for the RGSs. The flow rate was higher in the Ngare Ndare River compared to the Ngare Nything River. This could have been attributed to higher rainfall received in Ngare Ndare forest increasing in spring volume as shown in Figure 2.8.2:

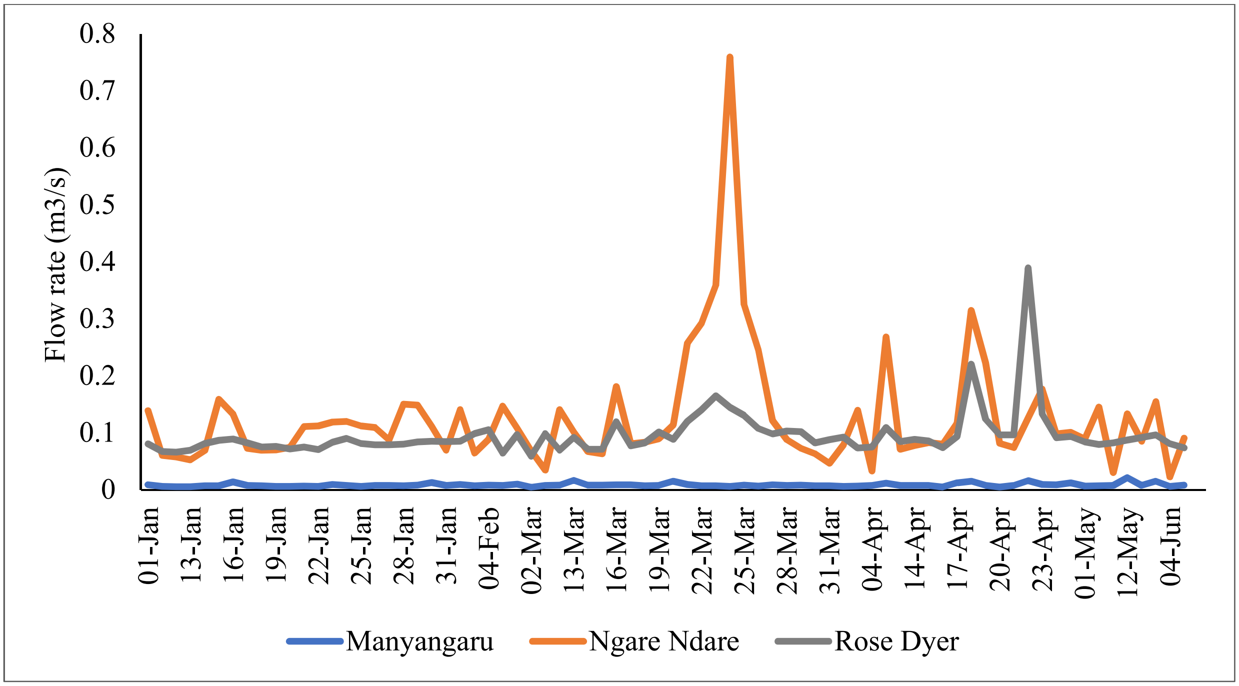


Figure 2.8.2: Flow rates by 3 RGS on Ngare Ndare and Ngare Nything rivers

2.8.3 Automated Weather Stations-AWSs

The AWSs have played an important role in obtaining and storing crucial weather data on LBL. The parameters include humidity, temperature, pressure, rainfall, irradiation and dewpoint. The AWSs are key in providing long-term data for accurate forecasting options in the landscape. These reports help in informing the management of the current state and also in modelling the future status of resource planning. It was observed that the relative humidity increased with rainfall and vice versa, while the atmospheric pressure decreased with an increase in temperature as shown in Figures 2.8.2and 2.8.3 below:

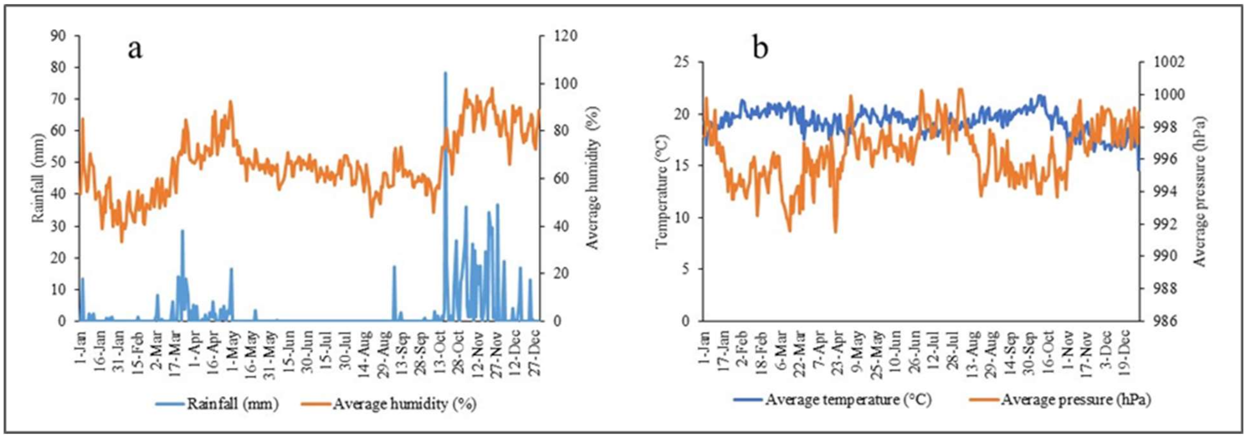


Figure 2.8.3: Graphs showing **a)** Lewa rainfall and average humidity for 2023, and **b)** Lewa average temperature and pressure for 2023

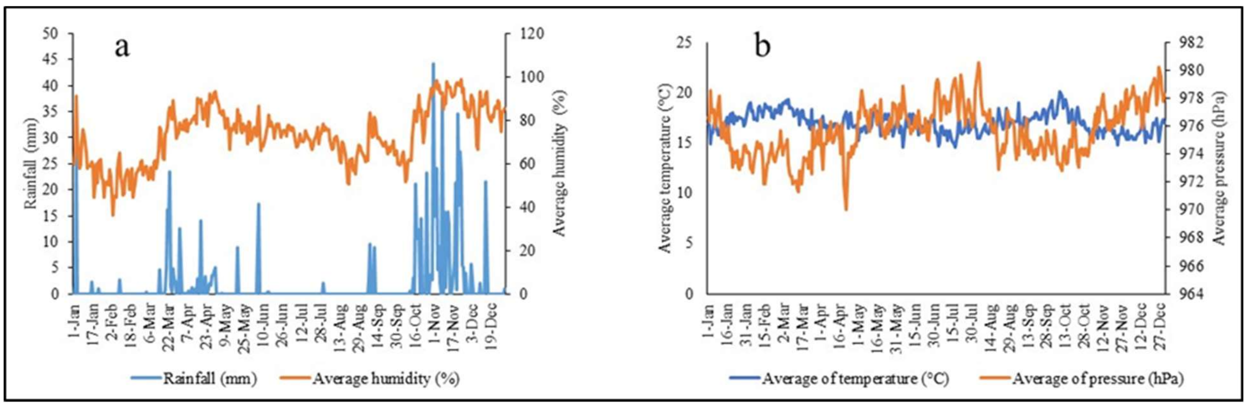


Figure 2.8.4: Graphs showing **a)** Borana rainfall and average humidity for 2023 and **b)** Borana average temperature and pressure for 2023

2.8.4 Hydrological Study

Lewa and Borana Wildlife Conservancies contracted Rural Focus Limited (RFL) to undertake a water resources baseline study at the MACPaL (Mountain, Agriculture, Conservation, and Pastoral Landscape) areas, located at the foot of Mt. Kenya. This was done in collaboration with various stakeholders including the Centre for Training and Integrated Research in ASAL Development (CETRAD), Water Resources Authority (WRA), Mount Kenya Ewaso Water Partnership (MKEWP), commercial growers under Mount Kenya Growers Group, Water Resource Users Associations (WRUAs), wildlife conservancies and the local communities. The project focused on understanding the status and trends of rainfall, climate, surface water, and groundwater within the MACPaL.

Rainfall data was collected from 27 rainfall stations within the study area. The start and end dates varied considerably across the stations, with the earliest data recording starting on January 1, 1939, at Timau-Marania, and the latest ending on February 28, 2023, at Ole Naishu. Preliminary findings indicate a decrease in precipitation, especially in the areas closer to the mountain (vicinity of Kisima and Timau-Marania stations), indicating a shift towards drier conditions in the more recent period. The analysis revealed that the long rains still occur between March and May (MAM) while the short rains are still experienced between October, November and December (OND). However, the fitted trendlines for MAM showed the days between the onset and cessation of rainfall are reducing, hence the rains experienced within the shorter time for most areas. The opposite holds for the OND short rains. A total of 98 springs in the study area were logged and mapped out. Out of these, 60 springs are located within the protected areas while 38 are within the surrounding communities. The study sampled 48 boreholes and 21 of the sampled were analysed for full chemistry. 18 water samples collected from boreholes within the study area were analysed for isotopes (18O and 2H). Preliminary findings show that the pH of the springs within the MACPaL generally varied with elevation while the pH in boreholes varied with borehole depth, geology and a minor influence was observed in elevation. The pH ranges from weakly acidic to strongly alkaline (6.4-8.7 in boreholes and 6.6-8.2 in springs). Electrical Conductivity (EC) ranges from 52 – 1550 µS/cm in springs and 130 – 1,210 µS/cm in boreholes. In general, pH values have a narrow range with the majority falling within the World Health Organization (WHO) recommended limits for utility, EC in both springs and boreholes are within the recommended limits as well. Spatially, springs and boreholes on higher elevations recorded lower EC and pH compared to springs and boreholes on lower elevations. The comprehensive findings of this study will be prepared and presented to the stakeholders.

3.0 CONSERVATION EDUCATION PROGRAMM (CEP)

In 2023, the Conservation Education Programme (CEP) achieved a significant impact by engaging with four beneficiary categories: primary schools, secondary schools, tertiary institutions (colleges and universities), and adult groups. A total of 130 groups were reached, benefiting 7,201 individuals, primarily students (77.75%) and adults (22.25%). Notably, the higher female representation was influenced by the sponsorship of girls from 27 Lewa-supported schools under the Denise Allen funding, aiming to provide mentorship and exposure to environmental and wildlife conservation.

Collaborating with the Pan African Conservation Education (PACE), the CEP hosted teachers from Lamu County for an exchange visit to integrate conservation lessons into the national curriculum. The program also reconstructed teaching exhibits and the demonstration garden, which offers hands-on lessons on various conservation techniques. Additionally, the CEP supported five schools from northern Kenya under the Disney Conservation Fund, providing a 2-day residential program to enhance conservation awareness.

3.1 In terms of engagements:

The program involved diverse participation from various educational levels and community groups. A total of 56 groups from 64 primary schools participated, comprising 2,752 individuals. Additionally, 43 groups from secondary schools benefited 1,905 students and 115 teachers. Six colleges were reached, impacting 685 beneficiaries, while three adult groups participated in guided game drives, reaching 88 individuals. Behind-the-scenes experiences were offered to ten groups, comprising 102 adults. Workshops and conferences, including four held in Lewa and five elsewhere, reached 684 adults. Conservation efforts extended to two significant events in Manyangalo village, engaging 519 students and 481 adults. The program's reach extended across at least 14 counties, with Meru County showing the highest participation, followed by Isiolo and Laikipia. However, representation from counties farther from Lewa was limited, and participation from the Diaspora remained modest.

4.0 PARTNERSHIPS AND COLLABORATIONS

4. I **Attachments and Internship Programmes**

In our effort to promote knowledge transfer to college and University students, we provided opportunities for on-the-job experience through attachments and internships to both local and international students. In 2023, we handled 5 trainees under various programmes.

4.2 Partnerships And Collaborations

In the year, we partnered with various organizations and conservation groups towards the realization of our goals:

a) Northern Kenya Research Consortium (UMAKA)

UMAKA is an acronym for the Northern Kenya Research Consortium which is composed of three Kenyan Universities and conservation organisations namely Nairobi, Kenyatta, Meru University and the National Museums of Kenya. We also signed a collaborative MoU with Embu University for further research on the northern rangelands. This collaboration was able to deliver important research reports including the recently published pancake tortoise research in northern Kenya.

b) Yale University

We collaborated with Yale University in the study of prehistoric archaeological sites on LBL looking for ancient residues to find clues to humanity's past. This led to the publication of a recent paper in an international journal. We aim to strengthen this collaboration to continue unearthing more information and knowledge of the region's history.

c) Wildlife Laboratory in Northern Kenya (LiNK)

This is a partnership effort between the local and international conservation and research institutions that came together to jointly establish the laboratory at Lewa for research and disease surveillance purposes. They include Kenya Wildlife Services, the Wildlife Research Institute, the San Diego Zoo, the Northern Rangelands Trust, and Lewa and Borana Conservancies.

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6.0 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.