LEWA WILDLIFE CONSERVANCY
A UNESCO World Heritage Site inscribed in 2013

BORANA CONSERVANCY

Conservation and Wildlife

Annual Report 2022

Authors:

Timothy Kaaria, Edwin Kisio, Saibala Gilicho, Hannah Mungai, Francis Kobia, Kenneth Onzere, Eunice Kamau, Jonathan Odongo and Dominic Maringa,

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The rhino population on Lewa-Borana Landscape (LBL) increased from 247 in 2021 to a total of 255 by end of 2022. This was occasioned by 20 births (11 black and 9 white) and 12 deaths (9 black and 3 white). There are now a total of 133 Black and 122 White rhinos on LBL. In a 3-year moving average, this trend translates to 7.0% biological growth for the Black rhino and 8.6% for the White rhino, which is above Kenya's National Rhino Strategy annual growth rate of 5%.

As the drought ranged in the region, we carried out Body Condition Assessments (BCS) of 39 rhinos comprising the old and the lactating, of which the majority scored 3 and above. A second assessment 3 months after the feeding intervention indicated majority had improved while others maintained a good BCS. During the same year, we achieved 100% of photographic identity files for all individuals on the landscape. We also noted that the population of identifiable ear-notched rhinos was below the recommended 60%, which we intend to increase in 2023 by notching approximately 40 individuals. Also, the translocation of 12 black rhinos to Loisaba Conservancy is scheduled for early 2023, which will ease the pressure on the LBL as we have surpassed the Ecological Carrying Capacity (ECC) by 18 individuals. This will be followed by carrying out an ECC assessment for white rhinos for the first time and updating the current one for the Black rhinos.

We monitored the predator population where the lion numbers stood at 59 individuals occurring in five prides and three coalitions. There were also 147 hyenas and 17 leopards documented. The cheetah population remains low with 8 individuals being recorded. There were 4 incidences of livestock depredation for which the lion, hyena, and leopard were responsible. We recorded at least 160 cases of wildlife mortality, of which the majority were buffaloes. The trial on lioness contraceptives ended successfully, and approval to extend the programme was granted by KWS. This will be crucial in regulating the lion population in order to protect the other endangered species in the LBL.

Despite the drought in the year, ungulates surveys showed almost all the indicator species remained stable within their recommended proportions. From the National Grevy's zebra database, we recorded 181 foals between 2021 and 2022. We also noted a considerable percentage of individuals with a BCS of less than 3.5. Supplemental feeding has significantly helped the ungulates to

maintain their population stability. A comprehensive annual wildlife count for 2023 will give near-accurate numbers for the population of each species.

Resident elephants comprised 11 matriarchal families with a total of 168 individuals, all residents on LBL. We also recorded 15 lone bulls on the landscape. We documented a total of 243 fence breakages and 34 crawling incidences under the 2-strand wire fence. Out of these, 83% (n=202) occurred in the exclusion zones while 17% (n=41) were breakages in the main boundary fence. In collaboration with Save the Elephants (STE), we collared one problematic female elephant *(Mugumo)* and replaced two old collars on two females of different families. Fence upgrades and the continued application of new technologies will prevail as we benchmark with other organizations.

The annual grass and woody vegetation assessment in pre-determined monitoring points showed reduced grass biomass, diversity, cover and average tree heights. This was attributed to excessive browsing and destruction primarily by the elephants as well as suppressed rainfall in the last two years as shown by the Normalize Difference Vegetation Index (NDVI) greenness maps. Available data has shown that creating and maintaining exclusion zones has encouraged woody vegetation growth for browsers particularly the endangered Black rhinos. We collaborated with the World Agroforestry Centre (ICRAF) to assess soil and ecosystem health on the LBL using the Land Degradation Surveillance Framework (LDSF), which showed varied results on wooded grasslands and grasslands on LBL.

In the year, we updated the LBL Birds Checklist, which currently consists of 488 species, representing 42% of the total bird species known in Kenya. We updated the LBL Photo Evidence File to 78%. We also conducted surveys on Il Ngwesi Community Conservancy which documented 206 species of which 90% have photo evidence. The Lewa Wildlife Conservancy was ranked the 1st birding hotspot while Borana Wildlife Conservancy was the 3rd in the just concluded bi-annual e-bird count led by Cornell University. The National Waterfowl Census survey led by the National Museums of Kenya (NMK) recorded a total of 1,029 water birds comprised of 29 species. A separate study on raptors recorded an estimated abundance of 0.0151 raptors/ha on LBL, which translated to an estimated 642±162 individuals on LBL. This work was presented at the 28th International Ornithological Congress (IOC) held in South Africa.

We have been monitoring and documenting the dynamics of herpetofauna species within LBL and the contiguous areas, and so far, we have documented 152 critically endangered pancake tortoises (*Malacochersus tornieri*), 6 leopard tortoises (*Stigmochelys pardalis*) and 22 terrapins (*Pelomedusa neumanni*). We extended this survey to include Leparua community areas, and Leparua, Il Ngwesi, and Lekurruki community conservancies. The results of these surveys were presented at the Joint Annual Conference of the Turtle Survival Alliance and the International Union for Conservation of Nature (IUCN) held in Tucson, Arizona in August 2022.

The Conservation Education Programme (CEP) reached out to a total of 8,879 individuals from neighbouring communities through environmental and wildlife awareness education. We organized day and residential trips to Lewa, virtual engagements and outreach programme. We sponsored a total of 11 schools from Isiolo, Samburu, Laikipia and Marsabit Counties to participate in the programme.

Implications for management

- Every year, we record at least 18 births of black and white rhinos, increasing the population of non-identifiable rhinos on the landscape. We, therefore, require an annual budgetary allocation for ear-notching.
- For efficient predator-prey management on LBL, the lioness contraceptive programme needs to be continued, alongside collaring a few identified representatives of lion prides, coalitions and hyena clans.
- A lot of time is spent processing Grevy's zebra images for individual identification using the national stripe identity database. We shall continue engaging the WILDBOOK team in the development and adoption of CODEX, an Artificial Intelligence (AI) software that will quicken image processing and allow near real-time monitoring of Grevy's zebra dynamics.
- To mitigate human-elephant conflicts, there will be a need to keep up the fence upgrading while embracing existing and new technologies such as drones, LoRaWAN, Earth-Ranger (ER), and collaring among other monitoring technologies on LBL and contiguous areas
- Due to the diminishing woody vegetation in the landscape occasioned by reduced rainfall and large groups of elephants on the landscape, we propose the continued establishment of exclusion zones as they encourage woody vegetation recovery for browsers.

- There is a need to strengthen the capacity of the CEP to enable it to carry out more community engagements and follow-ups in terms of environmental awareness.

1.0 INTRODUCTION

This report provides details of the activities undertaken by the Conservation and Wildlife department of the LBL in 2022. The year was characterised by significantly reduced rainfall (183mm) compared to 2021 (253mm) and the long-term (1975-2021) average of 505±26mm. This situation led to reduced forage quantity and quality which led to the introduction of supplementary feeding focusing on endangered, threatened, and vulnerable species. Over 10,000 bales of hay and 2,000 of Lucerne were fed to wildlife between May to December.

As a result of the persistent inconsistencies in rainfall patterns and adverse effects of climate change in the region, we have commissioned a comprehensive surface and sub-surface hydrological survey of the landscape and surrounding areas. This survey is aimed at assisting the members of the landscape to understand the current hydrological dynamics for sustainable water resource planning.

The landscape remains an important residence for wildlife species of key conservation concern. We continue to undertake research and monitoring for the critically endangered raptors and water birds, pancake tortoise within LBL and its contiguous areas. There is a need for sustained focus on herpetofauna in the region, as detailed data on their dynamics is crucial in developing their national recovery and conservation action plans.

Our rangelands' health remains a critical foundation of our conservation efforts. In recovering woody vegetation, multiple approaches have been tried this year, including extending and maintaining temporary exclusion zones. We are exploring various methods of grass management for increased diversity and palatability, as well as the identification and eradication of invasive and alien species on the landscape.

Below, we give a detailed account of various thematic areas under Research and Monitoring (R&M) and discuss the activities of the veterinary unit as well as those of the CEP.

2.0 RESEARCH AND MONITORING SECTION

This section gives details on the activities undertaken during rhino monitoring, predator monitoring, ungulates monitoring, elephant monitoring, rangeland monitoring, avifauna monitoring, herpetofauna monitoring, and hydromet monitoring.

2.1 Rhino Monitoring

The population of rhinos on LBL increased from 247 in 2021 to 255 in 2022. There are currently 133 black and 122 white in 2022 on LBL. In the year, there were a total of 20 births composed of 11 black and 9 white rhinos, as well 12 deaths composed of 9 black and 3 white rhinos. This was a low birth rate compared to 2021, when we recorded 35 births (17 black and 18 white) and 5 deaths (all white). Since the LBL has an inter-calving interval of 2.5 to 3 years, this was expected after the peak calving period in 2021. We anticipate more births in 2023.

2.1.1. Black rhino population performance

The population of Black rhinos on LBL increased from 131 to 133 after 11 births and 9 deaths were recorded as shown in Table 2.1.1 (Black rhino births) and 2.1.2 (Black rhino deaths). This represents a biological growth rate of 7 % in the 3-year average of 2020-2022 compared to 10.5% in the 2019- 2021 period as shown in Figure 2.1.1. These average growth rates are above the recommended 5% in the well-established rhino sanctuaries in the Country (KWS, 2017).

Table 2.1.1 Black rhino births on LBL in 2022:

#	Calf name	Date of Birth	Sex	Dam	Sire[i]
1	*Hodari Belle Calf 1*	3-Jan-22	M	*Hodari Belle*	*Rocky*
2	*Delia Calf 2*	16-Jan-22	F	*Delia*	*Lucky*
3	*Natumi Calf 6*	27-Feb-22	U	*Natumi*	*Lucky*
4	*Jackline Calf 2*	21-Mar-22	F	*Jackline*	*Sogomo*
5	*Zainab Calf 2*	8-Aug-22	M	*Zainab*	*Muturi*
6	*Linda Calf 4*	16-Sep-22	F	*Linda*	*Hisa*
7	*Ren Suen Calf 3*	2-Oct-22	M	*Ren Suen*	*Denny*
8	*Nerisa Calf 1*	19-Oct-22	M	*Nerisa*	*Sogomo*
9	*Lou Calf 3*	8-Nov-22	F	*Lou*	*Hisa*
10	*Senewa Calf 2*	11-Nov-22	U	*Senewa*	*Long'uro*
11	*Karimi Calf 2*	15-Nov-22	U	*Karimi*	*Elvis*

The table below shows the details of Black rhino deaths on LBL in 2022:

Table 2.1.2 Black rhino deaths on LBL in 2022:

#	Rhino name	Age at death	Sex	Date	Cause of death
1	*Edwina*	13 years	F	18-Jan-22	Birth complications
2	*Zenetoi Calf 3*	5.5 months	F	7-Jun-22	Injury (hit by an adult bull)
3	*Zoltan*	8.8 years	M	24-Jun-22	Injury (territorial fight)
4	*Natumi Calf 6*	4 months	U	2-Jul-22	Predation by hyenas
5	*Bahati Calf 2*	7.5 months	M	18-Jul-22	Predation by hyenas
6	*Zaria Calf 10*	11 months	F	8-Sep-22	Injury (hit by an adult bull)
7	*Mutane*	42.8 years	M	11-Oct-22	Old age
8	*Nerisa Calf 1*	8 days old	M	26-Oct-22	Predation by a lion
9	*Zenetoi*	17 years		31-Dec-2022	Natural (fell off a cliff)

The figure shows the details of the various trends of Black rhino population on LBL for the last 22years:

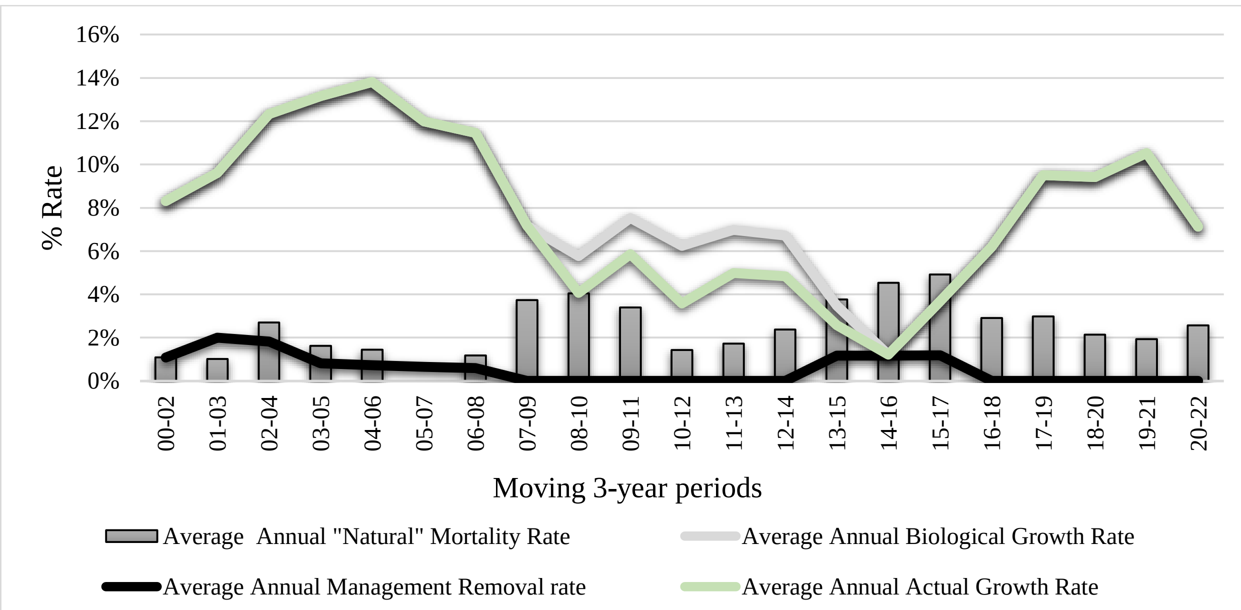

Figure 2.1.1 Key Black rhino population metrics on the LBL, 2000-2022. (**Biological growth rate** – Human-caused deaths, that is, poaching, treated as removals but includes translocations; **Actual growth rate** – Human-caused deaths not treated as removals; **Management removal** – rhinos translocated out).

2.1.2. Black rhino performance indicators

Reproductive performance indicators for Black rhinos include Underlying Growth Rate (UGR), the Mortality Rate (MR), the Proportion of Calves in the population (PCP), Age at First Calving (AFC), Inter-Calving Interval (ICI), Sex Ratios (SR), and yearly Percentage of Female Calving (PFC), (Law and Fike, 2018 and Okita-Ouma, *et al.*, 2021). In the last 20 years, the LBL UGR, SR, and ICI are rated as good to excellent, MR is moderate, PFC is Poor to moderate, and AFC and PCP are rated as poor as shown in the table below:

Table 2.1.3: Black rhino performance indicators in the 2020-2022 period:

Performance indicator	Performance in the 2020-2022 period	Benchmark (Ouma, 2004)
Underlying growth rate (UGR)	7%	Good-excellent
Mortality rate (MR)	2.8%	Moderate
Sex ratio, female: male (SR)	1.2:1	Good
Inter-calving interval (ICI)	2.6 years	Moderate – Good
Percentage of females calving (PFC)	32%	Poor – Moderate
Age at first calving (AFC)	7.4 years	Very poor - Poor
Percentage of calves in the population (PCP)	27%	Poor - Moderate

Delayed AFC and low PFC can be attributed to five females aged 7 years and above, who have not calved. These are *Subira* (8.6-year-old), *Sekelai* (8.6-year-old), *Nalotu* (8.4-year-old), *Nailepu* (8.1-year-old), and *Nasieku* (7.3-year-old). Poor to moderate PCP can be attributed to five calves that died this year.

The normal sex structure is when 54% of the rhino population are females and 44% are males. Presently the age structure is as follows: 51% are adults, 22% are sub-adults and 27% are calves as shown in the table below:

Table 2.1.4 Population structure of Black rhino on LBL, 2022:

Age Class	Male	Female	Unknown	Sub Total	Proportion in population
Calves (0<3.5yrs)	15	19	2	36	27%
Sub Adults (3.5<7 yrs) unless calved	14	15	0	29	22%
Adults (>7yrs)	30	38	0	68	51%
Grand Total	59	72	2	133	100%
Proportion in population	44%	54%	2%	100%	

These age-sex benchmarks are rated as moderate-good (Balfour, *et al.*, 2019).

2.1.3 White rhino population performance

The population of White rhinos on the LBL increased from 116 in 2021 to 122 in 2022 after 9 births and 3 deaths were recorded as shown in the tables below:

Table 2.1.5 White rhino births on LBL in 2022:

#	Calf name	Date of Birth	Sex	Dam	Sire[1]
1	*Rhoda Calf 2*	4-Jan-22	M	*Rhoda*	*Samawati*
2	*Jakwai Calf 11*	9-Feb-22	F	*Jakwai*	*Gordon-65*
3	*Nashepai Calf 2*	9-Apr-22	M	*Nashepai*	*Imado*
4	*Tale Calf 7*	29-Apr-22	F	*Tale*	*Mandela*
5	*Jane Calf 1*	22-May-22	F	*Jane*	*Motonto*
6	*Arot Calf 2*	27-May-22	F	*Arot*	*Moru*
7	*Schini Calf 8*	12-Sep-22	M	*Schini*	*Gordon-65*
8	*Gakii Calf 1*	15-Sep-22	F	*Gakii*	*Motonto*
9	*Lucy Calf 1*	13-Dec-22	U	*Lucy*	*Imado*

Table 2.1.6 White rhino deaths on LBL in 2022:

#	Rhino name	Age at death	Sex	Date	Cause of death
1	*Jane Calf 1*	2.4 months	F	11-Aug-22	Injury (hit by an adult bull)
2	*Arot Calf 2*	0.4 months	F	5-Nov-22	Drowned
3	*Ngura*	16 years	F	26-Nov-22	Impaction colic

These represent a biological growth rate for white rhino as 8.6% in the 2020-2022 average 3-year period compared to 11.5% recorded in the 2019- 2021 period as shown in Figure 2.1.2 below:

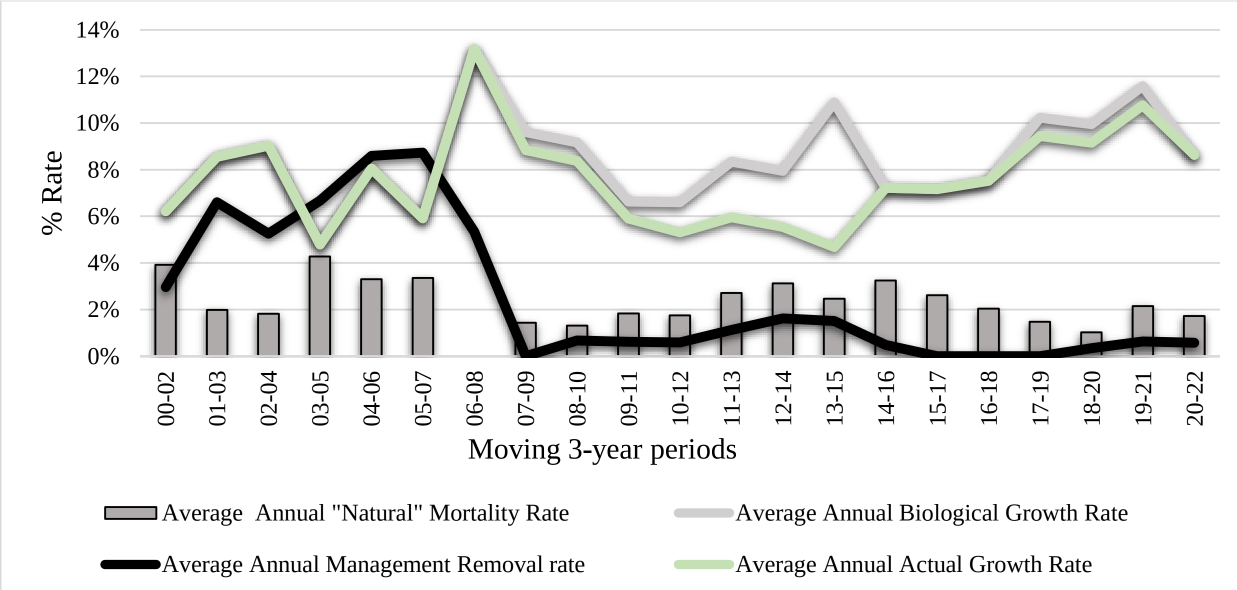

Figure 2.1.2 Key White rhino population metrics on the LBL, 2000-2022.

2.1.4 White rhino performance indicators

LBL white rhino population performance indicators in the 2020-2022 period have been rated as good as shown Table 2.1.7:

Table 2.1.7 White rhino performance indicators in the 2020-2022 period:

Performance indicator	Performance in the 2020-2022 period	Benchmark (Ouma,2004)
Underlying growth rate (UGR)	8.6%	Good-excellent
Mortality rate (MR)	1.7%	Good
Sex ratio, female: male (SR)	1:1.2	Moderate -Good
Inter-calving interval (ICI)	2.3 years	Good-excellent
Percentage of females calving (PFC)	43%	Good-excellent
Age at first calving (AFC)	6 years	Good-excellent
Percentage of calves in the population (PCP)	28%	Moderate - good

LBL's white rhino sex structure consists of slightly more males (53%) than females (45%). The age structure consists of 54% adults, 18% of sub-adults, and 28% of calves. These benchmarks are rated as moderate-good (Balfour, *et al.*, 2019). The table below shows the age and sex structure of the White rhinos:

Table 2.1.8 Population and sex structure of White rhino on LBL, 2022:

Age Class	Male	Female	Unknown	Sub Total	Proportion in population
Calves (0<3.5yrs)	21	12	1	34	28%
Sub Adults (3.5<7yrs) unless calved	11	12	0	23	19%
Adults (>7 yrs)	33	32	0	65	53%
Grand Total	65	56	1	122	100%
Proportion in population	**53%**	**46%**	**1%**	**100%**	

2.1.5 Sighting frequency

The average sighting frequency (SF) for Black and White rhinos was 2.6±0.1 days and 1.8±0.04 days respectively. This was within the recommended critical sighting frequency of 3 days in the LBL.

2.1.6 Notable shifts in home ranges

There were shifts in home ranges noted, *as Nasa*, a 7.7-year-old male white rhino, expanded his territory from the northern side of Lewa to the central part near the headquarters in the second quarter of 2022. *Agwambo*, an 8.9-year-old male black rhino, expanded his territory from the northeast side of Lewa to the central part near the headquarters in the first quarter of 2022. *Nalotu*, an 8.4-year-old female black rhino moved from the southern part of Lewa (Ngare Ndare forest) to the southern part of Borana Conservancy during the third quarter of 2022. *Nkodan-159*, a 9.7-year-old male white rhino moved from the northern part of Lewa to the south-eastern part of Lewa during the third quarter of 2022. The figures below show the shifting home ranges:

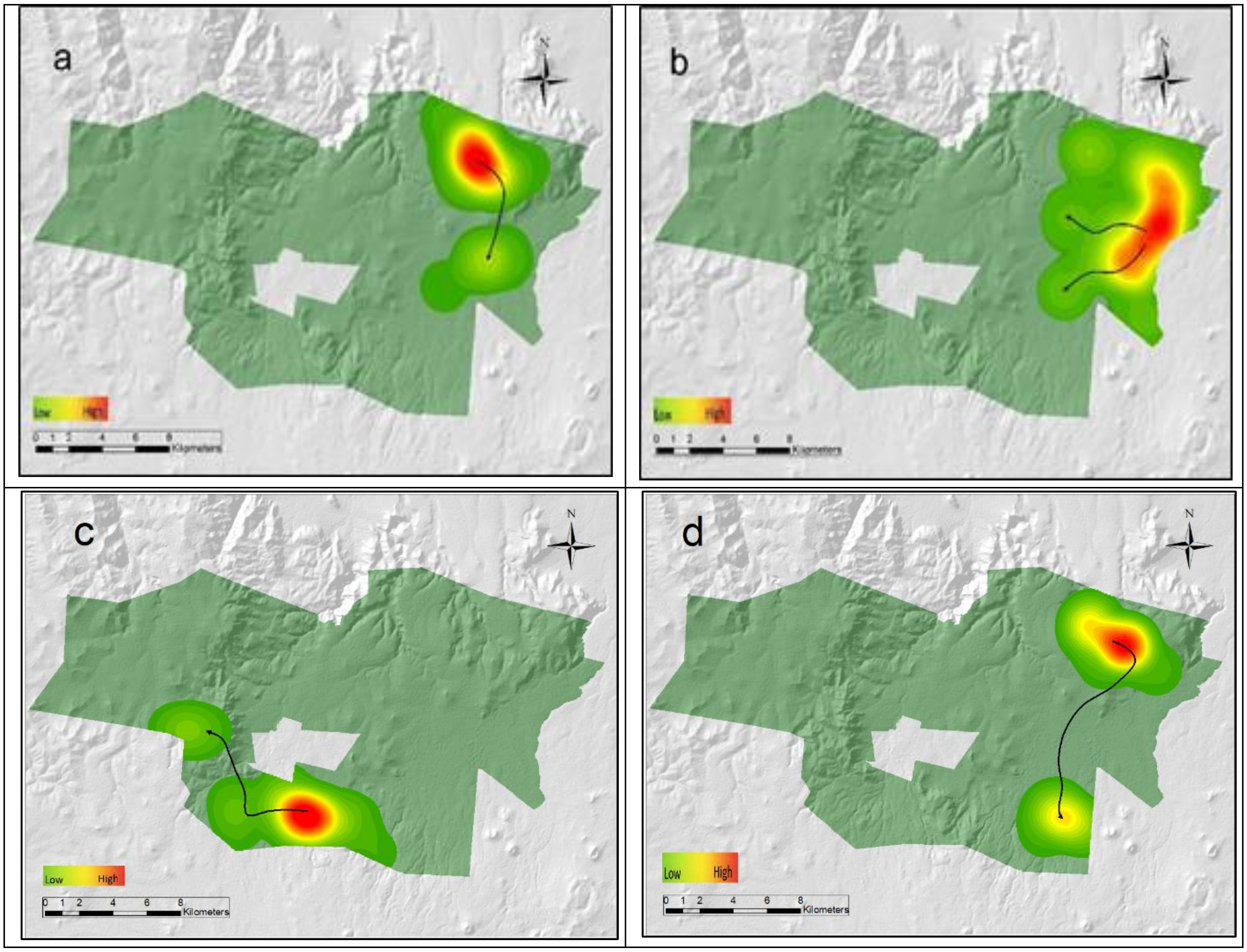

Figure 2.1.3 Changing home ranges for *(a)Nasa, (b) Agwambo, (c) Nalotu, and (d) Nkodan-159.*

2.1.7 Veterinary interventions

For all the several deaths that occurred as seen in tables 2.1.2 and 2.1.6 above, post-mortem examinations were conducted to determine their causes on nine rhinos (7 black and 2 white). Three calves consisting of 2 Black and 1 White rhino died as a result of injuries sustained after being hit by mature male rhinos. *Mutane*, a 43-year-old male Black rhino died due to old age, *Edwina*, a 13-year-old female black rhino died due to birth complications, *Zoltan*, an 8.8-year-old male black rhino died naturally, possibly due to injuries sustained earlier during a territorial fight, *Ngura*, a 16-year-old female white rhino died due to impaction colic and *Zenetoi* who died as a result of bone puncture of lungs after a fall.

Eighteen rhinos, of which 7 were black and 11 white, were sighted with minor injuries which did not meet the threshold for veterinary intervention and were later sighted having fully recovered.

Out of the 18 rhinos, eight were males (2 black and 6 white) who sustained injuries from territorial fights.

2.1.8 Body Condition Scores (BCS) and supplementary feeding for rhinos

The BCS targeting the older and lactating rhinos were conducted in April, July, and September 2022. The assessments were necessitated by the failure of the anticipated short rains during the April-May season, which resulted in reduced forage availability in the LBL. Therefore, it was deemed necessary to ensure the BCS are well known before the introduction of supplementary feeding to the weak, vulnerable and lactating females (Adcock, et al 2003).

In total, 39 rhinos (25 white and 14 black) out of a population of 51 breeding females were assessed in July 2022 and put on supplementary feeding. In September, 41 rhinos (16 black and 25 white) out of 52 breeding females on the programme were assessed. The majority of the rhinos maintained a BCS of 3, both in July and September 2022, which is a ‘Good” score as shown in the table below:

Table 2.1.9 The status of Body Condition Scores (BCS) of lactating females on LBL:

BCS (Adcock, et al, 2003)	July-22				Sep-22			
	Black rhino	% black	White rhino	% white	Black rhino	% black	White rhino	% white
5	0	0	0	0	0	0	0	0
4.5	0	0	0	0	0	0	0	0
4	1	7	4	16	1	6	3	12
3.5	9	64	21	84	11	69	21	84
3	3	22	0	0	2	13	1	4
2.5	1	0	0	0	1	6	0	0
2	0	0	0	0	1	6	0	0
1.5	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
Total	**14**	**100**	**25**	**100**	**16**	**100**	**25**	**100**

During the September assessment, we noted that the percentage of Black rhinos with a BCS of 3.0 and below increased from 22% to 25%, while those with 3.5 and above increased from 71% to 75%. White rhinos with a score of 3.0 and below increased from 0% to 4% while those with 3.5 and above reduced from 100% to 96%. From these figures, the supplementary feeding programme significantly assisted the rhinos in maintaining their body condition.

The supplementary feeding program was temporarily halted in mid-November 2022 due to relative improvement in forage quality and quantity following the little rains in the month. A rapid body condition assessment done in December showed that most rhinos had a score of 3.5 and above which is rated as “good”.

2.1.9 The 2022 evidence files

The 2022 master ID files for all the LBL rhinos were completed. Photos were obtained from hand-held cameras and camera traps that were deployed to capture rhinos in difficult areas like Ngare Ndare forest. Currently, 48% of black rhinos and 49% of white are identifiable through ear notches and natural marks. The identifiable population is below the 60% recommended of the independently identifiable rhinos (KWS, 2017). To date, 58 rhinos (26 White and 32 Black) are suitable candidates for ear notching. We have plans to ear-notch 40 rhinos in 2023 to reduce the current number of unidentifiable individuals.

2.1.10 Conclusion and recommendations

The supplementary feeding program was a successful intervention, which was able to sustain rhinos and other ungulates during the drought period. However, the November -December rains were not sufficient to support the wildlife population until the following rainy season (March-May 2023). We predict to resume supplementary feeding in late January 2023.

The Lewa side of the landscape currently has 88 black rhinos whereas the ECC is 70 rhinos. Despite the planned translocation of 12 rhinos from Lewa to Loisaba, the population will continue to surpass the ECC. To maintain high growth rates, rhinos must be kept below the ECC through a national annual removal strategy that will supplement other rhino sites and provide founder populations to new rhino areas in the country.

2.2 Predator Monitoring

To actively manage and conserve wildlife populations, it is essential to establish their abundance and distribution regularly. Obtaining accurate estimates of large carnivores is difficult because they are cryptic, wide-ranging, naturally occur in low density, and are most active during the night. This, therefore, reduces the chance of being detected during surveys. However, in closed and semi-closed reserves such as LBL, documenting large carnivore population dynamics is easier because of the moderately small size of the landscape which enables individual monitoring as in the case of lions.

2.2.1 Lion population performance

We monitored a population of 59 lions (42 adults, 3 sub-adults, and 14 cubs) occurring in five prides and three coalitions. Four new cubs were born in the year in which one survived and the rest fell victim to infanticide caused by dispersing young males.

Initially, there have been two dominant coalitions on LBL namely *Ntulele* and *Blackii* composed of four adult and three adult males, which roam on the eastern and western sides of the landscape respectively. Six of the nine young males from *Njaa's* pride that resided on the western side dispersed to the eastern side of the landscape, forming a new coalition. This became the largest coalition ever documented on LBL, as we have been documenting coalitions with a maximum of four individuals. This appeared to *Ntulele's* coalition out of the landscape as well as the three sub-adult males from *Sarah's* pride.

Sex-biased dispersal is a widespread phenomenon in mammals (Greenwood, 1980). On LBL, this has been skewed towards males. The two main theories explaining this are that females may gain more by remaining in their natal pride (Philopatry) and suffer greater impacts from dispersal than males because of infanticide and that because intersexual competition for mates is more intense among males than females, males may disperse further than females by gaining access to more mates. This kind of behaviour has been cited as an inbreeding prevention mechanism (Cockburn, Scott, and Scotts, 1985). The Research team monitored all sub-adult males within the population as this behaviour could be associated with increased occurrences of human-carnivore conflicts, especially when young males are evicted from their natal pride. The table below shows the ion population structure within LBL:

Table 2.2.1 Lion population structure on LBL:

Pride/Coalition	Adults		Sub adults		Cubs			Total by pride/coalition
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Unknown**	
Sarah's pride	3	1	0	0	0	0	0	4
Simone's pride	0	5	0	0	2	2	0	9
Dalma's pride	0	2	1	2	0	0	1	6
Carissa's pride	0	3	0	0	0	0	5	8
Njaa's pride	4	11	0	0	0	0	4	19
Ntulele's coalition	4	0	0	0	0	0	0	4
Blackii's coalition	3	0	0	0	0	0	0	3
Cattail's coalition	6	0	0	0	0	0	0	6
Total by sex	**20**	**22**	**1**	**2**	**2**	**2**	**10**	**59**

2.2.2 Prey selectivity by lions

To assess prey preference and selectivity by lions, Jacobs Selectivity Index (D) was used (Jacobs, 1974). Of the nine prey species, the lion showed a preference for buffalo and eland while the rest of the prey were completely avoided by lions as shown in the table below:

Table 2.2.2: Jacob's Index (D) values calculated for seven prey species on LBL, 2017-2022:

Species	Years					
	2022	**2021**	**2020**	**2019**	**2018**	**2017**
Plains zebra	-0.5	-0.1	0	0.3	0.2	0.2
Grevy's Zebra	-0.4	0.3	0	0.2	-0.1	0
Waterbuck	-0.4	-0.1	-0.2	-0.5	-0.2	0.1
Beisa Oryx	-0.6	0.4	-0.5	-0.6	-0.6	-0.6
Eland	0.5	0.4	0.6	0.5	0.5	0.4
Warthog	-1	-1	-0.2	0.3	0.6	0.5
Impala	-0.9	-0.9	-1	-1	-1	-0.8
Giraffe	-0.2	0.5	0.7	0.7	0.8	0.4
Buffalo	0.7	0.3	-0.5	0	-0.2	0

2.2.3 Scats analysis for prey preferences

Prey hair ingested by predators normally passes through their digestive system undamaged and can be collected in the form of scat. It is then extracted, cleaned, mounted, observed under the light microscope (400x Magnification), and compared to the reference hairs to discern the prey species involved. A total of 54 scat samples from lions (n=28) and hyenas (n=26) were collected and analyzed for prey hair content. Buffalo, Plains zebra, eland, and giraffe are important prey bases for lions and hyenas as shown in the figures below:

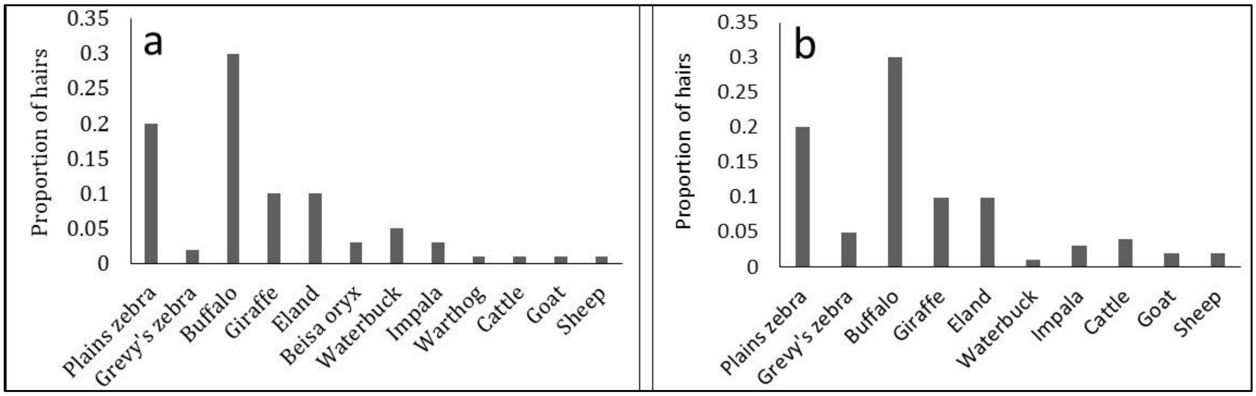

Figure 2. 2.4 Proportion of hairs found in (**a**) lion and (**b**) hyena scats.

2.2.3 Lion contraception trial

As the contraceptive trial cycle on LBL came to an end by December 2022, monitoring data shows that the non-lethal implants are effective. None of the implanted females came into oestrus or showed any adverse effects on behaviour, fitness, and social cohesion. Apart from stabilizing the lion population in the landscape, it has also stabilized the endangered Grevy's zebra and the critically endangered black rhino, among other key species that are sometimes preferred by the lions. However, we note several young females have reached adulthood which is likely to increase the population, potentially increasing the risk of human-carnivore conflicts among other density-dependent effects.

2.2.4 Spotted hyena

Spotted hyenas are primarily scavengers that ensure the ecosystem is clean by feeding on carcasses that potentially provide a conducive environment for the breeding of disease pathogens and other harmful microorganisms. By use of camera traps, we successfully recorded 147 individuals (138 adults, six sub-adults, and three cubs) distributed in five clans. Whilst we have a healthy population of hyenas, the impact on prey species has not been established in the context of hunting versus scavenging.

2.2.5 Leopard survey

Leopards are largely elusive and nocturnal making us heavily rely on camera traps to estimate their numbers. Camera traps have proved to be the most ideal tool for leopard inventories in most environmental conditions (Silveira, Jácomo, and Diniz-Filho. 2003). We mounted them on trees at intervals of 2.5km to avoid double count and on posts at a height of 40cm in areas historically known to have leopards based on scats and spoors observed. The survey recorded 17 individuals on the eastern side of the landscape during the year.

2.2.6 Cheetah survey

The cheetah population remains low with eight individuals (one adult male, two adult females, and five cubs) roaming in the landscape. This population excludes one (male) that was killed by a lion in the last quarter of the year.

2.2.7 Predator home ranges

Spatial monitoring of the carnivores included analysis of their home range where activities like food searching, mating, and caring for their young take place (Powell, 2000). In the case of lions, their home range is smaller in areas with higher prey abundance and readily available water and vice versa (Tumenta, *et al.,* 2013; Celesia, *et al.,* 2010; Orsdol, Hanby, and Bygott. 1985). Therefore, the LBL lions tended to have smaller home ranges.

The lion territories overlapped but each pride maintained a specific core area. Apart from *Sarah's* pride whose home range extended into the community areas, all the other lions have restricted their movements within the landscape as shown in the figures below:

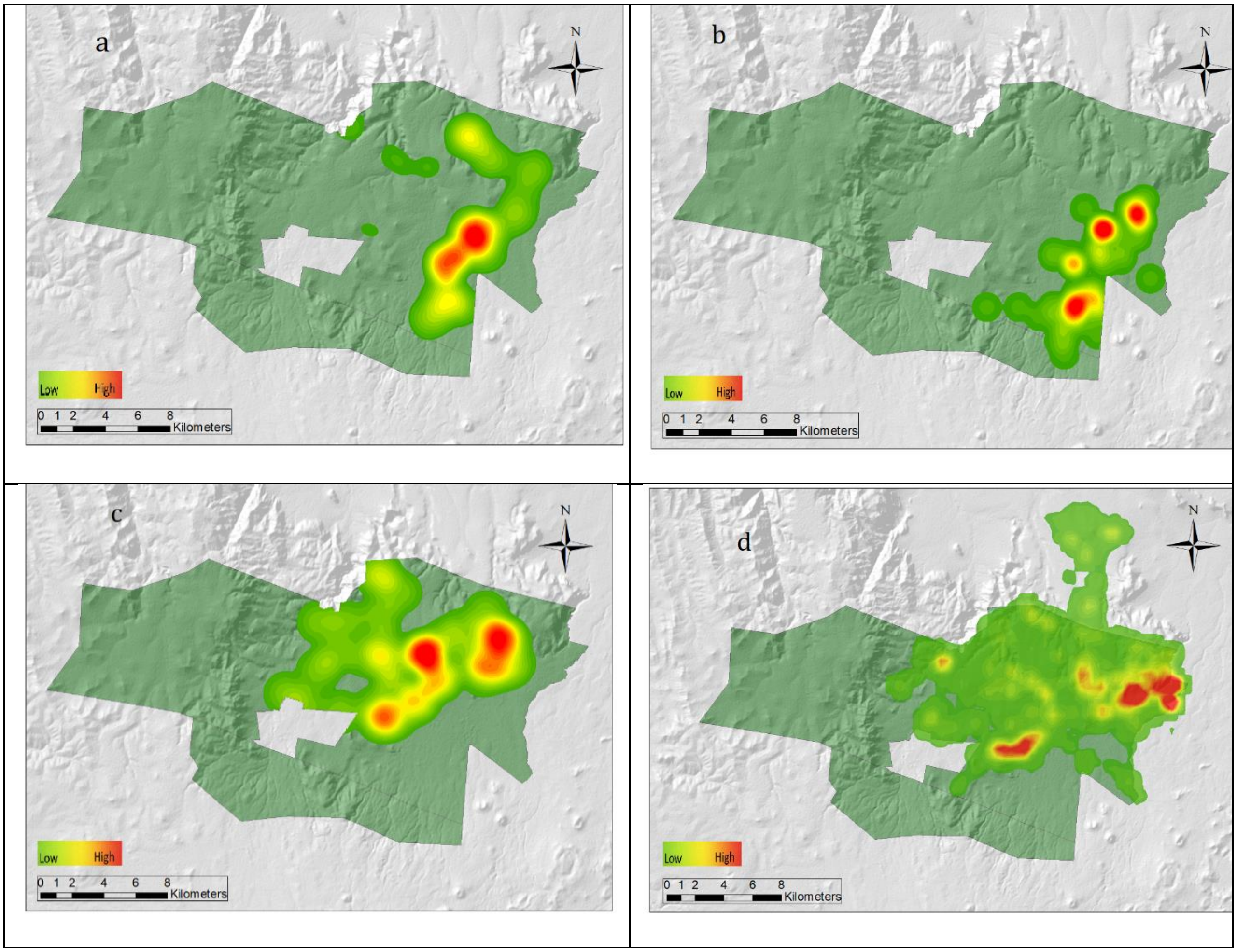

Figure 2.2.1 Ranging areas for (**a**) *Ntulele's* coalition, (**b**) *Dalma's* pride, (**c**) *Simone's* pride, and (**d**) *Sarah's* pride.

2.2.8 Human-Carnivore conflicts

Four incidences of livestock depredation were recorded during the year, leading to the killing of six goats, one sheep, and one cow. Lion, hyena, and leopard were responsible for all four cases. In those cases, the LBL Human-Wildlife Conflict team was involved in the interventions for co-existence, data collection and protection of wildlife and property.

2.3 Ungulate Monitoring

Wild ungulates are central to the functioning of rangelands and forest ecosystems which form parts of LBL (Ohashi and Hoshino, 2014). These wide-ranging species are known to influence ecological processes on many spatial scales (Dolman and Wäber, 2008). This has meant that ecosystem monitoring on LBL must go beyond the endangered species, to a more inclusive approach with an aim of understanding ecosystem function for all species (Western, *et al.*, 2009). In arid and semi-arid landscapes, seasonal and climatic variations influence ungulates dynamics because of variations in forage quantity and quality affecting their body fat reserves, movement patterns, and population dynamics (Illius and O'Connor, 2000).

To understand the status of wild ungulates, we undertook monthly surveys on the key ungulate species namely; Grevy's zebra (*Equus grevyi*), Plains zebra (*Equus quagga*), buffalo (*Syncerus caffer*), Beisa oryx (*Oryx beisa*), hartebeest (*Alcelaphus buselaphus lelwel*), giraffe (*Giraffa Camelopardalis reticulata*), and eland (*Taurotragus oryx*). We also analyzed data from the motion sensor camera traps placed at the four wildlife migratory gaps namely; the Mount Kenya forest gap, the Marania Underpass gap, the Mount Kenya underpass and the Northern gap.

2.3.1 Ungulates performance

When evaluating the performance of wild ungulates, growth potential and the proportion of sub-adults and young ones are two important parameters to consider as they determine the performance and stability of a population (Rubenstein, 2010). The self-sustaining and stable population of a species should have at least 30% of sub-adults together with young. The growth potential is based on the ratio of the 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 (Rubenstein, 2010).

Since 2018, buffaloes and Elands have scored above the 30% threshold on LBL. We also note hartebeest, oryx, and Plains zebra have in some instances hit the threshold. Grevy's zebra have not attained this mark but are very close. Giraffes have persistently scored below 20%. From these metrics, it can be observed that ungulates species have remained resilient from ecological disturbances such as the last prolonged dry period.

The population of hartebeest in the landscape is slightly below 100 individuals (Kaaria *et al.*, 2022). From a subset of the population of the hartebeest we monitored, in 2022, we recorded 7 births of which 6 died. This was a low performance compared to 2021 when we recorded 14 births of which 3 died.

At the beginning of the second quarter of the year, we noticed an increase in Grevy's zebra numbers on the western part of the landscape, which might have been influenced by rains received on that part of the landscape. Later, in the last quarter of the year, there were evenly distributed rains on both parts of the landscape which made a bigger proportion move back to the eastern part, an indication that these animals prefer areas of low altitude. The figures below show the Ungulates population performance on LBL:

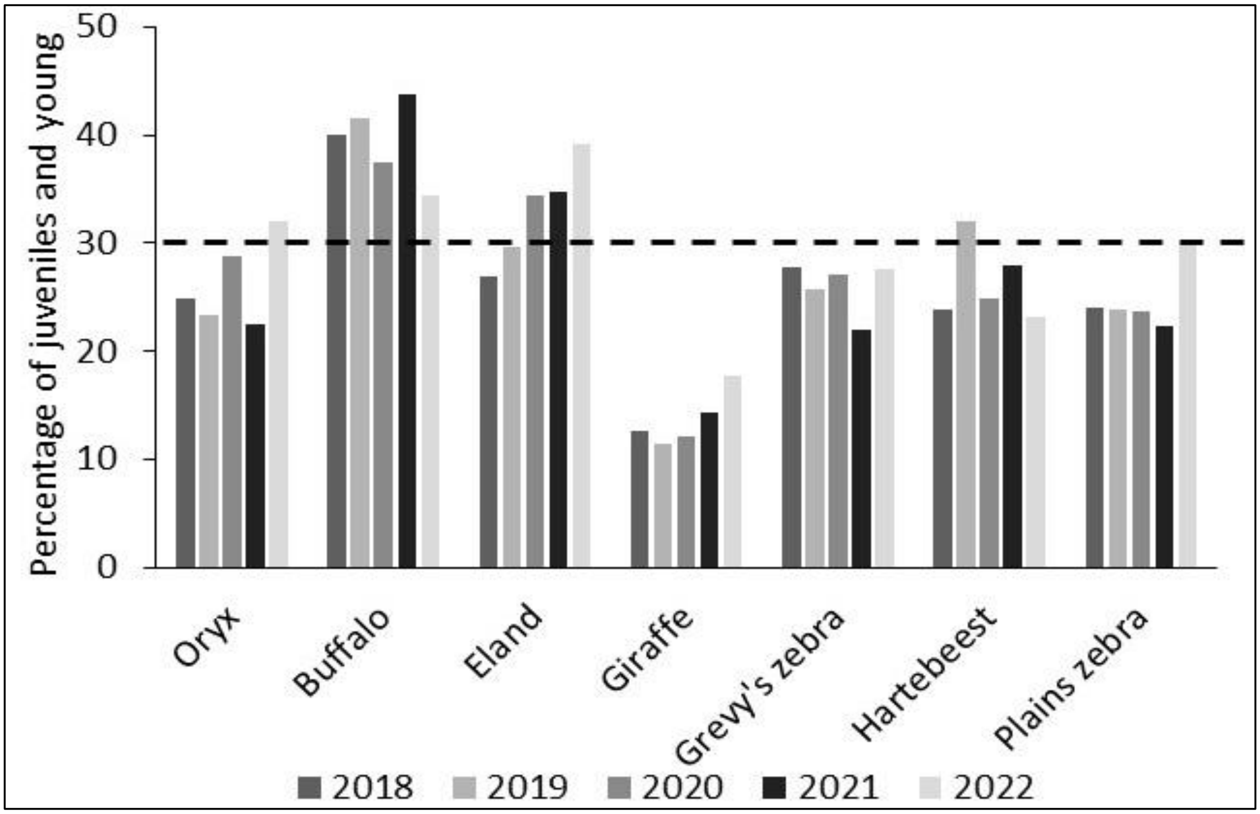

Figure 2.3.1 Proportion of young and juveniles. The dotted black line indicates the 30% recommended level for stable populations.

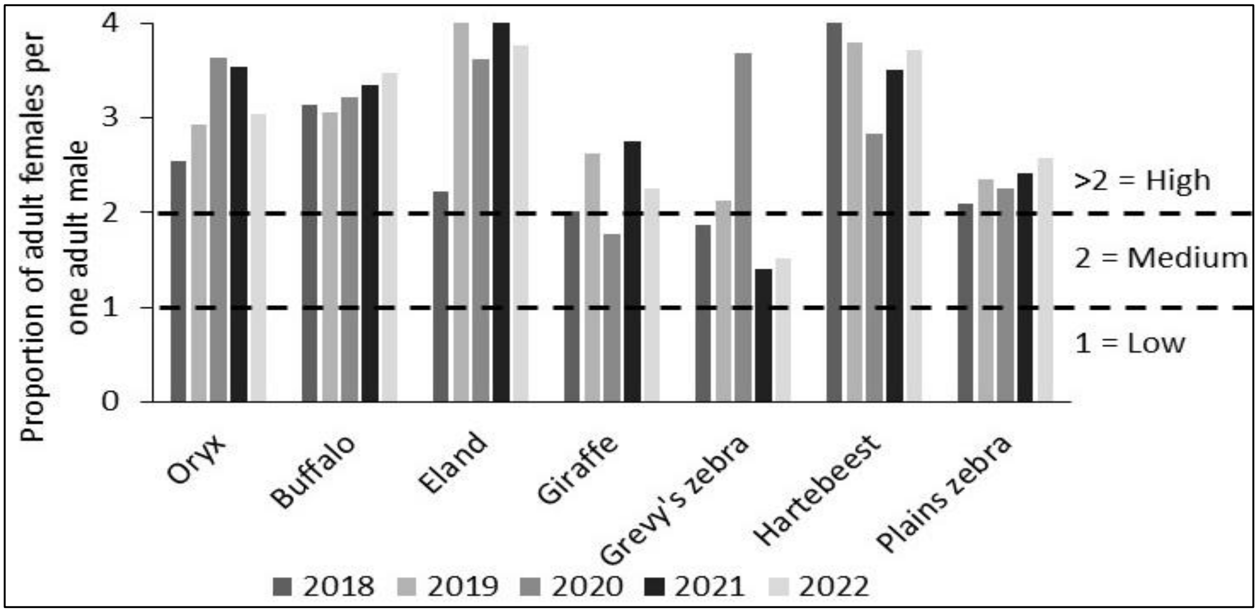

Figure 2.3.2 Proportion of adult females per one adult male. The black dotted lines indicate levels of various growth potential, that is, Low, Medium, and High.

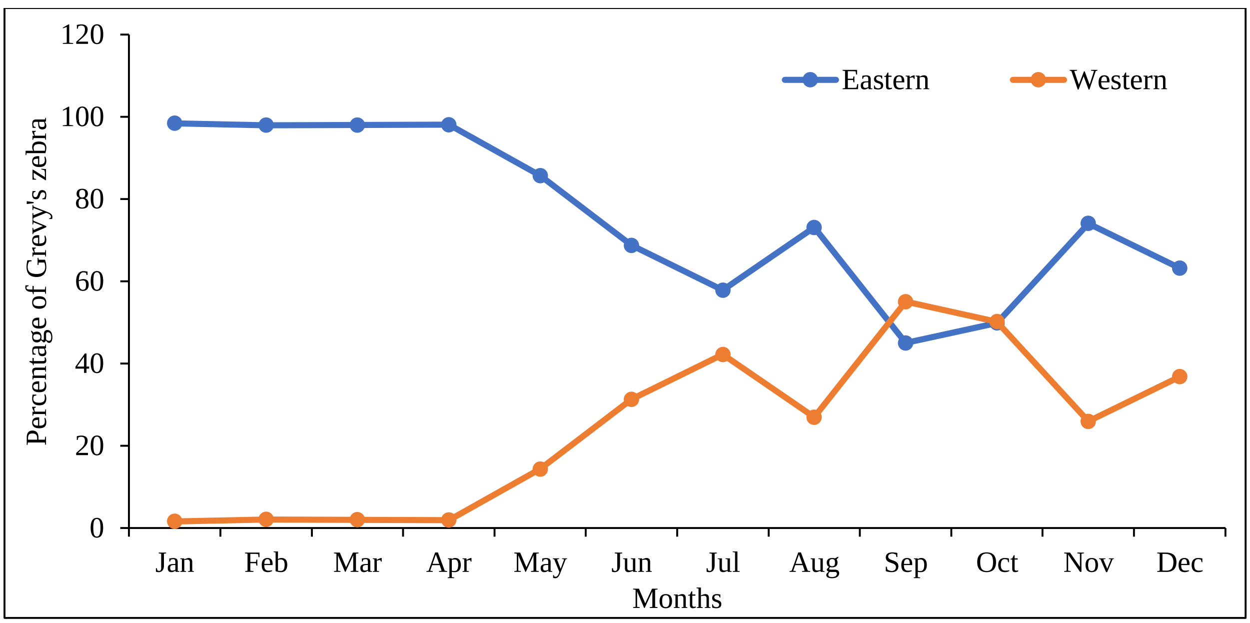

Figure 2.3.3 Grevy's zebra population trends (expressed as a percentage) on LBL, 2022.

2.3.2 Grevy's zebra survival rates

We used the National Grevy's zebra database to analyse the Grevy's zebra photos for unique identity. In 2021 and 2022, a total of 584 unique individuals were sighted of which 255 were foals. Any foal that was not sighted within 6 months was presumed dead. 50.3% were surviving by the end of the year while 49.7% were presumed dead. The distribution of these foals by age category indicates that 36.3% had graduated to the sub-adult age category as shown in the table below:

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	Sub - adults	**Total by sex**
Male	1	13	18	11	**43**
Female	1	9	16	22	**48**
Total by age category	**2**	**22**	**34**	**33**	**91**

2.3.3 Annual wildlife count

The annual wildlife census of the LBL was completed in Q1. The table below shows a summary of indicator species numbers as of the last game count 2022:

Table 2.3.2 Game count results for the indicator species from 2016 – 2022:

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

2.3.4 BCS for Ungulates

As a result of the reduced forage levels due to suppressed rainfall amounts in 2021 and 2022, the BCS for ungulates was equally affected in which buffaloes were the biggest casualties as shown in the table below:

Table 2.3.3 Percentage of the populations with the indicated BCS at the peak of the dry period in 2022:

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
4.5	0	0	0	0	0	0	0
4	54	64	67	80	27	71	90
3.5	20	29	27	20	66	28	7
3	15	7	6	0	7	1	3
2.5	6	0	0	0	0	0	0
1.5	0	0	0	0	0	0	0
1 (Emaciated)	5	0	0	0	0	0	0
Totals as per the LBL game count 2021	**1,901**	**247**	**331**	**119**	**92**	**1,557**	**310**
Percentage of the total population sampled	**12.80%**	**21.10%**	**14.50%**	**8.40%**	**28.30%**	**6.10%**	**73.20%**

We therefore intervened to supplement the forage with hay and lucerne to ensure a majority of the populations survive to the next rainy season. We, however, received some rains in the last quarter of the year which promoted vegetation recovery easing the feeding pressure. The pictures below show the feeding underway:

Picture 2.3.1 Wildlife feeding on hay and Lucerne.

2.3.5 Wildlife mortality

Like many parts of the country, this landscape received extremely low rains leading to low forage levels, which significantly influenced wildlife mortality in the landscape. The carnivore population benefitted from the weak and readily available prey. Buffalo was the most affected species, recording at least 150 deaths. Nearly all the unknown causes of all mortality were a direct effect of the prolonged dry period while most of the kills were facilitated by weak prey. Whereas this is the largest number ever reported since we began active monitoring of wildlife mortalities, we still note these figures as minimum numbers, and the annual wildlife census early next year will give a clearer estimate of what we might have lost. The concentration of carcasses was near the Lewa swamp, as this is where most wildlife concentrates during dry spells. The figures below show the causes and the distribution of wildlife mortality per species on LBL in 2022:

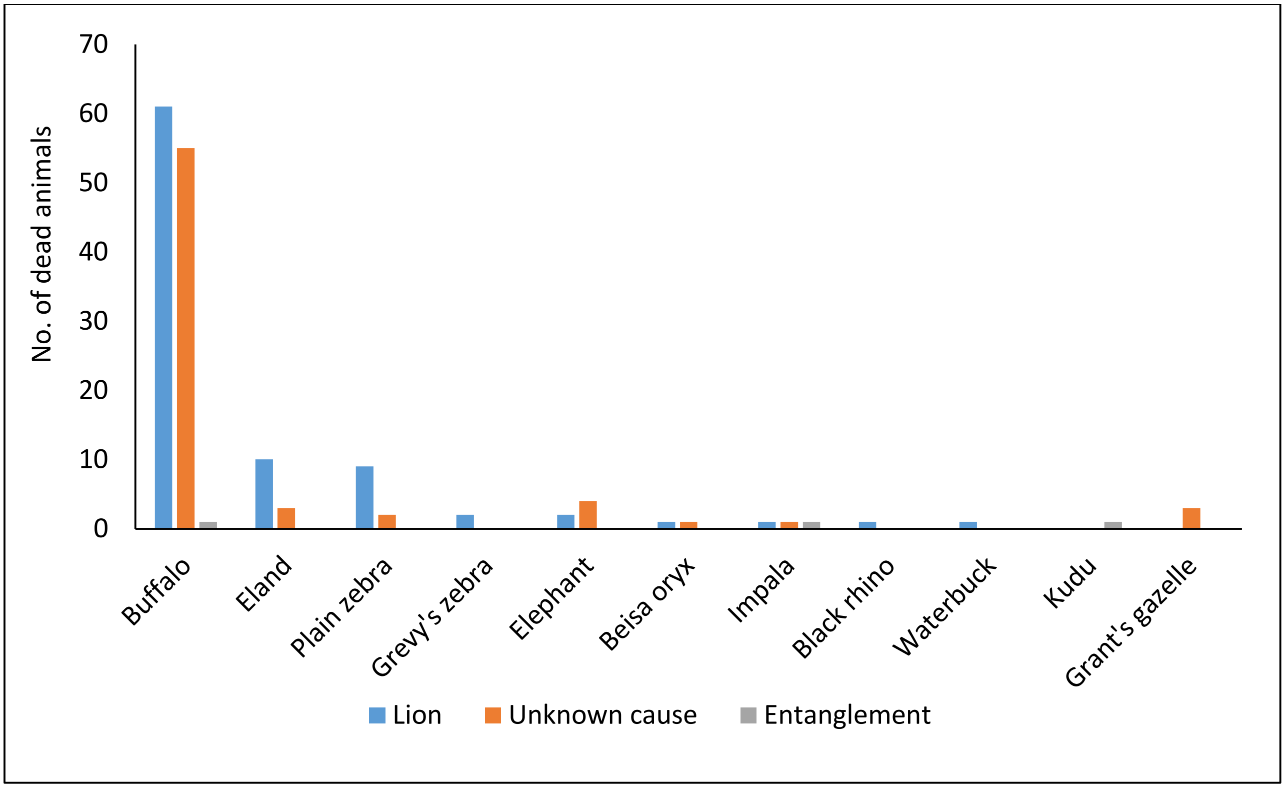

Figure 2.3.5 Causes of wildlife mortality on LBL, 2022.

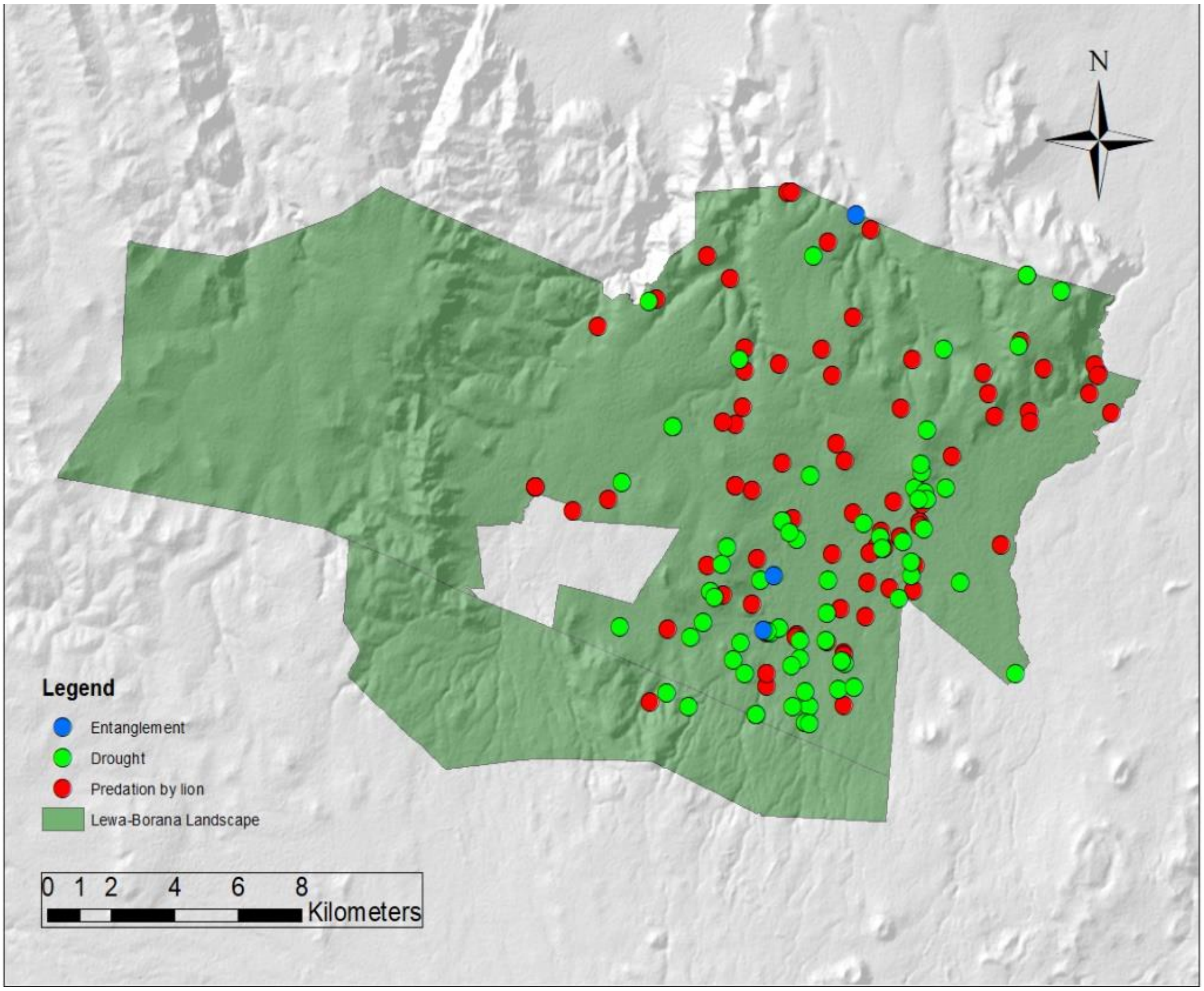

Figure 2.3.6 Spatial distribution of wildlife mortality in Lewa Wildlife Conservancy.

2.3.6 Wildlife movement through the migratory corridors

Connectivity is a landscape-level ecological requirement that leads to a properly functioning and more resilient ecosystem (Baguette, *et al.*, 2013). LBL has a number of wildlife corridors, which serve as passage routes between the larger northern Kenya and LBL, with connectivity to access other habitats like the Mt. Kenya forest to the south. This provides wildlife with vital roaming space for predation avoidance, access to larger habitats with more forage resources, escape human - wildlife conflict and at the same time reduce inbreeding, thus improving the genetic viability of the various species (Ojwang, *et al.*, 2017).

We have been monitoring wildlife movement through designated migratory routes using infrared camera traps. We analysed the movement patterns for the last ten years and compared the trends between the dry and wet periods. The gaps include the Mt. Kenya end pass which links animals to the Mt. Kenya forest, Mt. Kenya and Marania underpasses that serves animals crossing under the highways and the Northern gap.

2.3.6 (a) Mt. Kenya end pass

There was a significant difference in crossing events of all wildlife over the past 10 years on the Mt. Kenya end pass between the dry period (23,359) and wet period (27,732) (χ^2 = 374.3, df = 1, p = 0.0001). In 2022, there were more crossing events of elephants towards the corridor leading to Marania underpass (160) than towards Mt. Kenya forest (125) during the dry period (χ^2 = 4.2982, df = 1, p = 0.0382). During the wet season, there were more crossing events of elephants towards the corridor leading to Marania underpass (158) than towards Mt. Kenya forest (98) (χ^2 = 14.062, df = 1, p = 0.0002) (Figure 2.3.5b).

The trend indicates a significant increase in crossing events for all wildlife for the past 10 years (χ^2 = 16551, df = 9, p = 0.0001) (Figure 2.3.5c). The figures below show the trends in the gaps usage:

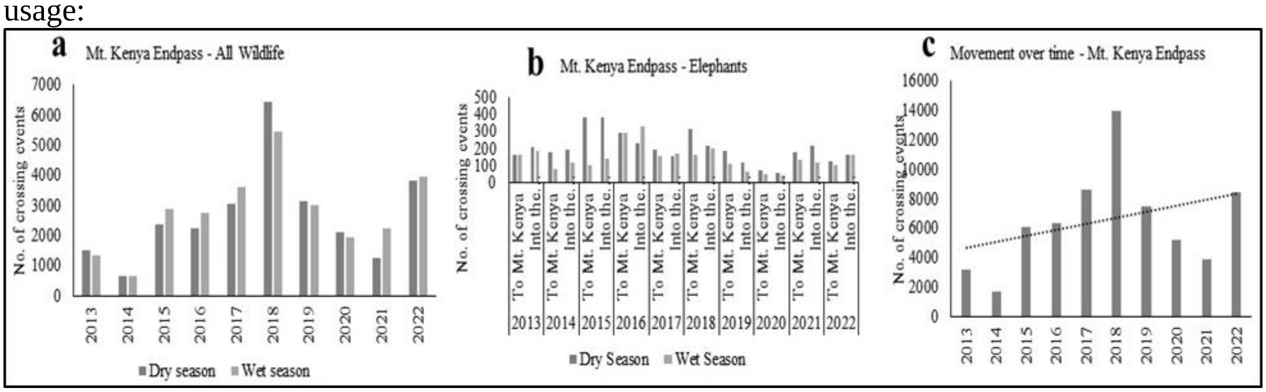

Figure 2.3.7 a) Seasonal movements of all wildlife species using the gap; **b)** Seasonal movements of elephants; and **c)** Trends of all wildlife species using the gap.

2.3.6 (b) Marania underpass

The Marania underpass has been in operation for the last 4 years. It facilitates animals crossing under the Marania-Meru highway. During this period the underpass recorded a total of 2,845 crossing events. There was a significant difference in crossing events between the dry season (1,058) and wet season (1,320) period (χ^2 = 28.866, df = 1, p = 0.0001). During the dry season, there were more elephant crossing events towards Mt. Kenya forest to the south than from the forest northwards (χ^2 = 0.2915, df = 1, p = 0.5893). During the wet period, there were more elephant crossing events from the forest towards Mt. Kenya underpass (207) (193) (χ^2 = 0.49, df = 1, p = 0.4839). The trend indicates a significant increase in crossing events for all wildlife from

2019 to date (χ^2 = 401.25, df = 3, p = 0.0001). The figure below shows the wildlife usage of the gap:

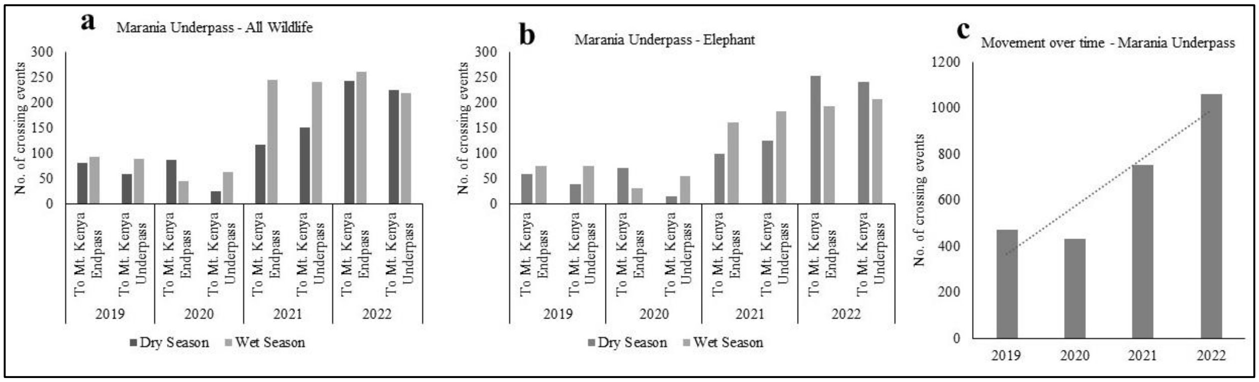

Figure 2.3.8 a) Seasonal movements of all wildlife species using the gap; **b)** Seasonal movements of elephants; **c)** Trends of all wildlife species using the gap.

2.3.6 (c) Mt. Kenya underpass

There was a significant difference in crossing events of all wildlife on the Mt. Kenya underpass for the last 10 years between the dry season (12,381) and wet season (9,434) (χ^2 = 398.11, df = 1, p = 0.0001). In 2022, there were more elephant crossing events towards Mt. Kenya forest through the underpass (385) than from the forest northwards to Lewa (330) during the dry period (χ^2 = 4.2308, df = 1, p = 0.0397). During the wet period, there were more elephant crossing events from the forest towards Lewa (244) than southwards to the Marania underpass through (208) (χ^2 = 2.8673, df = 1, p = 0.0904).

The trend indicates a significant increase in crossing events for all wildlife for the past 10 years ($\chi2$ = 4469.4, df = 9, p = 0.0001) through the underpass s shown in the figures below:

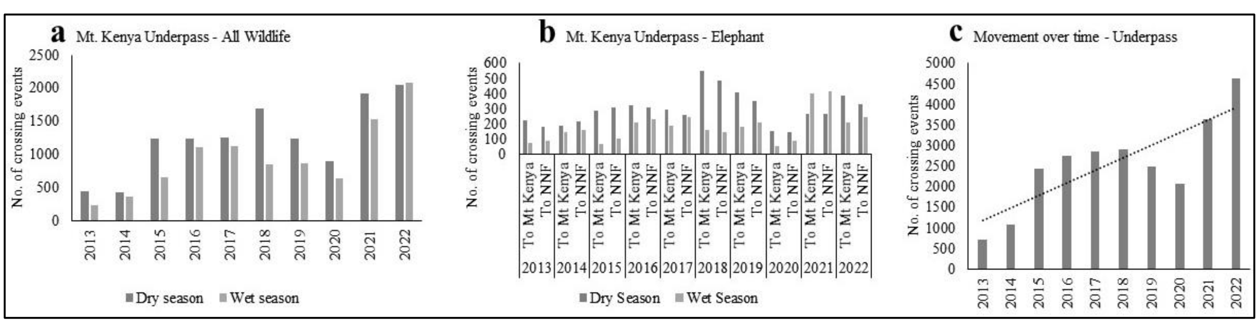

Figure 2.3.9 a) Seasonal movements of all wildlife species using the gap; **b)** Seasonal movements of elephants; and **c)** Trends of all wildlife species using the gap.

2.3.6 (d) The Northern gap

This is the gap that links LBL with the animal migrations to and from the northern Kenya conservancies. There was a significant difference in crossing events of all wildlife on the Northern gap for the past 10 years between the dry period (56,852) and the wet period (66,612) ($\chi^2 = 771.54$, df = 1, p = 0.0001). In 2022, there were more crossing events of elephants during the dry period into Lewa (1,324) than out of Lewa (1,316) ($\chi^2 = 0.0242$, df = 1, p = 0.8763). During the wet period, there were more elephant crossing events out of Lewa towards the north (1,676) than into Lewa from the north (1,293) ($\chi^2 = 49.407$, df = 1, p = 0.0001).

The trend indicates a significant decrease in crossing events for all wildlife for the past 10 years ($\chi2 = 7240.2$, df = 9, p = 0.0001) as show in the figures below:

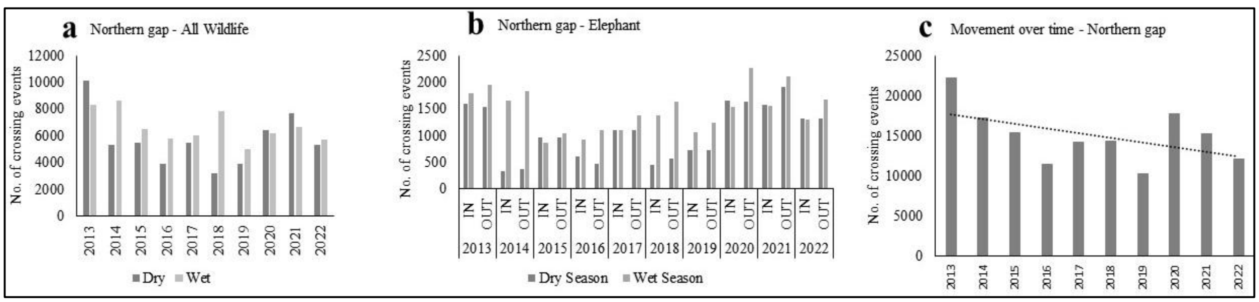

Figure 2.3.10 a) Seasonal movements of all wildlife species using the gap; **b)** Seasonal movements of elephants; and **c)** Trends of all wildlife species using the gap.

Rainfall distribution and seasonality is the principal driver of animal migration and dispersal as it influences the availability and quality of vegetation and surface water (Bartzke, *et al.*, 2018). 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.

2.3.7 Conclusion and recommendations

We continue to engage with the WILDBOOK team to complete the development of CODEX, a software that will use machine learning and artificial intelligence (AI) to process Grevy's zebra images, apply species labels, and suggest matching individuals from within the database. This being an automated system, will reduce the time taken to process the images for monitoring the survival of foals to near real-time.

2.4 Elephant Monitoring

Elephants (*Loxodonta Africana*) are known to manipulate the ecosystem through feeding and trampling thus modifying woody species composition in protected areas (Dublin, Sinclair, and McGlade. 1990). Long-term shifts in temperatures and weather patterns (climate change) influence the feeding behaviour of elephants leading to excessive vegetation damage and crop raiding due to reduced forage levels in protected areas. This excessive damage exposes trees to secondary damage by pests and diseases (Pamo and Tchamba, 2001**).**

The LBL experiences similar challenges within and on the surrounding community lands, especially during severe or prolonged dry periods such as this experienced year. We monitored elephant demographics to get insights on their usage of the landscape and document fence breakage and crawling incidences and at the same time identifying the culprits.

2.4.1 Population demographics and fence breaking incidences

During the year, we documented 11 resident matriarchal family groups comprising 168 individuals. We also recorded 15 lone bulls currently within the landscape. Other residential family groups moved to Mt. Kenya possibly in search of pasture during the dry period.

We documented a total of 243 fence breakages and 34 crawling incidences. Out of these breakages, 83% (n=202) affected the exclusion zones fence lines which involved snapping the wires and breaking the posts while 17% (n=41) were breakages on the main boundary fence. All 34 crawling incidences occurred in the exclusion zones as these were the only available areas of high woody vegetation concentration during the prolonged dry periods making them a target for elephants.

The most affected boundary fence lines were on the southwest parts of the landscape areas bordering wheat farms and other small-scale farms. The figure below shows the breakage hotspots:

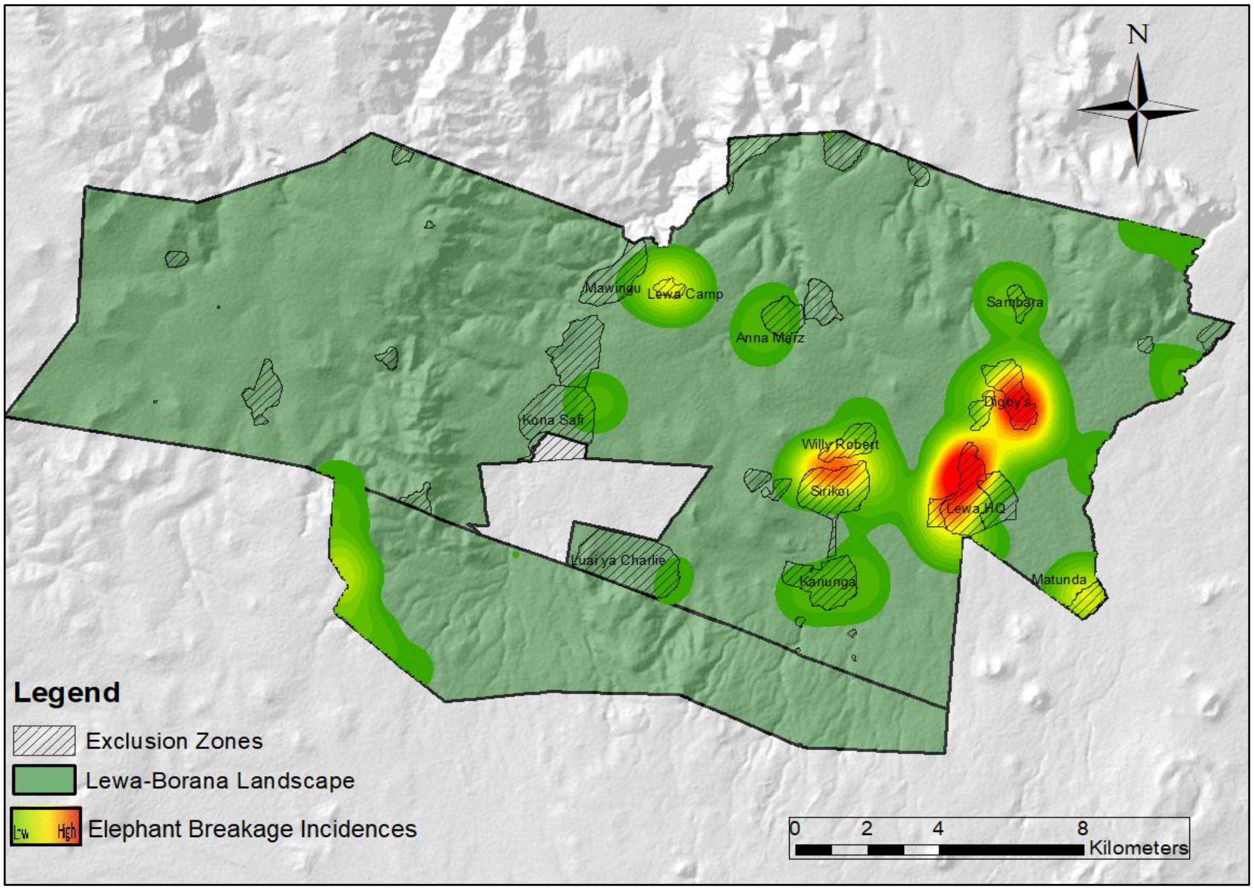

Figure 2.4.1 Heat map of elephants' breakage incidences on LBL.

The most affected exclusion zones were *Lewa HQ, Sirikoi, Digby's, Junction Tano and Lewa Safari Camp* as shown in the figure below:

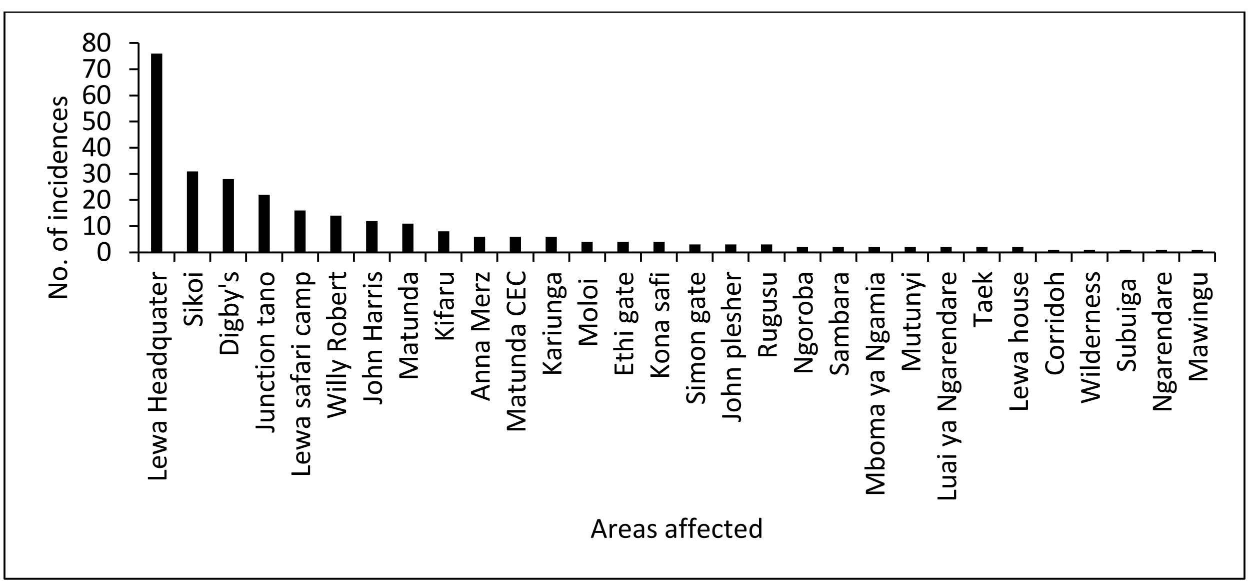

Figure 2.4.2 Incidences of breakages and crawling across various locations.

The matriarchal family groups namely, *Mugumo, Linnet, Sanaipei, and Mama Safi*, remained within the landscape throughout the year and continued to access the exclusion zones via crawling, with *Mugumo* having the highest incidences in the area as shown in the figure below:

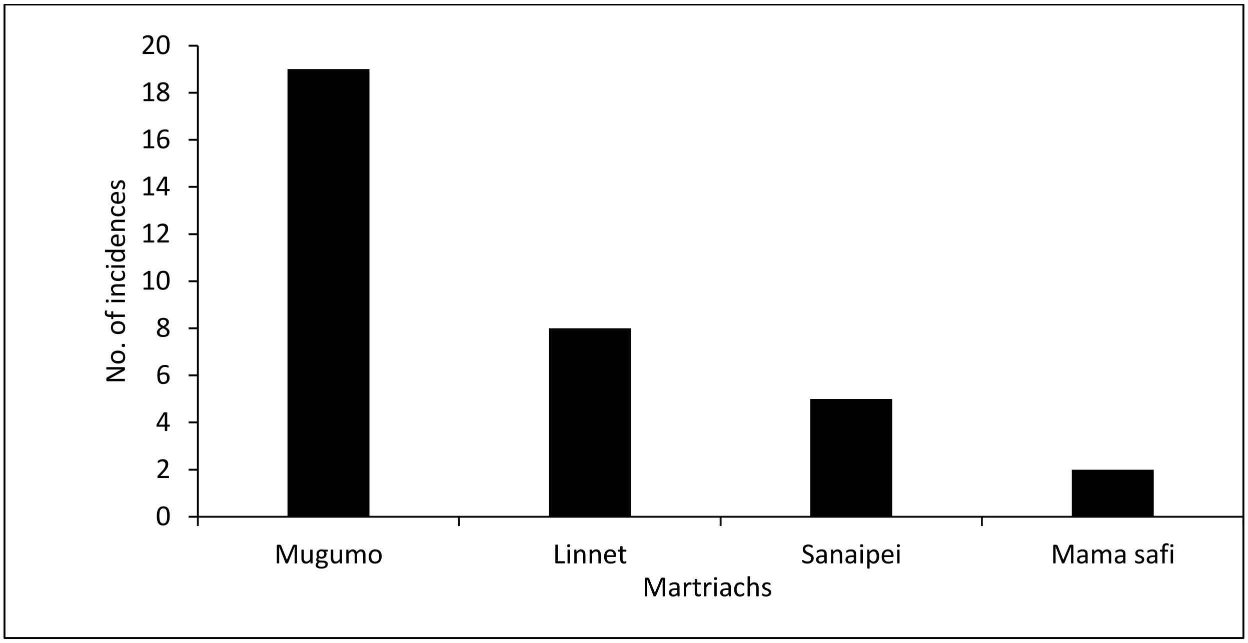

Figure 2.4.3 Family groups incidences of crawling under the exclusion zone wires.

Out of 15 resident bulls, *Mjasiri, Moreher, Budi, Mukume, Keke, One right tusker, Dumbo, and Odongo*, were the main bulls responsible for fence breakage incidences in the landscape as shown in the figure below:

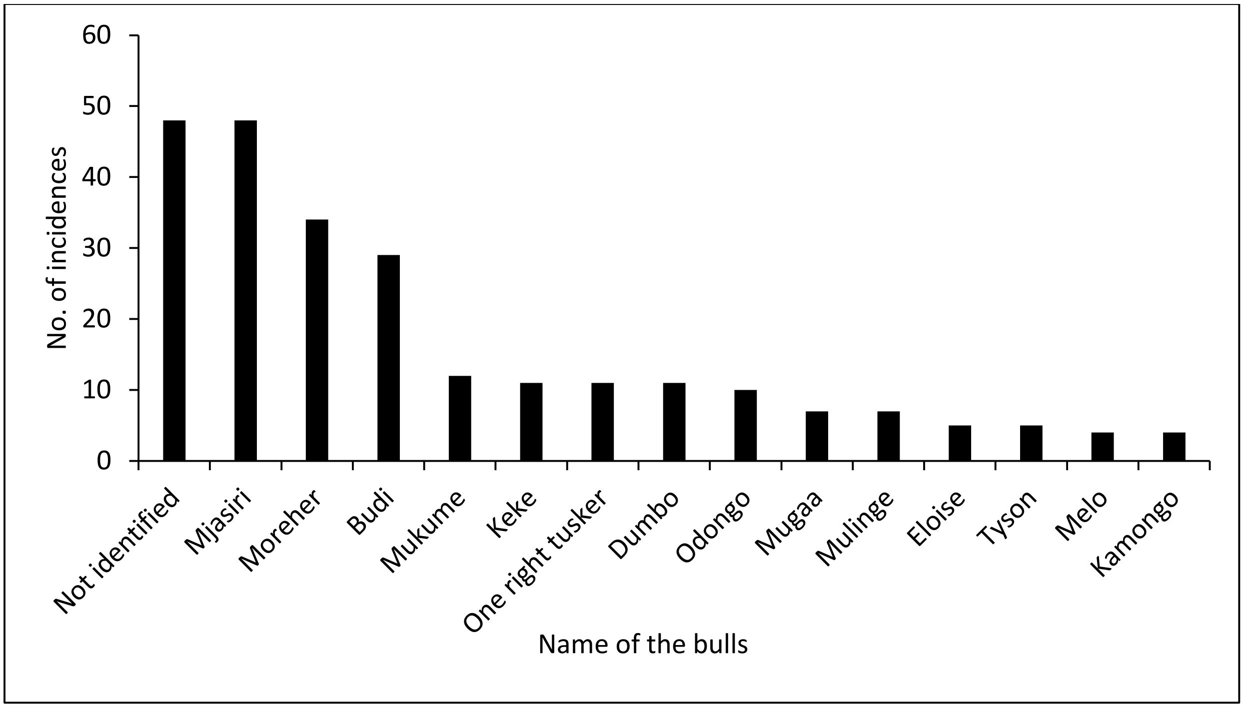

Figure 2.4.4 Elephant bulls responsible for fence breakages.

In collaboration with Save the Elephants (STE), *Mugumo* (an adult problematic female elephant), formerly known as *Natasha*, was collared to monitor her spatial-temporal movements through the Earth Ranger (ER) platform. This is helping provide early warning to the residents, tourist operators, as well as neighbouring communities. We also replaced two non-functional collars on two females of different groups namely *Naisula* from the *Samburu Girls family* and *Cointreau* from the *Tia Maria family*.

2.4.2 Conclusion and recommendations

Human-elephant conflict will continue to be a major conservation challenge to the landscape stakeholders including the communities within and surrounding their ranging areas. To mitigate these conflicts, there is a need to fast-track the fence upgrades and continue embracing existing and new technologies such as drones, EarthRanger (ER) for real-time monitoring, collaring, and enhancing capacity of the Human-Wildlife Conflict response teams, among other innovations for a swift response.

There is a need to benchmark with other organizations undertaking research, monitoring, and management of elephants such as the Mara Elephant Project for experience exchange.

Due to the increased number of elephants in this landscape and the possible expansion of their monitoring into Il Ngwesi and Leparua community conservancies, there is a need to source a compatible elephant database that will capture demographic data for all residents and non-resident elephants.

2.5 Rangeland Monitoring

Monitoring of rangelands is key in quantifying the impact of various drivers of ecosystem change over time (Giesen, *et al.,* 2017). Various rangeland interventions and natural causes have had an impact on the LBL rangelands which are important to document for informed management decisions. We describe various outputs on the annual grass and vegetation assessments that were undertaken on the landscape on fixed monitoring points to inform dynamics in the composition of tree species, diversity, and extent of damage or browse by different wild animals.

2.5.1 Grass assessment

The annual grass assessment in pre-determined monitoring points for the year was undertaken, covering four Management Units (MUs) namely (Plain – P, Forest – F, Rocky – R, and Riverine – RV). The assessment focused on biomass, diversity, and ground cover.

There was a significant difference in the mean biomass production across the years (2011 – 2022) ($F_{(10, 279)} = 10.41$, $p = 0.0001$). A drop in the mean biomass in 2021 and 2022 can be attributed to the depressed rainfall across the landscape. In 2022, we recorded a significant difference in mean biomass across the four MUs ($F_{(3, 23)} = 4.25$, $p = 0.0158$). Forest had the lowest above-ground grass biomass which could be attributed to heavy grazing by buffalo herds and unrestricted livestock access. The figures below show trends in the mean grass biomass across the management units:

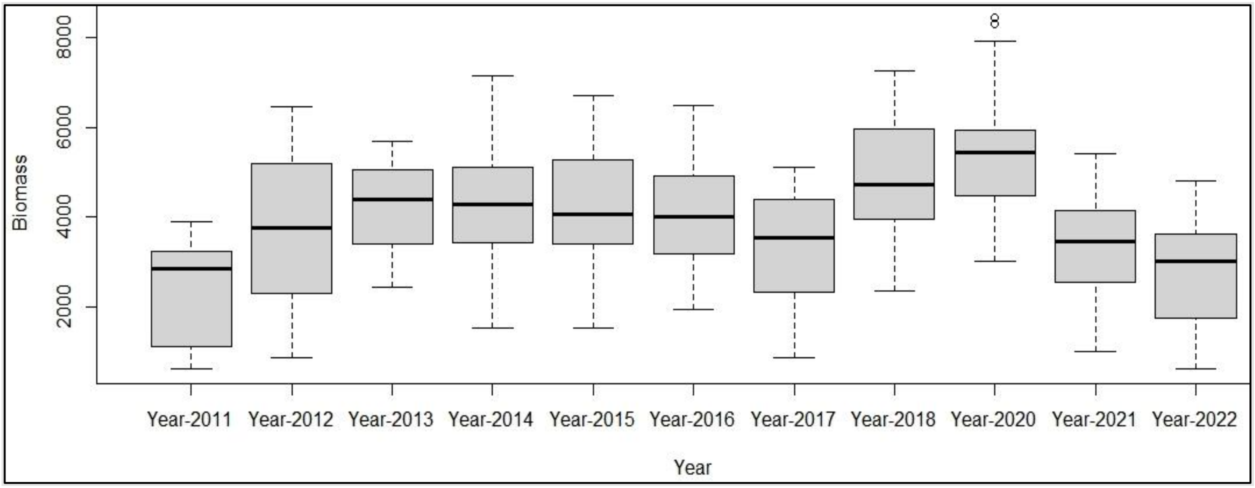

Figure 2.5.1 Annual fluctuations in mean grass biomass from 2011 – 2022.

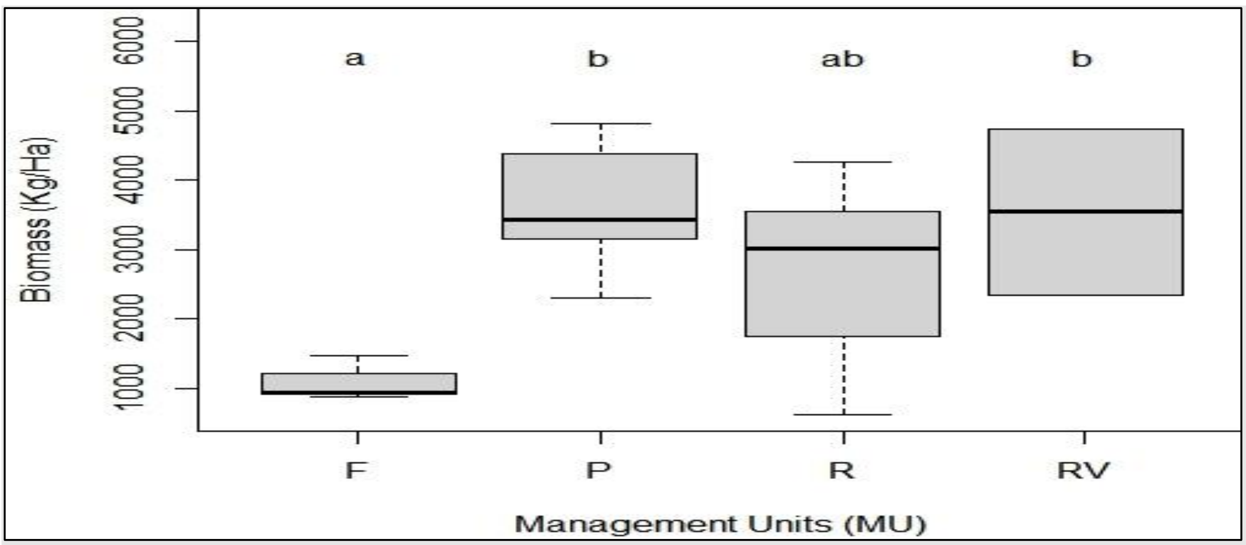

Figure 2.5.2 Mean grass biomass across management units in 2022.

The mean diversity varied significantly across the years (2011 – 2022) ($F_{(10, 270)} = 9.404$, $p = 0.0001$). This was attributed to depressed rainfall throughout the year which negatively affected the growth of annual and perennial grass species. This was also the reason for the lower species diversity in 2022 compared to most of the previous years. There was no significant difference in mean diversity across management units (MU) ($F_{(3, 23)} = 1.546$, $p = 0.2300$) as shown in the figures below:

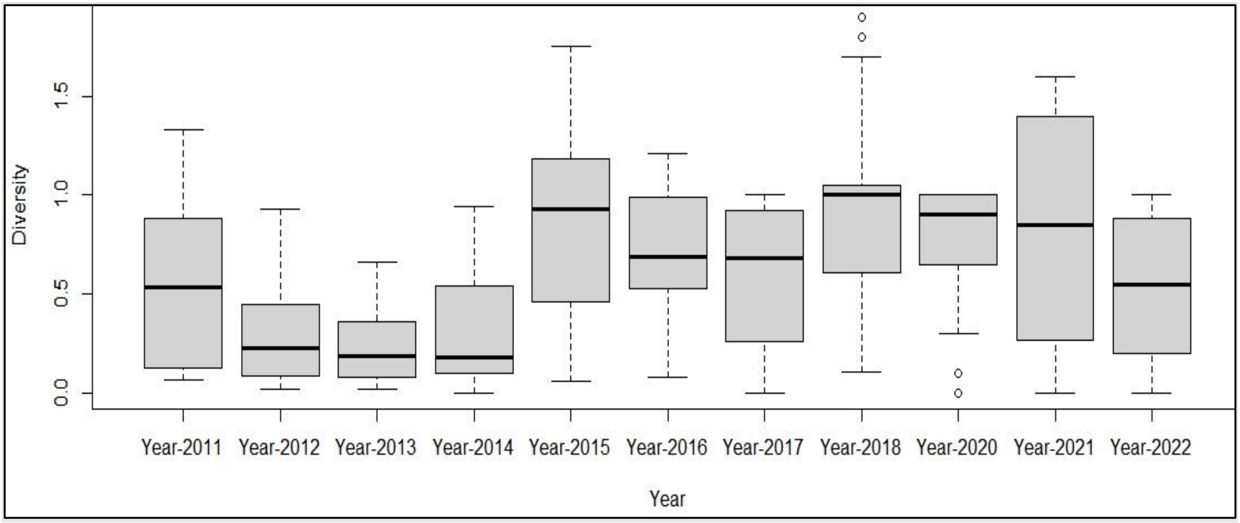

Figure 2.5.3 Annual fluctuations in mean species diversity from 2011 – 2022.

Kruskal-Wallis test indicates a significant difference in the medians of ground cover across years (2011 – 2022) (*H (10)* = 92.735, p = 0.0001). This was also attributed to the low rainfall. The median of cover across the management units was not statistically significant (*H (4)* = 7.9182, p = 0.0500) as shown below:

2.5.3 Normalized Difference Vegetation Index (NDVI)

NDVI is used to quantify vegetation greenness, which then helps in understanding vegetation density and assessing changes in plant health. NDVI is calculated as a ratio between the red (R) and near-infrared (NIR) values from satellite-derived multispectral images. Free Landsat 8 imageries for various months in 2021 and 2022 for LBL were downloaded from the United States Geological Survey (USGS) Earth Explorer platform and used to produce NDVI maps using ArcMap 10.8.1 for comparisons.

2021 and 2022 were generally low in terms of vegetation productivity. However, 2022 was worse compared to the last year occasioned by the prolonged dry period. The riverine areas, the Ngare Ndare Forest Reserve (NNFR), the swamps, and the *Sirikoi* exclusion zone near the *Lewa headquarters* prominently stood out in greenness which attracted wildlife during the dry periods. Even though the dense clouds in some months obstructed visibility, the western part of the landscape appeared slightly improved in vegetation productivity due to some rains that have been passing through that section. The figure below shows a comparison of changing trends of NDVI 2021 and 2022:

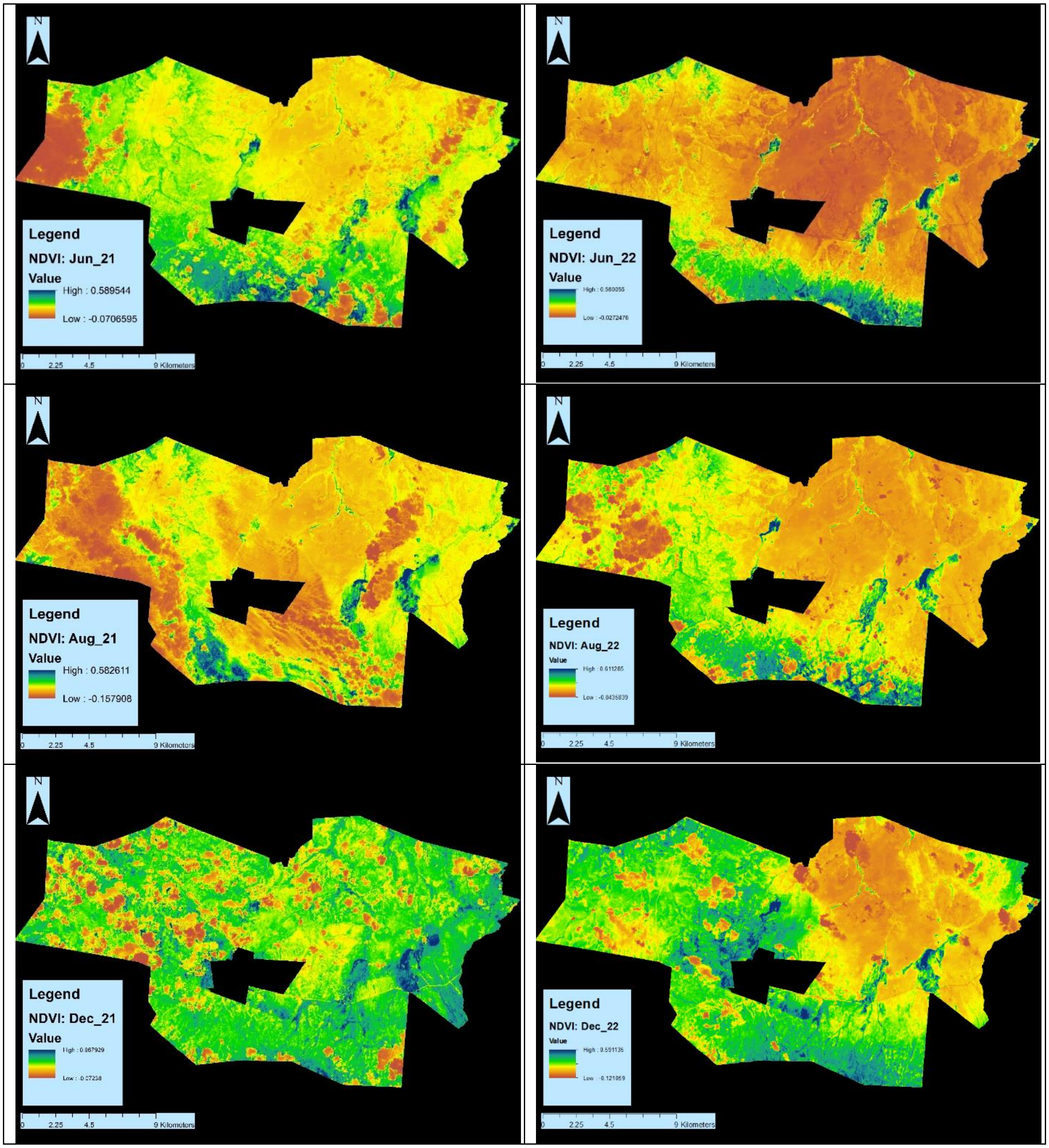

Figure 2.5.4 Comparison of NDVI for the Lewa - Borana Landscape for 2021 and 2022.

2.5.4 Woody vegetation assessment

Woody vegetation provides food and habitat for a variety of wildlife including herbivores and birds (Ogada, *et al.*, 2008). We assessed the 28 permanent monitoring sites on the Lewa side to quantify changes in woody vegetation and the impact of different browsers on the landscape. Data indicated a general decline as shown in the figure below.

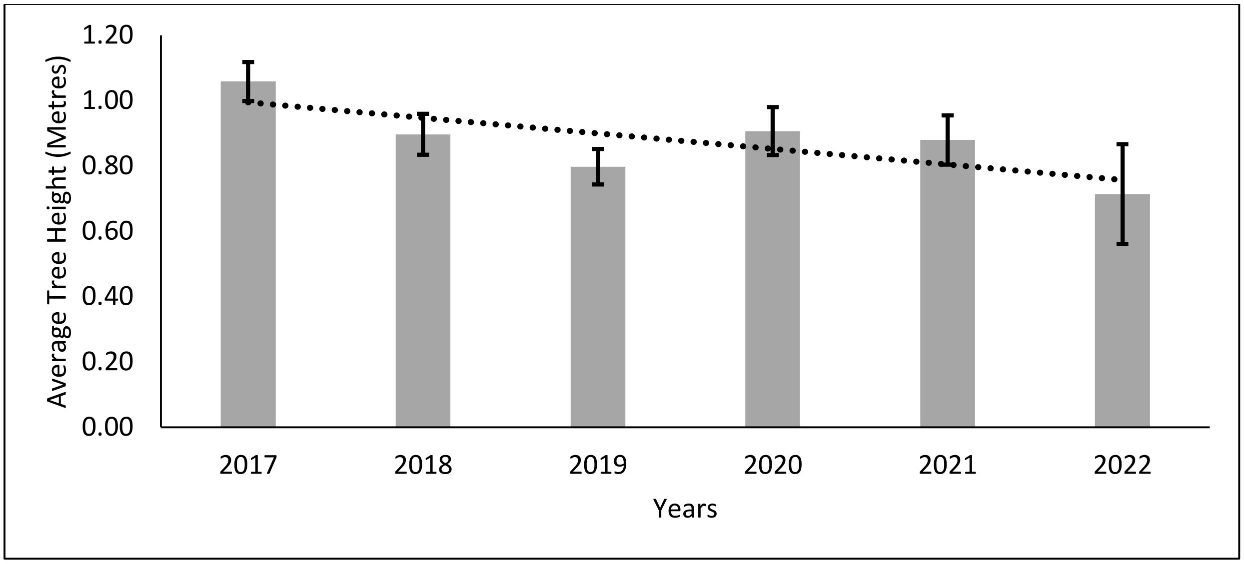

Figure 2.5.5 Average tree heights on the landscape.

The key species which had a significant impact on the woody vegetation through browsing were elephants, Black rhinos and giraffes (Birkett, 2002) as shown in the figure below:

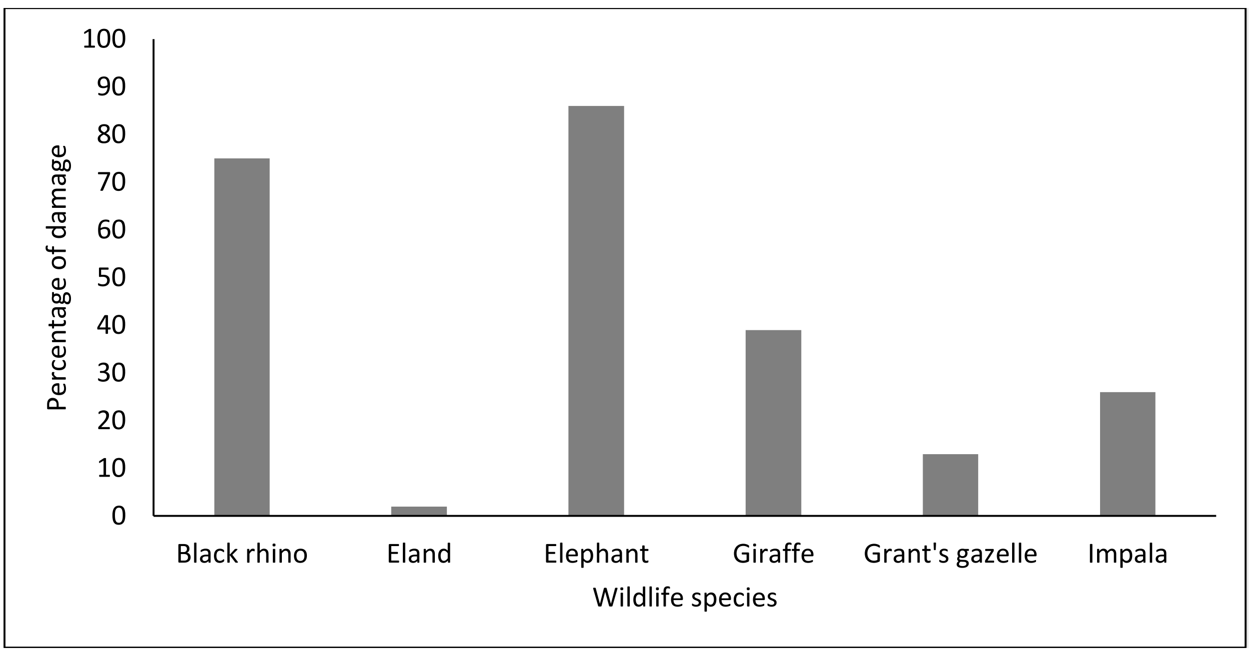

Figure 2.5.6 Cause of woody vegetation damage by wildlife species.

To reverse the declining trend, LBL management over the years has put in place intervention measures which include the creation of recovery zones and targeted reseeding / seedling. We monitored two fully excluded plots which were reseeded with *Acacia xanthophloea* in 2018 (Hq1 & Hq2). We also monitored another two partially excluded plots which were put under natural regeneration (As1 & As2). Both interventions recorded positive trends as shown in the figure below:

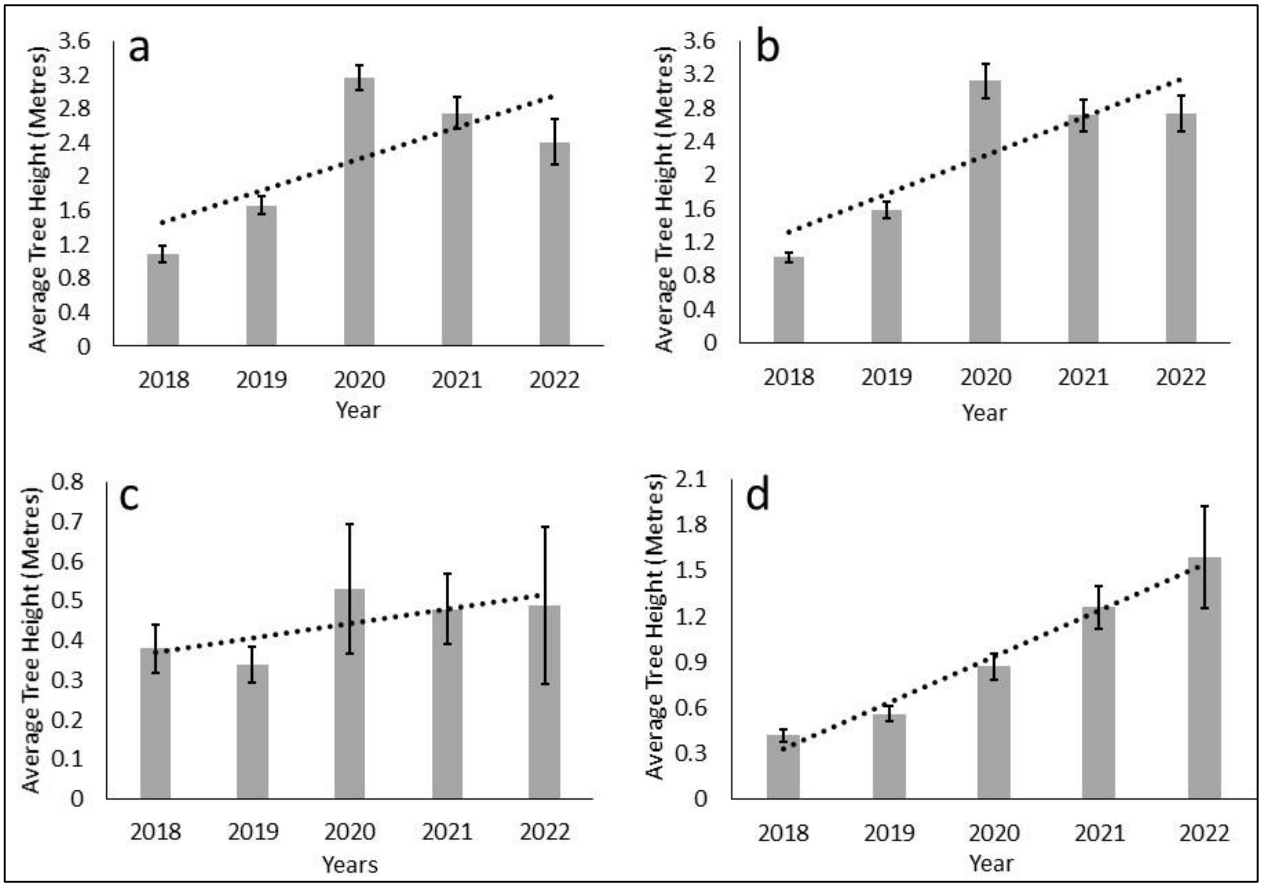

Figure 2.5.7a) Average tree height in plot Hq1; **b)** Average tree height in plot Hq2; **c)** Average tree height in As1; and **d)** Average tree height in As2.

2.5.5 Land Degradation Surveillance Framework (LDSF)

In 2021, we collaborated with the World Agroforestry Centre (ICRAF) to assess soil and ecosystem health on LBL using their LDSF. The framework offers a consistent set of indicators and field protocols to evaluate ecosystem health. The indicators consist of grass species diversity, shrubs, vegetation cover and structure, infiltration capacity, soil characteristics and land degradation status. The results were presented in October 2022 with the following findings:

- The landscape shows a high diversity of forbs and woody herbaceous plants in particular, but also highlights the importance of perennial grasses in facilitating this diversity.
- *Cenchrus stramineus* was the most dominant grass species on Lewa.

- Soil health assessments showed strong variations in infiltration capacity between clusters and across soil types. Nitisols were the most well-drained, as expected, but with high variability. Gleysols were the least well-drained.
- Soil Organic Carbon (SOC) showed high levels of variability both within and between LDSF sampling clusters, with the highest topsoil SOC concentrations found in freshwater aquatic systems, followed by forest areas.
- Wooded grasslands and grasslands had similar concentrations of SOC. The maps of soil properties have a wide range of pH values and generally low sand contents in top soils on Lewa. In other words, the clay content is relatively high in general.
- There was a strong variation in SOC in the grasslands with hilly areas having lower SOC and areas that were dominated by vertisols having higher SOC. (Vågen and Winowiecki, May 2022, unpublished draft report).

2.5.6 Conclusion and recommendations

As we observe a continuous increase in the herbivore population, especially of elephants on the landscape, we need to put in place innovative measures to increase woody vegetation cover through the creation of exclusion zones and maintaining the black rhinos within their carrying capacity.

2.6 Avifauna Monitoring

Birds are diverse and perform some of the most important ecological roles among vertebrates such as pest control, pollination, seed dispersal, fertilization of the soil, and plant reproduction (Parreno, *et al.,* 2020; Amat & Green, 2010). They also are threatened by activities like habitat loss and human persecution (Tabur and Ayvaz, 2010; Koskimies, 1989).

LBL is an important host to a diverse avian community offering a favourable stop-over for large populations of migratory birds from Europe and northern Asia. It also offers roosting, breeding, and foraging areas for resident birds. We aim to provide long-term data that allow evaluation of their conservation status (Schmeller, *et al.,* 2012). During the year, we kept an updated bird checklist, conducted monthly waterbird and raptors surveys, and also updated a preliminary checklist of the birds of Il Ngwesi Community Conservancy.

2.6.1 LBL Birds' checklist

The LBL birds' checklist has 83 families comprising 488 species of different categories of IUCN status. This represents over 42% of the 1,152 total species found in Kenya (Lepage, 2022). We collaborated with birders' clubs in the landscape to take photo-evidence and record sounds to ensure we got fully updated evidence files, which has improved from 75% in 2021 to 78% in 2022.

We also participated in the bi-annual global ebird count led by Cornell University, which supports the World Migratory Birds' Day celebrations. The first count in May recorded a total of 186 and 125 species in Lewa and Borana respectively (eBird, 2022a). In this count, the Lewa and Borana Conservancies were ranked 2nd and 5th in the Kenyan Birding Hotspots list respectively (eBird, 2022a). In the second count in October 2022, Lewa and Borana conservancies recorded a significant improvement where they ranked 1st and 3rd by recording 210 and 167 species respectively (eBird, 2022b). The table shows the IUCN status of key birds species found on LBL:

Table 2.6.1 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	469
Grand Total	**488**

2.6.2 Waterbirds' survey

The monthly waterbirds survey recorded an average of 514±83 individuals of 52 different species.[1]Simpson's Diversity Index (Okpiliya, 2012) recorded a value of 0.8820, indicating a high

[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.

diversity. The wet season had the highest number of waterbirds (n=2,836) compared to the dry season(n=2,515).

We participated in the National Waterfowl Census in February, led by the National Museums of Kenya (NMK), and recorded a total population of 1,029 individuals of 29 species of waterbirds. The figure below shows the seasonal trends of waterbirds on LBL:

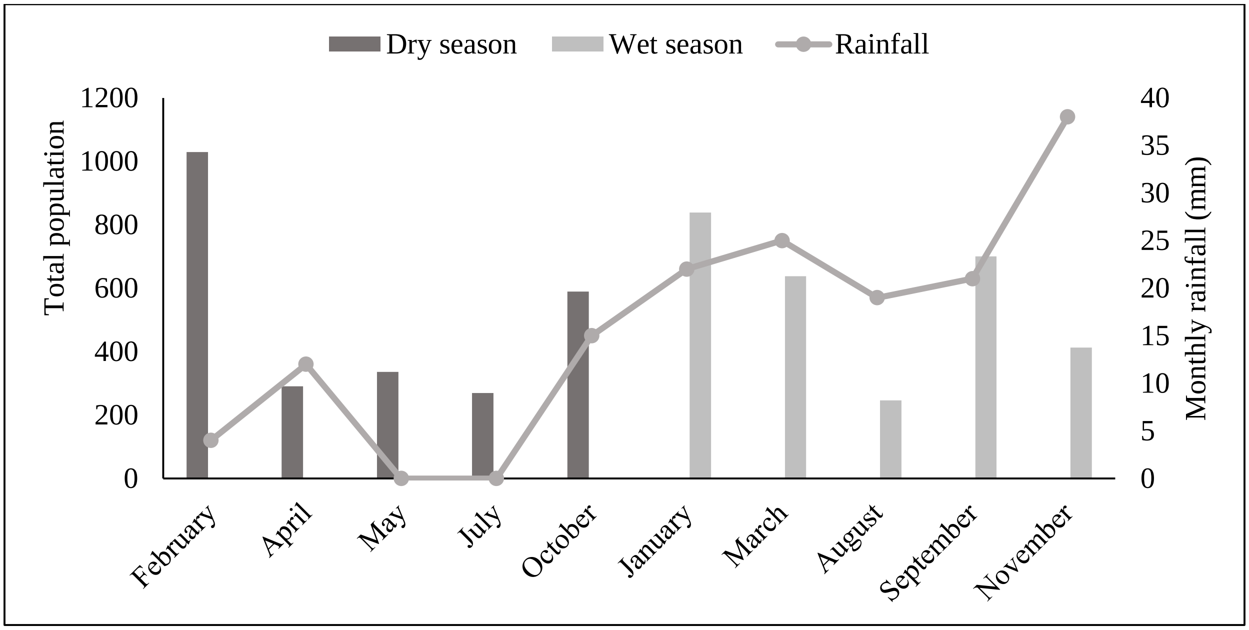

Figure 2.6.1 Seasonal waterbirds population on LBL.

2.6.3 Grey Crowned Cranes' survey

The Grey Crowned Crane (GCC) is classified as endangered by the IUCN Red List of Endangered Species (IUCN, 2022). The crane's population has been decreasing globally, attributed to habitat loss, fragmentation, hunting, and removal of eggs from the wild for food (IUCN, 2022). GCC is therefore a species of critical conservation concern on LBL as well as at the National level.

The monthly GCC surveys conducted on LBL recorded an average of 27±12 individuals. The wet period recorded significantly more individuals (167) compared to the dry period (133) ($\chi^2 = 3.853$, df = 1, p = 0.0497). The cranes make local and seasonal movements in response to rainfall, food availability, and nesting opportunities (Wamiti, *et al.*, 2020). This might have contributed to their higher numbers in the wet period. Although crane pairs were sighted on breeding displays, there were no chicks recorded. The figure below shows the population trends of GCC on LBL as recorded from our surveys:

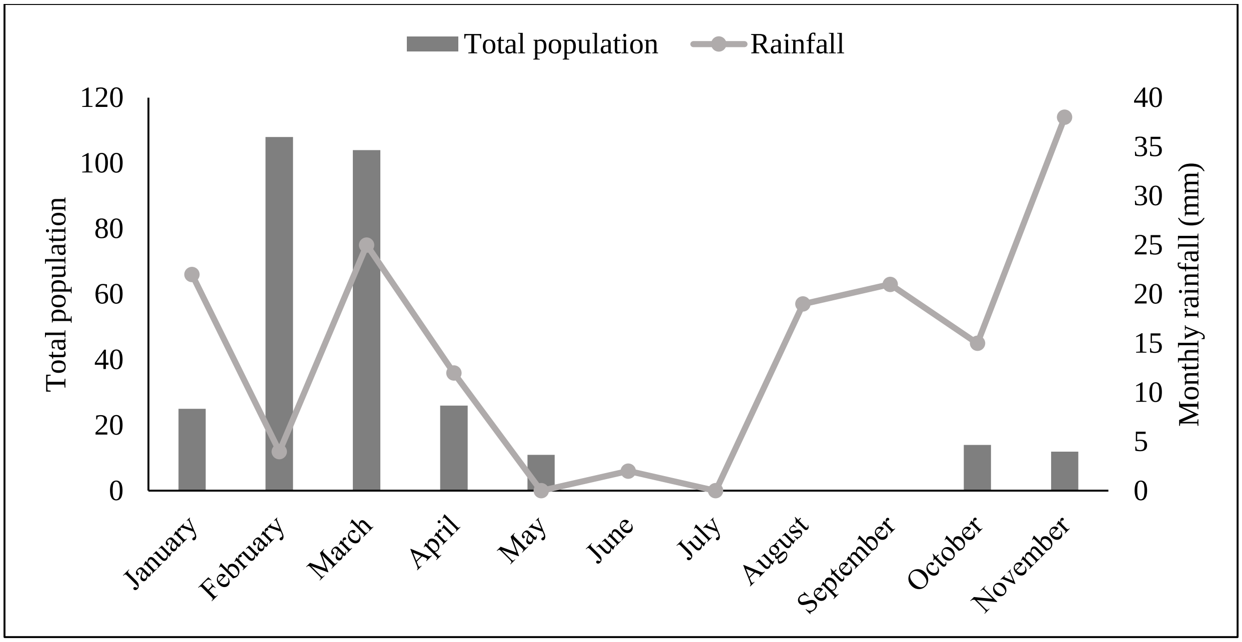

Figure 2.6.2 Total Grey Crowned Cranes population

2.6.4 Raptors' survey

There was a significant increase in the raptors population on LBL for the last four years (χ^2 = 480.24, df = 3, p = 0.0001), with the Simpson's Diversity Index indicating a higher diversity (*D* = 0.8635). Monthly surveys recorded an average of 65±11 individuals of 27 species. The dry period recorded higher numbers (424) compared to the wet season (252) period as shown in the figure below:

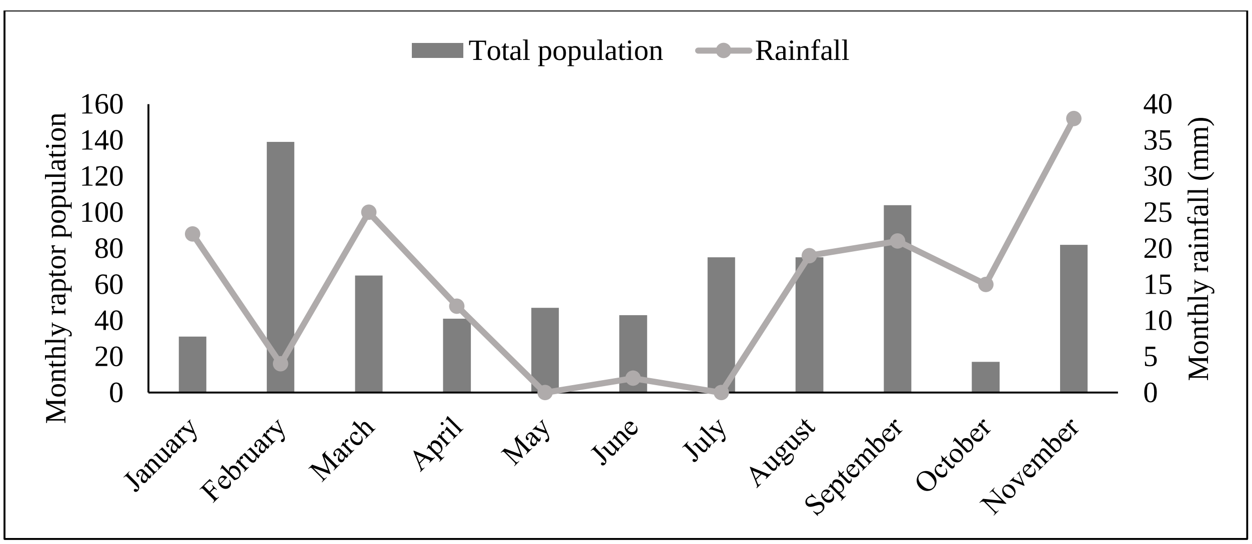

Figure 2.6.3 Monthly raptors population.

We mapped the raptors distribution and their nesting sites as shown in the figures below:

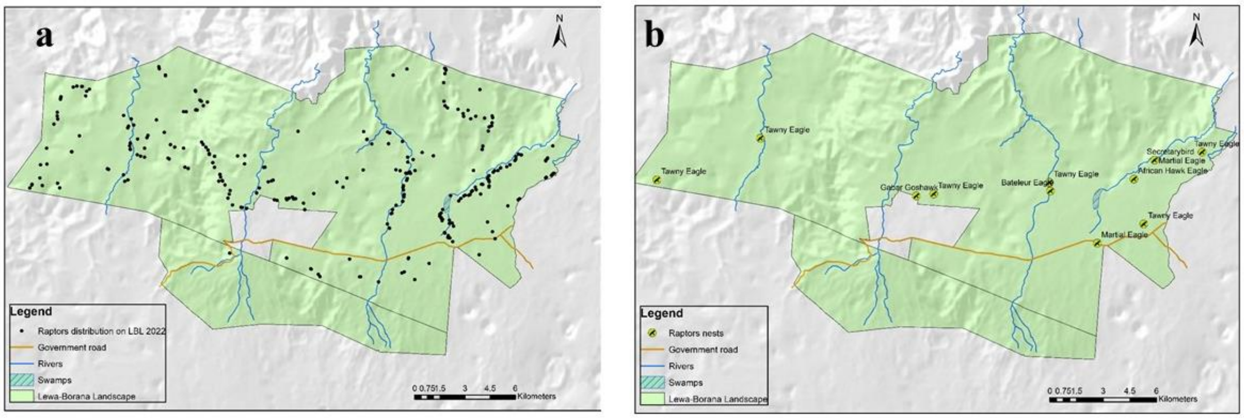

Figure 2.6.4 a) Raptors distribution on LBL; **b)** Location of nesting raptors on LBL.

We completed a one-year study to estimate the abundance, diversity, and threats facing raptors on the landscape and developed a long-term monitoring protocol. The results were presented at the 28th International Ornithological Congress held virtually from Kwa Zulu Natal, South Africa (Abstract booklet).

2.6.6 Conclusion and recommendations

From the data and findings, the LBL is a favourable home and a critical stopover for a large population of migratory birds. We recommend the use of modern effective technology for tracking their spatial-temporal movements and their diverse seasonal feeding grounds.

2.7 Herpetofauna Monitoring

Herpetofauna comprises of reptiles and amphibians. Most of these species are widespread, with hundreds of new ones being discovered every year (Wilson and McCranie, 2004). They are essential components of terrestrial and aquatic 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).

2.7.1 Herpetofauna surveys on the LBL and beyond

In 2019, we began a random survey for the critically endangered Pancake tortoise (*Malacochersus tornieri*) (Mwaya, *et al.*, 2019) that documented the presence of the species on LBL. Subsequent surveys that also included leopard tortoises (*Stigmochelys pardalis*) and terrapins (*Pelomedusa neumanni*) have so far documented 152 pancake tortoises, 5 leopard tortoises (*Stigmochelys pardalis*), and 22 terrapins on the LBL, Leparua Community Conservancy, Il Ngwesi, and Lekurruki Community Conservancies. This study documented their presence and geographic extent within and beyond our landscape.

The outcome of the surveys was presented during the Joint Annual Meeting of the Turtle Survival Alliance (TSA) and the IUCN Tortoises and Freshwater Turtles Specialist Group in August 2022 in Tucson, Arizona. The figure below shows the home ranges of the species on LBL:

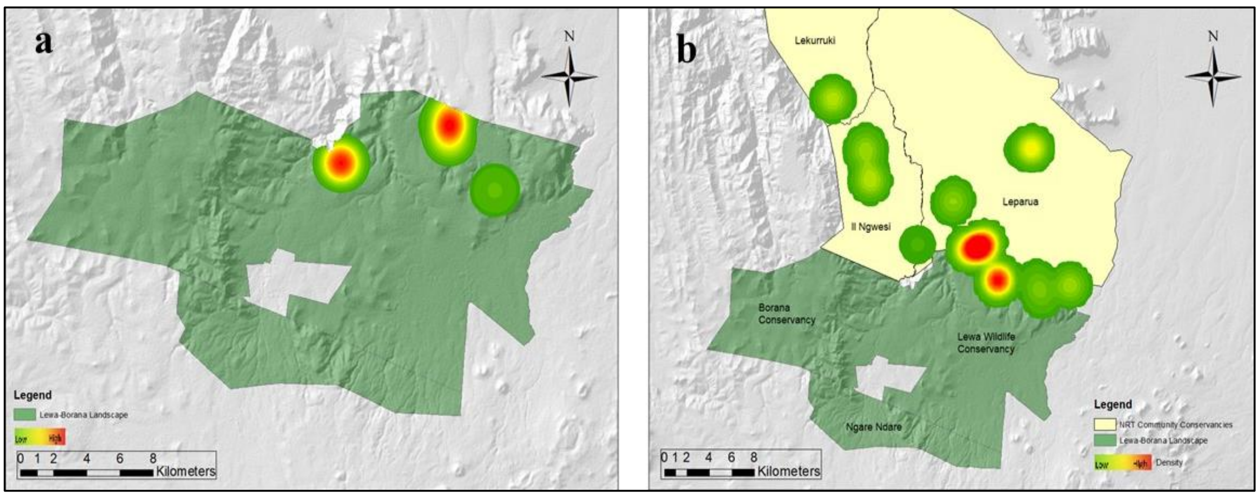

Figure 2.7.1 a) Heat map showing terrapins' home ranges on LBL; **b)** Heat map showing pancake tortoises' home ranges on LBL and Community Conservancies.

2.8 Hydrology & Weather Monitoring

We monitored, collected and analysed data on various hydrological, weather and climate-related aspects of the landscape to aid in decision-making as far as ecological management is concerned.

2.8.1 Rainfall

Rainfall for 2022 averaged 183mm, lower than the 253mm received in 2021. Additionally, this was lower than the long-term average rainfall of 505±26mm recorded in the last 47 years (1975-2021). The figures below show the rainfall trends in the short and long-term in the LBL:

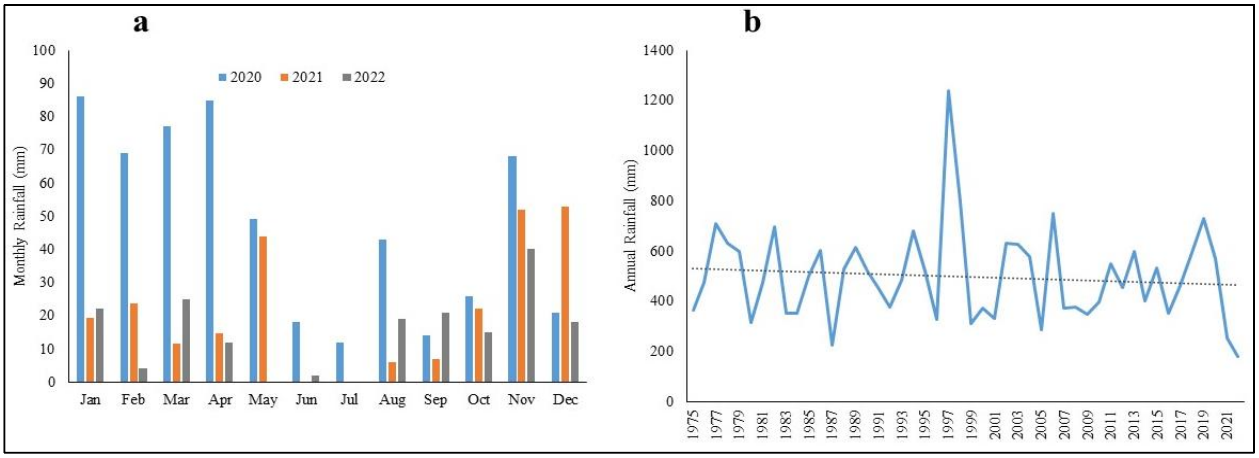

Figure 2.8.1 a) Monthly rainfall for 2020 - 2022, and **b)** Annual rainfall for the last 47 years.

2.8.2 Automated springs monitoring

We monitored river flow levels using automated River Gauging Systems (RGSs) installed at Ngare Ndare and Ngare Nyting rivers. Compared to the Ngare Nyting, there was an increase in flow rate recorded at the Ngare Ndare river from October 2022. This was attributed to higher rainfall received at Ngare Ndare forest thus increasing spring volume as seen in the figure below:

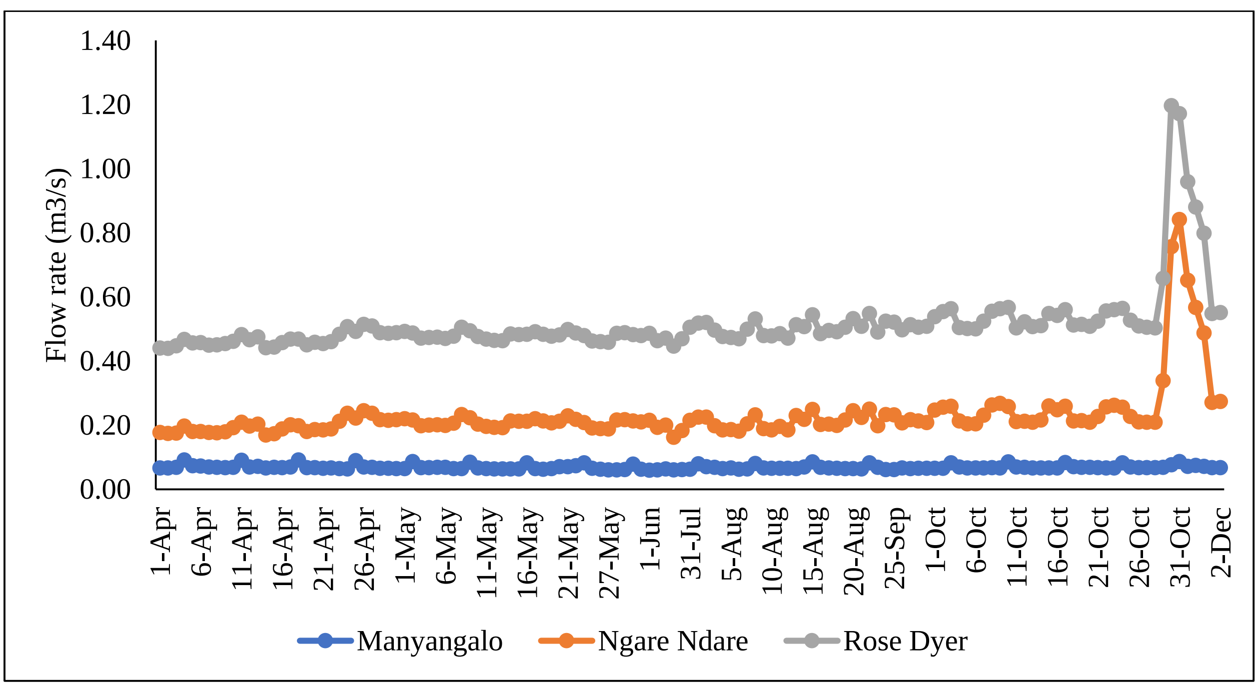

Figure 2.8.2 Flow rates by 3 RGS on Ngare Ndare and Ngare Nyting rivers.

As a result of the long drought experienced in the region, development of the flow rating equations has delayed since it requires data of both the lowest and the highest river volumes.

2.8.3 Automated weather monitoring

The calibration of the two weather stations installed at Lewa and Borana headquarters was completed and data is currently received by the EarthRanger (ER) platform through Long Range Wide Area Network (LoRaWAN).

The automated data collection is expected to replace our manual recording of weather parameters as we adopt more efficient technologies to ease the burden of data processing and sharing with our partners. The stations produce accurate weather parameters that will inform management of the current state and help us model future predictions in resource planning. The figure below shows reports from the two weather stations on LBL:

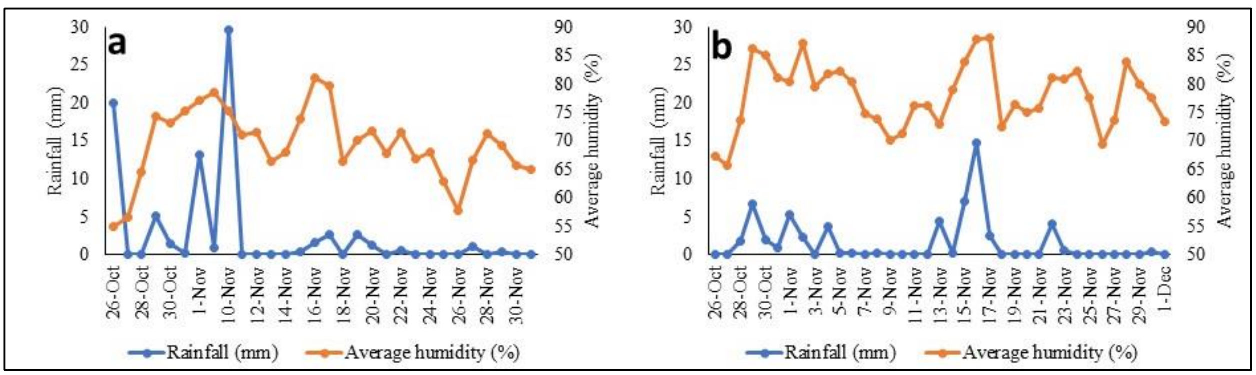

Figure 2.8.3 a) Lewa rainfall and average humidity for 2022, and **b)** Borana rainfall and average humidity for 2022.

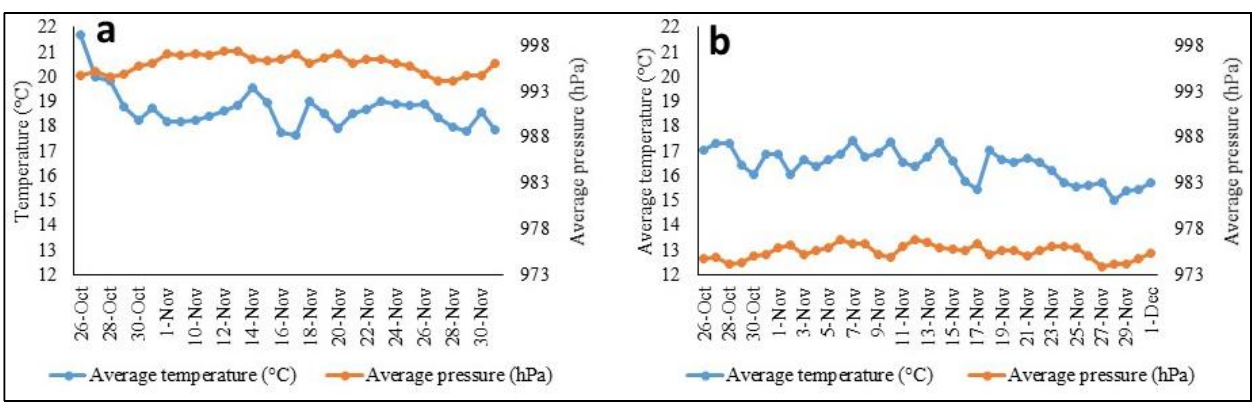

Figure 2.8.4: a) Lewa average temperature and pressure for 2022 and **b)** Borana average temperature and pressure for 2022.

2.8.4 Hydrological Survey of LBL

In partnership with local WRUAs we commissioned a comprehensive hydrological survey for LBL and neighbouring areas, which aims at understanding rainfall and climate status, surface and groundwater resources and their temporal trends. The project is being led by experienced water resource engineers subcontracted to deliver professional advice on water resource management to all the stakeholders within the agro-pastoral landscape. The team visited 120 springs and collected 41 water samples, of which 17 have been submitted to the laboratory for isotopic analysis. Also, 67 borehole sites have been visited, and 43 groundwater samples collected and submitted for isotopic analysis. This being a multi-stakeholders survey, the outcome will be shared with all concerned to help plan for the future sustainability of the resource and support government agencies on water policy formulation.

3.0 CONSERVATION EDUCATION PROGRAMM (CEP)

In 2022, the CEP directly reached a total of 8,879 individuals through various avenues including the organized day and residential group visits to Lewa, virtual engagements and the outreach programme. These groups comprised of 49 primary schools, 43 secondary schools, 7 tertiary institutions, and 17 adult groups.

In an effort to promote climate action by the youthful generation, we demonstrated this by overseeing the planting of 2,050 tree seedlings within the Lewa-supported schools in partnership with the Ewaso North Ecosystem Conservator, Ministry of Education, Ngare Ndare Forest Trust, the County Government of Meru and Mount Kenya Trust.

3.1 Day and residential programmes

The CEP runs both day and residential or boarding programmes for groups visiting the conservancy. The day programme runs between 9.00 am and 3.00 pm and is open to learning institutions that are able to participate and travel back to school or home in time.

The residential programme, on the other hand, is an option for those institutions that cannot learn and travel back within a day. Most of the institutions that participate in the residential programme come from the remotest areas of northern Kenya. The groups spend at least two nights in the CEP dormitory and be able to participate in additional activities such as the development of skits, public speaking, watching conservation films and gaining practical skills in waste management, organic farming, water and energy conservation.

From the pie chart below, it can be noted that the highest number of groups that benefitted from the CEP were primary schools (40%) followed by secondary schools (36%) while the least were mixed groups that comprised mostly of community members that participated in the outreach activities such as the World Wildlife Day, World Environment Day, conservation talks in schools and other public awareness events intended to engage the communities. See the figure below:

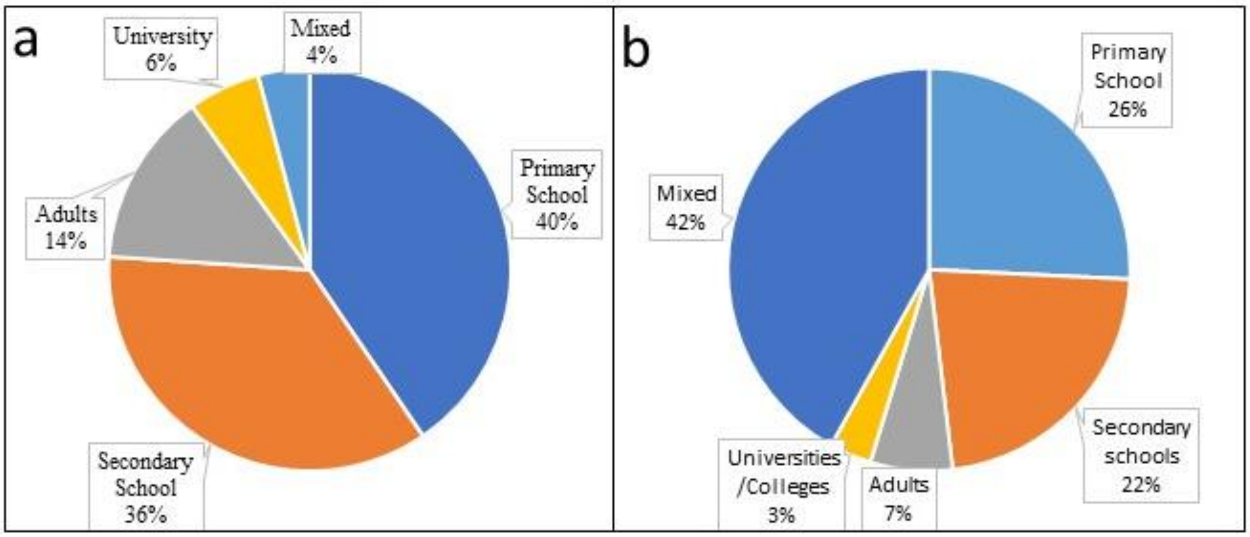

Figure 3.1.1 a) Proportion of groups from various learning institutions handled at the CEP in 2022, and **b)** Proportion of beneficiaries at CEP per learning institutions in 2022.

It is worth noting that by engaging more primary and secondary school groups, the CEP met its core objective of inspiring the young generation, often hailed as future leaders, as they had an opportunity to understand their role in the conservation and protection of the environment and wildlife and promotion of sustainable utilization of natural resources.

3.2 Sponsored groups

For three years now, the CEP has been sponsoring schools from the remote and marginalized parts of northern Kenya to visit Lewa Wildlife Conservancy. The sponsorship covers the students' transportation from their learning institutions to Lewa and back, accommodation and meals (while at Lewa) as well as the cost of the game drive and learning activities within the conservancy.

This year, with funding from the programme sponsored a total of 11 schools from Laikipia, Samburu, Marsabit, Isiolo and Meru Counties, directly impacting a total of 481 students and 41 teachers. 99.9% of the students acknowledged that these trips to Lewa were their first time visiting a conservation area.

4.0 ATTACHMENTS AND INTERNSHIP PROGRAMMES

In our effort to promote knowledge transfer to college and University students, we provide opportunities for on-job experience through attachments and internships. In 2022, we handled 5 trainees under various programmes.

5.0 PARTNERSHIPS AND COLLABORATIONS

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

a) 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 Universities, and National Museums of Kenya, Northern Rangelands Trust and Lewa Wildlife Conservancy. This collaboration was able to deliver important research reports including the Lewa Swamp Status Report 2022, and the Northern Kenya AgroPastoral Research Conference 2022.

b) ICRAF

We collaborated with the International Centre for Research in Agroforestry-ICRAF (World Agroforestry Centre), through the Land Degradation Surveillance Frame (LDSF) in which we delivered the LDSF report for LBL October 2022

c) North Kenya Veterinary Laboratory

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 across northern Kenya. They include Kenya Wildlife Service, the Wildlife Research & Training Institute, San Diego Zoo, the Northern Rangelands Trust, and Lewa and Borana Conservancies. In 2022 we were able to finalise the MoU and the Strategic plan. The veterinary laboratory is currently in its finishing phase.

d) Northern Kenya Conservation Educators Working Group (NKCEWG)

The NKCEWG supports underprivileged schools from northern Kenya to participate in Lewa's CEP. They include Wildlife Clubs of Kenya, Milgis Trust, Action for Cheetah in Kenya, Ol Pejeta Conservancy, Save the Elephants, NRT and Mpala Research Centre and San Diego Zoo Wildlife Alliance (SDZWA)

e) Pan African Conservation Education (PACE) and Digital Literacy Programme

The CEP together with the Digital Literacy Programme worked with Pan African Conservation Education (PACE) to digitize the conservation education resources to be accessed by the Lewa-supported schools. The content digitization was intended to augment the national school curriculum and enhance the teaching of environmental issues through the schools.

6.0 ACKNOWLEDGEMENTS

The Lewa-Borana Landscape Research and Monitoring Department would like to thank the following parties for their support in executing our mandate. We acknowledge with immense gratitude the management, staff and supporters of Lewa and Borana Conservancies, the Lewa International team in general for their continued technical and financial support. We also acknowledge the partnership and oversight offered by the Kenya Wildlife Service across our conservation programmes. In addition, we acknowledge the Bentley Foundation and the Prince Albert II of Monaco Foundation for funding our Hydrology and conservation programmes. We sincerely thank Tusk Trust for their invaluable support in technology and conservation efforts, Finally, we would like to thank all our other supporters for their technical and financial support to Lewa and Borana to undertake our research and monitoring programmes.

7.0 REFERENCES

Adcock, K., & Emslie, R.H., (2003). Monitoring African rhino: an AfRSG update of "Sandwith's" training course for field ranger, 5th edition: trainee's guide

Amat, J. A., & Green, A. J. (2010). Waterbirds as bioindicators of environmental conditions. In *Conservation monitoring in freshwater habitats* (pp. 45-52). Springer, Dordrecht.

Baguette, M., Blanchet, S., Legrand, D., Stevens, V. M., & Turlure, C. (2013). Individual dispersal, landscape connectivity and ecological networks. *Biological Reviews*, *88*(2), 310-326.

Balfour, D., Shaw, J., Banasiak, N., le Roex, N., Rusch, U. & Emslie, R. (2019). Concise best practice guidelines for the biological management of African rhino. WWFSA. 123pp.

Bartzke, G. S., Ogutu, J. O., Mukhopadhyay, S., Mtui, D., Dublin, H. T., & Piepho, H. P. (2018). Rainfall trends and variation in the Maasai Mara ecosystem and their implications for animal population and biodiversity dynamics. *PloS one*, *13*(9), e0202814.

Birkett, A. (2002). The impact of giraffe, rhino and elephant on the habitat of a black rhino sanctuary in Kenya. African Journal of Ecology, 40(3), 276-282.

Böhm, M., Collen, B., Baillie, J. E., Bowles, P., Chanson, J., Cox, N& Mateo, J. A. (2013). The conservation status of the world's reptiles. *Biological conservation*, *157*, 372-385.

Bohrer, G., Beck, P. S., Ngene, S. M., Skidmore, A. K., & Douglas-Hamilton, I. (2014). Elephant movement closely tracks precipitation-driven vegetation dynamics in a Kenyan forest-savanna landscape. Movement Ecology, 2(1), 1-12.

Celesia, G. G., Townsend Peterson, A., Kerbis Peterhans, J. C., & Gnoske, T. P. (2010). Climate and landscape correlates of African lion (Panthera leo) demography. *African Journal of Ecology*, *48*(1), 58-71.

Chamaillé-Jammes, S., Fritz, H., Valeix, M., Murindagomo, F., & Clobert, J. (2008). Resource variability, aggregation and direct density dependence in an open context: the local regulation of an African elephant population. *Journal of Animal Ecology*, *77*(1), 135-144.

Cockburn, A., Scott, M. P., & Scotts, D. J. (1985). Inbreeding avoidance and male-biased natal dispersal in Antechinus spp.(Marsupialia: Dasyuridae). *Animal Behaviour*, *33*(3), 908-915.

Dolman, P. M., & Wäber, K. (2008). Ecosystem and competition impacts of introduced deer. *Wildlife Research*, *35*(3), 202-214.

Dolman, P. M., & Wäber, K. (2008). Ecosystem and competition impacts of introduced deer. *Wildlife Research*, *35*(3), 202-214.

Dublin.H.T. (1986) *Decline of the Mara woodlands: The Role of fire and Elephants*. PhD thesis University of British Columbia.

Dublin, H. T., Sinclair, A. R., & McGlade, J. (1990). Elephants and fire as causes of multiple stable states in the Serengeti-Mara woodlands. *The Journal of Animal Ecology*, 1147-1164.

eBird, (2022a). Global Big Day 14th May, 2022. https://ebird.org/region/KE/hotspots?yr=BIGDAY_2022a&m

eBird, (2022b). Global Big Day 8th October, 2022. https://ebird.org/region/KE/hotspots?yr=BIGDAY_2022b&m=

Giesen, W., Giesen, P., & Giesen, K., (2017). Lewa Wildlife Conservancy Habitat Changes 1962-2006. Lewa Wildlife Conservancy. Laikipia District, Kenya.

Greenwood, P. J. (1980). Mating systems, philopatry and dispersal in birds and mammals. *Animal behaviour*, *28*(4), 1140-1162.

Hardey, J., Crick, H., Wernham, C., Riley, H., Etheridge, B., & Thompson, D. (2009). Raptors-a field guide to survey and monitoring. Scottish Natural Heritage and The Stationary Office.

Illius, A. W., & O'Connor, T. G. (2000). Resource heterogeneity and ungulate population dynamics. *Oikos*, *89*(2), 283–294. https://doi.org/10.1034/j.1600-0706.2000.890209.x

IUCN (2022). The IUCN Red List of Threatened Species. https://www.iucnredlist.org/species/22692046/93334893

Jacobs, J. (1974). Quantitative measurement of food selection. *Oecologia*, *14*(4), 413-417.

Kaaria, T, Kisio, E & Kimiti, D. (2022). Lewa - Borana Landscape wildlife count report. Unpublished report.

Khayale, C., Kariuki, L., Chege, G., Sibanda, M., Mulama, M., Okita-Ouma, B., & Amin, R. (2020). Progress on the Kenya black rhino Action Plan (2017-2021). *Pachyderm*, *61*, 109-119.

Khayale, C., Omondi, P., Kariuki, L., Muruthi, P., Gichohi, N., Stejskal, J.,& Amin, R. (2021). Kenya's first White Rhino Conservation and Management Action Plan. Pachyderm, 62, 112-118.

Knight, T. (2010). The Abundance and Diversity of Raptors along Three Riverine Transects within the Pacaya-Samiria National Reserve, Peru.

Koskimies, P. (1989, January). Birds as a tool in environmental monitoring. In *Annales Zoologici Fennici* (pp. 153-166). Finnish Zoological Publishing Board, formed by the Finnish Academy of Sciences, Societas Scientiarum Fennica, Societas pro Fauna et Flora Fennica and Societas Biologica Fennica Vanamo.

KWS (2021). White Rhino (Ceratotherium simum) Conservation and Management Action Plan (2021-2025) in Kenya, Kenya Wildlife Service, Nairobi.

KWS (2017). Black Rhino Action Plan 2017 – 2021 Sixth edition.

Law, P. R., & Fike, B. (2018). Testing ‘Proportion of Females Calving’as an indicator for population-level reproductive performance for black rhinoceros (Diceros bicornis). *PeerJ*, *6*, e5430.

Lepage, D. (2022). Checklist of the birds of Kenya. Avibase, the world bird database. Retrieved from: https://avibase.bsc-eoc.org/checklist.jsp?region=KE (Accessed: 8th December, 2022).

McClure, C. J., Carignan, A., & Buij, R. (2021). Lack of standardization in the use of road counts for surveying raptors. *The Condor*, *123*(1), duaa061.

Mwaya, R.T., Malonza, P.K., Ngwava, J.M., Moll, D., Schmidt, F.A.C. & Rhodin, A.G.J. (2019). *Malacochersus tornieri*. *The IUCN Red List of Threatened Species* 2019:

e.T12696A508210. https://dx.doi.org/10.2305/IUCN.UK.2019-1.RLTS.T12696A508210.en. Accessed on 14 December 2022.

Ogada, D. L., Gadd, M. E., Ostfeld, R. S., Young, T. P., & Keesing, F. (2008). Impacts of large herbivorous mammals on bird diversity and abundance in an African savanna. *Oecologia*, *156*(2), 387-397.

Ohashi, H., & Hoshino, Y. (2014). Disturbance by large herbivores alters the relative importance of the ecological processes that influence the assembly pattern in heterogeneous meta-communities. *Ecology and evolution*, *4*(6), 766-775.

Ojwang, G. O., Wargute, P. W., Said, M. Y., Worden, J. S., Davidson, Z., Muruthi, P., ... & Okita-Ouma, B. (2017). Wildlife migratory corridors and dispersal areas: Kenya rangelands and coastal terrestrial ecosystems. *Government of the Republic of Kenya, Nairobi*.

Okita-Ouma, B., van Langevelde, F., Heitkönig, I. M., Maina, P., van Wieren, S. E., & Prins, H. H. (2021). Relationships of reproductive performance indicators in black rhinoceros (Diceros bicornis michaeli) with plant available moisture, plant available nutrients and woody cover. *African Journal of Ecology*, *59*(1), 2-16.

Okpiliya, F. I. (2012). Ecological diversity indices: Any hope for one again. *Journal of Environment and Earth Science*, *2*(10), 45-52.

Orsdol, K. V., Hanby, J. P., & Bygott, J. D. (1985). Ecological correlates of lion social organization (Panthers, leo). *Journal of zoology*, *206*(1), 97-112.

Ouma, B. O. (2004). *Population performance of black rhinoceros (Diceros bicornis michaeli) in six Kenyan rhino sanctuaries* (Doctoral dissertation, MSc Thesis, University of Kent).

Pamo, E. T., & Tchamba, M. N. (2001). Elephants and vegetation change in the Sahelo-Soudanian region of Cameroon. *Journal of Arid Environments*, *48*(3), 243-253.

Parreno, Clarise & Sanchez, Irene & Vasallo, Angela & Vedra, Sonnie & Relox, Richel. (2020). Diversity and distribution of Avifauna in Mapawa Nature Park, Cugman, Cagayan de Oro City, Misamis Oriental.

Powell, R. A. (2000). Animal home ranges and territories and home range estimators. *Research techniques in animal ecology: controversies and consequences*, *442*, 65-110.

Rahman, F., & Ismail, A. (2018). Waterbirds: An important bio-indicator of ecosystem. *Pertanika Journal of Scholarly Research Reviews*, *4*(1).

Rodríguez-Estrella, R., Donázar, J. A., & Hiraldo, F. (1998). Raptors as indicators of environmental change in the scrub habitat of Baja California Sur, Mexico. *Conservation Biology*, *12*(4), 921-925.

Rubenstein, D. I. (2010). Ecology, social behavior, and conservation in zebras. *Advances in the Study of Behavior*, *42*, 231-258.

Santangeli, A., & Girardello, M. (2021). The representation potential of raptors for globally important nature conservation areas. *Ecological Indicators*, *124*, 107434.

Schmeller, D., Henle, K., Loyau, A., Besnard, A., & Henry, P. Y. (2012). Bird-monitoring in Europe–a first overview of practices, motivations and aims. *Nature Conservation*, *2*, 41.

Silveira, L., Jácomo, A. T., & Diniz-Filho, J. A. F. (2003). Camera trap, line transect census and track surveys: a comparative evaluation. *Biological conservation*, *114*(3), 351-355.

Tabur, M. A., & Ayvaz, Y. (2010, June). Ecological importance of birds. In *Second International Symposium on Sustainable Development Conference* (pp. 560-565).

Tolley, K. A., Alexander, G. J., Branch, W. R., Bowles, P., & Maritz, B. (2016). Conservation status and threats for African reptiles. *Biological Conservation*, *204*, 63-71.

Tumenta, P. N., Visser, H. D., van Rijssel, J., Müller, L., de Iongh, H. H., Funston, P. J., & de Haes, H. A. U. (2013). Lion predation on livestock and native wildlife in Waza National Park, northern Cameroon. *Mammalia*, *77*(3), 247-251.

Vågen, T and Winowiecki L. (May 2022). Assessment of Rangeland Health in the Lewa Wildlife Conservancy Land Degradation Surveillance Framework (LDSF) Analysis Report, May 2022. Unpublished draft report.

Vrezec, A., Duke, G., Kovács, A., Saurola, P., Wernham, C., Burfield, I., ... & Bertoncelj, I. (2012). Overview of raptor monitoring activities in Europe. *Acrocephalus*, *33*(154-155), 145-157.

Wamiti, W., Mwangi, J., Fox, D., Bakari, N., Schröder, W., Nowald, G., Walter, B., Ndung'u, G., Bii, E., Wanjala, M., Nekesa, V. & Kimani, D. (2020). Kenya's first countrywide census of Grey Crowned Crane: February–March 2019. Bulletin of the African Bird Club 27(2): 210–218.

Western, D., Russell, S., & Cuthill, I. (2009). The status of wildlife in protected areas compared to non-protected areas of Kenya. *PloS one*, *4*(7), e6140.

Wetlands International. (2010). Guidance on waterbird monitoring methodology: Field Protocol for waterbird counting. *Wetlands International*, (March), 1–15. Retrieved from https://europe.wetlands.org/wpcontent/uploads/sites/3/2016/08/Protocol_for_waterbird_counting_En_.pdf

Wilson, L. D., & McCranie, J. R. (2004). The herpetofauna of the cloud forests of Honduras. *Amphibian and Reptile Conservation*, *3*(1), 34.

Yallop, M. C. (2003). "Water birds Herbivory on a newly created wetland complex. Wetland eco, 395-408.

9.0 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 "Sire".