

Refining track-based surveys to support wildlife conservation and human coexistence in the Kalahari.

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Abstract

Amid the current ecological crisis, conservation efforts are expanding to balance rangelands and species preservation with the sustainable use of natural resources. Botswana's Kalahari Desert hosts one of sub-Saharan Africa's largest unprotected areas supporting free-ranging wildlife, the Western Kgalagadi Conservation Corridor (WKCC). Yet, its role as a habitat and movement corridor is increasingly threatened by agricultural land-use changes. Meanwhile, local communities lack nature-based livelihood alternatives, despite holding rich ecological Indigenous knowledge, including exceptional animal tracking skills.

This thesis asks: **What is the current status of large wildlife species populations within the WKCC, and can track surveys serve as a reliable wildlife monitoring method while also promoting coexistence and conservation?** The aim is to inform future land-use strategies that support both the WKCC's ecological function and local communities, highlighting the value of tracking-based livelihoods in this effort.

I first refined a century-old method of wildlife density estimation from track surveys, the Formozov-Malyshev-Pereleshin formula. Despite areas for further improvement, it proved to be a promising reliable wildlife monitoring tool. Using these refinements, I generated spatial insights into wildlife density, its spatial variation and movements across the northern WKCC. The area still retains its ecological function, albeit unevenly, for all studied species. However, the demonstrated impact of expanding livestock farming questions its long-term viability.

Marie-Charlotte, born in 1992 (Belgium), earned a Master's in Biology of Organisms and Ecology (UCLouvain) in 2015. That year she joined Cheetah Conservation Botswana's research team before starting her PhD in 2018. She spent a decade in the Kalahari, studying animal tracking and wildlife-community dynamics, in collaboration with the Botswana government, while also consulting for research and conservation projects.



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To the Kalahari,

To the Wild,

To the Track Readers,

Preface

This PhD thesis in conservation biology advances track survey methodology to assess wildlife densities, their spatial variation and movements within a key Kalahari conservation corridor. It also investigates how environmental and anthropogenic factors, particularly livestock farming, affect these parameters. By integrating the ancient practice of animal tracking with modern technology, this work presents a powerful and accessible approach to monitor and help preserving wildlife and habitats while supporting local communities.

Chapter 1 explores the (hi)story that shaped the Kalahari into its current state, highlighting the challenges the region faces regarding human-wildlife dynamics and the resulting wildlife decline. It sets the stage by explaining the relevance and context of this research within the broader conservation landscape.

Chapter 2 outlines the track survey methodology used as the primary data collection approach in this study —the Formozov-Malyshev-Pereleshin (FMP) for estimating absolute wildlife population abundance. It explains why the Kalahari's environment is well-suited for animal tracking and describes the practical process of counting animal tracks.

Chapter 3 addresses the probability of track detection by observers in large-scale driven track surveys, particularly within the FMP formula framework. Detectability has long been a critical issue in species conservation, as unmeasured or variable detectability can introduce significant biases in density estimates and related parameters. This chapter establishes a robust foundation for the data analysis and interpretations presented in subsequent chapters.

Chapter 4 expands on detectability by explaining how the probability of an animal crossing the transect is integrated into the FMP formula. It focuses on refining its critical parameter —the species' average daily travel distance estimate— to enhance the accuracy of population density estimates. The chapter demonstrates how traditional trailing techniques can effectively support this objective.

Chapter 5 demonstrates the practical application of tracking knowledge as a research and conservation tool. In the wildlife-livestock co-occurrence zone of the Western Kalahari Conservation Corridor, track counts along transects

were used to estimate wildlife density, identify influencing variables, and map higher species density areas and possible movement pathways. The findings aim to guide wildlife conservation, enhance human-wildlife coexistence, and inform future land-use planning in this unique region.

Chapter 6 serve as the general discussion and conclusion of this work, structured in two parts: the first reviews the overall research findings in light of the overarching question posed by the thesis, while the second offers a personal reflection on the conservation of the Kalahari landscape. The latter draws on concepts from evolutionary biology and socio-economics to propose a way forward in addressing the ecological crisis —particularly within the context of the Kalahari— through the concept of ‘reconnection with the rest of nature’.

More than the scientific value of this dissertation, this journey was driven by my passion. I was fortunate enough to set foot on the “Land of the Tswana” nearly a decade ago in 2015 during my Master’s degree. My time working at the research department of Cheetah Conservation Botswana in Ghanzi, within the largest farmlands of the Kalahari, deepened my understanding of the area and showed me its importance as one of the few remaining areas on Earth where large mammals still prevail. But also, where an amazing Indigenous knowledge can be still found nearly intact with some inhabitants.

From this experience arose the strong feeling of wanting to strive for what I believe in, which is the preservation of the natural world, which gives us what we need to survive, its beauty, and the ability to enjoy whatever that is what we enjoy. That is nothing new, one cannot only take without also giving, which is basically the concept of sharing. In fact, we do share common land with all other living and non-living elements on this planet. That is precisely how the San, the descendants of the first human lineages on Earth, originally led their lives in the Kalahari as gatherer-hunters. They knew, and their knowledge is one very precious legacy of humankind. Unsurprisingly eroding, as the wind of modern society blows in.

So today I’m looking at another Kalahari sunset, after a hot day. The smell of the warm sand, the breeze slowly travelling in between the bushes, finally breathing. The sounds of the birds fading. Soon the geckos will start barking in concert. The setting sun is bright red on the flat horizon, boundless harsh savannah. That’s my favourite moment of the day, so peaceful and soothing contrasting with the intensity, even difficult at times, of the wilderness. Maybe it’s time for a short walk to clear out the thoughts of the day, looking at the countless tracks of life in the sand. Tracks of life. What are they telling

us? When you get to learn to know them, not only are they beautiful drawings, but now they start telling you their story. Of the life which drew them. And life is a story, with a beginning and an end just like the day, a cycle starting again like a new chapter the next day. And this story is our best teacher about our own character and its role.

So, let me tell you a story, the one of the great Kalahari, or at least a piece of it, the play I was lucky enough to take part in. Because it taught me so much, I also would like to give it something back, first by offering you to get to know it. Then, by suggesting how to practically apply research findings into meaningful actions on the ground now, in order to preserve the Kalahari's future. Finally, I will let you, track makers, write the next chapters of this story. Make them good. "It" deserves it. You will see then, "It" will make you happy as you give back happiness too. Share.

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Secondly, I express my deep gratitude to the members of my supervisory committee. Dr. Derek Keeping, who first introduced me to tracking in my early years in Botswana and shared the passion that now drives me. From a research colleague to a mentor, you have been a constant source of inspiration and guidance. Thank you for involving me in various Kalahari projects. Dr. Leanne Van der Weyde, my research coordinator during my time at Cheetah Conservation Botswana (CCB), you have been a role model of capability, both in the field and in academia. You inspired me as a woman trying to pursue a similar path. Dr. Viktoriia Radchuk, I deeply appreciate your thoughtful and committed guidance during the analysis of my final study, especially within a short timeframe. Finally, I thank Prof. Eric Lambin for his insightful guidance on the geographic aspects of my thesis and for inviting me to attend his courses in my early years.

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A Lion's Share: Mitigating Human-Wildlife Conflict in New Xade:

<https://www.cheetahconservationbotswana.org/news/a-lions-share-mitigating-human-wildlife-conflict-in-new-xade>

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<https://creativecommons.org/licenses/by-sa/4.0/>

Children in the Wilderness:

<https://www.childreninthewilderness.com/>

CyberTracker:

<https://www.cybertracker.org/>

Engagement and Awareness-Raising:

<https://www.cheetahconservationbotswana.org/engagement--awareness.html>

Farmers' competition winners go on safari!:

<https://www.cheetahconservationbotswana.org/news/farmers-competition-winners-go-on-safari>

Greater Karoo & Kalahari Drylands bioregion:

<https://www.oneearth.org/bioregions/greater-karoo-kalahari-drylands-at9/>

Herding for Health:

<https://www.herding4health.net/>

Kalahari Camelback Trackers Project:

<https://tanate.org/kalahari-camelback-trackers/>

Meat Naturally:

<https://www.meatnaturallyafrica.com/>

Movebank:

<https://www.movebank.org/>

PDM 1.0:

<https://creativecommons.org/publicdomain/mark/1.0/>

The Old Way:

<https://www.theoldway.info/>

Tracking the Kalahari:

<https://www.trackingthekalahari.org/>

Video: Learning to rewild:

<https://www.youtube.com/watch?v=Lqzwbpc5o4>

Video: The Persistent Hunt:

https://www.youtube.com/watch?v=826HMLoiE_o&t=2s

Wild Entrust:

<https://www.wildentrust.org/post/cc-s-bushday-initiative-is-changing-views-on-human-wildlife-conflicts>

White Man's Game:

<https://us.macmillan.com/books/9780805097177/whitemansgame/>

List of Acronyms

AICc	Akaike Information Criterion corrected for small sample sizes
AIC	Akaike Information Criterion
AUC	Area Under the curve
BCa	Bias corrected and accelerated
CCB	Cheetah Conservation Botswana
CFA	Commercial Farming Area
CGA	Communal Grazing Area
CKGR	Central Kalahari Game Reserve
CMR	Capture-Mark-Recapture
COVID	Coronavirus Disease
CTSD	Continuous-time speed and distance
$\hat{D}$	Population density estimate
df	Degrees of freedom
DWNP	Department of Wildlife and National Parks (of Botswana)
FMD	Foot and Mouth Disease
FMP	Formozov-Malyshev-Pereleshin
GPS	Global Positioning System
H4H	Herding for Health
HII	Human Influence Index
HRCIW	Half Relative Confidence Interval Width
ICS	Index Calibration Survey
ILUMP	Integrated Land Use Management Plan
IUCN	International Union for Conservation of Nature
KALARIVA	Kalahari-Rift Valley
KGR	Khutse Game Reserve
KTP	Kgalagadi Transfrontier Park
LCL	Lower Confidence Limit
LEC	Leopard Ecology & Conservation
$\hat{M}$	Daily travel distance estimate
MAE	Mean Absolute Error
MSAVI	Modified Soil-Adjusted Vegetation Index
NGO	Non-Governmental Organisation
m_2	The number of tracks collected both by Team A and Team B
n_1	The total number of tracks collected by Team A
n_2	The total number of tracks collected by Team B

PA	Protected Area
PEC	Payments to Encourage Coexistence
PES	Payments for Ecosystem Services
$\hat{p}_1$	Probability that the animal movement paths intersect with the transect at least once
$\hat{p}_2$	Probability of track detection by the observers
p value	Probability value
r	Pearson's correlation coefficient
S	Total transect length
SD	Standard Deviation
SE	Standard Error
SGL	Special Game Licenses
TFCL	Transfrontier Conservation Landscape
TGLP	Tribal Grazing Land Policy
UCL	Upper Confidence Limit
UCLouvain	Université catholique de Louvain
x	Observed track count
$\hat{x}$	Estimated track count
$\frac{\hat{x}}{s}$	Estimated track index
X^2	Chi-square test statistic
WKCC	Western Kgalagadi Conservation Corridor
WMA	Wildlife Management Area
WP	Working Package

