Leopard Ecology & Conservation

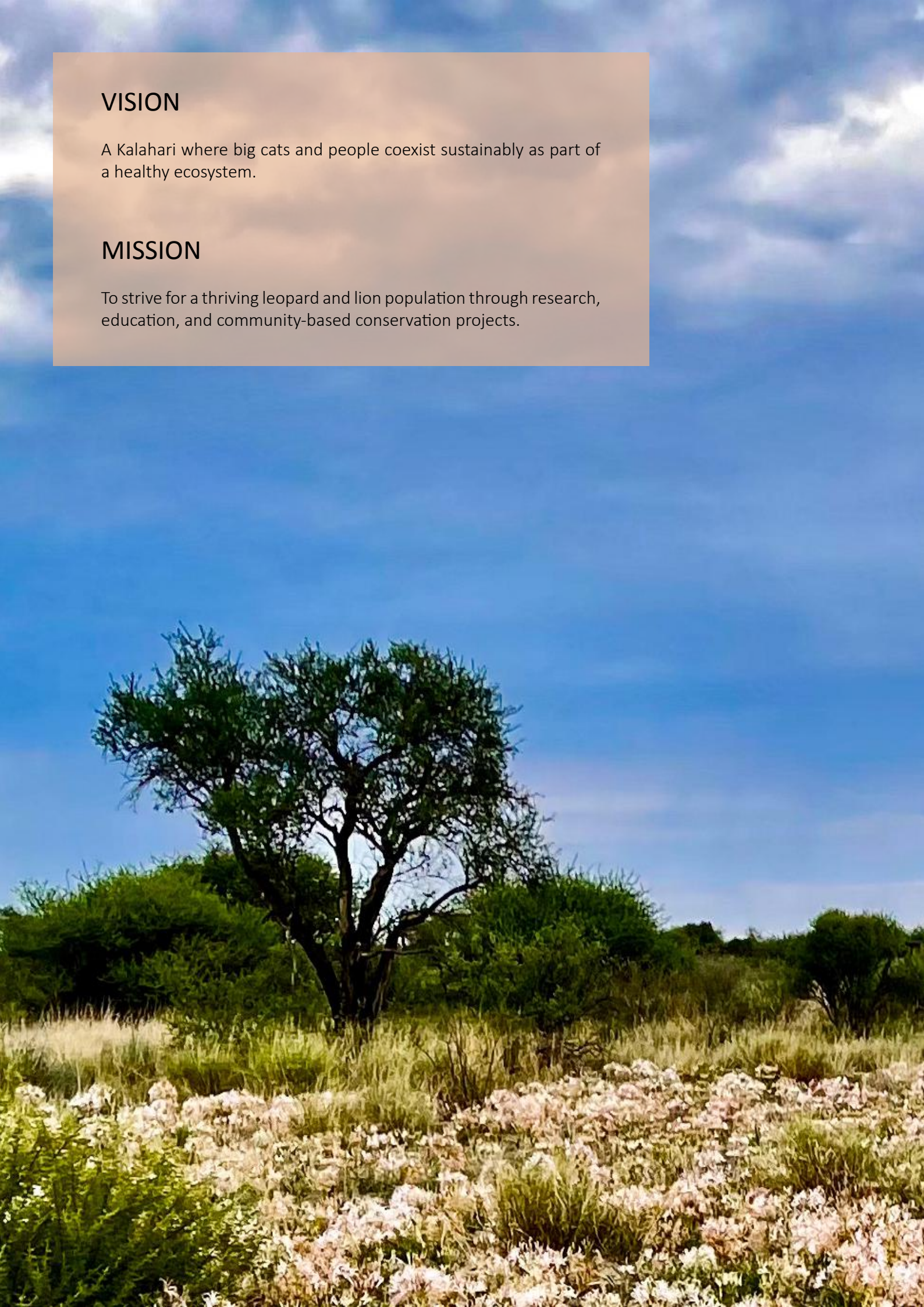
Annual Report 2024

VISION

A Kalahari where big cats and people coexist sustainably as part of a healthy ecosystem.

MISSION

To strive for a thriving leopard and lion population through research, education, and community-based conservation projects.



OBJECTIVE

Leopard Ecology & Conservation strives to make a meaningful contribution toward the long-term conservation of large felid predators as key components of a healthy, functioning ecosystem in Botswana. This requires an understanding of status and habitat needs of leopards and lions both within and outside formal conservation areas, as well as the development of appropriate and effective strategies to address the threats they face.

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Leopard Ecology & Conservation Trust
Botswana

People and Wildlife Trust
Botswana

African Cats & Conservation Foundation (ACACF)
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A list with explanations of the abbreviations is provided on page 46.
A map showing most of the places mentioned in the text can be found on page 48.

Letter from LEC Founder: Monika Schiess-Meier

Twenty-four years ago, we set out into the vast expanse of the Kalahari with a simple but ambitious goal: to better understand the behaviour of leopards. Two years later, recognising the need to study the interactions between these big cats, we expanded our focus to include lions. What began as a study of individual species quickly became something much larger—an evolving journey into the complexities of life in this arid landscape.

The early years were challenging. Unlike in more enclosed habitats, direct observation of predators in the Kalahari was nearly impossible. The terrain was too vast, the animals too elusive. But from the outset, we had something invaluable—partnerships with skilled San trackers. Their deep knowledge of the land and the wildlife within it made it possible to collect insights that even the best available technology at the time could not provide. Today, that technology has advanced so much that the devices we once relied on belong in museums. But back then, our data was limited, and every piece of information had to be painstakingly gathered.

Even as new tracking devices and analytical tools emerged, one thing remained constant: our commitment to combining traditional knowledge with the latest scientific methods. Our trackers not only adapted to new technologies but mastered them. They are now leading workshops, sharing their expertise with other researchers and conservationists. Through this fusion of old and new, we have built a foundation of data that is richer and more insightful than we could have imagined at the start.

Yet, as our understanding of wildlife deepened, it became soon clear that conservation cannot happen in isolation from the communities who share this landscape with predators. Our Community & Education (C&E) programme was born from the need to engage with livestock farmers and herders, helping to understand their challenges and promote coexistence. Over the years, the programme has grown to support sustainable livestock management, rangeland restoration, and community-led conservation initiatives.

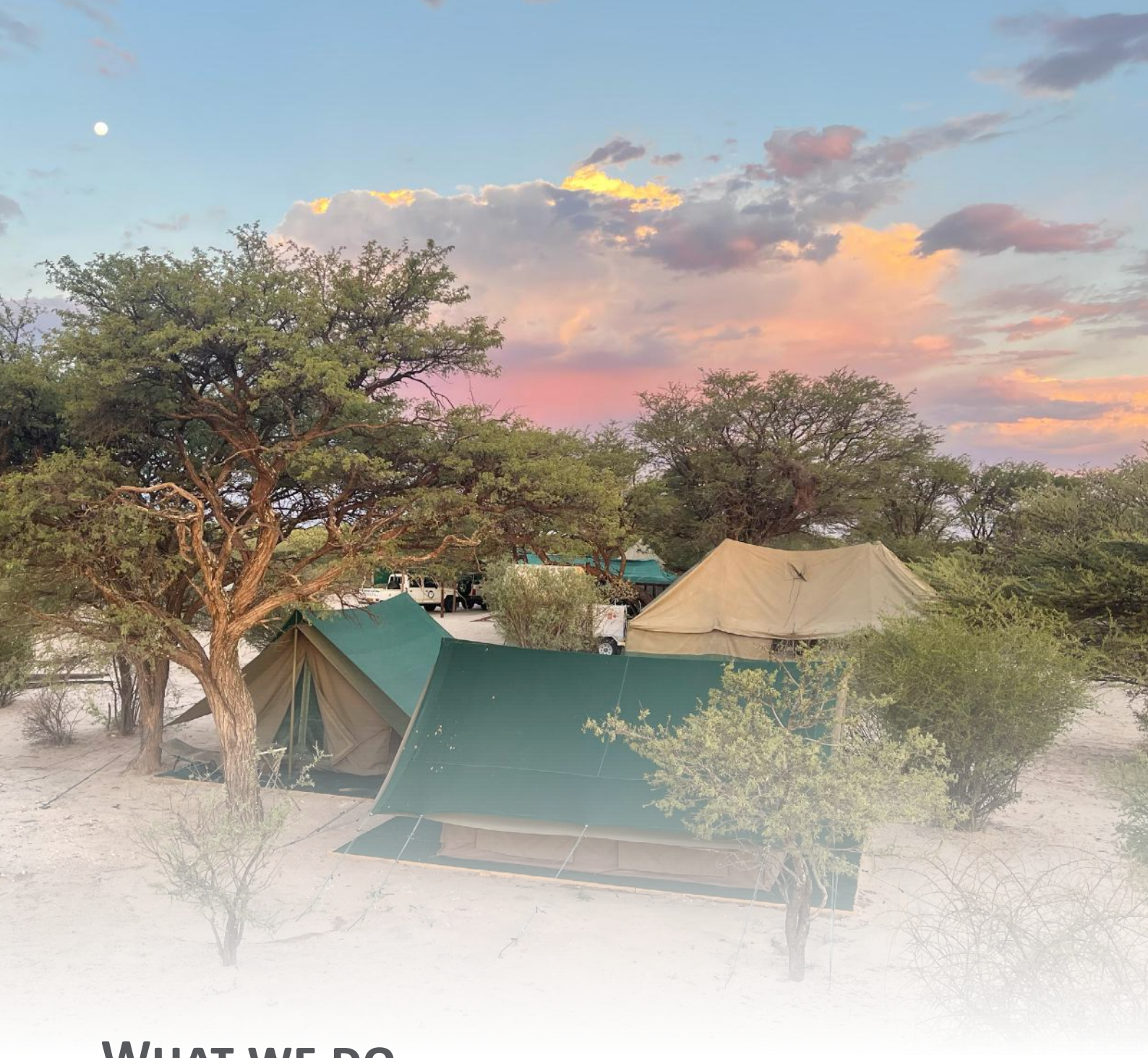
Tracking has also become a valuable tool for the C&E team, helping to identify the causes of livestock losses and guide mitigation strategies. By working closely with research, the C&E team ensures that data is not only used for science but also applied to support the people living alongside wildlife.

Looking back, we are grateful that we started collecting data when we did. It took us years to fully appreciate just how critical long-term studies are in understanding nature's complexities. Wildlife populations are not static; they are shaped by shifting landscapes, climate variability, and human activity. Some changes happen over seasons, others over decades—but only with long-term monitoring can we truly see the patterns emerge. Today, the volume of data available to us is greater than ever. Our team can follow tracks on foot while logging their findings in real time, and we can combine field observations with remote-sensing tools to reveal broader ecological trends. By tracking leopards and lions over decades, we can now see how birth rates, survival, and movements respond to environmental and human-driven changes. These insights don't just expand our scientific understanding; they inform policy, shape conservation strategies, and help communities navigate coexistence with wildlife.

After completing 24 years of operations, we reflect not just on how far we've come, but on the power of persistence. In conservation, impact is rarely immediate. The greatest discoveries—and the greatest successes—come from patience, collaboration, and the willingness to learn as we go. That is what has shaped our journey, and that is what will guide us into the years ahead.

With this in mind, I am pleased to share with you our 2024 Annual Report. I hope you find it both insightful and inspiring.

M. Schiess-Meier



What we do

The **LEC Research Programme** is made up of six core projects (see p. 7) studying the habitat of leopards and lions, their population status, and the human-predator conflict that exists between them and the local community. These core projects have produced long-term datasets on predator ecology and human-wildlife conflict, providing a longstanding perspective on the evolving ecological needs of, and threats to, predators in the Kalahari.

While we maintain continuity in data collection methods, we also adapt and modify our activities to ensure that the research topics and methodologies remain relevant and up to date, allowing us to inform current management strategies appropriately.

The **LEC Community & Education Programme** employs a team, made up of local residents and individuals with expertise in social science and community-based conservation. They work with farmers and herders to provide education about livestock predation mitigation measures. They also work with residents of the local village, Kaudwane, on a number of community projects, such as an organic vegetable garden, a community conservation club, a solar cooker project and practical animal husbandry education. LEC is particularly proud of the relationship which has developed over the past 24 years with the local community.

2024 in Numbers

Organisation

24 years operational

29 individuals from Botswana working at LEC

14 international collaborations

5 external training for LEC staff

4 international post graduate students and interns

3 Botswana interns

Leopards

2 collared leopards

21 minimum number of leopards identified during camera trap survey

1 study leopard shot by farmers

20 wildlife predation events by leopards

4 leopards shot by trophy hunters in Kaudwane area

Lions

245 lions sighted older than **6** months

235 wildlife predation events by lions

3 new lion litters detected from **2** different females

4 study lions shot by farmers

191 individual lion observations

Community and Education

15 indigenous trees planted at the school

339 dogs and cats vaccinated against rabies

26 School Environmental Education Club members trained in tree planting

30 dogs sterilised

104 visits to cattle posts

51 farmers attended educational lessons

83 farmers attending the workshops

5 cattle post lessons conducted

352 livestock trimmed

19 horses taking part in the horse evaluation

Promoting young talents

45 school children from Botswana participated in an educational game drive inside Khutse GR

8 school children were recognised for excellence in their studies and awarded prizes

Research

488 individual sets of tracks of lions and leopards collected (for WildTrack FIT algorithm library)

10 24h-trails of lions completed

4 DNWP Officers from Central District trained in programming GPS-collars and manage geo-fencing

304 camera traps deployed to cover an area of **4435** km^2 for the leopard population survey

15 DWNP officers from Kasane District trained at track survey techniques for research and monitoring wildlife population

45 largest group of elephants observed in Khutse Game Reserve in 2024

Research Programme

Research is one of the founding pillars of LEC. Climate change and increasing anthropogenic pressure are certainly the major threats to the long-term survival of leopards and lions in the Kalahari, but we need scientifically strong evidence to better understand the details of such threats. To understand the impact, we need to monitor the population status parameters such as the population size, spatial distribution, and demographic trends and how these link to changes in the environment and resources. Simultaneously, we have to comprehend the entirety of existing and new factors which will affect the ecology and conservation of wild carnivores. Only through long-term studies, it is possible to collect the needed data to then derive appropriate management strategies for the Kalahari ecosystem.

LEC is a long-term research project. In six core projects, we maintain continuity in our data collection for the key parameters of the leopard and lion populations within our study area. LEC is continuously striving to update our research methodologies as well as integrate innovative technological and methodological advances to maximise the value of our research activities. We contribute to a number of research collaborations and support students in their research beyond these six projects.

Project 1:
Landscape and habitat monitoring

- To define the Khutse landscape in terms of the key environmental features and their interactions.
- To monitor changes in landscape conditions that are biologically relevant, and which vary in both space and time.
- To monitor key climatic drivers of landscape change.

Project 2:
Prey Availability

- To monitor the distribution and relative abundance of potential prey species.
- To monitor the demographics (age class and sex ratios) and physical condition of the principal leopard and lion prey species.

Project 3:
Predation

- To describe leopard and lion predation patterns across the study area.
- To identify drivers that best predict leopard and lion predation patterns across the study area.
- To quantify the extent to which domestic and wild prey sources contribute towards the diet of leopards and lions in the study area.
- To quantify predation of livestock in terms of prey species, age class and sex.

Project 4:
Predator Movement and Habitat Selection

- To determine leopard habitat selection patterns inside and outside the protected area.
- To identify key resources across the study area for leopards and lions.

Project 5:
Predator Demographics

- To calculate population size of leopard and lion populations inside the protected area.
- To calculate population size of the leopard population outside the protected area.
- To understand sex ratios and age classes of both territorial and dispersing leopards.
- To determine the population structure, pride size and pride structure of the lion population, and how these change over time.

Project 6:
Human-Predator Conflict

- To identify the intensity and trends of human-predator conflict in the study area.
- To determine environmental and social factors affecting the coexistence of human activities and wild carnivores.
- To identify effective mitigation strategies.

Project 1.
Landscape and Habitat Monitoring

Understanding the landscape in which the study species live is essential for effective wildlife research. Monitoring environmental variables and identifying their trends across time and space are crucial for developing informed hypotheses and interpreting data related to wildlife population status. Being at the top of the ecological pyramid, lion and leopard population trends are driven by an extremely complex network of interactions between the biotic and abiotic components of the ecosystem in which they live.

The semi-arid Kalahari in Botswana represent one of the vastest landscapes in southern Africa and a large portion of it is virtually untouched. The Kalahari species inhabiting this harsh environment have adapted both physiologically and behaviourally to become extremely resilient to climate variations and cyclical climate events such as El Niño which can cause extended draught periods. Nevertheless, these coping strategies have slowly developed across millennia and the current anthropogenic threats to this fragile ecosystem are acting too fast to allow any adaptation. Wildlife corridors existing outside protected areas in Botswana have played an essential role in allowing long-distance migrations of herbivores during the draught periods. Currently new land use policies and growth of farming pressure along this corridors are causing habitat fragmentation and the wildlife populations inside the Kalahari protected areas are suffering from lack of food resources, pressure from an expanding elephant population and human-wildlife conflict from the neighbouring farming land.

To be able to study how these drivers of landscape change are affecting the ecology and behaviour of lions and leopards in the Kalahari, LEC continues to monitor how different habitat features evolve in the study area in the short and on the long term. In 2024, LEC maintained long-term data collection on vegetation and climate while monitoring elephant population trends, as their presence significantly contributes to rapid modification in the vegetation structure and the water availability for other species.

Vegetation in the study area appears to be influenced primarily by fires, rainfall, elephants, and livestock grazing. Fixed-point vegetation photos capture seasonal and annual trends. In 2024, we witnessed a slow but progressing change in the plant community structure mainly caused by the direct action of elephants and the presence of alien pioneer species infesting the communal grazing land. The poor and irregular 2023 - 2024 rainy season has directly impacted the food availability for several herbivore species and probably exacerbate human-driven phenomena such as overgrazing by livestock and consequent bush encroachment outside the reserve.

LEC's weather station at the entrance of Khutse GR and a network of rain gauges across the study area provided data on temperature, rainfall, and wind speed for the 2023 - 2024 austral seasonal year. Total recorded rainfall was 269.5 mm, a value notably below the average rainfall (425 mm) recorded by LEC in the last 24 years (Figure 1.1). The whole southern Africa region was deeply affected by El Niño. It was reported that February 2024 was the driest February of the last 40 years for Botswana. In the last years the rainy season seems to have shifted and become less predictable. For example, February 2023 was characterized by the heaviest rains (347 mm) while in February 2024 only 13.7 mm of rain were recorded. The changes in the periods of the rains might affect the survival of many desert-dwelling species even more than the overall amount of rainfall. Temperature patterns followed the typical seasonal cycle, with the hottest months between October and March and the coldest nights in July 2023 (Figure 1.2). The dry winter season

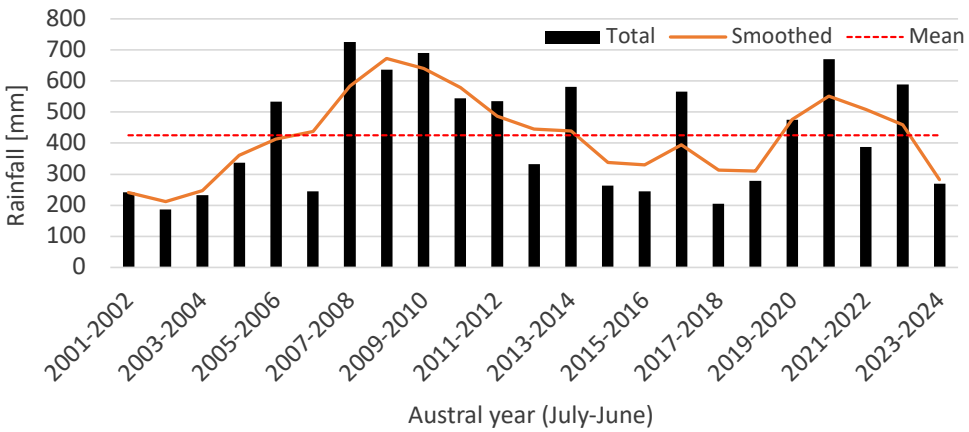


Figure 1.1. Annual rainfall recorded at the LEC research station (histogram). To highlight the trend within variable rainfall data these were smoothed (line) using a three-point weighted interpolation where annual rainfall (R) is the product of the current year's rainfall (R0) as well as the previous and following year's values (R-1 and R+1 respectively) (R = 0.25xR-1 + 0.5xR0 + 0.25xR+1).

(May to September) is also characterized by the wider temperature excursion within the 24 hours.

Wildfires are fundamental environmental drivers in maintaining healthy and productive grasslands and savannas across the world. This is particularly true for the semi-arid Kalahari where many plants have evolved to cope with fires and where many woody species would become dominant in the open grasslands if not controlled by periodic fires. The timing of fires and following rains is crucial to keep the fragile balance securing food resources for herbivores and the persistence of this open landscape. The central Kalahari is also characterized by a relatively poor sandy soil and the ashes from wild fires are essential fertilizers for the growth of new grasses. In 2024, the number of VIIRS (Visible Infrared Imaging Radiometer Suite) fire alerts registered across Botswana (4387) was a fourth of the alerts recorded in 2023 (19,220). As shown in the graph in Figure 1.3, the recorded VIIRS alerts were within the normal yearly range with a slight delay in the year. The typical peak is between August and September (Figure 1.4), while in 2024 fires were recorded inside LEC study area even in December. The reduction in overall fire alerts and their temporal shift is probably to the poor 2023 - 2024 rainy season and the above-average number of fires recorded in the 2021 - 2023 period which have brought a very reduced fuel load across the landscape. In addition, the late start of the 2024- 2025 rainy season with its lighting storms is probably the cause of the late fires recorded between November and December 2024.

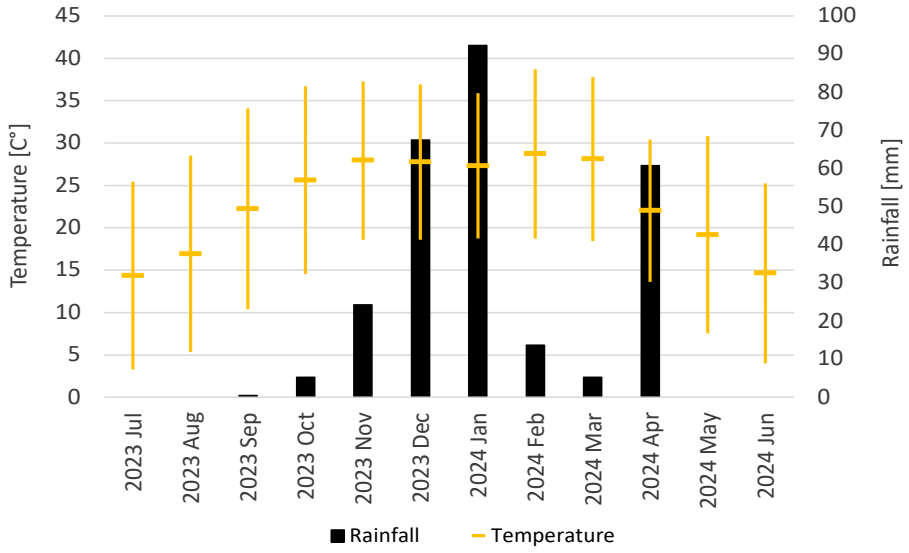


Figure 1.2. Monthly temperature and rainfall as recorded at the LEC research camp, Khutse GR, for the 2023 - 2024 seasonal year. The average median daily temperature is shown as a point, with the average daily minimum and maximums as bars.

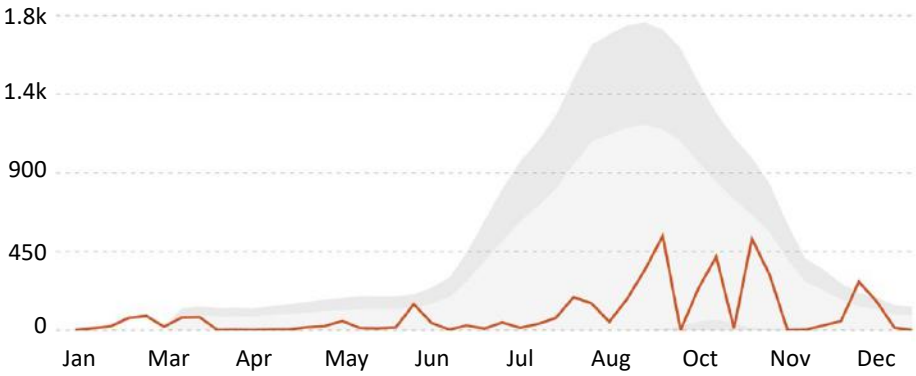


Figure 1.3. Monthly VIIRS fire alerts in Botswana in the period January 2024 to January 2025 (red). The Light grey area marks the normal range of fire alerts across the year; the dark grey area defines the above or below normal range of alerts in the last 15 years (https://www.globalforestwatch.org/).

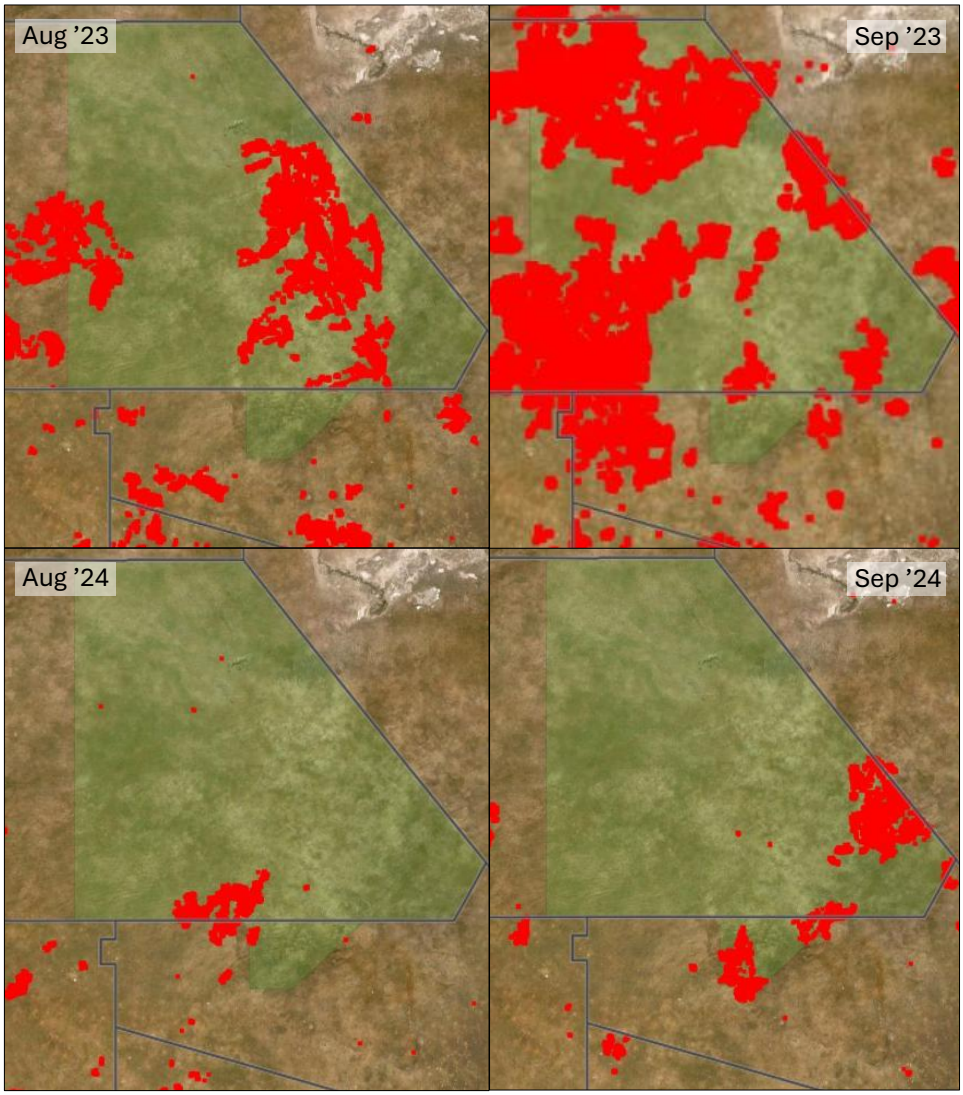


Figure 1.4. Fires active in Khutse GR, Central Kalahari GR and their surroundings in August - September 2023 and August - September 2024. (FIRMS-NASA).

Like many other protected areas in Africa, Khutse GR and CKGR have artificial waterholes to provide year-round surface water. Historically, Kalahari herbivores would migrate during the dry months to areas with permanent water sources, such as the Okavango Delta. However, veterinary fences and human activities have obstructed these migration routes, necessitating artificial waterholes.

The availability of year-round surface water has dramatically altered the Kalahari ecosystem. LEC prioritises waterhole monitoring due to their ecological significance. In 2024, elephant presence at Khutse GR continued to rise, correlating with waterhole availability. The poor 2023 - 2024 rainy season pushed wildlife to concentrate around waterholes for extended periods of the year. Since 2019, sightings and impacts of elephants, particularly near waterholes, have been documented. Elephants have damaged many of the waterholes in search of more water and their presence around the waterholes has caused rapid degradation of the surrounding vegetation, including uprooted trees and shrubs dug out for roots.

Only male elephants have been recorded over the past four years, except for one female spotted at Khutse 1 in November 2024. Comparing to the previous years, in 2024 we observed a more constant presence of elephants across the months (Figure 1.5). The average number of individuals observed at each sighting has constantly increased since 2020 (4.6 individuals/ observation) to reach 10.1 individual per observation in 2024 (Figure 1.6). In 2021, a large number of elephants congregated around Molose waterhole during end of the dry season and beginning of wet season with an average number of individuals per observation between 25- 30 in October and November 2021. These large congregations of elephants might be outliers across the general observed trend. The very poor rainy season might also explain why the peak of elephant observations was in February 2024 rather than May and June as generally expected.

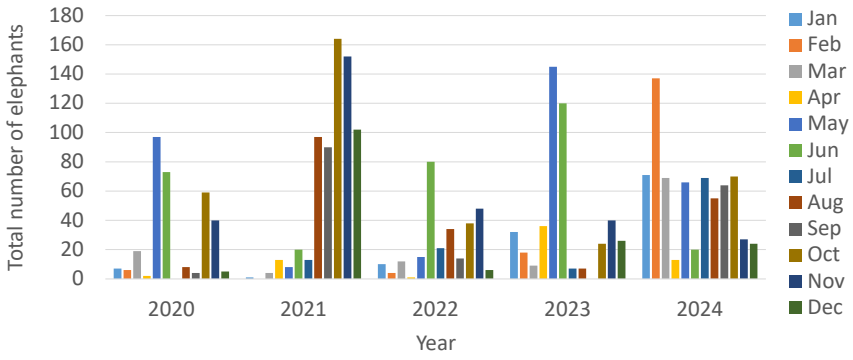


Figure. 1.5. Total number of elephants recorded per month from 2020 to 2024.

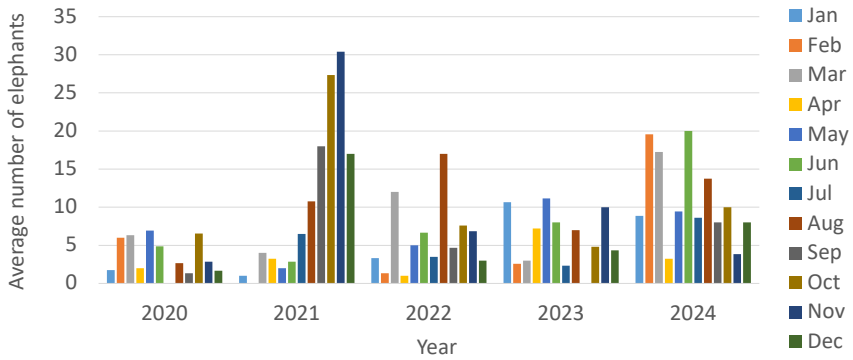


Figure 1.6. Average number of elephants at each observation recorded per month from 2020 to 2024.

Project 2.
Prey Availability

Prey availability and changes in the prey community have probably been undoubtfully the most relevant factor in carnivore population long-term viability in the Kalahari ecosystem. As mentioned, in several occasions, the Kalahari ecosystem is characterised by a high level of species richness but a low-density system when we look at population size. This is particularly true for medium to large herbivore species who have adapted to these harsh environmental conditions by forming smaller herds and by migrating long distances to find seasonal resources.

To monitor low-density populations, it is necessary to sample large areas using effective methodologies which can provide a sample size large enough to obtain realistic population estimates. At LEC, we use extensive track surveys to estimate carnivore and medium and large preys in LEC study area inside Khutse GR - CKGR and in the communal grazing land around Kaudwane village. The extensive track surveys are a LEC long-term research project aiming at monitoring herbivore and carnivore population trends using direct counts of tracks across a set of routes on a monthly basis for a period of one year. As these surveys are very resource-demanding, they are replicated every four years.

In 2024, we finalized our collaborative study with Marie-Charlotte Gielen to refine population density estimation using the Formozov-Malyshev-Pereleshin (FMP). In specific, we aimed to improve a key parameter of the formula: the daily travel distance (M) of the target species. M is used in the FMP formula to convert the track encounter rate into absolute estimates of population size (see Annual report 2023 for more details). In 2023, we completed the

fieldwork focused on obtaining empirical estimates of M of five key prey species for lion and leopards in the Kalahari. To do so, the unique skills of LEC trackers were applied to trail our target species along 24-hours-long paths. In 2024, the new empirical estimates were used to generate coefficients that can directly correct allometric M, an estimated value of M based on body size used when empirical M values are not available. We finally applied the empirical M and coefficient-corrected allometric M to our 2021-2022 track survey dataset (Table 2.1).

As expected, gemsbok are the most abundant prey species together with porcupines and steenbok. Giraffes, ostriches, red hartebeests and kudus can certainly be an important source of prey for lions in our study area, as well. Blue wildebeest show a clear migratory pattern as they leave the area during the dry season in search of surface water. Elands are certainly a key prey for lions, but they are resident more in the CKGR than in Khutse GR and the track survey covers a small portion of their range in the CKGR. We have also to notice that there are a couple of discrepancies in abundances with independent knowledge from our study area. Springboks are estimated at three individuals in the dry season over the entire study area, while we are aware though of at least three or four herds simultaneously present. This means that our track survey transect design did not survey variations in local densities of springbok in proportion. Indeed, transects go around but not through pans, which are springbok primary habitats from where they rarely move out, especially in the dry season. Moreover, the duiker shows density estimates three times higher in the wet season than in the dry season. The unexpected amplitude of the variation suggests a differential M between seasons, likely the duikers move more during the wet season compared with the dry season.

Table 2.1. Population density estimates per species per season in Khutse GR and southern CKGR, Botswana. The density per 100 km² and abundance estimates are presented with the 95% confidence intervals. The abundances are calculated using the track survey study area of 2761.56 km².

Species	M source	Season	Density/100 km²	Abundance
Aardvark (*Orycteropus afer*)	Empirical	wet	0.55 (0.37-0.99)	15 (10-27)
		dry	0.23 (0.12-0.48)	6 (3-13)
Blue wildebeest (*Connochaetes taurinus*)	Empirical	wet	0.85 (0.32-1.69)	24 (9-47)
		dry	0.04 (0-0.16)	1 (0-4)
Duiker (*Sylvicapra grimmia*)	Allometric	wet	8.08 (4.77-12.27)	223 (132-339)
		dry	2.47 (1.38-4.35)	68 (38-120)
Eland (*Taurotragus oryx*)	Empirical	wet	1.8 (0.7-4.27)	50 (19-118)
		dry	0.74 (0.38-1.44)	21 (10-40)
Gemsbok (*Oryx gazella*)	Empirical	wet	8.07 (5.95-11.17)	223 (164-309)
		dry	7.4 (5.85-9.63)	204 (162-266)
Giraffe (*Giraffa giraffa*)	Empirical	wet	2.57 (1.91-3.33)	71 (53-92)
		dry	1.94 (1.35-2.72)	53 (37-75)
Red Hartebeest (*Alcelaphus buselaphus*)	Empirical	wet	5.59 (3.95-8.95)	154 (109-247)
		dry	3.02 (2.15-4.84)	83 (59-134)
Greater Kudu (*Tragelaphus scriptus*)	Empirical	wet	3.26 (2.57-5.73)	90 (71-158)
		dry	2.7 (2.03-4.3)	75 (56-119)
Ostriche (*Struthio camelus*)	Empirical	wet	3.82 (2.26-7.83)	105 (62-216)
		dry	2.31 (1.53-4.49)	64 (42-124)
Porcupine (*Hystrix africaeaustralis*)	Allometric	wet	7.75 (4.5-66.66)	214 (124-1841)
		dry	12.87 (7.63-133.81)	355 (211-3695)
Springbok (*Antidorcas marsupialis*)	Empirical	wet	2.75 (0.52-7.01)	76 (14-193)
		dry	0.11 (0-0.38)	3 (0-11)
Steenbok (*Racipherus campestris*)	Empirical	wet	10.5 (8.29-14.03)	290 (229-387)
		dry	8.2 (6.6-10.75)	226 (182-297)
Warthog (*Phacochoerus africanus*)	Allometric	wet	1.59 (1.01-2.66)	44 (28-73)
		dry	0.61 (0.27-1.17)	17 (7-32)

Project 3.
Predation

In 2024, LEC researchers have continued to collect data and monitor leopard and lion predations inside and outside the protected area. This project is a key component to not only understand the ecology of these carnivores in the Kalahari, but also an essential information to tackle the human-carnivore conflict in our area. Since 2000, we have collected data on predations integrating several sources such as kill site investigation, visits to the cattle posts and formal reports from the Problem Animal Control (PAC) unit of DWNP. This long-term database allows us to define the trends in predations and try to predict how environmental changes such as growing livestock presence, wild prey availability and climate change might affect feeding behaviour in lions and leopards, and consequently how to design effective guidelines to mitigate human-wildlife conflict.

In 2024, we have had the opportunity to analyse key predation datasets to investigate prey selection and how kill sites can be used to determine habitat selection for the Kalahari leopards and lions. The main findings are presented in the section “Project in focus”.

As in many of our projects, tracking is a key method to have fine interpretation of how the predation took place. At each kill site, LEC trackers verify the predator species and how the prey was killed reading the tracks and signs left on the ground. LEC research assistant, Trevor Balon, has been leading the collaborative project on cooperative hunting behaviour in lions with the Max Planck Institute of Animal Behaviour in 2024. He presented the methodology and the findings to the Botswana Biodiversity Symposium in Kasane. The novel approach of using professional local trackers to reconstruct the exact movements of the lions and preys during the hunt was received with great interest, especially for its noninvasive approach and valorisation of traditional ecological knowledge. The study has brought some unique insights into the hunting behaviour of Kalahari lions. Lions in our study area seem to prefer hunting solitary (Figure 3.1.). Data have shown they are capable to successfully kill large prey such as adult giraffes even if alone. The solo hunts seem to take place even if other group members are in proximity, suggesting that solitary hunting is not related to the absence of possible cooperative individuals.

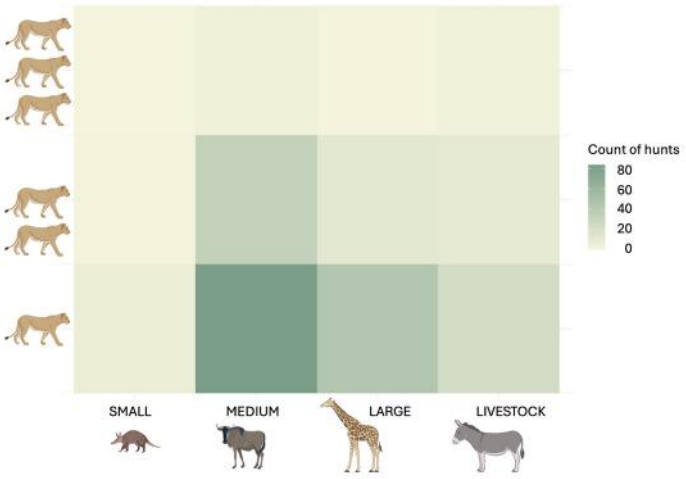


Figure 3.1. Schematic representation of how many lions are involved in the hunt according to the prey size and class. The class livestock includes donkeys, cattle and horses. Wildlife is divided in three size classes. (N. Borrego)

From the data collected, we can observe certain patterns (Table 3.1 and 3.2):

- In 2024, lion predations recorded inside of the protected areas are 123 (107 in 2023 and 114 in 2022). As observed in the last five years, the main prey species are eland (42) and gemsbok (32). The number of elands have almost doubled (23 in 2023) becoming the main prey species for lions.
- More wildebeest have been observed within the protected area in 2024 and we recorded 6 individuals killed by lions. By adding all predations on large herbivore species (eland, gemsbok, wildebeest, red hartebeest, kudu and giraffe), we can confirm that almost 90% of recorded predations from lions are on large species.
- Smaller species are hunted, but it seems they are not the preferred target. Nevertheless, it must be noted that smaller preys are more difficult to be recorded as the lions spend less time at the kill site to finish the prey and consequently they form smaller or no GPS-fixes clusters at the site. As we use GPS-clusters and direct resightings to investigate potential predations, we may underestimate the predations of smaller species.
- Predations on wildlife from leopards are very difficult to detect in the Kalahari if there are no collared individuals. Leopards hunt smaller preys than lions and they tend to consume their prey in very thick bushy vegetation and in holes, rather than securing their prey on trees like in other habitats. From the inspection of scats in the field, we confirm that a good portion of their diet is based on rodents and birds, typical of their opportunistic behaviour.
- Thanks to our work with the farmers, it was easier to record the impact of leopards on livestock in our area. The overall number of predations on livestock (16) is in line with the results of 2023 (19). The only adult individuals killed by leopards were one goat and one sheep, while most of the other killed livestock were juveniles (13). These numbers confirm that leopards are wrongly perceived as the serious thread to livestock in our area and that proper herding practices could reduce losses notably as the calves and foals could be protected more efficiently till they reach adulthood.
- Predation on livestock data (Table 3.3) shows that the overall livestock losses caused by predators is similar in 2023 and 2024 (156 in 2023 and 165 in 2024). Leopards have killed the same number of cattle calves in 2023 and 2024 (10). Recorded predations from wild dogs and jackals have decreased in 2024, while the number of livestock killed by lions changed from 94 in 2023 to 116 in 2024. If we observe the temporal scale of livestock predations (Figure 3.2), we notice that the pattern in 2024 is very different to 2023. The livestock predations are more spread across the year and the peak observed in the middle of the dry season in 2023 disappears in 2024 and is replaced with two peaks in April and November. The peak in April might be due to the very scarce rains recorded in the first half of 2024, the consequent reduction in wild preys and the need for livestock to graze further away from the cattle post earlier in the year. In addition, we hypothesize that fires in proximity to the park might have an impact, attracting livestock to graze on new grass growing in recently burnt area and, therefore exposing them to higher risk of predation. This would explain the peaks in August 2023 (fires were in June 2023) and in November 2024 (fires were in late September 2024).

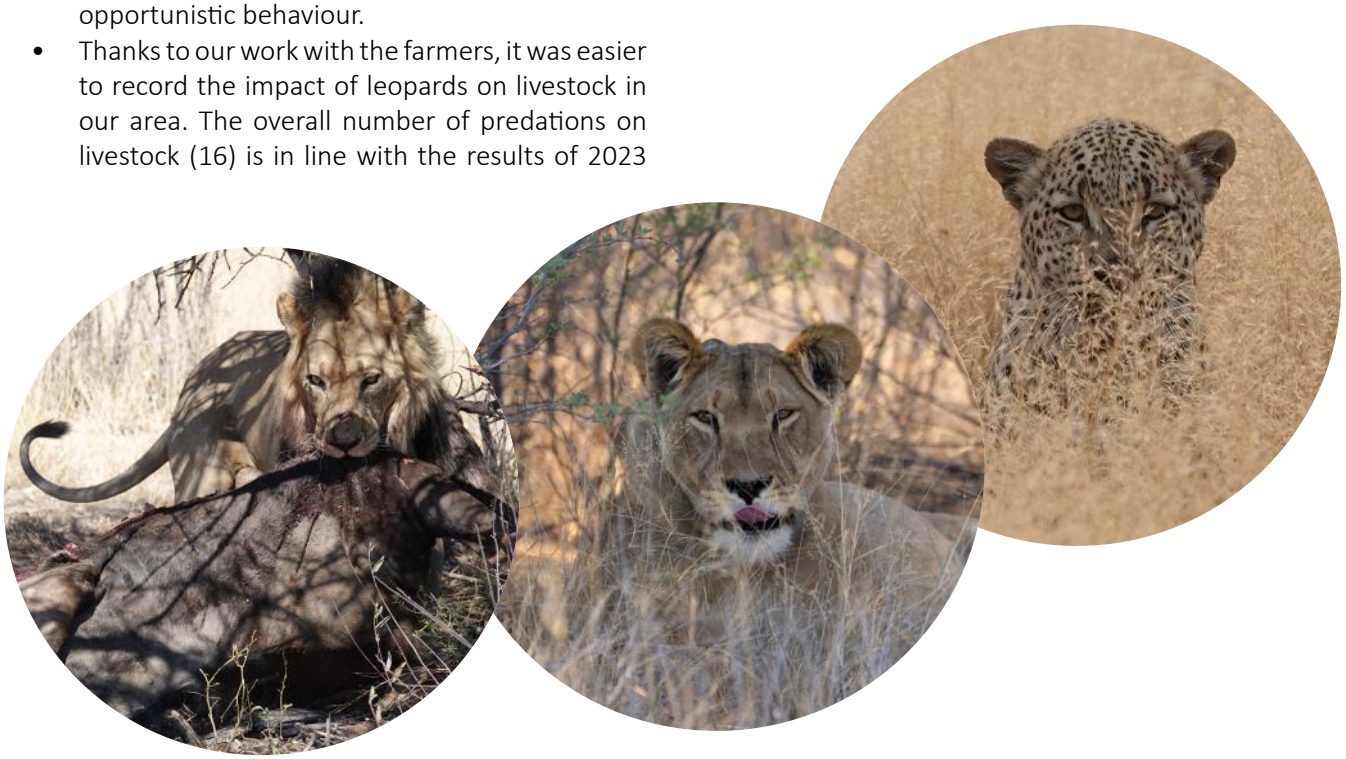


Table 3.1. Predations by lions inside and outside the reserve.

Species	adult		subadult		juvenile		**TOTAL**	
	in	*out*	in	*out*	in	*out*	in	*out*
Aardvark (*Orycteropus afer*)	1						1	
Blue wildebeest (*Connochaetes taurinus*)	5				1		6	
Cattle (*Bos taurus*)		59	1	12		14	1	85
Domestic dog (*Canis familiaris*)						1		1
Donkey(*Equus asinus*)	2	11		1			2	12
Duiker (*Sylvicapra grimmia*)	1						1	
Eland (*Taurotragus oryx*)	24		12		6		42	
Gemsbok (*Oryx gazella*)	27		2		3		32	
Giraffe (*Giraffa giraffa*)	3		2		1		6	
Goat (*Capra sp.*)				1				1
Hartebeest (*Alcelaphus buselaphus*)	7		2				9	
Horse (*Equus ferus*)		10		2		2		14
Kudu (*Tragelaphus scriptus*)	12	1	1		1		14	1
Ostriche (*Struthio camelus*)	1	1					1	1
Porcupine (*Hystrix africaeaustralis*)	3						3	
Springbok (*Antidorcas marsupialis*)							1	
Warthog (*Phacochoerus africanus*)	3	1					3	1

Table 3.2. Predations by leopards inside and outside the reserve.

Species	adult		subadult		juvenile		**TOTAL**	
	in	*out*	in	*out*	in	*out*	in	*out*
Aardvark (*Orycteropus afer*)	1						1	
Cattle (*Bos taurus*)						10		10
Duiker (*Sylvicapra grimmia*)		1						1
Goat (*Capra sp.*)		1						1
Gemsbok (*Oryx gazella*)					1		1	
Horse (*Equus ferus*)				1		3		4
Sheep (*Ovis aries*)		1						1
Steenbok (*Racipherus campestris*)	1						1	

Table 3.3. Livestock predation comparison 2023 / 2024.

Prey	Prey Age Class	Cattle	Chicken	Dog	Donkey	Goat	Horse	Sheep	**TOTAL**
Lion	adult	52/59			17/13		5/10		74/82
	subadult	12/13			2/1	0/1	1/2		15/17
	juvenile	5/14		0/1			0/2		5/17
Leopard	adult				1/0	2/1		0/1	3/2
	subadult	2/0			1/0		0/1		3/1
	juvenile	10/10			2/0		0/3		12/13
Black backed jackal	adult	1/0				11/7		4/7	16/14
	subadult					5/1		1/0	6/1
	juvenile	0/1				7/5		4/3	11/9
Caracal	adult		0/2			1/1		0/1	1/4
African wild dog	adult	4/2				3/0			7/2
	juvenile	2/2			1/0				3/2
Brown hyena	adult					0/1			0/1
TOTAL		88/101	0/2	0/1	24/14	29/17	6/18	9/12	156/165

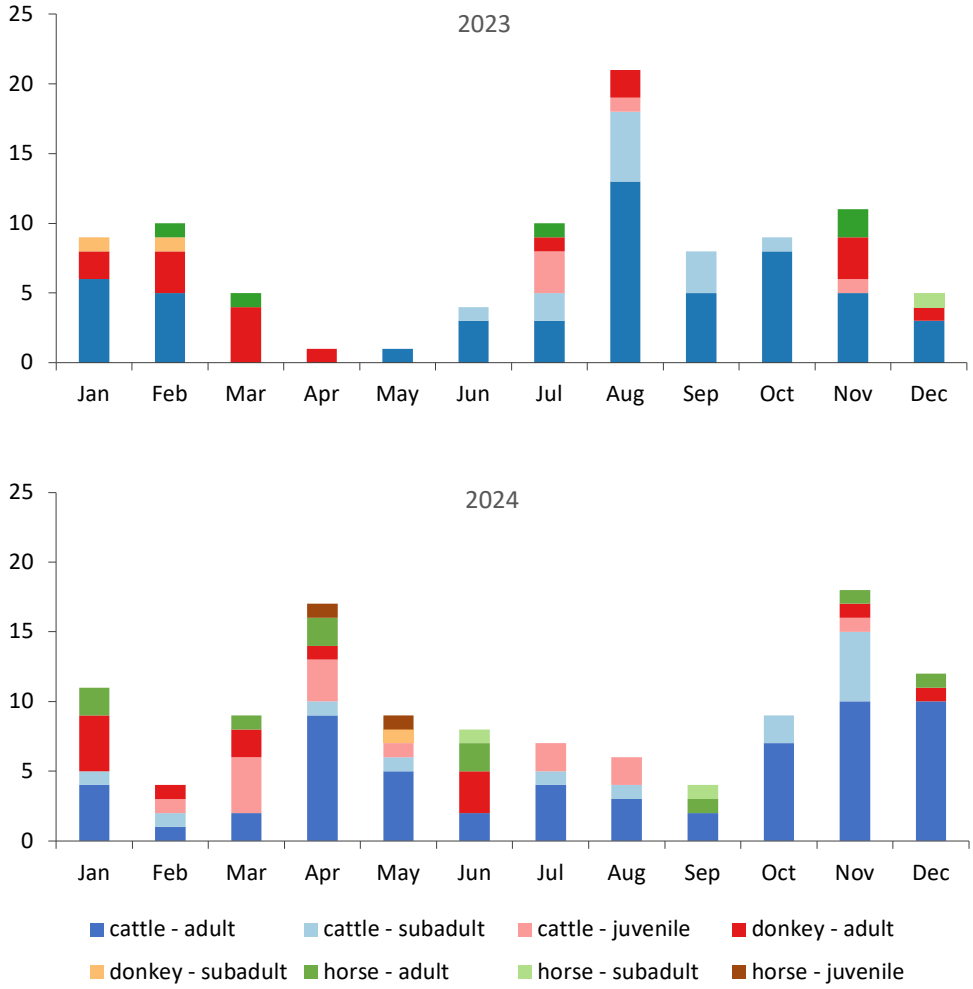


Figure 3.2. Temporal distribution of livestock predations (number of events) from lions in 2023 and 2024. The colours represent the different species and age classes in each cumulative column.

Project 4.
Predator Movement and Habitat Selection

Investigating the movement ecology of large carnivores is extremely important to understand their ecological needs and to have an effective monitoring of the status at individual and population level. Movement patterns are influenced by the complex interaction of environmental (e.g., climate, prey availability, landscape features), physiological (e.g., metabolism requirement, reproductive cycles, locomotion adaptation) and social factors (e.g., social structure, territoriality, intra-species communication).

In the Kalahari, the food sources can be extremely limited for all animal species in certain periods of the year. While some herbivores migrate long distances to find greener pastures, territorial carnivores such as lions and leopards have adapted their movement behavior by covering larger areas than their conspecifics residing in resource-rich areas. Home ranges become very large, and territory overlap increases as active territory protection becomes more energy-costly.

At LEC, a key tool to study carnivores' movements are the GPS collars deployed on selected study individuals. Not only allow us these devices to resight the animals and detect possible predation sites, but they also provide an invaluable information on how the animals move between direct observations without the possible bias caused by the presence of the observers. The collars we use at LEC are the most advanced collars currently available on the market allowing us to obtain fine-scale and precise continuous data across extended study periods covering the different life-stages of the study animals. We actively contribute to the development and refinement of these devices; for example, in collaboration with the Max Planck Institute of Animal Behaviour, Konstanz, Germany, we are currently testing new motion sensors based on magnetometers which will provide even better interpretation of behaviours from data obtained directly from the collars. LEC represents an ideal project to test this technology in one of the wildest and most challenging scenarios not only because we have worked for long time with leopards and lions in the Kalahari, but also because we integrate telemetry with traditional ecological knowledge and professional tracking methods to validate the data and test our interpretations.

In 2024, our extensive telemetry database has been used by LEC researchers and international students to provide key information for population management to our institutional stakeholders and to contribute to the international scientific community. GPS collar data from lions and leopards were used in combination with LEC kill site datasets and remotely sensed data on environmental features to investigate how leopards and lions move in our study area in relation to several parameters. This translated in a predictive habitat selection study which is presented in the Project in Focus section (page 34).

The LEC historical telemetry dataset was also used by two MSc students from CREEM (Centre for Research into Ecological and Environmental Modelling) at St. Andrews University in Scotland. Mr Muntasir Akash and Mr Natsani Dube investigated leopard movements under the supervision of Professor Sutherland. To estimate home-ranges, the researchers focused on resident leopards and the mean home range estimate was 956.85 km² (1405.41 km² – 1984.32 km²). This aligns with the existing knowledge of leopards living in arid and semi-arid southern Africa. The largest home range size was observed in the male PM008 - Bogarigka (2855.09 km²; 1782.39 km² – 4176.43 km², Figure 4.1 A), virtually covering the whole Khutse GR. A similar large range was recorded in arid southwestern Botswana, which, thus far, is the largest known home range across the species range. Moreover, it was found that there was no variation in home-range size across seasons or years. As anticipated above, it was also possible to prove that adult males' territories overlap quite extensively. For example, there was an almost identical overlap between two males (PM008 - Bogarigka and PM009 - Gham, Figure 4.1 C). When analysing how individuals moved within their range, it was found that male leopards covered longer distances with more constant direction than females, suggesting they actively patrol their territory more than females. The model estimated that female leopards were more mobile when further away from the reserve fence, after the rainy season, and near water sources. Their mobility also increased at lower temperatures, aligning with the energy-efficient nocturnal and crepuscular behaviours typical in the Kalahari's extreme day-night temperature excursion. Between the study leopards considered for this study, only PF007 - Ronja showed a home-range extending across the fence line (Figure 4.1 B), even if the core of her movements were inside the protected areas.

As mentioned above, details on how animal moves have important practical implications for many other research questions. As part of our efforts to improve the reliability of our track survey protocols, we strive to produce simulations using empirical movement data. In 2023, in collaboration with the University of

Louvain in Belgium, we carried out a field project to obtain empirical estimates of daily travel distances for five large herbivore species, a key parameter for estimating population densities from track surveys using the Formozov-Malyshev-Pereleshin (FMP) formula. In 2024, together with researcher Marie-Charlotte Gielen, we decided to understand if the FMP approach can provide reliable population estimates for lions in the Kalahari. The first step has been to obtain reliable empirical daily travel distances from our collar dataset and validate them through long-follows in the field. Our amazing tracking team has been back-tracking the trails covered by lions newly-collared in February 2024. The collars had a 5-minutes interval GPS schedule, and the team would collect the GPS fixes via UHF from the collar every morning before trailing the path the lion made in the last 24 hours (Figure 4.2). The estimates obtained by these long-follows (trailing) allowed us to see how reliable the estimates were produced by our modelling (Continuous-Time Movement Modelling, CTMM) using GPS fixes at 5-minutes and 1-hour intervals. The lion daily travel distance estimates obtained with CTMM were 18.15 km/day for hourly GPS fixes and 17.07 km/day for 5-minutes interval GPS fixes. Both were quite close to the observed average during long follows (16.94 km/day). Certainly, both estimates are much better than the distances calculated using the allometric approach (i.e., based on body size) or the Straight-Line Distance approach (i.e. direct distance between GPS fixes). Our CTMM estimates are nearly double the ones reported from the study lion population using summed straight-line distances (Büttner, 2019: 9-10 km/day) and are much closer to values obtained from desert lions using direct follows (Stander, 1998: 19 km/day). This validation of the CTMM approach is allowing us to be more confident in using its estimates and to define the ideal GPS fix frequency to estimate the daily travel distance.

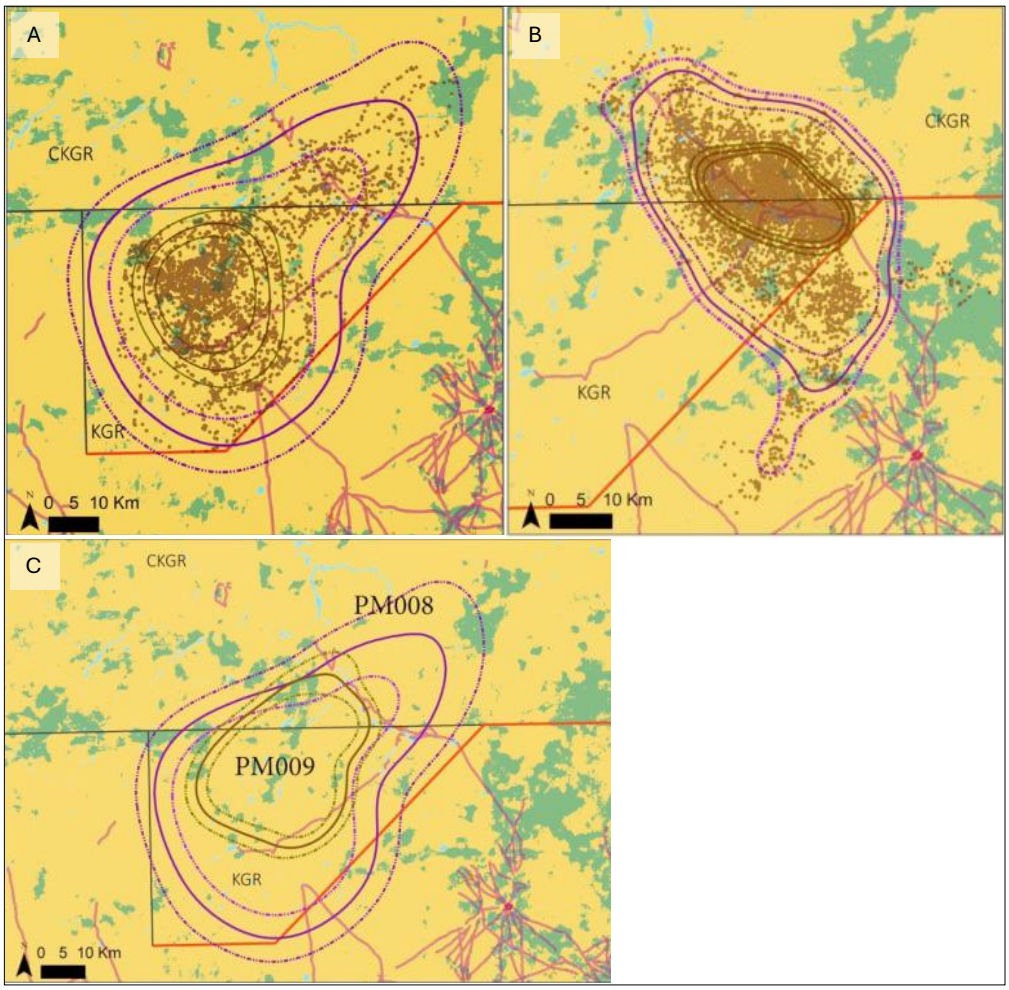


Figure 4.1. Visualisation of home range for PM008 - Bogarigka (A) and for PF007 - Ronja (B) estimated using the weighted aKDE (autocorrelated Kernel Density Estimation) approach. In each utilisation distribution, the solid line contour is the estimate, the dotted-line contours are respectively the upper (outer) and the lower (inner) limit of the 95% confidence interval. The red solid line represents the fence between the protected area and the communal grazing land. (C) Visualisation of home range overlap for PM008- Bogarigka (purple) and PM009- Gham (brown). (Image from M.Akash, 2024)

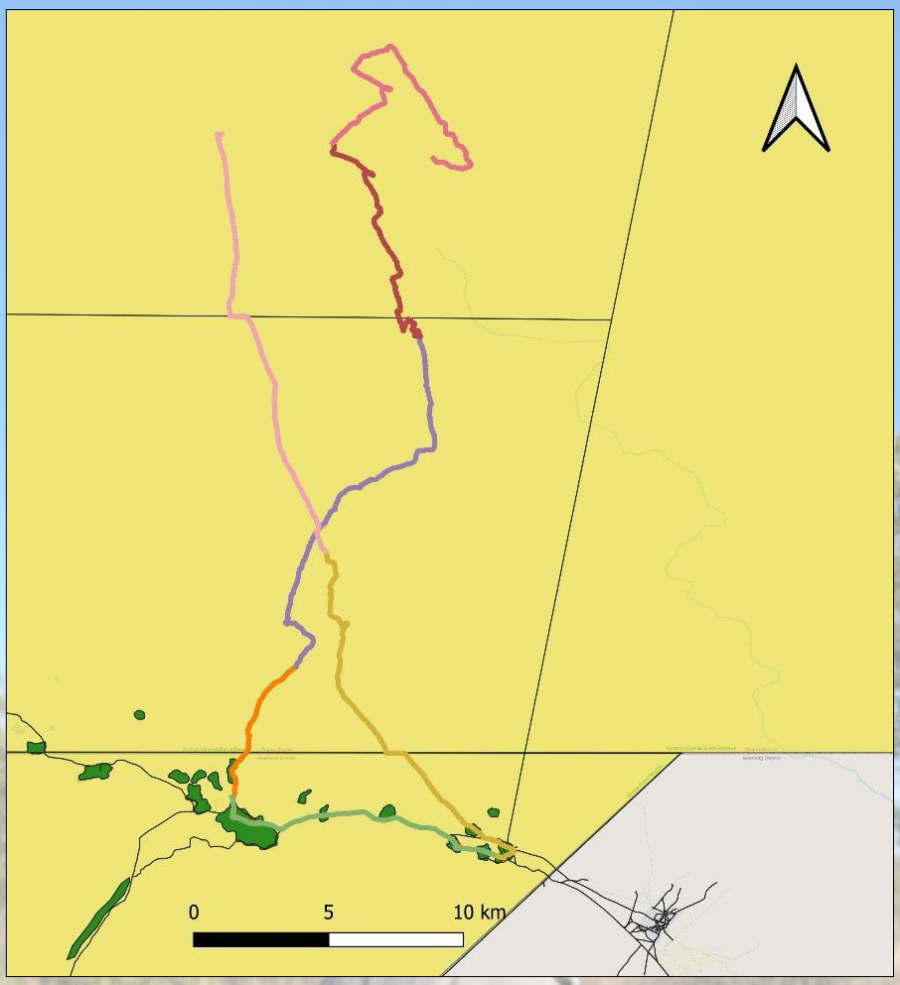


Figure 4.2. Map showing the reconstructed path travel by lioness LF064 Viva across 7 days in February 2024. Each colour represents a separate 24 h period. The tracks were collected using a customised CyberTracker App with an GPS accuracy of ±3 m.

Project 5.
Predator Demographics - Leopard

Leopard population monitoring is one of LEC's main long-term activities. The monitoring of demographic trends provides key information for developing population management strategies and act as preliminary alert system when a population is under stress. Investigating demographics of cryptic solitary carnivores in low-density habitats is extremely challenging as most survey methods require a minimum sample size (i.e., number of direct or indirect observations) obtained within a specific time frame to produce reliable estimates. Traditional surveys based on direct observations of the individuals are ineffective for elusive predators such as the leopards. This is particularly true for carnivore populations living in habitats with low prey density and, consequently, presenting vast home-ranges, as recorded in the Kalahari. In such scenario, survey methods using indirect observations are the only feasible solution to monitor leopard population trends.

In the period 2023 - 2024, LEC has completed the first large scale camera-trap survey in Khutse GR and southern CKGR. The main objective was to estimate the leopard population within the protected area and compare the results with the estimates we have obtained from our extensive track surveys in the period 2007 - 2022. Camera-trapping is undoubtedly considered as one of the most reliable techniques to assess leopard populations, and an alignment of our track survey results with the camera-trap survey would strengthen the output of our monitoring activities.

The camera-trap survey was designed in collaboration with Dr Chris Sutherland (CREEM – University of St. Andrews, UK) in 2023 and consists of two sampling seasons (S1 Dry – May to August 2023; S2 Wet - November 2023 to February 2024). The camera-traps were deployed within a grid, based on the Spatially-Explicit Capture-Recapture (SECR) approach, which accounts not only for the frequency of individual captures on camera traps but also for the spatial distribution of each capture within the study area. The whole survey covered an area of 4435 km² divided in four blocks for a total of 302 camera-traps deployed across 216 locations. Each of the four blocks was surveyed for 60 days in each sampling season.

The camera-traps produced more than 200'000 images which were processed using Conservation AI (www.conservationai.co.uk) for the initial image classification. Conservation AI offers a platform to automatically detect if the image contains an animal and, successively, classifies the species and the number of individuals. Simultaneously, all images were manually reviewed to make sure that all leopard related images could be detected, including images with portions of the tail or other body parts. Across the two seasons, 687 images of leopards were collected across 423 capture events (i.e., independent camera-triggering events). The images containing leopards were processed through African Carnivore Wildbook (ACW, www.africancarnivorewildbook.com) platform to create ID kits for every observed individual and to assign each image to the correct individual.

From the preliminary results, we could observe a clear reduction in leopard capture events on camera across the two seasons (Table 5.1), both considering absolute values (312 in S1 and 111 in S2) and weighted by the sampling efforts. In season 1 across the whole study area, we have one leopard captured by a camera every 42.7 camera-trap station days, while in season 2 we have one leopard captured by a camera every 123.5 camera-trap station days. If we consider the population of adult leopards to be relatively constant across the two seasons, this difference in leopard capture events might be due to a different movement behaviour between dry and wet season.

In both survey seasons, most of the leopard captures were recorded at camera-trap stations placed along existing roads (Figure 5.1 and 5.2). This confirms that leopards tend to use existing roads to move across their home-range and, therefore, camera-trap surveys using only roads for camera deployments might overestimate the population size.

After identifying the individual leopards with the assistance of the African Carnivore Wildbook platform, we could define the minimum number of individuals detected at least one time within each block per season (Table 5.2). While the number of different identified male leopards is similar across the two seasons (16 in S1 and 15 in S2), the number of identified females drops from 15 to 8 individuals. When we consider only the identified individuals detected on more than three events (Table 5.3), there is a clear decrease in the number of females in season 1 and in both sexes in season 2. This could suggest a different movement behaviour between male and females and across seasons. As per literature, males cover larger distances than females and therefore might be captured at different locations more easily. We may also suggest that during the dry season both sexes cover larger areas or are more active than in the rainy season.

The final results including the population size estimates calculated using the SECR approach will be finalized at the beginning of 2025, and they will provide further insight in the status of the leopard population in the protected areas where LEC works.

Table 5.1. Camera-trap (CT) station days and leopard captures across the survey blocks in the two seasons. Camera-trap station days represent the period when at least one camera-trap was active at the camera-trap station.

Block	CT stations	Season 1				Season 2			
		CT station days	Average CT station days	Leopard capture events	Leopard captures/ CT station days	CT station days	Average CT station days	Leopard capture events	Leopard captures/ CT station days
NW	56	3294	58.8	80	0.024	3250	58	18	0.006
SE	43	2611	60.7	73	0.028	3278	76.2	36	0.011
NE	57	3880	68.1	87	0.022	3249	57	26	0.008
SW	57	3542	62.1	72	0.020	3933	69	31	0.008
All blocks	**213**	**13327**	**62.4**	**312**	**0.024**	**13710**	**65.06**	**111**	**0.008**

Table 5.2. Number of different individual leopards captured within each camera-trap survey block. Some individuals were recorded in more than 1 block. The "Unknown Sex" category includes individuals which were assigned an individual ID thanks to their fur spot patterns, but which could not be sexed. The "Unidentified" category includes images where it was possible to classify the animal as a leopard, but which did not provide the elements to assign an individual ID (i.e. tip of tail, over-exposed images). Some individuals were captured in more than 1 block as they were active in areas on the edge of neighbouring survey blocks, hence the total number of identified individuals across the four blocks is lower than the sum of the single blocks.

Block	Season 1					Season 2				
	Male	Female	Unknown sex	Uniden-tified	Minimum total (no unidenti-fied)	Male	Female	Unknown sex	Uniden-tified	Minimum total (no unidenti-fied)
NE	7	3	1	10	**11**	3	2	0	5	**5**
NW	7	4	0	3	**11**	7	1	0	3	**8**
SE	5	5	1	10	**11**	5	3	0	6	**8**
SW	5	5	1	9	**11**	2	2	3	3	**7**
All blocks	**16**	**15**	**3**	**32**	**34**	**15**	**8**	**3**	**17**	**26**

Table 5.3. Number of different individual leopards captured within each camera-trap survey block on more than three events. Some individuals were recorded in more than one block.

Block	Season 1				Season 2			
	Male	Female	Unknown sex	Minimum total (no unidentified)	Male	Female	Unknown sex	Minimum total (no unidentified)
NE	4	2	0	**6**	2	1	0	**3**
NW	5	2	0	**7**	1	0	0	**1**
SE	3	0	0	**3**	2	0	0	**2**
SW	2	3	1	**6**	2	1	0	**3**
All blocks	**13**	**7**	**1**	**21**	**7**	**2**	**0**	**9**

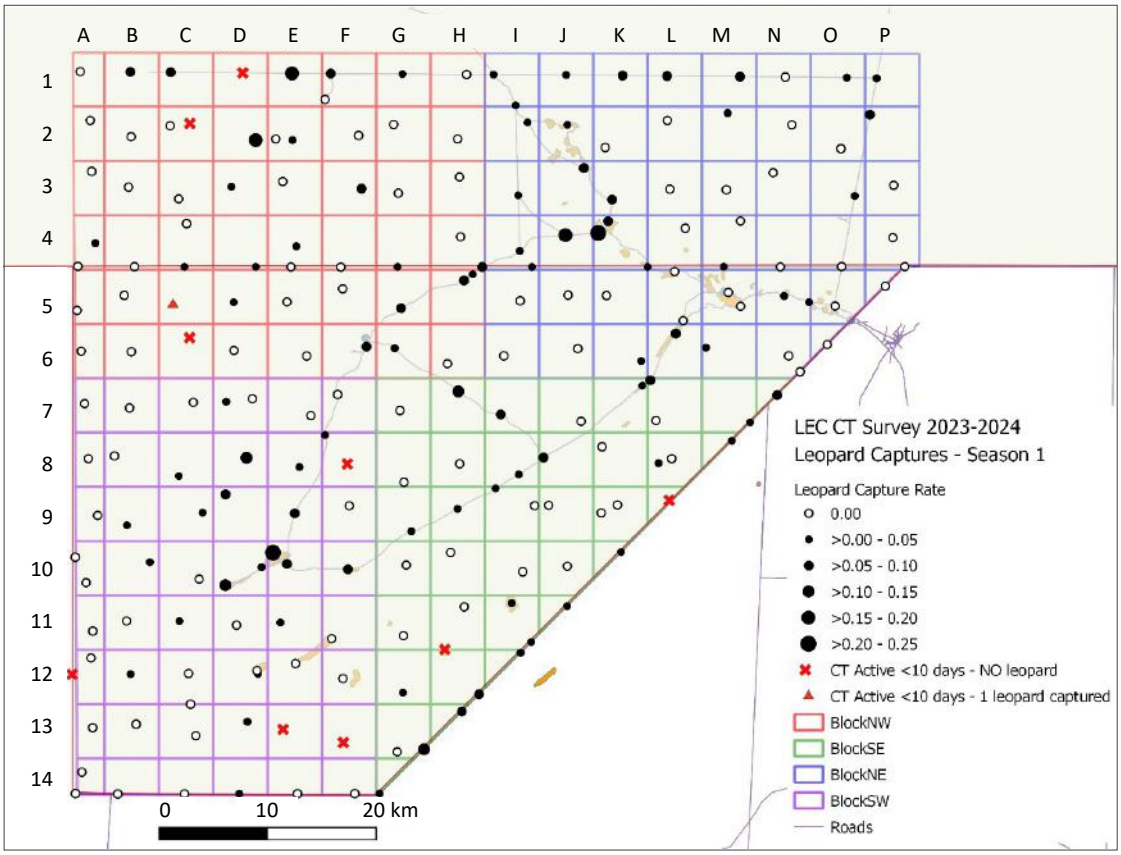


Figure 5.1. Distribution of leopard captures weighted by the camera trap station days (Leopard Capture Rate) in Season 1.

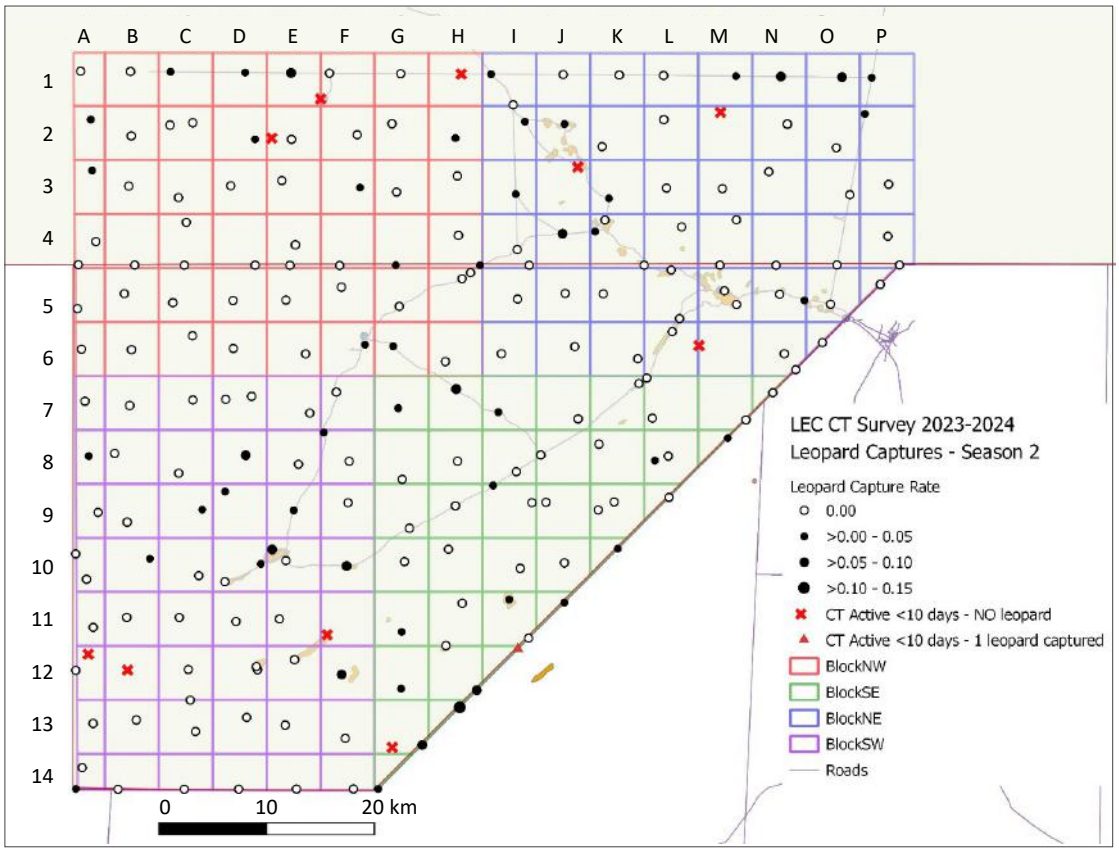


Figure 5.2. Distribution of leopard captures weighted by the camera-trap station days (Leopard Capture Rate) in Season 2.

Project 5.
Predator Demographics - Lions

LEC lion population monitoring activities consists in a series of field research activities aimed to estimate the population size and structure, as well as key demographic rates which measure population change over time.

Due to the low density lion population and the extremely large lion home-ranges in the LEC study area, two main techniques have been selected to monitor the lion population: Track surveys and GPS collaring for direct observations.

Track surveys provide an overall estimate of population size, while repeated observations of adult, resident, collared individuals and their uncollared associates allow us to monitor sex and age structure of the core study prides. By tracking these individuals over time via repeated sightings, we aim to estimate cub recruitment, survival rates and changes in group composition due to immigration and emigration processes.

In 2024, we presented to DWNP a report focusing on our lion population monitoring since 2007. As mentioned above, our primary method of tracking population size (or density estimates) over time for lion population is via track surveys reported every four years. It is striking how the track encounter rate of lions massively decreased in the communal areas following the completion in 2010 of the fence that separates those areas from the Khutse GR. The Formozov-Malyshev-Pereleshin (FMP) formula was applied to calculated lion densities from the track survey datasets. The lion densities outside the park decreased from 0.36 to 0.03 or less individuals per 100 km² after the fence was constructed (Table 5.4 and Figure 5.4). The lion track encounter rate also decreased on almost all the Khutes GR routes. The track encounter rate of lions in the Khutse GR in 2021 - 2022 has decreased by 40% of the value observed in 2007- 2009 and the lion density decreasing trend is shown in Figure 5.3.

In 2024, we have also looked at the survival rate of the litters born between January 2019 and December 2024 (Table 5.5). It is often hard to determine precise litter size as cubs are often hidden and difficult to observe, therefore we report the maximum litter size observed in the earliest sightings. Please note in few records, more than one mother is listed per each litter, in these cases none of the possible mothers were collared at the moment of birth and we could not exactly assign which female was the mother of which litter, as a result of joint care at time of first observation. Looking at females who had multiple litters during the monitoring period, we see a pattern of an interbirth interval of approximately two years when the litter survives at least one year. This is common in lions and corresponds to the time that the previous litter would usually be dependent on the mother. Infant mortality is typically highest in African lions in the first few months and thus the number of cubs to survive to one year of age is often used as a proxy for maternal productivity. Average rate of cub survival to year one for the litters we recorded is 49%, which is relatively high given the low food availability in the system. It is possible that we are somewhat overestimating cub survival to year one for uncollared females if the litters are lost before we can observe them. This is possible as females will often hide cubs in dense thickets for the first five to six weeks of age away from the rest of the group, meaning we would be unlikely to sight them with the collared individual until at least six weeks. If we try to estimate the survival rate at three and a half years, when lions may be considered reproductive, 88% of the cubs which survive one year are still alive. This estimate does not consider litters born after June 2021, obviously.

If we focus on the individuals directly observed in 2024, we counted a minimum 58 different individuals, including seven cubs (less than six months), across all our observation (Table 5.6). By the end of 2024, we could record the mortality of two adult males (Athos and one of his brothers), two adult females (Sarah and unidentified individual) and two subadult male (Sarah's cub born in 2023). In addition, two of Alice's cubs born in August 2023 died before reaching one year of age and none of the seven cubs of the new litters detected in 2024 survived.

Figure 5.3. Trend in lion density per 100 km² inside the protected area.

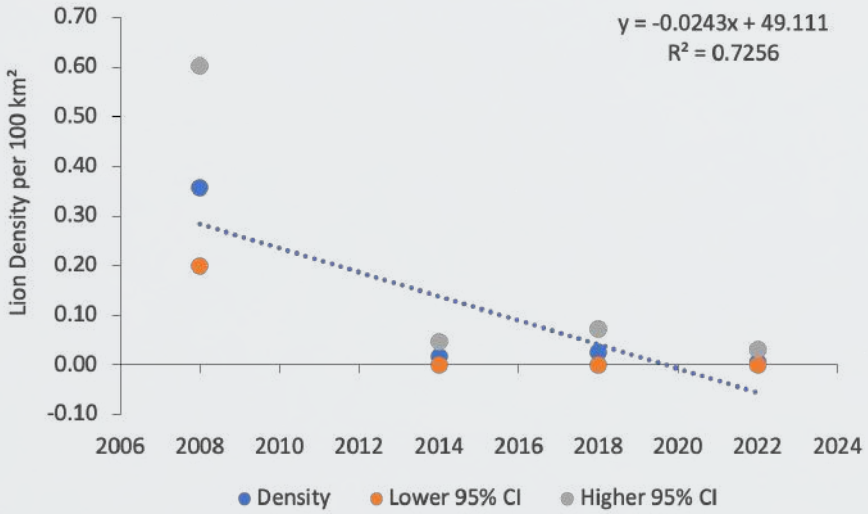


Figure 5.4. Trend in lion density per 100 km² in the communal grazing land.

Table 5.4. Lion density estimates obtained from extensive track surveys from 2007 to 2022 inside the protected area (Khutse GR and part of CKGR) and outside (Communal grazing land). The area size used to calculate the population size inside the protected area is equal to the area covered by the 2023 - 2024 Camera-trap survey. The area assigned to the communal grazing land is equal to the sum of KW4 and KW12.

Survey Period	Survey Area	Lion Density per 100 km² (95% - CIs)	Population Size	Area size [km²]	Method
2007-2008	Khutse GR	0.53 (0.35-0.77)	24 (16-34)	4435	FMP
2013-2014	Khutse GR	0.31 (0.16-0.55)	14 (7-24)	4435	FMP
2017-2018	Khutse GR	0.13 (0.08-0.20)	6 (4-9)	4435	FMP
2021-2022	Khutse GR	0.20 (0.11-0.34)	9 (5-15)	4435	FMP
2007-2008	Communal grazing land	0.36 (0.20-0.60)	5 (3-9)	1414	FMP
2013-2014	Communal grazing land	0.02 (0.00-0.05)	0 (0-1)	1414	FMP
2017-2018	Communal grazing land	0.03 (0.00-0.07)	0 (0-1)	1414	FMP
2021-2022	Communal grazing land	0.01 (0.00-0.03)	0 (0-0)	1414	FMP

Table 5.5. Summary of observed litters in the last five years (2019- 2024).

Mother	Age of Mother [y]	Pride	Litter size (max observed)	Born (approx.)	No. survived to year 1	No. survived to year 3.5 (possible age of first reproduction)
Alice &/or Alexa	5	Molose	5	Mar- 19	0	0
Nina	9.5	East Khutse	4	Sept- 19	3	3 (2 males shot in 2024)
Notch	10	East Khutse	3	Dec- 19	0	0
Sarah	10	East Khutse	3	Jan- 20	0	0
Peggy	10	East Khutse	3	Jan- 20	3	1
Alice	6	Molose	4	Mar- 20	0	0
Alexa	6.5	Molose	3	Sept- 20	3	3
Alice	6.5	Molose	4	Oct- 20	3	3
Notch	11	East Khutse	3	Nov- 20	0	0
Desi or Joyce	8	Molose	3	May- 21	3	3
Desi or Joyce	8.5	Molose	2	Oct- 21	2	2
Verity	14	East Khutse	2	Jan- 21	0	0
Sarah	11.5	East Khutse	2	Apr- 21	0	0
Notch	11.5	East Khutse	2	Apr- 21	0	0
Tuelo &/or LF076	5	NA	5	Nov- 22	5	NA
Poona	3	East Khutse	4	Oct- 22	0	0
Poona	3.5	East Khutse	2	Apr- 23	2	NA
Sarah (shot in 2024)	13	East Khutse	4	Jan- 23	4	NA
Alice	9	Molose	4	Jul- 23	2	NA
Alexa	9	Molose	4	Aug- 23	2	NA
Desi	10.5	Molose	4	Oct- 23	3	NA
Joyce	10.5	Molose	3	Nov- 23	3	NA
Viva or LF065	7.5	East Khutse	1	Jan- 24	0	0
Viva	8	East Khutse	2	Aug- 24	0	0
LF065	8	East Khutse	2	Aug- 24	0	0

Table 5.6. Summary of the minimum number of different individuals recorded across 2024 observations. Adult individuals include young adults in dispersal. Juveniles are individuals less than one year of age. Records are divided according to known or unidentified individuals. In red, the mortalities.

	Adult Male	Adult Female	Subadult Male	Subadult Female	Juveniles
Known	16 (-2)	12 (-1)	12 (-1)	8	9 (-9)
Unidentified	1	2 (-1)	0	0	0

Meet the class of 2024

East Khutse Pride

The 2024 might be considered the first year of a new generation of lions moving in the northeast area of Khutse GR. Sarah was the only female still alive of the East Khutse pride generated from a group of females born between 2007 and 2010 (Verity, Nina, Peggy, Notch) in the Molose area. Already in the second part of 2023, Sarah and her four male cubs established themselves in the cattle post area between the park boundary and Mangadiele. In March 2024, she was shot with one of her male subadults as problem animals. Fortunately, the remaining three subadults joined Poona and her two male cubs born in April 2023. Poona is the daughter of Peggy, and we managed to collar her at the end of August 2024. She has been moving with the five subadult males between Khutse 1 pan and the communal grazing land around Kaudwane.

Another two lionesses, Viva and LF065, were spotted around Khutse 1 at the beginning of the year. They have been identified as the daughters of Notch from a 2016 litter. Their last observation was in 2019. We could collar Viva in February 2024. They move in the area between Khutse 1 and the second cutline in CKGR. In March they were seen in very poor conditions together with an older unidentified female who died after few days for unknown reasons. They managed to recover well, and they had three litters between the two of them, but unluckily none of the cubs survived more than six months.

Athos, Portos and Aramis established themselves around Gope village in CKGR. The three males born in 2019 were forming a very strong coalition after dispersing from the mother Nina. Athos was also observed mating with an unknown female towards the end of 2023. On the 9th of March, Athos and one of the two brothers were shot as problem animal after killing a horse on a farm neighbouring CKGR. Unluckily, it was not possible to identify which brother was shot as we were informed only few days after when we managed to retrieve the collar. The fate of the third brother (Portos or Aramis) is unknown.

Molose Pride

In the last five years, we have been able to continuously follow two cohorts of females with their offsprings moving in the areas. The four older females are from the large Molose pride (27 individuals) which fell apart between 2016 and 2017.

In 2024, Alice and Alexa established their core area between Molose and Khukhamma waterhole in CKGR. They moved with four of their cubs born in 2023 and with Alexa's daughter LF072 born in 2020. The group moved extensively between Khutse GR and CKGR following the big herds of elands in that area. LF072 was seen moving between this group and the group of dispersing males composed by Sepekere. Mookodi and LM097.

In early 2024, during collaring operations to replace the collars on Alice and Desi, we found minor injuries on both females which could have been caused from an interaction between the two cohorts as hypothesized from their GPS-collar data. For the entire 2024, Desi and Joyce (LF047) moved with their six cubs (late 2023) between Moreswe and Molose covering large distances between the eastern and western boundaries of Khutse GR.

The males dispersing from the 2020 litters of Alice and Alexa and the 2021 litters of Desi and Joyce have created coalitions moving between Molose and Khukhamma waterholes. In February 2024, Sepekere (LM098) was collared while he was moving with four other males (LM098, LM099, LM100, LM101). Sepekere and his brother LM097 are the two male offspring of Alexa who moved with Desi and Joyce and their litter in 2022/2023 which included LM099, LM100, LM101, LM102 and LF074. Mookodi (LM102) joined the coalition and was constantly observed with Sepekere since June 2024. In the same month the coalition split in two with Sepekere, Mookodi and LM097 on one side and the other 3 males moving away from the area. Mookodi is the youngest of the above-mentioned litters and he has been collared in October 2024 to understand how he will disperse and if he will stay with the two older males.

Sekaka group

In October 2024, a group formed by two adult females and five 2-years-old subadults (three males and two females) were spotted close to the CKGR fence towards Tshipidi cattle post. The two females (LF075 and LF076) were part of the litters born between 2017 and 2018 in the East Khutse Pride. We could collar Tuelo (LF075) and monitor her movements. Immediately after the collaring, she separated from the rest of the group for one month before regrouping in the CKGR area north of the second cutline between Sekaka, Gope and Mothomelo. The group seems to cover extremely large distances and Tuelo has been very successful in killing large preys even by herself.

Rocket and Snooks

Rocket and Snooks, are still active throughout most of Khutse GR even if their tenure has been challenged in 2024. In February, Snooks was found seriously injured to his front left leg. The injury was probably a consequence of a fight with another male and he was in very poor conditions. He was collared to monitor his fate and understand if other males would challenge him again. Unexpectedly, he managed to recover and after one month, he rejoined Rocket and, by monitoring their movement from the collars on the two males, we could see how Rocket actively supported Snooks by hunting and waiting for the coalition partner. Since he recovered, Snooks has a permanent limp which does not impede him to cover large distances and successfully hunt independently.

Spiderman and John

Spiderman and John are two adult males in their prime (7 - 8 years). They were seen for the first time in December 2020 while they were trying to establish their first new territory after dispersal in the Khukhamma area. Spiderman was collared immediately after the first observation, but his collar stopped working in January 2022. After few opportunistic resightings, in June 2024 Spiderman and John were observed with Viva and they are probable candidates to have fathered Viva's second litter in 2024. They move between Khankhe area and Khutse 1 and they have probably established their territory in this section of CKGR becoming prime contenders to Rocket and Snook's tenure. Spiderman's collar was lost towards the end of 2024 when the automatic drop-off system triggered.

Project 6.
Human-Predator Conflict

Human-predator conflict is certainly the most relevant type of human-wildlife conflict in LEC study area. In the recent years, the number of elephants has increased and seriously impacted the landscape and the artificial waterholes inside the protected area, but the damages to human activities from elephants or other crop raiders is still very limited as crop farming is almost inexistant in the area. On the contrary, livestock losses caused by wild carnivores is the main source of conflict. Livestock farming in the communal grazing land adjacent to the park boundaries has steadily been growing in the last ten years with an increasing overall presence of cattle post and livestock. Livestock farming in the area is based on a free-roaming practice where the livestock moves freely during the day and may return to the cattle post where water is provided, and animal can be secured in kraals (enclosures) during the night. The Kalahari landscape poses major challenges for livestock farming as during the dry season the livestock needs to cover large distances from the cattle post to find palatable grasses and fulfil their feeding needs. In addition, herding is not a practice culturally diffused in this part of Botswana and livestock owners often do not have a daily check on their livestock. The combination of these two factors with the close proximity to the national park translates in the livestock moving in high predation-risk areas far from the kraal where the human presence could act as deterrent.

The 2023 - 2024 rainy season was extremely poor increasing the competition for food resources for both wildlife and livestock. Wild prey availability, reduced mainly due to less births and carnivores, had to expand their activity ranges to search for preys. Livestock had to cover larger distances to find food and often they would not return to the kraal every day. Moreover, the overall health conditions of livestock were lower than average, causing more losses to disease and making the

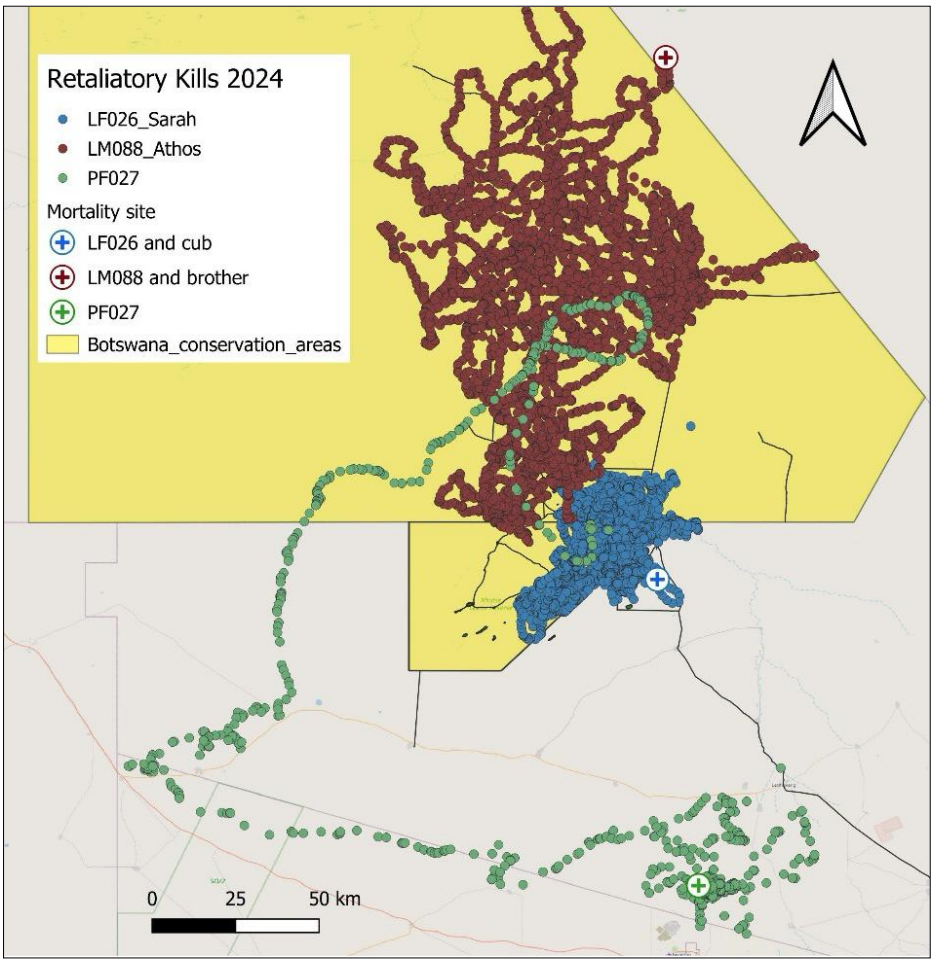


Figure 6.1. The map shows the movement of the collared individuals who were shot by farmers in 2024. The mortality sites are marked with crosses. Athos' brother was shot in proximity to Athos (LM088) and the male subadult cub of Sarah (LF026) was shot on a separate date but in proximity to his mother's kill site.

debilitated livestock easier preys for wild carnivores.
Nevertheless, the data presented in Section 3 (Predation, page 13) shows that the overall predations on livestock have not increased from 2023, even if the number of losses caused by lions passed from 94 in 2023 to 116 in 2024. Lions are generally more affected by drought years as on average they need larger preys to survive and are less opportunistic than leopards, jackals and caracals which can survive on a larger prey species spectrum.
In 2024, we also witnessed a relatively high number of retaliatory kills on carnivores in our study area and across Botswana. Within a few days in March 2024, we lost four study lions which were shot by farmers (Figure 6.1). Sarah and one of her subadult males were shot in Mangadiele area while Athos and one of his brothers were shot the first time, they left CKGR to venture in the central district farmland. At the end of May 2024, the translocated female leopard PF027 was shot by a farmer north of Jwaneng mining area. She established herself in the area and gave birth to at least two cubs but they were too young by the time her death was confirmed.
In addition, four adult male leopards were legally shot by trophy hunters and at least two of them were partially resident inside Khutse GR. For the first time after many years, no leopards were translocated to LEC study area.
Even if strongly publicized for electoral purposes in 2024, the destruction of several predators had no impact on livestock losses with the overall recorded livestock killed by predators reaching the same values of 2023. It seems empirically evident that the direct persecution of carnivores is not the correct strategy for reducing human-carnivore conflict and that resources should be focused on proactive management of livestock through better herding and the creation of alert systems to inform of lions approaching sensitive areas.
In this perspective, towards the end of 2024 LEC started a pilot project aiming to better understand how cattle move outside the reserve and to identify areas where the risk of predation is higher. In collaboration with one of the farmers based along Khutse eastern boundary, we placed two GPS ear tags on his cattle to monitor their movement and see how useful they can be to the farmers in managing their livestock. The initial results are promising as the farmer is actively using the ear tag to recover cattle when they do not return to the kraal. In 2025, we hope to deploy ear tags on at least other eight cattle and together with the data from the lion GPS collars understand the areas of overlapping.
To investigate the effectiveness of early warning systems, together with the Max Planck Institute of Animal Behaviour (MPI), Konstanz, Germany, we have provided four GPS collars for lions and trained the DWNP research officers from Central District to establish a monitoring of problem lions translocated to CKGR. The training focused on geofencing, a methodology which consists in creating a virtual geographical boundary that triggers an alert when the collars on the lion leaves the set perimeter. The collars will be deployed by DWNP in 2025 and LEC will continue assisting with technical support to optimize the early warning system and its application.

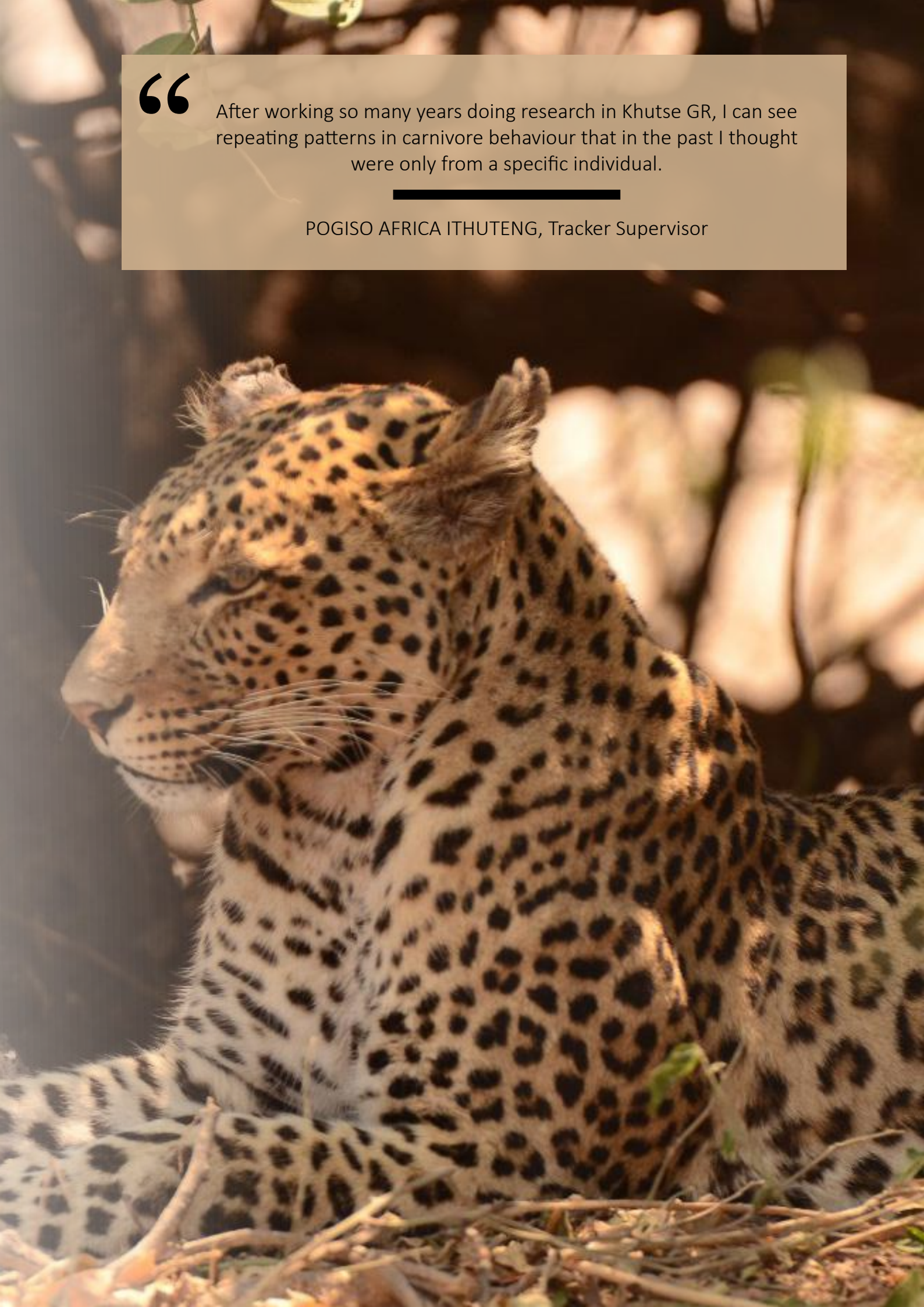
Project in Focus.

LEC - A longstanding Research and Conservation Project

As LEC is approaching its first jubilee in 2025, we would like to highlight the importance of long-term research studies which can provide further insight in the ecosystem trends and how wildlife adapts to new environmental conditions. Long-term comparable datasets are fundamental to monitor how climate change, new anthropogenic pressure and loss of habitat are impacting the wildlife population viability on the long-term, avoiding natural short-term fluctuations to mislead future conservation strategies.
This is particularly true for the Kalahari. This landscape is characterized by high climate variability, including irregular rainfall patterns, extreme temperatures, and prolonged droughts. Simultaneously, some ecological processes in arid and semi-arid environments, like vegetation recovery, soil development, livestock overgrazing, or the movement of wildlife populations, occur slowly over many years. Kalahari plant and animal species are extremely resilient species selected by extreme environmental conditions and their adaptation to the new challenges might be perceived only when the ecosystem community has been monitored for extended periods of time.
While data collection needs to cover extended periods of time, it is also crucial that the analysis of the datasets and the monitoring of data collection is constant and time-effective. The results provide essential feedback to field researchers and other stakeholders as well as key information to review and improve the current study designs.
In 2024, we focused on existing long-term and historical LEC datasets to investigate two essential aspects of large carnivore research: Predation and Habitat Selection.

Predation

The data analysis led by LEC researcher Dr Leandra Stracquadanio focused on investigating lion and leopard prey selection and the environmental factors influencing the predation of wild prey and livestock. The analysis considered the extensive LEC predation dataset from 2006 to 2024 in combination with the prey population estimates generated from LEC long-term extensive track surveys. Our findings, using Jacobs' D index to indicate animal preference or avoidance of prey species, revealed that lions and leopards exhibit different prey preferences, with lions favouring large wild species while leopards act as generalists, showing less preference for specific prey, as partially expected (Figure F1).
When we investigated the spatial distribution of the recorded predations, we observed that Lions predated primarily on large ungulate species in open habitats near water sources. However, wildebeest were hunted opportunistically without a clear environmental association. The tendency to hunt warthogs and porcupines in pans or bare areas suggests a hunting strategy probably linked to the absence of burrows where the prey can find refuge (Figure F2).
Duikers were the most preferred and most frequently predated species by leopards. Their predations were mainly associated with increased distances from roads. Given that duikers do not form herds and were not hunted near resources that promote group aggregations, such as water sources, this suggests that leopards select duikers and other non-herding species more based on the fact that they are catchable rather than based on their abundance (Figure F3). Predations on livestock typically occurred away from water points, which are generally surveyed by farmers, but relatively close to areas of human activity and along the protected area boundary, especially for lions. These findings highlight areas that could be targeted for conservation activities to reduce human-carnivore conflict.



> After working so many years doing research in Khutse GR, I can see repeating patterns in carnivore behaviour that in the past I thought were only from a specific individual.

POGISO AFRICA ITHUTENG, Tracker Supervisor

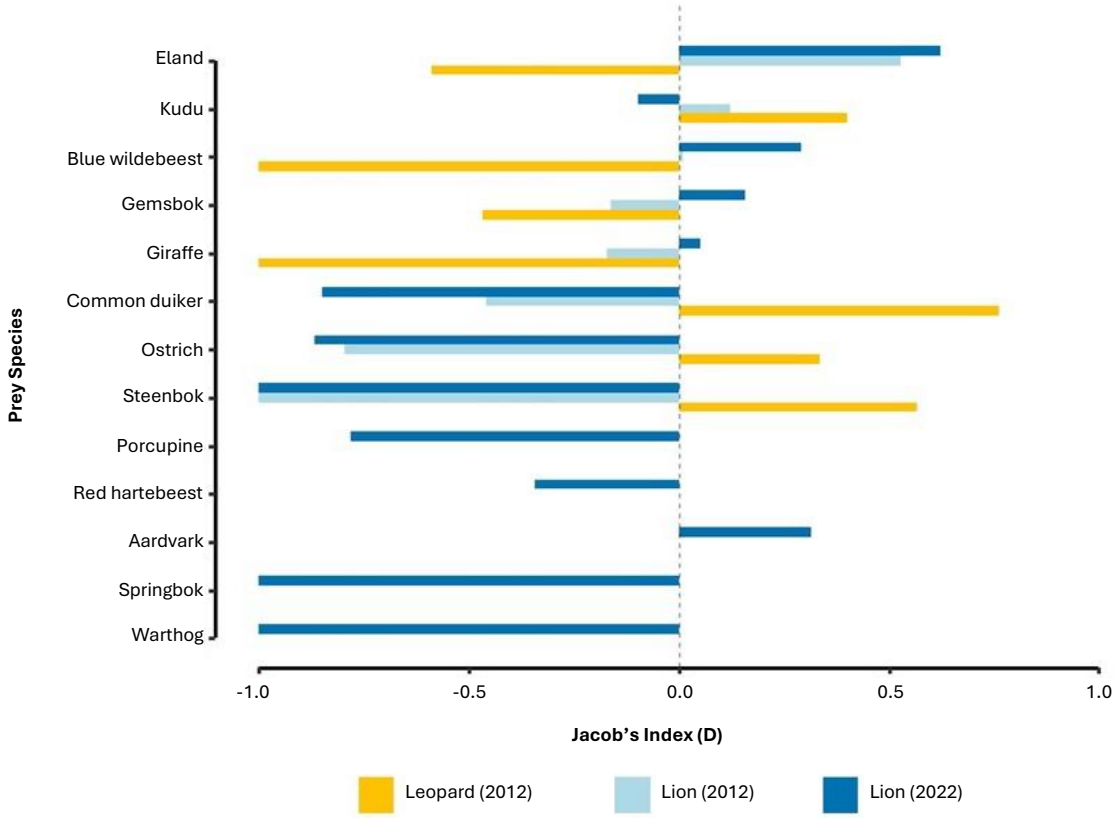


Figure F1. Jacobs' D prey selection indices for 2012 and 2022 of lions and 2012 for leopards. Blanks represent when a selection value was zero. The grey box represents when density data was not available for a prey species in 2012 for lions (Porcupine, Springbok, Warthog, Aardvark, Red Hartebeest). (Stracquadanio et al., in review)

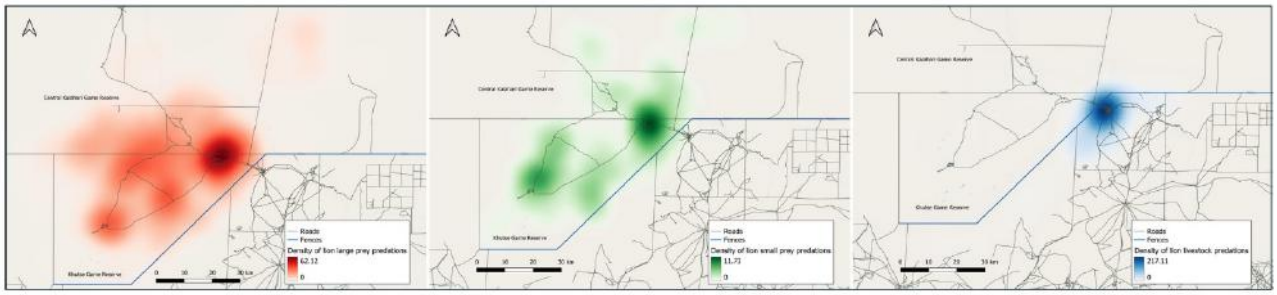


Figure F2. Kernel density estimate (KDE) heat map of lion predations of large wild prey (left), small wild prey (middle), and livestock (right). Density values were calculated using a radius of 10 km. Basemap sources: ©OpenStreetMap contributors and OpenStreetMap Foundation (2024). (Stracquadanio et al., in review)

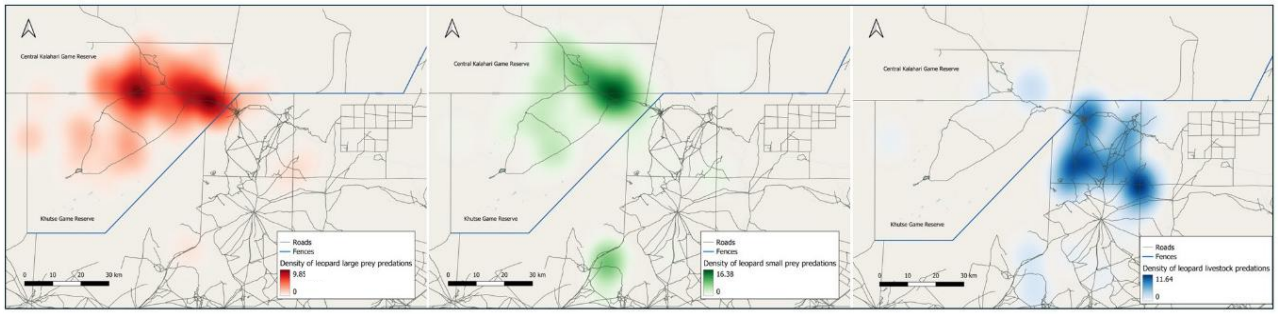


Figure F3. Kernel density estimate (KDE) heat map of leopard predations of large wild prey (left), small wild prey (middle), and livestock (right). Density values were calculated using radius of 10 km. Basemap sources: ©OpenStreetMap contributors and OpenStreetMap Foundation (2024). (Stracquadanio et al., in review)

Habitat Selection

Dr Kieran O'Malley from LEC research team combined historical LEC telemetry datasets and remote-sensed habitat features with the intensive kill site study carried out by LEC between 2011- 2013 to understand habitat selection and hunting behaviour. GPS collar data from 16 lions and five leopards monitored between 2011 and 2013 and fine-scale predation records were analysed using recently developed movement models (integrated step selection functions) enabling us to assess the relationship between leopard and lion habitat selection and movement patterns. The results confirm our previous assumption that predators strongly select pan habitats relative to other areas of the landscape but make larger movements (step lengths) when within them. Additionally, predator distribution at these broader scales appears to reflect potential movements of herbivores, from rain-fed pans in the wet season to artificial waterholes in the dry season (Figure F4). The analyses also confirmed a result from 2007 (Trüssel & Lerch) that predators were more likely to make kills in open areas, whilst they rested at sites where vegetation structure provided greater cover. These findings both shed light on the important role that pans play in the Kalahari landscape and have significant implications for management strategies, highlighting the importance of maintaining waterholes year-round. In addition, the proven impact of vegetation structure on leopard and lion hunting behaviour and thus predator-prey dynamics has important implications in the context of the arrival of elephants and the impact these 'ecosystem engineers' is potentially having on the Kalahari carnivore populations and more generally this environment.

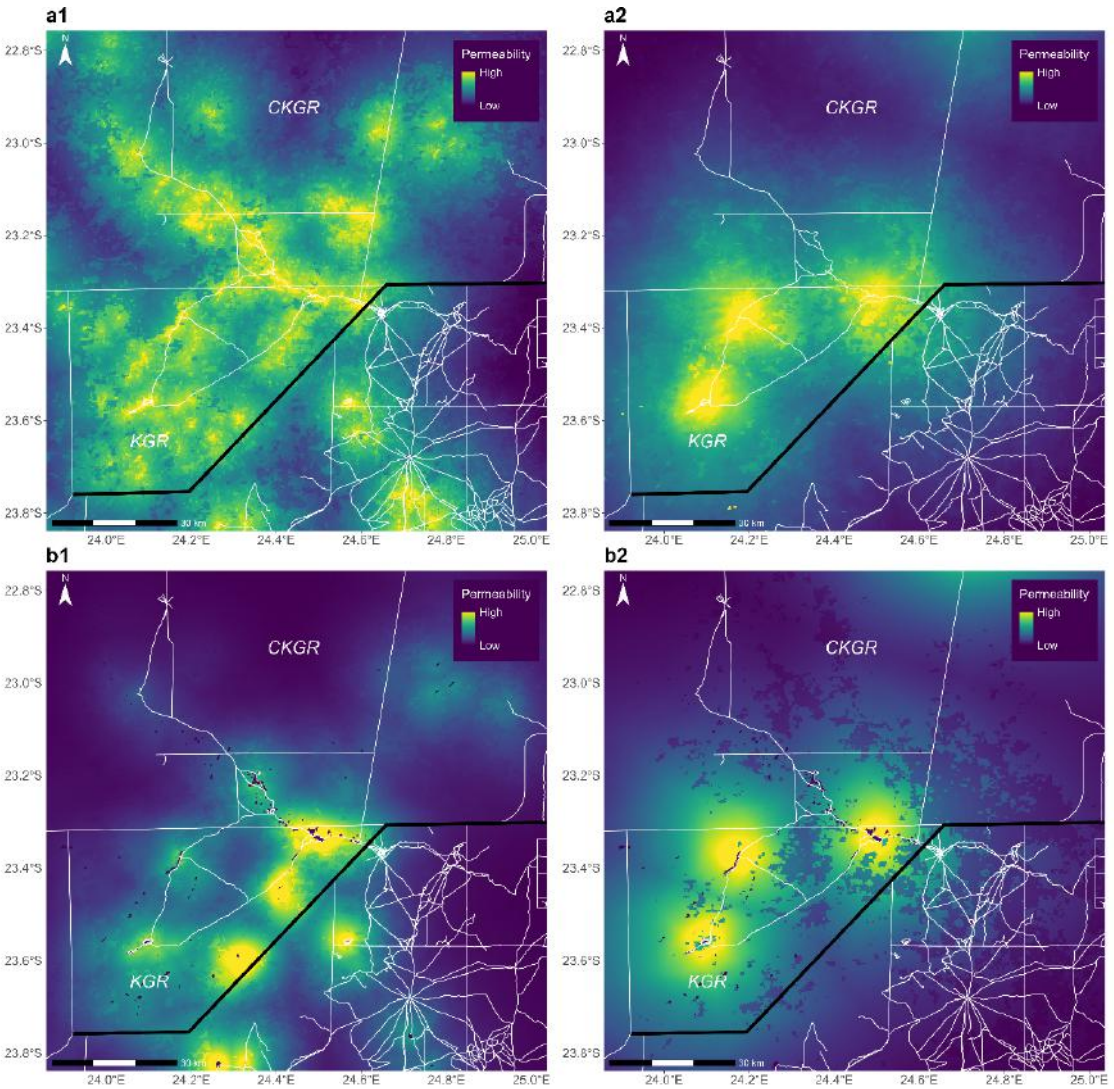


Figure F4. Predicted permeability maps for Khutse GR and the southern regions of CKGR. Each inset represents the permeability surface for (a1) lions in the wet season, (a2) lions in the dry season, (b1) leopards in the wet season, (b2) leopards in the dry season. These maps show the main areas where predators are supposed to be active in the two seasons according to the model produced by the analysis. (O'Malley et al., in review).

Community & Education Programme

Conflict between humans and wildlife is one of the most widespread and intractable issues facing conservation today. In many places, human–wildlife conflicts are increasing, as the growing human populations move further into previously uninhabited areas, and as some species re-colonize parts of their range. So, any factor that forces wildlife and people into closer contact makes conflicts more likely. The Khutse area is no exception, the area has experienced an increase in livestock populations over the past few years as farmers move their livestock around seeking better pastures.

LEC understands the need to reduce the levels of conflict and improve coexistence to ensure that where people do live with wildlife the benefits are greater than the costs.

The C&E programme works closely with farmers and herders to educate them on livestock predation mitigation, animal husbandry and disease management. The team also collaborates with residents of Kaudwane, on small-scale community empowerment projects. Over the past 24 years, we are proud to have cultivated a strong and mutually beneficial relationship with the local community.

Central to this are two key areas of work: fostering an interest and passion for wildlife and conservation and minimising the conflict between people and wildlife and hence improving coexistence.

C&E team carries out weekly cattle posts visits to- in addition to the educational aspects- collect numbers of predation events and other mortality cases, to gain a clear understanding of how the conflict evolves with the aim of coming up with relevant mitigation strategies.

Objectives for the period 2020–2025

- Work together with the Research Programme to use the research findings to better inform our conservation and education activities.
- Undertake research to better understand the nature of the conflict between livestock farmers and predators and evaluate practical measures to minimise this conflict.
- Empower farmers and herders, through education and capacity building, so they become knowledgeable and effective managers of livestock and rangelands, to facilitate coexistence.
- Provide disease prevention and livestock management training opportunities, to building positive relationships with farmers and encourage effective and environmentally-friendly livestock production.
- Continue to support the people of Kaudwane via capacity development projects that encourage active community participation in conservation activities and the sustainable use of natural resources.

The community and Education programme consist of two modules: Education and Capacity Building as well as Community Support and Development.

Education & Capacity Building

Communities living near protected areas play a vital role in the success of conservation efforts. Their proximity to wildlife habitats often places them at the forefront of both the benefits and challenges associated with conservation.

Education and empowerment are critical for fostering sustainable coexistence and conservation. Through tailored educational programs and skill development initiatives, communities can gain a deeper understanding of the value of conservation and acquire practical tools to address challenges.

C&E continues to empower the local community with the knowledge, skills, and tools necessary to address prevailing challenges such as human-wildlife conflict and unsustainable natural resources utilisation. C&E has several long-running education and capacity building projects, that involve targeted workshops and training sessions with farmers, the community of Kaudwane and the school children.

The cattle post educational program continued in 2024, with the aim to empower farmers and herders through education and capacity building to improve the skills and status of these livestock managers. For this year we have experienced challenges in delivering the educational program due to various factors beyond our control, herder turnover being the major problem. Most herders are employed on short term basis and sometimes continuity and maintaining relationship in the long run is not possible. However, for those employed on long term we have developed a healthy relationship, and we continue working together on other empowering projects.

The number of lessons delivered to farmers were reduced drastically due to the aforementioned factors, but we still managed to deliver five lessons and for the future we plan to focus only on farmers/herders that express desire to learn and gain from our educational programs. Our team continues to engage farmers (especially those expressing interest in learning) on how best we can proceed with the educational programme. To further improve the programme in the coming year, we have planned to introduce mini workshops for each

> “LEC cares about both lions/leopards and the people because the community is sensitised on matters of conservation and co-existence strategies through workshops, meetings, seminars, etc.

MRS LESEGO, Kaudwane Primary School, School Head

> “LEC keep us informed about the predations happening at the cattle post and where required, provide much needed assistance with transport to attend to the predation reports from the farmers

MR PIET MOROLONG, DWNP Problem Animal Control Officer, Kaudwane

cattle post to address specific challenges applicable to each area.

The focus for this year has been educating farmers on the management of livestock diseases which are prevalent in the area, that is, identifying disease symptoms, control, prevention, and refresher training in administering vaccines. From the data collected in 2024, diseases and other factors related to poor management have caused more livestock losses as compared to losses from predation, (153 livestock lost to predation, 166 lost to other factors other than predation). However, farmer’s reactions from predator loss are notably of that of rage, as compared to losses from diseases, this is an indication that they still under-estimate the impact of disease mortality on livestock. Lions continue to cause livestock losses, though symptoms associated with Pasteurella disease caused the biggest number of livestock mortality.

The annual farmers workshop is a platform to engage stakeholders and farmers collectively to discuss challenges and opportunities facing farmers in the area and to come up with strategies/interventions to mitigate human-wildlife conflict in the Khutse area. It also presents an opportunity to share LEC’s mandate and communicate ongoing data collection with farmers, herders, and stakeholders. Throughout the year, we collect data on livestock mortality from the eight cattle posts in our study area and the data is presented during the workshop. The data reflects the status and trends of livestock losses from both diseases and predators and possible solutions. By bridging knowledge gaps and fostering collaborations, education and capacity building ensure that communities become active participants in conservation.

Through education farmers learn to understand the relationship between resources on their lands, including free ranging carnivores, and can come to management decisions that promote sustainability. The successful implementation of such a programme depends on a trustful relationship between the conservation organization such as LEC and the stakeholders such as the farmers in the cattle posts, the Kaudwane community, authorities and institutions.

The set of hoof-trimming tools issued to the eight cattle posts in the LEC study area are regularly monitored for their usage and condition. In 2024, there was a notable increase in the number of livestock trimmed, we saw an increase from 169 (in 2023), to 352 in 2024. The most frequently trimmed animals are small stock (goats and sheep).

> If you ignore your goats and leave their hooves overgrown, they will not be attractive to buyers, and they also become an easy prey for Jackals.

MR GEORGE PIHELO, Custodian of Hoof-trimming tools, Kaudwane

For the third year running, C&E collaborated with the Botswana Society for the Prevention of Cruelty to Animals (BSPCA) and Department of Veterinary Services to carry out a cat & dog sterilization and vaccination campaign. This project is aimed at improving the general welfare of cat & dogs as well as reduce roaming and fighting tendencies thus reduce the chance that they will be exposed to rabies and transmit it to wildlife. Because the pets in this area of Khutse live within the wildlife area so the risk of contact with wildlife is high, thus vaccination and sterilization minimise the risk of exposure to rabies from wildlife. To achieve this, C&E focused on facilitating dog sterilisation, vaccination and educating the community on practical means and ways of managing, and improving care given to cats and dogs. This year, C&E extended its footprints into the settlements within Central Kalahari Game Reserve (CKGR), particularly Gughamma and Mothomelo, where pets and wildlife live even closer together. C&E aims to further includes more settlements in CKGR in the future. The vaccination and sterilization exercises were conducted in two weeks period with a total of 30 dogs successfully sterilized, and 339 animals (307 dogs and 32 cats) were vaccinated for rabies.

The horse evaluation project consists of a three-stage training that aims to educate community, horse owners about the holistic care and management of horses. C&E registers all the interested horse owners from the eight cattle posts in the LEC study area, and a professional farrier was invited to visit three times between February and June 2024 and met with horse owners in the cattle posts within LEC's study area to provide valuable training to them on general horse management. The focus of the training was on hoof care, deworming, proper horse handling, saddling, and riding. As a motivation, the third and final evaluation saw each participant farmer receive a reward based on the assessment carried out by the farrier. The rewards are meant to help improve horses' welfare and comprised saddles, bridles, dewormers, tick grease and fly sprays. This project is aimed at encouraging improved general horses' welfare as horses are a mode of transport for farmers in rounding livestock for kraaling and to search for those that might have gone astray. A total of 19 horses were registered and participated in the final horse assessment.

Community Support & Development

C&E has also been working closely with Kaudwane primary school on a few projects aimed at supporting the empowerment of the learners' activities and motivating the learners, one of which is the school game drive project that takes students on a full day excursion into the park. In 2024, C&E in collaboration with Special Support Group (SSG) – Khutse base, and the DWNP took 45 pupils on a full day's excursion inside Khutse Game Reserve, they were accompanied by one of their teachers and a representative of the School Parents Teachers Association (PTA). The goal of this excursion is to expose the children to a learning environment outside of the classroom, teach them about the importance of protected areas, and to introduce them to the work being done inside the park.

C&E also supports the Kaudwane Primary School through the donation of clothes for them to sell and raise money towards the fundraising committee. These funds were used to purchase awards for the 2024 best students from each grade during the prize giving ceremony.

In 2019, C&E established a voluntary Community Conservation Club (CCC) in Kaudwane, an initiative designed to engage community members in conservation efforts while promoting sustainable coexistence with wildlife. The clubs typically focus on awareness, and active participation in LEC community projects. The club consists of six members from the Kaudwane community who are regularly engaged by C&E on community projects. To motivate and acknowledge efforts of the CCC members, C&E issued them with start-up materials, such as net shading and seeds, to build mini gardens for themselves. C&E continues to work closely with CCC to provide support to the members with initiatives that empowers them. The annual World Nature Conservation Day (WNCD) event was commemorated on the 28th of July 2024, and the theme for this year was to educate the community on the most environmentally friendly ways to manage waste. The focus was on reusing waste material or parts of material again if they are still usable or repairing furniture, appliances, and other items instead of throwing them away. To attract interest and motivate the community, C&E introduced the Waste material Art and Design Competition whereby participants must design items from waste materials. The finished products were categorized into Plastic, Metal, Cloth, and Papers and prizes awarded according to the best designs.

> My desire to learn combined with my passion for serving the community is what motivated me to join the Community Conservation Club

REFILWE DIGOBE, Community Conservation Club Member, 2024.

LEC Open Day

In December, LEC hosted a one-day Open Day for LEC in Kaudwane Primary School.

The Open Day served as a platform to engage, educate, and build relationships with the community while providing transparency and insight into LEC's operations. The day was a vital event for bridging the gap between LEC, the community and stakeholders alike. This event provided an opportunity for the community and stakeholders to know more about the projects that LEC does in Kaudwane, neighbouring cattle posts as well as the work done by research division in Khutse Game Reserve.

Testimonies were shared with the audience by community members and local stakeholders who have either benefitted from LEC project(s) in the past or done some collaborative work. The enthusiastic participation of stakeholders, community members, and partners reflects the growing interest and support for our work. Feedback received during the event has provided valuable insights that will help us refine our approaches and enhance future initiatives.

Looking ahead, the momentum generated by this event offers a strong foundation for further strengthening partnerships and amplifying the impact of our efforts. We remain committed to building on this success and continuing to work collaboratively towards our shared goals.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Appendix I

Table Leopard Telemetry. Animals monitored by LEC during 2024.

ID	Name	Origin	Collar active in 2024	Notes
PF027		Translocation	01.01.-31.05.2024	Retrieved- Animal shot by farmer
PM034		Resident	01.01.-23.02.2024	Retrieved- Animal deceased

Table Lion Telemetry. Animals monitored by LEC during 2024.

ID	Name	Group	Collar active in 2024	Notes
LF026	Sarah	East Khutse	01.01.-14.03.2024	Retrieved- Animal shot by farmer
LF041	Desi	Molose	01.01.-31.12.2024	On animal. Collar replaced 19.02.2024
LF060	Alice	Molose	01.01.-31.12.2024	On animal. Collar replaced 20.02.2024
LF061	Alexa	Molose	01.01.-31.12.2024	On animal. Collar replaced 17.10.2024
LF064	Viva	East Khutse	19.02.-31.12.2024	On animal
LF069	Poona	East Khutse	30.08.-31.12.2024	On animal
LF075	Tuelo	Sekaka	16.10.-31.12.2024	On animal
LM073	Snooks	Snooks & Rocket	17.02.-31.12.2024	On animal
LM085	Rocket	Snooks & Rocket	01.01.-31.12.2024	On animal
LM088	Athos	Dispersed males from East Khutse	01.01.-09.03.2024	Retrieved- Animal shot by farmer
LM098	Sepekere	Dispersed males from East Khutse	20.02.-31.12.2024	On animal
LM102	Mookodi	Dispersed males from East Khutse	17.10.-31.12.2024	On animal

Abbreviations

aKDE	autocorrelated Kernel Density Estimation
ACACF	African Cats & Conservation Foundation
ACW	African Carnivore Wildbook
AI	Artificial Intelligence
BSPCA	Botswana Society for the Prevention of Cruelty to Animals
BCF	Botswana Carnivore Forum
BIUST	Botswana International University of Science and Technology
BUAN	Botswana University of Agriculture and Natural Resources
CCC	Kaudwane Community Conservation Club
C&E	Community & Education
CKGR	Central Kalahari Game Reserve
CREEM	Centre for Research into Ecological and Environmental Modelling
CTMM	Continuous Time Movement Modelling
DTD	Daily Travel Distance
DWNP	Department of Wildlife and National Parks
FMP	Formozov-Malyshev-Pereleshin
GR	Game Reserve (as in Khutse GR)
HWC	Human Wildlife Conflict
KTP	Kgalagadi Transfrontier Park
LEC	Leopard Ecology & Conservation
LF	Lion Female (*Panthera leo*)
LM	Lion Male (*Panthera leo*)
M	Daily travel distance
MPI-AB	Max Planck Institute for Animal Behaviour
NP	National Park
PAC	Problem Animal Control
PF	Leopard Female (*Panthera pardus*)
PM	Leopard Male (*Panthera pardus*)
PTA	Parents Teachers Association
SECR	Spatially Explicit Capture – Recapture
SSG	Special Support Group
VIIRS	Visible Infrared Imaging Radiometer Suite
WNCD	Worl Nature Conservation Day
UHF	Ultra High Frequency
UZH	University of Zurich

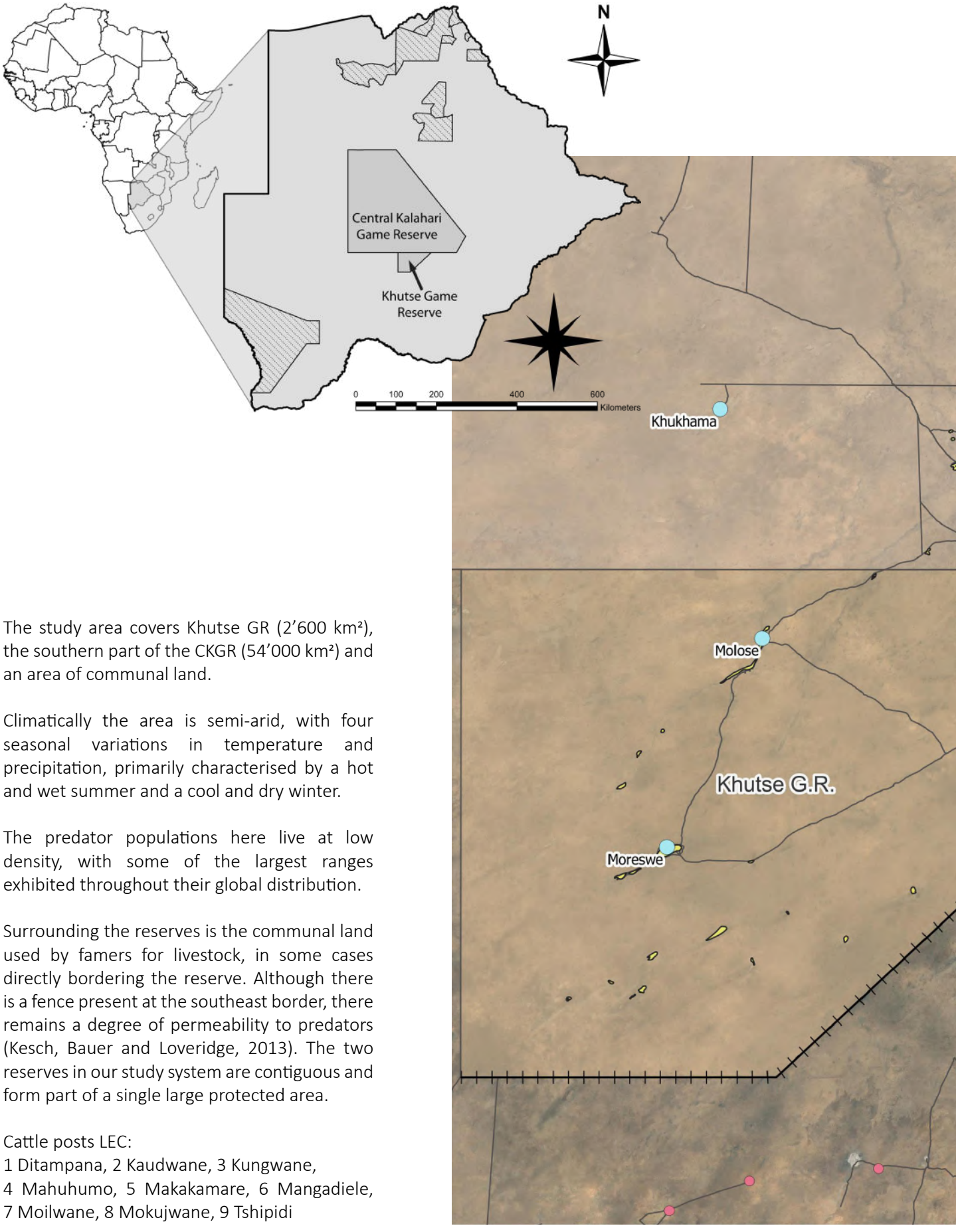
Acknowledgements

The Government of Botswana, through the Ministry of Environment, Natural Resources Conservation and Tourism and the Department of Wildlife and National Parks, has for over 24 years granted permission to Leopard Ecology & Conservation to undertake research and conservation projects. We appreciate the ongoing support received from all levels of these departments.

We also sincerely thank our sponsors for their commitment to the conservation of leopards and lions in the Kalahari. We wish to express our appreciation to the members of the African Cats & Conservation Foundation, the Leopard Ecology & Conservation Trust, the People and Wildlife Trust and the Act Now for Tomorrow Steering Committee for their ongoing support and guidance. We also value the support provided by the Institute of Evolutionary Biology and Environmental Studies of the University of Zurich.

Finally, our success is a direct result of the dedication shown by all members of the Leopard Ecology & Conservation team, both in Botswana and Switzerland, as well as the numerous individuals associated with this project.

Study Area



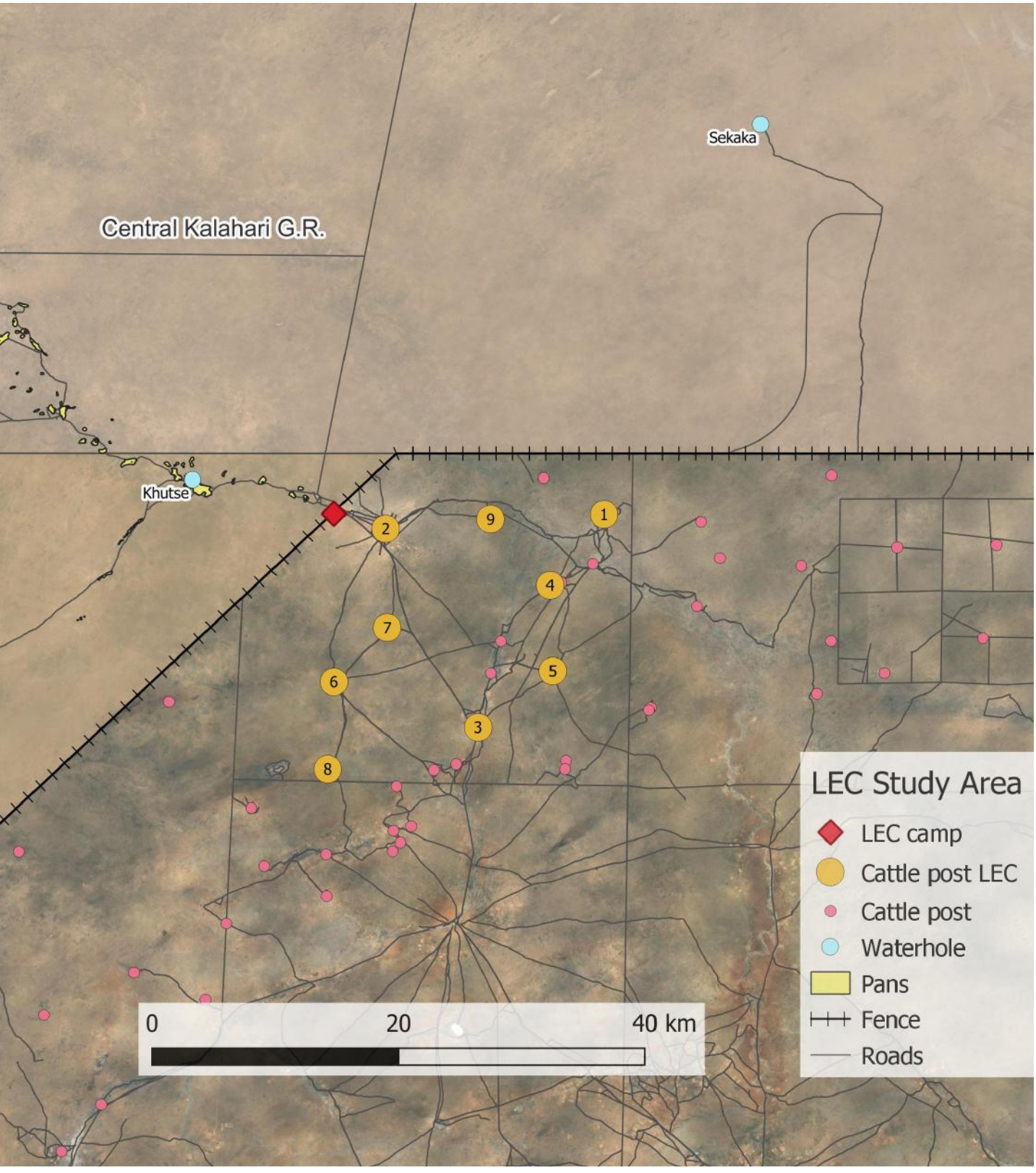
The study area covers Khutse GR (2'600 km²), the southern part of the CKGR (54'000 km²) and an area of communal land.

Climatically the area is semi-arid, with four seasonal variations in temperature and precipitation, primarily characterised by a hot and wet summer and a cool and dry winter.

The predator populations here live at low density, with some of the largest ranges exhibited throughout their global distribution.

Surrounding the reserves is the communal land used by famers for livestock, in some cases directly bordering the reserve. Although there is a fence present at the southeast border, there remains a degree of permeability to predators (Kesch, Bauer and Loveridge, 2013). The two reserves in our study system are contiguous and form part of a single large protected area.

Cattle posts LEC:
1 Ditampana, 2 Kaudwane, 3 Kungwane,
4 Mahuhumo, 5 Makakamare, 6 Mangadiele,
7 Moilwane, 8 Mokujwane, 9 Tshipidi


Sekaka
Central Kalahari G.R.
Khutse
1
2
3
4
5
6
7
8
9
0
20
40 km
LEC Study Area
LEC camp
Cattle post LEC
Cattle post
Waterhole
Pans
Fence
Roads

Team, Collaborations and Students

LEC aims to act as a bridge between people and wildlife, as platform where stakeholders with different needs and competencies can meet to successfully achieve a long-lasting co-existence between human development and the Kalahari ecosystem. This is why we are very proud of the many collaborations with institutions, herders, researchers and members of the community that LEC has fostered in the last 24 years. Our partners are deeply involved in our long-term projects and their input is fundamental for our growth. Across the previous sections of this report, you have already had the opportunity to see how students have joined our research to grow as scientists and to bring their passion and knowledge to LEC. In particular, we could host 2 students from the BSc course in Wildlife Management (Botswana University of Agriculture and Natural Resources, BUAN) who spent 6 weeks learning field biology techniques and understanding the human-carnivore conflict dynamics.

Local and international institutions have played a major role to develop programmes in the Kaudwane community. In particular, a project is the emblematic representation of this collaborative effort: the Kaudwane Beekeeping Project. In 2021, the Italian Fondazione Zoom and LEC have initiate a programme to train Kaudwane community members in beekeeping to provide a new source of income. Across the years the project has evolved and it has involved the Department of Agriculture, FAO, DWNP, University of Torino and BUAN. In 2024, we continue our research efforts to understand which plants were most important for bee honey production in our area. Our assistant Kagiso Mabu monitored vegetation, flowering and hive dynamics for the whole year. Prof Monica Vercelli (University of Torino) together with Mr Yari Roggia (Fondazione Zoom) provided a one-week training workshop on how to create pollen libraries for BUAN researchers. In Kaudwane, the beekeepers registered the Gene Xlhauu group and they kept working hard to make sure the bee families survive this very dry year. Their efforts were reported to the US embassy in Gaborone and LEC was invited to submit an application for a small grant who was awarded in October 2024 and who provided further

training and bee families with equipment to all the beekeepers.

LEC is very proud to be part of the Botswana Carnivore Forum (BCF) which group all the researchers, conservationists and DWNP officials involved in carnivore conservation in Botswana. Together with WildCRU and DWNP, we organised a 4-day workshop on tracking practices and how to implement track surveys for monitoring wildlife in Kasane. Our certified trackers shared their knowledge with the Chobe DWNP Research Officers and a customised CyberTracker app was designed together with the officers to survey carnivores in Chobe National Park. Across the following months, LEC could assist remotely in making sure the survey could be implemented successfully.

Our efforts in training DWNP officers have doubled this year, as the Max Planck Institute researchers Dr Natalia Borrego and Dr Genevieve Finerty could secure fundings to provide DWNP Central District officers with four lion collars. The officers were trained at LEC camp in Khutse to programme and deploy collars on problem lions translocated from farmland. The training focused on virtual geo-fencing for early warning systems to detect when a collared lion would be approaching farms or cattle posts. As in the past, we valued this training opportunities with the DWNP teams as we have the opportunity to learn and refine our conservation projects including their fundamental perspective.

Effective collaborative conservation strategies and local capacity building are two of the main pillars of LEC. We are looking forward to establish new collaborations and develop the existing synergies as we believe it is the only way to achieve our mission: a Kalahari where people and carnivores co-exist in harmony.

Besides all the ongoing and new collaborations in the research and C&E department, our own team also went through some changes in 2024. We thank Ms Ditshupo Kegakilwe and Mr Isaac Muzila for their contributions to LEC and wish them well on their future paths and welcome Ms Sheila Boupegile as Housekeeper in Gaborone and Mr Mompoloki Banophi as Camp Manager in Khutse.

Appendix II

The Leopard Ecology & Conservation Team

- Araldi, Alessandro, Field Research Coordinator, Italy
- Balone, Trevor, Research Assistant, Botswana
- Banopi, Mompoloki, Camp Manager, Botswana
- Chepete, Donald, Groundskeeper, Botswana
- Dr Finerty, Genevieve, Head of Research, UK
- Gabaikanye, Tebelelo, Research and Administration Assistant, Botswana
- Gabanapelo, Tefo, External Community & Education Advisor, Botswana
- Gabotshwanelwe, Sebakeng, Housekeeper, Botswana
- Gagosimologe, Tshoganetso Ernest, Community Conservation Programme Officer, Botswana
- Gana, Moisapodi, Tracker, Botswana
- Haas, Fabian, Head of Community & Education Programme, Switzerland
- Ithuteng, Goitseone, Camp Administrator, Botswana
- Ithuteng, Masente, Camp Maintenance and Mechanic Assistant, Botswana
- Ithuteng, Pogiso Africa, Field Research Assistant and Tracking Team Leader, Botswana
- Dr Kalberer, Stephanie, Co-Managing Director, Switzerland
- Kegakilwe, Ditshupo, Housekeeping, Botswana
- Kegakilwe, Phana Segametsi, Administration and Operations Manager, Botswana
- Köpfler, Marianne, Administration, Switzerland
- Lebotse, Mokobya, Student Attachment, Botswana
- Lentle, Mahlalela, Student Attachment, Botswana
- Majafe,Kobe, Maintenance Officer, Botswana
- Mamou, Mosepele, Tracker, Botswana
- Mokgwathi, Kefilwe, Community & Education Programme Assistant, Botswana
- Monnaanoka, Supula, Tracker, Botswana
- Molefatholo, Bampifetse, Housekeeper, Botswana
- Motsididi, Komano, Community & Education Assistant, Camp Administration, Botswana
- Mosikare, Neo, Cook and Housekeeper, Botswana
- Mosweu, Kebaabetswe Alfred, Community & Education Programme Coordinator, Botswana
- Nkadima, Phalatsa, Senior Tracker, Botswana
- Ndove, Kevin, Administration Assistant, Botwana
- Obotseng, Obakeng John, Education Liaision Officer, Botswana
- Ofitlhile, Mphoeng, Community & Education Programme Officer, Botswana
- Dr O'Malley, Kieran, Researcher, Ireland
- Podidaroma, Sokwa, Tracker, Botswana
- Pule, Setshiro, Local University Liaison Officer, Botswana
- Rampepele, Lebogang Sophie Seolwana, Accounts and Administration Officer, Botswana
- Schiess, Philipp, IT Specialist, Switzerland
- Schiess-Meier, Monika, Founder and Managing Director, Switzerland
- Seganaphofu, Duela, Contracted Driver, Botswana
- Dr Stracquadanio Lea, Researcher, US
- Speedy-Dusty, Project Dog, Botswana
- Etna, Project Cat, Botswana
- Tshiama, Mpho, Tracker, Botswana
- Tshiama, Meno, Tracker, Botswana

Academic collaborations

- Akash, Muntasir, MSc Student, University of St. Andrews, UK
- Badubi, Maano, Intern, Botswana
- Dr Basupi, Vincent, School of Earth Sciences and Engineering, Botswana International University of Science and Technology (BIUST), Botswana
- Dr Chamaille-Jammes, Simon, Centre d'Ecologie Fonctionnelle et Evolutive, Centre National de la Recherche Scientifique (CEFE-CNRS)- Montpellier, France
- Dr Dithologo, Marks, Department of Biological Sciences, University of Botswana (UB), Botswana
- Prof. Sutherland, Chris, Centre for Research into Ecological & Environmental Modelling, University of St. Andrews, UK
- Dube, Natsani, MSc Student, University of St. Andrews, UK
- Gielen, Marie-Charlotte, Quantitative Conservation Biology, Université catholique de Louvain, Belgium
- Grube, Natalia, PhD Student, Anthropological Genomics Laboratory, PennState University, USA
- Prof, Crofoot, Meg, Ecology of animal Societies, Max Planck Institute of Animal Behavior, Germany
- Dr Kotze, Robynne, WildCRU, University of Oxford, UK
- Dr Jewell, Zoe, WildTrack, USA
- Dr. Borrego, Natalia, Lion Research Center, Universtiy of Minnesota, USA, and MPI-AB, Germany

- Garbeli, Jary, molecular genetic analysis, Institute of Evolutionary Biology and Environmental Studies, University of Zurich, Switzerland
- Prof. em. König, Barbara, Department of Evolutionary Biology and Environmental Studies, University of Zurich, Switzerland
- Prof. Manser, Marta, Department of Evolutionary Biology and Environmental Studies, UZH, Switzerland
- Dr Morris, Gerrald, project veterinarian, Botswana
- Dr Neo-Mahupeleng, Gosiame, Wildlife Ecology lecturer, Botswana University of Agriculture and Natural Resources, Botswana (BUAN), Botswana
- Prof. Packer, Craig, Lion Research Center, University of Minnesota, USA
- Prof. Rampart, Melusi, Department of Range and Forest Resources, Botswana University of Agriculture and Natural Resources, Botswana
- Roggia, Yari, Fondazione Zoom, Italy
- Dr Sianga, Keoikantse, Department of Wildlife and Aquatic Resources, Botswana University of Agriculture and Natural Resources
- Prof. em. Zucchini, Walter, Department of Economic Sciences, Georg August University Göttingen, Germany

Collaborating Institutions from Botswana

- BirdLife Botswana
- Botswana Carnivore Forum (BCF)
- Botswana Society for the Prevention of Cruelty to Animals (BSPCA)
- Cheetah Conservation Botswana (CCB)
- Community of Kaudwane
- Community Conservation Club, Kaudwane
- Department of Animal Production
- Department of Veterinary Services
- Department of Wildlife and National Park (DWNP) (Groups: Community Service and Outreach, Parks, Problem Animal Control, Research, Veterinary)
- Kalahari Research and Conservation
- Kaudwane Primary School
- Kuanghoo Community Trust
- Kweneng Lang Board
- Letlhakeng Sub-District Council
- Village Extension Team and Village Development Committee (Kaudwane)

International Collaborating Institutions

- African Carnivore Wildbook, Vancouver, Canada
- Conservation AI, Liverpool, UK
- CyberTracker, South Africa
- EarthRanger, Seattle, USA

Support in Botswana (permits, information and logistics)

- Department of Animal Production
- Department of Forestry and Range Resources, Letlhakeng Forestry Tree Nursery
- Department of Research, DWNP
- Department of Veterinary Services, DWNP
- Ministry of Environment, Natural Resources, Conservation and Tourism, Research and Development Department
- Ministry of Environment, Natural Resources, Conservation and Tourism, Environmental Affairs Department
- Special Support Group (SSG), Khutse Base Camp
- Dr Flyman, Michael, Food and Agriculture Organisation
- Munyadzwe, Mercy, Regional Wildlife Officer Molepolole
- Sekhute, Stephen, Park Manager, Khutse GR
- Mr Siku & Mr Tibi, Farrier
- Batshabang, Moemi Raeshimane, Director, DWNP

International Support (Professional, logistical and material support

- Aebersold Digitaldruck, Switzerland
- BGS-Architekten, Switzerland
- Feusi Optik AG, Switzerland
- FlyAway Reiseerlebnisse GmbH, Germany
- Dr. Forrer Mathias, Schulthess Klinik, Switzerland
- Holzinger, Rosmarie, Switzerland
- Lobatse Canvas, Botswana
- Maier, Reto, Universität Zürich, Switzerland
- Nakano, Michel, technical support, University of Zurich, Switzerland
- Schiess, Fritz, Switzerland
- Schmid, Peter & Susanne, Switzerland
- Solar International and Solar West, Botswana
- Toyota Motor Centre, Botswana
- Wagner Elicar, Luxembourg
- Vectronics Aerospace GmbH, Germany

Leopard Ecology & Conservation Trust
- Schiess-Meier, Monika (Chair), Switzerland
- Schiess, Fritz, Switzerland
- Gutmann, Dieter, Germany
- Kegakilwe, Phana Segametsi, Botswana

People and Wildlife Trust
- Gabanapelo, Tefo (chair), Botswana
- Dr Flyman, Michael, Botswana
- Schiess-Meier, Monika, Switzerland
- Haas, Fabian, Switzerland

African Cats & Conservation Foundation Switzerland
- Bissegger, Eveline (chair), Switzerland
- Gutmann, Dieter, Germany
- Oeri, Catherine, Switzerland
- Schiess-Meier, Monika, Switzerland
- Schrepfer, Willi, Switzerland

Educational Project (ANFT) Steering Board
- Director of Animal Production, Department of Animal Production, Botswana
- Chief Wildlife Officer, Community and Extension Services, Department of Wildlife and National Parks, Botswana
- Deputy Director, Department of Veterinary Services (disease control), Botswana
- Chief Forest Resources Officer, Department of Forestry and Range Resources, Botswana
- LEC, C&E Programme Coordinator, Botswana
- LEC, C&E Assistant, Botswana
- LEC, Managing Director
- People and Wildlife Trust (Mr. Gabanapelo, Dr. Flyman)
- Farmer representatives (Sebolao, Peter and Gaothetswe, Mmitsa), Botswana
- Dintle, Edwin, Botswana Housing Corporation,
- Dr. Matsika, Albertinah, Botswana University of Agriculture and Natural Resources (Department of Wildlife & Aquatic Resources)
- Mr. Mosinki, former Kweneng Land Board Employee
- Mr. Sekano, Ngwato Land Board

Scientific Publications & Conference presentations
- Akash, M. (2024) 'Understanding Home Range, Behaviour, and Fence-Crossing in African Leopards in a Data-Deficient Central Botswana Game Reserve.' University of St. Andrews.
- Alessandrello, V. et al. (2024) 'A second chance? Movement pattern of resident versus translocated leopards (Panthera pardus) in Botswana.' Frontiers in Conservation Science.
- Bauer, D.T. et al. (in prep). 'Sex and age predict habitat selection in the world's most geographically extensive lion population."
- Balone, T. (2024) 'KSI – Kill Site Investigation- Novel approach to investigate hunting behaviour in Kalahari lions using Indigenous tracking skills.' The 5th Botswana Biodiversity Symposium, Kasane, Botswana.
- Dube N. (2024) 'Unraveling Leopard Spatial Ecology: A Study of Sex-Specific Home Range Dynamics and Conservation Implications in Semi-Arid Ecosystems of Botswana.' University of St. Andrews.
- Finerty, G.E. et al. (2024) 'Movement reveals water-dependent thermal performance in wild lions.' Current Biology.
- Finerty, G.E. et al. (2024) 'Assessing the performance of the Formozon-Malyshev-Pereleshin formula to monitor animal populations based on track counts: a case study on the Kalahari lion Panthera leo.' Frontiers in Conservation Science.
- Finerty, G.E. et al. (2024) 'The Crossroads of Tradition and Modern Technology: Integrative Approaches to Studying Carnivores in Low Density Systems.' Frontiers in Conservation Science, 5.
- Finerty, G.E. (2024) ''Out-of-the-box' Approaches to Studying Behaviour in the Kalahari's Lion Populations.' Guest Presenter for Integrated Behavioral Research Group meeting, Department of Ecology and Evolutionary Biology, Princeton University, United States.
- Gielen, M.C. et al. (2024) 'Refining population density estimation from track counts: Improving daily travel distance estimates through trailing of large herbivores in the Kalahari, Botswana.' Biodiversity and Conservation.
- Gielen, M.C. & Araldi, A. (2024) 'Improving daily travel distance estimates of five herbivores to refine population density estimation from track counts in the arid Kalahari ecosystem.' The 5th Botswana Biodiversity Symposium, Kasane, Botswana.
- Jardeaux, M. (2024) 'Quantification of daily travel distance for five large herbivore species as a prerequisite to estimate their population abundance in Botswana.' Catholic University of Louvain.
- O'Malley, K. & Stracquadanio, L. (2024) 'Kill site distribution and habitat selection of two apex predators in the semi-arid Kalahari environment of Botswana.' The 5th Botswana Biodiversity Symposium, Kasane, Botswana.
- O'Malley, K. et al. (in review) 'Kill site distribution and habitat selection of two apex predators in the central Kalahari, Botswana.'

- Stracquadanio, L. et al. (in review) 'Using long-term data to investigate the influence of environmental factors on large predator prey selection in the central Kalahari, Botswana.'

Workshops

- C&E providing Farmer Education Workshops "Act Now for Tomorrow", Gaborone and Kaudwane, Botswana
- LEC Research providing GPS Collar Management Training for DWNP officers- Khutse G.R., Botswana
- LEC Research providing Tracking Training for DWNP officers – Chobe National Park, Kasane, Botswana.
- LEC Research Workshop at Kalahari Research Centre, South Africa, November 2024
- Strategy Workshop by Martin Davies, March 2024.
- Conflict Management, and Interpersonal and Intercultural Communication Workshop in Khutse by Melissa Davies, March 2024.

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- Fliedner, Monika, Switzerland
- Fraser, Jill, Botswana
- FlyAway, Germany
- FS Communication, Switzerland
- Gantner, Fiona, Switzerland
- Hauser, Regula, Switzerland
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- Moser-Meyer, Gabriela, Switzerland
- Rüegg, Eveline, Switzerland
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