



Leopard Ecology & Conservation

Annual Report 2023



MISSION

Fostering an understanding of the status and habitat needs of leopards and lions both within and outside formal conservation areas, as well as the development of effective strategies to address the increasing human-predator conflict.

VISION

The Kalahari is a place where big cats and people coexist in a sustainable way. LEC makes a meaningful contribution toward the long-term conservation of large felid predators as key components of a healthy, functioning ecosystem.





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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A map showing most of the places mentioned in the text can be found on page 48.

LETTER FROM LEC FOUNDER: MONIKA SCHIESS-MEIER



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Cultivating a deep understanding of peoples past history, origin, and culture nurtures a strong foundation, much like roots sustain a growing tree.

MONIKA SCHIESS-MEIER, Founder and Director

When I first set foot in the Kalahari 24 years ago with the intention of studying leopard behaviour for three years, little did I anticipate the profound impact it would have on my life. The sheer vastness of the landscape, the untamed wilderness, it all captivated me from the outset. However, it was that unforgettable moment accompanying the trackers, witnessing their innate connection with the land, that truly touched me.

Watching them effortlessly decipher the secrets hidden within the sand, akin to reading like in a book, or observing their skilful extraction of a water giving root from the most inconspicuous blade of grass, vital for survival in the harsh Kalahari, was a revelation. In that moment, I realized that together our expertise – their traditional wisdom and our scientific knowledge – would lead to new innovative ideas and new ways of thinking.

As we reflect on our journey at Leopard Ecology & Conservation, it's evident that our roots run deep in the Kalahari landscape and culture. Over the past two decades, our mission to preserve the leopard and lion populations and foster sustainable coexistence has remained unwavering.

Just as traditional skills are ingrained in cultural heritage, our approach to research and nature conservation is rooted in time-honoured techniques, adapted, and applied to current challenges. For instance, the meticulous tracking of herbivores for hunting, a practice passed down through generations, forms the basis of our innovative daily travel distance project, helping in monitoring Kalahari wildlife populations.

Moreover, our tree planting project, a key project of our Community & Education program, not only contributes to environmental sustainability but also symbolizes the importance of laying strong foundations for future growth.

Thus, as we navigate the various challenges ahead, let us never lose sight and respect the importance of understanding our roots – both as individuals and as an organization. With this in mind, I am delighted to present the annual report for 2023.

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 23 years with the local community.

2023 IN NUMBERS

Organisation



23 years operational

21 individuals from Botswana working at field site in Khutse GR

12 international collaborations

3 external trainings for LEC staff

1 Botswana intern

3 international post graduate students and interns

Leopards

2 collared leopards

23 sightings of collared leopards



1 litter detected

25 wildlife predation events by leopards

6 translocated leopards

107 wildlife predation events by lions

512 lions sighted across

Lions

186 direct observations

10 sightings of lion matings



6 lion litters with **20** cubs

146 cluster visited, with **42** lion hunting paths recreated

Community and Education

206 indigenous trees planted in the community



171 dogs and cats vaccinated against rabies

74 community members trained in tree planting

104 visits to cattle posts

28 dogs sterilised

19 educational workshops with farmers



206 farmers attending the workshops

83 hoof-trimming equipment borrowed

169 livestock trimmed

14 horses taking part in the horse evaluation



Promoting young talents

46 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

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



61 24h-trails of 5 large herbivore species completed

22 trackers from accross Kalahari

together with **3** DWNP officers attended the CyberTracker workshop

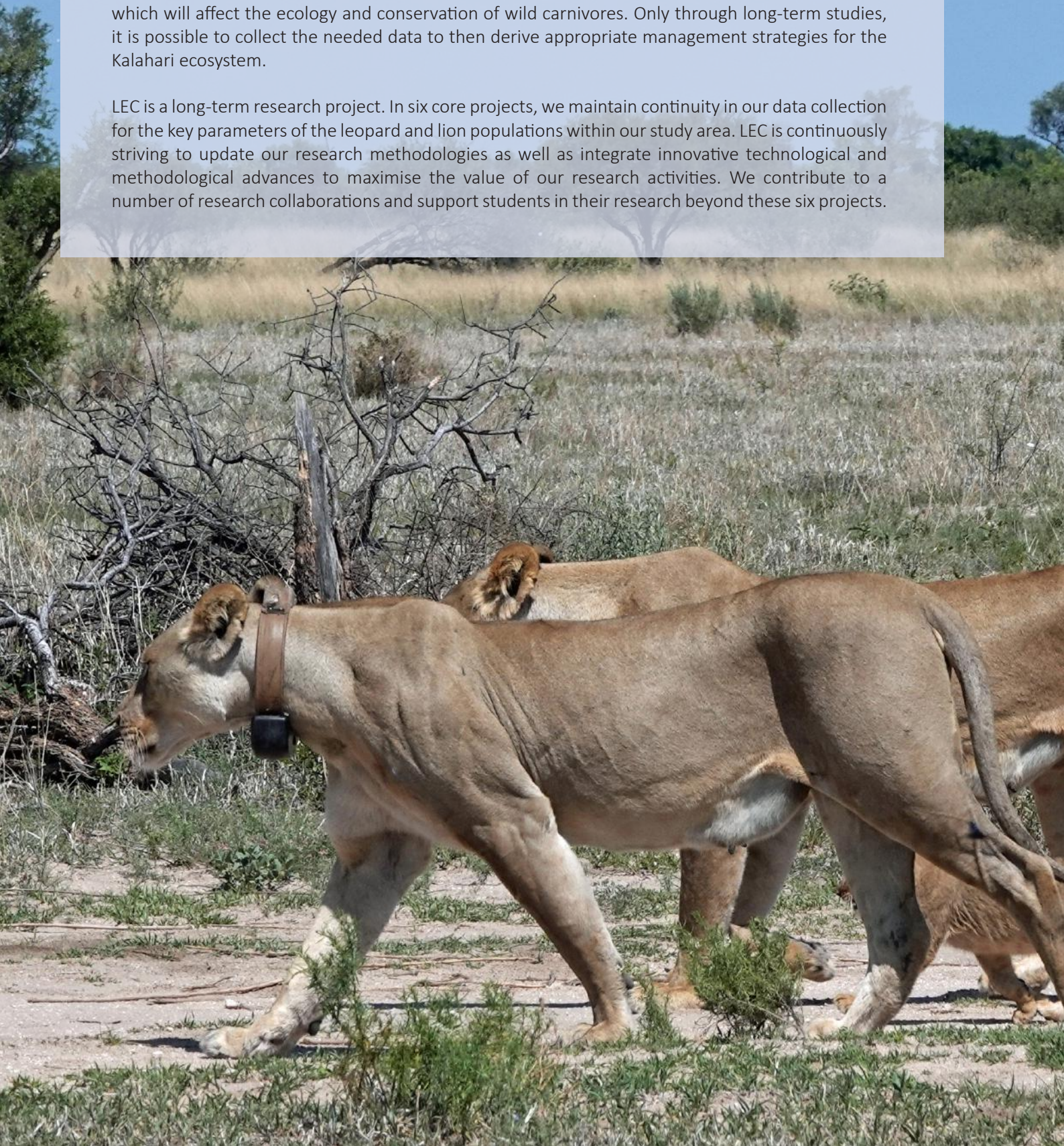
302 camera traps deployed to cover an area of **4435** km²

16 DWNP officers trained at track survey techniques for research and monitoring wildlife population

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:

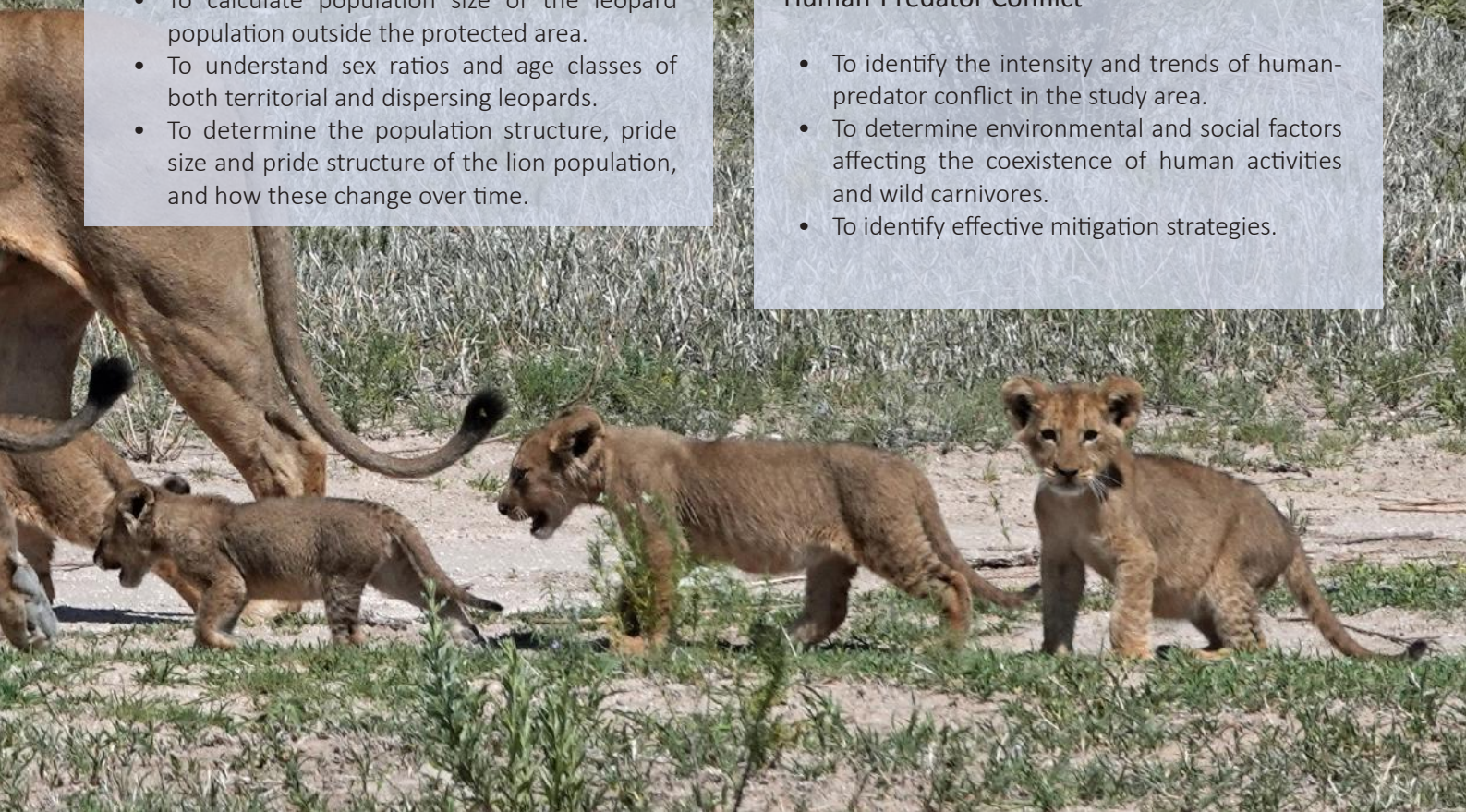
Predator Demographics

- 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

When studying wildlife, it is crucial to have a good understanding of the landscape in which the target species lives. To make informed hypotheses and to interpret the data, we need to monitor the environmental variables that drive animal ecology and determine their trends across space and time. When the target species are top predators, such as lions and leopards, the complexity of the factors to take into consideration is very high.

The Kalahari is a fragile, dynamic ecosystem in which long-term processes can be accelerated by even rare events. While climate change is certainly a main actor, in the last decades landscape modifications, anthropogenic pressure and the arrival or return of other species, such as elephants, are currently reshaping this semi-arid landscape. The COVID epidemic has generated awareness that Botswana needs to become less dependent for its food needs on neighbouring countries. This translated in an increased pressure to allocate new land for farming and financial support for any farming activity. The legal and illegal encroachment of human activities in Wildlife Management Areas is causing loss of areas for wildlife and increase human-wildlife conflict.

In the perspective of these drivers of landscape change, LEC continues to monitor the evolution of the landscape in the study area to determine if the habitat for leopards and lions is changing and how these changes are affecting their ecology. This includes changes in the neighbouring parts of the country which can affect even the protected areas. In 2023, we continued our long-term data collection on the vegetation and climate. We also continued monitoring the elephant presence trends within the study area as they are a key element in the landscape changes observed in the last years.

On a short temporal scale, vegetation in our study area seems to be mainly affected by fires, rainfall, elephants, and livestock grazing. We use fixed-point photos of the



vegetation to observe the trends across seasons and years. In 2023, we observed that vegetation regeneration after the fires was relatively fast for the grasses but that a delay in the rains particularly affected the fruiting and flowering of the shrubs. The vegetation images collected outside the protected area provided another important confirmation that livestock is overgrazing the communal land with very few herbaceous plants and a growing presence of bush encroachment.

In the Kalahari ecosystem, wildfires play a crucial role in keeping the savannah healthy and productive. But

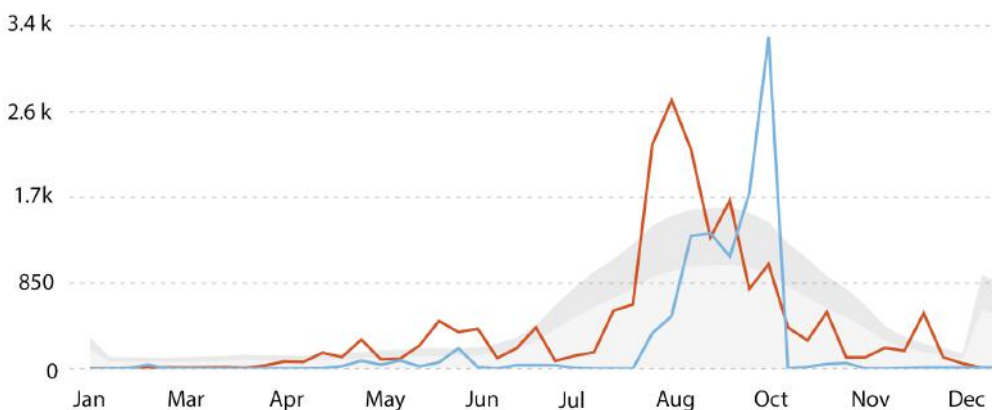


Figure 1.1. Monthly VIIRS fire alerts in Botswana in the period January 2023- January 2024 (red) and the period January 2022 - January 2023 (blue)(<https://www.global-forestwatch.org/>).

anthropogenic fires developing too early or too late in the year may heavily alter the fragile balance of the whole Kalahari food chain. Generally, the peak of fires in Khutse GR is expected between August and September. In this period, most of the wildfires are ignited by the thunderstorms preceding the first rains. In 2023, Khutse GR experienced an unexpected and intense fire activity between June and July. This early onset of the fire season was registered across the Country (Fig. 1.1). From our investigations, the fires were started by people in the community grazing land east of Khutse GR and very strong winds moving north-west spread the fires inside the protected areas. Most of these fires are generally started to encourage faster renovation of grasses for livestock around cattle posts and to scare predators away. Before the end of July very few sections of Khutse GR were not burnt (Fig. 1.3). Such extensive fires so early compared to the rains, might have had a serious impact on wildlife which we will only be able to observe in 2024 after the rainy season. As mentioned above, fires are essential for grasses regeneration, but when fires burn entire protected areas, herbivores are forced to move temporarily to neighbouring areas and this migration has become less possible due to human activity encroachment in the surrounding Wildlife Management Areas. In 2023, Botswana was characterized by a very high number of VIIRS (Visible Infrared Imaging Radiometer Suite) fire alerts (19,220 in

total), almost reaching the levels of 2021 (21,688). In the recent years, Botswana witnessed an increase in fires (Fig. 1.2), this could be due to climate change and the growing impact of human activities, especially livestock farming, in the rural areas.

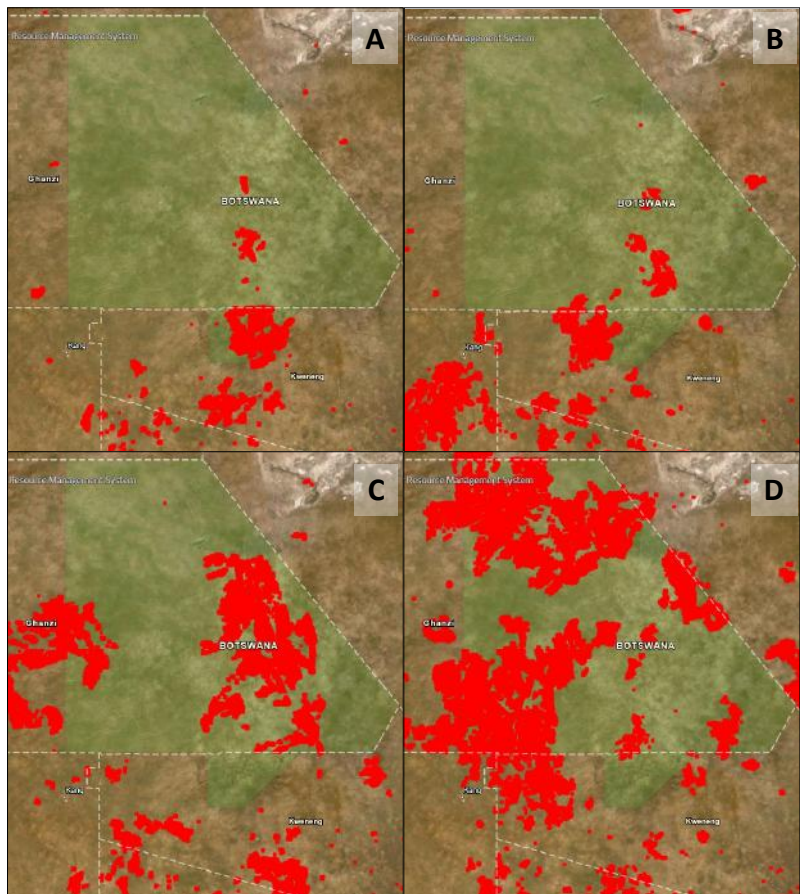


Fig. 1.3. Fires active in Khutse GR, Central Kalahari GR (green) and their surroundings (brown) in June (A), July (B), August (C) and September (D) 2023 (FIRMS-NASA).

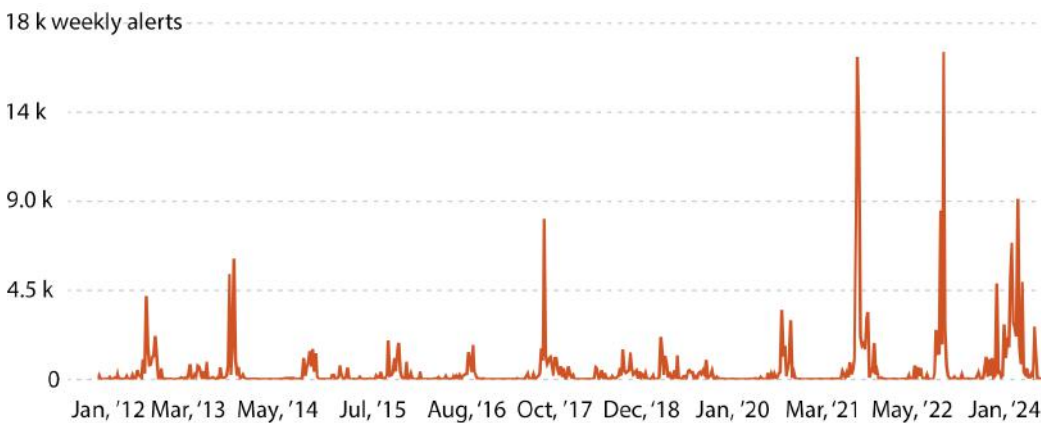


Figure 1.2. VIIRS fire alerts recorded between January 2012 and January 2024 (<https://www.global-forestwatch.org/>).

Our weather station at the entrance of Khutse GR and the set of rain gauges deployed across the study area allowed us to monitor temperature, rainfall and wind speed throughout the 2022 - 2023 austral seasonal year.

During the austral year (July to June) 2022- 2023, the total recorded rainfall was 589 mm. As experienced in 2022, most of the rainfall was in February (347 mm, Fig. 1.4). Considering the average rainfall in the last 23 years (432 mm), 2022-2023 austral year has been a good year for rains but the fact that almost 60% of the total rainfall fell in February certainly impacted the habitat. Temperature followed the typical hot-cold season pattern, with the hottest months between October and March. While the coldest nights were recorded in June 2023 (Fig. 1.5).

As with many protected areas in Africa, Khutse GR and Central Kalahari Game Reserve (CKGR) have a system of artificial waterholes inside the reserves to provide surface water across the whole year. The waterholes were created to provide water in the dry months, when otherwise there would be little to no surface water

available. In the past, most of the water-dependant animals migrated during those time periods towards the Okavango Delta or other areas with surface water across the whole year. The creation of veterinary fences and encroachment of human activities around the protected areas limited wildlife movement between these regions, therefore requiring the creation of artificial waterholes to provision water. In semi-arid ecosystems such as the central Kalahari, the addition of permanent surface water availability has substantially modified the typically water-limited dynamics and as such, we can consider that any new waterhole may have large impacts on the wildlife community. As such, LEC has always considered the monitoring of waterholes as a priority in its research efforts. In 2023, we could appreciate further the correlation between waterholes and the growing presence of elephants in Khutse GR. Since 2019, we have recorded any encounter with elephants and during the camera-trap survey deployment we witnessed their impact on the vegetation, especially around the waterholes. As observed in the last four years, only male elephants

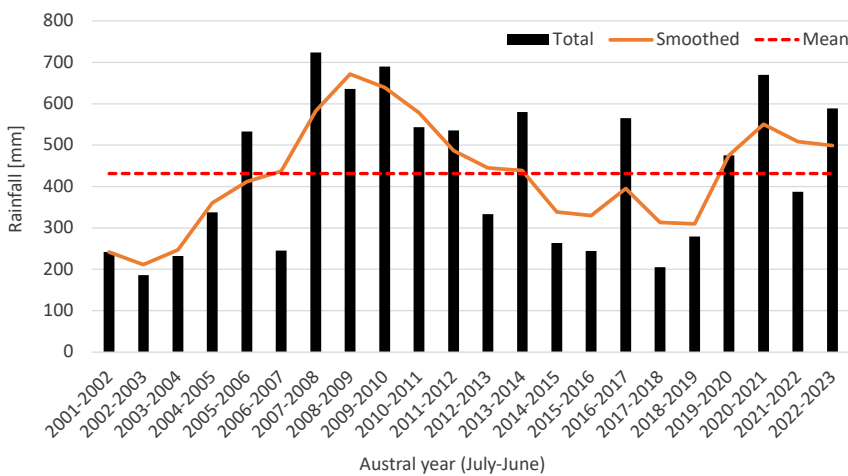


Figure 1.4. Annual rainfall recorded at the LEC research station (histogram). To highlight the trend within variable rainfall data these were smoothed (line) using a three-point weighted interpolation where annual rainfall (R) is the product of the current year’s rainfall (R0) as well as the previous and following year’s values (R-1 and R+1 respectively) ($R = 0.25 \times R-1 + 0.5 \times R0 + 0.25 \times R+1$).

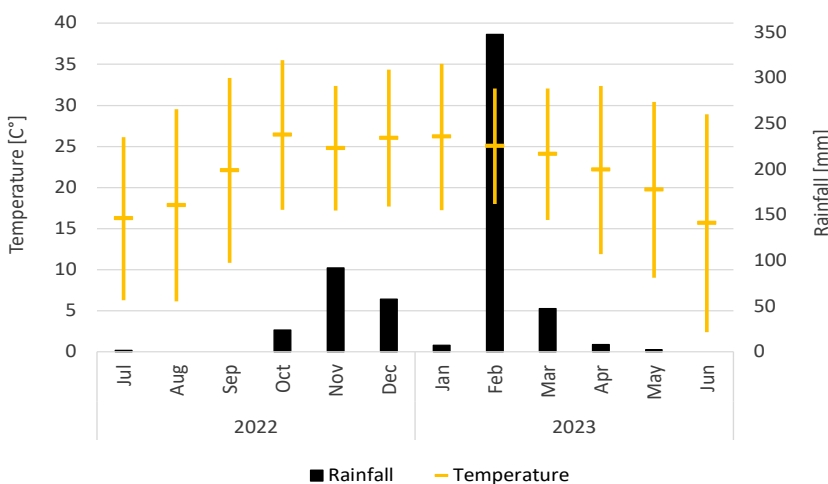


Figure 1.5. Monthly temperature and rainfall as recorded at the LEC research camp, Khutse GR, for the 2022-2023 seasonal year. The average median daily temperature is shown as a point, with the average daily minimum and maximums as bars.

were recorded, and the largest group was a gathering of 60 individuals at Molose waterhole in May 2023. Although we have observed elephant signs across the entire study area, most of their movements are between Molose waterhole in Khutse GR and Kukamma waterhole in CKGR. The area between Molose pan and the western and northern boundary of Khutse is now characterized by uprooted trees and shrubs dug out by elephants in search of nutrients and water in the roots. During the camera trap study, we travelled large distances off-road to place the camera traps. While we were visiting these parts of the park, far from the roads, we observed that elephants have created quite clear animal paths connecting Molose, Kukamma and Gope mine. This finding strengthens our hypothesis that the return of elephants to Khutse GR is probably linked with the closure of the mine in Gope, a village in the central-east section of CKGR. The mine was created in 2014 and extraction operations stopped in 2018. The mine built a large water reservoir within its perimeter, unluckily fence maintenance reduced drastically after the activities

were interrupted and elephants were able to access and started to use the water inside the mine. Together with the elephant population expansion of the last decade, this new water source provided the needed stepping stone for the elephants from the north to reach the artificial waterholes of Khutse GR. We hope that the results from the camera trap survey and a collaboration with the CKGR elephant project led by BUAN might highlight the elephant occurrence pattern and, potentially, the main paths taken by elephants in the study area.

The return of the elephants may seem a positive event at first sight, but the reality is that Khutse GR habitats were never meant to support large number of elephants, permanently, for extensive periods of the year. Historically, elephants travelled across Khutse GR and continue their trip south towards richer habitats. Nowadays, such movement to the south is not possible anymore due to the presence of human activities and the elephant reaching Khutse GR are seriously reshaping the ecosystem and, consequently, impacting the other resident species.



Project 2. Prey Availability

Top predator population dynamics and movement behaviour are closely connected with prey availability in the study area. In 2022, we presented medium and large herbivore population estimates from our extensive track survey over the period 2021 – 2022. The track surveys are a long-term research project aiming at monitoring trends in herbivore and carnivore populations. While these surveys provide critical estimates for conservation, they are also very resource demanding as a team of trackers survey an extensive set of roads inside and outside the protected area every month for a period of 12 months. Therefore, we replicate these surveys every four years to observe long-term trends, while balancing effort across LEC's portfolio of conservation and research projects. As

we carry out the surveys, we continuously horizon scope to explore methodological developments for estimating wildlife populations and to refine our monitoring techniques without losing comparability with the existing datasets.

In 2023, in collaboration with Marie-Charlotte Gielen, a PhD student at Catholic University of Louvain in Belgium, we developed a study to obtain empirical estimates of the daily travel distances of five key prey species for lion and leopards in the Kalahari. The new daily travel distance estimates will improve the population density estimates obtained from the track survey using the Formozov-Malyshev-Pereleshin (FMP) formula (for more details see Project in Focus, p. 32).

This year we have also embarked upon an ambitious camera trap study to estimate leopard densities (see Project 5- Leopard Demographics, p. 20). As by-product, we are obtaining a large volume of images of prey species allowing us to investigate prey occurrence at a finer scale in our study area. We will also investigate if we can produce population estimates for certain prey species using the unmarked approach of Rowcliffe et al. (2008). Finally, during the camera trapping survey seasons, we implemented track surveys along all the roads included in camera trap survey for a total of four replicates from May 2023 to February 2024 (see Fig. 2.1). This should allow further comparison between the different methodologies. Preliminary results will be obtained after the first two camera trap survey seasons in March 2024.

While deploying camera traps, we had the opportunity to gain a “first feeling” of animal presence in areas that we visit less frequently. To choose the location of our camera trap stations, we had to follow animal paths and place the devices in strategic positions to optimise the chances for capturing leopards and other wildlife. We could then easily appreciate that the South-West of Khutse GR seems to host even lower densities than the north, especially along its borders where several signs of poaching were detected. On the contrary the North-West corner of Khutse and the above section of CKGR showed intense wildlife activity and big herds of

elands were seen. From what we experienced as we carried out our survey, prey availability seems to have a gradient from South and Southeast to Northwest. This is probably due to the increasing anthropogenic pressure around Khutse GR, with poaching from the South and livestock farming from the East. Khutse GR doesn't have a functional buffer zone and could in fact itself act as a form of buffer zone for CKGR. Over the coming year, we will use the results from our camera trap study to investigate these suspicions.

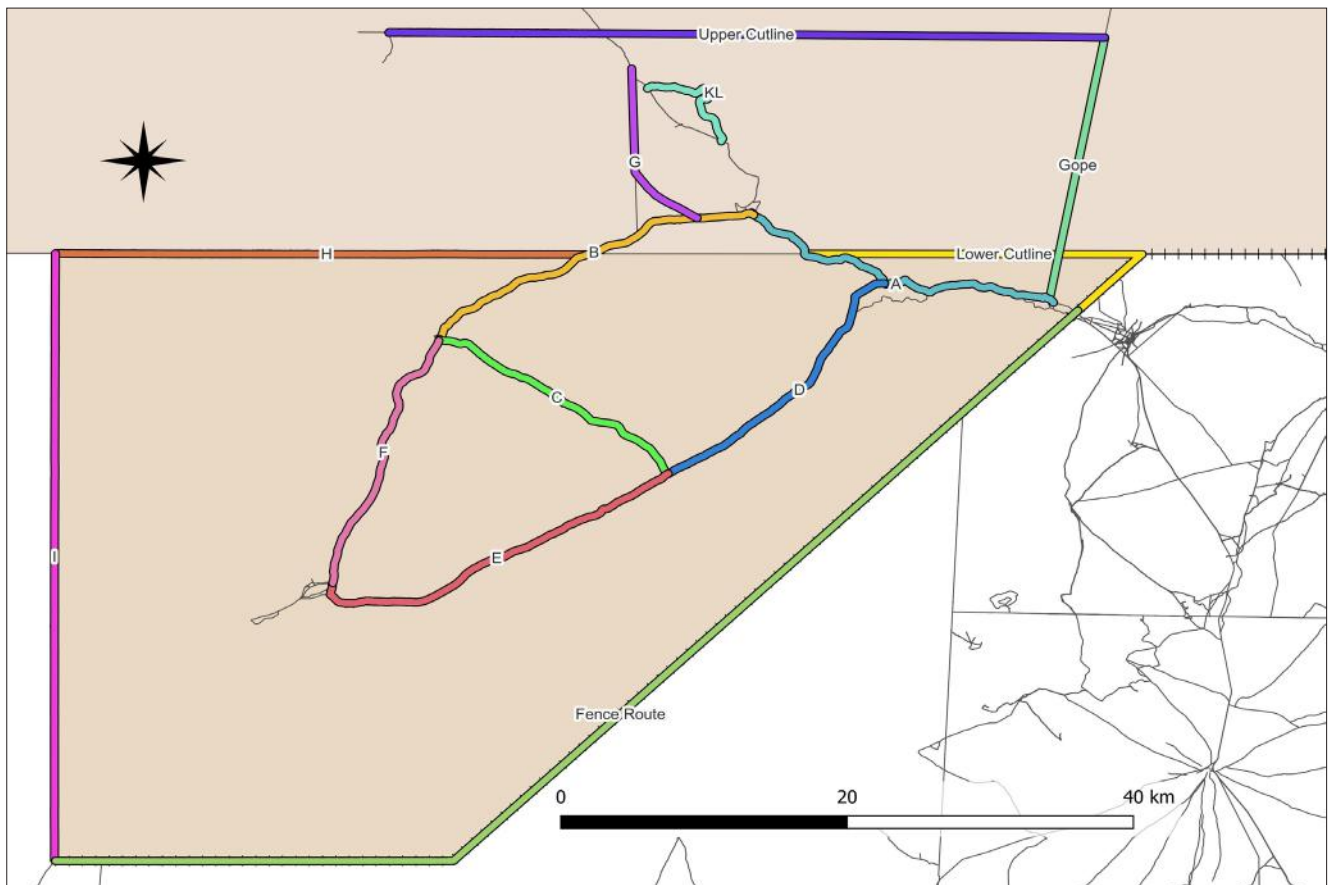


Figure 2.1. Map of the routes sampled for the track survey during the camera trap deployments in 2023.

Project 3. Predation

LEC studies and monitors leopard and lion predations inside and outside the protected area, since 2000. This allows us to build a better picture of the prey species lions and leopards rely on to thrive in this part of the Kalahari and to understand how they adapt to changes in prey availability across seasons and across years. The investigation of predation events in the communal grazing land bordering the reserve forms a key element of how we evaluate the impact of predators on the local rural livestock farming. It also provides an indication of wild prey availability outside the reserve. Lions and leopards exhibit differences in the prey species they target and gathering information on their hunting behaviour in mixed-use landscapes such as the communal grazing lands can help support the development of human-carnivore conflict mitigation solutions.

The low densities of prey and predator populations, the extensive range of both lions and leopards in the Kalahari, and the vegetation structure in our study area make detecting predation events a challenging task. Through many years of experience, LEC team has refined techniques to optimise our chance to find kill sites. There are two main methods we use to detect potential kill sites. Inside the reserve and in its immediate surrounding, we take advantage of the information gathered from the GPS collars deployed on lions and leopards. When the daily downloads show clusters of GPS fixes, it is likely the collared predator was either resting, denning or on a kill. Clusters of GPS fixes during night hours are typical of predation events, as this is when both lions and leopards in our area tend to be active and hunt. Whereas they usually are found resting during day-light hours when temperatures are higher. We therefore visit

these night-time clusters to investigate potential locations of kill sites. In addition to the visits to GPS clusters, we investigate predation events detected opportunistically during our regular resightings or by following vultures, as these can be good indicators that a carcass is present. Outside the protected area, in addition to the clusters from collared individuals, we strongly rely on livestock predation reports from the cattle posts. Whenever a kill site is reported, or the GPS data indicates a possible predation event on livestock, the LEC team needs to react quickly to collect the required data. This is because both predators and scavengers can quickly consume the whole carcass. Unless disturbed, lions and leopards tend to fully utilize their prey in the Kalahari. Scat analyses have shown that both lions and leopards start by consuming the flesh, but, when possible, they eat more bones and fur than has been observed in less challenging habitats.

In 2023, we were able to monitor a resident leopard and a translocated leopard who moved extensively inside the protected area before returning to the communal grazing land. This allowed us to gather more information on leopard predation events inside the protected area compared to 2022.

Lion predation events are easier to detect in our study area because the average prey is larger than those killed by leopards. This means the collared animals are likely to remain with the carcass for a period long enough to detect a cluster and often large bones cannot be ingested meaning evidence of the predation events persists for more days. Moreover since 2018, LEC has collaborated with Dr Natalia Borrego to investigate the hunting



behaviour of lions in the Kalahari ecosystem. The project started as a collaborative project with Dr. Borrego and Professor Craig Packer at the University of Minnesota’s Lion Centre funded by a National Geographic grant. The collaboration was developed further when Dr. Borrego and LEC’s head of research, Dr. Genevieve Finerty, were awarded a Collaborative Research Grant to extend the research from the Max Planck Institute of Animal Behaviour in Constance. Notably, by working alongside our highly skilled tracking team, the researchers have circumvented traditional challenges of collecting data on lion hunting behaviour. Lion hunts often occur quickly, in dense bush, and at night, making them nearly impossible to observe, and collect detailed data on. Additionally, typically information is limited to the collared individual, constraining our ability to gather information on the prey or other individuals involved in the hunt. By combining the information from our GPS collars with the remarkable skills of the trackers,

we can locate the site where a hunt occurred and gather extraordinary information on a hunting event by interpreting spoor. This “crime scene investigation” approach has resulted in an exceptional level of detail in our dataset, allowing us to recreate the movements and behaviours of both lions and their prey during a hunt (see Fig. 3.1). As a result, we have amassed a rich dataset on approximately 200 hunting events. As exciting news, after almost six years of data collection, this project has now entered the data analyses phase; LEC team members, along with our collaborators, are delving into the dataset to discern the ecological and behavioural determinants of lion hunting behaviour. We are considering factors like prey species, habitat type, pursuit distances, and the number, age, and sex of hunting lions. Our initial data exploration, as described below, has already uncovered exciting findings. In general, lions in the LEC study area exhibited a preference for solitary hunting, with 73% of the recorded hunting events involving a single lion pursuing prey.

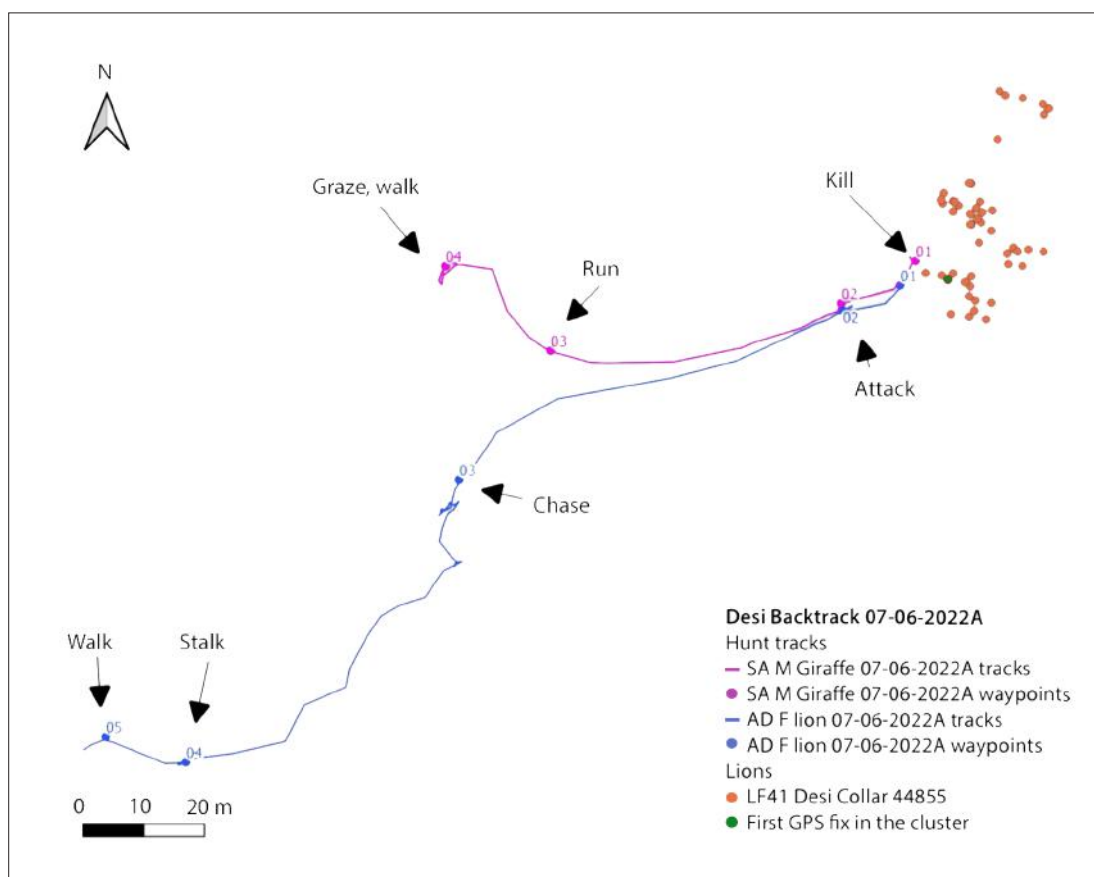


Figure 3.1. Example of the reconstruction of a lion hunt from the tracking data collected in the collaborative project with the MPI team. Desi, an adult female lion, stalks and takes down a sub-adult Giraffe. Although Desi hunting this giraffe by herself, spoor from another adult female and five sub-adults were found at the carcass, indicating that non-participating pride members fed from the carcass. The kill site was detected by investigating a cluster of GPS fixes (orange dots) from Desi’s collar. Desi stalked the giraffe till she was 20-30 m from it. The giraffe started to run away (point O3, pink) but Desi managed to attack it after a chase of 50 m (point O2, blue), before killing it 10 m further. Desi and the rest of the pride spent more than two days close to the carcass as proven by the very large cluster of GPS hourly fixes.

Remarkably, contrary to expectations, our research has revealed a lone lion is capable of successfully hunting, and taking down, large, challenging prey. For instance, we have witnessed adult female lions displaying exceptional hunting abilities, independently taking down formidable prey like giraffes. This unexpected finding has raised intriguing questions about lion behaviour and the underlying drivers of cooperation in the context of hunting. Given the low prey density in semi-arid environments, like Khutse, and lions' tendency to spend significant time apart or in small units, it appears that an immediate hunting opportunity, regardless of its solitary nature, is too crucial to forego. This necessity might outweigh the hypothesized costs of solo hunting, such as higher risk, increased energy expenditure, and potentially lower success rates. Our preliminary results challenge the common assumption that cooperative hunting is essential for taking down challenging prey, highlight lions' behavioural flexibility and how exceptional the lions in the Khutse region are. Interestingly, although lions mainly hunted and captured prey by themselves, spoor from other lions was frequently found near the carcass (preliminary analyses indicate close to 75% of the time), suggesting the presence of potential "co-operators" within a recruitable proximity. Therefore, not only do Khutse lions often choose to hunt alone, but they do so despite the nearby presence of other 'non-participant' lions that avoid the costs of hunting but still benefit by feeding on the kill. We are exploring the possibility that the non-participating lions are younger offspring not yet old enough to hunt, potentially accompanied by a pride mate who stays with them during the hunt.

Our findings so far challenge established notions of lion behaviour, specifically as related to cooperative hunting. Lions in semi-arid systems, like Khutse, face distinct challenges, and as our study indicates, these unique challenges influence their behaviour, differentiating them from other populations. We eagerly await the insights that our more in-depth analyses in 2024 will provide.

From the data collected, we can observe certain patterns:

- In 2023, we recorded 107 lion predation events inside of the protected areas (114 in 2022). As observed in the last four years, the main prey species are gemsbok (50) and eland (23). The two species together represent 68% of the recorded lion predation events inside the protected area.
- Numbers of predation events on kudu (8) and on red hartebeest (10) are consistent with the last three years, while recorded predation events on giraffes slightly decreased from ten in 2022 to four in 2023.
- Large antelopes account for 90% of the recorded predation events. This is consistent with previous findings that they are the preferred prey for lions. Nevertheless, the number of small preys is probably underestimated due to how potential kill sites are detected (see above). The larger the prey, the longer the lions are likely to stay at the kill site and the more chance we will detect a kill site from GPS clusters.
- Lion predation events are mainly recorded in the savanna environment with a woody canopy cover between 25% and 75%. Very few lion predation events were observed in the thicket and the open pans.

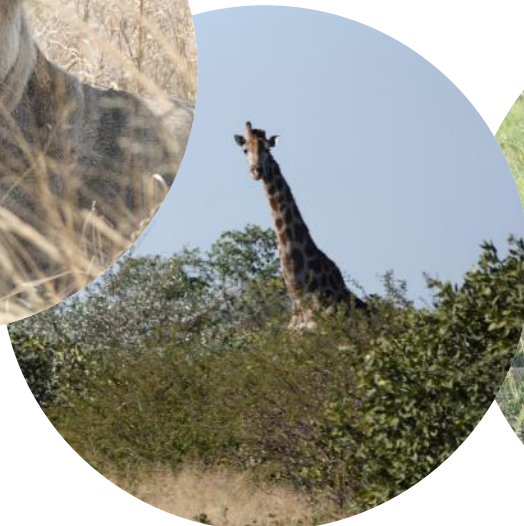


Table 3.1. Predations by lions inside and outside the reserve.

Species	adult		subadult		juvenile		TOTAL	
	in	out	in	out	in	out	in	out
Aardvark (<i>Orycteropus afer</i>)	2						2	
Blue wildebeest (<i>Connochaetes taurinus</i>)	1						1	
Cattle (<i>Bos taurus</i>)		52		12		5		69
Donkey (<i>Equus asinus</i>)	3	14	1	1			4	15
Duiker (<i>Sylvicapra grimmia</i>)	1						1	
Eland (<i>Taurotragus oryx</i>)	13	1	6		4		23	1
Gemsbok (<i>Oryx gazella</i>)	31		15		4		50	
Giraffe (<i>Giraffa giraffa</i>)	3		1				4	
Hartebeest (<i>Alcelaphus buselaphus</i>)	9	1			1		10	1
Horse (<i>Equus ferus</i>)		5		1				6
Kudu (<i>Tragelaphus scriptus</i>)	8						8	
Porcupine (<i>Hystrix africaeaustralis</i>)	2						2	
Springbok (<i>Antidorcas marsupialis</i>)	1						1	
Warthog (<i>Phacochoerus africanus</i>)		1			1		1	1

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

Species	adult		subadult		juvenile		TOTAL	
	in	out	in	out	in	out	in	out
Aardvark (<i>Orycteropus afer</i>)	1						1	
Cattle (<i>Bos taurus</i>)				2		10		12
Duiker (<i>Sylvicapra grimmia</i>)			1		1	1	2	1
Donkey (<i>Equus asinus</i>)		1		1		2		4
Eland (<i>Taurotragus oryx</i>)					4		4	
Goat (<i>Capra sp.</i>)		2						2
Gemsbok (<i>Oryx gazella</i>)	1				6		7	
Hartebeest (<i>Alcelaphus buselaphus</i>)			1		1		2	
Ostrich (<i>Struthio camelus</i>)					1		1	
Porcupine (<i>Hystrix africaeaustralis</i>)					1		1	
Steenbok (<i>Racipherus campestris</i>)	5						5	
Warthog (<i>Phacochoerus africanus</i>)	1						1	

Table 3.3. Livestock predation.

	Prey Age Class	Cattle	Chicken	Goat	Sheep	Horse	Donkey	TOTAL
Lion	adult	52				5	17	74
	subadult	12				1	2	15
	juvenile	5						5
Leopard	adult			2			1	3
	subadult	2					1	3
	juvenile	10					2	12
Black backed jackal	adult	1		11	4			16
	subadult			5	1			6
	juvenile			7	4			11
Caracal	adult			1				1
African wild dog	adult	4		3				7
	juvenile	2					1	3

- Inside the protected area, leopards seem to prefer hunting small antelopes or juveniles of larger ungulates. As is typical of the species, leopards are very opportunistic examining the remains from scats confirms that rodents, birds, and lizards are an important component of their diet in the Kalahari.
- We recorded a total of 19 leopard predation events outside the reserve. Compared to 2022, the percentage of livestock prey in these records has increased notably. This is likely a result of the fact that in 2022, most recorded predation events were from collared females which settled in communal grazing land but exhibited limited predation on livestock. Whereas, in 2023, the bulk of recorded predation events from leopards outside the park are from cattle post reports. Out of the 19 predation events, only two goats and one donkey were adult individuals.
- Predation on livestock data (Table 3.3) shows that leopards have been responsible for more predation on cattle than in 2022. It is important to note that 10 out of 12 individuals were juveniles and killed in densely vegetated areas. Better kraaling, especially of juvenile cattle and donkeys, is therefore a practical approach to reduce livestock loss due to leopards.
- Black-backed jackals continue to have the greatest impact on small livestock, suggesting that this may be an area we could target to reduce the loss of small stock in our study area.
- Recorded lion predation on livestock has almost doubled from 53 records in 2022 to 94 in 2023. The most relevant increase is for adult cattle which has increased by a factor of five from 10 in 2022 to 52 in 2023. This is partially a result of Sarah and her four cubs settling permanently outside the reserve in Mangadie area. Poona, another uncollared females from East Khutse pride, has also been active outside the reserve extensively in 2023. Their continuous presence has translated to greater livestock losses, and we suspect that there might have been a potential increase in false reporting to gain access to compensation from the government. Unluckily, not all reported predations can be investigated by our team as we do not always receive the reports immediately. We recorded a total of 69 cattle kills by lions during 2023. LEC trackers were able to investigate and confirm that 49 of these kills were the result of lion predation.



Project 4. Predator Movement and Habitat Selection

LEC's most impressive research dataset is certainly the long-term study of movement patterns in leopards and lions. Most of the movement data are obtained through the collaring of resident and translocated individuals. Throughout the years, we have combined the use of GPS collars with inbuilt accelerometers with traditional tracking. As collaring is an invasive practice for the animal, we try to reduce to a minimum the number of darting events each study animal experiences. To achieve that, we follow best practice collaring guidelines aimed to minimize the stress and we setup our collars to reach the

longest battery life without impacting the needed data quality. Currently, our lion collars collect one GPS fix every hour and last around 24 months, while the leopard collars collect one GPS fix every three hours lasting 12 months. The difference in battery lifespan is due to the different size of batteries we can deploy on the two species without impacting their health and behaviour.

Specific movement patterns obtained from the collar GPS fixes provide immediate information on the behaviour of the animal and we can use this

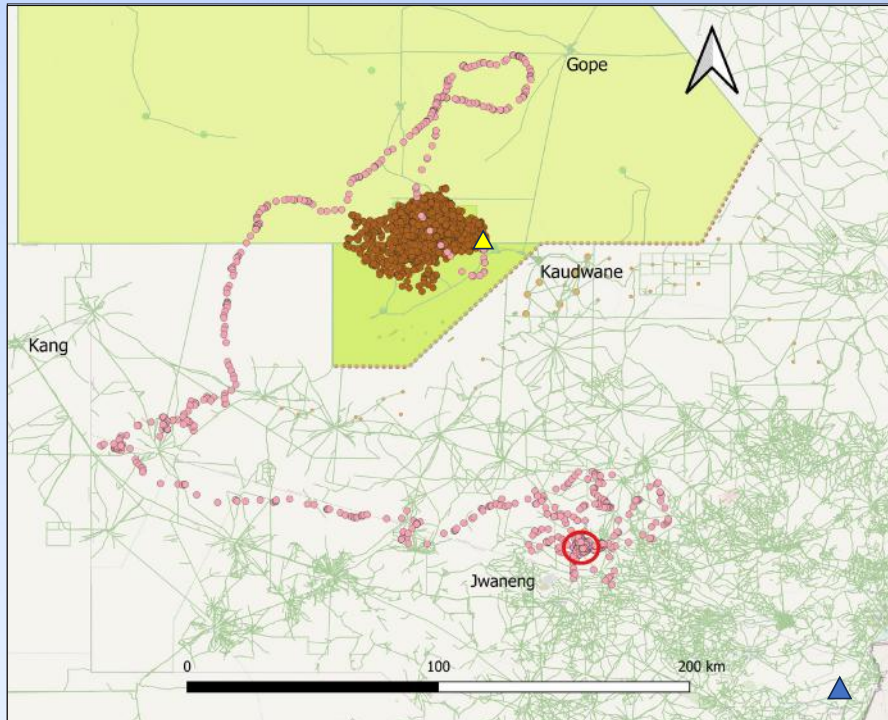


Figure 4.1. Map of the movements of leopards PF027 (pink) and PM034 (brown). The translocated leopard PF027 was captured in Otse (blue triangle) and released in Motailane pan (yellow triangle) in Khutse GR. In December 2023, PF027 gave birth to her litter just north-east of Jwaneng mine (red circle).

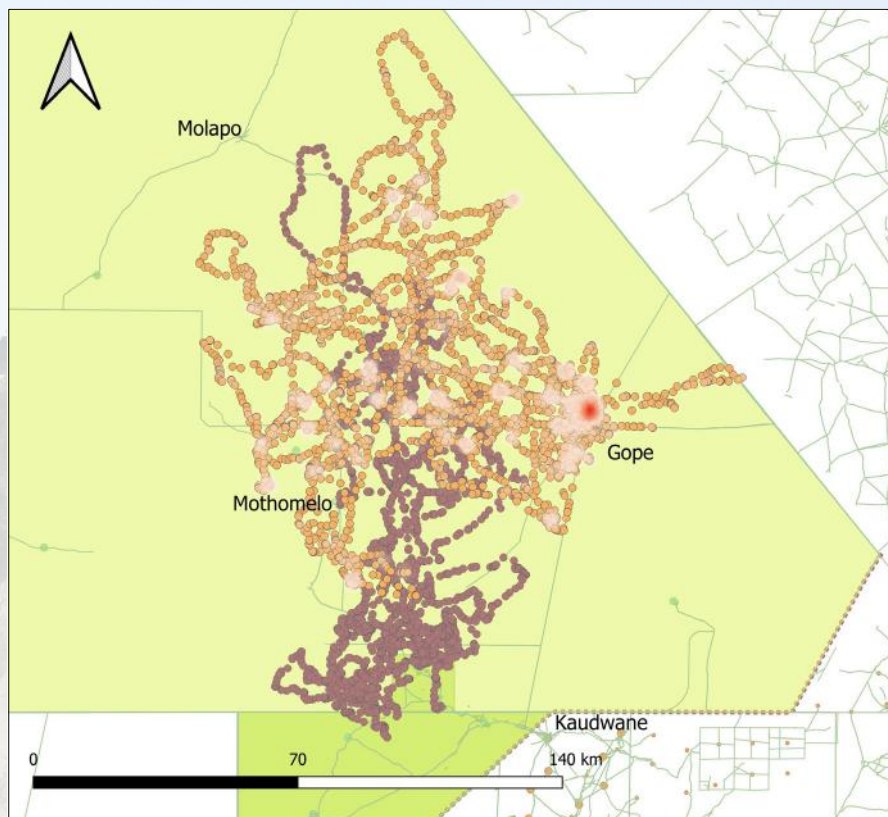


Figure 4.2. Athos LM088's GPS fixes since the deployment of collar 16379 on 26/03/2022. The GPS locations for 2023 are highlighted in orange. The heatmap layer shows the areas with the highest density of GPS fixes, i.e., where Athos was most active.

information to plan our daily resighting activities. To mention few examples, large GPS clusters (group of GPS fixes within a range of 50 m) during night hours are generally associated with a kill site for lions. In female leopards, missing GPS fixes alternated with complete fixes across few days may inform us that the leopard is likely in a den with newly born cubs. While the use of GPS collar technology has revolutionised the field of remote monitoring of animals, the devices still have limitations. We overcome these by leveraging the considerable skill of our field teams, while at the same time, reducing our reliance on invasive techniques alone. One of the techniques we use at LEC, is the 24-hours long-follows of the animals by tracking. During these “long-follows” we follow the tracks of the target predator and record the precise path walked by the animal between the GPS fixes over a 24-hour period. The “long-follows” allow us to not just measure the exact distance covered by the animal, but we can also obtain information on the behaviour of the animal, e.g., successful or unsuccessful hunt attempts and if other individuals joined the collared animal in their movement. This is only possible thanks to the incredible skills of our trackers. Moreover, the behavioural observation recorded from direct tracking in the field is essential to validate and correlate the data from the inbuilt accelerometer and other sensors of the collars. For example, we can potentially explain specific peaks or patterns of the accelerometer data with a hunt or with mating behaviour.

In 2023, we continued to deploy GPS collars on resident lions and leopards as well as on translocated individuals released by the Department of Wildlife and National Parks (DWNP) within our study area to collect information on their movements. Vera Lucia Alessandrello, University of Zurich, has presented her findings on translocated leopards post-release movement patterns at the Global Leopard Conference with very encouraging feedback. Her results will be submitted for publication in 2024.

In 2023, only two leopards were translocated to Khutse GR and one of them was collared. PF027 is an adult female leopard captured on the 14/06/2023 after predated on livestock in Moroekwe Farm (Otse, 30 km south-west of Gaborone). She was released in Motailane pan the same day and immediately showed the typical movement pattern exhibited by many translocated leopards (Figure 4.1). Nevertheless, her exploratory phase has covered an impressive area, and the extended time she spent inside the protected area until the 2nd of August is a

good indication that she was able to survive hunting wildlife. We hypothesize that the presence of other resident leopards in CKGR is the main reason for her movements south towards the town of Kang. She has finally settled down north of Jwaneng where she gave birth to a litter of at least two cubs. The contrast with the movement pattern of the resident male PM034 is evident. In LEC study area, the resident individuals cover large territories which may shift slightly across seasons and years. The range shifts appear less evident in males than in females. PM034 is showing a roundish home range which are typical in homogeneous habitats without major landscape constraints such as fences, rivers, or mountains.

Our movement dataset on resident lions is probably the most studied dataset at LEC. In 2023, the movements of the collared lions did not change significantly from the past years, except for two individuals: Sarah (LF026) and Athos (LM088).

With the presumed deaths of Notch and Verity in 2022, and the death of Nina in September 2023, we witnessed the complete disruption of the East Khutse pride (more details in Project 5- Lion Demographics, p. 24). The remaining females of the pride, Sarah, and Poona (LF069), gradually moved the core of their activities between communal grazing land and the eastern boundary of Khutse GR. In the second quarter of 2023, Sarah and her cubs established their new home range outside the reserve (see Figure 6.1 in Project 6 - Human-Predator Conflict, p. 30). The distances covered by Sarah across the month are reduced in comparison with her movements when she was inside. This is probably due to the distribution of prey and restricted movement in a shared landscape with humans. Outside, there is very limited wild prey but an abundance of livestock on which she can easily prey without covering large distances. Inside the reserve, wild herbivores are the only available prey for lions, but they are widely dispersed in the habitat and lions need to cover large distances to hunt.

Athos (LM088) is part of a coalition of three brothers with Aramis (LM089) and Portos (LM090). They were born on the 10th of September 2019, and they soon moved north into CKGR with the mother, Nina (LF027). On the 15th of February 2023, Nina and the three males split permanently close to Mothomelo. Athos and the two brothers continued their dispersal exploration over an enormous area between Mothomelo, Molapo and Gope villages inside CKGR. In the second half of 2023, their movement started to centre more around Gope where there is water continuously available from the mine (Figure 4.2).

Project 5. Predator Demographics - Leopard

Leopards are the reason LEC was created in 2000, and yet they are certainly the most difficult species we are studying. Leopards are solitary cryptic carnivores which can survive within urbanized areas without ever being seen. In addition to this secretive lifestyle, leopards in our study area present some of the largest recorded home ranges for the species. Such large home ranges in territorial carnivores are generally associated with low population densities. Our research has always held the monitoring of leopard population trends as one of the main objectives. Nevertheless, the reasons mentioned above make monitoring the Kalahari leopard population through direct observation extremely challenging. Track surveys are a great indirect approach to reliably obtain population size estimates for many wildlife species, including leopards, in Khutse GR and CKGR. The long-term track survey dataset at LEC has already provided important information on population trends from 2000 to 2022 (see Annual Report 2022). Nevertheless, we also are interested in validating the absolute values of our estimates by using other methodologies. Camera trapping is one of the most successful and commonly used techniques to assess leopard populations globally. Leopards are easily identifiable at individual level from their unique fur spot patterns and therefore, the images from camera traps makes them ideal candidates for applying capture-recapture analytical frameworks. Camera traps also produce a large volume of useful by-catch data on other species, and provide additional information on the animals they capture, such as body condition, behaviour, and social associations.

In 2023, LEC has started an ambitious camera trap survey to estimate leopard population in Khutse GR and in a section of southern CKGR in collaboration with Dr. Chris Sutherland (CREEM – University of St. Andrews). The survey will also contribute towards the Leopard National Survey led by DWNP.

We designed the camera trap grid for camera deployment according to the Spatially-Explicit Capture-Recapture (SECR) approach which not only considers the times each individual is captured on camera-trap photo, but also how each capture is spatially located in the study area. We deployed the cameras following a 5 km grid design. We determined the spacing between camera traps based on an index of home range size calculated for leopard populations in similar ecosystems (i.e., Kgalagadi Transfrontier Park) and the average distance from the centre of LEC collared leopards' home-ranges limits. Between May and June 2023, the cameras were deployed in the Northwest and Southeast blocks, while in July and August the cameras were moved in the remaining two blocks Northeast and Southwest (Figure 5.1). We repeated the same deployment scheme during our rainy season, from November 2023 to February 2024. The whole survey covers an area of 4435 km² with a total of 302 camera traps deployed across 216 locations.

This immense effort has produced a large amount of images and we are currently working with Conservation AI (www.conservationai.co.uk) for the first phase of the image processing. Conservation AI is



PF027 Collaring operation and veterinary check-up before release, with Dr Morris under the supervision of DWNP officers.

a nonprofit organization aimed at developing tools to facilitate biodiversity data processing using artificial intelligence. For camera trapping, Conservation AI offers a platform to automatically detect if the image contains an animal and, if an animal is detected, to classify the species and the number of individuals. The images containing leopards are subsequently processed using African Carnivore Wildbook (ACW, www.africancarnivorewildbook.com) platform. ACW's AI platform has been designed to identify leopards and other African carnivores to the individual level by using unique features such as spot patterns, whisker patterns and overall body shape and size. In 2024 we will be able to provide the first estimates of leopard population density in the study area with this method. An additional value of the deployment effort has been the opportunity to visit areas seldomly monitored due to their distance from roads and from LEC study animals. This has allowed us to gather important information on landscape features such as new pans as well as detecting poaching activities, which we report immediately to the authorities.

In 2023, we were able to monitor the movement patterns and hunting behaviour of three leopards, a male and two females, using GPS collars. The females were translocated into the reserve as problem animals, while the male is a resident leopard.

Rena

Rena (PF023) is an adult female translocated from Tuli block (Dovedale Game Ranch) in August 2021. She was collared and released in the Molose area and after about a month moved south and left the protected area. She has since established her home range in the area between Salajwe and Takatokwane which is a densely vegetated livestock farming area. Her collar stopped working at the beginning of 2023, but we have received information from the herders that she is still moving in the same area and that she has caused only minor losses for the moment. We decided to not upset this fragile balance of coexistence and we stopped searching for her.

PF027

PF027 is a fully grown female cage trapped and collared in Moroekwe farm (Otse) on the 14th of June 2023 as a problem animal. She was released in the Khutse GR at Motailane Pan. After her release, she moved south-west towards the communal grazing land, but luckily before leaving the protected area she made a sudden u-turn and started an impressive journey north into the Central Kalahari GR reaching Gope village and then aiming for the town of Kang in the Kalagadi District. After leaving CKGR on the 2nd of



August, she moved towards the hills north of Jwaneng where she settled and, in late December, gave birth to her first litter after release. Her story has very similar pattern to most of the translocated female leopards LEC has monitored across the last two decades. After exploring the protected area, they leave to settle outside the reserve and give birth to a litter. The survival of the leopard and the litter often depends on the prey availability around the denning site. Having small cubs limits the hunting area for the female and, consequently, conflict with livestock farming may arise and cause the death of the mother and subsequently also the cubs, as it happened to Feeli in 2022. But we are hopeful, PF027 will be able to bring her cubs to adulthood.

PM034

PM034 is a resident adult male leopard that was captured and collared on the 7th of December 2022. He is quite a big male for his estimated age (5-6 years) in the Kalahari area and in the last year he has grown bigger. It seems also his activity range is getting wider as in the second part of 2023 he has often moved to Molose and further west. He is probably in the process of establishing a larger territory and he covers long daily travel distances. His home range is completely included in our camera trap grid and cameras have captured him while closely following other males moving in his territory. From our observations, during the calving season he has often killed juveniles and subadults of large antelopes, such as gemsboks and elands.

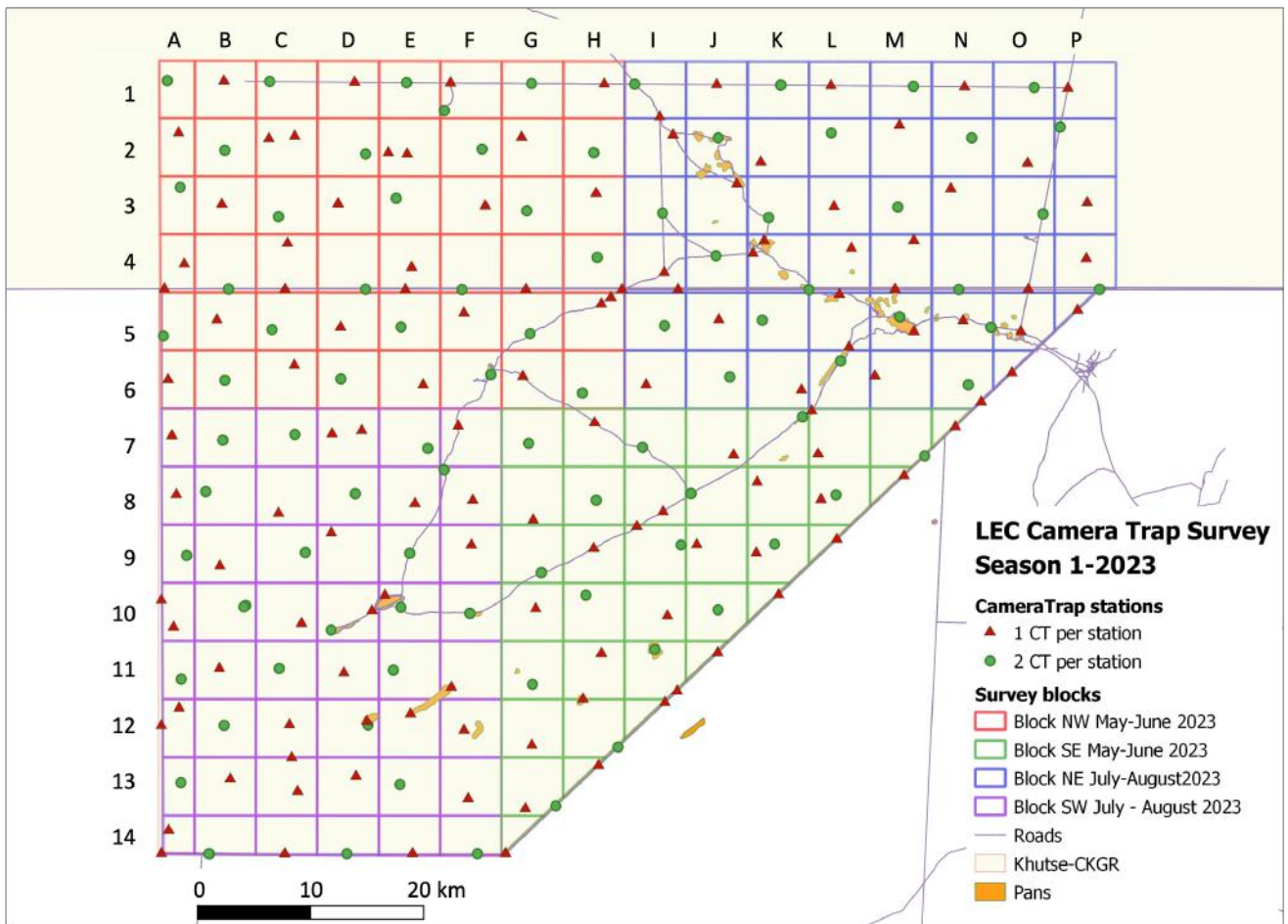


Figure 5.1. Set up of the camera trap survey to estimate the leopard population in Khutse GR and in a section of southern CKGR.



Project 5. Predator Demographics - Lions

Lion density in Khutse GR and southern CKGR is quite low as observed from our extensive spoor surveys since 2007 (see Annual Report 2022). Even if the protected area of CKGR and Khutse GR is one of the biggest in Africa, its characteristic low density in wildlife makes the monitoring of population trends a major priority for any conservation efforts. The existing ecological corridors, acting as source of new individuals from outside the protected areas, are under strong pressure from anthropogenic development. Currently the main corridor is connecting the South-West of CKGR with the Kalagadi Transfrontier Park in southern Botswana through the Wildlife Management Areas. Other lions may disperse through the porous northern CKGR fence with individuals crossing game farms from Makgadikgadi Pans National Park.

This is the reason why in 2023, we started exploring with other researchers across the Botswana Kalahari what could be the most efficient methodology to survey lion populations. Our team joined the Kalahari Research & Conservation lion survey in the Wildlife Management Areas at the northern boundary of the Kalahari Transfrontier Park (KTP). During the survey, different teams led by trackers scanned the roads for fresh tracks of lions. When a fresh track was found, the team would follow the tracks till the lions were found and good images of their whisker spots were obtained for individual identification. The data were then analysed in a Spatially-Explicit-Capture-Recapture framework together with any other opportunistic sighting of lions or images from camera traps. We look forward to learning the findings during 2024. In 2024, LEC will pilot an intensive lion track survey which will be completed daily across all roads in the protected area for a total of seven days. If the overall number of lion tracks detected across the seven days is considered sufficient, we will implement the full-scale survey for three months involving all researchers in the area and combine it with our camera trap survey.

In parallel with these new developments, we continue our long-term lion resighting activities. Throughout the year, our teams target collared lions and



record any changes in the group structure and any temporary association. Together with opportunistic sightings, we are able to provide not only the minimum number of lions active in our study area, but we can record births, deaths, mating and any social interaction we encounter.

In 2023, we counted a minimum of 51 different individuals, including 20 cubs (less than six months), across all our observation (Table 5.1). If we consider the individuals within our main study area covering all Khutse GR and 2000 km² of the southern section of CKGR (for a total of 5000 km²), we recorded 46 individuals. The coalition of Athos, Aramis and Portos (three adult males) are stable around Gope village in CKGR outside our main study area and two unidentified adult females were observed north of

the upper cutline in CKGR. By the end of 2023, we could record the mortality of two adult females (Nina LF027 and a female probably translocated by DWNP in March 2023), one subadult female and two cubs from the latest litter of Alexa. All the other 18 cubs born in 2023 were alive by the end of the year. As mentioned in several of our reports, lions in our study area cover very large home ranges (see example Figure 5.2), therefore many of the unidentified animals counted in our area may actually have the core of their home range outside LEC study area. Especially male lions have been recorded travelling for more than 40 km in 24 hours.

Table 5.1. Summary of the minimum number of different individual recorded across 2023 observations. Juveniles are individuals less than 1 year of age. Records are divided according to known or unidentified individuals. In red the individuals which died.

	Adult Male	Adult Female	Subadult Male	Subadult Female	Juveniles
Known	6	7 (-1)	8	2	20 (-2)
Unidentified	2	5 (-1)	0	1 (-1)	0

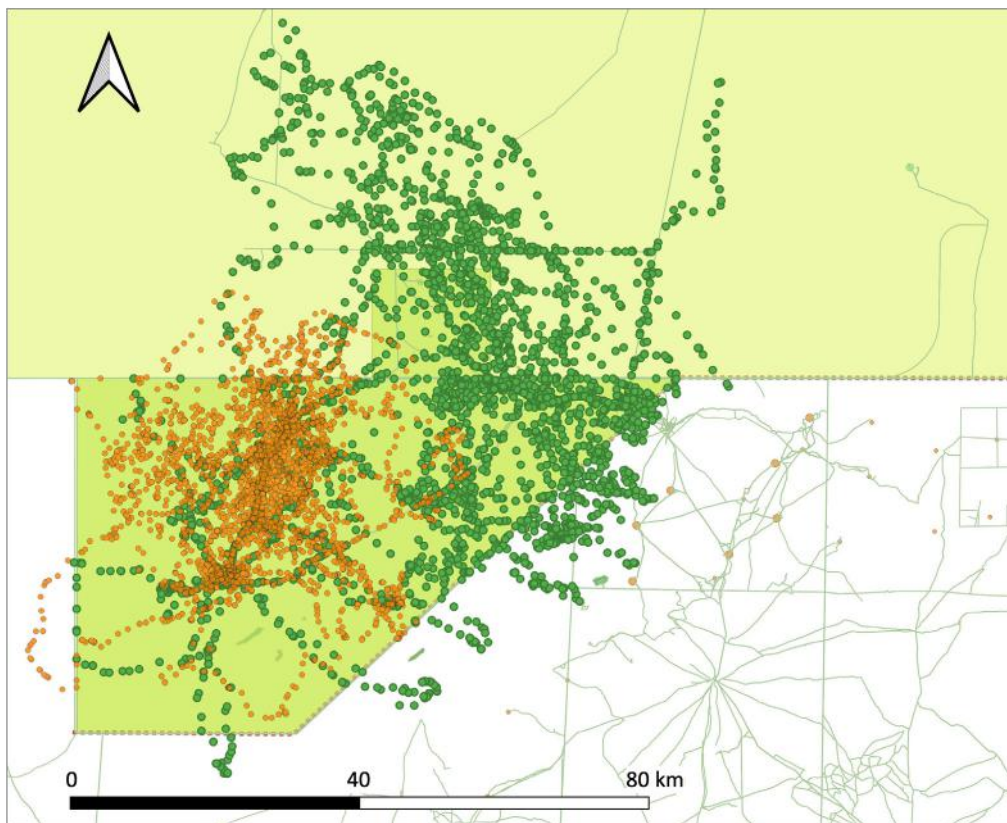


Figure 5.2. Hourly GPS fixes for Desi (LF041- orange dots) and Rocket (LM085 – green dots) from the 1st of January 2023 to the 31st of December 2023.

Meet the class of 2023

East Khutse Pride

The females originally forming the East Khutse Pride were born into the Molose pride around 2007 (Verity) and 2010 (Notch, Nina, Peggy and Sarah). The group however dispersed east and left their natal pride when they were subadults and has been resident in the eastern part of Khutse since around 2012. Unluckily, between 2022 and 2023, we witnessed the complete disruption of the pride. Notch was last sighted in October 2021, after Peggy was shot in July. Verity died one year later, and Nina was found dead on the 13th of September 2023. Of the different litters since 2019, only the three male offspring of Nina, and Poona (daughter of Peggy) survived.

In the first semester of 2023, Sarah and Poona have often been seen together moving between Khutse 1 and the eastern Khutse GR boundary. Since July, Peggy with her four cubs (born in January 2023) moved and settled outside the reserve becoming a major cause of conflict with the livestock farmers. Poona has been seen with her two cubs (born in April 2023) visiting a cattle post close to the fence, but she is not permanently moving with Sarah. From the farmer reports, we suspect she is still mainly active outside the reserve.

Nina, after finally splitting from her fully-grown cubs (Athos, Aramis & Portos - 3.5-years old) in February 2023, moved back south towards Khutse 1 pan. She mated with Rocket and Snooks in the area close to Khankhe loop. In July and August, she was stable around Khutse 1 waterhole, where she was found dead on the 13th of September. The cause of death is unclear as she was found in the water but without any evident sign of trauma or injury.

Athos, Portos and Aramis have continued in their dispersal across the central section of CKGR. As presented in the section on lion movements, their activity in the second semester focused around Gope village. The three males are forming a very strong coalition and have most probably taken control of the area around the mine. Athos was also observed mating with an unknown female towards the end of December 2023.



Xlara

Xlara (LM103) is a resident male lion collared in the month of July 2022. Unluckily, his collar has not worked continuously since its deployment. But from the data retrieved till October 2023 and the opportunistic resightings, he has been active between Sekaka waterhole in South-East CKGR and the upper cutline leading to Kukamma waterhole. Since his interaction with Rocket and Snooks in October 2022, they both seem to avoid any overlapping activity.

Rocket and Snooks

Rocket and Snooks, are still the prime resident males of Khutse GR, as witnessed in the last years. But in 2023, new strong males, including Xlara, have been observed mating with the females across Khutse GR. Rocket's collar has collected data throughout the year. In the first semester, he moved mainly close to Moreswe and Molose, while in the second half he has preferred the area between the two cutlines in CKGR with routine visits to predate on livestock in communal grazing land. Snooks is not collared and very shy and most of its observations were during targeted attempts on Rocket or one of the collared females. Snooks and Rocket have been seen together less often than in the previous years. Their age is estimated to be around 10 years and they might have passed the peak of the fitness for male lions in the Kalahari. We aim to have collars on both individuals in 2024 to monitor what could be a transition phase in the lion male dominance in Khutse GR.





Molose Pride

Molose pride used to be the largest pride in the Khutse Game Reserve, reaching up to 27 individuals. In the last six years the group has collapsed due to younger cohorts' dispersal and natural death of some adult members of the group. In 2023, we observed an increase in the presence of lions around Molose. This was due to several reasons.

Two groups of females, born from the original Molose pride, move between Moreswe and the Khutse-CKGR cutline. Each of these female coalitions is composed by two adult females, Alice-Alexa and Desi-LF047, have been very successful in raising their litters. Alice and Alexa gave birth to 6 cubs in late 2020 and they have all survived. Two of the males joined the group of Desi and LF047 who had a litter of other four subadult males and one female born in early 2021. In 2023, the cubs started to disperse, but five subadult males from the two groups formed a coalition which has been moving and hunting around Molose pan. In the while, Alexa and Alice moved the core of their movements towards the North-West corner of Khutse GR where they were seen with an unidentified male. Both Alice and Alexa gave birth to four cubs between end of July and the second half of August 2023, but Alexa lost two of her cubs in November 2023. Desi and LF047 were found with another male in August, and they gave birth to three cubs each between October and November. The evidence of mating with individuals which are not Rocket and Snooks is promising for the genetic viability of the population.

Molose pan is also known as the epicentre of the elephants return in Khutse GR. In the last years, we observed the resident lions being very shy towards the elephants and kept good distance to avoid any interaction. This year, we observed that the group of subadult males generated from Molose's females were probably less stressed by the elephants and on several occasions, they were seen along the waterhole even if elephants were drinking in it. Probably the new generations of Khutse lions are already getting used to elephants as they have experienced their presence since birth.

Project 6. Human-Predator Conflict

There is a clear lesson we have learned across our long-term research projects at LEC: the extreme Kalahari ecosystem exists with a fragile balance between all its components. This is especially true when we start to consider the complex interactions between human activities and the wildlife community. Reserves throughout sub-Saharan Africa face pressure from alterations in temperature and rainfall patterns associated with climate change. The growing anthropogenic pressure in the land bordering the reserve and wildlife management decisions have also had a clear impact on this unique environment. These external circumstances have the potential to exacerbate human-carnivore conflict (HCC) and threaten the long-term survival of large carnivore populations in the region. Therefore, to fully understand the nature of HCC in the study area we need to both study HCC events, but also the events running in the background that might interconnect with HCC. The projects and datasets presented in the previous pages are the tiles of the complex mosaic to better understand how lions and leopards interact with our communities.

A key source of conflict in our study area is the predation of livestock in the communal grazing land. In 2023, we witnessed quite a steep increase in

livestock losses caused by lions (see results in Project 3- Predation, p. 13). In response to this, we present here a deeper look into the recorded data together with some hypotheses of what might have caused such an increase.

As you can see in Figure 6.2, in 2023 lion predations on cattle have a peak around August with important losses reported in July, September and October. The dry season generally starts between May- June and gradually the grazing resources around the cattle posts start to be depleted. Livestock therefore starts to move further away from the cattle posts towards the reserve boundaries. In the local farming culture, there is very limited herding and the cattle are seldomly kraaled at night. Simultaneously, the wild prey populations start to become scarce and lions have difficulty in finding wild prey. This combination is likely the cause of this seasonal peak in livestock losses due to wild carnivores.

But why did we observe such an overall increase in livestock predations in 2023? One possibility is the delayed onset of rains compared to the past years. Rains generally start in November, but in 2023 the first good rains arrived in the second half of December. The overall volume of rain recorded in the last two months of 2023 was nearly half of the

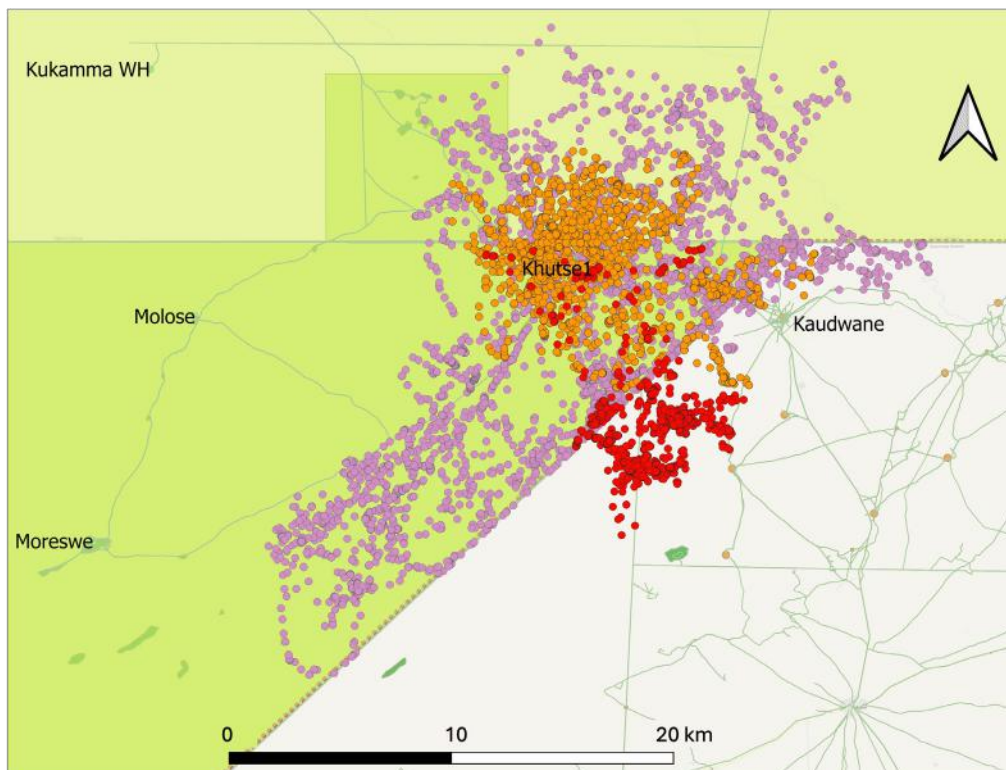


Figure 6.1. Sarah – LF026's hourly GPS fixes since collar's deployment on the 03/11/2021 (purple dots). In orange, her movements in the first semester of 2023 and, in red, her locations in the second semester of 2023.

rainfall recorded in the same period in 2022. This may have protracted the period where lions relied on livestock for prey and explain why we observed relatively high numbers of reported losses well into October, and even into January/February.

It is also worth mentioning that more than 50% of the recorded livestock predations from lions in 2023, were caused by two individuals: 23 kills from Sarah (LF026) and 30 from Rocket (LM085). Rocket has already been known to be the cause of livestock losses with his one-night forays into the communal grazing land before returning inside the reserve before sunrise. In contrast, Sarah very seldomly crossed the park boundary before 2023, but in July 2023 she decided to leave the Khutse 1 area and settled with her four, seven-months-old cubs outside the reserve (see Figure 6.1). Sarah was part of the East Khutse pride, a group of lions which unluckily experienced severe disruption between late 2021 and 2023. The East Khutse pride dispersed into the Khutse 1 region from Molose as group of four young adult females and one older female. Four of these five original group members have now been lost due to natural deaths and targeted removal from the population as “problem animals”. The disruption of the pride may have pushed Sarah to leave the reserve to find easier prey outside. A clear consequence of Sarah and her cubs settling in the grazing land has been an increase in livestock losses because of the extremely low presence of large wild herbivores outside the reserve, as reported from our track survey in 2022. Our observations this year highlight a clear need to understand the impact of social disruption to lion groups in the context of behaviours that potentially bring them into

contact with humans and their livelihoods.

Our field observations in 2023 remind us that coexistence between humans and carnivores in our area is extremely fragile and might be jeopardized by both systemic reasons (rainfall, farming practices, wild prey abundance) and behaviour of single individuals. Thus, any effective conflict mitigation strategy should include actions to tackle the current landscape challenges (facilitate wild prey population recovery, habitat connectivity, establishment of effective buffer zones, herding and kraaling practices) alongside interventions that target the individual animals most at risk of encountering livestock and conflict with humans (establishment of GPS- geofencing, early alarm systems, deterrents).

2023 has also proven that LEC has correctly invested in building education and communication within the community in the last 23 years. The increase on livestock losses has certainly upset many livestock owners but they have never interrupted the communication channels with LEC. In response, LEC has facilitated many meetings with the responsible authorities and has continued to inform farmers on the current presence of lions in their area. No lions or leopards were killed by farmers in the areas where LEC has been working with the cattle posts across the last years.

Within this spirit, in 2023 LEC has invested in inclusive consultations within the community and started collaborations with other NGOs facing similar challenges and scenarios. The efforts will translate to a series of pilot projects to better understand how cattle move in the grazing land and to try to establish an effective lion alert system for the cattle posts herders.

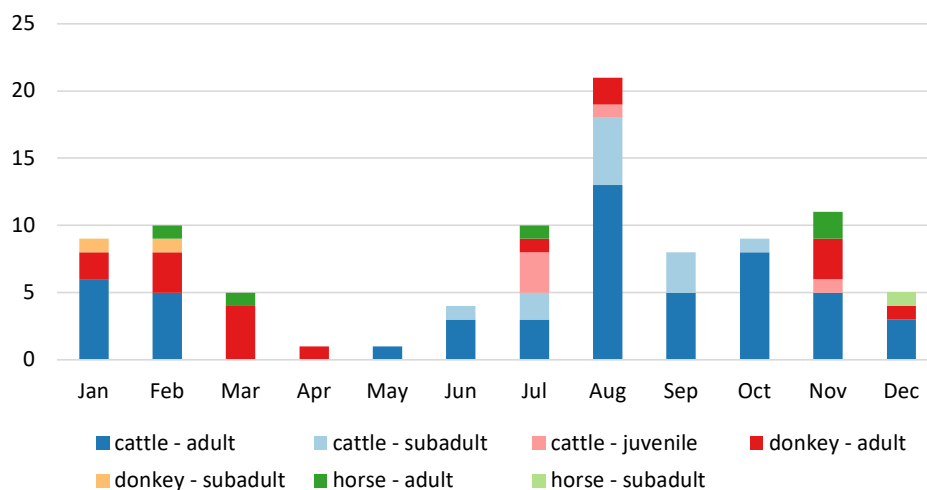


Figure 6.2. Livestock predations by lions across 2023.

PROJECT IN FOCUS.

FINDING THE RIGHT SOLUTION AT THE ROOT

At LEC, we believe in innovative solutions to our scientific questions and needs. Our first step in any new project is to understand what the available resources are to achieve our goals. And very often we find the right tools and approach looking at our roots. Since LEC's beginning in 2000, we have placed indigenous knowledge front and centre in our approach to tackle scientific questions in the Kalahari. Traditional knowledge and skills, such as the art of tracking, have been an invaluable asset to our research, providing insight into animal behaviour, movement and allowing us to track animals across the vast landscape. Simultaneously scientific research provides job opportunities to people with this knowledge and, consequently, promotes transmission of this culture to the new generations.

The Daily Travel Distance project (DTD)

In 2023, the LEC research team collaborated with Marie-Charlotte Gielen, PhD student at Catholic University of Louvain in Belgium, to design a study to obtain the first empirical daily travel distance estimates for five large- and medium-sized herbivore species in the Kalahari: kudu, eland, red hartebeest, springbok and ostrich. This is an iconic example of how we combine the local traditional skills with technology and new analytical framework to create new monitoring tools for the Kalahari wildlife populations.

But why do we need the daily travel distance estimates (\bar{M}) for these species? To answer this question, we need to quickly go a few steps back. One of the key long-term projects at LEC is the extensive track surveys that our team completes every four years. During these surveys, we sample the same set of roads in our study area every month for a 12-month period. The objective is to use the number of tracks counted along these roads to estimate wildlife population abundances. LEC has used



“

It's like going back to our childhood when we would follow our parents for hunting, or we would play following the tracks of animals in the bush.

DUELA SEGANAPHOFU, Tracker and Driver

“

Humility and Respect: I enjoyed working with the trackers mostly because of their humility, they know no rank and age, younger than them as I was, they worked with respect for me just for virtue of being a human being which is a trait we could all learn from.

SEITSHIRO PULE, Research Assistant

track surveys to monitor carnivore abundance since the beginning of this project. Up until 2021, we used distance sampling (i.e., direct observations), run concurrently with the track surveys, to monitor herbivore populations. However, in the last years, the low herbivore densities and the limited road network has resulted in sample sizes too small for reliable density estimation using this approach, creating an open challenge. A recently re-discovered analytical approach, the Formozov-Malyshev-Pereleshin (FMP) formula, has provided a promising solution. The FMP overcomes many of the limitations of other track-based methods, such as the need to discern between crossings of different individual animals, which is particularly challenging for hooved species. We adopted this approach in 2021 and expanded our track surveys to include herbivores alongside carnivore track records, as presented in the Annual Report 2022.

The FMP formula allows researchers to estimate population densities (\hat{D}) by converting the total number of track crossings (x) during the last 24 hours over the total transect length (S), using a model based on the average distance animals travel daily (\hat{M}) (see Figure P1 for a graphic explanation). Since the model uses daily travel distance (\hat{M}) as a key parameter, getting this right is one of the crucial elements to producing accurate density estimates. Where this is unknown, it is possible to use a proxy based on e.g., the average body size (kg) of the species (Carbone et

al. 2005) i.e., “allometric” daily travel distance (such as we did in 2021-2022). However, such estimates are coarse, which may bias the accuracy of FMP density estimates. Therefore, when possible, the daily travel \hat{M} for each species should be estimated from empirical data collected in the survey area or similar ecosystems to ensure this best reflects animal behaviour. Accurately monitoring herbivore populations is critical for conservation efforts. However, the challenge we faced is that for five of our target species, we only had allometric \hat{M} available. This formed the motivation for the collaborative project.

Once it was clear that we needed these values, the next solution we had to find was, how do we collect empirical data on how far animals’ move in our ecosystem? The short answer is, we looked to our roots. We collaborated with highly skilled Kalahari trackers and sought technical advice from experts such as Dr Derek Keeping (Okavango Research Institute), who has studied track-based approaches in the Kalahari for more than 15 years, to design a data collection protocol. The finalized protocol consisted of a two-day fieldwork schedule. On day one, the team led by Marie Jardeaux (UCLouvain MSc student) and Seitshiro Pule (LEC Research Assistant) spotted an individual or a group of the target species in the middle of the day, recording the time, GPS coordinates and several other additional parameters to provide insight in the group structure and behaviour. On day two, the team would return to the exact point were

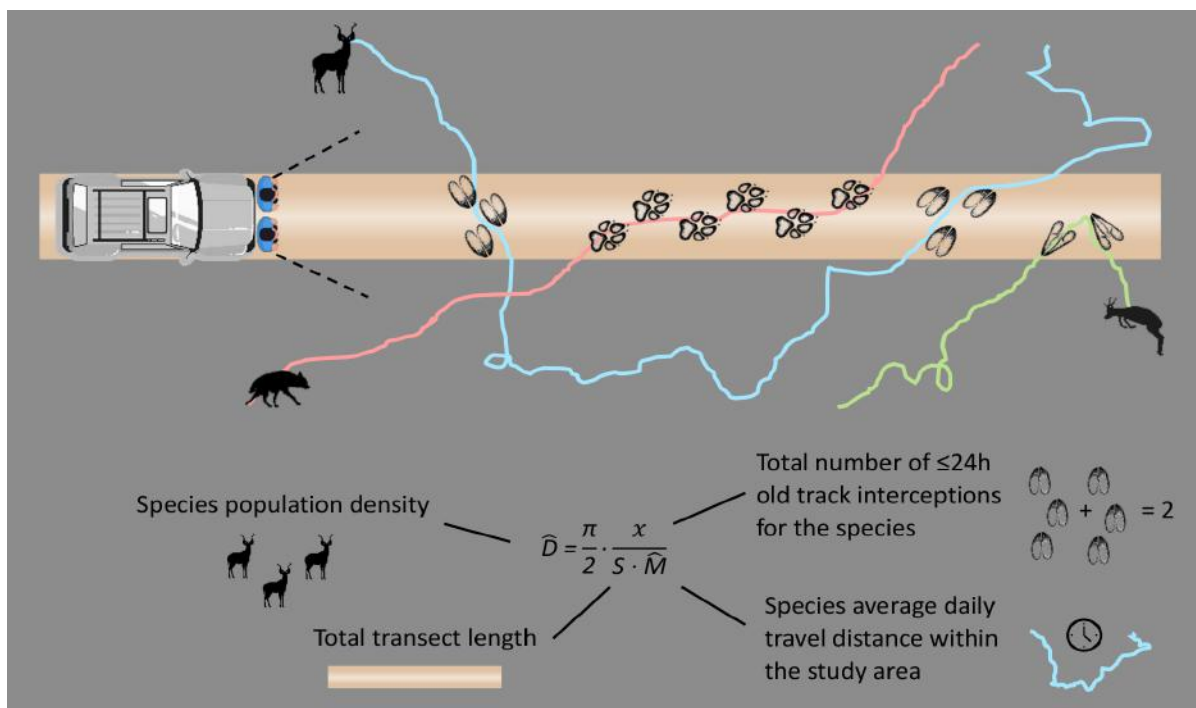


Figure P1. Schematic representation of the parameters used in the FMP formula to analyse track counts collected during track surveys (Figure adapted from Gielen et al. 2024, <https://doi.org/10.1016/j.gecco.2024.e02924>). In the example proposed, the survey will consider two crossings of the kudu (blue line) even if it's the same animal.

the animals were spotted, four to five hours before the spotting time of the previous day. From this location, the trackers (Duela, Fire, Senxwai and additional LEC trackers on rotation) would start trailing the target animal(s) with the objective to re-sight it at the same time it was spotted the day before, thus covering its 24h movement path. Throughout the trailing, a custom-designed CyberTracker application (www.cybertracker.org) allowed the team to record the exact travel path of the targeted animal(s) and any behavioural data interpreted from the encountered tracks and signs. This resulted in an extremely fine-scale record of the movements of the targeted animal(s) over the course of 24-hours.

Soon, the whole fieldwork became an exciting challenge for all the trackers involved and their skills and senses were awakened day by day. It was very similar to the processes of traditional hunting in several aspects. The trackers needed to be sure to always follow the same animals and to be very aware of their movements and the surrounding environment to avoid any impact on the movement behaviour of the targeted animals. To obtain reliable 24-hours travel distances, it was essential to find and re-sight the animals close to the spotting time of the previous day, without startling them before. It was a game of “wait and chase” continuously adjusting the pace, smelling the air and looking through dense vegetation.

The project results were above expectations; in only three months the team managed to record 14 eland trails, 21 kudu trails, 13 red hartebeest trails, 13 springbok trails

and 10 trails from ostriches. We found that allometric \hat{M} consistently underestimates the daily travel distance (empirical \hat{M}) for all the targeted species in the Kalahari habitat. And, importantly, that using the larger empirical \hat{M} in the FMP formula translates to lower density estimates. We used this systematic discrepancy between allometric \hat{M} and empirical \hat{M} to build a factor to correct the allometric \hat{M} for all the remaining species lacking empirical \hat{M} . Ms Gielen in collaboration with LEC is currently writing up these findings for publication in 2024. Combining local knowledge on the art of tracking, app-based data collection and expertise from Dr. Derek Keeping has enabled us to obtain the first empirical daily distance values for these species in the Kalahari. This approach embodies what we strive for at LEC, an inclusive, integrative approach to producing new scientific knowledge.

We would also like to highlight the unexpected results we obtained with this project. We have already mentioned the enthusiasm generated in the research team, but what is even more relevant is that within few weeks all trackers involved had refreshed or improved their trailing skills. And we could quantify this improvement thanks to the annual CyberTracker certification workshop in November 2023. Assessors Adriaan Louw and Andrew Kearney (Cyber Tracker) were impressed by the evident improvements with an average score on trailing increasing from 96.7% in 2022 to 99.1% in 2023 and with two trackers awarded the Trailing Specialist certificate.

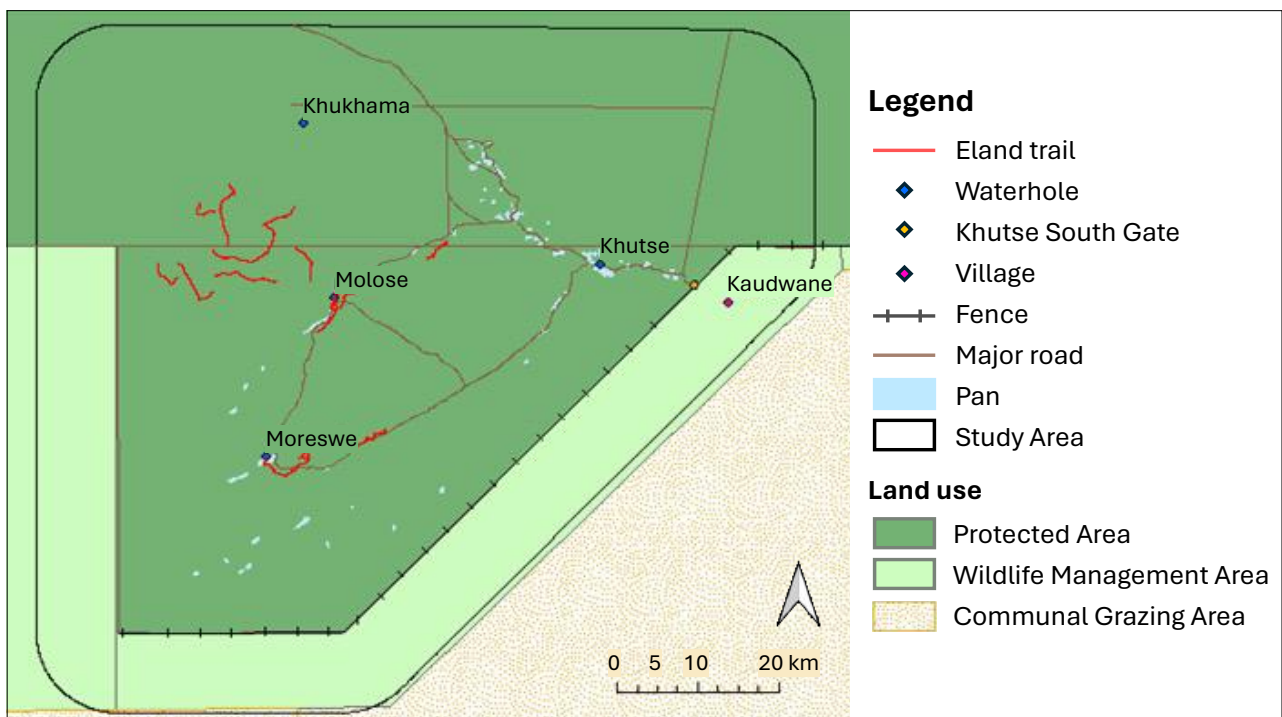


Figure P2. Map of the eland trails completed during the daily travel distance project (copyright Marie Jardeaux).

STARTING TO TEACH – DWNP tracking training workshop and collaborations across the Kalahari

For many years, we have been aware of the incredible cultural richness still present in the local community, especially with respect to tracking skills. In 2023, we had confirmation that such skills can be rejuvenated by being included in new research projects and that practice is the key to safeguard this knowledge. But we are also aware that cultural roots are not just a source of inspiration and solutions to our questions, roots need to be fostered and nourished. Modern lifestyles and source of livelihood are causing the gradual loss of ancient traditional skills and, if we value their existence, there is an evident need for transmitting these precious skills by adding modern value and making them appealing to the new generations. To contribute towards this objective, LEC has organized workshops and collaborations focused on tracking.

The Department of Wildlife and National Park (DWNP) has also recognized the value of tracking for management purposes and the incredible related skills present among some Botswana's citizens. In April 2023, LEC, with the support of WildCRU, organized a training workshop on track surveys for wildlife abundance estimation and fence monitoring. For four days, a team of 15 DWNP officers from the Central District attended lessons by Alessandro Araldi and Marie-Charlotte Gielen in the LEC camp on how to design track-based surveys and which software can be used for data collection, visualization and analysis. The track identification training session were carried out by experienced LEC trackers Pogiso "Africa" Ithuteng and Supula Monnaanoka. The field sessions were eye-opening for the very participative officers, and Supula and Africa were correctly titled "Professors".

LEC strongly believes in the need of connecting trackers across the country. For the second consecutive year, trackers from other parts of Botswana joined LEC team for the annual CyberTracker evaluation workshop (www.cybertracker.org, co-founded by Louis Liebenberg and Justin Steventon). This year the WildCRU team from Chobe and Boteti came to share their knowledge and passion in Khutse GR. Earlier in

the year, LEC trackers joined Kalahari Research and Conservation for their lion survey in the Kalagadi District and for a meeting on traditional hunting skills. Both opportunities gathered trackers from the whole Kalahari region. The trackers are realizing that there is a network of people across the country which share the same or similar knowledge and that there is a future for developing job opportunities around indigenous skills. There is water for the roots.





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Sharing knowledge and witnessing the mutual interest reflected in each other's eyes was a fulfilling experience that we hope to repeat.

MARIE-CHARLOTTE GIELEN, PhD student

COMMUNITY & EDUCATION PROGRAMME

With the Community & Education Programme, LEC endeavours to support the community in developing a system that allows them to coexist with wildlife and live sustainably. Central to this are two key areas of work: fostering an interest and passion for wildlife and conservation and minimising the conflict between farmers and carnivores. One highly appreciated aspect of this work is the level of trust and collaboration we have cultivated between LEC and the local farmers.

Over the past 20 years, we have learned that by integrating research and education we can more effectively reduce or mitigate human-wildlife conflicts in our study area. And by working hand-in-hand with the community, we are able to facilitate an effective and open interaction with the people living alongside the carnivores.





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.

As both human and wildlife populations increase, and people expand into new territories, the likelihood of conflict between humans and wildlife is expected to rise. Recognizing this, LEC acknowledges the importance of mitigating such conflicts to ensure that the benefits of coexisting with wildlife outweigh the associated costs. Through the Community & Education Program (C&E), LEC aims to support the community in developing sustainable coexistence strategies with wildlife, developing diverse approaches and effective tools to mitigate human-wildlife conflict (HWC). Central to this are two key areas of work: firstly, fostering an interest and passion for wildlife and conservation, and secondly, minimising conflict between people and wildlife. The C&E team conducts weekly visits to cattle posts to gather data on predation events and other mortality cases. The aim is to gain a comprehensive understanding of how the conflict evolves and to develop relevant mitigation strategies. In addition to working with farmers and herders, LEC also collaborates with the local village community of Kaudwane on small-scale projects to promote conservation practices and improve their livelihoods. Since the inception of the C&E Program in 2004, LEC takes pride in the strong level of trust and collaboration established between LEC and the local farmers despite the challenges posed by the environment.

Education & Capacity Building

To ensure progress towards our long-term objectives, the C&E team continues to empower the local community to act as guardians of their land and livestock in a manner that supports effective and sustainable resource management. LEC conducts several long-term education and capacity building projects including targeted workshops and training sessions with farmers and the community of Kaudwane, as well as with school children.

The cattle post educational program continued in 2023 for the second consecutive year after COVID. It aims to empower farmers and herders to improve their skills and status as livestock managers through education and capacity building. The focus thus far has been on educating farmers about the management of livestock diseases prevalent in the area, including identifying disease symptoms, control, prevention, and practical training in administering



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Under the C&E department, as a team we were on the mark, we focused on improving how we did things using our experiences as a learning curve. Through perfect coordination, planning and timeliness we managed to emerge successful at the end of the year 2023.

OBAKENG JOHN OBOTSENG, Education Liaison Officer

vaccines. Through interactions with farmers, it has been observed that they sometimes underestimate the impact of disease mortality on livestock, reacting more strongly to losses from predators. To recognize and motivate committed farmers, an attendance certificate is issued for every five lessons attended. In 2022, each of the eight cattle posts within LEC's study area and in Kaudwane received a set of hoof-trimming tools shared among livestock owners. We continued to monitor their condition and usage with a notable increase in the number of livestock hooves trimmed in 2023, rising from 143 in 2022 to 169 in 2023.

For the second consecutive year, LEC collaborated with the Botswana Society for the Prevention of Cruelty to Animals (BSPCA) to conduct a cat and dog sterilization and vaccination campaign. This project aims to improve the general welfare of cats and dogs by improving animal health and lowering the risk of aggression between unneutered individuals. Given the proximity of pets to wildlife areas, this reduces the likelihood of disease transmission in the study

area, particularly rabies. To achieve this, LEC 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. The campaign resulted in the successful sterilisation of 28 dogs (16 males and 12 females) over four days.

As in previous years, the horse care evaluation and training, conducted from February to June, involved a professional farrier visiting horse owners in eight cattle posts within LEC's study area to provide valuable training on general horse management. Also in 2023, the focus was on hoof care, deworming, proper horse handling, saddling, and riding. As a motivation, after the third and final evaluation each participant received a reward based on the successful health assessment carried out by the farrier. This project aims at encouraging improved horses' welfare. Horses are a mode of transport for farmers in rounding livestock for kraaling and to look for cattle that might have gone astray.

After a three-year suspension due to COVID-19 restrictions, the farmers' workshop was reinstated in 2023. This platform engages stakeholders and farmers collectively to discuss challenges and opportunities in the area, including the development of strategies 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. We presented data during the workshop on the observed pattern of livestock losses from both diseases and predators at the cattle posts and discussed possible solutions.

Community support & Development

As part of the Botswana Government's "Adopt a School" initiative, LEC adopted the Kaudwane Primary School (KPS) in 2013. Through this initiative, LEC's C&E program continues to facilitate small-scale projects that directly benefit children through



education. One example is the school game drive project, which takes students from Kaudwane Primary School on a full day excursion into the park. 2023 was no exception, LEC collaborated with the Special Support Group (SSG) – Khutse base and the Department of Wildlife and National Parks (DWNP), to take 46 Standard seven learners on a full-day 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 provide children with a learning experience out-side the classroom, educate them about the importance of protected areas, and introduce them to the work conducted within the park.

LEC also supports Kaudwane Primary School by donating clothes for them to sell and raise money for the school's fundraising committee. The proceeds directly support learner empowerment activities, enhance their experiences, and contribute to their studies. In 2023, these funds were used to purchase awards for the best students from each grade during the prize-giving ceremony.

The Community Conservation Club (CCC) collaborates closely with the C&E team to implement community projects thereby enhancing the synergy between LEC and the community. The club is made up of six volunteers from the Kaudwane community who are engaged by LEC for community projects. To recognize their effort and motivate the CCC members, LEC provided them with branded dust coats and boots as safety clothing for their community work. In addition to the uniforms, CCC members were rewarded for their previous year's effort (2022) with start-up materials for building mini gardens. Each member received a piece of net shade and seeds to build

small backyard gardens at their homes. While the club members planted various vegetables for subsistence, some yielded surplus produce, which was sold within the community.

For the third consecutive year, we continued our tree planting initiative for the annual World Nature Conservation Day (WNCD) event held on July 28th. We invited local stakeholders to engage with the community and share their conservation roles. The project aims to demonstrate the value of trees for both ecosystems and people to the community, thereby also reducing deforestation to ensure a healthy habitat for wildlife. LEC distributed 206 trees to interested community members and provided pre-training on how to properly care for the trees for participants. The trees were donated to LEC by the Department of Forestry and Range Resources (DFRR) in Letlhakeng. In 2021, when the tree planting project started, village wards engaged in friendly competition to demonstrate their ability to care for their trees effectively. Subsequently, in 2023, an adjudication process took place with support from DFRR and the Agriculture Field Officer from Salajwe. Monaanoka ward emerged as the winner and received 20 chairs as a prize. Additionally, three individual prizes were awarded to participants who excelled in tree care.

At LEC, we recognize the importance of engaging and giving back to the communities we work with. This commitment is essential as it helps foster goodwill and strengthen relationships. In line with this, LEC donated a new branded netball kit, seven pairs of trainers, two balls, and seven training bibs to the Desert Eagles Netball Club in Kaudwane village, the female netball in team of Kaudwane. As part of the handover event, a practice match was arranged with the LEC team to tighten the bond with the community.



Team Reflections: Human-Wildlife Conflict Workshop

In November, LEC hosted a one-day internal Human Wildlife Conflict (HWC) workshop in Khutse LEC camp. The overall objective of the workshop was to create a platform for open discussion about LEC's past, present, and future HWC interventions and invite LEC members to share their personal experiences with HWC in the region. In doing so, we aimed to develop a shared understanding of the current challenges and opportunities, while considering the diversity of contexts, approaches, and resource availability. The outcome of the workshop is intended to inform LEC

about approaches to HWC related projects and to set the stage for designing practical tools that people will actually use. Most importantly, the workshop brought all team members together under one roof to discuss issues and topics that affect them as farmers and at the same time are also relevant to their work at LEC. Participants valued the participatory approach and there was an expressed need to take part in developing ideas for future LEC projects.

“

I feel that a great empowerment to the community is providing educational training on issues that affect their livelihood the most, as livestock farming forms the back-bone of the economy of Kaudwane village and LEC is providing this to community.

MPHOENG OFITLHILE, Community & Education Programme Officer



INTERVIEW

BONTSHALETSE CHELETE, WINNER OF TREE CARE COMPETITION

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Taking care of a tree, is like taking care of a child. A tree always needs careful and persistent effort.

BONTSHALETSE CHELETE



Can you tell us about yourself?

I am Mrs. Bontshaletse Chelete, a resident of Kaudwane village, Moatshe ward. I am an ardent tree lover, and my dream is to make a living out of trees one day. I want to have a lot of fruit trees as well as for shade and decoration. However, I like fruit trees more.

Have you always been fond of trees and why?

I have always loved trees from way back, because they are a good source of fruits, shade, wood, and they make a place look attractive.

Which trees have you planted in your yard?

I plant all sorts of tree types; indigenous, exotic, both for fruits and shade. In my yard right now, I have planted guava (*Psidium guajava*), orange (*Citrus sinensis*), bird plum (*Motsengtsela*), sickle bush (*Moselesele*), silver leaf terminalia (*Mogonono*), flowers and wisteria (*Mosokaphala*).

From the trees you have planted, which ones are close to your heart and why?

I like trees in general, but fruit trees such as orange, mango and guava top the list of those I like the most. However, I still have a shortage of fruit trees and my wish is to plant more, so that I can make a living out of them. I have always dreamt of owning a botanical garden that I can rent out to people for photo shoots and host events as a way to make a living out of it. I also would love to acquire more training on the management of trees. If LEC could offer me that opportunity to increase my knowledge on trees, I would very much appreciate it.



LEC had a competition between the wards for the best tree care. You scooped the first position. What do you think it takes to be the best in the management of trees?

When it comes to looking after trees, I have so much perseverance. I give my plants attention, love, and care. I would say, taking care of a tree is like taking care of a child, a tree always needs careful and persistent effort.

How have you benefitted or what have you learnt from the LEC tree planting project?

I have received theoretical and practical lessons on planting trees in general. I have further learnt the importance of trees in our environment and that they are key to maintaining a healthy ecosystem.

Would you recommend that the tree planting project continues?

I will strongly recommend that this project continues. It encourages the community to learn about the importance of trees and their uses.

What are the main challenges you face with planting trees in your area?

The biggest challenge in this area are termites although there are other pests. I try to use home remedies to control them, and it seems to work. For the termites, I apply wood ash and use water with liquid soap to control other pests.

How can the tree planting project be improved?

Offer extra training to those passionate about trees (myself included) to increase the knowledge, then the knowledge can be passed on to others at community level. I also recommend that more fruit trees are donated to the community as they are more useful.

What advise can you give others regarding the taking care of trees?

I can only encourage the community to develop interest in planting trees and not just planting them and then not taking care of them. People need to know that trees take time to reach their maturity and that one needs to be perseverant.

Interview conducted by Ernest Gagosimologe and Mphoeng Ofithile.

APPENDIX I

Table Leopard Telemetry. Animals monitored by LEC during 2023.

ID	Name	Origin	Collar active	Notes
PF027		Translocation	14.06.-31.12.2023	On animal
PM034		Resident	01.01.-31.12.2023	On animal

Table Lion Telemetry. Animals monitored by LEC during 2023.

ID	Name	Group	Collar active	Notes
LF026	Sarah	East Khutse	01.01.-31.12.2023	On animal
LF027	Nina	East Khutse	01.01.-13.09.2023	Animal died and collar was retrieved
LF041	Desi	Molose	01.01.-31.12.2023	On animal
LF060	Alice	Molose	01.01.-31.12.2023	On animal without functioning satellite communication
LF061	Alexa	Molose	13.01.-31.12.2023	On animal
LM085	Rocket	Snooks & Rocket	31.10.22-31.12.23	On animal
LM088	Athos	Dispersed males from East Khutse	01.01.-31.12.2023	On animal
LM103	Xlara	East Khutse	01.01.-05.10.2023	Collar dropped off as planned. Retrieved.

Abbreviations

ACACF	African Cats & Conservation Foundation	DTD	Daily Travel Distance
ACW	African Carnivore Wildbook	DWNP	Department of Wildlife and National Parks
AI	Artificial Intelligence	FMP	Formozov-Malyshev-Pereleshin
BSPCA	Botswana Society for the Prevention of Cruelty to Animals	GR	Game Reserve (as in Khutse GR)
BCF	Botswana Carnivore Forum	HWC	Human Wildlife Conflict
BIUST	Botswana International University of Science and Technology	KTP	Kgalagadi Transfrontier Park
BUAN	Botswana University of Agriculture and Natural Resources	LEC	Leopard Ecology & Conservation
CCC	Kaudwane Community Conservation Club	MPI-AB	Max Planck Institute for Animal Behaviour
C&E	Community & Education	NP	National Park
CKGR	Central Kalahari Game Reserve	PAC	Problem Animal Control
CREEM	Centre for Research into Ecological and Environmental Modelling	PTA	Parents Teachers Association
DFRR	Department of Forestry and Range Resources	SECR	Spatially Explicit Capture – Recapture
		SSG	Special Support Group
		VDC	Village Development Committee
		VIIRS	Visible Infrared Imaging Radiometer Suite
		WNCD	World Nature Conservation Day
		UZH	University of Zurich



Acknowledgements

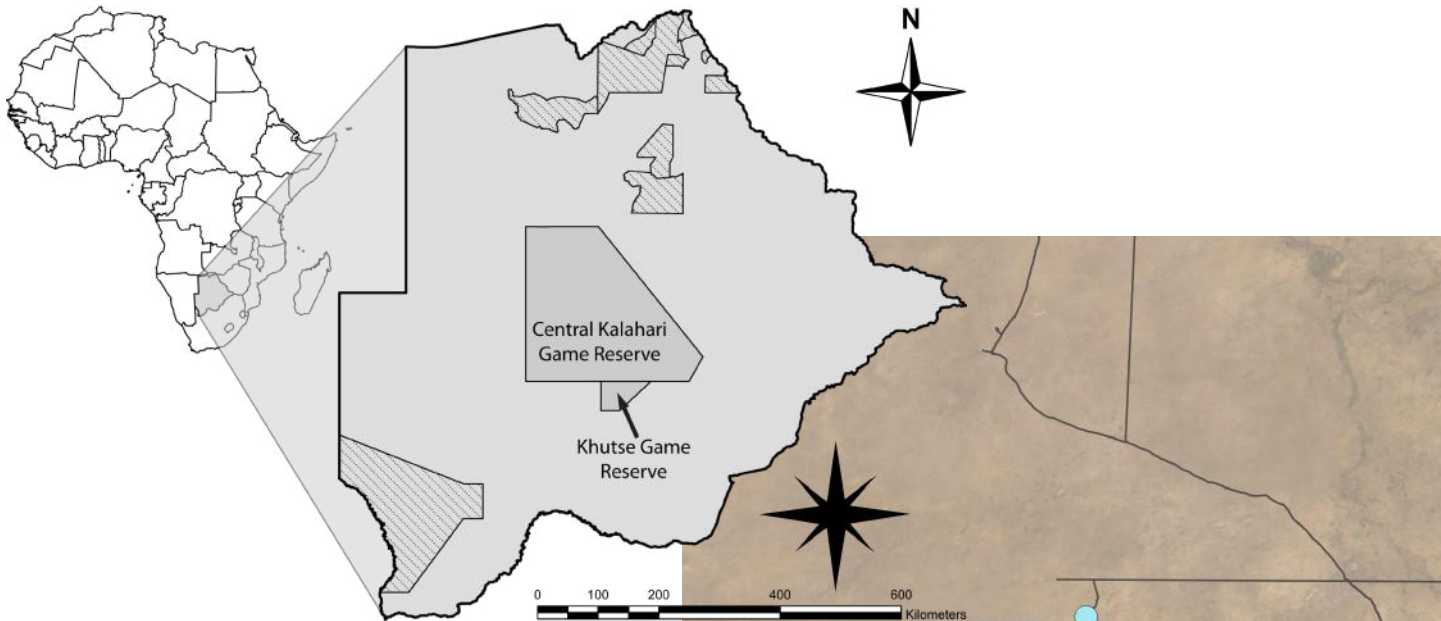
The Government of Botswana, through the Ministry of Environment, Natural Resources Conservation and Tourism and the Department of Wildlife and National Parks, has for over 20 years granted permission to Leopard Ecology & Conservation to undertake research and conservation projects. We appreciate the 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.

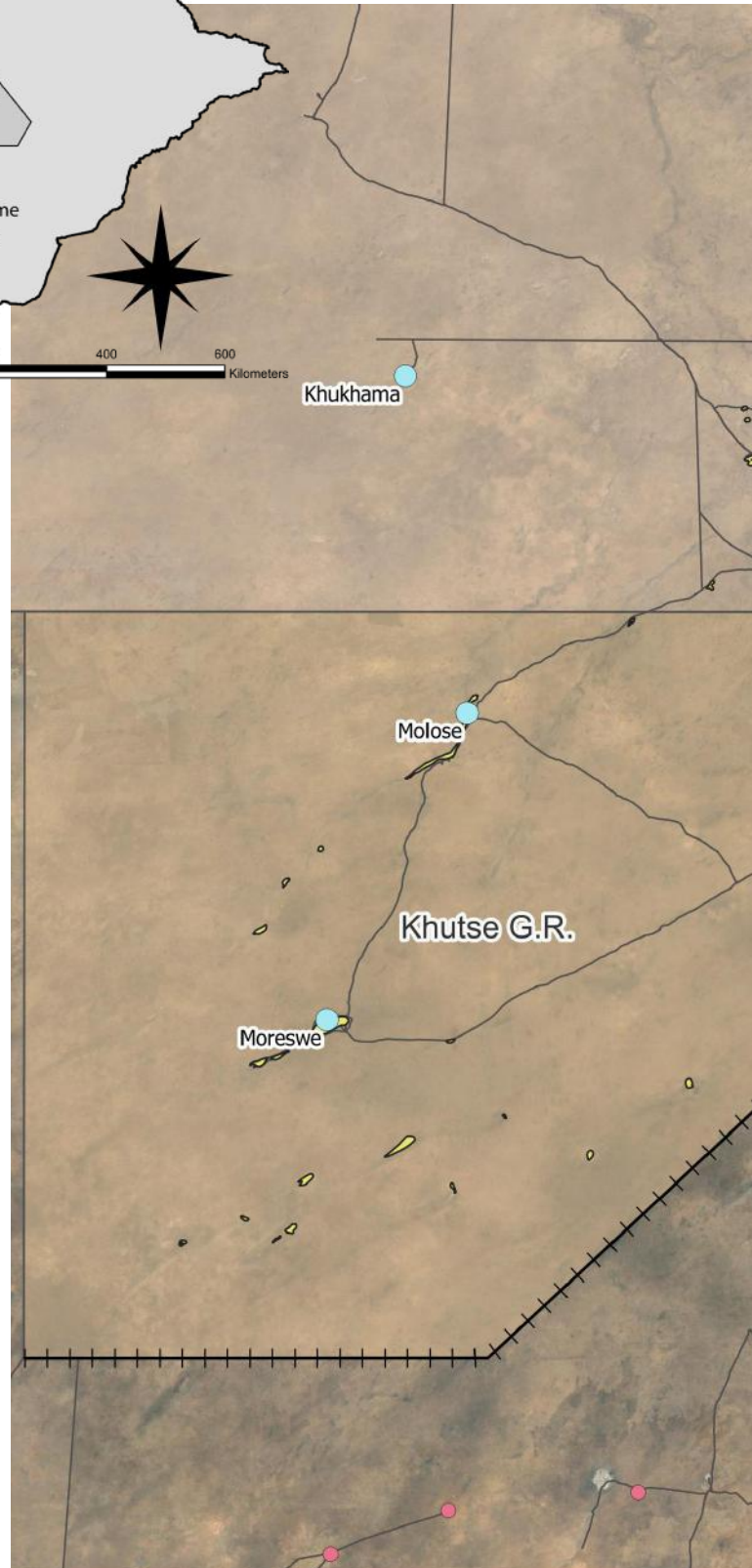
Climatically the area is semi-arid, with four seasonal variations in temperature and precipitation, primarily characterised by a hot and wet summer and a cool and dry winter.

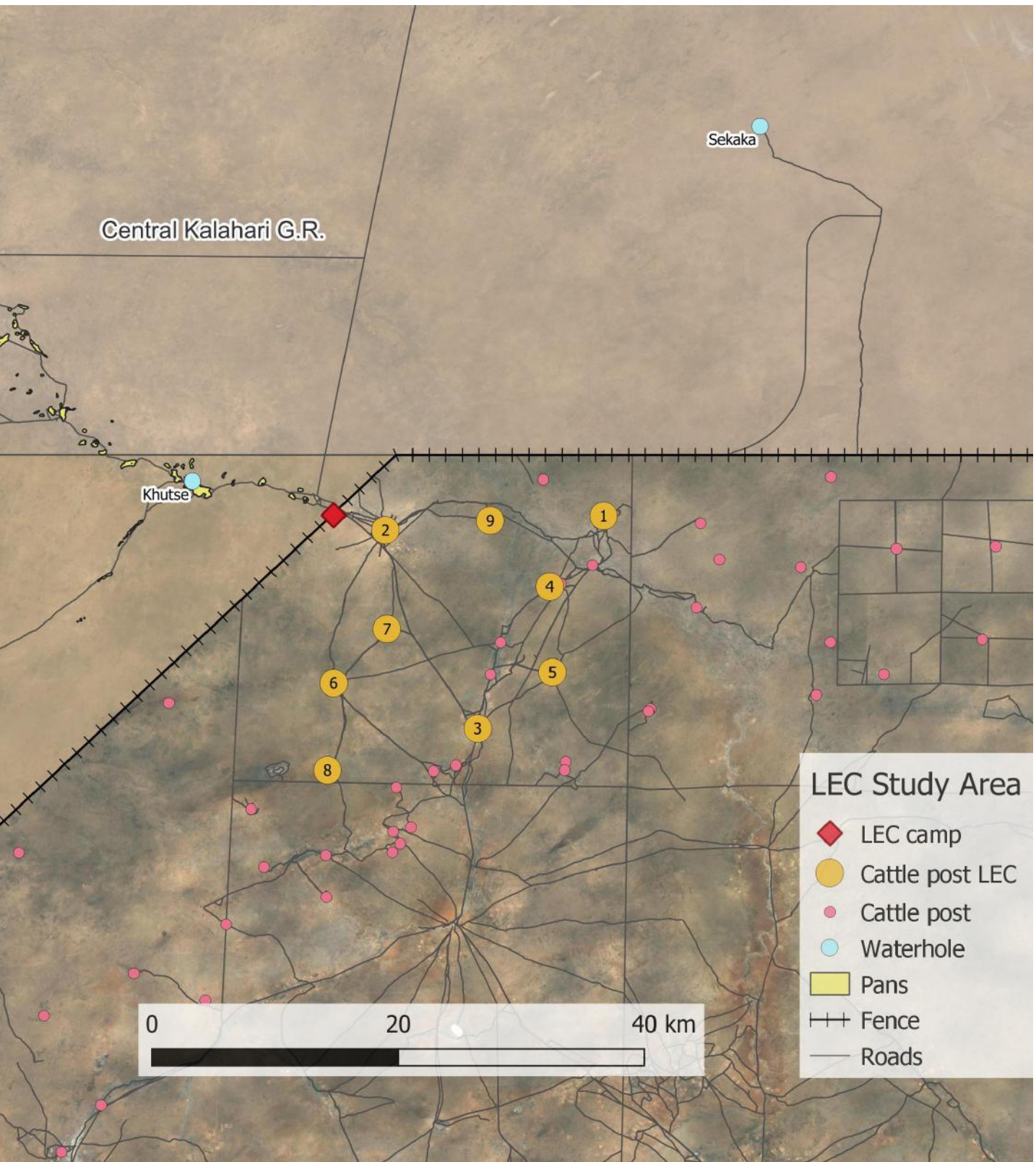
The predator populations here live at low density, with some of the largest ranges exhibited throughout their global distribution.

Surrounding the reserves is the communal land used by farmers 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 Mangadieie,
- 7 Moilwane, 8 Mokujwane, 9 Tshipidi





TEAM, COLLABORATIONS AND STUDENTS

LEC strongly believes in creating a tight network of researchers, communities, institutions and private stakeholders who collaborate to find solutions to scientific and conservation challenges. In 2023, we created new partnerships to grow alongside the long-term collaborations LEC has fostered across the years. We introduced the new collaboration with Marie-Charlotte Guilen from UCLouvain on large herbivore daily travel distance in our “Project in Focus”. The project success was possible due to the synergy between LEC tracker expertise and the analytical expertise of UCLouvain researchers. Thanks to this collaboration, MSc student Marie Jardeaux and LEC intern Seitshiro Pule not only collected important data for their academic career, but they gained the opportunity to exchange knowledge and experiences which enriched them deeply.

In the predation section, we reported that the fieldwork of our collaborative study on group lion hunting with the Max Planck Institute for Animal Behaviour (MPI-AB) has been completed and the project has moved to the analysis stage. We are pleased to report that this successful collaboration will continue, expanding to study other aspects of our lion population from 2024. Together with MPI-AB, we continued our exciting collaboration with WildTrack (www.wildtrack.org) to

develop an AI-based tool to individually identify lions and leopards from images of their tracks. We have now built up a solid foundation of reference prints to act as a training and test set for the models and are excited to see them develop into practical tools over the coming year.

In some cases, existing collaborations have evolved and changed, such as the beekeeping project in the Kaudwane community managed in association with Fondazione Zoom. In 2023, LEC and Fondazione Zoom invited BUAN (Botswana University of Agriculture and Natural Resources) to join the collaboration to further develop the research component of the project. Apiaries have been placed at three different sites (Village, Grazing Land, Reserve) and the honey produced at each apiary will be analysed to determine which plants are the main source of food for bees at each site. Simultaneously, Kagiso Mabu, one of the local beekeepers trained by the project, has become the new research assistant in charge of monitoring the flowering season and the species of the plants around the apiaries. Samples of flowers have been collected to create a pollen “library” for the local plant species, which is necessary for determining



which plants are important for bees by analysing their honey.

Other long-term collaborations are showing the results of the investments from the past years. CyberTracker workshops (www.cybertracker.org) and a strengthened collaboration with other researcher of the Botswana Carnivore Forum have generated opportunities for trackers around the country to meet, share knowledge and develop their skills.

In 2023, LEC was approached by several non-profit organizations interested in joining efforts and supporting our mission. To mention few examples, LEC has joined the EarthRanger (www.earthranger.com) community and can now benefit from a user-friendly interface to monitor and plan our activities. Conservation AI (www.conservationai.co.uk) and African Carnivore Wildbook (www.carnivore.wildbook.org) have assisted LEC with camera-trap image identification at species and individual levels. All our existing GPS collar data from lions and leopards are now stored on MoveBank (www.movebank.org) and researchers can contact us to create new collaborative studies. In most of these projects we are at the early stages, but we

have already seen major improvement and progress towards ensuring our valuable long-term data is maintained, preserved and set up to best support our efforts on-the-ground.

In the last quarter of 2023, LEC systematically approached local universities to establish long-term formal collaboration for new research projects and to offer opportunities for their students. This renewed energy to continue to develop our collaboration with local institutions has already produced a busy calendar of activities for 2024, including student attachments and collaborative studies from BUAN, course practical excursions from University of Botswana and MSc projects with BIUST (Botswana International University of Science and Technology).

Our own team also went through some changes in 2023. Dr. Stephanie Kalberer joined LEC as Co-Managing Director, Ms. Lebogang Rampepele as Accounts and Administration Officer, and Mr. Mphoeng Ofitlhile as C&E Programme Officer. Mr. Alfred Mosweu got promoted to C&E Coordinator, Kevin Ndove to Administration Assistant and Setshiro Pule to Local University Liaison Officer. Ms. Frances Hannah left and has been replaced by Mr. Isaac Muzila as Camp Manager. We welcome everybody new to the team and congratulate the others to the promotion.



APPENDIX II



The Leopard Ecology & Conservation Team

- Araldi, Alessandro, Field Research Coordinator, Italy
- Alessandrello, Vera Lucia, Msc Student and Intern, Switzerland
- Balone, Trevor, Research Assistant, Botswana
- Chepete, Donald, Groundskeeper, Botswana
- James Clark, Intern, 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, Moisaopodi, Tracker, Botswana
- Gielen, Marie-Charlotte, Research Advisor, Belgium
- Dr. Gusset, Nicole, Programme Management, Switzerland
- Haas, Fabian, Head of Community & Education Programme, Switzerland
- Hannah, Frances, Field Conservation Coordinator, SA
- Ithuteng, Goitseone, Camp Administrator, Botswana
- Ithuteng, Masente, Camp Maintenance and Mechanic Assistant, Botswana
- Ithuteng, Pogiso Africa, Field Research Assistant and Tracking Team Leader, Botswana
- Jardeaux, Marie, MSc student, Belgium
- Dr. Kalberer, Stephanie, Co-Managing Director, Switzerland
- Kegakilwe, Ditshupo, Housekeeping, Botswana
- Kegakilwe, Phana Segametsi, Administration and Operations Manager, Botswana
- Köpfler, Marianne, Administration, Switzerland
- 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
- Mosololo, Senxwai, Tracker, Botswana
- Mosweu, Kebaabetswe Alfred, Community & Education Programme Coordinator, Botswana

- Mporofu, Donald, Groundskeeper, Botswana
- Muzila, Isaac, Camp Manager, Botswana
- Nkadima, Phalatsa, Senior Tracker, Botswana
- Ndove, Kevin, Administration Assistant, Botswana
- Obotseng, Obakeng John, Education Liaison Officer, Botswana
- Ofithile, Mphoeng, Community & Education Programme Officer, Botswana
- 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
- Seganaphofu, Fire Xee, Tracker, Botswana
- Speedy-Dusty, Project Dog, Botswana
- Etna, Project Cat, Botswana
- Tshiana, Mpho, Tracker, Botswana
- Tshiana, Meno, Tracker, Botswana

The following people / institutions are involved

Research support and collaboration

- African Carnivore Wildbook, Vancouver, Canada
- Centre d'Ecologie Fonctionnelle et Evolutive- Centre National de la Recherche Scientifique (CEFE-CNRS), Montpellier, France
- Centre for Research into Ecological & Environmental Modelling, University of St. Andrews, UK
- Conservation AI, Liverpool, UK
- EarthRanger, Seattle, USA
- Max Planck Institute of Animal Behavior, Germany
- Université catholique de Louvain, Belgium
- WildCRU, University of Oxford, United Kingdom
- WildTrack, USA
- Dr. Borrego, Natalia, Lion Research Center, University of Minnesota, USA, and MPI-AB, Germany
- Garbeli, Jary, molecular genetic analysis, Institute of Evolutionary Biology and Environmental Studies, UZH, Switzerland
- Prof. em. König, Barbara, Department of Evolutionary Biology and Environmental Studies, UZH, Switzerland
- Kearney, CyberTracker, South Africa
- Louw, Adriaan, CyberTracker, South Africa

- Prof. Manser, Marta, Department of Evolutionary Biology and Environmental Studies, UZH, Switzerland
- Dr Morris, Gerrald, project veterinarian, Botswana
- Dr Neo-Mahapeleng, Gosiame, Wildlife Ecology lecturer, Botswana University of Agriculture and Natural Resources, Botswana
- Prof. Packer, Craig, Lion Research Center, University of Minnesota, USA
- Roggia, Yari, Fondazione Zoom, Turin, Italy
- Prof. em. Zucchini, Walter, Department of Economic Sciences, Georg August University Göttingen, Germany

Support in Botswana (permits, information and logistics)

- Department of Forestry and Range Resources, Letlhakeng
- Department of Research, DWNP
- Department of Veterinary Services, Letlhakeng
- Minister of Environment, Natural Resources Conservation and Tourism
- Special Support Group (SSG), Khutse Base Camp
- Dr. Dikolobe, Mmolotsi, Veterinary Officer
- Dr Flyman, Michael, Food and Agriculture Organisation
- Mrs Munyadzwe, Mercy, Regional Wildlife Officer Molepolole
- Dr. Nkgowe, Comfort, Veterinary officer, DWNP
- Sekhute, Stephen, Park Manager, Khutse GR
- Dr Senyatso, Kabelo Jacob, Director, DWNP

Professional, logistical and material support

- Aegersold Digitaldruck, Switzerland
- Albrecht Druck, Switzerland
- BGS-Architekten, Switzerland
- Feusi Optik AG, Switzerland
- Fly Away Reiseerlebnisse GmbH, Germany
- Hilti, Switzerland
- Holzinger, Rosmarie, Switzerland
- LC Lenz Caemmerer, Switzerland
- Lobatse Canvas, Botswana
- Lüthi, Sabine, Switzerland
- 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
- Wehrli-Oehler Hannelore & Bernhard, Switzerland
- 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
- Kweneng Land Board Secretary, Botswana
- LEC, Education Programme Officer, 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, Workshops & Media

- Alessandrello, V.L., A Second Chance? Movement Pattern of Resident versus Translocated Leopards (*Panthera pardus*) in Botswana – Global Leopard Conference (2023)
- Balone, T., attended the Kalahari field course: becoming a (field) biologist. Kuruman River Reserve (Kalahari Meerkat Project), Southern Kalahari, Northern Cape, South Africa.
- Finerty, G. E., Cushman, S.A., Bauer, D.T, et al. (2023) Evaluating connectivity models for conservation: Insights from African lion dispersal patterns. *Landsc. Ecol.* 38, 3205–3219
- Pule, S. & Mosweu, A., attended the National Human Wildlife Pitso 2023: Exploring innovative ways to manage the human wildlife interface to sustain livelihoods.
- CyberTracker Workshop in Khutse GR done by Andrew Kearny and Adriaan Louw (CyberTracker Assessors), November 2023.
- Intercultural Communications Workshop in Khutse by Craig Hartley, August 2023.
- Strategy Workshop in Zurich by Sabine Lüthi, June 2023.
- Track-based approaches to monitor wildlife for DWNP. A workshop provided by LEC and Marie Charlotte Gielen in collaboration with WildCRU.

Collaborating Institutions from Botswana in 2023

- BirdLife Botswana
- Botswana Carnivore Forum BCF
- Botswana International University of Science and Technology (BIUST)
- Botswana Society for the Prevention of Cruelty to Animals (BSPCA)
- Botswana University of Agriculture and Natural Resources (BUAN)
- Cheetah Conservation Botswana
- Community of Kaudwane
- Community Conservation Club, Kaudwane
- Department of Wildlife and National Parks
- Department of Forestry and Range Resources
- Farriers, Mr. Siku & Mr. Tibi
- Kalahari Research and Conservation
- Kaudwane Primary School
- Kuanghoo Community Trust
- Letlhakeng Sub-District Council
- Okavango Research Institute, Botswana
- Okavango Air Rescue, Botswana
- Village Extension Team and Village Development Committee (Kaudwane)

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- Cécile Mode, Switzerland
- DeZeew, Elisabeth, Switzerland
- Devilliers, Lindy, Botswana
- Dürst, Jeanette, Switzerland
- Egger, Sandra, Switzerland
- Department of Evolutionary Biology and Environmental Studies, UZH, Switzerland
- Fliedner, Monika, Switzerland
- Fraser, Jill, Botswana
- Fly Away, Germany
- Furrer, Marie-Theres, Switzerland
- FS Communication, Switzerland
- Gantner, Fiona, Switzerland
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- Humbel, Juliette und Tonio, Switzerland
- Interbit AG, Basel, Switzerland
- Jackson, Lalage, Botswana
- Jäggi, Monika, Switzerland
- König, Barbara, Switzerland
- Kupferschmied, Basil, Switzerland
- Lechner-Laur, Sophie, Switzerland
- Libert, Francoise, France
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- Meister, Claudia, Switzerland
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