Leopard Ecology & Conservation

Khutse Game Reserve

Annual Report 2019

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Acknowledgements

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BUAN	Botswana University of Agriculture and Natural Resouces
CREEM	Centre for Research into Ecological and Environmental Modelling
CKGR	Central Kalahari Game Reserve
DWNP	Department of Wildlife and National Parks, Botswana
GR	Game Reserve (as in Khutse GR)
HTC	Herder Training Course
LEC	Leopard Ecology & Conservation
MEWT	Ministry of Environment, Natural Resources Conservation and Tourism
NP	National Park
PA	Protected Area
UZH	University of Zurich

BACKGROUND

LEC has been conducting research and community projects within the Central Kalahari region of Botswana since 2000. The overarching goal is "to make a meaningful contribution towards the long-term conservation of large felid predators as key components of a healthy, functioning ecosystem in Botswana". This requires an understanding of the status and habitat needs of leopards and lions both within and outside conservation areas, as well as the development of appropriate and effective strategies to address the threats they face, such as human–predator conflict.

The Central Kalahari region is a unique and dynamic environment. Rainfall is the primary driver of variability in the ecosystem, and this fluctuates significantly from year to year as well as over longer time periods and spatially across the ecosystem. But there are many other factors which impact on the ecosystem, including pressure from a growing human footprint, as well as disease, fire and the emergence or loss of key species. Factors like these can have an impact on the ecosystem across all trophic levels, and particularly on the predators at the top of the trophic pyramid.

The Central Kalahari region is increasingly recognized as an area of international conservation significance for large predators. LEC with its long-term project in this area is in a position to play a critical role in the research and conservation of large predators at an international level. This is reflected in LEC's monitoring and research activities which range from rainfall and temperature data collection to ungulate demographics and predator behaviour. It is LEC's aim to understand all aspects of the ecosystem that impact on leopard and lion and use this data for informed management strategies and interventions to ensure their long-term survival in the region.

From a research perspective, 2019 was a challenging year with the repeated failure of GPS collars on lions, the loss of the only collared leopard to a human-wildlife conflict event, and several unsuccessful attempts to capture and collar leopards. However, 2019 has also been a year of changes and development, starting with the retirement of our long-standing research coordinator and with the appointment of a new management team. As such, a significant proportion of the second half of the year was used to familiarize the team, but also to rethink and further develop existing research methodologies.

We have also taken the opportunity to reflect on where the project is now and develop an updated 5-year workplan to be implemented from 2020. This workplan is largely focused on further increasing the value of our research and community work

and enabling LEC to have greater conservation impact. A significant part of this 5-year plan involves investigating the possibility of some exciting new collaborations, including with Snapshot Safari and the University of Minnesota Lion Center, to deliver a large-scale camera trapping project, and with the Centre for Research into Ecological and Environmental Modelling, at the University of St Andrews, who are offering their students to undertake statistical analysis of LEC research data as part of their degree coursework.

In the Community & Education Programme, LEC continued to work closely with the Community Conservation Club on many activities and events throughout the year, for example one project is developing low cost solar cookers. The Community & Education team are also currently working with the Maun Animal Welfare Society to deliver a dog vaccination and neutering programme for 2020. An activity focused on supporting an understanding of the importance of animal welfare.

Possibly the biggest achievement of the year for the Community & Education team however has been the development of their herder training programme. This programme, which is being delivered in partnership with the BUAN, has been designed to build capacity within the farming community so that farmers and herders become effective managers of all available resources in their area. A pilot training programme was delivered in 2019, with great success and positive engagement from the community. LEC has now applied for accreditation for the course so that it can be rolled out to the entire study area in 2020. As part of this programme, LEC will be conducting pre- and post-training surveys in order to evaluate the impact.

We are looking forward to the coming year during which LEC will be celebrating its 20 years anniversary. A good time to look back on everything we have accomplished. But also, the time to step into the future with new projects.

Elephants at Khutse Gate. (Photo: Pogiso Ithuteng)

RESEARCH PROGRAMME

Predator Habitat Monitoring

Weather

LEC recorded 279 mm of rainfall in camp during the 2018–2019 austral year (July–June), substantially less than the average annual rainfall recorded at the same location between July 2002 and June 2018 (410 mm). It has been proposed that rainfall in savanna regions of southern Africa follows an 18-year quazi-cycle, with a nine year period of typically above average rainfall followed by a period of typically below average rainfall (*Tyson, P.D. 1986. Climatic change and variability in southern Africa, Oxford University Press. Cape Town, 220 pp*.) and that the El Niño–Southern Oscillation, which exerts a strong influence on weather in southern and eastern Africa follows a similar 18-year interdecadal oscillation (*Mason, S.J. & Jury, M.R. 1997. Climatic variability and change over southern Africa: a reflection on underlying processes. Progr. Phys. Geogr. 21:23–50*.). LEC's rainfall data (Fig. R1) show that in the period 2005–2006 to 2013–2014, seven of the nine years received more than 500 mm. In the period before (2001–2002 to 2004–2005) and after (2014–2015 to 2018–2019), seven of the nine years received less than 300 mm.

The mid-summer period, December–February, accounted for 85% of the rainfall recorded in 2018–2019 (Fig. R2). Furthermore, 73 of the 88 mm recorded in December fell in the last three days of that month. Similarly, 87 of the 88 mm recorded in February fell within the first two weeks of that month. Consequently, 80% of the rainfall recorded in 2018–2019 fell in the seven-week period from the 29th December 2018 to the 15th February 2019. This represents a short and intense wet season, even by local standards (Table R1).

The rain gauges at Moreswe Pan, Molose Pan and Khanke junction were removed due to excessive damage by elephants. Rain gauges were retained at the fixed-point photo locations F1, B2 and G2. An additional rain gauge was set up adjacent to Khutse 1 Pan in January 2019. Elephants disturbed the rain gauges at Moreswe (F1) and Molose (B2) in December 2018 and April 2019 respectively.

Rainfall across the study area followed a similar pattern to that observed in camp, namely a short wet season comprising the months December, January and February (Figure R3).

Rainfall has a direct impact on the availability of drinking water for predators. However,
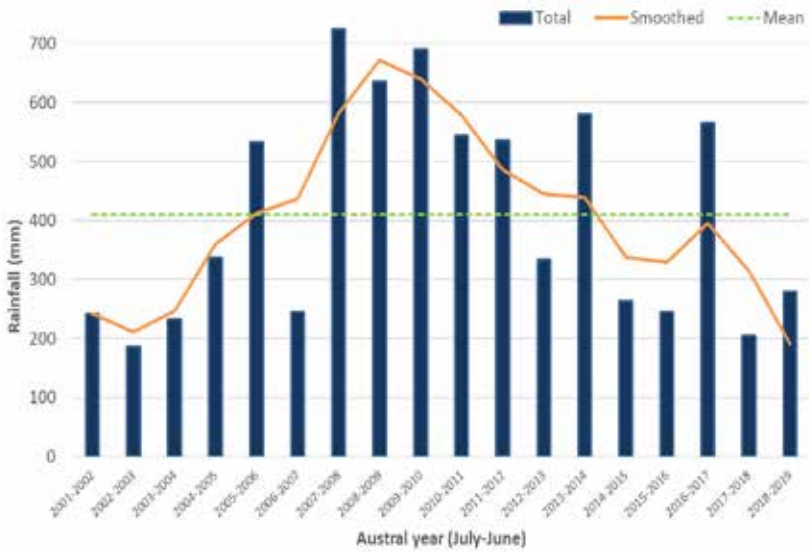
Figure R1. Annual rainfall recorded at the LEC research station (histogram). To highlight the trend within variable rainfall data these were smoothed (line) using a three point weighted interpolation where annual rainfall (R) is the product of the current year's rainfall (R0) as well as the previous and following year's values (R-1 and R+1 respectively)(R = 0.25xR-1 + 0.5xR0 + 0.25xR+1).
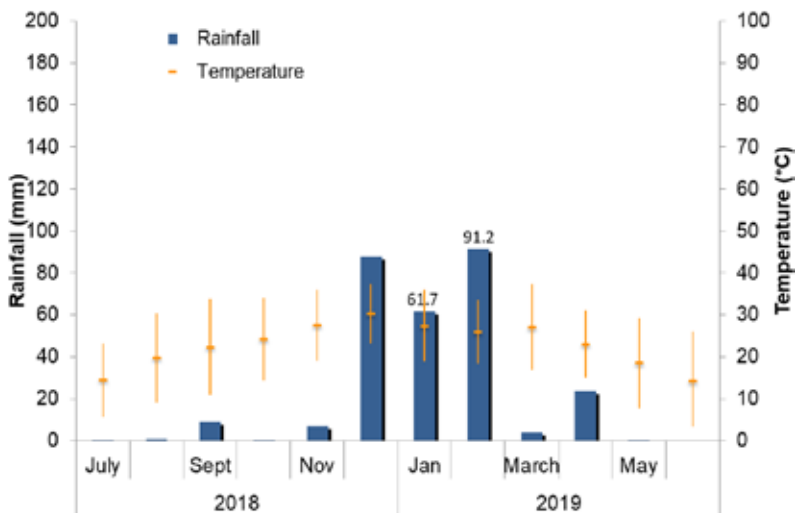
Figure R2. Monthly temperature and rainfall as recorded at the LEC research camp, Khutse GR, for the 2018–2019 seasonal year. The average median daily temperature is shown as a point, with the average daily minimum and maximums as bars.
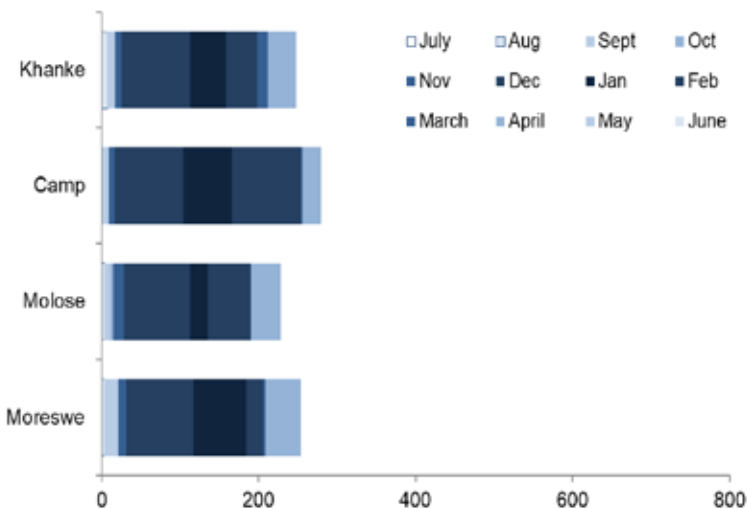
Figure R3. Accumulative monthly rainfall recorded at stations within the LEC study area between July 2018 and June 2019. Elephants disturbed rain gauge F1 in December 2018 and B2 in April 2019; values for these months were estimated as the weighted average of the remaining three gauges, with the nearest gauge having twice the impact of the other two.

Table R1. Monthly rainfall (mm) as recorded at the LEC research camp, Khutse GR from July 2018 to December 2019. Mean monthly rainfall is derived from data collected at camp between February 2001 and June 2019 (n = number of years included).

| year	J	A	S	O	N	D	J	F	M	A	M	J
2018–2019	0.0	0.0	9.0	0.5	7.1	87.7	61.7	88.0	1.6	23.7	0.0	0.0
2019–2020	0.0	0.0	0.0	0.0	56.5	98.2						
mean	1.4	1.0	3.5	25.0	50.9	78.0	93.3	89.1	56.3	41.3	9.9	8.6
n	14	13	13	15	17	16	16	18	18	17	14	13
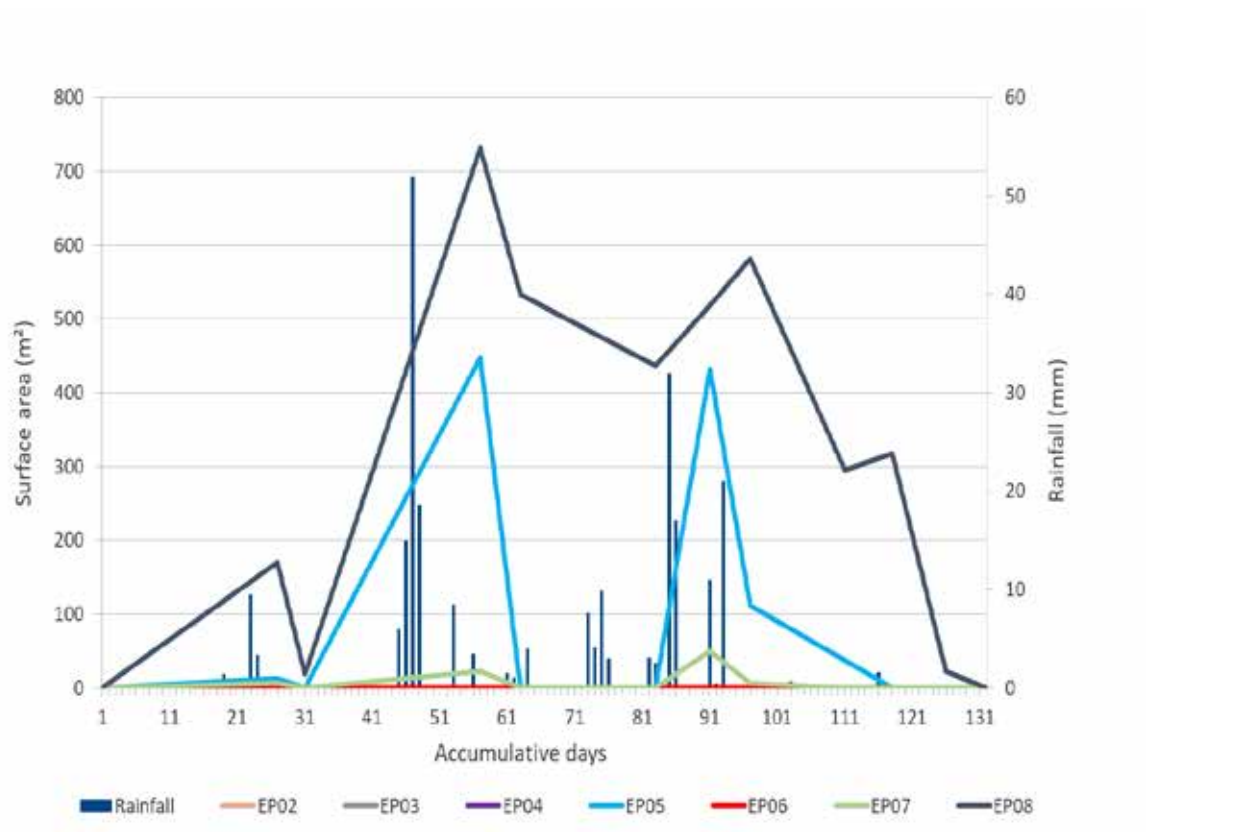
Figure R4. The relationship between natural pan surface water and rainfall on Khutse 1 between the 15th November 2018 and the 26th March 2019. The area of surface water was calculated as the ellipsoidal area derived from the longest length and greatest perpendicular length of water. Daily rainfall was measured the LEC research camp.

Table R2. The potential size of monitored natural pans. Size is the GPS measured area of unvegetated ground.

	EP02	EP03	EP04	EP05	EP06	EP07	EP08
area (m²)	912	598	869	1894	263	17	628

Tender blossom in Khutse.
(Photo: Monika Schiess-Meier)

this impact of rainfall on the accumulation of surface water and its persistence over time is influenced by other environmental conditions such as soil type (i.e. percolation), catchment area, topography (pan depth) and preceding rainfall (i.e. soil saturation and run-off). In an attempt to understand the relationship between rainfall and available drinking water within our study area we monitored the surface area of water in seven natural pans of different size (range: 17 to 1894 m²) from mid-November 2018 to the end of March 2019, the principle 2018–2019 rainfall period (q.v. Fig. R2 and Table R1). To minimize the influence of the other environmental variables, all pans were located on Khutse 1, consequently they have comparable soil conditions and catchment, and were subject to the same rainfall regime. The potential size of each pan was taken to be the area of unvegetated ground (Table R2). The relationship between rainfall and the area of surface water for each monitored pan is shown in Fig. R4. The data suggest that potential area (bare ground) is an imprecise predictor of surface water area or persistence. However, as expected pans with a large surface water area persist longer than smaller pans. Smaller pans are more episodic in nature. Anecdotal reports suggest that EP08 on Khutse 1 is the second most important natural pan within our immediate study area, with Motailane being the largest and most persistent.

Kalahari rainfall is most frequently a consequence of localized convection air flow rather than extensive frontal systems, and as such is patchy in space and time. Reliable rainfall data across the study area cannot be gathered directly at a spatio-temporal resolution consistent with the leopard and lion telemetry data. Consequently Prof. Dr Zucchini investigated the value of the CHIRPS (see also page 10) satellite-derived rainfall data within our study area for the period 2008 to 2018. He concluded that while potentially an enormous advance over the limited rain gauge data, the accuracy of the CHIRPS data is of concern, at least if one wishes to use daily measurements. Monthly totals are more accurate but, ideally, they should be calibrated using ground-based rainfall gauges. An internal LEC report (Estimating daily precipitation over the LEC Khutse study area using CHIRPS data; March 2019) describes his study in greater detail.

Telemetry collars include a temperature logger. This records the temperature within the collar where it sits above the neck of the study animal. Using available Vectronic collars and the Davis weather station, Prof. Dr Zucchini compared the values from collars

Springbok in Khutse.
(Photo: Monika Schiess-Meier)

with the ambient temperature in camp. He found that the collars were slower to respond to change in temperature. On average, the collar thermometers recorded a higher temperature than the Davies weather station, especially at low temperatures. When collar thermometers were fitted to an animal the discrepancy in recorded temperature was much larger than when the collars were tested in camp. A possible explanation for the higher temperature is that the protective case may have an effect on how quickly the sensor responds to changes in temperature and that the body temperature of the animal may buffer the recorded temperature especially at lower temperatures. The heat produced by the body would justify the higher discrepancy at low temperatures. Further analysis could test the minimum recorded temperatures instead of the mean, we would expect to observe an even higher discrepancy. The large discrepancies between the temperatures recorded on (attached) lion and leopard collars and the ambient temperature cannot be accounted for by a systematic bias in the collars or in the Davis thermometers. Therefore, the temperature data from collars cannot be used as reliable reflection of environmental temperature. Nevertheless, the data can still be used to highlights trends in temperatures which are important to understand the behaviour

and energetic needs of the individuals. The detailed results of this study were written in a report entitled "Comparison of ambient temperature to the temperature recorded on lion and leopard collars" (March 2019).

Vegetation

Fixed-point photographs were taken each month at five savanna locations (A1, A2, B2, F1 and G2) and the five pans (Khanke, Khutse 1, Mahurushele, Molose and Moreswe). These provide a record of the changes in vegetation phenology and horizontal density over time. A portion of this long-term dataset has been used by Caroline Buettner as ground-truthing data for satellite image analysis (see research box page 10).

Vegetation has been heavily affected by the extended presence of elephants, especially in the Molose area, as explained in the following section.

Prey

Following the completion of the extensive prey count in October 2018, it was decided not to repeat the intensive spoor and prey survey

Hartebeest. (Photo: Alessandro Araldi)

but to rather focus our effort and resources on leopard and lion collaring.

Between the 20th and the 24th July, DWNP released 72 elands in proximity of Khutse 1 pan and close to the lower cutline. The eland moved across Khutse GR and CKGR reaching Moreswe in the south and Gukgama waterhole in the north. The largest observed herd was of 15 individuals. The individuals released included adult males and adult females; the sex ratio was not communicated.

For the third consecutive year elephants remained within the PA throughout the dry season. The impact of these ecosystem engineers is currently most visible around the artificial water points. The woody vegetation that previously enclosed Molose has largely been removed. The water pipes at both Molose and Morewse water points had to be replaced in February after elephants dug them up. By early April elephants had dug up the pipe at Moreswe, once again. The Molose pipe was dug up once again in June and in December

the elephants completely destroyed the solar water pump at Molose. The December rains partially filled the concrete basins at Molose but water availability is very scarce in the area and elephants seem to be moving north. The elephants' presence at the waterholes and their effect on the vegetation is heavily impacting several species which are potential prey for lions and leopards. Browsers, like kudus, may be suffering from the systematic destruction of trees and bushes. They are also directly impacting predator access to waterholes and we have observed them chasing away lions from their kills. Elephants are opening large paths through the vegetation to reach Moreswe and Molose, and many other animals started to use these paths preferentially. In addition to the direct impact elephant activity is having on the vegetation and access to water, it is likely that they might be influencing movement choices and habitat use of our focal animals, lion and leopards, as well as the prey they depend upon. It is therefore something we believe will be important to understand and quantify moving forwards.

Research Box:
Movement Patterns and Use of Space and Vegetation

This study used LEC's long-term animal movement dataset to analyse the Kalahari habitat and the behaviour of wild lions and leopards regarding their space use, movement patterns, and vegetation use. To characterise the habitat over the seasons, remote sensing data from the Google Earth Engine were used. Extensive data on daily precipitation and 3-hourly temperature values of the sparsely monitored area were obtained from Climate Hazards group Infrared Precipitation with Stations (CHIRPS) by Funk et al. 2015 and the Global Land Data Assimilation System (GLDAS) from the National Aeronautics and Space Administration (NASA). Furthermore, Modis images were used to derive the Normalized Difference Vegetation Index (NDVI) as a vegetation condition measurement, and the Vegetation Morphology Map by Mishra et al. 2015 provided information about the vegetation density. Long-term GPS data on free-ranging lions and leopards were provided by LEC.

Habitat Analysis

The results showed that the Kalahari habitat experienced seasonal changes, but also revealed spatial heterogeneity among dryer or sparser vegetated areas. Temperature and rain did vary over a year, but the wet seasons from 2011/2012, 2012/2013 and 2014/2015, 2015/2016 could be identified as comparably dry years. In spatial terms, the precipitation was not homogenous. The Khutse GR received more rainfall than most parts of the southern CKGR. On average, the NDVI was relatively homogenous between 2011 and 2017. Only when examined on a yearly basis it becomes clear that in the dryer years 2012/2013 and 2015/2016, multiple patches with low vegetation indices occurred, often in the CKGR but not exclusively. This might lead to yearly differences in the spatial use of KGR and the southern CKGR by herbivores and could therefore change prey availability for resident lions and leopards.

Behavioural Analysis

Both lions and leopards showed seasonal and sex-specific differences in the size of their space use, daily distances covered, and the selection of specific vegetation types. Kalahari lions and leopards roamed over very large areas (average 7821 km² for lions and 3709 km² for leopards) but reduced their space use during the hot, wet seasons. The daily distances of lions and leopards were affected by sex, identity (ID), and in part by NDVI. In both species, males walked longer daily distances than females, and some individuals were observed to walk generally longer daily distances. The NDVI had little effect on the movement patterns of these two cat species. However, maximum daily temperature had a highly negative effect on the distance walked per day, especially during the wet seasons. The vegetation use of predators mostly corresponded to that available according to NDVI characteristics. During the wet seasons, however, leopards and male lions appeared to more frequently use lower NDVI areas, which other studies have reported as foraging hotspots for small and medium herbivores that need high quality food. However, denser vegetation was more frequently used by leopards.
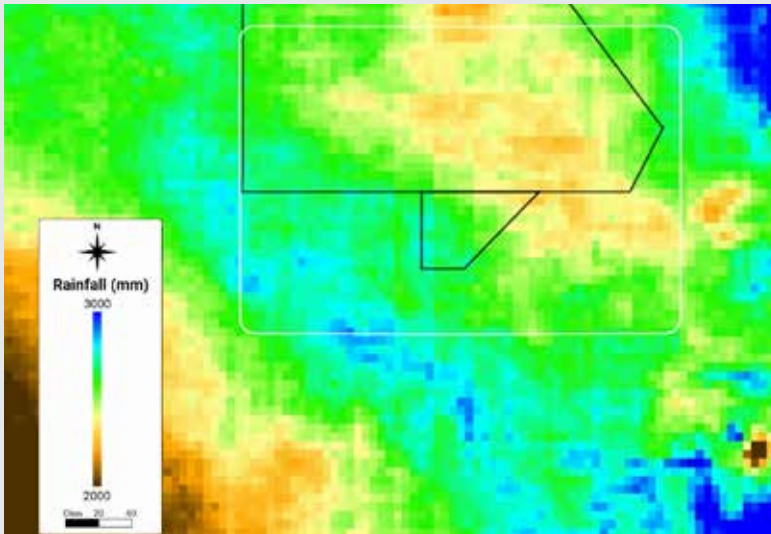
Map. Spatial precipitation sum from 2011–2017. (Study area: white border, GR: black borders)
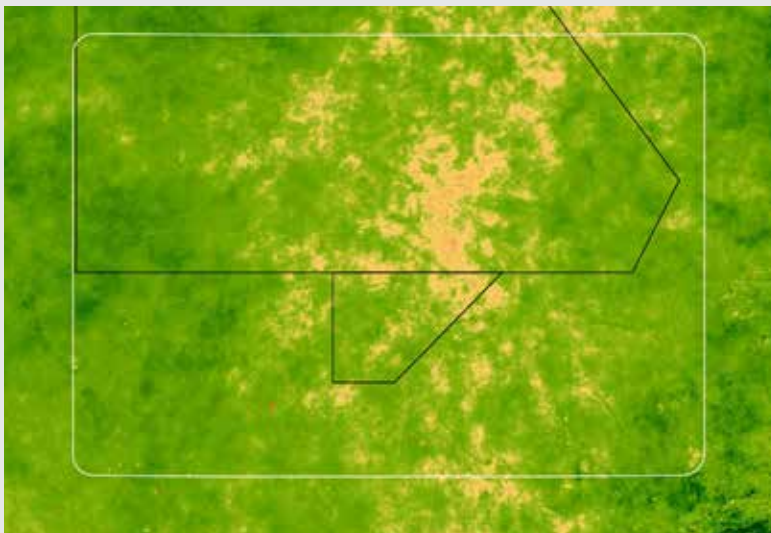
Map. Spatial NDVI mean for 2016.
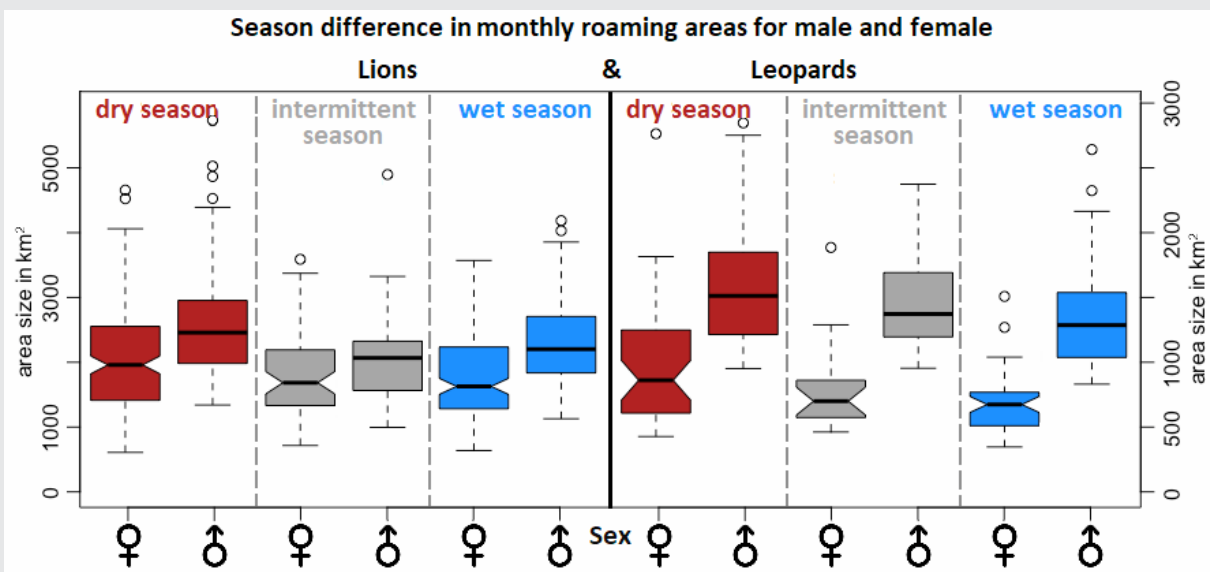
Boxplot. Seasonal comparison of the mean roaming area size.

Release of male leopard.
(Photo: Monika Schiess-Meier)

Leopard Research

Study Animals – Leopard

During 2019, we only had one leopard with a GPS-collar. Despite repeated efforts to capture and collar additional study animals throughout the year, we were not successful. In order to improve our chances, we decided in November to assign a tracking team to focus exclusively on leopards. The initial results are promising as we have already tracked three individuals (two males and one female) consistently in the same areas. Fresh baits have been placed in strategic locations and camera-trap images have confirmed that one male in particular is returning to the bait frequently. Due to administrative constraints and availability of veterinarians, it was not possible to collar any leopards in the latter part of the year. Efforts will resume in early 2020. (Appendix I, Table 1).

Tsholofelo (PF021): Tsholofelo was an adult female leopard translocated to Khutse GR on the 26th February 2018. She soon left the PA to establish her home-range in the communal grazing land outside the south-eastern corner of CKGR. During 2019, she had been stable in the area without causing conflict with local farmers and the last observation we had of her, on the 8th September, confirmed that she had one or more young cubs. On the

10th September she was killed by farmers from X/aabeka Cattle Post, after she depredated a one-day-old calf, which had been born far from the protection of the kraal. The location of the cubs at the time was unknown, it is unlikely that they will have survived long as they were very young and dependent on their mother.

Translocated leopards
- On the 11th February, the DWNP office in Machaneng informed LEC that they were planning on translocating a captured leopard. The next day LEC members met with DWNP at the Regional Office in Molepolole where a young adult female was immobilized and fitted with a collar. Unfortunately, she never recovered from the immobilization and died later that evening.
- On the 31st August, another leopard was translocated to Khutse GR in 2019, as part of DWNP's human-predator conflict mitigation strategy. A male leopard, from the Sokoma area, was released at the Molose water hole with our assistance. LEC was not informed prior to the arrival of this animal and so we were not able to fit a collar. Photographs were taken for future identification and hair samples were collected from the cage for genetic analysis. Subsequently, tracks of a male leopard

Male leopard at cage trap. (Photo: LEC Camera Trap)

have been found in the area on several occasions, but it has not been possible to determine if it was the same male released in August.

In an area such as the Khutse GR where direct observation is challenging, tracks are often the only sign of animal presence. In the future, we will be leveraging the power of new analytic techniques to explore methodology to help us to identify individuals from these tracks to help us better monitor the predator populations.

Leopard Demographics

The results of the extended spoor survey from 2018 showed a clear reduction in the leopard spoor density inside Khutse GR, especially compared to the surveys in 2001 and 2009 (see also research box, page 22). This trend is consistent for both of our study predators and determining the cause is a clear priority for future research for LEC. Using the frequency of spoor recorded on roads to estimate population densities has the limitation that a reduction in spoor could be due to a net reduction in the leopard population size or the consequence of variation in the movement behaviour of leopards in response to roads in Khutse GR. It also means inference is limited

to areas well represented by a road network. To establish reliable data on the leopard population across the whole study area, LEC is designing a new camera-trap survey. This has two major benefits, firstly that we will be able to validate the trends from the spoor data, and secondly that the estimates provided will not confounded by the selection of features such as roads by our study area.

Leopard Predation

Due to the lack of collared leopards inside the PA, data on leopard predation of wild prey are almost non-existent. The only confirmed predation is on an adult male kudu killed on the 12th November by a male leo-ard observed in the area between Gope road and the upper cutline. On the 8th February, Tsholofelo killed an adult female aardwolf in the grazing land outside the PA. No other predation of wildlife by leopards were recorded.

Data collected at cattle posts by LEC confirm that leopard in the study area predate small- and medium-size livestock. In 2019, there have not been any predation from leopards on livestock larger than young calves (Table R3). From our recent MSc study by Tshepho Tsito we have seen that leopards are one of the largest reported contributors to livestock losses over

Elands. (Photo: Pogiso Ithuteng)

the past years. Understanding the pressure on leopards outside the park that link with regards to selection of wild prey vs livestock is another future avenue we wish to explore.

Table R3. Livestock predation by leopards at cattle posts.

Species	Total	Adult	Sub-adult	Juvenile
Cattle (*Bos taurus*)	6			6
Horse (*Equus ferus*)	1			1
Goat (*Capra aegagrus*)	5	5		
Donkey (*Equus asinus*)	2			2

Table R4. Predations by lions in LEC study area. (A=adult; see pages 18 and 19)

Species	Total	A male	A female	A, sex unknown	Sub-adult	Juvenile
Aardvark (*Orycteropus afer*)	5	2	1	1	1	
Blue wildebeest (*Connochaetes taurinus*)	9	2	6		1	
Cattle (*Bos taurus*)	11	3	5		3	
Donkey (*Equus asinus*)	2	1			1	
Eland (*Taurotragus oryx*)	28	6	9		13	
Gemsbok (*Oryx gazella*)	25	11	6		6	2
Giraffe (*Giraffa camelopardalis*)	6	1	2		2	1
Horse (*Equus ferus*)	2	1	1			
Kudu (*Tragelaphus scriptus*)	4	3		1		
Ostrich (*Struthio camelus*)	4	1			3	
Red Hartebeest (*Alcelaphus buselaphus*)	6	2	3	1		
Springbok (*Antidorcas marsupialis*)	1		1			
Warthog (*Phacochoerus africanus*)	2	1	1			

Notch with her cub. (Photo: Alessandro Araldi)

Lion Research

Study Animals – Lion

In 2019, a total of 246 data records for individual lions have been collected, not including records of juveniles younger than 6 months. Of these 246 records, 109 were observations of collared lions. The sampling effort for direct sightings of lions has notably increased from the previous year when the total records were 145 (42 collared lions).

The Molose pride, of which Inca was the only adult female with a collar in 2018, has fragmented even further in 2019, and following her death in January, LEC could no longer monitor this group intensively. To solve the situation, in July, LEC collared Alice, an adult female originally from a litter of the Molose pride.

East Khutse pride members fissioned for an extended period at the beginning of 2019, but the pride coalesced again around Khutse 1 waterhole towards the end of the dry season (October–November). An additional female (Nina) was collared to better monitor the pride after the temporary shift north of Notch (LF018) in the first half of the year. The pride males are Snooks and his coalition partner Rocket. This coalition seem to have established a territory that covers most of Khutse GR reaching as far as Molose pan in the west. In the south-west section of Khutse GR, another coalition of two young males, Aaron and Moses, seem to be establishing a territory in the same area used by Princess Fiona and her three cubs. Peanut has been ranging in the area between Sekaka waterhole and Gope mine. The presence of adult females with him during the last few observations suggests that he may be in the process of settlement to become pride male in the area.

In 2019, four lion collars failed as the drop-off system triggered prematurely, impacting our telemetry data extensively. The collar provider is busy determining the causes. (Appendix I, Table 2).

Princess Fiona (LF009): Princess Fiona is a lioness who was first observed in May 2009, and collared in April 2011 for the first time. Unfortunately, due to malfunctioning drop-off systems, she lost two collars in 2019. The first collar was fitted in August 2018 and we recovered it on the 7th June 2019 due to an early triggering of the drop-off system. After an extensive search, we were able to capture and re-collar Princess Fiona on the 5th November, but the drop-off failed again and she lost the collar on the 29th November. When we were able to obtain visuals of her during the year,

Handling immobilised Alice. (Photo: Pogiso Ithuteng)

she was moving with her three cubs in her traditional territory in the south-west. The cubs were born in April 2018 and they were observed to be in optimal condition.

Notch (LF018): Notch moved north into the CKGR for the first half of the year. She was observed hunting with another adult female and a subadult female. They seemed to be successful in killing gemsbok and giraffe. In August, she moved back south and was moving with Nina. She was observed mating with the East Khutse coalition males, Snooks and Rocket. She gave birth to three cubs on the 26th December in the same area where Nina had her litter in September, just South of Khutse 1 pan. Her collar will need to be changed in March 2020, when the battery is due to end.

Nina (LF027): Nina was collared on the 18th April 2019 for the first time. At the time of collaring, she was observed mating with Snooks. Either he, or his coalition partner Rocket, is most probably the father of the litter she gave birth to on the 10th September. Since October she has been observed associating with Notch regularly.

Inca (LF043): The female, originally from the Molose pride, was observed in a poor condition at the beginning of 2019 and she was found dead around the 18th January. The exact causes of death were not determined. The juvenile observed with her in September and

December of 2018 has not been seen since.

Ditampana (LF059): Ditampana is an adult female translocated from Ditampana cattle post in collaboration with DWNP on the 28th June 2019. She was released in CKGR 40 km north of the border with Khutse GR, with an uncollared subadult male. They have been hunting and appear to be settling in the area north of their release site. They were observed feeding on female gemsbok and her calf a few days before her collar prematurely failed on the 1st September. The collar was retrieved, and along with the other failed collars has been sent off for testing.

Alice (LF060): Alice is an adult female from the Molose pride. She was coded LX003 as a juvenile in 2015. She had been observed with another adult female and three cubs in June and July, however the cubs were found dead on the 19th July. Alice was collared for the first time on the 24th July, since which time she has been active around Molose pan. The elephants have been continuously at Molose during daylight hours, so the two females were approaching the water only during the night for few hours before going back to hunt and rest in the areas surrounding the pan. The presence of the elephants is almost certainly one of the main reasons why the Molose pride has not come back together around the waterhole as has been observed in the past. As with other lion collars this year, Alice's first collar failed at

Cubs of Alice's pride. (Photo: Pogiso Ithuteng)

the beginning of August, however we managed to re-collar her on the 21st August.

Snooks (LM073): Snooks collar was changed on the 3rd August. Snooks and his coalition partner Rocket have been observed extensively in 2019 thanks to the uninterrupted presence of a GPS collar on Snooks. The coalition roams across the entire Khutse GR area with peaks of activity around Khutse 1 waterhole and in the area between the two cutlines and Gope road. They have been observed mating with Nina, Notch and many uncollared females of the Khutse pride. In November, the East Khutse pride coalesced around Khutse 1 waterhole and the two males were often seen playing with Nina's cubs. It can therefore be assumed that Snooks and Rocket are the new pride males of the East Khutse pride. Towards the end of 2019, the two males have repeatedly travelled outside the reserve, towards Kaudwane, for few hours during the night. It is likely they have been attracted by the numerous new cattle calves in the area.

Peanut (LM074): Peanut is an adult male who has moved from Khutse GR to CKGR and in the first half of the year, he travelled as far as Gope mine in the north. His collar was replaced on the 27th April 2019. In July he travelled outside the CKGR eastern border into commercial grazing land. However, since September he has consistently been in the area between Sekaka waterhole and Gope road and has not left the

PA again. His activity range has little overlap with the area used by Snooks and Rocket. The two territory seems clearly separated and the stable presence of females with Peanut may suggest that he is the pride male of a currently unknown pride in Sekaka area. We aim to identify and catalogue this pride over the coming months.

Aaron (LM084): Aaron and Moses (LM086) are two young males (about 4-years-old) moving in the southern part of Khutse GR. Aaron was collared on the 5th November 2019 for the first time. The two males are active and cover long distances over the course of a few days, with several rapid excursions outside the reserve. Collaring Aaron may fill an important gap in our study area. In the same section of the PA, we have had data only from Princess Fiona and very rarely Snooks. Data from this coalition may provide further understanding around the conflict between lions and livestock in the grazing land in the south of Khutse GR.

Lion Demographics

The year 2018 was characterized by a temporary disruption of the Khutse lion society with the Molose pride fracturing and the East Khutse pride males (Orange and Max) moving north in CKGR. In 2019, we could observe a new phase where the social landscape has started to stabilise again.

Nina's cub Motailane. (Photo: Genevieve Finerty)

Snooks and Rocket are the new pride males of the East Khutse pride and several females have been recorded mating with the two males. The pride coalesced again in September–November after months of separation, as expected from the fission-fusion society typical of the prides in our study area. Both Nina and Notch gave birth to litters at the edge of Khutse 1 pan in proximity of Khutse viewpoint. Nina gave birth to four cubs on the 10th September, one was dead within three weeks. The remaining three cubs benefited from a harsh end of dry season which provided easy, weak prey for Nina around Khutse waterhole. Notch gave birth to three cubs on the 26th December and all cubs were in good condition in January 2020.

Adults from the Molose pride have been observed roaming the Molose neighbourhood in pairs. Molose is at the crossover point between Snook's and Aaron's ranges. The continuous presence of elephants at Molose waterhole and the consequent destruction of it may have had a huge impact on prey availability and lion activity in the area. Alice and another female were the study animals who moved the most around Molose. Alice lost three cubs (less than 6-months old) on the 18th July, probably killed by another lion. That could be proof of an unstable situation with different males roaming in the area. Aaron and Moses are still quite young, but,

in the coming future, they may become the dominant males of the southern section of Khutse G.R. including Molose and Moreswe pans. Princess Fiona with her three 20-month-old cubs, Alice and at least other three adult females would be the potential prides they could associate with which reside in this area.

Peanut is associating with an uncollared pride of females around Sekaka waterhole. Further investigation is needed to fully determine the social dynamics in this area.

Other than the cubs mentioned above, lion mortalities include the death of Inca in January 2019 and the killing of one male and one female who were raiding livestock at Ditampana cattle post in June 2019. No other retaliatory killing on lion in the study area outside the PA were reported.

Lion Predation

In 2019, we collected data from 105 predation events (Table R4, page 14). This is three times the number of recorded predation events in 2018 (n=33). This is mainly due to the increase in sampling effort resulting from the National Geographic grant funded study carried out by LEC Research Assistant Keitumetse Ngaka, in collaboration with Prof. Packer and Dr Borrego.

Moses. (Photo: Alessandro Araldi)

Two species of prey were recorded that had not been recorded in 2018, ostrich (making up 4% of the records) and springbok (making up 1% of the records). As in the previous years, the gemsbok is one of the primary prey species for lions in the study area, accounting for 24% of the overall recorded predations. In 2018, gemsbok accounted for 21% of the predation events and in 2016, 25%.

The most predated species in 2019 was eland (27% of predation events), while in 2018 eland accounted for only 3% of predation events. This significant increase in eland predation could be explained by the fact that 72 elands were released onto Khuse GR in July 2019 and that translocated animals can be particularly vulnerable to predation as they have not adapted to the new environment. We recorded six eland kills in the seven months leading up to the release and 21 in the remaining five months of the year, showing a marked increase in eland predation post-release. A similar trend was observed in 2018 when wildebeest were released onto Khutse GR. That year wildebeest made up 21% of lion kills, whereas prior to the release wildebeest had been virtually absent from the predation list, and in 2019, wildebeest accounted for only 9% of the total predation events.

If a similar trend is observed again, it may be necessary to investigate the efficacy and sustainability of the current translocation strategy. The released herds may not be resilient enough to withstand the impact from predators before the population reaches sustainable levels. At the same time, the Kalahari savanna is a low-density habitat for many species and it may not sustain large herds for an extended period of time, and so the reduction in wildebeest and eland post release may be just stabilizing the population back to what is naturally supported by the environment. Furthermore, the release of potential prey may provide a short-term solution to alleviate the predation on livestock, but in the long-term it may generate a growing population of lions which cannot be naturally sustained in the study area and, therefore ultimately the predation on livestock may actually increase. Further understanding on the post-translocation dynamics in the study area is needed to better address future management strategies.

In 2019, predation on livestock made up 14% of the total number of predation events. This result is in line with what we have observed in 2018 (12%) and it continues a trend of reduced livestock predation compared to the 5 years prior to 2018. As also mentioned above, it could be an effect of the recent herbivore translocations. In contrast with 2018, more cattle than donkeys were predated in 2019.

Miscellaneous – Research

Genevieve Finerty's PhD programme is progressing well. Fieldwork has been completed and her PhD thesis will be submitted by April 2020. Ms. Finerty has also made a substantial contribution toward the collating and processing of LEC's data. Furthermore, she has been leading in the drafting of the 5-year plan for LEC.

Keitumetse Ngaka's study of lion and leopard predation patterns and associated environmental drivers has continued, with financial support from a National Geographic grant (see below). The study is largely based on work currently being undertaken by LEC and aligns directly with our research goals and aspirations. Furthermore, it forms part of a collaborative study with Dr Borrego and will be used by Mr. Ngaka as the basis for a PhD thesis. In preparation for his PhD programme, Mr. Ngaka has been accepted onto a seven-month Post-Graduate Diploma course at the University of Oxford in 2020.

Dr Natalia Borrego returned to Khutse in January and in November to continue fieldwork for her study on co-operative hunting in lions. Dr Borrego is the principle researcher in this collaborative project between LEC and the Lion Research Center, University of Minnesota. She has secured funding from National Geographic, and this project temporarily employed an additional three San trackers to collect data. The study overlaps with Keitumetse Ngaka's research programme and the two projects will be sharing resources and data.

Professor Walter Zucchini returned to LEC from the 29th January to the 31st March. During his time in camp, he undertook a study on satellite derived rainfall data in our study area, a calibration and assessment of collar temperature data and a review of Ronja's telemetry data. Furthermore, he assisted LEC research staff with various statistical analyses.

The annual BirdLife Botswana National Bird Population Monitoring survey was conducted in February and in November. LEC once again participated with two counts, one inside the PA and one outside.

LEC assisted DWNP with predator management outside the PA within our study area:

- 27–29 January: LEC set a cage trap for a leopard that had killed a calf. The leopard did not return.
- 12–13 April: Two farmers shot and wounded a male lion on the 11th. On the 12th and 13th, LEC joined a team comprising members of the Kaudwane PAC office, DWNP and the SSG to track the animal. The lion returned to the PA of its own accord.
- 18 April: LEC assisted DWNP in tracking lions that were within the grazing lands.
- 21–25 June: On the 20th June it was reported that a group of lions were killing livestock in the vicinity of Ditampana cattle post. LEC assisted the Kaudwane PAC officer and DWNP in tracking these animals. Two lions were shot, one by farmers and the other by DWNP. Three were darted and translocated to the CKGR. Of these three, one female, Ditampana, was collared.
- 31 August: LEC assisted DWNP in releasing a male leopard at Molose waterhole. The leopard was translocated from Sokoma cattle post where he killed a calf. No GPS collar was placed on the leopard because LEC was not informed in advance and, therefore, the veterinarian was not on site. A leopard male, which could be the released male, has been spotted around Molose waterhole two more times in October and December.
- LEC team has helped PAC on several occasions to facilitate the inspection of kill sites reported by farmers.

Senior DWNP research and veterinary members Mr. Gadimang, Dr Ruben and Dr Dikolobe visited camp in March to discuss our research programme. In April, Ms. Munyadzwe, the Regional Wildlife Officer, and other members of the DWNP office in Kweneng visited camp to discuss LEC's research and conservation efforts as well as opportunities for greater collaboration.

In September, LEC obtained the new research permit from the MEWT. It covers the period from September 2019 to December 2024. The related entry permit to the PA has been provided by DWNP.

On the 29th November, Alessandro Araldi, Genevieve Finerty and Keitumetse Ngaka met with Mr. Gadimang at DWNP offices to update and report on the running research projects at LEC. The meeting was requested by Mr. Gadimang to evaluate our request for a new collaring permit.

According to its ethics and policy, LEC continues its efforts in improving and developing new techniques to capture and collar study animals. To date the most effective and humane way to capture leopards has been to cage trap animals prior to immobilization. However, this is not a particularly effective method, especially with individuals that have been cage trapped previously. Furthermore, despite efforts to minimise stress, animals may injure themselves when held and darted within a cage. Consequently, LEC has been working with engineers from the Physical Science Department of the UZH to develop a remote-controlled darting device. At the beginning of October, LEC Field Research Coordinators went to Zurich to test the device and to receive training in how to operate it. Under laboratory conditions, the device is performing above expectations, the next phase consists in testing it in the field in Botswana. DWNP is supporting LEC in obtaining the necessary permits to import the device. It should be sent to Botswana in the first half of 2020.

Protocols for collecting samples during collaring or necropsy operations were reviewed and updated in collaboration with Jari Garbely, UZH, and Prof Emily Mitchell, University of Pretoria.

Through Dr Derek Lee and Dr Monica Bond, LEC was in contact with the Microsoft team in charge of developing algorithms to automatically classify species from camera-trap pictures. LEC provided a subset of its camera-trap images to test the software which was created for surveys in the Serengeti NP. The initial results are promising for medium- and large-sized herbivores, but the software needs to be calibrated for our local species which are not present in the Serengeti ecosystem. Results are not so encouraging for carnivores and for small-sized species or with images containing multiple species. Once our camera-trap survey is running, we will test the software with a new set of images.

LEC has decided to re-organize the storage of its datasets in a new server hosted in Switzerland. The structure of the server has been partially defined and the archiving process of the existing datasets has started and will be completed by end of 2020.

In December, LEC team started discussing about possible collaboration with different institutions:

- Snapshot Safari is a project within the University of Minnesota Lion Centre involving camera-trap surveys across Africa. LEC will collaborate and design a camera-trap survey to establish wildlife population estimates in Khutse GR, with a special attention on leopard densities. The results will be compared with other Snapshot Safari sites when needed.
- LEC was contacted by Prof. David Borchers, director of the CREEM at the University of St Andrews, to investigate a possible collaboration within their MSc programme in Statistical Ecology. Their students would have the opportunity to work with field researchers and conservationists and in exchange they would provide statistical expertise to improve data analysis and survey design.
- Following three suspected events of poisoning (2 bateleur and 1 brown hyena) at Khutse1 pan, LEC has contacted Andre J. Botha, the Vultures for Africa Programme manager at the Endangered Wildlife Trust. In April 2020, LEC and DWNP will host a workshop in Khutse about the management of poisoning incidents of wildlife, led by Mr. Botha.
- Finally, LEC contacted WildTrack team to explore the suitability of their Non-invasive Wildlife Monitoring Footprint Identification Technology (FIT) in Khutse GR. This technology may substantially expand the information we are able to gather from our tracking activities.

Research Box:
Spoor Counts

Background

Approximately every five years, we conduct spoor surveys over 285.3 km of sand roads in Khutse GR and adjacent farmland. Working with skilled San trackers, spoor counts were one of the first methods we used in 2001. They allowed us to understand the distribution of leopard activity across the park and, when coupled with long follows of individual leopard spoor, they gave us our first glimpse into leopard behaviour in the Kalahari. These counts allow us to track long term trends in carnivore density across the study area and to compare densities inside and outside of the reserve.

Spoor counts are an important management monitoring tool used across Africa to track trends in large carnivore densities. Despite their widespread use, it is important to remember that many things can influence the relationship between population density and the frequency with which a species uses roads. The dynamics in each area are unique and the conclusions we draw from our results must be viewed conservatively.

Comparisons inside and outside the PA

Across all years, densities of all species except brown hyenas were lower in grazing area. Brown hyenas rarely take large prey and are not perceived as a serious threat to livestock. Other explanations for the higher densities in grazing area might be reduced interference competition with leopards and lions or the presence of abundant small prey.

Temporal trends inside Khutse GR

Our results suggest that densities of lions, leopards and brown hyenas in the PA have declined over time, while cheetah densities have risen. Both leopards and lions supress cheetah populations through interference competition. Reductions in their populations in recent years may therefore have released the cheetah population within Khutse. Correlations such as this provide strong motivation to design studies to explore possible mechanisms that underlie interspecific interactions, something we hope to explore further.

By similar logic, we would have expected the observed decline in lion numbers in the PA to accompany an increase in leopard numbers. The absence of this patterns suggests that the decline may be driven by something that affects carnivores more ubiquitously, such as annual variation in the mean and variability of climate and thus prey availability.

Another possibility is that changes in the behavioural patterns of road use of either species (e.g. an increase in road use by lions might be followed by a decrease in road use by leopards to minimise potentially lethal lion encounters) might confound our ability to accurately estimate population densities from a single relationship between spoor density and population density. Future studies to determine the use of roads by our focal species and allow us to better account for detectability of spoor will improve our ability to interpret these estimates.

Currently, the exact reasons behind the decline in the remaining large carnivores are unclear. In 2008, Khutse experienced a severe drought that displaced or killed large numbers of prey. Around this time lions were discovered dying from an unidentified disease and it is thought that the population experienced a significant crash. Assuming an approximate area of 2000 km², our highest mean density estimate would provide a figure of around 30 lions in the Khutse GR, compared to the 60 reported by Sandra Ramsauer's

thesis 2003–2005. This would represent a substantial decline in the known population and suggest it may not have recovered to pre-2008 figures. We are currently carrying out genetic studies into the lion and leopard populations in the CKGR that may help to support this hypothesis via the detection of bottlenecks in the data. Identifying the key factors that govern mortality rate and limit population growth in our system will be a focus for LEC over the next five years.

Temporal trends in the adjacent farmland
Brown hyenas, lions and cheetah all experienced a reduction in their population densities outside the protected area between 2008 and the following time periods. Most notably, our figures suggest that cheetahs are functionally absent from the grazing lands and lions exist at such a low density that any tracks observed are unlikely to represent individuals permanently resident outside the park.

In 2009, an electric fence was erected along the south-eastern park boundary with the aim of reducing conflict between farmers and large carnivores in the adjacent farmlands. The ability of predators and small prey to dig under the fence or travel through small holes make this a partially permeable physical barrier at best and individuals have been observed to make excursions into farmland and kill livestock. Despite the lack of a permanent barrier, the density of resident lions outside the park appears to have plummeted following the erection of the fence. This is backed up by what we have observed from the movement data and personal observations. A possible explanation for this is that the fence actually decreased tolerance for lions, by promoting the idea they should "remain inside" the park and led to increased retaliatory killings of any remaining

resident lions in the farmland area.

In contrast to this pattern, leopard densities in farmland increased between 2008 and 2013 onwards. We feel it is likely that the restriction of lion movement, and absence of resident prides in farmland, has allowed leopards to operate more freely in grazing area. Teasing apart the interactions between species, such as this, will be a focus for future work. It is worth noting that although the leopard population density has increased in the farmlands (also due to translocations), it still remains at a rather low density. Leopards are able to thrive on smaller prey like duikers and steenboks and we would expect their densities to be much higher than currently observed in areas where lions are no longer resident. It is likely that high levels of retaliatory killing by farmers or low prey availability due to an impoverished habitat continues to depress the leopard population outside the park.

Spoor counts in Khutse provide us with important information that can guide further research. In particular, the decline in both lion and leopard densities is concerning. The large confidence intervals around our estimates make robust statistical inference challenging and it will be important to explore further methods to improve the accuracy and precision of these values and validate our results with other data streams. We will continue to track these populations to understand the population density in the Kalahari and to identify key conservation interventions required to prevent further decline.

For details on the methods and detailed results please feel free to contact our research team.

EDUCATION AND COMMUNITY PROGRAMME

Act Now for Tomorrow

The "Act Now for Tomorrow" education programme started in 2008 as a response to increasing human-carnivore conflict around the Khutse GR area. LEC selected seven cattle posts with the high levels of conflict along Khutse GR and southern CKGR as its study area to implement the "Act Now For Tomorrow" Conservation education programme. The programme focused primarily on promoting co-existence of farmers with free ranging wild carnivores through improved livestock management, capacity building and conservation education. The programmes targeted at achieving two broad objectives:

- Develop an inclusive conservation education programme that promotes a balanced environment through sustainable and diversified land use.
- Empower participants through education and capacity building in the selected cattle posts so that they become knowledgeable and effective managers of all available resources.

For the purpose of identifying clear areas of focus, the "Act Now for Tomorrow" education programme is sub-divided into two parts;
- the education projects and
- the community projects.

The education programme focuses on capacity building on animal husbandry and non-lethal predator management options in the selected seven cattle posts. The community programme focuses on conservation education through event based programs and small-scale projects in the villages of Kaudwane and Salajwe.

Education Projects

During the course of 2019, members of the education projects continued working with farmers in the seven cattle posts of the study area. This was done through weekly consultations. Here, we collected livestock predation and disease data, monitored implemented projects and engaged farmers on non-lethal predator management strategies.

During the course of the year, we collaborated with DWNP PAC office on problem animal control activities such as capturing and translocation of problem animals.

Livestock predation

We collected livestock predation data to better understand how the human-carnivore

Cattle on communal lands. (Photo: Tshepho Tsito)

conflict is evolving in the area and to give feedback to farmers, DWNP and other stakeholders for decision-making. During our weekly consultations, we received positive feedback about our efforts and projects in the cattle posts. Farmers appreciate LEC conservation efforts and have showed improved interest to co-exist with wildlife in the communal areas. We partnered with DWNP to offer support to the continuously running problem animal control exercises in the communal areas. These are short term intervention operations aimed at assisting farmers to deal with imminent predator attacks in a non-lethal fashion. Patterns of livestock predation in LEC study area are shown in Figures E1 and E2.

In 2019, 16 adult goats, 13 cows and 11 calves were killed. We only reported two kills in juvenile donkeys and adult sheep each. In 2018, predation on livestock was more diverse across livestock species than in 2019. The total number of livestock killed increased from 38 in 2018 to 44 in 2019.

Black backed jackal (*Canis mesomelas*) and Cheetah (*Acynonix jabatus*) were not recorded to kill livestock in 2019 while in 2018 we documented 13 killed livestock. Lion (*Panthera leo*) predation increased from nine in 2018 to 20 in 2019. On the other hand, there was no recorded predation of Caracal (*Caracal caracal*) in 2018 while in 2019 it rapidly increased to 12.

The results show that the conflict between livestock farmers and carnivores outside the PA is not yet solved. Consequently, our conflict mitigation initiatives need to be further implemented and monitored.

Livestock disease management

LEC education project recognizes the importance of livestock diseases as an important factor in the human-wildlife conflict. We collect data on disease induced livestock mortality within our study area. The main reasons for collecting such data are:

- Sick livestock is more susceptible to predation than healthy livestock, so predation opportunities may increase when there is more unhealthy livestock.
- Carnivores scavenge on livestock that dies from disease and the dead livestock would be blamed on those carnivores, which perpetuates the conflict.
- We compare the livestock losses by carnivores with other causes of death.

Course with farmers. (Photo: LEC)

From 2015 to 2019, livestock predation mortality was higher than disease induced mortality. However, predation was lower than disease mortality in 2014. The overall 5-year trends show a decreasing tendency of total livestock mortality. The lowest mortality was in the year 2017. In 2018 and 2019, mortality started increasing again and we intend to keep collecting the data to establish trends in predation and mortality over a longer period.

Disease induced livestock mortality dropped from 30 in 2018 to 13 in 2019. This is likely to be caused by several factors including good disease management by farmers, low disease prevalence in 2019 and reduced livestock numbers. Also our disease management education through forums such as the HTC and annual workshops contribute to the adaptation in behaviours of farmers towards livestock management.

Livestock management

LEC promotes sustainable livestock management as a predation mitigation measure. During weekly cattle post meetings with farmers, we encourage herders to herd livestock during the day, kraal livestock at night and build predator proof kraals to reduce predation risk.

Herders Training Course

LEC has collaborated with BUAN to set up a herders training course programme to be implemented in LEC study area. The HTC overall goal is to reduce human-carnivore conflict in LEC study area through capacity building (education and training) as a means to assist farmers make informed decisions in managing available resources in their cattle posts.

In June 2019, LEC successfully hosted the last of three requisite course trials in Kungwane cattle post. The feedback received from farmers and trainers were incorporated into the course content to make it even more relevant. There was a lot of interest and enthusiasm and farmers asked relevant questions and actively participated. LEC and BUAN team is satisfied with the progress so far. LEC has also completed drafting of contracts needed to jointly submit an application for course certification in April 2020. The certified course will be in October 2020.
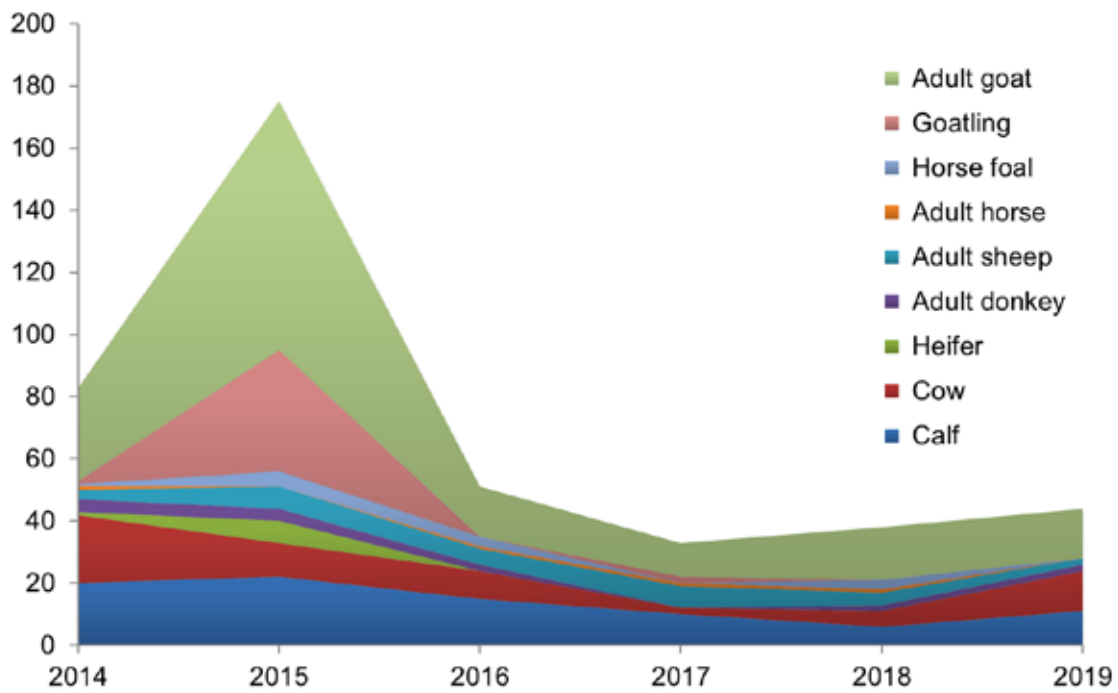
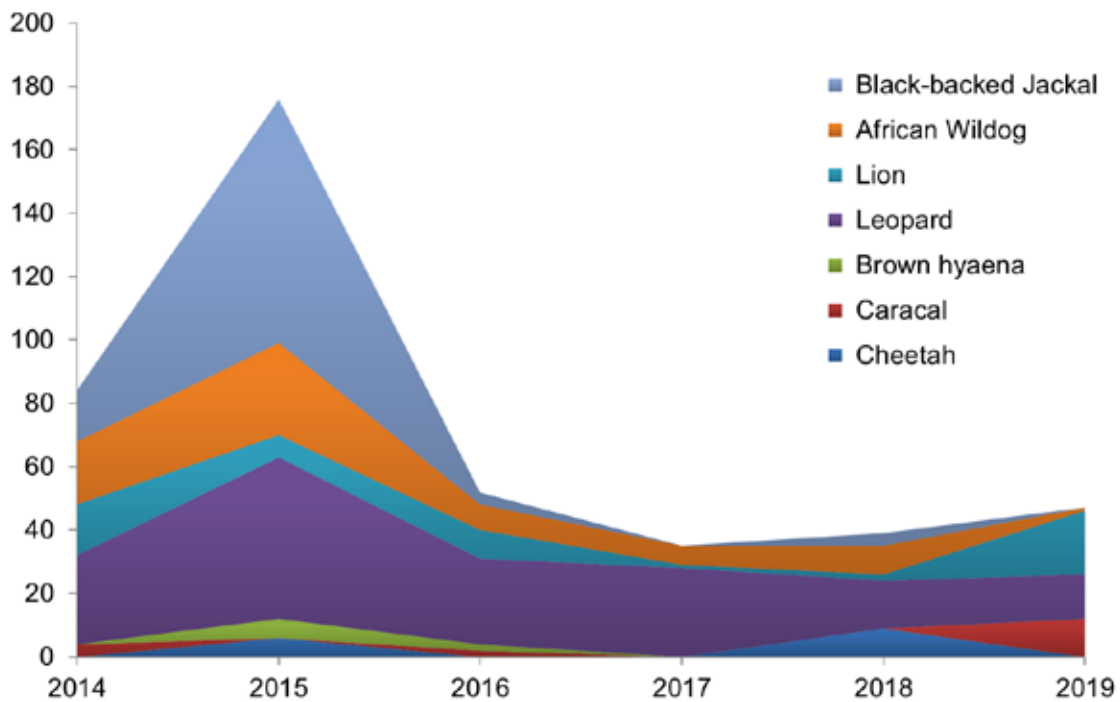Figure E1. Livestock predation patterns from 2014 to 2019.

Figure E2. Number of kills by different predators from 2014 to 2019.

Students city tour trip. (Photo: LEC)

Community Projects

The Community programme helps LEC to consolidate its relationship with the community, while raising awareness about conservation issues affecting the community. In addition, the projects help to contribute to the improvement of livelihoods of community members through supporting various small-scale projects in the community such commemoration of nationally recognized conservation related days.

- **Horse race project**
  The LEC-Kaudwane horse race project started in 2017. The project aims to promote good animal husbandry in the farming community of LEC study area. Good animal husbandry is a human-carnivore conflict mitigation measure, which promotes conservation as envisioned by LEC. The horse race project is also a platform to spread conservation education message to local people. Conservation educators from other NGO's and government departments are invited to participate in the event through education of horse race attendees.

  In 2019, we prepared the next horse race that is planned for the 8th May 2020. We made major adjustments to the planned accompanying dog and donkey parade by

shifting our focus to reducing the risk of disease transmission between domestic dogs and wild carnivores and humans. This will be done through a vaccination and sterilization campaign targeting dogs in the area, which has already been accepted by Kaudwane village leadership.

- **Kaudwane Primary School projects**
  LEC adopted Kaudwane primary School in 2013 through the Government of Botswana's 'Adopt a school' initiative. Since then our community projects team has been working with the school to implement projects aimed at improving academic performance of students.

  Students city tour trip: LEC organized a city tour for the best Kaudwane Primary School students in April 2019. The objective of the trip was to motivate and reward students for the notable improvements they made in their studies and also to broaden the students understanding of life issues beyond Kaudwane village by exposing them to a different environment.

- **Kaudwane hoof trimming project**
  The Kaudwane hoof trimming project

Hoof trimming. (Photo: LEC)

was started to promote healthy livestock herds as a way of minimising predation on livestock in the Kaudwane area. The project focuses on cutting overgrown hooves on livestock in Kaudwane and encourage farmers to independently cut overgrown hooves on their livestock. In 2019, LEC made structural changes and decided to host training workshops on hoof trimming and animal welfare in the community of Kaudwane; and later supply the community with hoof trimming equipment so that the community can play an active role in management of their livestock. The training workshops will start early 2020.

- **Itsoseng non-profit making shop**
  Itsoseng non-profit making shop in Kaudwane has continued to support the welfare of Kaudwane residents by selling good quality cloths at low costs and use the proceeds from the shop to sponsor community projects in the village.

- **World Lions Day**
  LEC commemorated the World Lions Day on the 10th of August 2019 at Kaudwane Kgotla. By commemorating the day, LEC aimed to open a platform to discuss conservation issues relating to lion conservation and its interaction with the farming community of Kaudwane. The day was filled with conservation-oriented activities such as litter picking; and with several speeches and talks that aimed at sensitising local farmers about key conservation issues in their community.

- **Community Conservation Club**
  In 2019, LEC made an important milestone in community conservation engagement through initating a community conservation club at Kaudwane. The club is driven by six individuals from the community. So far, the club has started a solar cooker project and they have already built and experimented on three different solar cookers. A final cooker will be adopted and rolled out in the community during the year 2020.

Also it has been achieved to receive consent from the community leadership and securing land and water rights to build a sustainable organic garden for the community. The garden structure, training, planting and subsequently monitoring will be started in 2020.

MISCELLANEOUS

Visitors

LEC hosted a number of visitors to camp in 2019, all of whom contributed toward our research and conservation goals. These include:

- Prof. Dr Walter Zucchini returned to camp for two months (February to March) to undertake statistical analyses of LEC data and assist our research staff and students.
- Dr Natalia Borrego visited camp in January and November as part of the collaborative research on lion predation.
- Shani Baumgartner, a post-graduate student at the UZH, visited camp in November to familiarise herself with environmental conditions and data collection protocols to design her MSc thesis project with Prof. Dr Arpat Ozgul, UZH, for 2020.

Administration

LEC continues to liaise closely with DWNP to keep them informed of our research and conservation work and ensure that these remain relevant to the national conservation agenda. In particular, meetings were held regularly with Ms. Dintwa, the Manager of Khutse GR, and Johnson Lebotse, acting Manager during the period Ms. Dintwa was seconded to the Regional Head Office, as well as Phemelo Gadimang, the Head of Research and Statistics, and Dr Michael Flyman, who is now with the Ministry of Environment, Natural Resources Conservation and Tourism. LEC developed a strong collaboration with DWNP Veterinary Department, especially with Dr Reuben and Dr Dikolobe.

Infrastructure and Various

Camp LEC developments in 2019 include:

- A new large safari tent for the second Field Research Coordinator has been purchased. The construction of bathroom facilities will be concluded in January 2020.
- LEC acquired an additional research vehicle, a 2016 Land Cruiser SW, in December to replace the 2008 Land Cruiser SW used by the tracking team. The vehicle will be driven by Pogiso Ithuteng and his team who will focus on leopard research.
- Two field vehicles have had tracker seats installed to better facilitate spoor counts and tracking.
- All computers operating Windows 7 OS have migrated to Linux Ubuntu 18 to avoid any security issue when Windows 7 support will be terminated in January 2020. The oldest three laptops were donated to the ICT Innovation and Info Hub Program, a Kaudwane-based project aiming to provide

Steve Henley's fare well party. (Photo: LEC)

basic computer literacy to the community in Kaudwane.

- A new set of batteries was purchased for 1 of the 4 solar panel systems in camp.
- The fence around the camp has been improved to avoid any livestock entering the camp.
- A field first aid course was provided to all LEC staff in Botswana by Okavango Air Rescue instructors. The supervisors of each department in LEC followed a Level 2 training, while the rest of the staff successfully achieved the Level 1 certificate.

LEC Team

- Dr Steve Henley left the position as Research Coordinator at the end of September. LEC is grateful for the great passion and energy he put in the project during the last 6 years.
- Alessandro Araldi and Rosie Miles joined LEC as Field Research Coordinators in July 2019. The handover with Dr Henley took place from July to September to assure that all LEC activities could continue smoothly and that the new coordinators could be introduced to LEC partners and collaborators. The two new coordinators were introduced by Monika Schiess-Meier to part of the team (Genevieve Finerty, Fabian Haas, Nicole Gusset) in Zurich.
- Dr David Mills, former research coordinator until 2011, has joined LEC as scientific

consultant in July. His expertise in carnivore ecology and his knowledge of LEC and Khutse GR are an important asset for the team.

- Keitumetse Ngaka, LEC research assistant, has been accepted to the Post-Graduate Diploma in International Wildlife Conservation Practice at the University of Oxford. For 2020, he plans to attend a 7-months course in UK.
- As in 2018, LEC sadly lost a member of staff in 2019. After a long disease, in April 2019 Ngmanyana Kefeletswe passed away. She started working for LEC as housekeeper in our camp in 2005. In the last two years, she was managing the Itsotseng non-profit shop in Kaudwane. LEC team will miss greatly such a loved member of the staff.
- Tebelelo Gabaikanye, from Kaudwane, joined LEC in January, assisting Mgwanyana Kefelekswe in the shop. Later she started managing the shop and her tasks in LEC administration have grown exponentially. Since August, she has been assisted in the shop by Komano Motsididi and the shop is now open 5 days a week.
- Sebakeng Gabotshwanelwe came back from maternity leave in February. Neo Mosikare was on maternity leave from May to August. Omponye Rabanyana joined us as a temporary replacement in both cases.
- A team of three trackers and one driver has been hired through the NatGeo grant to assist Keitumetse Ngaka and Dr Borrego in their study on lion kills.
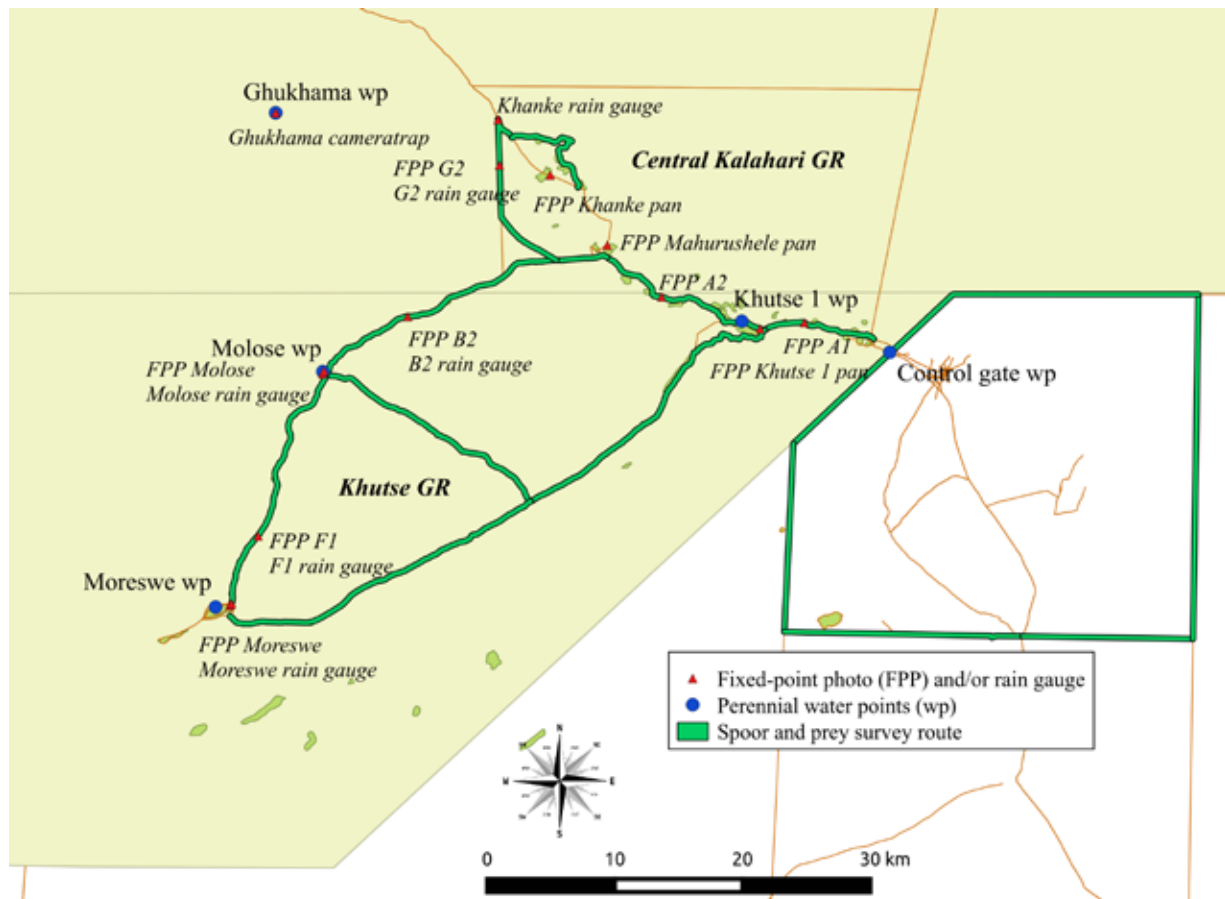
Appendix I
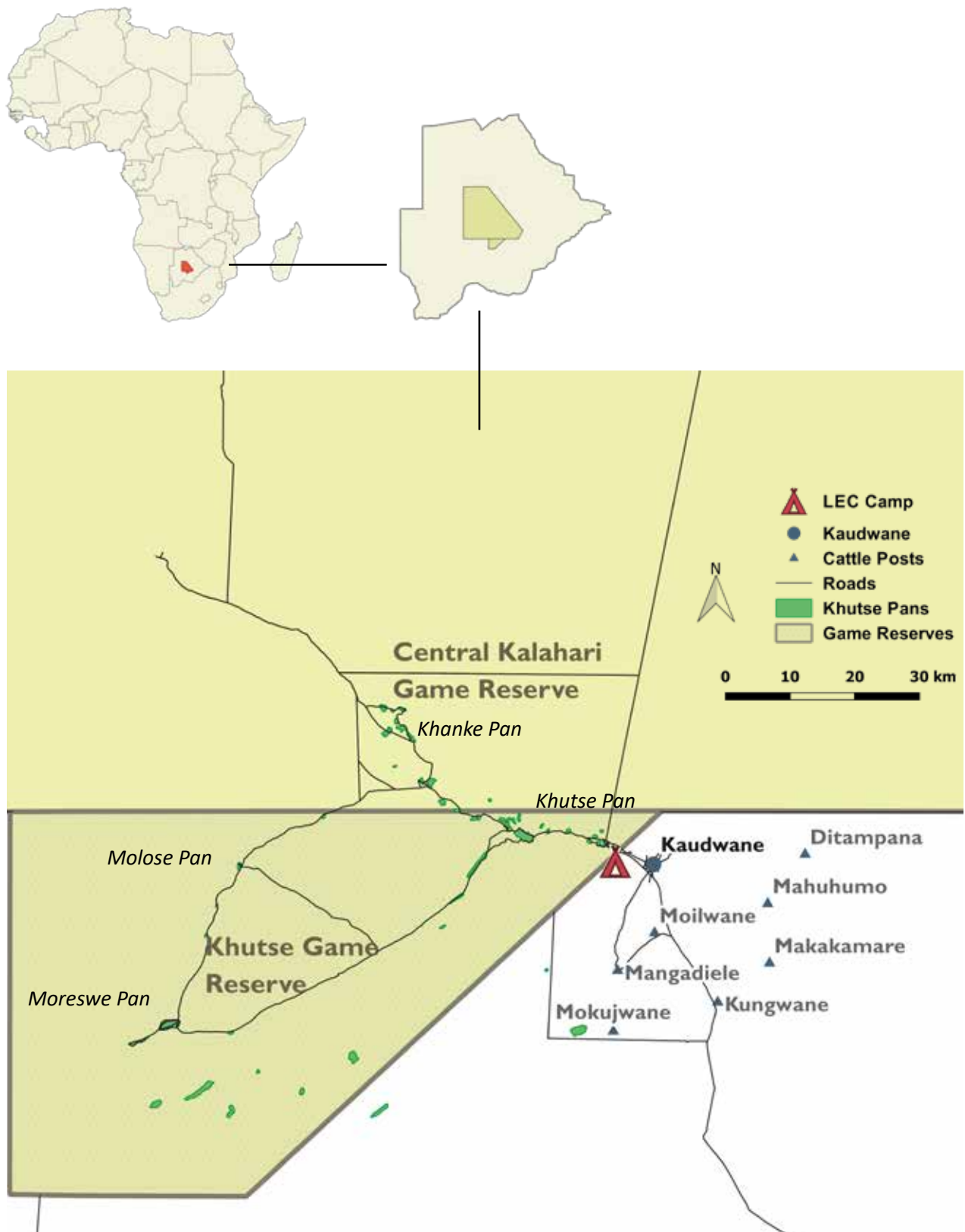
Map of Khutse Game Reserve, southern Central Kalahari Game Reserve and adjacent communal lands.

Table 1 Appendix. Leopard Telemetry. Animals monitored by LEC during 2019.

ID	name	first collared	status
PF021	Tsholofelo	26 February 2018	dead, shot on 10 September

Table 2 Appendix. Lion Telemetry. Animals monitored by LEC during 2019.

ID	name	first collared	status
LF009	Princess Fiona	18 April 2011	drop-off failed 1 June; recollared 5 November; drop-off failed 29 November
LF018	Notch	6 June 2013	collar to be replaced in 2020
LF027	Nina	18 April 2019	collared 18 April
LF043	Inca	17 March 2016	dead 22 January
LF059	Ditampana	27 June 2019	collared 27 June; drop-off failed 3 September
LF060	Alice	24 July 2019	collared 24 July; drop-off failed 2 August; recollared 21 August
LM073	Snooks	8 February 2018	collar replaced 3 August
LM074	Peanut	8 February 2018	collar replaced 27 April
LM084	Aaron	5 November 2019	collared 5 November

Habitat monitoring map showing the locations of FPP and rain gauges and the route of spoor and prey survey.

APPENDIX II

The Leopard Ecology & Conservation Team
- Monika Schiess-Meier, MSc Zoology, founder and managing director, University of Zurich, Switzerland
- Dr Stephen Henley, PhD, field coordinator and researcher, South Africa
- Alessandro Araldi, MSc, field coordinator, Italy
- Rosie Miles, BSc, field coordinator, UK
- Dr Nicole Gusset, PhD, project management, University of Zurich, Switzerland
- Genevieve Finerty, research biologist, UK
- Dr David Mills, PhD, research consultant, South Africa
- Phana Segametsi Kegakilwe, BAcc, administration, Botswana
- Tefo Gabanapelo, community and education programme coordinator, Botswana
- Fabian Haas, MSc, education programme and data management, Fundraising, Switzerland
- Tshepho Tsito, BBA, education and community programme officer, Botswana
- Kefilwe Mokgwathi, BBA, education assistant, Botswana
- Keitumetse Ngaka, MSc, researcher, Botswana
- Tshoganetso Ernest Gagosimologe, graphic designer, assistant camp and shop interim manager, Botswana
- Keolebetse Otukile, education & community liaison, Botswana
- Doris Barouk, MA Social Behavior Science, monitoring and evaluation, Germany
- Sylvia Senz, lic. phil.I, public relations, Switzerland
- Marianne Köpfler, administration, University of Zurich, Switzerland
- Pogiso Ithuteng, field research assistant, tracker supervisor, Botswana
- Phalatsa Nkadima, Supula Monnaanoka, Mosepele Mamou, Sokwa Puridaroma: tracking, Botswana
- Bontle Raseme, vehicle maintenance, Botswana
- Kobe Majafe, camp maintenance, Botswana
- Goitseone Ithuteng, Sebakeng Gabotshwanelwe, Neo Mosikare: camp staff, Botswana
- Ngmanyana Kefeletswe, shop, Botswana
- Tebelelo Gabaikanye, camp administration and shop assistant, Botswana
- Komano Motsididi, shop assistant, Botswana
- Onthusitse Kelatlhegile, Kelatlhegile Pulaekae: animal husbandry project, Botswana
- Masente Ithuteng, camp maintenance & vehicles assistant, Botswana
- Ditshupo Kegakilwe, housekeeping, Botswana
- Ronald Mpofu, garden maintenance, Botswana
- Philipp Schiess, IT specialist, Zurich, Switzerland
- Joshua Pata, administrative assistant, Botswana
- Omponye Rabanyana, assistant, Botswana

Puff Adder. (Photo: Steve Henley)

The following people / institutions are involved
Research support and collaboration (leopard and lion behaviour, population genetics and health)
- Prof. Barbara König, Department of Evolutionary Biology and Environmental Studies, UZH, Switzerland
- Prof. Craig Packer and Dr Natalia Borrego, Lion Research Center, Universtiy of Minnesota, USA
- Prof. Regina Hofmann-Lehmann, Clinical Laboratory, Vetsuisse Faculty, UZH, Switzerland
- Prof. Robert Weibel, GIS, UZH, Switzerland
- Dr Rob Jackson, project veterinarian, Botswana
- Dr Gosiame Neo-Mahupeleng, Wildlife Ecology lecturer, Botswana University of Agriculture and Natural Resources, Botswana
- Prof. Walter Zucchini, Department of Economic Sciences, Georg August University Göttingen, Germany
- WildCRU, University of Oxford, United Kingdom

Support in Botswana (permits, information and logistics)
- Hon. Kitso Mokaila, Minister of Environment, Natural Resources Conservation and Tourism
- Major General Otisitsew B. Tiroyamodimo, Director, DWNP
- Dr Cyril Taolo, Deputy Director, DWNP
- Dr Michael Flyman, Ministry of Environment, Natural Resources Conservation and Toursim
- Dr Phemelo Gadimang, Chief Wildlife Officer, DWNP
- Mrs Oganeditse Dintwa, Park Manager, Khutse Game Reserve
- Dr Mmadi Reuben, Principal Veterinary officer, DWNP
- Dr Mmolotsi Dikolobe, Veterinary Officer, DWNP
- Special Support Group (SSG), Khutse Base Camp, Botswana
- Regional Wildlife Officer Molepolole, Botswana
- Department of Veterinary Services, Letlhakeng

Professional, logistical and material support
- Aebersold Digitaldruck, Jona, Switzerland
- Albrecht Druck, Obergerlafingen, Switzerland
- Fly Away Reiseerlebnisse GmbH, Germany
- Hilti, Switzerland
- Rosmarie Holzinger, MD, Zurich, Switzerland
- Toyota Motor Centre, Gaborone, Botswana
- Michel Nakano, technical support, University of Zurich, Switzerland
- Fritz Schiess, Zürich, Switzerland
- Pieter & Susanne Schmid, Oberwil, Switzerland
- Solar International and Solar West, Botswana
- Elicar Wagner, Kockelscheuer, Luxembourg
- Hannelore & Bernhard Wehrli-Oehler, Feldbach, Switzerland
- Vectronics Aerospace GmbH, Berlin, Germany
- Reto Maier, Universität Zürch, Switzerland
- Glättli Thomas, Switzerland

Steve and Monika. (Photo: Pogiso Ithuteng)
When elephant meets lion. (Photo right:Genevieve Finerty)

African Cats & Conservation Foundation Switzerland
- Christine Kämpf (chair) Switzerland
- Eveline Bissegger (chair), Switzerland
- Philippe Jan, Switzerland
- Dieter Gutmann, Germany
- Catherine Oeri, Switzerland
- Monika Schiess-Meier, Switzerland

Khutse Leopard Trust
- Monika Schiess-Meier (Chair), Switzerland
- Doreen Khama, Botswana
- Tefo Gabanapelo, Botswana

LEC Trust
- Monika Schiess-Meier (Chair), Switzerland
- Dieter Gutmann, Germany
- Fritz Schiess, Switzerland
- Steve Henley, SA

Educational Project (ANFT) Steering Board
- Chief Scientific Officer (ruminants), 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 (Tshepho Tsito), Botswana
- Khutse Leopard Trust (Monika Schiess-Meier, Doreen Khama and Tefo Gabanapelo), Botswana
- Farmer representatives (Pako Keokilwe and Boometswe Mokgothu), Botswana
- Edwin Dintle, former Land Registration Officer of Rolong Land Board (now with Botswana Housing Corporation), Botswana

Collaborating Institutions from Botswana in 2019
- Department of Wildlife and National Parks
- Community of Kaudwane
- Kaudwane Primary School
- BUAN
- University of Botswana, Botany Department
- Cheetah Conservation Botswana
- Kalahari Research and Conservation
- Tau Consultants
- BirdLife Botswana
- Village Extension Team and Village Development Committee (Kaudwane)
- Thapong Visual Arts Centre
- Kuanghoo Community Trust
- Letlhakeng Sub-District Council

Scientific Publications, Workshops & Media

- Finerty, G. E. et al. (2019) Range expansion: Servals spotted in the Kalahari, Cat News, 69(Spring), pp. 9–11.
- Finerty, G. (expected 2020) Ecology, conflict & connectivity: lions in the Kalahari. University of Oxford. PhD Thesis.
- Büttner, C. (2019) Effects of environmental factors on space use, behaviour and movement patterns of Khutse lions and leopards. University of Zurich. MSc Thesis.
- Tsito, T. (2019) How do landscape attributes correlate with livestock predation patterns around Khutse Game Reserve? University of Botswana. MA Thesis.
- Zucchini, W. (2019) Estimating daily precipitation over the LEC Khutse study area using CHIRPS data. Report.
- Zucchini, W. (2019) Comparison of ambient temperature to the temperature recorded on lion and leopard collars. Report.
- Haas, F. and Schiess-Meier, M. (2019) Threatened predators of the Kalahari. University of Zurich. Invited Talk.
- "ANFT" Steering Committee meetings

Workshops in Botswana:

- Achieving Success with Community-Based Conservation Engagement: Answering Perception and Evaluation Research Questions; by CCB, 4-6 November 2019.

- Farmer Education Workshops "Act Now for Tomorrow", Gaborone, Botswana.

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www.leopard.ch

Photos on cover and back: Pogiso Ithuteng