



Free-Roaming Cheetah Census – South Africa 2022 to 2025

Marna Smit¹  Nynke Wemer^{2,3} 

¹ Corresponding author, Ashia Cheetah Conservation, Paarl, South Africa,

² Behavioural Physiology and Ecology Group, Groningen Institute for Evolutionary Life Sciences (GELIFES), University of Groningen, Groningen, the Netherlands

³ Postdoctoral Researcher, Groningen, the Netherlands

Publisher: Ashia Cheetah Conservation NPC (www.ashia.co.za)

FRCC logo: Marna Smit, marna.smit@ashia.co.za

Photographs: COT (pages 14,29), Kagiso Masinge (pages 14,19), Louis Heyns (page 19), Nynke Wemer (page 14), local farmers (pages 14, 68)

Layout: Marna Smit & Nynke Wemer

Copyright © 2026, Ashia Cheetah Conservation

 **CC BY-ND 4.0**

The data is licensed by Ashia Cheetah Conservation NPC as creator under the Creative Commons Attribution-No Derivatives 4.0 International license (CC BY-ND 4.0 International). This license requires that users of the FRCC data or part thereof give credit to the creator. It allows new users to copy and distribute the material in any medium or format in non-adapted form only, even for commercial purposes.

Table of Contents

Abbreviations.....	4
Project summary and abstract.....	5
1. Introduction & Context.....	7
1.1 Management challenges.....	8
1.2 Knowledge gaps.....	9
1.3 Global implications of the FRCC.....	9
2. Study area.....	10
3. Census methods.....	12
3.1 Questionnaires.....	12
3.2 Camera Trapping.....	13
3.3 Public sightings.....	17
3.4 Telemetry.....	17
3.5 Scat.....	18
3.6 Genetics.....	19
4. Results.....	21
4.1 Farm land-use.....	21
4.2 Individuals.....	23
4.3 Telemetry.....	30
4.4 Dietary Results.....	36
4.5 Activity behaviour.....	39
4.6 Subjective landowner observations versus objective presence data.....	43
4.7 Genetics.....	48
5. Policy and Management in South Africa.....	54
6. Census logistics and resources.....	56
7. Conclusion.....	60
8. Case studies.....	64
8.2 Persistence under pressure: cub survival in a challenging landscape.....	64
8.3 Site loyalty in the Northern Cape.....	66
8.4 Persecution without prosecution: tolerance and enforcement gaps in a human-dominated landscape.....	68
8.5 Rare king cheetah sighting in the study landscape.....	69
Special Acknowledgements.....	70
References.....	72
Appendices.....	78

Abbreviations

Abbreviation

Definition

ACC	Ashia Cheetah Conservation
AWCRC	Alldays Wildlife and Communities Research Centre
AWT	African Wildlife Tracker
BMP	Biodiversity Management Plan
CAG	Cheetah Advisory Group
COT	Cheetah Outreach Trust
DNA	Deoxyribonucleic Acid
ESV	Exact Sequence Variant
FPIC	Free, Prior and Informed Consent
FRCC	Free-Roaming Cheetah Census
FTE	Full time equivalent
FTM	Field team member
GPS	Global Positioning Systems
GSM	Global System for Mobile Communications
IUCN	International Union for the Conservation of Nature
IZW	Leibniz Institute for Zoo and Wildlife Research
NCBI	National Center for Biotechnology Information
NEMBA	National Environmental Management Biodiversity Act
NGO	Non-governmental Organization
NP	National Park
NPAPC	National Problem Animal Policy Committee
PA	Protected Area
PCR	Polymerase Chain Reaction
ppl	People
QDGC	Quarter degree grid cell
RUG	University of Groningen
SANBI	South African National Biodiversity Institute
SMS	Short Message Service
SOP	Standard Operating Procedure
SSR	Simple Sequence Repeat
ST	SpoorTrack
TBD	To be determined
TP	Transfrontier Park
TOPS	Threatened or Protected Species
Vu	Vulnerable

Project summary and abstract

In South Africa, cheetah are managed across four distinct populations: the captive population, the metapopulation in private fenced game reserves and national parks, semi-protected populations in Kruger National Park (KNP) and Kgalagadi Transfrontier Park (KTP), and the free-roaming population persisting on private and commercial farmlands along the borders with Namibia, Botswana, and Zimbabwe [58]. The first free-roaming cheetah population estimates (~600 individuals) in South Africa date back to 2002 [6], relying heavily on regionally isolated population studies with minimal data [79]. Subsequent and more recent estimates lower than ~600 individuals, have likewise depended on modelled densities derived from localised study populations [97]. Given the documented 76% decline in average African wildlife populations between 1970 and 2024 [100], these largely model-based estimates are likely outdated and underscores the urgent need for robust national census data. With national policy documents explicitly stating that "no reliable estimates for the wild population are present" [66], Ashia Cheetah Conservation (ACC, South Africa) initiated the development and coordination of the Free-Roaming Cheetah Census (FRCC; the Census) in 2021, with fieldwork beginning in October 2022. This multi-year initiative (2021-2026) collaborates with Cheetah Outreach Trust (COT, South Africa) and the University of Groningen (RUG, Netherlands).

Of the official IUCN cheetah range in South Africa (~130,000 km²), **the census focused on ~99,800 km²** of unprotected free-roaming cheetah habitat in the Northern Cape, North West, and Limpopo provinces along the country's northern border. This study area consists primarily of livestock, game and agricultural farming, interspersed with protected unfenced wildlife areas, cities, towns, and large rural settlements [51]. Throughout the fieldwork period, areas of high human densities, fenced game reserves and national parks, geographical barriers such as mountains were systematically validated year by year by the field team to be inaccessible. This left a total area of ~73,200 km² in which to specifically execute camera-trapping. Additionally, due to the high population density running through the middle of the IUCN range between Mahikeng in South Africa to Gaborone in Botswana, the assumption was made that this acted as an artificial barrier for natural cheetah movement. For this reason, Northern Cape and most of North West were grouped as **Region 1**, and a smaller portion of North West and Limpopo as **Region 2** (Fig. 3).

The fieldwork during the FRCC involved multiple teams conducting farmer/landowner **interviews (N = 299)** for perceived predator/cheetah presence and conflict, land-use, and livelihood impacts. The team also executed systematic **camera-trapping (>5.2m images)** for actual cheetah presence and individual identification, genetic sampling through **scat (N = 164)** and **blood collection (N = 33)**, and **GPS collaring (N = 20)** to track movements and reveal potential fragmentation barriers.

Population counts were based on standard population estimates, just taking adult individuals older than 24 months into consideration. A total of 119 unique cheetah individuals were identified, **of which only 83 were adult cheetah**, distributed between Region 1 (Northern Cape + North West; N_{Adults} = 33; Table 4) and Region 2 (North West + Limpopo; N_{Adults} = 50; Table 4). The identified individuals reside in a highly fragmented landscape largely caused by differing land use, fencing types, and human population density. Although predators on farmland are often indiscriminately targeted due to perceptions of livestock predation, cheetah are more frequently observed during the day, early morning and early evenings, contributing to them being disproportionately blamed for livestock losses. However, DNA sequencing confirmed that **no livestock** (i.e. cattle, goat, sheep and chicken) **were found in the samples** and at least 52% of the scat samples with prey detected were small game species.

Telemetry data and camera-trap data reflected the cheetahs' activity patterns as well as the **movement differences between the two main study regions: Region 1** has a more open, arid landscape with extensive connections to Botswana, while **Region 2** is more constrained and essentially functions as an isolated population with minor movement between Botswana, protected areas in southern Zimbabwe and South Africa, particularly

due to dense human settlement and impermeable (game) fencing. This fragmentation prevents connectivity between the regions which in turn increases isolation and potential inbreeding.

Nonetheless, genetic results are still indicative of a relatively connected population. At this stage, biological fragmentation between the two regions does not appear to be strong **yet**, suggesting that until now or at least recently the gene flow has occurred and the two regions have been genetically connected. However the ecological evidence does point to increasing restriction of movement between the regions, particularly where human population density and impermeable fencing create barriers. Genetic differentiation in long-lived mammal populations, like the cheetah, often becomes detectable only after several generations, typically in the order of 5–15 generations. Given a cheetah generation time of ~4–6 years, this suggests that **measurable genetic structuring may lag behind landscape fragmentation by several decades** [2][33]. **Thus, although full genetic separation has not yet occurred, the conditions are in place for this process to continue if connectivity declines further and population numbers remain below 100** [68]. This provides an important conservation opportunity: if connectivity can be maintained, genetic exchange may support population resilience and reduce long-term isolation risk.

The FRCC findings have direct relevance for national and international policy change. The substantially lower population number identified reflects a combination of improved survey accuracy resulting from the first coordinated cross-country census, as well as ongoing population declines driven by habitat loss, landscape fragmentation and anthropogenic pressures. The Regional Conservation Strategy for Cheetah and Wild Dog in Southern Africa (2015) adjusted the population estimate for free-roaming cheetah in unprotected range in South Africa to ~300 individuals [73]. This new count contributed to the population data utilized by the IUCN Red List Assessment (2021), which estimated ~3526 adult individuals in Southern Africa, retaining its Vulnerable status [26]. In contrast, **the FRCC detected a minimum of 83 adult individuals, representing estimates approximately 72% lower than previously assumed**. Given that the FRCC was the first coordinated multi-year census across free-roaming cheetah range in South Africa, incorporating extensive detection methods across a three-year field period, it is unlikely that a substantial proportion of the population remained undetected. This finding points toward the potential **reclassification of the national free-roaming population to Endangered status under the Regional Red List of South Africa** criteria [29], despite the species not necessarily qualifying as Endangered globally just yet. The study also supports **updating the IUCN range** for southern African cheetah in South Africa. The new range should be based on a combination of confirmed cheetah occurrence, potential suitable habitat, land-use, fragmentation, and social factors affecting the persistence of cheetah in the landscape.

Additionally, the FRCC data are intended to inform the ongoing South African **Biodiversity Management Plan** for cheetah and should be used to strengthen future monitoring and reporting. The report highlights the need for coordinated action across the different cheetah populations in South Africa, including free-roaming cheetah, the semi-protected populations in Kruger NP and Kgalagadi TP, the metapopulation in fenced reserves and the captive population. A more connected national, and eventually southern African regional approach will be essential if South Africa is to maintain viable free-roaming cheetah populations into the future.

Key partner contributions included 1) **Ashia Cheetah Conservation**; primary funder of the FRCC, providing ~70% of the camera traps, 75% of the Global Positioning Systems (GPS) collars, miscellaneous field equipment, continuous in-field staff, management of the timeframe and field coordination. 2) **Cheetah Outreach Trust**; the lead on cheetah capturing, GPS collaring and monitoring. They also provided part of the cameras used in the field and dedicated a significant portion of their time to additional FRCC fieldwork. 3) **University of Groningen**; the PhD student from RUG collected data during an eight-month field period and further analysed all incoming fieldwork data throughout the census. The university provided the funding for the student in the form of a monthly salary. The student acquired additional funding from the 4) **Dr. D.L. Dobberke Foundation** (Dobberke/2229/202225) and 5) the **LNVH Advancing Women in Biology Fund** for travel between countries and a part of the cameras used in the field.

1. Introduction & Context

The Southern African free-roaming cheetah (*Acinonyx jubatus jubatus*) range, modelled by the IUCN to reflect potential suitable habitat based on environmental features rather than confirmed sightings [76], extends across most of southern Africa, crossing Angola, Namibia, Botswana, Zambia, Zimbabwe, Mozambique and South Africa (Fig. 1). This once suitable range is now heavily affected by the growing human population and its accompanying influence on climate and environment, as human settlements and infrastructure encroach upon the cheetah's natural habitat. By 2050, the African human population is expected to have grown to 2.5 billion, a 63% increase of the ~1.55 billion in 2025 [84], suggesting that even further range contraction and loss will be inevitable.

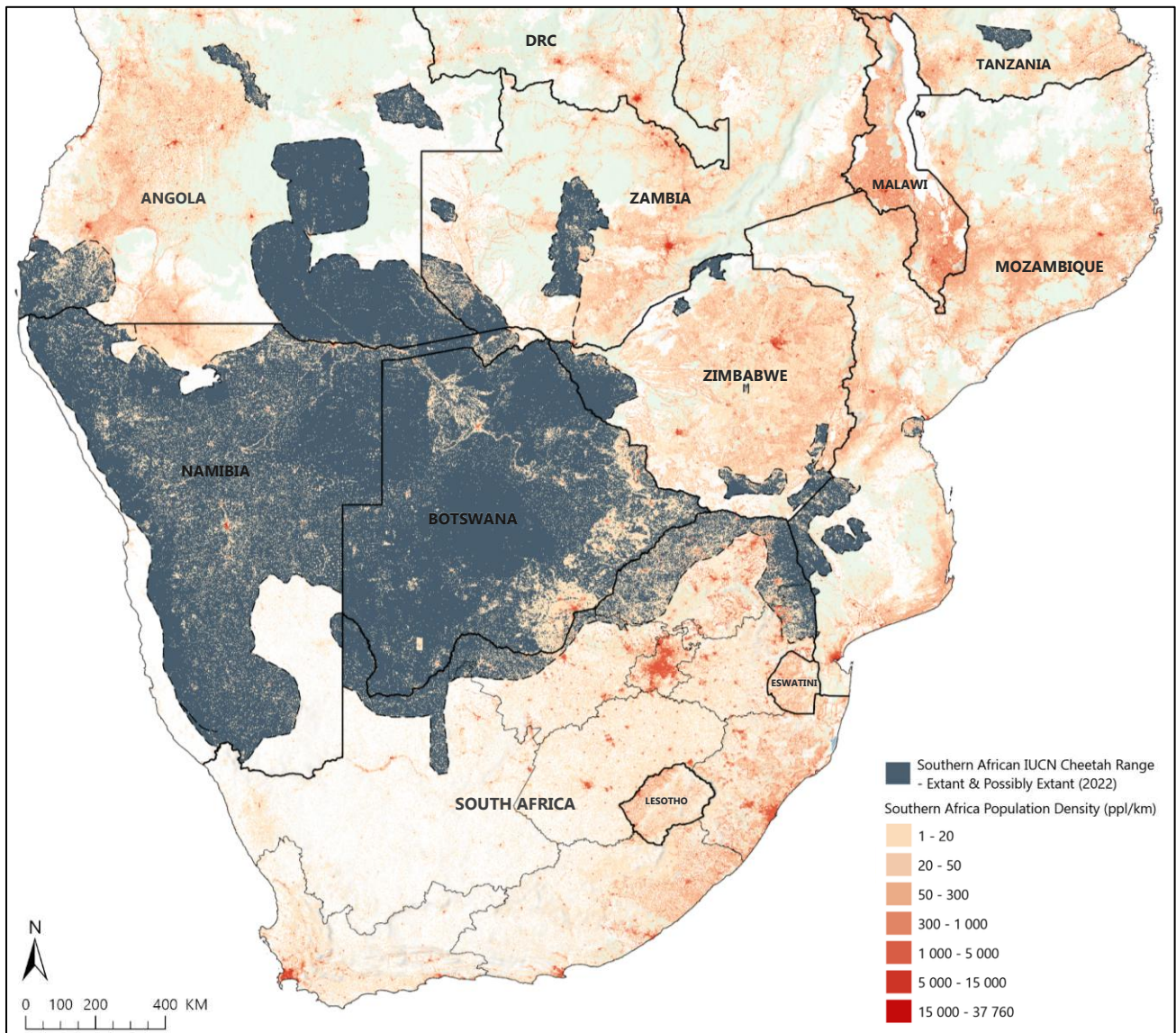


Fig. 1: Map of Southern Africa with IUCN *A. jubatus jubatus* range (2022) with human population density overlap showing the fragmentation and loss of potential cheetah habitat to further human settlement.

South Africa has the 6th highest population density in Africa, with approximately 63 million inhabitants unevenly spread across nine provinces with higher densities along the coast and in large cities [35]. Northern Cape is the least populated, with an estimated population of 1.4 million people at 4 ppl/km², followed by North West with 4.2 million people at 40 ppl/km², Mpumalanga has 5.1 million people at 64 ppl/km² and Limpopo has 6.4 million people at 50 ppl/km² [73].

South Africa's free-roaming cheetah population inhabits one of the most fragmented and human-populated areas of the species' southern African IUCN range, concentrated along the northern border of the Northern Cape, North West and Limpopo provinces (Fig. 2) and consists of approximately 130,000 km² potentially suitable habitat [32][56].

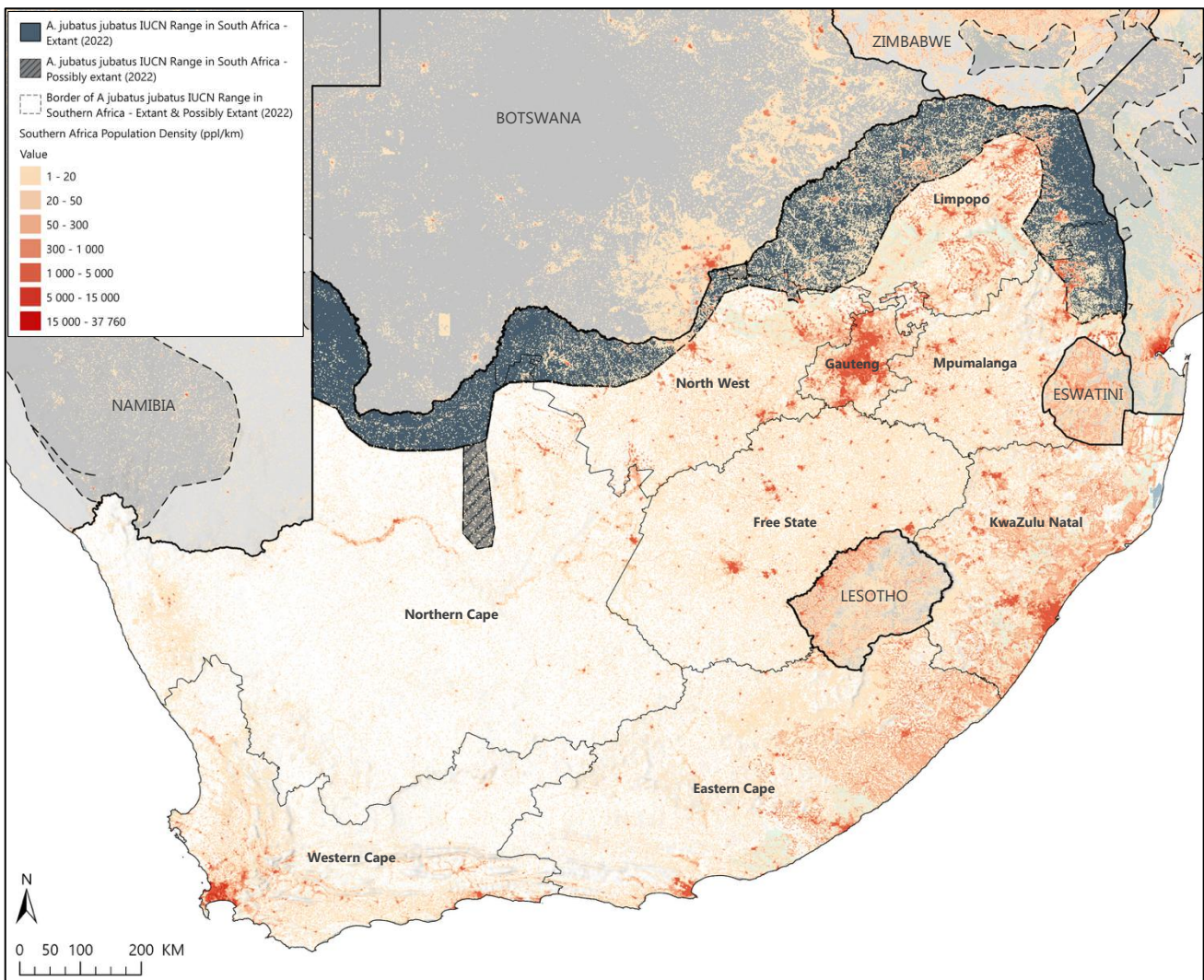


Fig. 2: The Southern African IUCN cheetah range with a population density overlay depicting the ongoing fragmentation of previously suitable habitat within South Africa.

Within this 130,000 km² are semi-protected/fenced areas, such as Kgalagadi TP and Kruger NP, fully fenced NPs and private game reserves, urban settlements, towns and cities. Moreover, this range spans a highly fragmented region encompassing ~17,000 farms, forming a mosaic of private and communal lands [28]. Kgalagadi TP and Kruger NP have their own managed cheetah populations [32][13], with low confidence of confirmed natural dispersals in or out of these protected areas (PAs) within South Africa. This makes South Africa a critical area as it holds the southernmost extent of the largest contiguous cheetah range on the continent where fragmentation from various farming practises, (semi-) permeable fencing, and human settlement are main factors of free-roaming population decline [43][69].

1.1 Management challenges

Habitat and land fragmentation restricts animal movement by creating barriers that limits dispersal between populations. This hinders gene flow, increasing the risk of potential inbreeding, and subsequent reduced genetic diversity. Along with limited genetic flow, South African free-roaming cheetah face acute threats from (perceived) livestock/game depredation leading to persecution, road fatalities, and natural prey depletion due

to landscape change [19][74]. This is exacerbated by the country's high human population density (52.8 ppl/km²) and intense farmland fragmentation compared to its surrounding countries like Botswana and Namibia (4.4 ppl/km² and 3.7 ppl/km² respectively; [35]), where vast farmlands enable cheetah movement across larger, less obstructed ranges [8][20][56][94]. With ~75% of South African cheetah range outside fenced PAs, this demographic pressure heightens human-wildlife conflict, demanding targeted management [26][94][53].

Current government conservation strategies and policies lag to maintain and conserve the South African free-roaming cheetah population. Initial calls for a Biodiversity Management Plan (BMP) emerged in 2009 via the South African Action Plan for Cheetah and African Wild Dog Workshop under the National Environmental Management: Biodiversity Act [67], but progress stalled until ACC's 2021 and the Cheetah Advisory Group's (CAG) 2023 efforts, however still no finalised BMP exists. This leaves population genetics neglected, persecution weakly regulated, and potential compensation schemes inadequate, inconsistent or narrowly targeted [3][63][96]. High levels of livestock and game farming make depredation from any predator species one of the most perceived top loss drivers in South Africa, and predatory tolerance is eroded due to financial consequences of high theft, disease and weather pressures and the increase of human infrastructure [60]. This lack of consistent predator management, combined with the ongoing fragmentation of South Africa's landscape, highlights the importance for new, empirical data.

1.2 Knowledge gaps

Reliable data on the current condition of South African free-roaming cheetah is missing. Cited literature is outdated, done on a small-scale or within PAs, and most studies use theoretical models rather than actual observations. Prior estimates of the free-roaming population numbers in South Africa, through theoretical modelling, ranged from 600 individuals in 2002 to 400-800 in 2021 [26][6][97]. The application of theoretical models to management decisions can be constrained by incomplete occurrence data or poor range representation, which hinder accurate species distribution and number estimates and give unreliable predictions when extrapolated across large, unsampled areas [16][54]. Despite this, these early studies did provide invaluable initial insights, highlighting population declines, pinpointing cheetah hotspots, and establishing a moderate understanding of free-roaming distribution and threats in this fragmented landscape. However, consistent landscape transformations, changes in prey availability, human population growth, and the intensification of human-cheetah conflict make it difficult for publications to keep up [14][50], resulting in decision-makers to rely on old figures obtained in only a fraction of the landscape.

The goal of the FRCC was to fill this knowledge gap by gathering directly observed data via landowner surveys, systematic camera trapping, the collection biological samples, and satellite collar tracking within the South African IUCN range. Outcomes include individual identifications for an accurate cheetah count, perceived presence and conflict mapping, genetic analysis for inbreeding, diet analysis to identify favoured prey species, and confirmation of extent of cross-border movement between range countries, replacing assumptions with factual, range-wide data.

1.3 Global implications of the FRCC

By providing updated South African free-roaming cheetah data, the global IUCN assessments can be revised to portray its true state. The cheetah (*A. jubatus*) is classified as Vulnerable (Vu) and current estimates are that southern Africa holds >50% (~3,526 mature individuals) of the remaining global population [26], with South Africa responsible for 10% (~300 mature individuals) within this southern extent [72], but numbers obtained within the FRCC will adjust these estimates substantially downwards. As South Africa makes up the southern range edge, the FRCC informs transboundary connectivity, inbreeding risks resulting in low genetic diversity, and policy like BMPs, influencing Red List updates, funding, and strategies to hopefully slow further global decline of the free-roaming cheetah range (already 91% loss of historic range; [25]).

2. Study area

The aim of the census was to more accurately estimate the South African free-roaming cheetah population size and occurrence outside of fenced/actively monitored PAs within the current IUCN range. Thus the following was excluded from the census: Kgalagadi TP and Kruger NP, the ~13,000 km² range in Mpumalanga (no confirmed free-roaming cheetah sightings; human settlement barrier causing separation from the cheetah population in Limpopo), a portion of the possible extant range in the Northern Cape looping southward (historically no free-roaming individuals have been confirmed) and all fenced PAs such as game or nature reserves. Accordingly, of the total IUCN cheetah range in South Africa (~130,000 km²), the census focused on ~99,800 km² of unprotected range.

Due to the high population density running through the middle of the IUCN range between Mahikeng in South Africa to Gaborone in Botswana, the assumption was made that this acted as an artificial barrier for natural cheetah movement. For this reason, Northern Cape and most of North West, characterized predominantly by semi-arid savannah habitat, were grouped as Region 1, and a smaller portion of North West and Limpopo, dominated by grassland and bushveld habitat, were grouped as Region 2 ([51] ;Fig. 3).

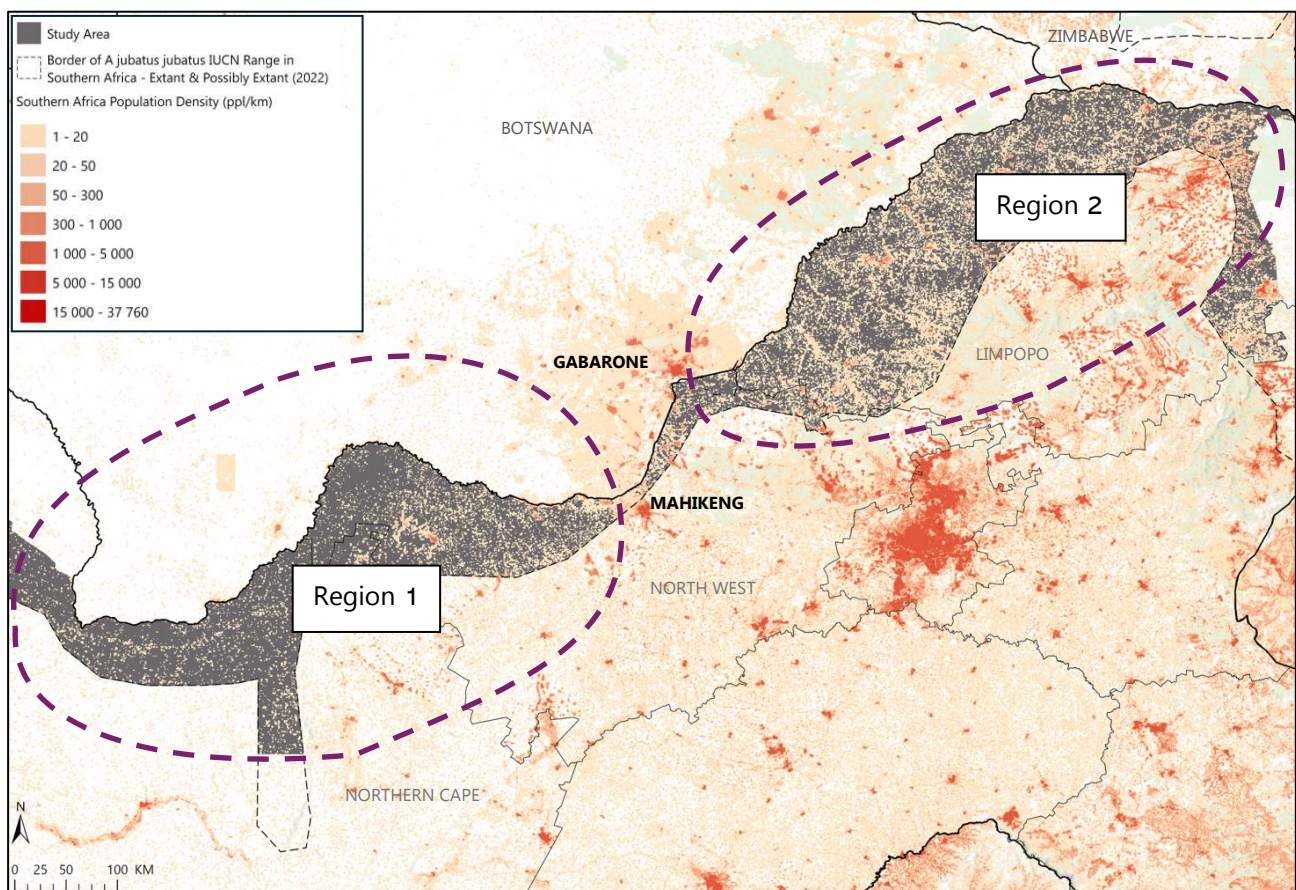


Fig. 3: The division of the study area in Region 1 (Northern Cape + North West) and Region 2 (North West + Limpopo) due to the high human population density between Mahikeng (South Africa) and Gaborone (Botswana).

The census range (~99,800km²) was overlaid with a quarter-degree grid consisting of ~25 x 25 km cells (QDGC; Fig. 4), which ensured a systematic approach to data collection. Each QDGC had its own name based on province, column and row number (i.e. NW_D4 is in the North West province, in column D, row 4). Within this study area, the landscape consists primarily of livestock, game and agricultural farming, interspersed with protected wildlife areas. Additionally, part of the study area contains cities, towns, and large rural settlements.

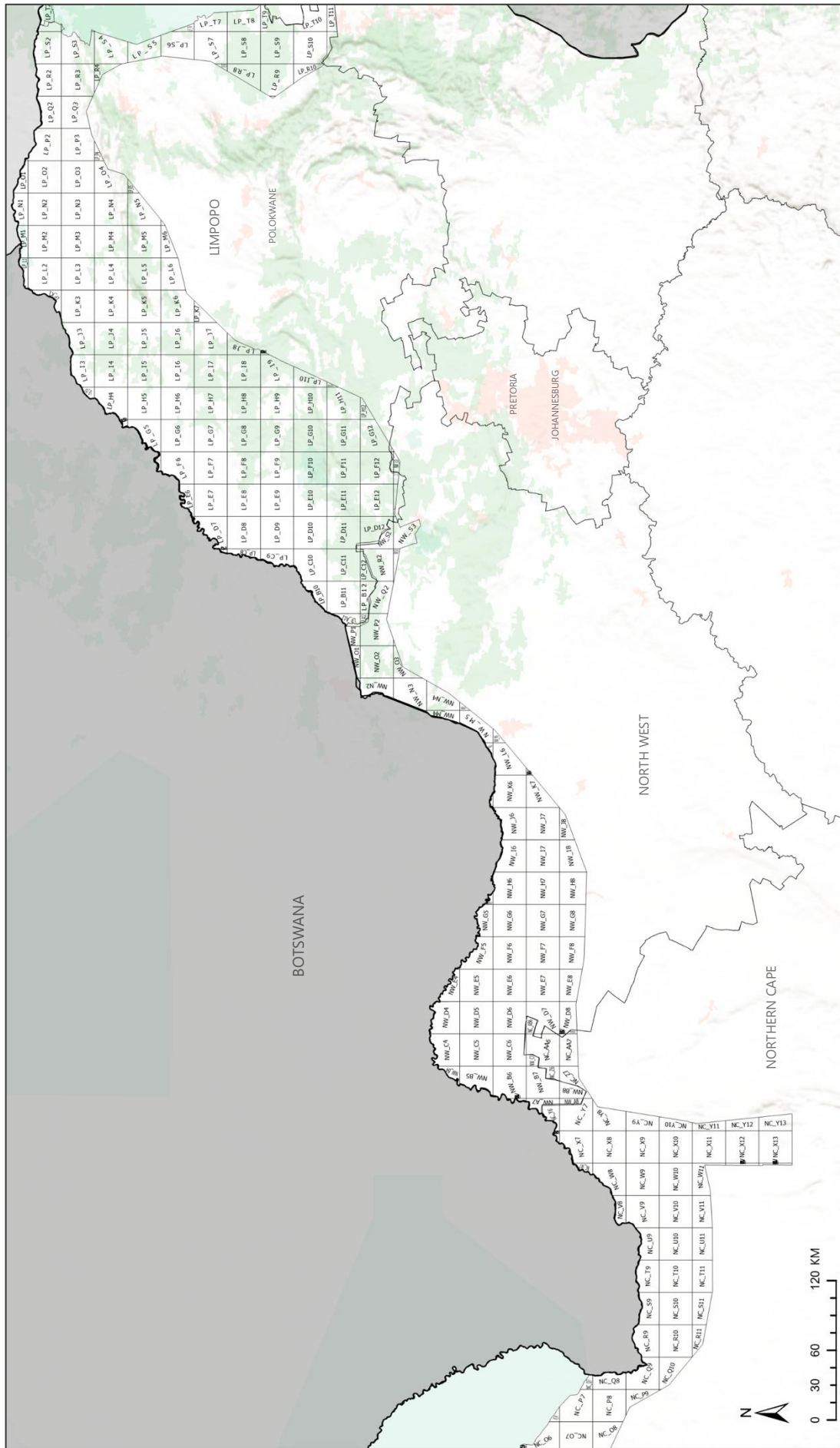


Fig. 4. The study area, minus Kgalagadi TP and Kruger NP, with a QDGC overlay for systematic sampling. The area is overlaid by a total of 261 grid cells.

3. Census methods

The FRCC utilised five survey techniques: questionnaires with landowners/farmers/workers, camera-trapping, biological sample collection (i.e. scat and blood), public sightings and telemetry data from collared individuals.

3.1 Questionnaires

The use of questionnaires was essential for a better understanding of the human attitude towards various species and conservation efforts that camera traps or remote sensing only could not capture. The questionnaire used for the FRCC was developed by the census collaborators in KoboToolbox, a free, online software for collecting and managing data [62], and comprised of 329 questions (Appendix I). Not all questions needed to be answered, as conditional branching (skip logic) questions were used, meaning that many follow-up items were only displayed when participants answered 'yes' to certain questions.

The survey covered a broad range of topics including, but not limited to, general farm and farmer information, land-use practises (agriculture, ecotourism, game and livestock farming), and the presence of and conflict with free-roaming predators. The validity of predator-related responses were analysed with the help of a predator recognition section within the survey (Appendix II). Participants were shown one-to-two randomized full body and fur-only pictures, where they needed to specify the specific predator presented to them.

Questions on livestock/game losses, predator presence and conflict, captured not just self-reported economic costs and species numbers but also emotional and social impacts, revealing tolerance levels critical for predator coexistence on farmlands. Livelihood loss questions quantified predation versus other causes (e.g. disease and theft), while questions related to welfare gave insight into broader hardships like financial strain from lacking adequate fencing or insufficient compensation, informing why farmers tolerate or persecute predators. The combination of perceptive survey data with actual camera trapping and GPS data highlighted biases, such as overestimating cheetah presence despite moderate reports.

3.1.1 Questionnaire spread

The surveys were executed flexibly to maximize participation across the vast study area. Meaning that participants completed them independently via an online KoboToolbox form, with a fieldwork team member physically present, or telephonically. All participants were informed of the study's purpose, procedures, and potential risks, and Free, Prior and Informed Consent (FPIC) was obtained in accordance with established social-science protocols [47]. Respondents could choose to remain anonymous, which promoted honest reporting of sensitive information and reduced bias, particularly regarding controversial practices. The questionnaire spread primarily through word-of-mouth among farmers, amplified by flyers featuring a direct link and QR code to the survey for easy access. To boost appeal, COT offered prizes; extensive toolboxes, an MSC cruise to Mozambique and a tourism package to the Limpopo Lowveld, with winners randomly selected at the end of each census year. Non-anonymous participants received follow-up contact from FRCC team members, inviting them to join an already established WhatsApp group of >200 farmland owners. This platform shared census updates, cheetah sightings, farmer opinions, and contacts. Such engagements built lasting trust and might enhance long-term conservation collaborations.

Questionnaire responses were submitted both inside and outside of the study area. Submissions outside the study area (N = 36) were valuable, as reports of absent or present cheetah or other predator sightings beyond their recognized range provided important information for understanding current perceptions of distribution.

For upcoming questionnaire analysis, only responses within the study area were used (N = 299). Response rates were highest during the autumn and winter months, with numbers going up to 30 surveys in August 2024. The holiday periods resulted in calmer months with (close to) zero responses (Fig. 5).

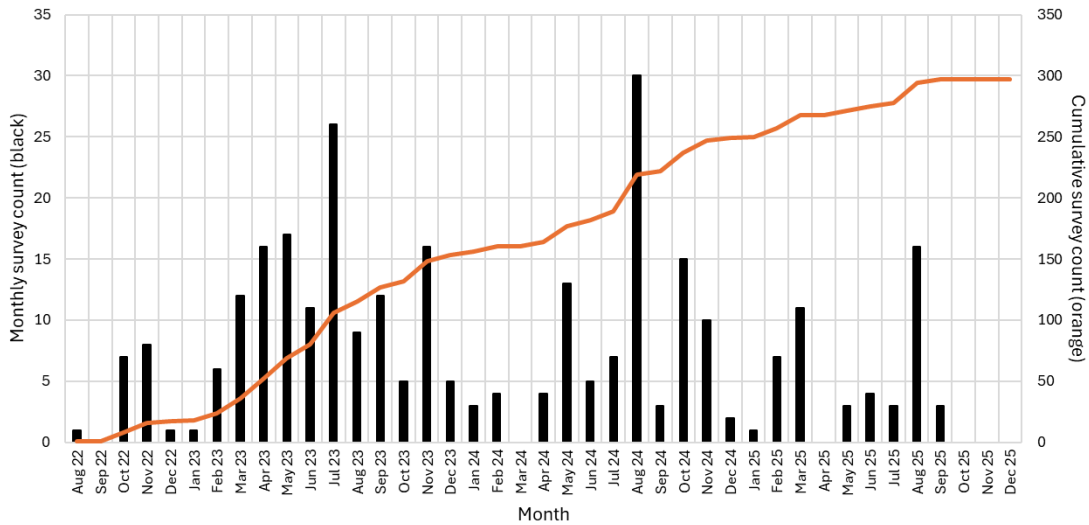


Fig. 5: The cumulative number of surveys during the study (orange line), going up to 299 surveys, and the number of surveys executed in each month separately (black bars).

3.1.2 Importance

The FRCC questionnaire data can help inform South African policy about the extent of **perceived** cheetah presence and conflict to advocate expanded compensation schemes, permeable fencing incentives, and wild prey maintenance on game farms to reduce depredation. Beyond metrics, this questionnaire created a focus that was not only ecology, but also human-centred, which is vital in these human-dominated landscapes and builds necessary social connections with the farmers, fostering trust through face-to-face interactions.

3.2 Camera Trapping

Camera trapping was designed to focus on fine-scale cheetah presence, activity patterns and, most importantly, individual cheetah identification for an accurate baseline of the free-roaming cheetah numbers in South Africa. During the initial phase of the census, camera trap placement was strategically guided by farmer reports of cheetah sightings from the landowner questionnaires, which directed us to high-priority areas of confirmed or perceived cheetah presence. This survey-informed camera placement maximized early detection success across fragmented farmlands, before expanding to broader deployment to also confirm cheetah absences. Throughout the fieldwork period, areas of high human densities (i.e., informal settlements, towns, cities), fenced game reserves and national parks, geographical barriers such as mountains were systematically validated year by year by the field team to be inaccessible for camera-trapping. **This left a total area of ~73,200 km² accessible to specifically execute camera-trapping.**

3.2.1 Preparation

Four quadrants (~12.5 x 12.5 km) were established within each QDGC and used to ensure camera sites were not spaced too far apart, while optimizing limited cameras and resources across the vast study area (Fig. 4). This spacing kept the distances between cameras well within free-roaming cheetah home range sizes, ensuring all individuals had a chance of being photographed at least once. Specifically, single male home ranges could span from 494 to 663 km² (~24 x 24 km), coalitions could go up to 849 km² (~29 x 29 km), and females could range from 241 to 306 km² (~17 x 17 km) [85][70][42]. Quadrants of 12.5 x 12.5 km thus fell within these ranges, increasing the chance of individual capture.

Before going into the field, each camera received a unique, permanent 3-digit label on both the camera itself and the inserted SD card according to the Standard Operating Procedure (SOP; Appendix III).

3.2.2 Sentinel sites

Within each QDGC, potential sentinel sites were identified across the landscape to guide camera trap deployment. These sites may act as communication hubs and therefore have a high likelihood of having cheetah present. Sites were confirmed to be potential communication hubs with cheetah presence from either physical sightings or surveys and the identification of scent marking such as spoor, scat or scratching. Alternatively, areas where cheetah passage seemed most probable due to landscape features like fence gaps or waterholes, were also marked as potential camera deployment options [27][89].

Marking/play trees were the preferred sentinel sites for camera placement, and potential marking trees could be identified by climbable, almost horizontal branches offering vantage points for cheetah [27][55]. Favoured tree species within our study area were the Shephard's/Witgat and Marula tree as these trees often have low-hanging, sturdy branches, allowing cheetah to climb (Fig. 6). Thereafter, fence holes were prioritized if there was a clear animal pathway with predator signs present or, in the best-case scenario, cheetah spoor/fur evidence. Fixed water sources (boreholes, pumps, troughs) provided a final option. These places are not often visited by cheetah due to their low water dependency [89], but they do attract multiple (predatory) species and are used as areas of communication.

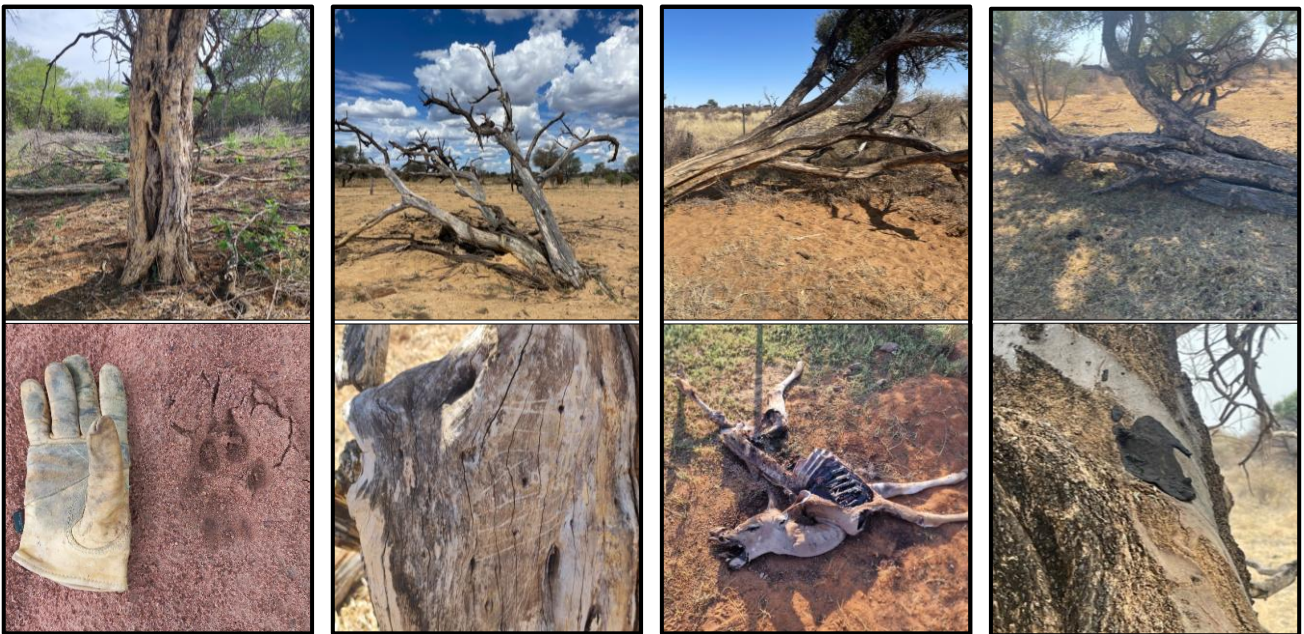


Fig. 6: Four different Shephard's trees, each with their own potential cheetah sign present. Left to right: spoor, scratches, possible kill and scat.

Even in quadrants where no cheetah sightings were reported, cameras were deployed at possible sentinel sites to confirm absence rather than assuming it from perceptions alone. This approach provided empirical evidence of cheetah distribution limits, distinguishing true absence from perceived absence due to under-reporting or tolerance biases in survey data. For a full grid cell (~25 × 25 km, unaffected by borders) to be completed, the aim was to have a minimum of **three** permanent camera sites, each with active camera pairs, distributed across at least three quadrants (Fig. 7). The maximum number of sites were left up to the field staff, as cameras could be moved around the grid to increase capture potential. Sites received unique names combining province code (NC for Northern Cape, NW for North West, and LP for Limpopo), grid identifier (column letter + row number), and a number restarting at 001 per province-grid combination. For example, the

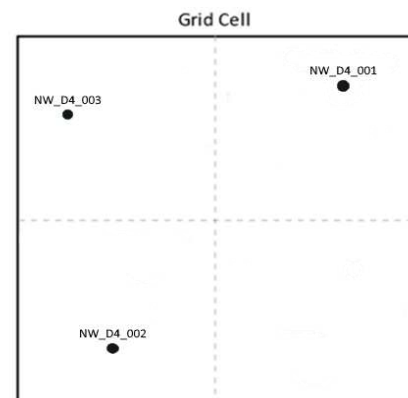


Fig. 7: The identification and naming of sentinel sites in a grid cell divided into four quadrants (dotted lines).

first site identified in grid D4 in the North West province will be called NW_D4_001. Multiple "001" sites could exist across provinces but not within the same grid cell. Cameras could be deployed immediately upon site identification or later on, but the sentinel site number remained fixed to its original location, even during inactive periods without cameras.

3.2.3 Camera placement

The placement of cameras was done in pairs, where two cameras would face the sentinel site in a north-south direction to minimize sun glare during sunset and sunrise, but they would never directly face each other to prevent triggering and blinding the opposite camera with the flash (Fig. 8A). By using two cameras, both the left and right flanks of passing cheetah could be photographed, which was crucial for individual identification based on unique spot patterns (Fig. 8B). In the case of too much uncertainty about the success rate of a newly chosen sentinel site, the site would start of as an unpaired 'recce' site. These sites would only have one camera active for a short period of time to scout the area for wildlife activity. These temporary setups quickly assessed whether a potential sentinel site was suitable to become a paired 'permanent' site for cheetah identification before using too many resources.

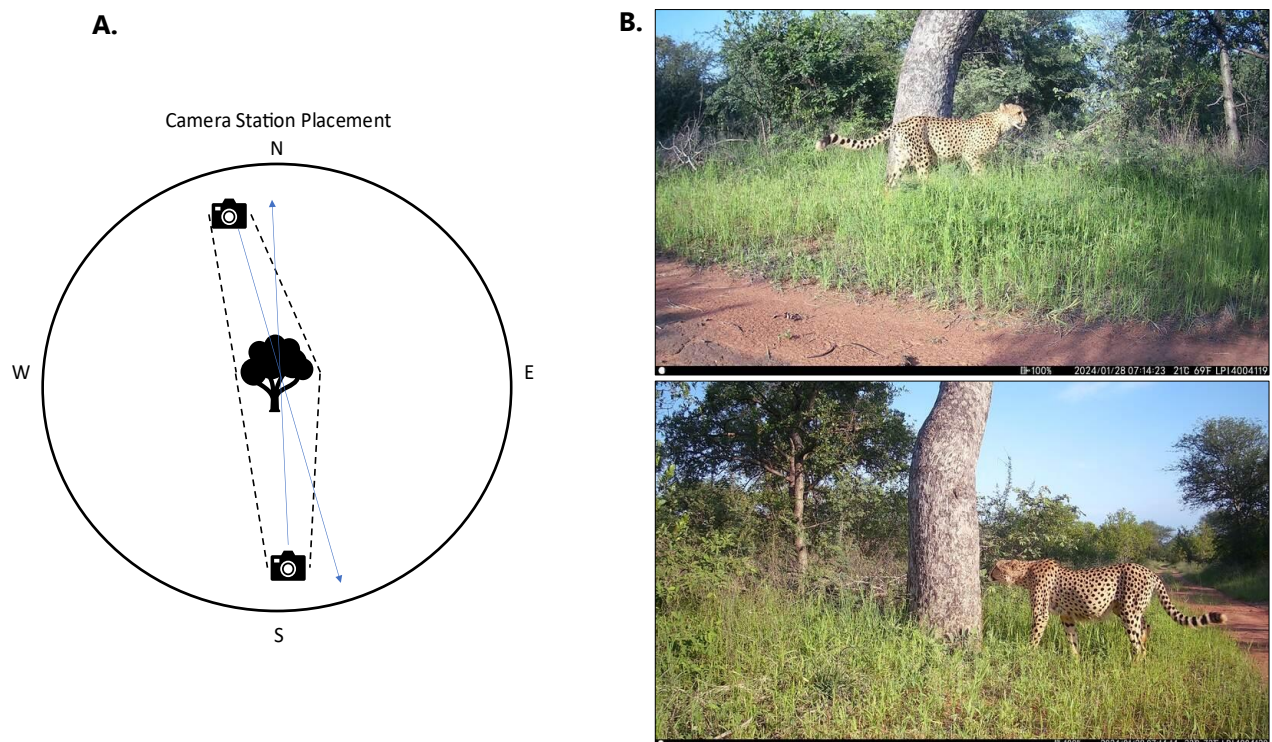


Fig. 8: **A.** Camera trap placement at a play tree in north-south directions, while avoiding direct flash triggers. **B.** The imagery of both left and right flanks of a single individual at the same time for correct identification.

The distance of the cameras from the sentinel site was on average between 5–8 m. Once optimal camera positions at a site were identified, features in the landscape such as fence lines and trees were used for mounting cameras. If this was not available, rough, triangular steel droppers/poles (used for a better grip in the soil compared to smooth, round poles) were utilised and hammered ~20 cm into the ground, extending ~1.80 m above the surface. Cameras were secured inside protective metal cages (when available) and mounted with cable ties/wire at a height of ~1.60 m. This height was optimal for capturing full flank profiles (ideal for cheetah identification) while deterring damage from most wildlife. Before activation, sites were cleared of long grass, overhanging branches, loose twigs and rocks to minimize false triggers. Cameras were configured consistently, with the date and time set to DD/MM/YY HH:MM format. The cameras were set to high trigger sensitivity with 5-second intervals. This sensitivity could be changed lower or higher if needed (e.g. when the site produced

many false triggers, or no images at all). The temperature was set to Celsius, sounds of the camera were disabled, and the overwrite function was turned off to prevent any loss of images.

After camera activation a 'reference sheet' was held up in front of both cameras that provided information on what action was done (camera activation or check), farm name, site ID, date/time and camera numbers. This provided timestamp recovery if cameras reset to default (often to 01-01-2020) from animal impacts or falls and, to factor in human error and location recovery if image folders were labelled incorrectly. When a site was activated for the first time, the aim was that the first site check was executed 48 hours after set-up to confirm if the positioning and photo angles were correct.

After this, preferably 6-8 week servicing intervals for battery/SD card/site maintenance were used, where images of a site were uploaded onto a hard drive in a site-specific folder. These folders were labelled by province, grid, site, camera and the date between which the images were taken (e.g. NW_D4_001 Cam_023 01/01/2023 – 15/02/2023). After emptying the SD card and replacing the batteries, the cameras would get reactivated. Reactivations used identical reference sheets as the initial activation. After each check farmers received ≥ 1 photo per detected species per visit with full image reviews available on request. At times, access to camera sites to meet the 6-8 week servicing window were limited due to heavy rains, unavailable landowners or other logistical complications.

All activations, checks, and retrievals were systematically logged via an online site operations KoboToolbox form created by the census' collaborators, which recorded the date of site identification, location, type of sentinel site including an image, installation dates, placed cameras, and subsequent checks and removals of the cameras (Appendix IV). Subsequently, this information was relayed to an online ArcGIS map for field staff to refer to. By the end of the census, a total of 389 cameras of 11 different models were deployed (Table 1; Appendix V).

While camera sites were primarily retrieved after a grid cell was considered complete (i.e. three camera sites across three quadrants for a period of ≥ 100 days), additional retrievals could occur when a site showed low camera safety. For example, sites were deactivated if one or both cameras were stolen to prevent any further losses, or when certain wildlife presence causes damages by knocking down or rubbing against cameras. Combined with weather damage and a handful of faulty units, these factors resulted in 106 damaged cameras (27%) and 27 stolen (7%).

3.2.4 Importance

Knowing the baseline number of free-roaming cheetah in South Africa is critical for effective conservation planning, as an estimated 25% of the southern African population resides here [25]. Previous estimates from Buk *et al.*, (2017; [13]) and Weise *et al.*, (2017; [97]) relied either on small-scale studies that were extrapolated across vast landscapes or the use of model estimations, often overestimating actual numbers. The FRCC's grid-based, landscape-scale approach provides the first robust cheetah numbers and distribution on these fragmented farmlands, avoiding extrapolation biases and delivering precise data for IUCN assessments.

Table 1: The different camera trap models used for the FRCC.

	Camera Model	N
1	Browning BTC-5HDX	7
2	Bushnell 5710	3
3	Bushnell 119932C	4
4	Bushnell 119936C	6
5	Cuddeback 1279	58
6	Panthera V7	31
7	Rik Rhino BG583	3
8	Solar Ceyomur CY95	60
9	Solaris Weapon 4K	20
10	Solar Wifi	25
11	Spartan SR3-CX	139
12	Spartan SR4-BK	32
13	Vista Trail	1
		389

3.3 Public sightings

Beyond systematic camera traps and questionnaires, public cheetah sightings were actively collected. When visiting the farmers for questionnaires or camera work, the field team invited them to join a dedicated WhatsApp group (>200 members across the study area) created by COT prior to the census and served as a real-time platform for sharing cheetah sightings, suspected predation, spoor and scat. The team provided participants of this group with census updates via infographics, and any questions with regards to the work, both field and desktop, were answered. Farmers typically reported sightings via this WhatsApp group with GPS coordinates and accompanying photos or videos when available, specifying cheetah numbers and sometimes even sex and age. If preferred, farmers could also message field team members privately. Troublesome or large groups of cheetah that were reported that needed urgent reaction, would fall under COT purview for potential conflict mitigation options and/or capture and satellite collaring.

Due to inherent reporting bias, public sightings without image evidence always required cautious interpretation when physical follow-up was infeasible. Farmers with low tolerance for cheetah were more likely to report potential sightings and predation, which could shift the blame from a more likely predator, such as leopard (*Panthera pardus*) or black-backed jackal (*Canis mesomelas*), creating inflated cheetah presence estimates. This tolerance-driven bias underscores why it was important to have sightings cross-validated with camera trap data, survey predator recognition scores, and/or photographic evidence, to ensure reliability. Nevertheless, this open contact system extended monitoring reach beyond physical visits, while building community trust and engagement.

3.4 Telemetry

Tracking data gained from satellite collared cheetah provided complete movement data that were used to assess transverse patterns across farmlands, and determining landscape connectivity, providing a complimenting addition to the static camera trap data. In an ongoing effort of conflict mitigation, COT trapped, collared, and at times relocated, in coordination with provincial authorities, suspected damage-causing cheetah to prevent deadly retaliation by farmers.

3.4.1 Cheetah capture

Various capture methods consisting of free-darting from a helicopter or from the ground if the individuals' location is known, to capture cages at sentinel sites, were utilised. When the decision was made to trap, a suitable sentinel tree was selected and a temporary "fence" of branches and dense thorn bushes constructed around it, creating a single access point to the scent-marking site (Fig. 9). This is where the trap was positioned, sometimes baited with scat from other cheetah sourced from field collections or facilities.

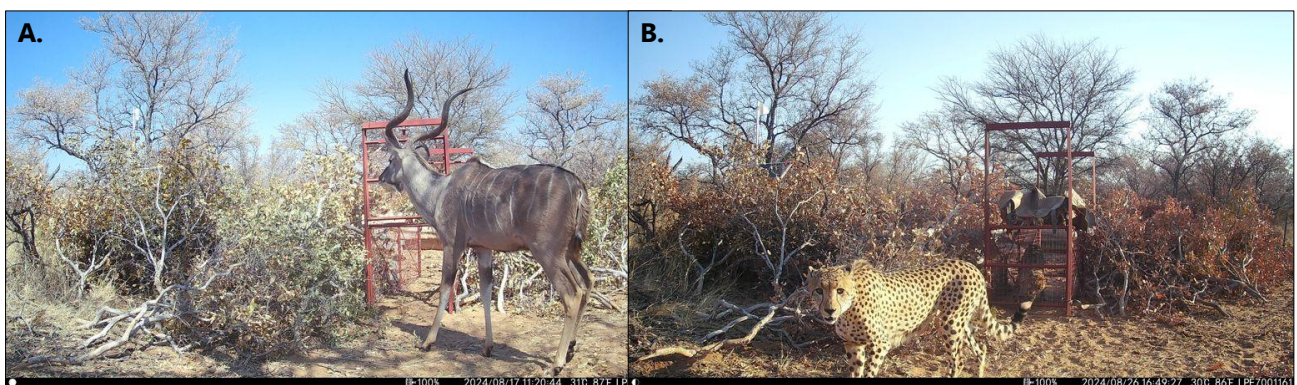


Fig. 9: A trap cage set-up at site LP_E7_001 (Region 2). **A.** Open cage surrounded by branches leaving the cage itself as clear path for cheetah to use. **B.** A cheetah individual has triggered the cage mechanism and is captured, his coalition mate close by.

Two different trap cage systems were used during the census: 1) mechanical trigger cages with an open trap door on either side with a pressure plate. When the animal steps on the plate, both doors drop simultaneously. These trap cages were monitored daily to see if a cheetah had been captured. 2) Solar powered magnetic sensor trap cages that closes upon animal entry as sensors are triggered, simultaneously notifying field staff via a GSM Commander Unit (a monitoring system sending real-time SMS or App alerts). This type of trap cage is ideal when daily checks were impractical and was designed and first utilised in Namibia during another free-roaming cheetah project by Leibniz-IZW, coordinated by J. Melzheimer [81].

Once a cheetah had been trapped, it would either be sedated while still inside the capture cage or alternatively be channelled into a transport crate and transported to a temporary holding facility pending release at the capture site or nearby. During sedation both the left and right flank of the individual were photographed for individual identification. Biological samples were collected for analysis to provide prey preference, relatedness and assess inbreeding in the free-roaming population (sections 3.5, 3.6). The date of capture, number of individuals captured and collared, the sex, estimated age, and collar numbers were recorded in KoboToolbox (Appendix IV).

Lastly, a SpoorTrack (ST) or Africa Wildlife Tracking (AWT) satellite collar was fitted, leaving a two-finger width gap between collar and neck to prevent the collar from slipping into the mouth but loose enough to avoid constriction or choking. The ST collars have rechargeable solar batteries and could last the potential lifespan of a cheetah (averaging to eight years in the wild, [49]). The AWT collars often last for approximately 5,000 location pings (or ~1.5 years) before the battery is depleted. Because of this, AWT collars had drop-off units attached, which auto-release after a set date (~1.5 years from activation), transmitting a final location for recovery. Both collar types send location updates every 4–6 hours (customisable based on needs). If signals were not transmitting properly, not transmitting at all or showed suspicious behaviour (i.e., static next to a road) a field team member would visit the area to investigate the last confirmed location. In return for allowing trapping of cheetah on their land, COT occasionally shared the GPS locations with the farmers who would use this information to predict cheetah movements and safely move their livestock and/or game to a different kraal.

3.4.2 Importance

The use of GPS collars revealed how cheetah moved across the area and showed some cheetah mortality and its rate, giving real-time insights as an addition to the static data of surveys and camera traps.

3.5 Scat

Cheetah roam farmlands holding a variety of animal stock and have long been the scapegoat for small-sized livestock losses on top of the expected game losses experienced in these remote areas. By collecting suspected cheetah scat samples, these claims were tested. Scat analysis offered two key insights: host identification and prey identification. Hair found in the scat were compared to reference hair databases to match samples to specific prey species [88][1][11], and DNA sequencing confirmed both the prey and host species [91][87]. This ultimately revealed whether cheetah predominantly preyed on (wild) game, livestock, or a mix of both. Furthermore, cheetah DNA from scat were linked to genetic profiles, tying diet to specific areas.

3.5.1 Collection

Scat was collected opportunistically during field work. Cheetah scat was recognized by its relatively short sections and the absence of white, calcium-rich material (Fig. 10), typical of hyaena or leopard scat, and often found on or around sentinel trees or prominent bushes. Once located, each scat sample was collected in a brown paper envelope, receiving a standardized sample code starting with "S" (e.g. S_001), followed by farm name, precise coordinates, scat condition (soft, hairy, hard), date/time, and the confidence scale (1-5) that it was cheetah. This same information, with an option to add an image of the scat, was uploaded in an online KoboToolbox form (Appendix IV). Only a portion of the scat was sampled to maintain the individual's scent at the site, encouraging cheetah to continue using the area. The collected samples were kept out of direct sunlight until transferred to ACC for storage.



Fig. 10: Scat found on the trunk of a Witgat tree (A and B), and cheetah scat found in a small bush on the ground (C).

Despite frequent cheetah detections on camera traps at certain sentinel sites, scat could not always be found during site checks. The lack of scat at these sites could be explained by seasonal rainstorms in the northern provinces disintegrating and washing away possible scat before collection, other predators having eaten the scat (coprophagia), telecoprid behaviour of beetles (sculpting and rolling balls of scat away; [22]), or the cheetah could just be passing through without defecating. This mismatch between cheetah captures on camera versus cheetah scat highlights why camera trapping and scat collection complement rather than substitute each other.

3.5.2 Importance

Cheetah scat collection and subsequent analyses directly addressed farmer perceptions of livestock/game predation by providing diet evidence, revealing prey preferences. This evidence can boost farmer tolerance by demonstrating low livestock depredation rates, supporting targeted interventions like wild prey enhancement on game farms. These results could educate farmland owners and reframe cheetah as ecosystem regulators in the form of top-down control, meaning that cheetah selectively target weaker, possibly diseased animals, preventing pathogen spread and maintaining herd health [98].

3.6 Genetics

Genetic sampling was opportunistically incorporated into the census as a complimentary component. While not the central focus, it did provide an additional layer of information that enhanced the understanding of the population structure and connectivity between the two regions.

Given that this type of sampling is uncertain in terms of sample quantity and quality, an integrated and varied approach was undertaken. Microsatellite analysis, also called Simple Sequence Repeat (SSR) genotyping, was employed for all genetic samples collected. Microsatellites are highly variable, meaning that the number of times a short DNA sequence is repeated in tandem at a specific genomic location differs between individuals within a population, and thus provides a high-resolution tool for distinguishing between individuals. It also differentiates between homozygous (inheritance of the same allele from both parents, e.g., AA or aa) and heterozygous (inheritance of two different versions of an allele, e.g., Aa) markers. Identifying heterozygous individuals is important as it shows that an individual carries two different versions of a gene at a locus, which is one sign of genetic variation within the population. The more heterozygous individuals are present in a population, the more genetic diversity the population is likely to have overall.

3.6.1 Scat samples

Non-invasive DNA was extracted from scat samples following standard laboratory protocols at the Jonah Ventures (laboratory) in Boulder, Colorado, USA and split between host DNA and prey DNA. The confirmed cheetah host DNA were analysed by the University of California Davis Veterinary Genetics Laboratory in Davis, California, USA., for individual identification and familial relationships.

3.6.2 Blood/Skin samples

Samples were collected during collaring and sedation procedures or opportunistically from deceased animals. In addition, archived samples from the SANBI Biobank were incorporated to expand the dataset. The inclusion of these samples was important for comparative purposes, improving confidence in individual identification and the broader population-level interpretations. All collected samples were analysed by the Unistel Medical Laboratory in Cape Town, South Africa.

The dual lab approach was largely due to logistical and regulatory complexities associated with international sample export, particularly the permitting requirements under CITES. Despite these constraints, the inclusion of genetic data aimed to strengthen the overall FRCC dataset and provide valuable, albeit supplementary, insights to the remaining population.

4. Results

4.1 Farm land-use

Responses occurred within 147 grid cells, covering ~80,900 km², of which ~59,000 km² (73%) is inside South Africa's IUCN cheetah range. A total of 299 farmers within this range filled in their responses (Table 2), which is considered sufficient for covering our study area based on a published and internationally recognised cheetah presence study by Van der Meer (2018; [93]), where 1,209 people were interviewed across Zimbabwe which has a size of 399,757 km². This indicates that within the FRCC study area, of size 99,800 km² (section 2), 302 surveys are needed for similar coverage. With 299 respondents, the census was on target for the needed amount to match the coverage of Van der Meer.

Table 2: Census effort resulted in a total of 335 executed questionnaires, of which 299 (89%) were within the study area.

	Inside IUCN range	Outside IUCN range	Total questionnaires	Total anonymous
Region 1	141	33	174	20
Region 2	158	3	161	29
	299	36	335	49

This section summarises the results of the survey questions relating to land-use practices across the study area. The land-use categories identified include agriculture, livestock farming, game farming, and ecotourism, where participants were able to reply with multiple land-use practices if applicable. For livestock and game farmers, further distinctions were made between different species to provide a more detailed understanding of land utilisation and how both domesticated and wild species occupy the landscape.

To spatially represent these data, each grid cell was subdivided into four quadrants, similarly to the camera trapping methodology. Each quadrant was assigned a land-use category based on the proportional representation of questionnaire responses within that grid cell. For example, if four questionnaires were conducted within a grid cell and two responses reported agriculture, one reported game farming, and one reported ecotourism, the cell was visualised with two quadrants representing agriculture, one representing game farming, and one representing ecotourism. This approach firmly shows the dominant land-use practices within each grid cell and may give insight into ecological behaviour of cheetah.

The resulting land-use map (Fig. 11A) indicates clear spatial differences between the two regions. Region 1 is predominantly characterised by livestock farming, followed by game farming, but with limited agriculture and ecotourism. In contrast, Region 2 is largely dominated by game farming, with smaller presence of the other land-use types. These differences in land-use are closely associated with underlying habitat characteristics. Region 1 primarily consists of grassland and semi-arid habitats, whereas Region 2 contains more thick vegetation, including shrubland and woodland systems [51][80]. Livestock farms are typically associated with more open landscapes, like Region 1, that support grazing species such as sheep and goats [37]. In contrast, areas with denser and less disturbed vegetation, Region 2, are more conducive to wildlife-based land-uses, such as game farming and ecotourism, where habitat structure supports higher biodiversity and a more natural ecosystem [61].

Differences in land-use practices are further reflected in fence types (Fig. 11B). Participants reported the use of various fencing types, including no fencing, small strand (2-4) fencing, game fencing, and predator-proof fencing, along with the proportion of each fence type. Using a similar spatial representation as for land use, comparisons between land-use and fencing types can be made. The livestock dominated areas more commonly use small-strand fencing, whereas game fencing is more prevalent in Region 2. While game fencing can support wildlife management and reduce certain types of human-wildlife conflict, it also contributes to landscape fragmentation. Impermeable fencing restricts the movement of wide-ranging species, including cheetah, limiting access to prey and habitat. At the same time, this fencing can confine predators within fenced areas, potentially increasing the likelihood of human-wildlife conflict.

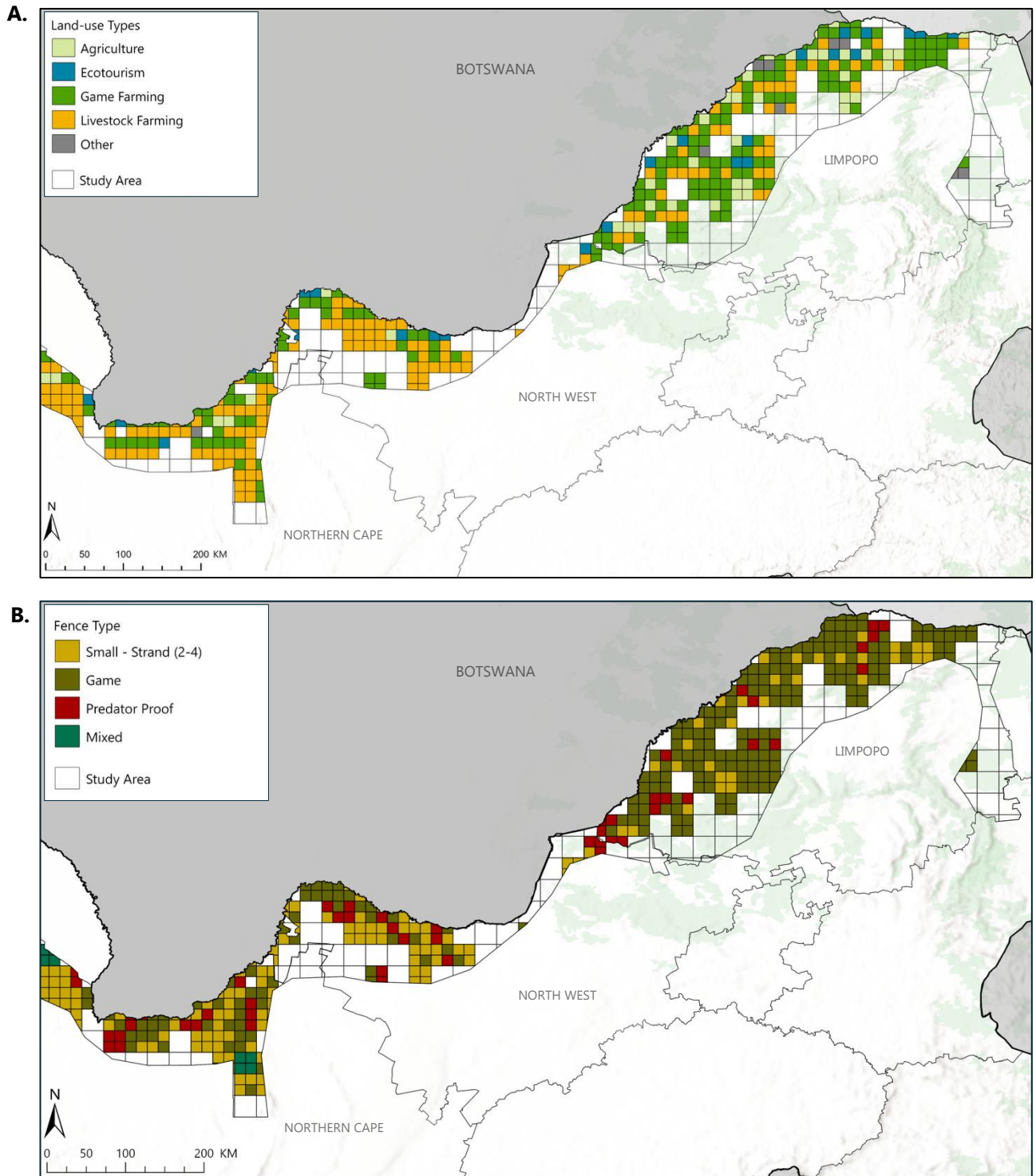


Fig. 11: The different land-use (A) and fencing (B) types mapped across the study area as stated by the farm occupants.

4.2 Individuals

The following sections examine the presence, numbers, and movement patterns of cheetah populations within these fragmented landscapes. The **central objective** of the FRCC, establishing robust baseline numbers of free-roaming cheetah in South Africa, required accurate identification and individual recognition of cheetah. A total number of 5,212,796 images were uploaded in TrapTagger ($N_{\text{Region1}} = 2,823,736$; $N_{\text{Region2}} = 2,389,060$), an open-source AI-assisted web application designed for wildlife camera-trap data [99].

4.2.1 Dataset preparation

TrapTagger offers an initial workflow for processing large camera-trap datasets and facilitating species identification and individual-level differentiation. Within the software, the images collected from the field were uploaded according to QDGC (per year) into one project called a "survey". Each new survey was named according to "FRCC_year_province_grid" (e.g. FRCC_2023_LP_L3), resulting in a total of 198 surveys across 93 unique grid cells. To upload the 5.2 million images, approximately 2,700 hours (113 full, 24h days) was spent on ~12.5 TB of data and a total of 621 hours (26 full, 24h days) was spent on subsequent analysis by hand.

In preparation for image analysis, Static Detection was applied to filter out empty images. TrapTagger automatically draws sighting boxes around detected animals/objects that are believed to have triggered the camera. These boxes make Species Detection easier for the assigned annotator (i.e. the person manually labelling the images). During the Static Detection, TrapTagger would present the annotator with groups of images where the camera was triggered at the same space on the image multiple times. The annotator could then verify whether an animal triggered this space continuously (reject as Static Detection) or if it was an inanimate object such as a branch or grass (accept Static Detection).

After the Static Detection, the annotator supplies the survey with an annotation set. An annotation set is a default set that consists of the species most likely to occur in your study area. By adding this set, TrapTagger knows which species it should look for inside the images. Within the census the 'sub-Saharan Africa' species classifier set was used. This 'sub-Saharan Africa' set still missed various species marked as highly present or important, resulting in the addition of the hyrax, ground squirrel, vulture, kori bustard, owl, meerkat and dromedary. Besides adding species, the group of 'Vehicles, humans, livestock' was manually subdivided into 'human and vehicle', 'goat and sheep', 'horse and donkey', and 'cattle'.

Once the annotation set was applied, an 'area' needed to be established, which can be a self-determined area. Within TrapTagger every survey was placed in an area based on their placement in either Region 1 or Region 2 (Fig. 3)

4.2.2 Image analysis

By default, approximately 70% of the images have been annotated by AI and the remainder (30%) manually. However, to increase the accuracy of the data, around 70% was **manually** annotated instead. Analysis of the 5.2 million images started with Species Group Labelling. Rather than reviewing individual photos, TrapTagger groups images into clusters. Clusters are groups of images where each group is ≤ 30 minutes apart, treating long-lasting individual presence (e.g., pacing back and forth) as one event rather than separate detections [95]. A total of 266,092 clusters has been analysed in the Group Labelling phase, with cluster size differing from one image to just over 1,000 images (e.g. due to antelope or cattle herd). Group Labelling involves the classification of groups, such as antelope, rather than the specific antelope species. This Group Labelling is mandatory to be able to continue to the next steps of the analysis, while the specific Species Labelling is optional but regarded as highly important for the census. The groups that were de-grouped and classified as species specific were 'vehicle, human, livestock', 'small and medium cats', 'hyaena', 'jackal', 'antelope', 'bird', 'pig', 'primate', 'mongoose' and 'sundry'. Other, already species-specific clusters were also double checked manually for a more accurate species count. These consisted of lion (*Panthera leo*), leopard (*P. pardus*), cheetah (*A. jubatus jubatus*) and wild dog (*Lycaon pictus*).

Whenever a species was mentioned as present in a study area where the annotator found a low probability of that being true, these images were confirmed manually. If, during the Species Labelling phase, a camera was marked as knocked down, a knocked down analysis would follow immediately after. For the duration of the census, cameras were actively taking pictures (i.e. cameras not broken, batteries empty or knocked down) for 58,768 days, of which cameras were knocked down for 797 days (1%).

In Region 1, cameras were active for a total of 29,395 days across 165 sites, equalling to an activity of 178 days/site. Region 2 had cameras active for 29,373 days across 155 different sites, resulting in an average site active period of 190 days/site. After de-grouping and labelling within each group or species, an AI Check, Multi-species Differentiation, Sighting Box Correction and, if cheetah seen, Individual Identification were executed in that exact order. The AI check presented with all the clusters where the AI disagreed with the labels manually given to the images. Hence this analysis was used as a control for the work that was done during the Species Labelling phase.

When multiple species appeared within a cluster during the Species Labelling phase, TrapTagger draws a large sighting box around the entire image, requiring the annotator to scroll through the cluster images to reveal the image with multiple species. If multiple species were indeed present, these clusters will be re-annotated during the Multi-Species Differentiation phase. The Multi-Species Differentiation takes all clusters labelled as containing multiple different species and presents them to the annotator to manually give each species its appropriate label. This analysis type is of high importance as it gives a more accurate count of the species, making it especially valuable for the predator species (Fig. 12).



Fig. 12: A cluster containing eight images where cattle and warthog were labelled as present after de-grouping the groups 'Vehicles, humans, livestock' and 'pig' that were given during the Species Labelling phase. **A.** All individuals are currently labelled as cattle. **B.** All species labelling have been corrected and boxes not containing an animal have been removed.

For each survey with cheetah presence ($N_{\text{survey}} = 59$, $N_{\text{grid}} = 28$), Individual Identification was executed. The first step consists of ensuring that each sighting box that supposedly contains cheetah, indeed contained a cheetah. Similarly, extra sighting boxes had to be added to the image containing a cheetah not spotted by TrapTagger. These practices were executed during the Sighting Box Correction analysis, where all clusters containing cheetah were presented to the annotator for corrections (Fig. 13).

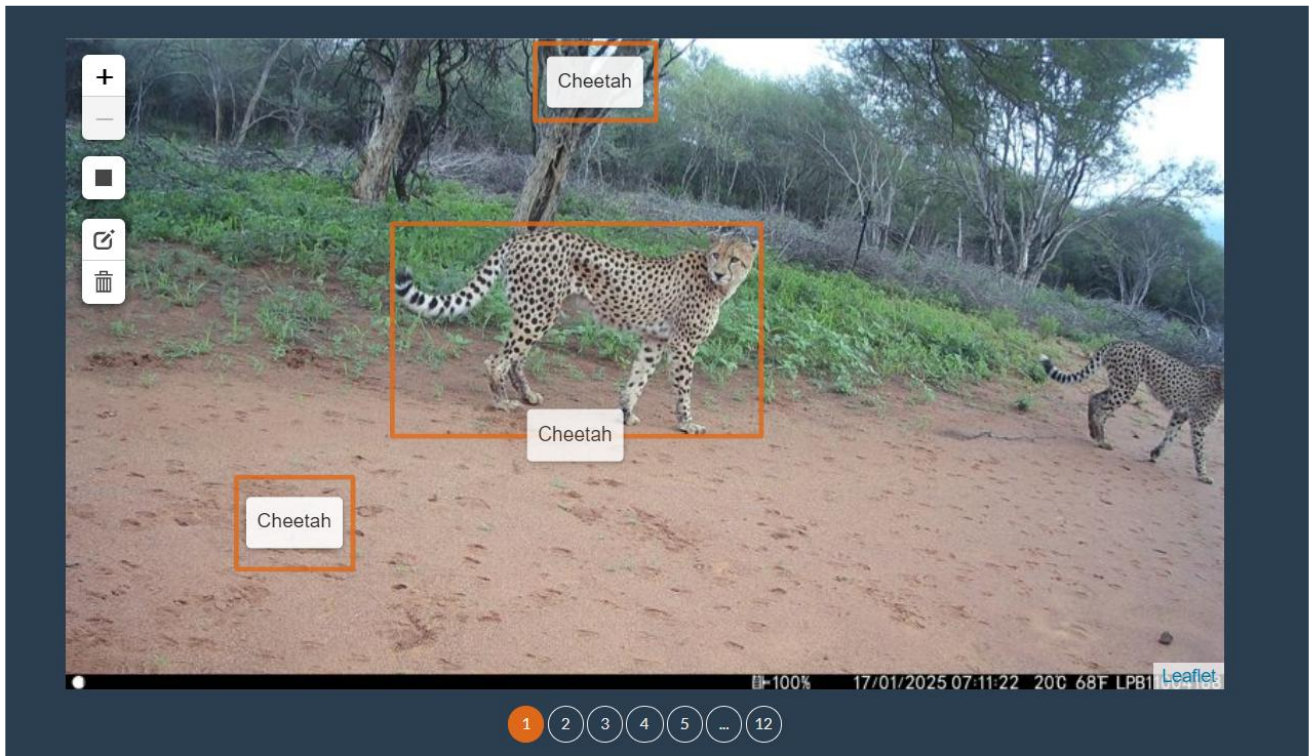


Fig. 13: Sighting Box Correction for a cluster with 12 images annotated to contain cheetah. Only one of the three boxes created contains a cheetah. The annotator needs to manually remove the two extra boxes, while adding a new box to the cheetah sighting for the individual on the right.

4.2.3 Individual identification

The final step in data processing contained the actual Individual Identification of all clusters containing cheetah images ($N_{\text{clusters}} = 1,886$; $N_{\text{Region1}} = 986$; $N_{\text{Region2}} = 900$). The identification process consists of two steps: Within Survey Identification and Between Survey Identification. The process starts with Within Survey Identification, where TrapTagger presents the same cluster next to each other to the annotator. By doing so, it was possible to check whether the cheetah seen on image one in the cluster, is the same as the individual seen on image two, etc (Fig. 14).

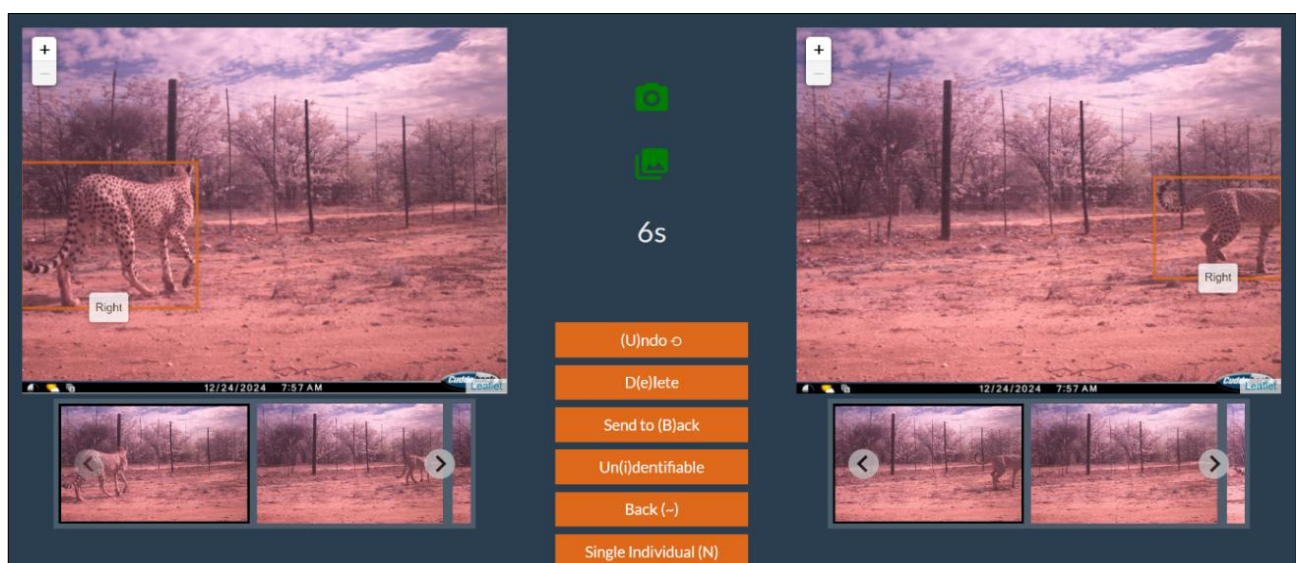
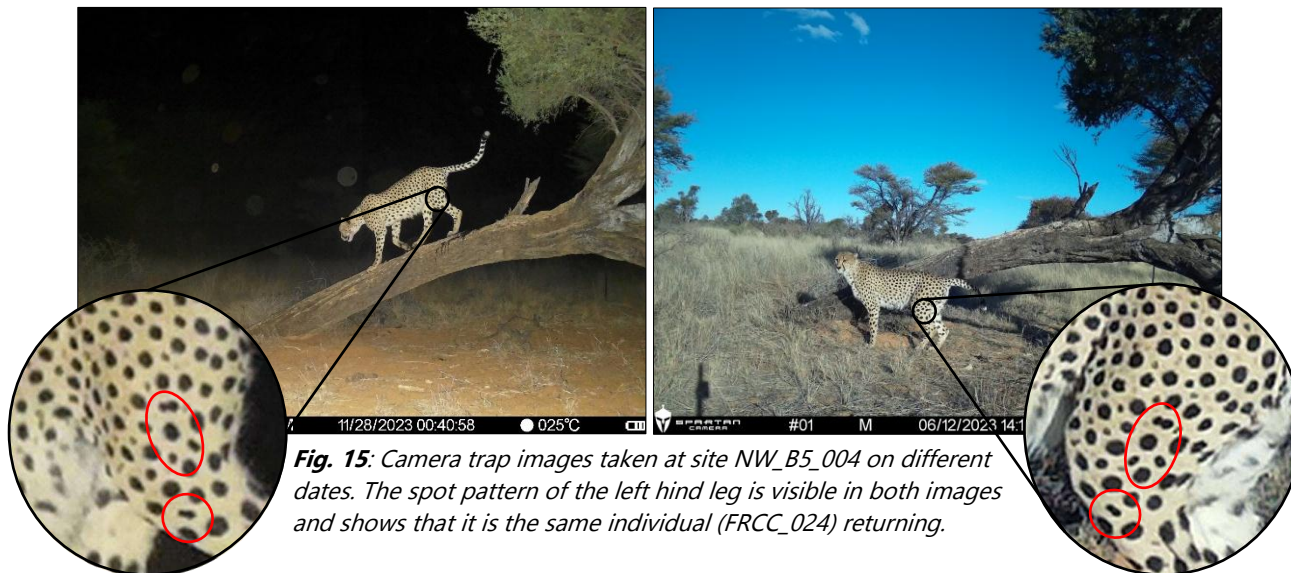
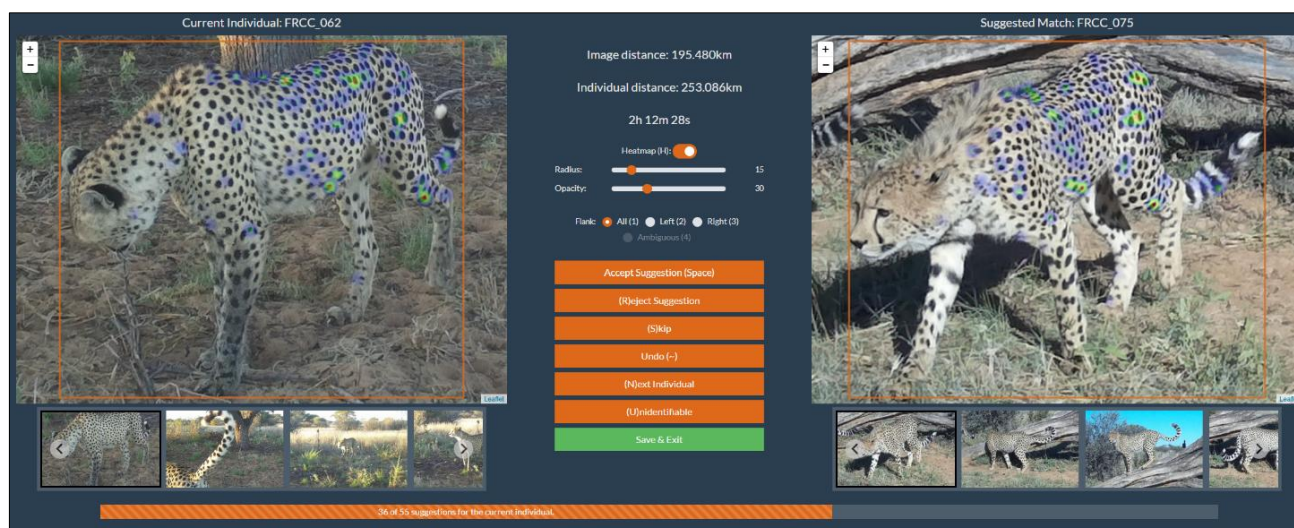


Fig. 14: The left image is photo number one, while the right image shows the second photo from the same cluster. They are taken six seconds apart by the same camera and both containing the right flank of a cheetah individual. The spot patterns are used to manually show that these are not the same individual, but a coalition of two brothers.

The identification of cheetah was done with the help of their unique spot patterns. The focus for identification lies especially on the legs, shoulders and buttocks as these areas stretch the least after a heavy meal, during pregnancy or movement to maintain similar spot patterns (Fig. 15). This process was therefore done manually and was repeated for all clusters marked with cheetah present within a survey.



Once the Within Survey Identification finished, an additional analysis was executed: Between Survey Identification. With this identification analysis, all other surveys within the same area (i.e. Region 1 or Region 2) are compared to each other. This process shows all previously identified cheetah individuals within an area and compares them with the newly added individuals from the Within Survey Identification process. During this phase, built-in heatmaps for easy similarity detection were used to help decide if the individual is truly new, or if it was seen somewhere else within the area (Fig. 16).



4.2.4 Identified individuals

A total of 119 unique cheetah individuals ($N_{\text{camera}} = 95$, $N_{\text{collar}} = 10$, $N_{\text{report}} = 14$) were identified across the study area (Table 3), distributed between Region 1 (Northern Cape + North West; $N = 58$) and Region 2 (North West + Limpopo; $N = 61$). For standard population estimation, adults >24 months of age, of which 83 individuals were confirmed, were used for population counts. The confidence of every individual is rated on a scale of 1–5, with one indicating high identification uncertainty (e.g. few images, blurry images, only one flank, cubs) and five indicating strong confidence in the identification of that individual. This scaling is converted to percentages for each category in Table 3 with the formula:

$$\text{Conf} = \frac{\text{Total confidence per category}}{(\text{Total individuals per category} * 5)} * 100\%$$

For example, there are 30 adult males in Region 2, with a confidence sum of 131 (all confidence rates for each adult male in Region 2 added together). The maximum confidence of 30 males (if all individuals have a surety of 5) is $30 * 5$. This would create the formula:

$$\text{Conf} = \frac{131}{(30 * 5)} * 100\% = 87\%$$

The total number of individual cheetah present in the study area were identified, how often they were recaptured at sites, what times they were active and their possible mortality rate. A cheetah ID kit (Appendix VI) was created which supplied individual flank images, estimated age and sex, location and sighting timeframe.

Table 3: The number of identified individuals across the study area subdivided into age (cub ≤ 12 months; sub-adult 12 < x < 24 months; adult ≥ 24 months) and sex categories. Confidence in identification is marked in %.

Category	Region 1 (NC + NW)	Region 1 Confidence	Region 2 (NW + LP)	Region 2 Confidence	Total
Adult Males	20	98%	30	87%	50
Adult Females	11	91%	17	88%	28
Adult Unknown	2	50%	3	69%	5
Adult Subtotal	33	93%	50	86%	83
Sub-adult Males	3	100%	2	100%	5
Sub-adult Females	4	95%	2	100%	6
Sub-adult Unknown	2	40%	2	60%	4
Sub-adult Subtotal	9	84%	6	87%	15
Cub Unknown	16	46%	5	20%	21
Grand Total	58		61		119

4.2.5 Mortality

The census identified 58 individuals in Region 1 ($N_{\text{adults}} = 33$; $N_{\text{sub-adults}} = 9$; $N_{\text{cubs}} = 16$), 10 of these individuals are confirmed dead, consisting of five adult males, one sub-adult female, one sub-adult of unknown sex, and three cubs. In Region 2, 61 individuals ($N_{\text{adults}} = 50$; $N_{\text{sub-adults}} = 6$; $N_{\text{cubs}} = 5$) were identified, of which 14 are confirmed dead, consisting of 12 adults (seven males and five females), and two sub-adults of unknown sex. The confirmed individual mortality data consisted of a relatively small sample size ($N = 17$), with a pronounced sex

bias ($N_{\text{Female}} = 5$, $N_{\text{Male}} = 12$). Across both regions another four individuals were confirmed dead during the census period, but they could not be individually identified and thus not be linked to the ID kits.

For further insight into mortality causes, the mortality dataset was increased by adding confirmed deaths from 2021 and 2022. This resulted in an additional five individuals, making the total confirmed deaths 29 ($N_{\text{Region1}} = 14$; $N_{\text{Region2}} = 15$). The cause of death was confirmed in 15 out of 29 total mortalities. These deaths were mainly driven by human-related (anthropogenic) factors (Table 4; Fig. 17). A total of 13 individuals (86%) died from human-induced causes, including shooting, snaring, and vehicle collision, and two individuals died due to suspected predation. The cause of death remained unknown for 14 individuals.

Table 4: This table represents each confirmed death for all census identified individuals (FRCC_000) and individuals confirmed as deceased between 2021 and 2022 (n/a). Each row indicates the cause of death and its corresponding category. Individuals that were no longer recaptured along with their coalition or litter mates, were assumed dead.

Individual	Age category	Sex	First seen	Last seen	Cause of death	Category of death
Region 1						
n/a	Adult	Male	2020/10/19	2021/07/16	Snare	Anthropogenic
n/a	Sub-adult	n/a	2021/02/16	2021/02/16	Roadkill	Anthropogenic
n/a	Adult	Female	2021/03/31	2022/02/04	Snare	Anthropogenic
n/a	Adult	Female	2021/08/03	2021/08/03	Unconfirmed	n/a
FRCC_025	Adult	Male	2023/08/01	2023/08/01	Disappeared	n/a
FRCC_026	Adult	Male	2023/08/01	2023/08/01	Disappeared	n/a
n/a	Sub-adult*	n/a	2024/02/09	2024/02/09	Road fatality	Anthropogenic
FRCC_066	Adult	Male	2024/06/26	2024/09/03	Disappeared	n/a
FRCC_071	Cub	n/a	2024/07/04	2024/07/04	Disappeared	n/a
FRCC_073	Cub	n/a	2024/07/04	2024/07/04	Disappeared	n/a
FRCC_074	Cub	n/a	2024/07/04	2024/07/04	Disappeared	n/a
FRCC_084	Adult	Male	2024/07/19	2025/04/13	Disappeared	n/a
FRCC_085	Adult	Male	2024/07/19	2025/04/05	Disappeared	n/a
n/a	Sub-adult*	Female	2025/08/16	2025/08/16	Road fatality	Anthropogenic
Region 2						
FRCC_001	Adult	Male	2021/05/16	2024/07/07	Shot	Anthropogenic
FRCC_008	Adult	Male	2021/07/29	2022/03/08	Disappeared	n/a
n/a	Adult	Male	2022/01/20	2022/01/20	Unconfirmed	n/a
FRCC_100	Adult	Female	2022/04/20	2024/07/22	Unconfirmed	n/a
FRCC_101	Adult	Female	2022/04/20	2024/09/17	Snare	Anthropogenic
FRCC_102	Adult	Female	2022/04/20	2023/07/22	Shot	Anthropogenic
FRCC_103	Adult	Male	2022/07/09	2022/08/17	Leopard	Predation
n/a	Sub-adult*	n/a	2023/04/05	2023/04/05	Lion**	Predation
n/a	Sub-adult*	n/a	2023/04/05	2023/04/05	Likely shot**	Anthropogenic
FRCC_038	Adult	Female	2023/11/19	2023/12/11	Likely shot	Anthropogenic
FRCC_044	Adult	Female	2023/12/07	2025/06/04	Unconfirmed	n/a
FRCC_114	Adult	Male	2024/03/26	2024/03/26	Disappeared	n/a
FRCC_049	Adult	Male	2024/05/01	2025/06/13	Road fatality	Anthropogenic
FRCC_050	Adult	Male	2024/05/01	2025/06/13	Road fatality	Anthropogenic
FRCC_052	Adult	Male	2024/05/01	2025/06/13	Road fatality	Anthropogenic

* These individuals have been confirmed dead, but due to their found physical state, no proper identification could be done. This means that it is not known if these individuals are part of the ID kit created during the census

** These individuals broke into a fenced game reserve where one was killed by lions, and the other on community lands.

Mortality rates are generally identified based on adults only. When looking at solely the adult mortalities observed within the census years (FRCC_000; 2022–2025, $N = 17$), a mortality rate of 15% in Region 1 and 24% in Region 2 was calculated, with 20% adult mortality throughout the study area. This means that one fifth of the known free-roaming population died during the 3.5-year census period. This figure reflects only the confirmed mortalities, so the true mortality rate is likely higher.

Estimated age at last detection was determined by combining averaged age observed at first sighting with the elapsed time between the first and last detection. In instances where individuals were first captured as cubs or sub-adults, the body size could be used as a marker for the estimated date of birth. These estimates were used directly to assign an approximate age in months. In cases where precise age estimations were not possible, individuals were assigned age values based on categorical age classes. Midpoint values were used for each class

(cub: 6 months; sub-adult: 18 months; adult: 39 months). For adult individuals, the midpoint value was based on a 30 – 48 month range. Individuals that are confirmed dead, had the time between first and last detection added to the determined age at first observation to obtain an estimated age at death.

As age estimates were partly derived from categorical classes (cub, sub-adult, adult), these values should be interpreted as approximations rather than exact ages. However, the use of midpoints and field-informed estimates provides a consistent and biologically realistic framework for comparative analysis. Average age at death was calculated using only confirmed mortalities and estimated ages at the time of death were summarised across individuals to obtain a mean value.

Within the managed metapopulation, the average lifespan of cheetah is 5.94 years (± 2.81 years), with anthropogenic causes accounting for 17% of the ~500 data points recorded in these reserve populations, while non-anthropogenic causes accounted for 46% [82]. In contrast, the free-roaming individuals identified during the census exhibited a markedly earlier average age at death of 3.72 years. A study in Namibia strengthens these outcomes with their findings on Namibian farmlands where free-roaming cheetah have an ~84% risk of dying between independence and six years of age [53].

This reduced lifespan occurs despite the absence of major natural predators, such as lions (*Panthera leo*), within the free-roaming landscapes, suggesting that other factors, of which most likely anthropogenic pressures, play a significant role in limiting survival. Consequently, one fifth of the known South African free roaming population died during the 3.5-year census period. This figure reflects only the confirmed mortalities (20%), so the true mortality rate is likely higher.



Fig. 17: Three individuals found dead. One after a suspected leopard attack (FRCC_103; left), one caught in a gin trap (n/a; both middle images) and one sub-adult road fatality found next to a busy gravel road (n/a; right).

4.3 Telemetry

Data from 20 collared individuals ($N_{\text{Region1}} = 7$; $N_{\text{Region2}} = 13$; Table 5; Fig. 18) were used to gain insight into how individuals utilise the landscape beyond static detection records. As collaring of individuals was done opportunistically and undertaken by COT in response to human-wildlife conflict incidents, the number of collaring events in Region 1 during the field work period (2022 – 2025) were limited relative to Region 2. Therefore, six individuals with telemetry data from earlier deployments (2020 – 2021) by COT were incorporated for Region 1 to ensure an adequate sample size. Using older satellite data from previously collared cheetah was deemed appropriate, as the interval between collaring and the start of the census was shorter than a free-roaming cheetah's typical lifespan (avg. 4.6 years, [97]). Therefore, these records likely reflect comparable movement based on land-use conditions to those during the study period.

Table 5: All collared individuals between 2020 – 2025 including the monitoring period during which the individual was fitted with the collar. The collars with outcome 'ongoing' are set to the census' end date (31-12-2025) as that is the last date used for the analysis, but the collar is still active.

Individual	Collar	Sex	Start Date	End date	Active (days)	Mean Daily Distance (km)	Spatial extent (km ²)	Outcome
Region 1								
n/a	AWT 4213	Male	2020/10/19	2021/07/16	270	4.34	618	Mortality
n/a	AWT 4154	Male	2021/03/13	2022/06/14	458	5.39	6,171	Drop-off
n/a	Tel 723586A / AWT_4709	Female	2021/03/31	2022/02/04	310	1.96	173	Mortality
n/a	Tel 723419A	Male	2021/06/02	2021/10/13	133	6.89	2,490	Drop-off
n/a	Tel 723587A	Male	2021/05/25	2021/12/04	193	6.37	5,126	Collar fail
n/a	Tel 721907A	Female	2021/08/04	2022/06/20	320	6.04	4,991	Drop-off
FRCC_039	AWT 4709	Female	2022/03/26	2023/06/21	452	3.73	1,945	Drop-off
Region 2								
n/a	AWT 4679	Male	2022/01/20	2023/01/26	371	5.22	2,971	Drop-off
FRCC_100	AWT 5682 / 5681	Female	2022/04/24	2024/07/22	819	2.89	1,292	Mortality
FRCC_103	AWT 5681	Male	2022/07/09	2022/08/17	40	1.55	1.4	Mortality
FRCC_101	AWT 5680	Female	2022/08/04	2024/09/17	775	4.41	1,589	Mortality
FRCC_102	AWT 5683	Female	2022/08/04	2023/07/22	352	3.72	1,286	Mortality
FRCC_038	ST 1172	Female	2023/11/22	2023/12/02	10	4.61	33.8	Collar fail
FRCC_001	ST 1233	Male	2024/02/21	2024/07/07	136	6.21	213	Mortality
FRCC_044	ST 1269	Female	2024/06/20	2025/06/04	348	3.76	748	Mortality
FRCC_050	AWT 7898 / 10056	Male	2024/08/27	2025/06/23	300	7.16	559	Mortality
FRCC_064	AWT 10112	Male	2025/06/11	2025/12/31	203	6.80	1,117	Ongoing
FRCC_096	AWT 10342	Male	2025/09/11	2025/12/31	111	4.10	169	Ongoing
FRCC_097	AWT 10339	Male	2025/08/31	2025/10/08	38	5.28	32	Collar fail
FRCC_095	AWT 10340	Male	2025/10/13	2025/12/31	78	6.73	293	Ongoing

Along with limited sample sizes, tracking duration was often constrained by mortality or collar failure. Traditional approaches for estimating home range, such as kernel density estimation (KDE), rely on assumptions of smooth and continuous space use (i.e. no barriers) and require relatively large, temporally extensive datasets to produce reliable estimates [31]. Similarly, Minimum Convex Polygons (MCP) may overestimate space use due to inclusion of outlier movements [12][83]. Given these limitations, estimates are more appropriately interpreted as spatial extent rather than true home range, reflecting the geographical area utilised during the monitoring period without assuming stable, long-term use.

Accordingly, spatial extent was estimated using a cluster-based convex hull approach, in which location data were partitioned using k-means clustering (which groups data points into clusters based on how close they are to each other) and convex hulls were generated for each cluster before being merged to represent overall spatial extent. Similar multi-hull approaches have been shown to better reflect patterns of space use by constructing polygons around localised groups of points and reducing the inclusion of unused areas [36][15]. Importantly, this approach allows for standardised comparisons across individuals and regions, while minimising methodological bias introduced by uneven data quality.

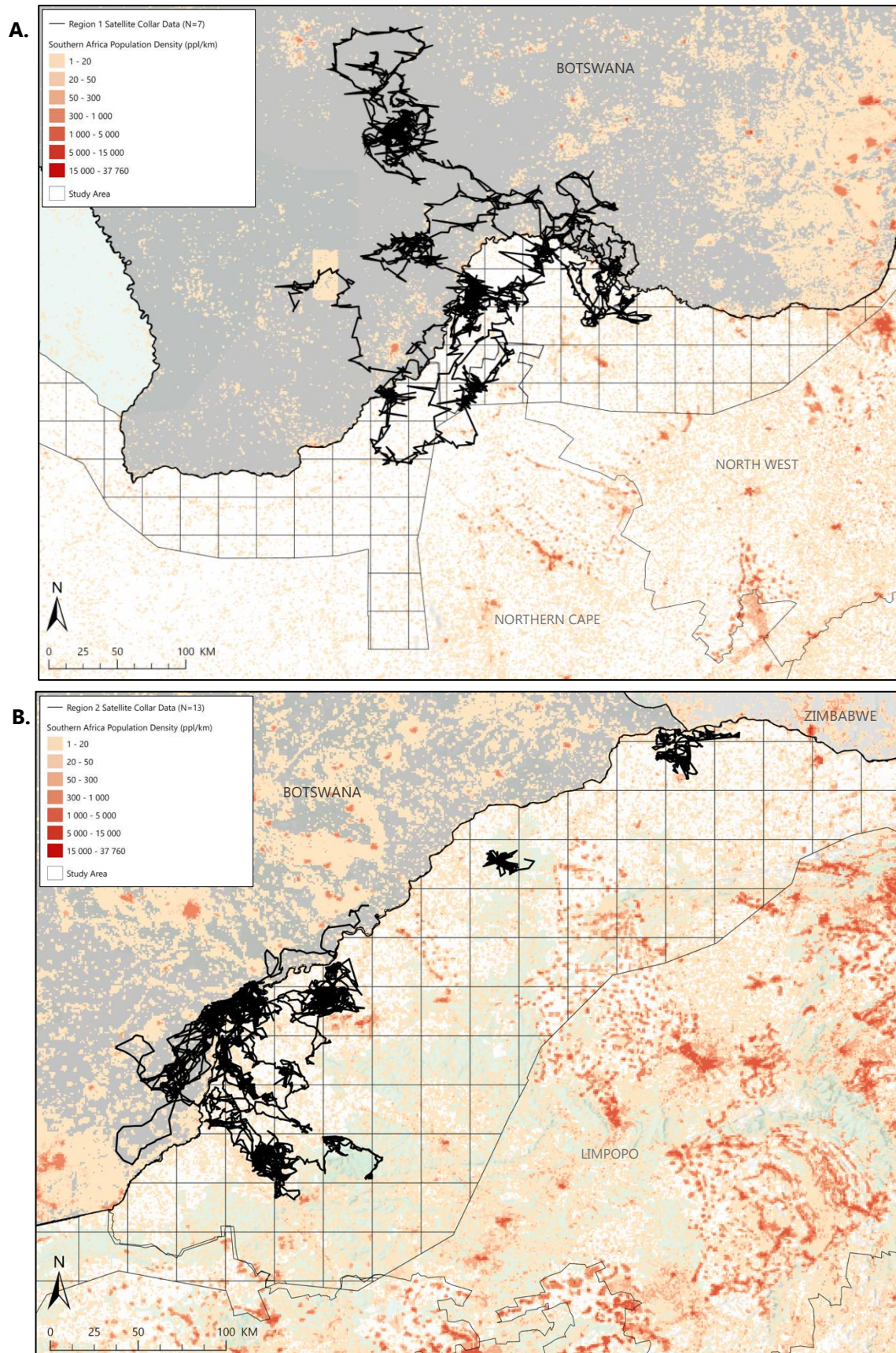


Fig. 18: All collared individuals per region. Region 1 (**A**) shows a larger movement range with more opportunities to move into neighbouring countries. Region 2 (**B**) shows how human population causes restricted movement, with individuals crossing the country border eventually being blocked from further inland movement.

To account for differences in monitoring duration and sampling effort, spatial extent estimates were interpreted alongside tracking duration (days) and movement metrics, specifically mean daily distance travelled. Daily movement distances were calculated by summarising step lengths (i.e. the distance between consecutive GPS fixes per individual per day) and provided an additional measure of space use. This allowed a more nuanced interpretation of spatial extent, particularly where tracking periods are short, and helped distinguish between large extents resulting from extensive daily movement versus those with prolonged monitoring periods.

4.3.1 Distances travelled by individuals

Daily distance travelled was fairly similar between regions ($N_{\text{Region1}} = 4.78$ km, $N_{\text{Region2}} = 4.46$ km) with a nearly identical median value of ~ 3.6 km/day per individual (Fig. 19). This indicates, that on average, individuals in both regions exhibit comparable day to day movement in terms of travel distance. However, **similar values of distance do not necessarily imply equal range use**, as the total area an animal uses over time can differ.

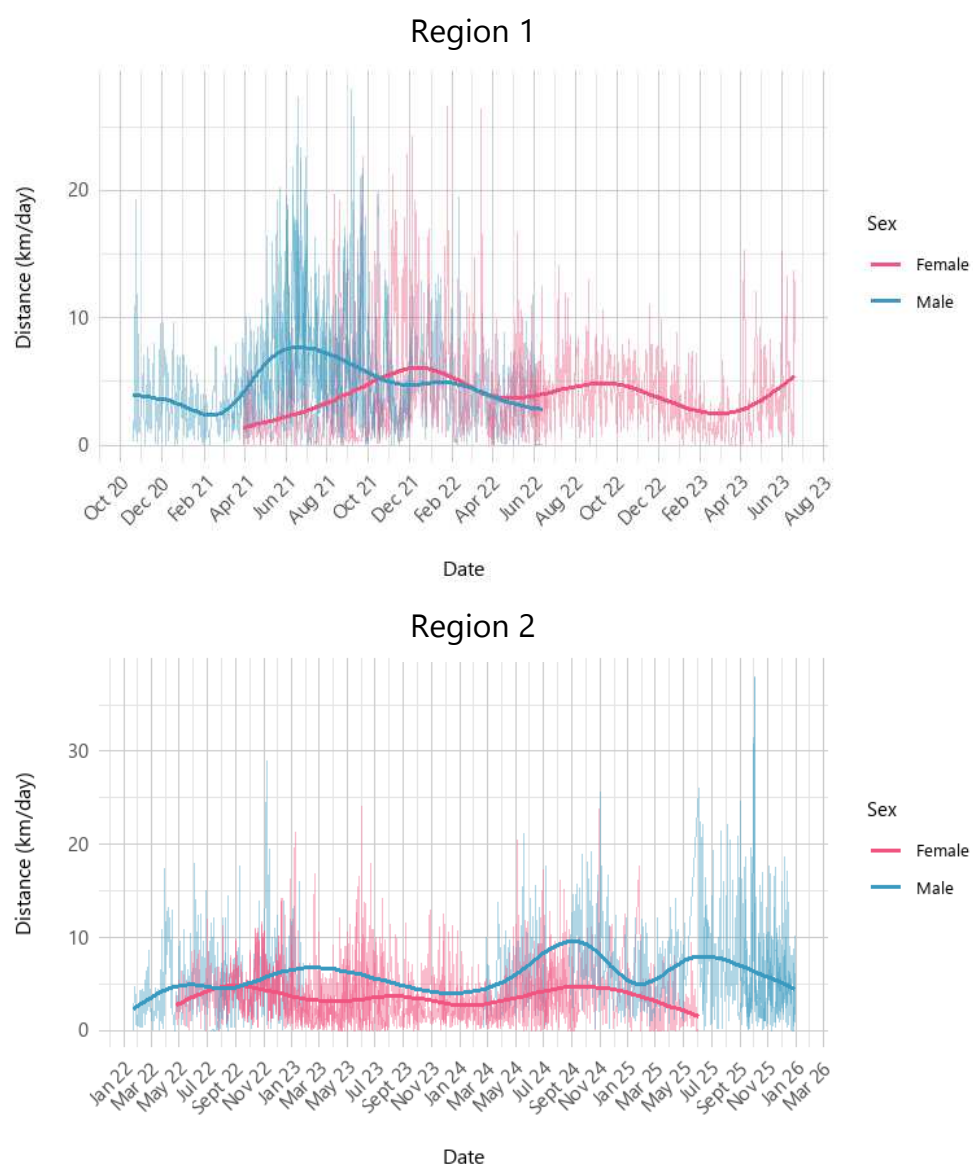


Fig. 19: Daily movement distances (km/day) of collared individuals over both regions. Thin lines show daily data for females (pink) and males (blue) accompanied by their respective trendlines. Both regions had a near identical median value of ~ 3.6 km/day per individual.

Despite the similarity in distance travelled, differences were found between the regions in movement variability when assessed at the individual level. To account for unequal sample sizes, individuals in Region 2 were randomly subsampled to match the number of individuals in Region 1. While typical levels of variability were similar between regions, the spread of variability (measured using the interquartile range (IQR), which represents the spread of the middle 50% of values) was much greater in Region 2 (IQR = 0.218) compared to Region 1 (IQR = 0.061). This indicates that movement behaviour in Region 2 is less consistent, with some individuals showing very stable movement patterns, while others displayed more variable behaviour that likely reflects differences in landscape structure (e.g. fragmentation and the presence of boundaries) that influence how individuals move through the environment.

In both regions, males and females exhibited occasional spikes in daily movement distances, with some movements exceeding 20 km/day. Sex-based differences in movement were present but not pronounced. Males tend to exhibit slightly higher variability and more frequent long-distance movements, while females showed more consistent daily movement patterns. However, the overall overlap between sexes suggests broadly similar movement behaviour.

It is important to note that monitoring duration differed substantially between the regions, with Region 2 contributing a larger number of tracking days ($N_{\text{Region1}} = 2,077$ days, $N_{\text{Region2}} = 3,507$ days). This increased sampling effort may influence the likelihood of capturing rare long-distance movements and should be considered when comparing variability between regions. Overall, these findings indicate that, no matter the region or sex, daily distance is relatively similar, meaning that differences in spatial extent between regions are unlikely to be driven by daily movement alone. Instead, landscape barriers and spatial constraints are likely to play a more significant role in shaping overall space use.

4.3.2 Spatial Extent

Spatial extent showed how far individuals moved from their release point during the monitoring period. In Region 1, spatial extent varied considerably among individuals ($N = 7$), ranging from relatively small areas (~100 km²) to extremely large extents exceeding 6,000 km² (Fig. 20). These extreme values were facilitated by cross border movement into the Kgalagadi District of Botswana (Fig. 18A), with larger, less fragmented farmland areas that allow for more extensive movement before encountering human settlement barriers [94].

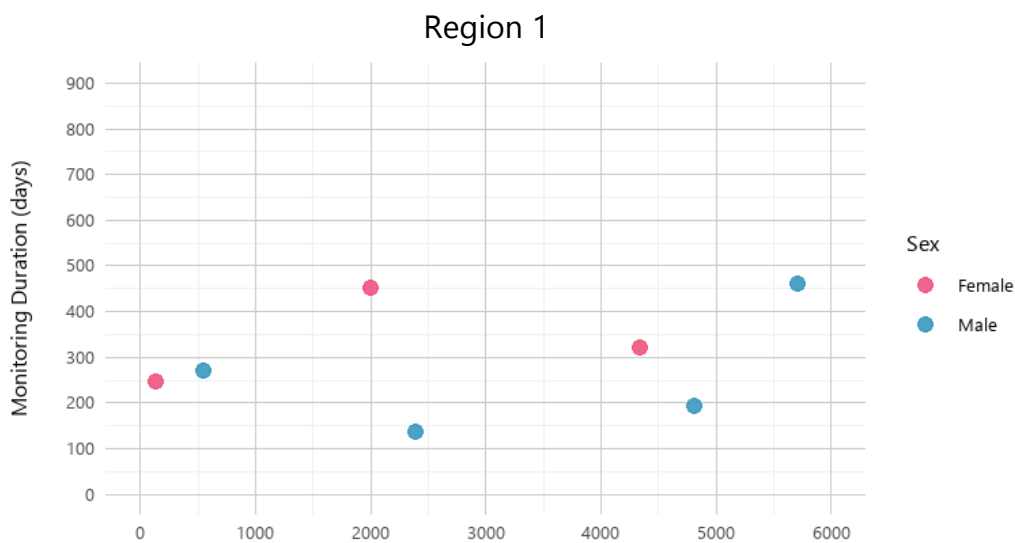


Fig. 20: Region 1 spatial extent and monitoring duration plotted by sex indicating the relatively mixed estimates.

Such large extents likely reflect atypical dispersal or exploratory behaviour rather than stable space use, as similar patterns were observed in the above individuals coalition mate (~5,000 km²) and an unrelated female (~4,000 km²). However, these observations remain ecologically significant, as they suggest that Region 1 may represent one of the few landscapes within the free-roamer range where large-scale, unrestricted movements of this magnitude is still possible. This highlights the role of landscape permeability in facilitating connectivity and long-distance movement, even if such behaviour is not representative of typical space use [42][57].

There is no clear relationship between monitoring duration and spatial extent, as individuals tracked for shorter periods often exhibited extents comparable to, or larger than those monitored for longer durations. This is consistent with the daily movement patterns observed, where individuals displayed frequent long-distance movements. As a result, spatial extent in Region 1 appear to reflect broad and flexible space use rather than constrained movement in clearly enclosed areas.

In contrast, Region 2 exhibits generally smaller and more constrained spatial extents, with most individuals (N = 13) occupying areas below 1,500 km² (Fig. 21). The few individuals who occupied ranges exceeding this threshold moved beyond the region into Botswana, particularly into sparsely populated areas running east along the border. Further movement into Botswana is still largely restricted by high human settlement density, particularly in the South-East district (Fig. 18B). However, movement along the South Africa-Botswana border towards PAs such as Gonarezhou (Zimbabwe) and Kruger TP (South Africa, Zimbabwe, Mozambique), seems likely and appear to be one of the few possible movement corridors keeping the Region 2 population connected within South Africa.

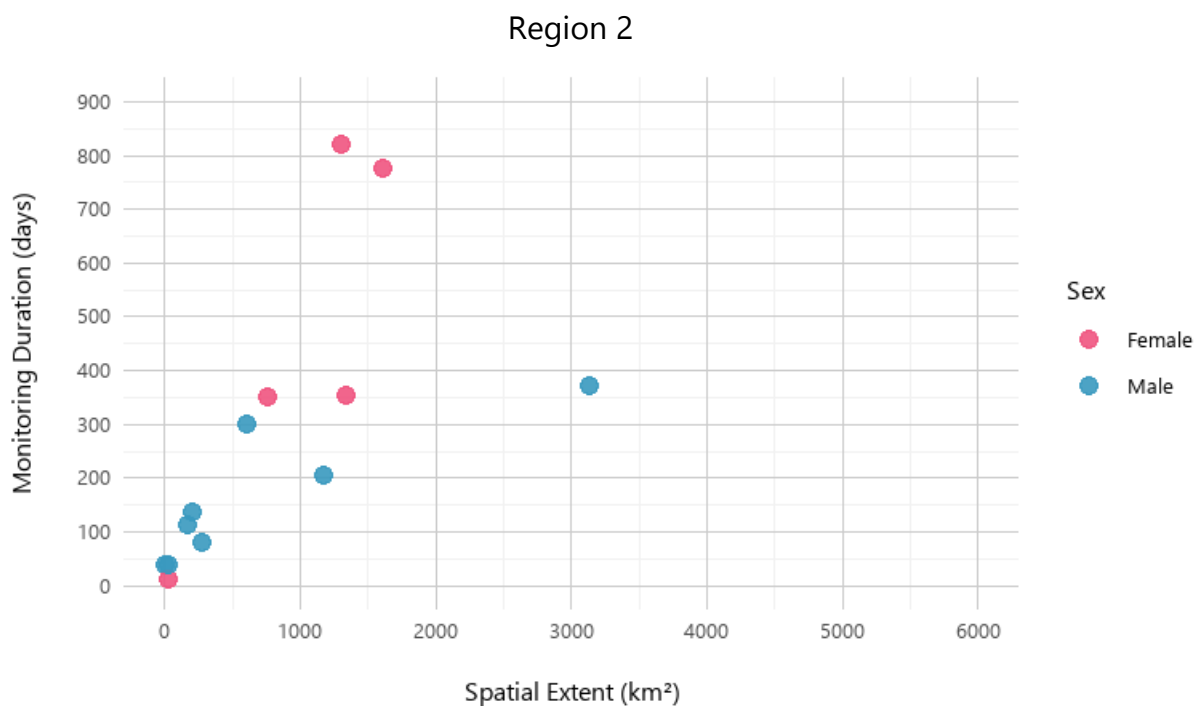


Fig. 21: Region 2 spatial extent and monitoring duration plotted by sex indicating the relatively mixed estimates.

Although some individuals with longer monitoring durations showed moderately larger extents, the overall spread remained limited compared to Region 1. The predominance of game fencing in Region 2 likely imposes structural constraints on movement, restricting the extent to which individuals can range. Consequently, spatial extent in this region is more confined and consistent across individuals.

Variation in spatial extent among females may also reflect reproductive behaviour during the monitoring period. Female cheetah with dependent cubs typically reduce their movement while denning and raising young. As a

result, spatial extent estimates derived during these periods are likely to be smaller and may not represent the full extent of space use under non-reproductive conditions. This is consistent with the observed movement data, where females generally exhibited more constrained daily movement compared to males. Periods of reduced movement associated with denning would therefore contribute directly to smaller spatial extents.

The relationship between spatial extent and monitoring duration (Fig. 22) further highlights the importance of extended tracking periods for reliable estimates. Individuals with shorter monitoring periods (often due to mortality or collar failure) tend to show highly variable spatial extents, which may underestimate or inconsistently represent true space use. In contrast longer monitoring durations appear to produce more stable and representative estimates.

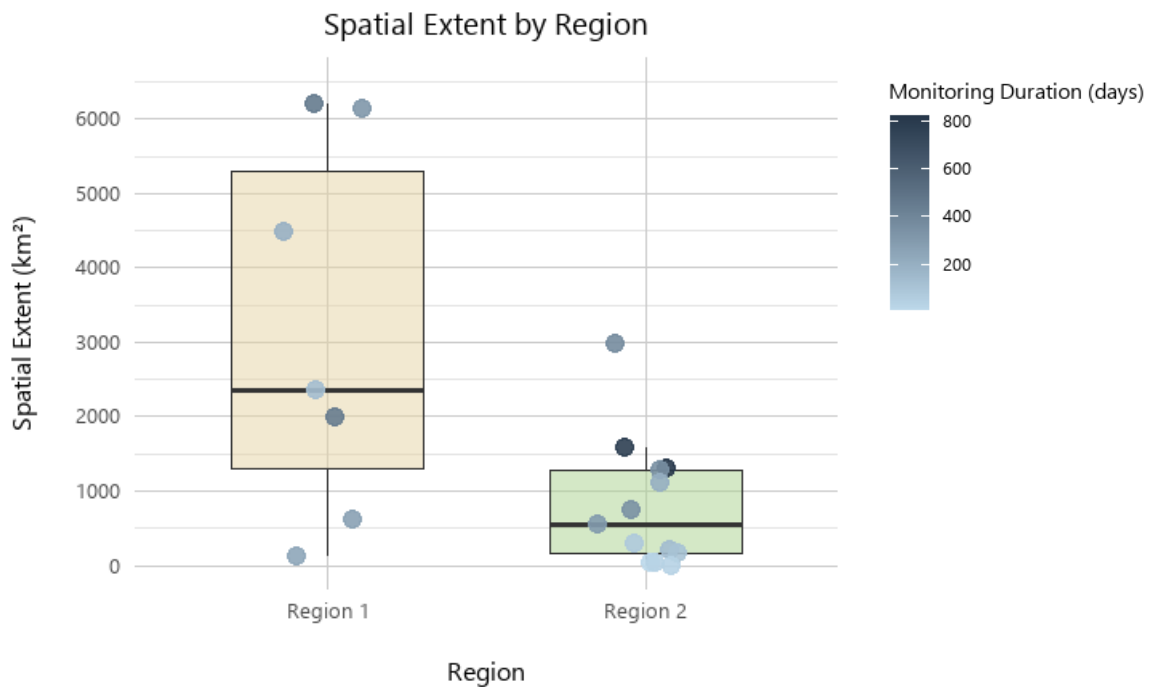


Fig. 22: Spatial extent by region concluded from a cluster based convex hull approach. Points represent individuals and are shaded by monitoring duration (days). Region 1 shows larger and more variable space use, while Region 2 shows low variability despite differences in monitoring duration.

Given these limitations, subsequent analyses were restricted to a subset of individuals ($N_{\text{Region1}} = 5$, $N_{\text{Region2}} = 7$) with monitoring durations exceeding 200 days to derive representative estimates of spatial extent for each region. **The median spatial extent in Region 1 was approximately 2,032 km², compared to 1,332 km² in Region 2.** These findings suggest that human density, land-use practices and associated fence types play a key role in the shaping of cheetah movement and range establishment. Open landscapes and permeable livestock-dominated systems support wider-ranging movement, while more managed, fenced wildlife systems constrain movement.

4.4 Dietary Results

4.4.1 Host/Prey hair cross-section analysis

During the initial phase of the census, hair cross-section analysis was considered an adequate tool for determining host and prey species [49]. Unfortunately, as the analysis progressed, confidence in the results dropped. Hair cross-section identification can wrongly identify species with similar hair structure, completely miss rare species and vary due to observer bias [87][24]. Of the 164 samples collected, 73 underwent hair cross-section analysis.

4.4.2 Host hair cross-section and DNA sequencing comparison

To compare methods, 62 faecal samples of the original 73 samples that were washed for hair analysis and had adequate remaining material to perform DNA sequencing were used. Of these 62 samples, 15 showed no genetic material available. Thus, only 47 samples that have undergone both analyses and resulted in a host species finding, were compared (Table 6).

Table 6: Direct comparison of 47 samples that underwent both hair cross-section analysis and DNA sequencing for host species determination.

Host Predator Species	DNA Analysis	Hair Analysis	Hair sample – false positive	Hair sample – false negative
Cheetah (<i>A.jubatus jubatus</i>)	34	39	23% (9)	-
Leopard (<i>P. pardus</i>)	3	4	75% (3)	-
Brown Hyaena (<i>Parahyaena brunnea</i>)	2	0	-	100% (2)
Caracal (<i>Caracal caraca</i>)	1	0	-	100% (1)
Black-backed jackal (<i>C. mesomelas</i>)	7	0	-	100% (7)
Chacma baboon (<i>Papio ursinus</i>)	0	3	100% (0)	-
Nothing found	0	1	100% (0)	-
	47	47		

Along with the host species comparison, prey species results also differed between the analyses, with only 23% of 38 comparable samples agreeing on the result. It is worth noting that some DNA could have been lost during the washing process, which must be considered when looking at the comparison between analyses. As a result of the above comparison, hair cross section analysis was discarded in favour of DNA sequencing that offers results with definitive identification at the molecular level.

4.4.3 Prey DNA sequencing results

DNA sequencing was done on all 164 faecal samples ($N_{\text{Region1}} = 138$; $N_{\text{Region2}} = 26$) at the Jonah Ventures lab. Of these, 106 samples have confirmed cheetah as the host species (65%) of which prey DNA was detected in 54 samples ($N_{\text{Region1}} = 46$; $N_{\text{Region2}} = 8$). Within one scat sample, multiple prey species can be identified. All identified prey belonged to game species, which were categorised into either small (<100 kgs) or large game (≥ 100 kgs; [75]) as shown in Table 7. This categorisation was used to check for small versus large game preferences and directly compare with camera trap dominant game species captured around the scat collection area.

Spatial buffers were generated around all confirmed cheetah scat collection points (Fig. 23) to represent the potential span of daily movement across different land-use types (section 4.3). Because the exact time of defecation was unknown, buffers were designed to represent the area within which an individual could

reasonably have moved and eaten prior to sample collection. Although some of these areas included cattle, goat or sheep farms, **none of the scat sampled contains livestock DNA.**

Table 7: All game species found in cheetah faecal samples based on DNA sequencing categorised into small and large species. The nr. samples indicates how often that species has been identified in cheetah scat. One faecal sample can have multiple prey detected in it

Game Species	Avg. weight (kg)	Category	Nr. samples
Blesbok (<i>Damaliscus pygargus phillipsi</i>)	80	Small	1
Blue wildebeest (<i>Connochaetes taurinus</i>)	260	Large	5
Bontebok (<i>Damaliscus pygargus pygargus</i>)	60	Small	8
Burchell's zebra (<i>Equus quagga burchellii</i>)	290	Large	1
Cape porcupine (<i>Hystrix africaeaustralis</i>)	17	Small	2
Duiker (<i>Sylvicapra grimmia</i>)	20	Small	4
Eland (<i>Taurotragus oryx</i>)	550	Large	6
Impala (<i>Aepyceros melampus</i>)	50	Small	6
Kudu (<i>Tragelaphus strepsiceros</i>)	240	Large	9
Oryx (<i>Oryx gazella</i>)	200	Large	1
Red hartebeest (<i>Alcelaphus buselaphus caama</i>)	130	Large	8
Scrub hare (<i>Lepus saxatilis</i>)	3	Small	2
Springbuck (<i>Antidorcas marsupialis</i>)	40	Small	8
Steenbok (<i>Raphicerus campestris</i>)	12	Small	1
Waterbuck (<i>Kobus ellipsiprymnus</i>)	220	Large	1

To reflect the ecological movement differences between regions, these base buffer sizes were calculated using a movement-based approach, defined as the sum of the median and upper quartile (75th percentile) of daily movement distances for each region ($N_{\text{Region1}} = 9.46$ km, $N_{\text{Region2}} = 9.33$ km). The base buffers in Region 1 were increased by 20% to account for generally greater spatial extent, while buffers in Region 2 were reduced by 20% to reflect more spatially restricted movement associated with a more fragmented landscape. This modest proportional adjustment is supported by the presence of long-distance movements observed in Region 1, compared to more constrained and consistent movement patterns in Region 2 (section 4.3.2). This resulted in final buffer distances of ~11.4 km in Region 1 and ~7.4 km in Region 2. Individual buffers were subsequently dissolved within each region to produce a continuous spatial extent representing the cumulative area of potential cheetah movement.

Of the 54 samples with game DNA present, 29 (54%) matched the dominant game type that was observed on camera traps, meaning that cheetah preyed on what was most abundant locally, regardless of whether the scat deposited was on a livestock farm. In the 25 samples where cheetah ate prey not of the local dominant type, large game species were featured as mostly eaten, even when small game was more common in the area. However, this does not necessarily prove a strong preference for large game. DNA sequencing cannot distinguish adults from juveniles, so many 'large game' detections may represent young animals, effectively aligning them with small game in size and vulnerability. **At least 52% of the samples with prey detected in the scat were small game species.**

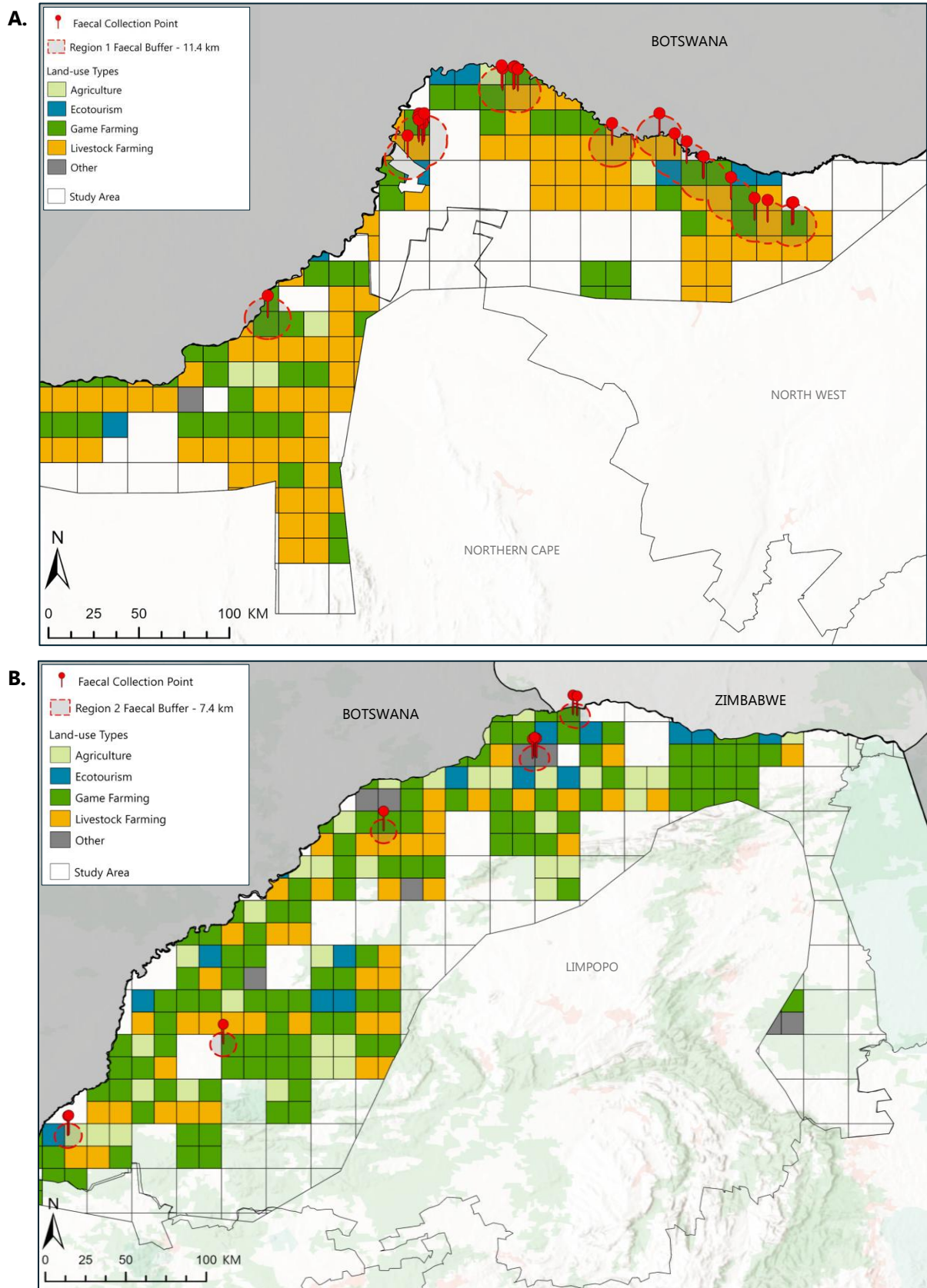


Fig. 23: Confirmed cheetah scat collection locations (black) as an overlay of different land-use types in Region 1 (A) and Region 2 (B). The buffer around the collection point provides an indication of the lands on which the cheetah might have hunted before defecating.

4.5 Activity behaviour

4.5.1 Revisitation rate

The revisitation rate measures how frequently a cheetah individual returns to the same sentinel site. The rate is calculated as the average days between recaptures on camera across clusters for individuals or coalitions that were detected more than once at a site. Knowing the revisitation rate of cheetah captured on camera gives an indication of their movement behaviour and site use. These outcomes are essential for the census to estimate movement range, identify key habitat areas and possible conflict hotspots.

The revisitation rate analysis was focused solely on the adult individuals seen on camera traps ($N = 66$) since sub-adults and cubs that are still with their mother are dependent on her movement. Individuals that are a part of a coalition or a female with a litter are seen as one group as they revisit sites together. After removing individuals that have not been recaptured at any given site, 18 groups in Region 1 (10 single individuals, five coalitions and three litters including the mother) across 24 different sites and 16 groups in Region 2 (12 single individuals and four coalitions) across only 15 sites were left (Fig. 24).

In Region 1, analysis of these 18 groups resulted in an average recapture rate of 164 days between visits, ranging from 2-440 days, with multiple individuals taking on average more than 400 days between revisits (Fig. 24A). Region 2 exhibited more frequent recaptures, averaging 128 days (ranging between 3–378 days), with only one occurrence above 300 average days between clusters (Fig. 24B). Notably, no individuals from either region were recaptured in the alternate region, indicating no evidence of cross-regional movement during the study period. These patterns suggest greater dispersive behaviour in Region 1 compared to Region 2, supported by the representative spatial extent of 2,032 km² and 1,332 km² respectively (section 4.3.2).

The Region 1 individuals collared during the FRCC were never captured on camera, however, in Region 2, four of the 13 collared individuals were captured on camera trap during the census, all of whom have since died. Seven of the total collared individuals in Region 2 have confirmed mortalities, two are unconfirmed and four are alive. This high mortality of the collared cheetah makes the data for direct comparison of a collared individual with its camera trap recaptures insufficient. However, by plainly observing the movement pattern of all collared individuals, constrained space use can be observed for Region 2 (section 4.3), supporting the camera trap recapture analysis: Region 2 individuals have more restricted movement compared to Region 1 individuals.

The reason for these regional differences in cheetah revisitation rates likely stems from a combination of ecological and anthropogenic factors based on habitat preference and landscape barriers. Human population density plays a key role as fig. 3 reveals that the cheetah IUCN range in Region 2 is encircled by high human density areas, making it an 'island population'. This effectively isolates the Region 2 population, with no dispersal to Region 1 but limited movement only into bordering countries (e.g. Botswana or Zimbabwe). Additionally, Region 1's landscape (desert and shrubland) is more appropriate for livestock farming, while the farms in Region 2 mostly consist of game farms, with denser vegetation [37][61] (Fig. 11A), attracting cheetah and other large predators (≥ 15 kg) due to a higher abundance of preferred prey species (Table 8). However, game farms generally use large game-proof fencing to keep their stock inside versus small strand fencing often used for livestock. These game fences are often impermeable, only making passage possible due to holes in or under the fencing, increasing fragmentation and restricting movement in Region 2 (Fig. 11B).

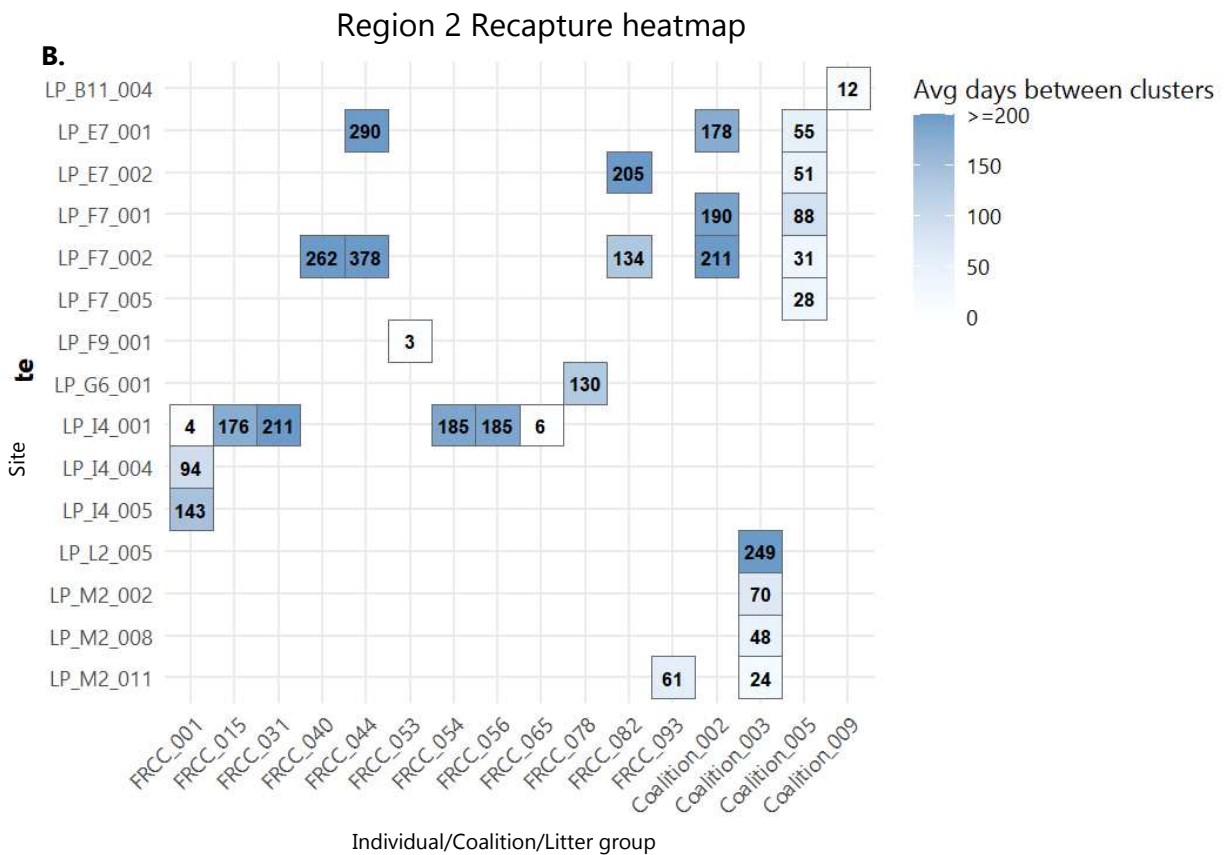
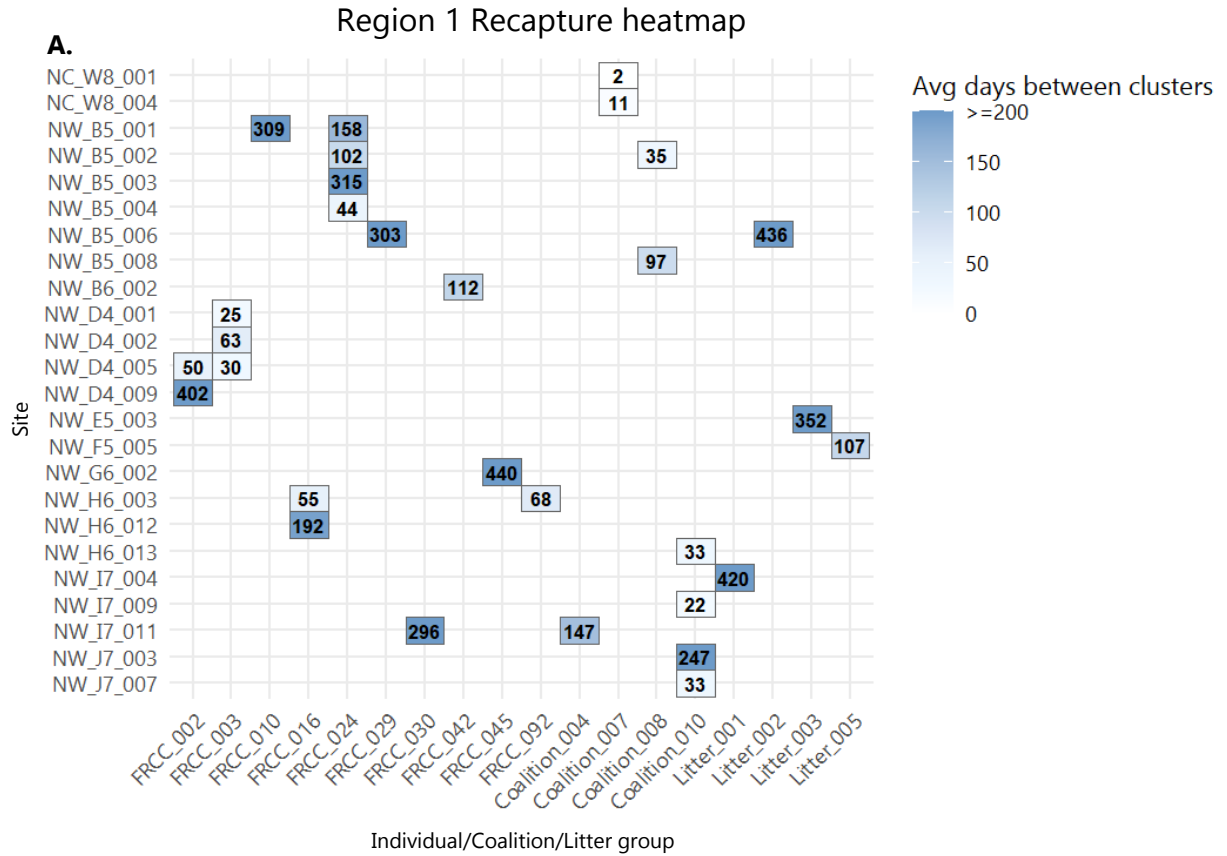


Fig. 24: Recapture heatmaps for Region 1 (A) and Region 2 (B). Light blue coloration is directly linked to low numbers inside the blocks, which indicate that the average days between a recapture of a specific individual at a specific site is low (i.e. fast recapture rate).

Table 8: The image count of each predator captured on camera trap per region. Note that the high cheetah image count compared to the other predators is not necessarily because of more individual presence compared to other predators, but due to the camera site placement being aimed to capture cheetah over other predators.

Predatory species	Avg. body weight (kg)	Region 1 (NC + NW)	Region 2 (NW + LP)	Total
Afro-Asiatic wildcat (<i>Felis lybica</i>)	5	640	859	1,499
Black-backed jackal (<i>C. mesomelas</i>)	9.5	11,267	11,077	22,344
Brown hyaena (<i>P. brunnea</i>)	42	1,071	3,127	4,198
Caracal (<i>C. caracal</i>)	13	1,105	1,003	2,108
Cheetah (<i>A. jubatus jubatus</i>)	48	7,313	8,570	15,883
Leopard (<i>P. pardus</i>)	46.5	287	2,130	2,417
Serval (<i>Leptailurus serval</i>)	13	35	102	137
Spotted hyaena (<i>Crocuta crocuta</i>)	63	35	844	879
Wild dog (<i>L. pictus</i>)	27	-	47	47

4.5.2 Activity patterns

The more restricted movement of Region 2 is also reflected in the cheetahs' activity patterns. Activity patterns show when cheetah are active over the 24-hour cycle estimated from the times at which individuals are recorded (by means of camera trap timestamp). Since activity is a function of time, it is usually visualised as circular density plots (0 to 2π radians) to visualize the continuation of days. For easier readability, non-circular graphs (Fig. 25) were created with both a radian axis (top) as well as a more intuitive 0-to-24-hour axis (bottom). The y-axis shows density, which represents the proportion (or probability) of clusters occurring at each time of day. A higher density value at a given time means that proportionally more clusters fall at that hour.

These activity graphs help us to identify main activity windows (e.g., nocturnal, crepuscular, diurnal) and to compare temporal niches between sexes, or regions. Region 1 exhibited a single, broad peak (Fig. 25A: density = 0.10 between 02:30–05:30 h), whereas Region 2 showed two higher, narrow density peaks (Fig. 25B: density = 0.125 between 04:00–05:00 h; density = 0.11 between 15:30–17:00 h). The fragmentation of Region 2 likely concentrates individuals' movement to a limited number of areas, increasing their detection frequency at specific

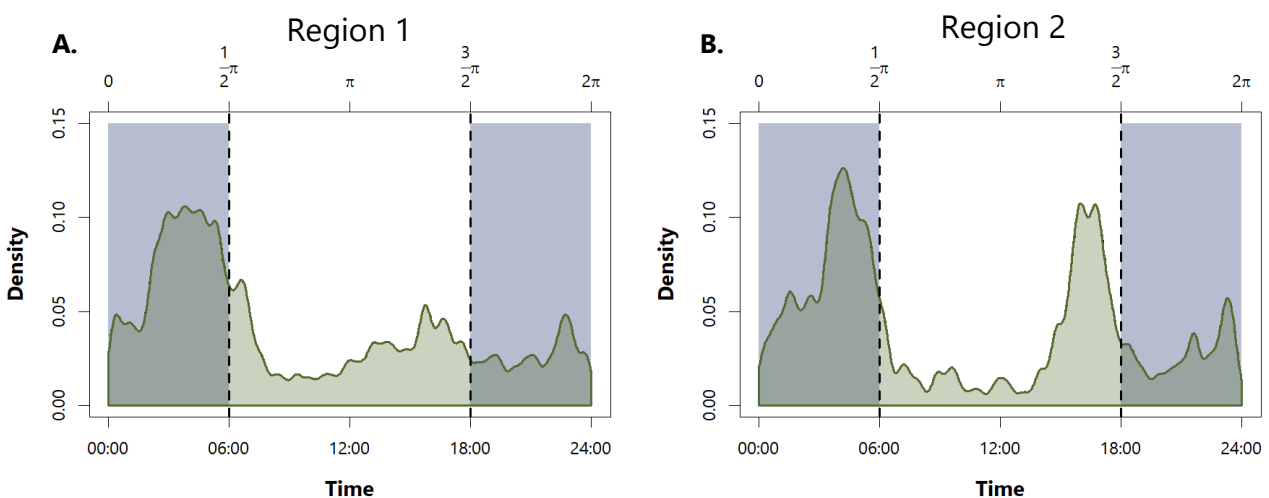


Fig. 25: Activity pattern graphs for Region 1 (A) and Region 2 (B). The green area under the curve equals to one to create proportional activity for each hour.

camera sites. With slightly fewer distinct groups and a higher revisiting rate by the same individuals, these repeated detections amplify the apparent height of the activity peaks.

Sex-specific patterns highlighted more female activity peaks during the day compared to males for both regions (Fig. 26). Region 1 females (N = 11) peaked sharply at dawn (Fig. 26A: density = 0.29 at 07:00h), while Region 2 females (N = 12) showed multiple moderate peaks (Fig. 26B: density = 0.15) throughout the 24hours. Male activity remained more uniform across both regions (N_{Region1} = 15, N_{Region2} = 13), resembling the pooled sex patterns of Fig. 25. Females with litters need to hunt opportunistically to meet their demand for food. This can push them to be active throughout the day. Females without litters are solitary, often having a wider range to search for prey and potential mates. In contrast, male coalitions defend stable territories, actively using sentinel points (whereas females use them re-actively) which reduces their need for wide-ranging movement, slowing down their activity pattern and “smoothing out” their activity peaks over time [20][59].

Overall, cheetah showed a preference for crepuscular activity **but also exhibited relatively high peaks during both daytime and nighttime periods**. This temporal flexibility likely stems from the diverse activity rhythms of key prey species such as springbuck, steenbok, hartebeest, and impala, which are active across 24h cycle, as well as the opportunistic hunting demands of mothers provisioning for their young at any time of day. Understanding these activity patterns is important for free-roaming cheetah, as it informs human-wildlife conflict mitigation (e.g., timing livestock or game protection), and supports habitat management to align predator-prey dynamics in fragmented landscapes.

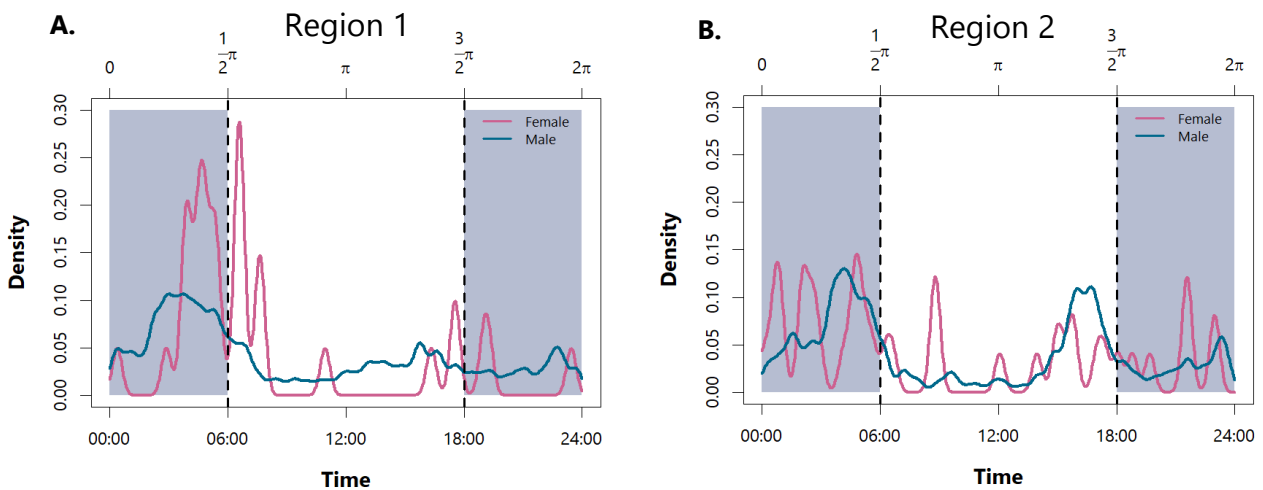


Fig. 26: Sex-specific activity patterns for Region 1 (A) and Region 2 (B). Male coalitions and mothers with cubs are counted as one individual.

4.6 Subjective landowner observations versus objective presence data

The questionnaire provided a different data type compared to our objective methods. While camera traps, satellite collars, and DNA analysis yield factual/objective evidence of cheetah presence, questionnaire responses rely on landowners' perceptions and tolerance of predators, producing more perceived/subjective data.

4.6.1 Presence

Across 175 grids, data collected was either subjective, objective or both (Table 9). In total, 147 grids had subjective survey responses, and 110 had objective data. Of the 147 grids surveyed with a questionnaire, cheetah presence was perceived across 85 grids (58%; Fig. 27A), although, the objective data only confirmed cheetah presence in 75 grids (68%; Fig. 27B).

To evaluate both datatypes properly, all grids with both perceived and effort for proven cheetah presence (N=77) data were compared (Table 9). Of these grids, objective evidence supported landowners' claims in 53 grids (69%). In the remaining 31% of grids (24 out of 77) where landowners reported cheetah presence, but objective data found none, perceptions differed from reality. This mismatch suggests false positives mostly driven by past (>5 years ago) personal or familial cheetah sightings, conflict with predators in general and people's tolerance.

Table 9: This table shows the respondent and grid count for both the subjective (questionnaire) and objective (confirmed cheetah based on camera trap, telemetry, sightings with proof, DCA removals and faecal data). The numbers with which the percentages have been calculated are presented between the brackets for clarity.

Metric	Sample size (N)	Percentage
Respondents	299	-
Grids subjective data	147	-
Grids objective data	110	-
Grids subjective + objective data	84	
Respondents reporting presence	189	63% (189/299)
Grids subjective presence	85	58% (85/147)
Grids objective presence	75	68% (75/110)
Grids subjective presence + objective data collection	77	92% (77/84)
Grids subjective presence with proof of cheetah presence	53	69% (53/77)
Respondents reporting presence and conflict	35	19% (35/189)
Grids subjective conflict	30	35% (30/85)
Grids subjective conflict + objective data collection	28	36% (28/77)
Grids subjective conflict + objective presence	21	27% (21/77)

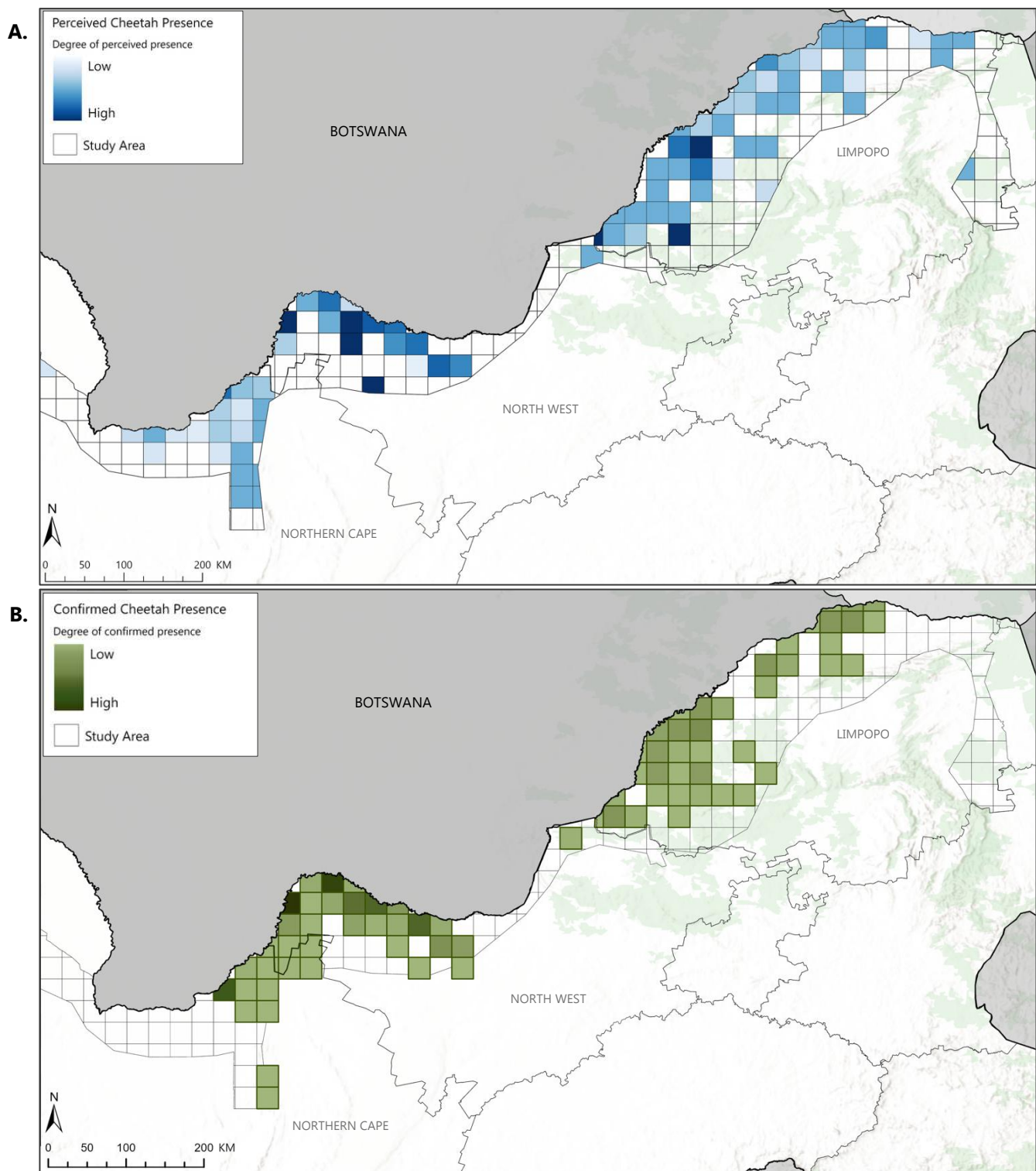


Fig. 27: Cheetah presence as indicated in **(A)** questionnaires and **(B)** confirmed with camera traps, mortalities, collars, scat collection and or video/photo evidence from landowners. The low and high degree of perceived presence **(A)** is based on the number of respondents in the grid that mentioned cheetah presence, compared to the total number of respondents in that same grid. The low and high degree of confirmation **(B)** is based on how many different types of data (1 – 5) have confirmed cheetah presence.

The total area of confirmed cheetah presence was estimated by combining all 25 x 25 km QDGC in which cheetah occurrence was verified. Using this approach, **confirmed presence extended across ~ 21,875 km² in Region 1 and ~25,000 km² in Region 2.**

4.6.2 Conflict

Within the questionnaire, 189 (63%) out of 299 respondents within the study reported cheetah presence, with 35 farmers (19%) also reporting conflict with cheetah specifically across 30 different grids (Fig. 28). Conflict was determined on a low to high scale using conflict reports (yes/no) in the questionnaire, where the proportion per grid equals the number of participants reporting conflict divided by the total responses in the grid.

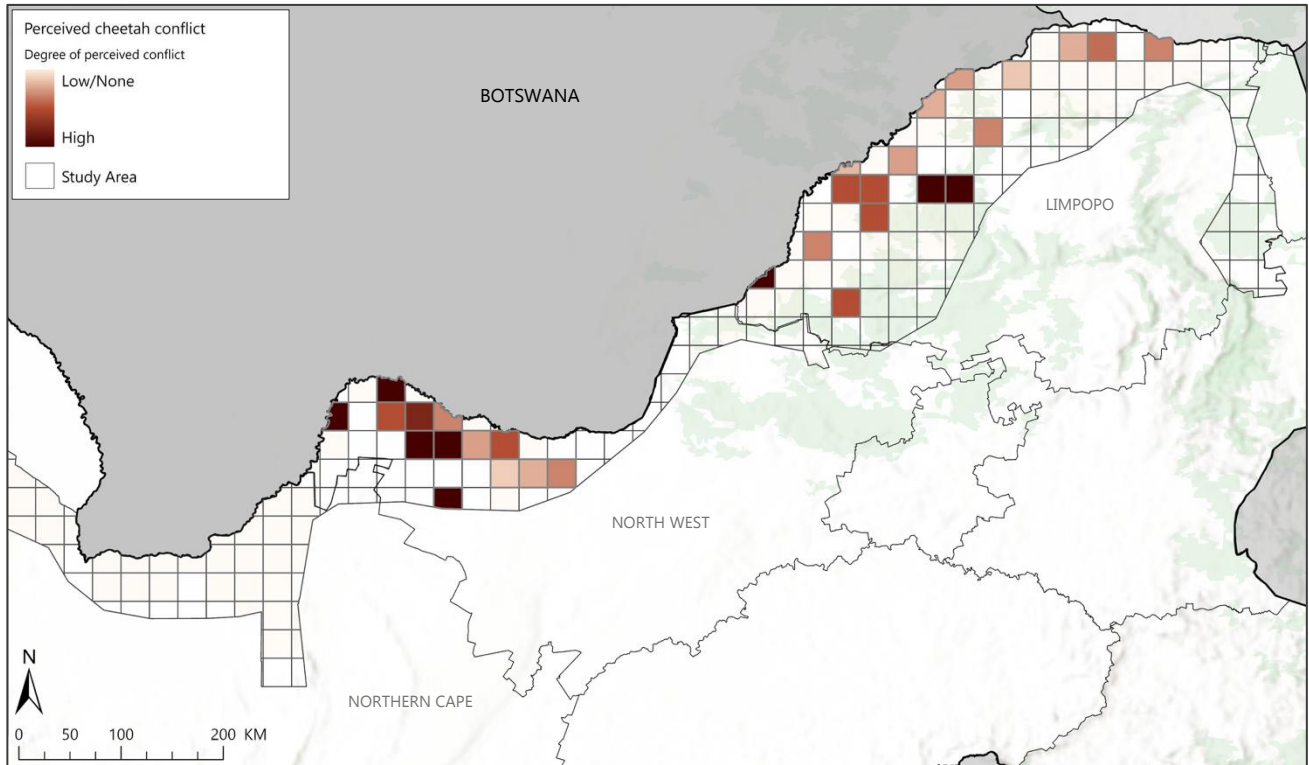


Fig. 28: All grids in which participants have mentioned cheetah presence together with cheetah conflict. The fully transparent grids have not reported any cheetah presence.

Pearson’s correlation analysis across 21 out of the 30 grids with additional camera trap presence, was executed to check whether a fast recapture rate (i.e. restricted movement; section 4.5.1) increases this human-cheetah conflict (Fig. 29). The Pearson correlation coefficient (r) measures the strength and direction of a relationship between two variables. It ranges from -1 to +1, with values near +1 meaning a strong positive relationship, and values near -1 meaning a strong negative relationship. Values near 0 mean little or no relationship [77]. Additionally, the analysis will provide a significance (p) value that indicates how likely the observed outcome was influenced by chance rather than facts. A small p -value means that the observed pattern is unlikely to be due to random chance. Therefore, true significant differences are obtained with low p -values (i.e. <0.05 , which means that there is less than a 5% probability of seeing this result due to chance) [30].

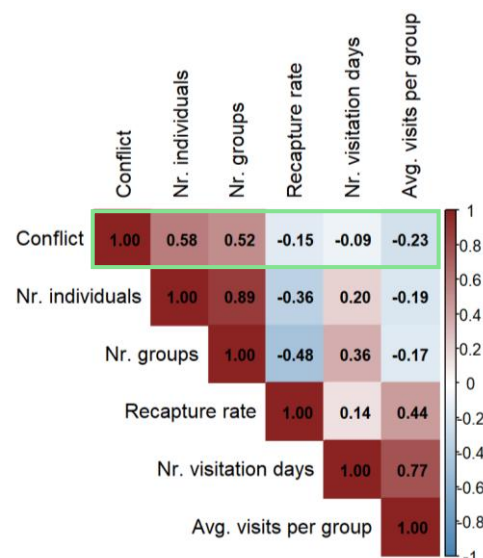


Fig. 29: Correlation matrix showing the effects of individuals, groups, recapture rate, visitation days and average visits per group on perceived conflict (green outline). Values <0 indicate a negative effect on conflict (e.g. high recapture, less conflict), while >0 values indicate a positive

The analysis revealed that cheetah abundance (total individuals per grid) was the primary driver of perceived human-cheetah conflict ($r = 0.58$; $p < 0.01$), followed by the number of groups ($r = 0.52$; $p < 0.05$). Recapture rate, the number of days between a cheetah capture on camera within a grid, and average visits captured on camera within a grid did not have any significant effects on the

perceived conflict. Thus, increased perceived conflict is not related to how often/long a cheetah is present on a farm, but it is more related to the actual number of individuals being present in the area regardless of their actions (e.g. passing through, resting, hunting).

For each grid with reported cheetah conflict, dominant land use types (agriculture, ecotourism, livestock, game, or other) were identified based on the primary cover within each cell. Whenever a grid cell had equal mixes of multiple land use types, all types present were counted. High perceived conflict occurred exclusively in game/livestock-dominated grids (9 grids total), while low-to-medium conflict spanned 21 grids across varied land uses.

4.6.3 Tolerance

Tolerance (i.e. the willingness or ability of individuals or communities to deal with potential costs, both mental, physical and financial, from living alongside wildlife) and conflict are often considered closely linked to one another. To test whether this is the case within the census, tolerance was similarly scaled as the conflict (low to high) based on five questions assessing attitudes toward larger predators in general (Fig. 30).

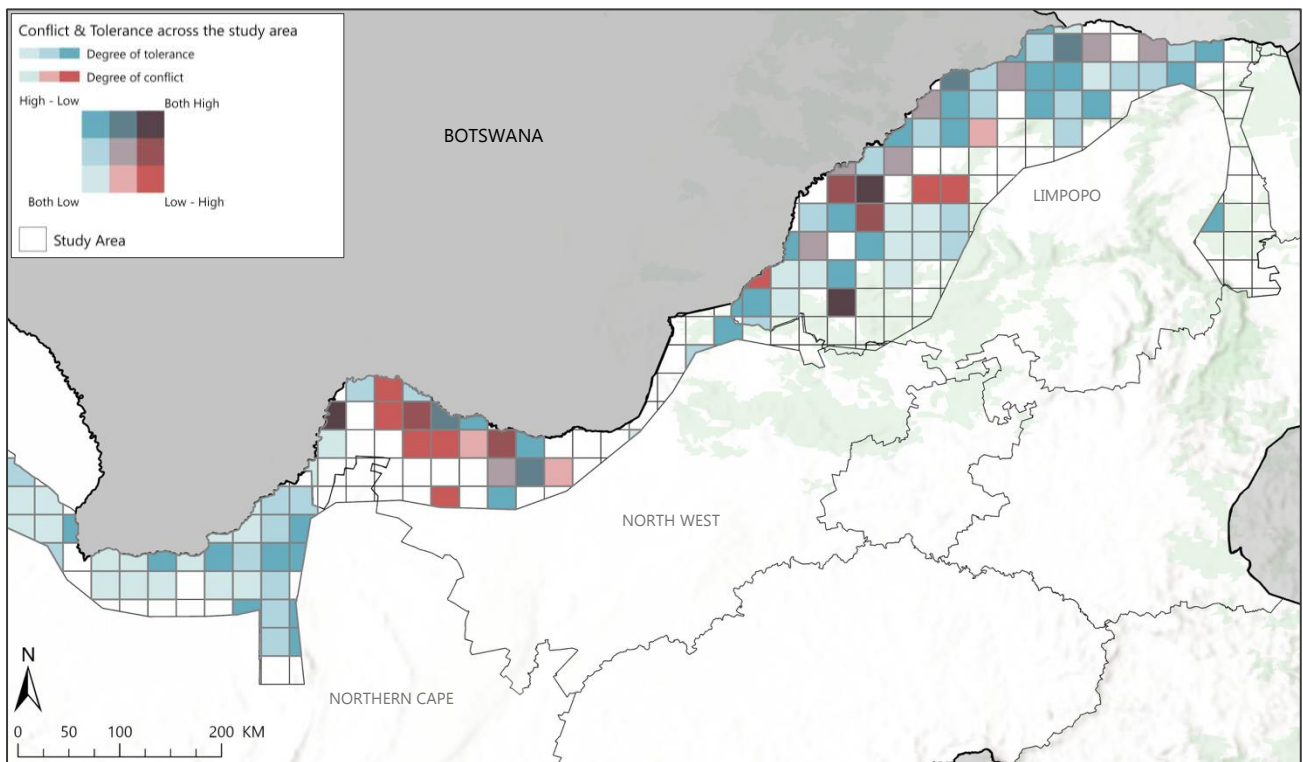


Fig. 30: A perceived conflict and tolerance map. The map consists of nine different colours, ranking from low conflict and low tolerance (light blue) to high conflict and high tolerance (dark red). This map indicates people's tolerance while taking conflict occurrences into account.

Almost a third (31%) of the conflict grids showing low conflict paired with high tolerance, 10% exhibited very high conflict and very low tolerance, 25% reported both low conflict and low tolerance, and 3% endured high conflict yet remained highly tolerant. This pattern reveals that conflict and tolerance, while closely related, are distinct; high conflict does not inevitably result in low tolerance. For identifying new conservation areas or cheetah corridors, both conflict and tolerance must therefore be considered. Farmers in South Africa would like to be supported in ways that increase their tolerance towards predators.

From a conservation perspective, areas with high tolerance, even amidst high conflict, may present opportunities for the development of functional corridors that facilitate cheetah movement. Importantly, these findings highlight that range maps should extend beyond ecological suitability alone to incorporate socio-ecological

factors such as conflict intensity and tolerance, as areas with high conflict may ultimately represent low habitat viability for sustaining cheetah populations despite otherwise suitable environmental conditions.

Differences in conflict perception and tolerance are likely shaped by cultural values, education, financial constraints, and access to mitigation interventions. Within the questionnaire, 227 responses were submitted from farmers experiencing yearly unwanted predator interactions, of which 75% mentions their tolerance towards predators will increase when there is sufficient support. These participants also responded to questions specifically aimed at how they would like to be supported. This open-ended question resulted in seven distinct types of support requested (Table 10). The most frequently requested form of support was financial assistance. Importantly, this was not limited to direct financial aid, but also compensation for lost livestock or game, assistance with veterinary costs following predator attacks, and support for anti-poaching efforts, since poaching combined with depredation can further intensify hardship. Although financial aid is difficult to provide without government involvement, some NGOs, such as COT, are already contributing through research support, trapping and relocation assistance, and training guard dogs.

Table 10: Questionnaire responses of 227 participants on how they would like to be supported to increase their tolerance towards free-roaming predators.

Support requests	Region 1	Region 2	Total
Financial support	94	47	141
Predator trapping and relocation assistance	26	21	47
Predator based research and monitoring	3	12	15
Hunting permits	3	7	10
Guard dogs	1	5	6
Funding to place and maintain fencing	0	5	5
Education on coexistence with predators	0	3	3
			227

4.7 Genetics

4.7.1 Scat DNA sampling

A total of 106 cheetah host DNA samples extracted by Jonah Ventures were analysed by the University of California Davis Veterinary Genetics Laboratory for relatedness. After microsatellite genotyping, 26 individuals ($N_{\text{female}} = 6$; $N_{\text{male}} = 20$) were identified ($N_{\text{Region1}} = 18$; $N_{\text{Region2}} = 8$) from 82 samples, while 24 samples (22%) yielded no result. These 'failed' samples could be due to either low-quality, degraded DNA or environmental contamination [45]. Of the 26 individuals, seven individuals were completely unrelated, while the remaining individuals formed six unrelated lineage groups. Further in-depth analysis for relatedness and inbreeding, although possible, was not done due to the relatively small sample size and low-quality DNA samples (extracted from scat) as this could provide inconsistent results [71]. Thus, it was not possible to confidently determine the degree of relatedness among individuals. Despite this, the spatial distribution of these lineages across the study area (Fig. 31 and Fig. 32) provided valuable insight into movement patterns and landscape use.

Region 1 distribution indicated a relatively high degree of connectivity, despite the absence of confirmed relationship degree. Multiple lineage groups are detected across a wide geographic extent, with movement patterns suggesting that some individuals transverse considerable distances between sampling locations. Importantly, several distinct lineage groups converge on the same sentinel sites, where repeated detections occur over time. This provides strong evidence of functional connectivity and that individuals are not always spatially restricted.

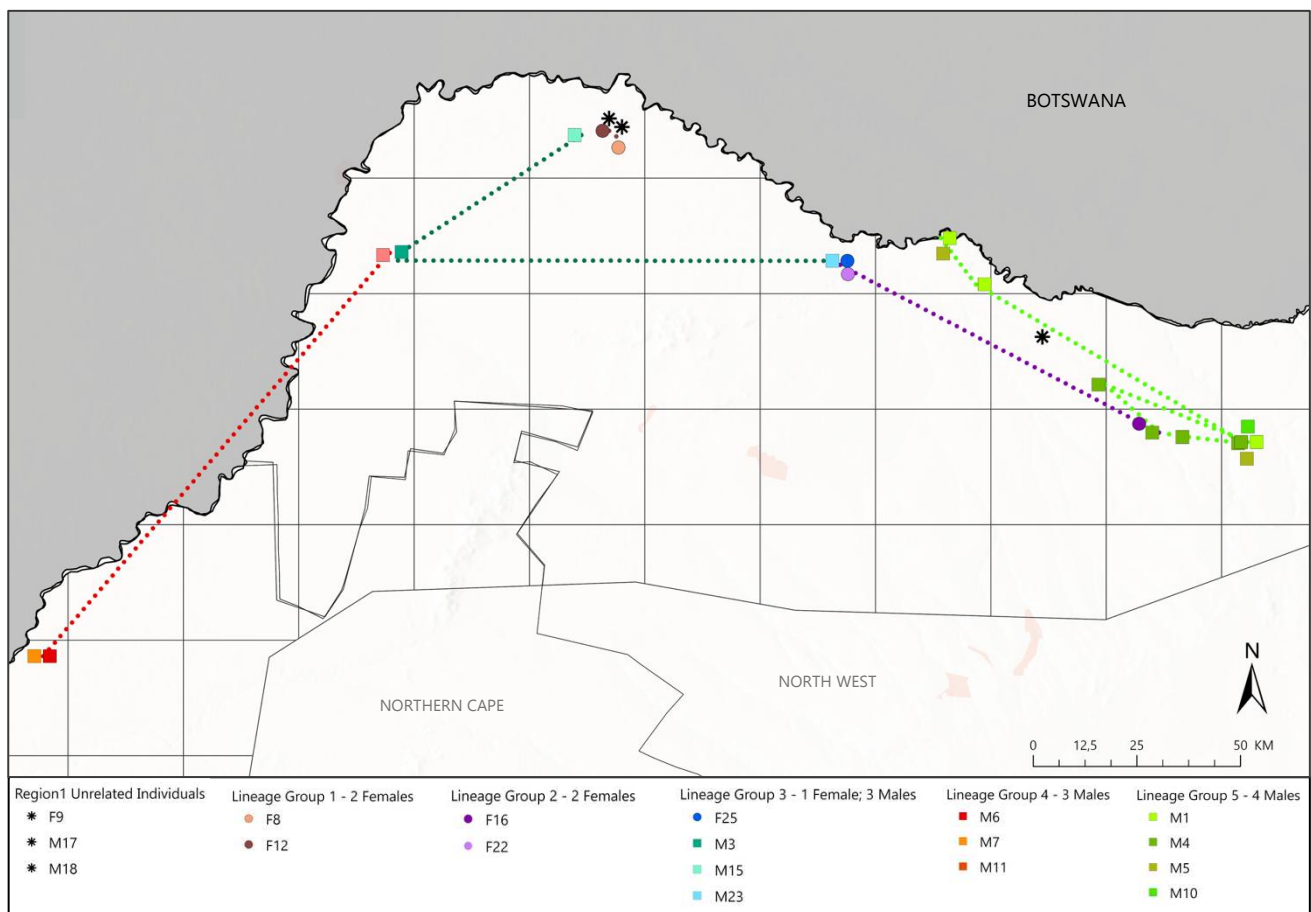


Fig. 31: Distribution of genetically identified cheetah lineages in Region 1. Each colour within a region denotes a unique genetic lineage, with connecting lines illustrating inferred movement. Lineage assignments are based on genetic differentiation and do not represent degree of kinship or relatedness.

In Region 2, the distribution of lineage groups suggested spatially constrained movement, although connectivity is still evident. Individuals show movement across the landscape, with some convergence occurring at shared

sentinel sites. However, compared to Region 1, the spatial spread of detections was more limited. It is important to note that sampling effort was considerably lower than in Region 1, largely due to logistical constraints that included weather conditions and limited habitat accessibility. As such, the observed patterns likely underrepresent the true extent of movement and site use.

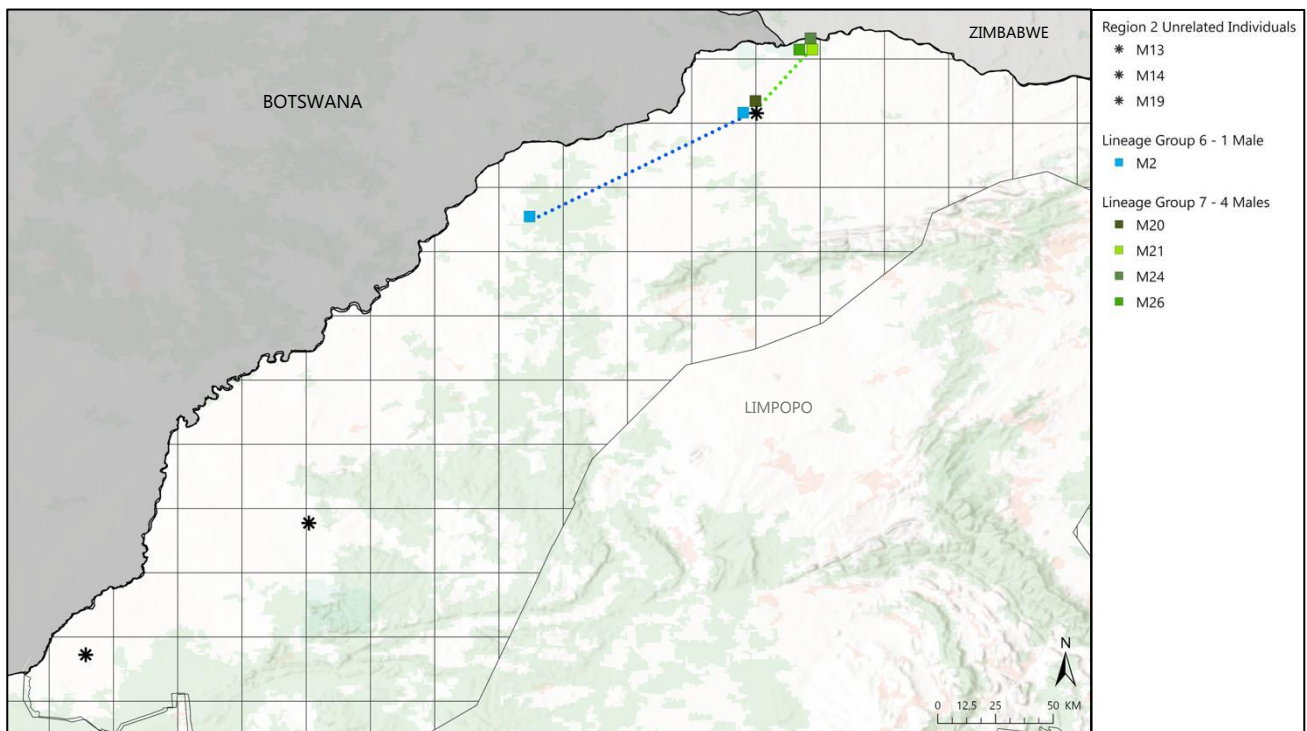


Fig. 32: Distribution of genetically identified cheetah lineages in Region 2. Each colour within a region denotes a unique genetic lineage, with connecting lines illustrating inferred movement. Lineage assignments are based on genetic differentiation and do not represent degree of kinship or relatedness.

An effort was made to integrate these genetic results derived from scat with camera trap detections; however, it was not possible to confidently match genetically identified individuals to those observed on camera. Besides a lone 2-male coalition (Lineage Group 4) in the Northern Cape, this uncertainty was further pronounced at sites where multiple cheetah were present. Consequently, genetic and camera trap datasets were interpreted independently, with any potential overlap considered suggestive rather than conclusive.

4.7.2 Blood/Skin sampling

Samples ($N = 46$) that were obtained from cheetah from within the two regions were analysed by the Unistel Medical Laboratory in Cape Town, South Africa (Appendix VII). DNA was extracted from whole blood, blood on Guthrie-cards and tissue using the E.Z.N.A. Blood DNA Mini Kit., although only 33 samples ($N_{\text{Region1}} = 11$; $N_{\text{Region2}} = 22$) were successfully amplified on the UML Feline Predator STR panel. Interpretation of Region 1 samples should however be approached with some caution due to the smaller sample size available. For this report, the diversity indices of the Number of Alleles (N_a), the Effective Number of Alleles (N_e), Heterozygosity (H_o and H_e), Fixation Index (F_{IS}) Inbreeding Coefficient and the Relatedness between individuals were summarized.

4.7.2.1 Allele Diversity

Number of Alleles (N_a)	Calculates how many variants are found at each genetic marker within the dataset.		
	<i>Interpretation</i>	<i>Value</i>	<i>Favourable Outcome</i>
	<p>Higher N_a (2 – 5): indicates a greater variety of genetic options within the group.</p> <p>Lower N_a (1.5 – 2): suggests a limited number of alleles, which can be attributed to previous population declines, small population size and isolation or limited gene flow.</p> <p>N_a values lower than 1.5: can be seen as a cause of concern.</p>	<p>Identifies uncommon alleles that might not significantly influence heterozygosity (the possession of two different alleles of a particular gene). Aids in monitoring the decline of genetic diversity over time. Valuable for pinpointed populations that may have experienced bottlenecks. Crucial for assessing long-term adaptive capacity, even when the present health of the population appears stable.</p>	<p>A higher number of alleles per locus is generally favourable, with values above 4 – 6 indicating good genetic diversity, while very low values (<2) may suggest reduced variation or isolation.</p>
Effective number of Alleles (N_e)	Estimation of how many alleles are effectively contributing to genetic diversity, considering how evenly allele frequencies are distributed.		
	<i>Interpretation</i>	<i>Value</i>	<i>Favourable Outcome</i>
	<p>N_e close to the N_a value: alleles are evenly distributed.</p> <p>N_e value lower than N_a: a few alleles dominate the population.</p> <p>N_e of 1.3 – 2.5: adequate diversity.</p> <p>N_e of 1.1 – 1.3: caution is advised.</p> <p>Very low N_e (<1.1) cause for concern – reduced functional diversity, even if multiple alleles exist.</p>	<p>N_e is more informative than N_a for understanding real genetic diversity and is a strong indicator of population stability, genetic drift and long-term evolutionary potential.</p>	<p>Both N_a and N_e is low but values remain stable across loci and groups over time. If N_a is moderately high but N_e is very low – this would suggest some alleles although present, are being lost through genetic drift.</p>

The Region 1 dataset exhibited moderate allelic diversity (Fig. 33), with a mean number of alleles ($N_a = 4.16$) and an effective mean number of alleles ($N_e = 2.8$). The Region 2 dataset also exhibited moderate allelic diversity, with a mean number of alleles ($N_a = 4.8$) and an effective number of alleles ($N_e = 3.29$). Both indicate a relatively even distribution of alleles across loci (the fixed physical location of a DNA sequence on a chromosome).

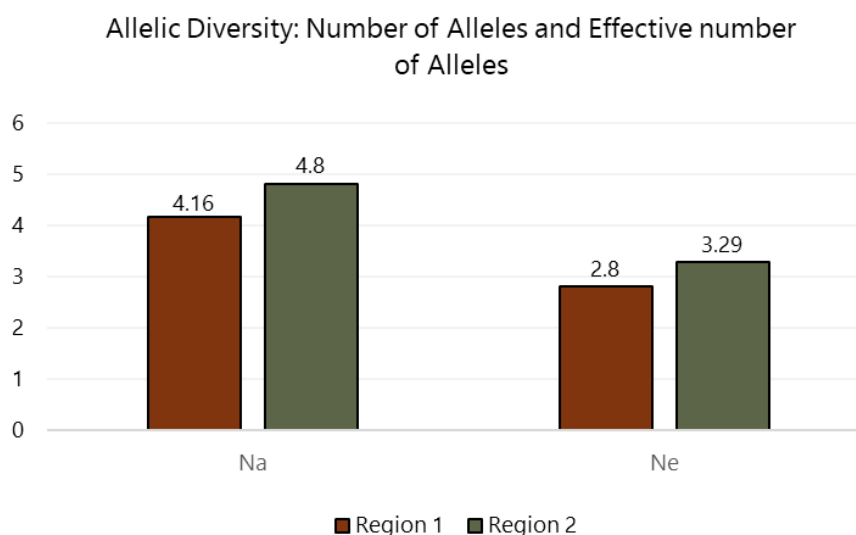


Fig. 33: The mean number of alleles (N_a) and effective number of alleles (N_e) for both regions.

4.7.2.2 Heterozygosity and Fixation Index

Heterozygosity (H_e and H_o)	Utilised to assess the degree of genetic diversity present within a population. H_e: what is expected. H_o: what is observed		
	<i>Interpretation</i>	<i>Value</i>	<i>Favourable Outcome</i>
	H_o and H_e are close in value: indicates healthy genetic mixing. H_o lower than H_e: possible inbreeding or separation into sub-groups. Values between 0.3 – 0.5: no cause for concern. Values below 0.3: caution. Values below 0.25: concerning.	Higher genetic variation generally indicates better adaptability and resilience to diseases and environmental changes.	Higher values are considered more favourable, however, within cheetah groups, values are expected to be lower than in many species.
Fixation Index (F_{is})	Measuring whether animals are more genetically similar than expected which would indicate whether animals within a sub-population is breeding mostly among themselves.		
	<i>Interpretation</i>	<i>Value</i>	<i>Favourable Outcome</i>
	Values close to 0 (0-0.10): indicates that individuals within the group are likely mating at random (showing no significant signs of inbreeding). High positive value (0.1–0.15): suggest there is less diversity observed within the group than expected. <i>Values greater than 0.15 is a cause for concern.</i> Negative value: indicates more diversity within the group than expected, which may rise from admixture between groups or sampling bias within the dataset.	Positive values may indicate inbreeding, restricted mate choice or hidden population subdivision.	Values close to 0 are ideal.

In Region 1, observed heterozygosity (H_o = 0.580) slightly exceeded expected heterozygosity (H_e = 0.568), resulting in a mildly negative inbreeding coefficient (F_{is} = -0.034; Fig. 34). This pattern suggests a small excess of heterozygotes and indicates little evidence of widespread inbreeding within the population. In Region 2, observed heterozygosity (H_o = 0.527) was lower than expected heterozygosity (H_e = 0.639), resulting in a positive inbreeding coefficient (F_{is} = 0.155).

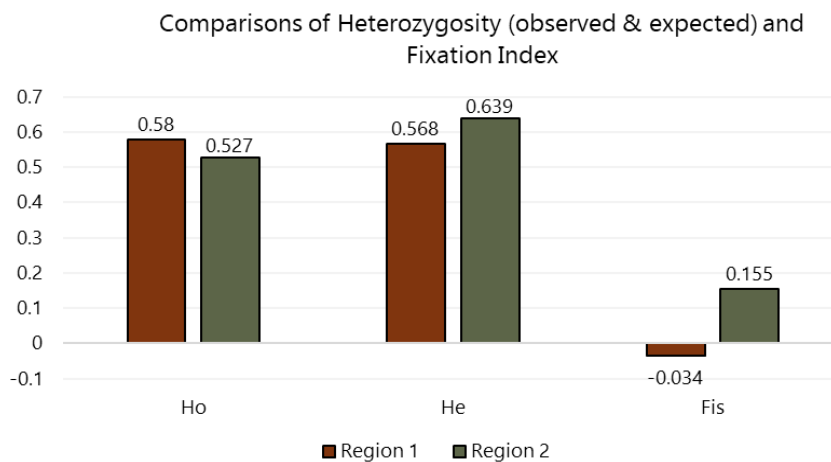


Fig. 34: The observed heterozygosity (H_o) and expected heterozygosity (H_e) for both regions.

This pattern within the Region 2 population indicates a deficit of heterozygotes, suggesting possible inbreeding, population substructure (the division of a larger population into smaller, distinct, and often genetically differentiated groups due to non-random mating, geographic barriers or limited migration), or the presence of highly related individuals within the sampled population.

4.7.2.3 Inbreeding coefficients and relatedness estimates

Relatedness	Measures how genetically similar two animals are. It estimates whether two animals are likely to be close relatives or not.		
	<i>Interpretation</i>	<i>Value</i>	<i>Favourable Outcome</i>
	High Values (0.1 – 0.2): likely close family (siblings, parent-offspring). Values close to 0 (-0.05 – 0.1): Unrelated animals Values larger than 0.2 can be seen as cause for concern.	If many animals within a group share close genetic ties, it may indicate restricted movement, limited mating options and reduced population size.	Most animals should not be closely related. A certain level of relatedness is typical, but a population primarily composed of close relatives could face potential risks.
Inbreeding coefficient	Estimates how likely it is that an animal inherited the same genetic material from both parents, i.e., how closely related were the animals' parents to each other.		
	<i>Interpretation</i>	<i>Value</i>	<i>Favourable Outcome</i>
	Values close to 0 (0-0.1): parents were not closely related. Higher values (0.1-0.15): increased level of inbreeding. Values larger than 0.15 should be seen as a cause for concern.	High inbreeding can reduce fertility, survival, and disease resistance over time.	Low values are best. While some inbreeding is anticipated because of historical population declines, excessively high levels could be concerning, particularly if they continue to rise.

Pairwise relatedness was estimated using the Trio Maximum Likelihood (TrioML) estimator in the software package Co-ancestry, which is used to estimate the degree of kinship between individuals based on molecular data such as microsatellites (Fig. 35A). Additionally, the Dyadic Maximum Likelihood (DyadML) estimator was also utilised. This is a statistical approach used to estimate the pairwise relatedness or kinship coefficient between two individuals (a dyad) based on their microsatellite genotypes, without relying on a pre-existing pedigree. Both estimators are widely regarded as two of the most accurate estimators when dealing with inbred populations, small sample sizes or data containing genotyping errors [38]. For individual inbreeding coefficients, Ritland estimators (Ritland and LynchRD) are widely used to estimate the distribution of inbreeding in natural populations where pedigrees are unknown as well as estimate how related two individuals are and how inbred a single individual is (Fig. 35B,[34]).

Although relatedness and inbreeding are closely linked, they capture different aspects of population genetic structure. Relatedness reflects the average degree of kinship among individuals within a population, whereas inbreeding measures the probability that an individual has inherited identical alleles from related parents [10]. As a result, populations may exhibit elevated relatedness without strong inbreeding if close relatives are not mating, or elevated inbreeding without uniformly high relatedness if related matings occur within particular subgroups.

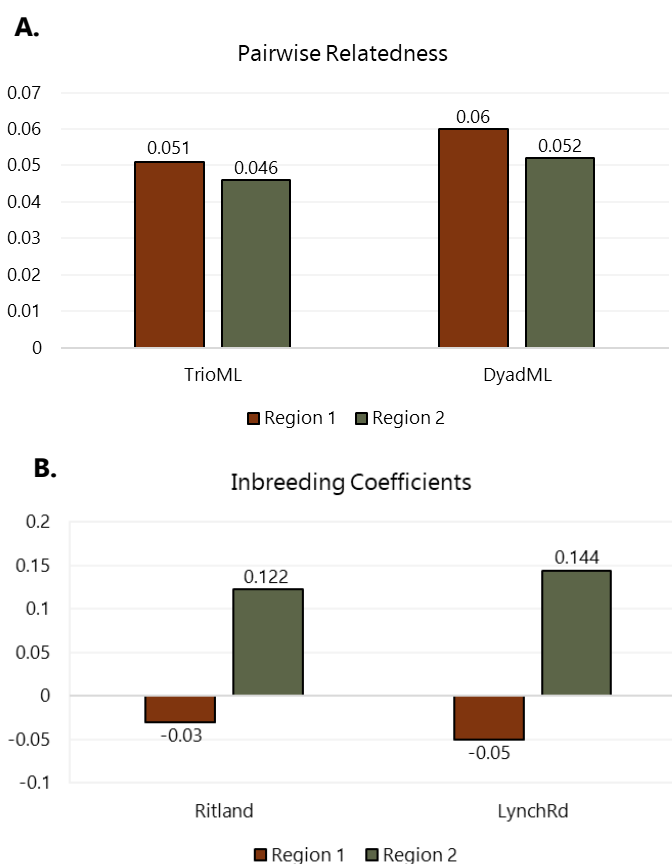


Fig. 35: The pairwise relatedness, kinship among individuals within a population, (A) and inbreeding coefficient, inheritance of identical alleles, (B) for both regions. The negative inbreeding value for Region 1 (LynchRd of -0.0046) does not indicate outbreeding, but it means that the estimate is slightly below zero because the individual appears to be a bit less related to the reference population than expected.

Mean relatedness values were low in both regions, indicating that most sampled individuals were not closely related. Region 2 exhibited lower relatedness estimates (TrioML = 0.046; DyadML = 0.052), consistent with a broader genetic base and greater mixing among individuals. However, inbreeding coefficients for this region were moderately elevated (Ritland = 0.122; Lynch & Ritland = 0.144), suggesting some mating among related individuals or the presence of population substructure.

Region 1 displayed similarly low relatedness estimates (TrioML = 0.051; DyadML = 0.060), indicating limited overall kinship among individuals supporting the interpretation of a relatively well-mixed population. Inbreeding estimates for Region 1 were near negative (Ritland = -0.030; LynchRd = -0.050), indicating little evidence of close kin breeding. Together, these patterns suggest that while Region 1 individuals may share ancestry due to localised founder effects and the presence of family groups, breeding practices appear to limit inbreeding. Conversely, Region 2 reflects a broader genetic base but exhibits signs consistent with substructure or restricted gene flow that may increase inbreeding risk.

4.7.3 Relationship between the two regions

Further analysis (population genetic distance, identity, gene flow and the Bayesian package called STRUCTURE) was undertaken to assess the overall relationship between the two regions. These results indicated that there was movement between the regions, resulting in only moderate genetic differences. Overall, the population appeared to be broadly connected, relative to genetic distances, rather than strongly isolated.

Taken together, these findings indicate that the sampled cheetah form a genetically connected population with localised family groups but with no strong regional isolation as of yet. Close relatives occur within the population, although individuals from different areas share ancestry and contribute to a shared gene pool. Although genetic analysis indicates ongoing or recent activity between the two regions, ecological evidence suggests that barriers such as increased human population density are becoming more restrictive. Parapatric structuring is observed when neighbouring populations are separated by a semi-permeable barrier, that limits, but does not completely prevent, dispersal [94]. While full speciation, the process by which a single population splits into two groups that become genetically distinct, has not occurred, the system reflects conditions consistent with parapatric differentiation driven by reduced but not entirely absent, gene flow [39].

This emerging isolation is of particular concern given the small number of mature individuals ($N_{\text{Adults}} = 83$; $N_{\text{Region1}} = 33$; $N_{\text{Region2}} = 50$) identified during the census. Small and fragmented populations are especially vulnerable to genetic drift, inbreeding, and the gradual loss of genetic diversity, all of which may reduce long-term adaptive potential and population persistence. Conservation genetics frameworks proposed the "100/1000 rule" for low breeding mammals, suggesting that a minimum effective population size of approximately 100 individuals is required to limit short-term inbreeding effects, while 1000 or more individuals are necessary to maintain long-term evolutionary potential [69].

5. Policy and Management in South Africa

South Africa's northern regions face ongoing human-predator conflicts, as a large variety of predators occasionally prey on game or livestock, threatening farmers' livelihoods [92]. Therefore, balancing cheetah conservation within a human dominated system requires robust and clear policies, yet South Africa's policy framework remains as a mostly outdated, patchwork of rules that are often challenging to navigate. This section in the report briefly reviews past and current predator management related policies, rules, farmer interventions, attitudes, and principles for adaptive management to improve coexistence.

Both in the past and present, the black-backed jackal (*C. mesomelas*) and caracal (*C. caracal*) are perceived as high-conflict animals due to large, abundant populations compared to scarcer large predators such as leopard and cheetah [90]. This resulted in often lethal predator control with strong government backing. A very popular method was the rise of hunting clubs. In the 1960s, subsidized hunting clubs were so successful that the government believed that the depredation problems were under control by 1967 [18][7]. However, most hunting regulations are not target specific and often lead to lethal captures of other species, including large predators which naturally suppress the presence of mesopredators through competition for prey and occasional predation. With free-roaming lions eradicated from South Africa, African wild dogs nearly extinct, and cheetah numbers dwindling rapidly, this top-down control is lost. This results in the opposite effect where mesopredators like the jackal and caracal can once more roam unchecked [7][9].

This loss of larger predators, together with a rise in environmentalists, brought on a more restricted use of predator interventions. The 1970s brought restrictions via the Hazardous Substances Act 15 of 1973, which prevented the use of poison. By the early 1990s governmental subsidies decreased to a minimum [7], the Firearms Control Act 60 (2000) banned unethical devices like coyote getters to protect non-target species and CapeNature partnered with NGOs to phase out gin traps and night hunting [18]. By 1995, the National Problem Animal Policy Committee (NPAPC) imposed stricter rules, disfavoured the once popular hunting clubs, and creating more managed and regulated hunts. CapeNature followed in 1996, requiring consultations with animal rights groups, environmentalists, farmers, and academics for damage-causing animal control. Currently, no unified legal framework governs predator management. Instead, disconnected, outdated legislations create conflicts between groups, with administratively burdensome permit systems [23][44]. There is no coordinated conflict monitoring across provinces, with declining governmental aid for fencing or control [8][44].

With South African farmers mostly left to fend for themselves, while following an unclear set of rules and guidelines, frustration levels increase while tolerance towards predators decline. In the questionnaire (section 3.1), respondents were asked how predatory interactions affected their wellbeing. Almost 90% indicated that their wellbeing is strongly dependent on how well their farming is doing (i.e. livestock/game survival, maintenance and financial stability). However, 61% explicitly linked predator conflict to negative impacts on their farming practises and, consequently, on their overall wellbeing. Farmers employ diverse interventions, often favouring non-lethal options such as predator-proof/game fencing and livestock guard animals like dogs, llamas, alpacas, and donkeys [78][9]. Unfortunately, almost all participants reported receiving no governmental support, either financially or for mitigating/preventing conflict, resulting in farmers often opting for lethal methods to eradicate the problem.

Lethal methods are mostly used on larger predators (≥ 15 kgs) as they are often considered the main cause for stock losses on farmland. Currently the cheetah is one of the predators struggling the most with human persecution. The lethal methods oftentimes used on cheetah are not just a matter of budget or to prevent further livelihood losses, but also hinge on cultural traditions, ethics, and neighbours' perceptions and actions [92][78]. The high persecution rates have caused the cheetah to be marked as Vulnerable on the IUCN Red List. They have been on South Africa's Endangered Species List since 1970 and under CITES Appendix I protection since 1975 [4]. The Endangered listing is strictly for national/domestic protection of the species, while CITES Appendix I bans international commercial trade in cheetah or their parts, aiming to prevent overexploitation.

The combination of IUCN status and CITES listing, caused the cheetah to fall under the threatened or protected species (TOPS) regulations [4]. Under South Africa's National Environmental Management Biodiversity Act (NEMBA) [67], Section 101 outlines clear criminal offences related to TOPS. Here it states that a person may not carry out a restricted activity involving a specimen of a listed alien species, invasive species or TOPS species without a permit. However, permit holders can commit an offence by violating permit conditions, performing activities outside authorized terms, or allowing others to breach the rules. It is an offence to fraudulently alter, or forge permits, possess fake permits, or make false statements to obtain one.

A person convicted of an offence under NEMBA Section 101 faces imprisonment for up to five years, a fine which is equal to three times the commercial value of the specimen, up to R5 million, both, or, for second/subsequent offences, fines up to R10 million or imprisonment up to 10 years, or both. Fines are calculated using a standard formula in the Adjustment of Fines Act 1991 [65], which links fine amounts to imprisonment length via ratios set under the Magistrates' Courts Act 1944 [64]. The maximum is either the prescribed amount under the Adjustment of Fines Act or three times the commercial value of the protected specimen, whichever is greater. Cheetah fall directly under these penalties [4][44]. Killing or harming one without a permit triggers Section 101 offences, with fines escalating to three times the cheetah's commercial value (typically between R100,000 – R150,000 within the cheetah trade) plus up to five years imprisonment.

Despite these TOPS regulations there has rarely been, if ever, a successful case brought against an offender for killing cheetah. These laws are for the protection of cheetah only but do not offer solutions or plans of compensation for the farmers whose stock is targeted. Therefore, harmful practices toward cheetah continue, as enforcement of these penalties rely on proven intent, rendering protections largely ineffective in practice. Near-certain evidence is needed that harm to the cheetah was deliberate, not accidental (e.g., mistaking a cheetah for another predator). This creates an evidentiary deadlock in which, regardless of the presence of regulations and penalties, environmentalists struggle to secure convictions without witnesses, ballistics, or confessions, while farmers claim "self-defence" or error. As a result, fines or jail time are rare despite frequent illegal killings. Therefore, cheetah populations continue to decline rapidly, with free-roaming numbers dwindling due to preventative or retaliatory killings, poaching, and habitat fragmentation, underscoring enforcement gaps along northern borders [4][9].

6. Census logistics and resources

Conservation projects are judged by the work on the ground. Success, however, often depends on the systems created prior. Due to the novelty as the first nation-wide free-roaming cheetah census in South Africa, there was little information to guide the census regarding budgeting or logistical needs. Thus, the initial planning for the census started approximately one year before fieldwork began in October 2022 and included in-depth discussions between the collaborators (ACC and COT) to understand what limitations and complications would be faced in attempting to survey to this spatial and logistical scale. A PhD student doing a double doctorate with the University of Groningen in the Netherlands and Stellenbosch University in South Africa, was brought on board to further expand the census planning with protocols and systems for data capture and analysis.

An incremental planning approach was adopted, limiting the spread of fieldwork to areas within confirmed cheetah range, allowing the team to field-test survey methodologies. This allowed for insight to time constraints, data collection practicalities and logistical requirements, which in turn informed the broader census design. During the testing phase of the census (Sept. 2022 – Oct. 2022), the initial team consisted of 1 x ACC staff/Student team with a company vehicle, and 2 x COT staff, each with company vehicles. A critical need for a scat detection dog was identified, especially in remote areas where the project could stall due to time constraints in finding appropriate sentinel sites to place cameras at. Detection dogs have been widely used in conservation projects to a high degree of success, even for animals occurring at low densities [41]. An Australian Cattle Dog (Blue Heeler), known for their sharp sense of smell, was sourced and trained by Rox Brummer at Green Dogs Conservation in Limpopo to specifically detect cheetah scat.

As the scope of the census increased, additional field team member (FTM) options were assessed in 2023. A local research organisation, Alldays Wildlife and Communities Research Centre (AWCRC) assisted by servicing camera sites on or near their area in Limpopo, COT employed another staff member, and ACC committed two more full time staff members to field work only. In total, there were seven field teams (three full time across the whole range and four in selected areas) (Fig. 36). Note that >100% FTM percentages do not reflect reduced workload, but include periods when fieldwork was not possible (e.g., holidays or restricted-access periods). During all available fieldwork periods, all teams operated at full capacity **relative to their role in the census**.

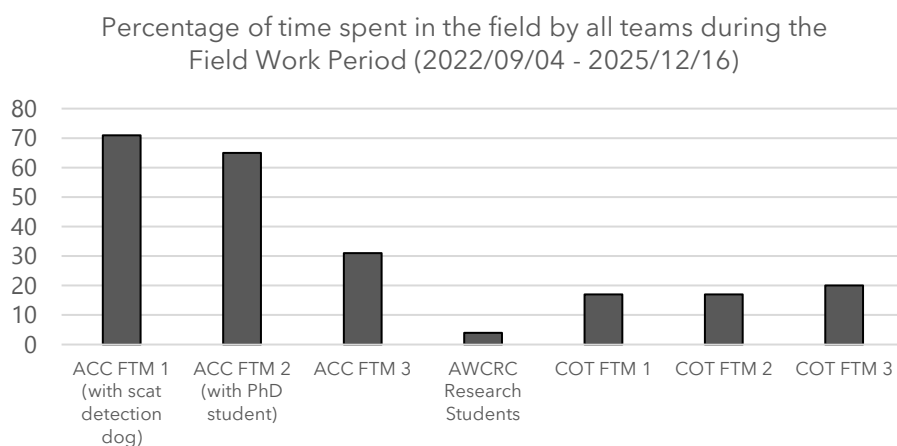


Fig. 36: Bar graph showing all field team members' (FTM) percentage of time spent on the ground doing camera trap and questionnaire fieldwork.

To support the implementation of this census, a centralised project coordination and data management system was established at the Ashia Center in Paarl. This functioned as the operational core for distributing equipment, collection and processing of field data and the continuous resupply of material for the field teams to ensure efficiency was maintained in both data handling and resource allocation. Camera traps, along with camera necessities (e.g. SD Cards and batteries), were procured and labelled before being distributed to the field teams.

When servicing sites, teams would collect image data and, where possible, scat samples. After transferring the images to external hard drives, these drives would be couriered at regular intervals back to Ashia for storage, processing and uploading to TrapTagger. Similarly, any scat samples collected were sent along with the image data for storage until DNA analysis could commence. Equipment was replenished and distributed as needed, allowing the field teams to continue working efficiently across the study area.

Despite the above framework, external factors (e.g. weather and seasonal farmland practises) still influenced the consistency of the survey efforts. Heavy summer rain often limited accessibility, particularly in areas with poor road infrastructure, and would wash away any possible scat samples. Conversely, the winter hunting season in South Africa posed additional challenges, as many properties were inaccessible as property owners would be hesitant to allow field teams to service or place cameras during this period. The hesitancy was due to the safety risk to the field teams, or (primarily) the risk of the field teams creating unnecessary disturbance and noise while well-paying hunting clients are on the property. Throughout the whole study area, access during all seasons relied on the landowners' availability, which did delay planned surveys in certain areas.

Even with the extensive planning and coordination, most field operations ultimately depended on the reliability and condition of the vehicles used, especially given the remote locations travelled to during the census. Frequent wear and tear required regular servicing, and tyre replacements were common due to punctures and damage sustained in the field. Flat tyres were a routine occurrence and often had to be dealt with without any external assistance. For this reason, vehicles were fitted with reinforced sidewall-layered tyres for durability and for increased resistance to damage on gravel road. An additional layer of risk was the high presence of wildlife which required constant awareness to avoid collisions during periods of increased animal activity. Accidents still happened, and two vehicles sustained damage during the census period. One ACC vehicle was completely written off and required replacement, while the COT vehicle was damaged by a kudu, but was repairable.

Next to the constant and adaptive planning, significant financial investment was also required to sustain such a large operation. As the primary funder and coordinator of the FRCC, ACC carrying >60% of the total project expenses, excl. capital cost, of **USD 740,800** (R12.6m; Fig. 37, Fig. 38).

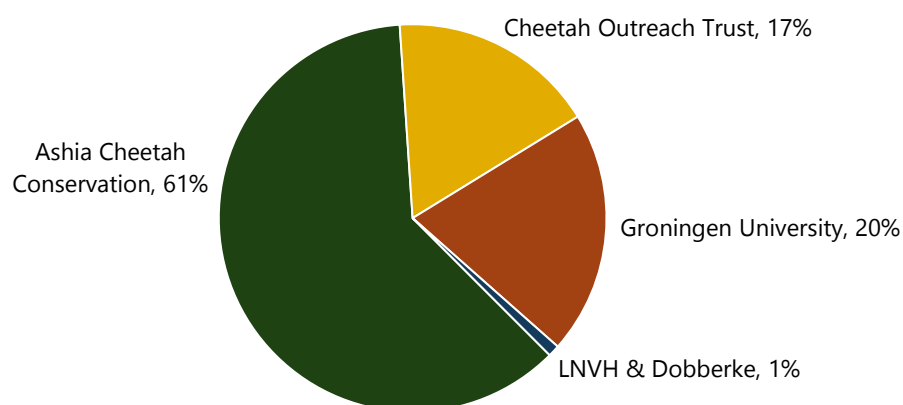


Fig. 37: All financial contributions of each collaborator in USD (1ZAR=17USD on average) The percentage contribution made by each collaborator grouped together for the distribution of the total spend USD 740,800.

Collaborator contribution to project cost | USD 740,800

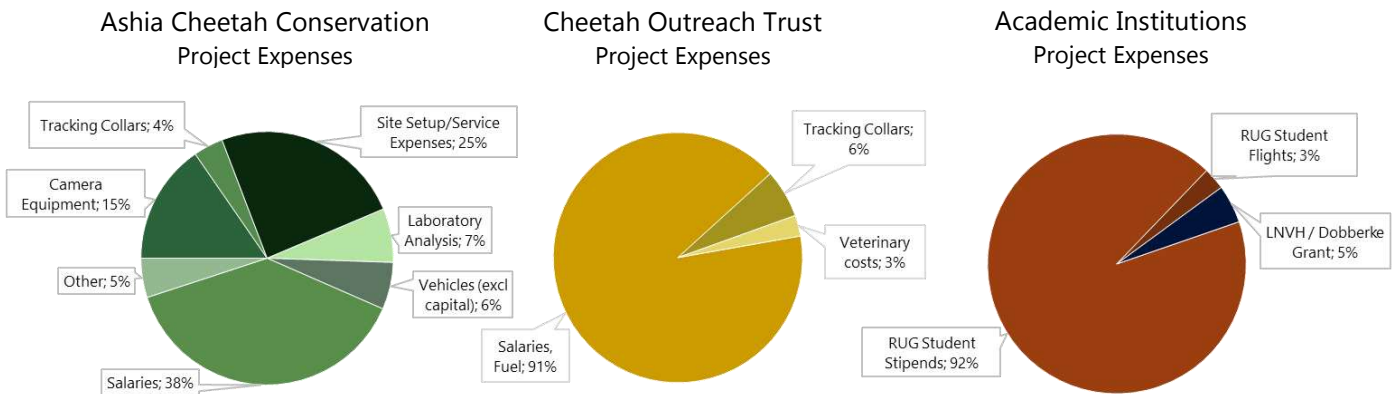


Fig. 38: Separate pie charts for the division of expenditures for each collaborator.

The operational costs (25% of ACC’s project expenses) associated with setting up and/or servicing cameras in the field are summarised in the figure below (Fig. 39). Fuel costs were a substantial portion of the total expenditure, highlighting the extensive distances travelled. Over the course of the project, field teams cumulatively drove over 400,000 km, close to the distance from the earth to the moon. Accommodation in isolated areas were limited with only a few suitable options near camera sites. These costs were partially mitigated through discounted rates offered by property owners and, at times, even complimentary accommodation. Where feasible, lower-cost alternatives were used, including camping.

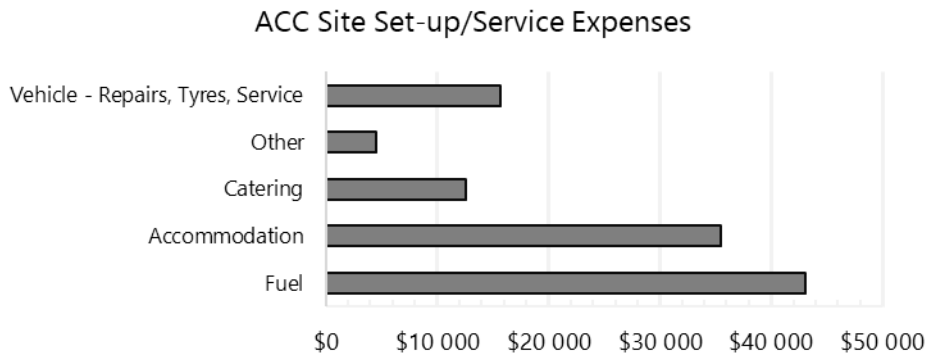


Fig. 39: Bar graph showing the break-down of site set-up/service expenses for the entire field work period (Sept 2022 – Dec 2025) for ACC only.

The substantial human resource investment required to implement the census at this scale was assessed by partitioning full-time equivalent (FTE) contributions into three components: fieldwork, desktop analysis and project oversight. The proportional contribution of each component between 2022 and 2026 is presented in Fig. 40. Fieldwork included all on-site census activities (questionnaire distribution, camera deployment, scat sampling, etc.), while desktop analysis encompassed data processing, image classification, and data management. Project oversight comprised coordination, planning, stakeholder engagement and overall project management.

Field work accounted for the largest proportion of effort overall (60%), reflecting the intensive nature of on-the-ground data collection required for a census of this scale. However, the distribution of effort varied temporally, with earlier phases (2022 – 2023) characterised by higher relative investment in project oversight and setup,

followed by a peak in fieldwork effort during 2024-2025 as data collection intensified. In the final phase (2026), effort shifted toward desktop analysis, reflecting data processing and synthesis as field activities were finalised. In full-time equivalent (FTE) terms, the collective effort of the FRCC equated to ~13 person-years of work (154 months; 4,692 days).

Proportional allocation of project effort (FTE) 2022 - 2026

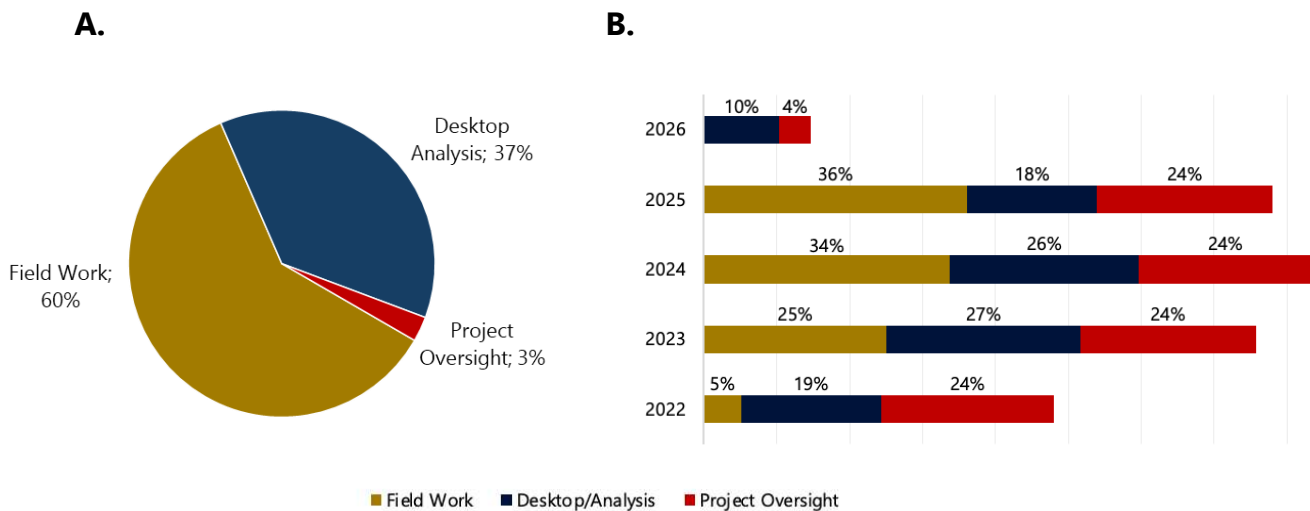


Fig. 40: Pie chart for the break-down of project effort through the entire FRCC period. B. A horizontally stacked bar chart to divide the project effort between the three categories across the years for all partners.

7. Conclusion

The Free-Roaming Cheetah Census was established to address a major knowledge gap in the status and distribution of free-roaming cheetah in South Africa. Previous estimates were largely based on expert opinion, small-scale studies, or extrapolation across extensive areas, which can easily inflate population estimates when the initial data is obtained from cheetah abundant areas. To counter this, the FRCC used a large-scale, direct observational approach based on questionnaire surveys, systematic camera trapping, telemetry, biological sample collection, and DNA analysis (faecal and blood) across the South African IUCN cheetah range (Fig. 41). This provides a more robust basis for a confirmed observed count of cheetah, distribution, and movement than earlier studies that relied heavily on modeled or extrapolated data.

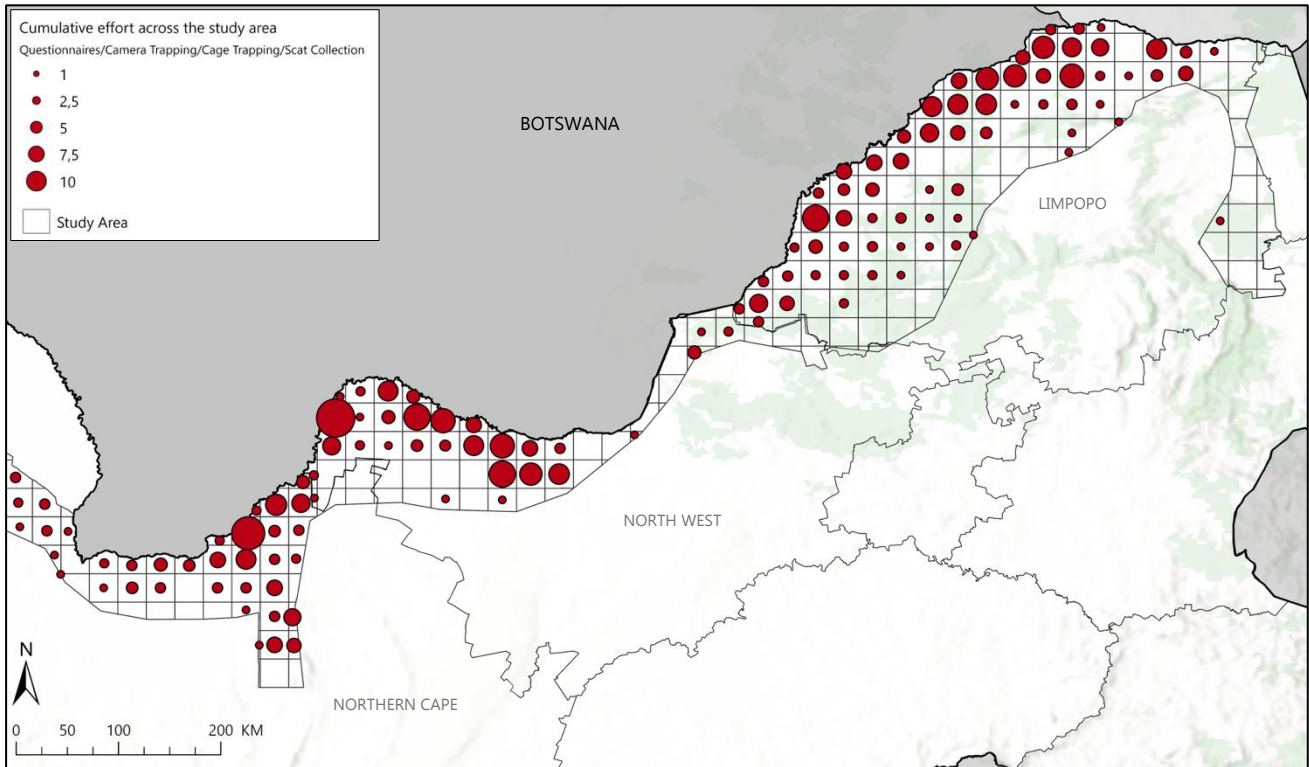


Fig. 41: Combined survey effort across the study area in the IUCN cheetah range in South Africa, integrating questionnaire data, camera trapping, cage trapping and scat collection. Sampling intensity is represented by proportional symbol size, with larger circles indicating greater cumulative effort per grid cell.

The census identified a minimum of 83 adult cheetah individuals across the study area, with an additional 36 young cubs or subadults, totaling to only 119 unique free-roaming individuals. Of the 83 individuals, 68 (82%) had an individual confidence level of four and higher. This individual count is substantially lower than previous estimates.

Weise *et al.* (2017) estimated free-roaming cheetah numbers in southern Africa by applying inferred cheetah densities to broad habitat and ecoregion classifications across areas of confirmed occurrence [97]. If applying this method to the FRCC study area with verified cheetah presence (Fig. 27B), Region 1 (21,875 km²; semi-arid savanna) should support an estimated population size of ~116 mature individuals, while Region 2 (25,000 km²; grassland and bushveld), should support ~120 cheetah. However, the FRCC confirmed only a minimum of 33 adult cheetah in Region 1, and 50 adults in Region 2, highlighting the gap between broad-scale density extrapolations, which do not account for demographic characteristics such as age and sex, and documented individuals. Given that the census was conducted over a three-year field period using multiple detection methods, it is unlikely that such a substantial proportion (60 – 70%) of the population remained entirely undetected. This further highlights the uncertainty associated with regional cheetah population estimates,

historically relying on inferred densities, mapped occurrence and extrapolation approaches in the absence of landscape-level empirical surveys [25][79]

Of the adults recorded in the census, 17 individuals had died by the end of the census period, representing 20% of known adult mortality. Such losses are especially concerning in a population that is already very small. The death of this many individuals, particularly reproductively viable adults, slows recovery and makes population growth challenging [46][17]. Adult sex ratios were broadly similar between the two regions; Region 1 showed a female to male ratio of 1:1.8, and Region 2 showed a ratio of 1:1.9, meaning that both regions were effectively close to a 1:2 female to male balance. Because males use sentinel sites more frequently than females, it is likely that female numbers are underrepresented in the data. If female detections matched male detections more closely, adult female numbers may rise slightly, potentially to match the male numbers.

The identified individuals are confirmed to reside in a highly fragmented landscape (Fig. 42) largely caused by differing land use, fencing types, and human population density. Telemetry data confirmed that movement differs between the two main study regions: Region 1 has a more open, arid landscape with extensive connections to Botswana, while Region 2 is more constrained and essentially functions as an isolated population with minor movement between Botswana and PAs in southern Zimbabwe and South Africa, particularly due to dense human settlement and impermeable (game) fencing. Camera-trap data reflected the movement findings

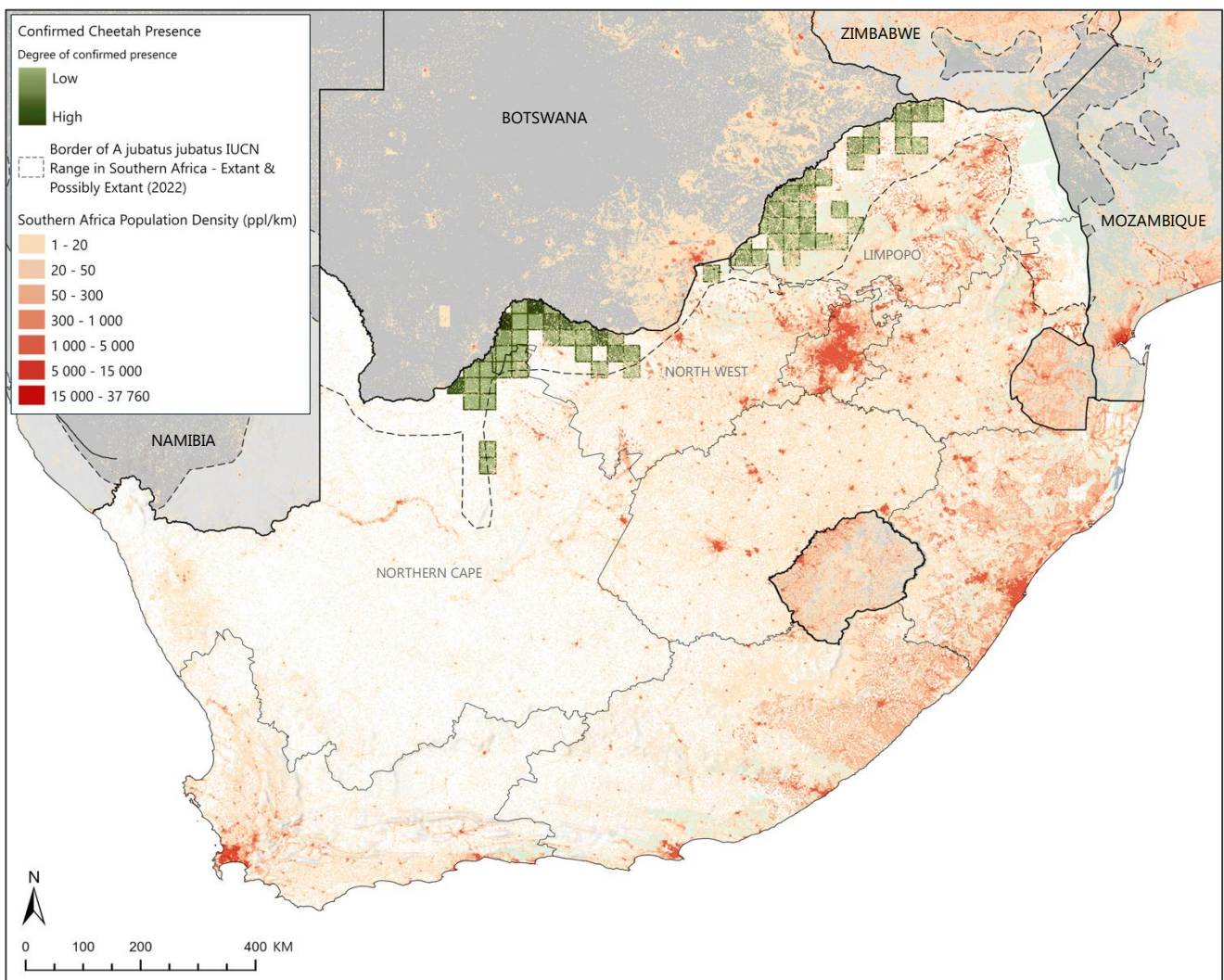


Fig. 42: Distribution of confirmed cheetah presence overlaid with human population density across South Africa. Presence is shown as grid cells scaled by degree of confirmation. The overlap between confirmed cheetah occurrence and area of elevated human density underscores the increasing constraints on suitable habitat and the challenges of long-term survival.

in the cheetahs' activity patterns in Region 2; fragmented land concentrates movement to a small number of areas and therefore increases detection frequency at specific camera sites. This fragmentation prevents connectivity between the regions which in turn increases isolation and potential inbreeding.

However, while land-use and fencing create visible barriers, human perceptions, conflict, and tolerance create boundaries that can be equally destructive for cheetah movement and survival. While many participants associated cheetah with livestock losses, DNA-based scat analysis found prey DNA only from game species, with no evidence of livestock in the cheetah host samples analysed. This indicates that farmer perceptions of cheetah as a livestock threat may overestimate actual predation risk in some areas. Such mismatches between perception and evidence are highly relevant for coexistence planning, as conflict and tolerance are related but not identical (i.e. high conflict does not automatically mean low tolerance).

Questionnaire data also showed that subjective cheetah presence and conflict do not always match objective data from camera traps, GPS collars, and found cheetah scat. In some areas, cheetah were reported where no objective evidence was found, suggesting that tolerance, prior experiences, and perceptions can strongly shape how people report presence. Adding these subjective types of information to range maps that use habitat and population density data is important as areas with low tolerance may become functionally unsuitable even when habitat appears suitable. At present, the legal and administrative process following the hunting and killing of a cheetah is difficult to interpret and even harder to enforce in practice. Although cheetah are legally protected, the procedure that goes from incident to meaningful legal action is unclear. To date, no known cheetah killing has resulted in a successful prosecution, which highlights a significant gap between legislation and implementation.

Despite the physical and social fragmentation of the landscape, the genetic results are still indicative of a relatively connected population. At this stage, biological fragmentation between the two regions does not appear to be strong yet, suggesting that gene flow has occurred relatively recently and that the two regions have remained genetically connected up to now. However, as aforementioned, the ecological evidence does point to increasing restriction of movement between the regions, particularly where human population density and impermeable fencing create barriers. Genetic differentiation in long-lived mammal populations, like the cheetah, often becomes detectable only after several generations, typically in the order of 5–15 generations. Given a cheetah generation time of ~4–6 years, this suggests that measurable genetic structuring may lag behind landscape fragmentation by several decades [2][33]. Thus, although full genetic separation has not yet occurred, the conditions are in place for this process to continue if connectivity declines further. The likely isolation of the population in Region 2 ($N_{\text{Adults}} = 50$) due to movement being restricted by human settlement are especially vulnerable to genetic drift, inbreeding, and the gradual loss of genetic diversity, already indicated by the positive inbreeding coefficient ($F_{IS} = 0.155$). With a minimum effective population of 100 needed to limit short-term inbreeding effects [68], the current Region 2 population size suggest that it may already be approaching levels associated with future genetic erosion. This provides an important conservation opportunity: if connectivity can be maintained, genetic exchange may support population resilience and reduce long-term isolation risk

The FRCC findings have direct relevance for national and international policy change. The substantially lower population estimate identified reflects a combination of improved survey accuracy resulting from the first coordinated cross-country census, as well as ongoing population declines driven by habitat loss, landscape fragmentation and anthropogenic pressures. The Regional Conservation Strategy for Cheetah and Wild Dog in Southern Africa (2015) adjusted the population estimate for free-roaming cheetah in unprotected range in South Africa to ~300 individuals [72]. This new count contributed to the population data utilized by the IUCN Red List Assessment (2021), which estimated 3526 adult individuals in Southern Africa, retaining its Vulnerable status [26]. In contrast, the FRCC detected only 83 adult individuals, representing an approximate 72% lower estimate than previously assumed. These findings point towards the potential reclassification of the national free-roaming population to Endangered status under the Regional Red List of South Africa criteria, despite the species not necessarily qualifying as Endangered globally just yet. The study also supports updating the IUCN range for

southern African cheetah in South Africa. The new range should be based on a combination of confirmed presence, potential suitable habitat, land-use, fragmentation, and social factors affecting the persistence of cheetah in the landscape.

The FRCC data are intended to inform the ongoing South African Biodiversity Management Plan for cheetah and should be used to strengthen future monitoring and reporting. Given the scale and complexity of the landscape, continued census work will be necessary, ideally at regular intervals using standardised protocols that allow comparisons through time. However, since projects of this scale require sufficient time, funding and people, appropriate planning and teamwork are of the utmost importance.

The report also highlights the need for coordinated action across the different cheetah populations in South Africa, including free-roaming cheetah, the semi-protected populations in Kruger NP and Kgalagadi TP, the metapopulation in fenced reserves and the captive population. A more connected national, and eventually southern African regional approach will be essential if South Africa is to maintain viable free-roaming cheetah populations into the future.

8. Case studies

The following case studies are included to highlight important findings from the FRCC. Together, they illustrate the biological, social, and legal dimensions of free-roaming cheetah conservation in South Africa. Some cases demonstrate population resilience and rare biological events, while others reveal the continuing challenges of conflict, coexistence, and law enforcement. These case studies provide a more detailed view of relationships between cheetah and people in the study area.

8.2 Persistence under pressure: cub survival in a challenging landscape

In July 2024, an adult female cheetah was first recorded in grid NW_G6 in Region 1, accompanied by a litter of remarkable size, consisting of seven cubs (Fig. 43). Based on their size and development, the cubs were estimated to be 6-7 months of age at the first observation. This is notable as cheetah litter sizes are typically much smaller, with an average of three cubs [86][5]. Although larger litters have been documented, for example, a litter of eight was recorded in captivity in 2017, and more recently, another litter of seven was observed in Kruger NP, these instances are rare. Cub mortality is usually very high, with less than half of the cubs surviving into sub-adulthood [86]. The fact that seven cubs had already survived to this stage therefore represented an unusual and encouraging reproductive event for the free-roaming population.



Fig. 43: Individual FRCC_068 seen with her seven cubs in grid NW_G6.

The F and G grids in North West, Region 1, were characterised by high levels of perceived conflict with cheetah. The grid in which the mother and cubs were first recorded also showed exceptionally low tolerance towards predators in general (Fig. 30), suggesting a challenging social landscape for cheetah persistence in the area. When first observed, the mother and cubs remained at a sentinel tree for approximately 20 minutes and appeared relaxed.

The family group was later encountered again for a time span of 13 minutes on 31 May 2025 in a nearby grid, NW_F5, where only four of the original seven cubs, now sub-adults, were found without the mother. At this

stage, the sub-adults were approximately 15 months old, which is toward the lower end of the age range at which young cheetah may begin to become independent, typically between 15 and 20 months [48]. Three of the four individuals were females, and female individuals are not expected to form coalitions in the same way as males. This suggests that the four were likely still associated as a sibling group rather than functioning as independent adults just yet. The mother may have dispersed to a new area for mating opportunities or may have been killed.

The absence of the remaining three sub-adults most likely indicates that they did not survive. Notably, the F5 grid in which the sub-adults were found again, despite also showing high conflict, was characterised by high tolerance towards predators (Fig. 30). This contrasts with the G6 grid where the mother and litter were first observed. It is possible that the sub-adults later remained in this more tolerant grid after supposed familial losses.

A few months later, on 19 August 2025, only two of the sub-adults were encountered again, both females. Their continued association is consistent with an immature sibling group, and the disappearance of the other two individuals from the group suggests additional mortality from unknown causes. Even with only two individuals confirmed to be alive, and five of the seven individuals likely deceased, the case remains remarkable. It demonstrates that, under the right conditions, cheetah in the free-roaming landscape can successfully raise exceptionally large litters to near sub-adulthood, despite the many challenges facing cub survival in fragmented farmland systems.

8.3 Site loyalty in the Northern Cape

In August 2024, a coalition of two male cheetah was first recorded at a sentinel site in grid NC_W8 in Northern Cape, Region 1 (Fig. 44). From that point onward until their last confirmed detection in November 2025, the coalition returned to the same sentinel site with remarkable frequency. On average this coalition revisited the site every two days (Fig. 24A), and on some occasions multiple times within a single day, resulting in a total of 3,573 images of these cats. They were also observed at a second site, on average every 11 days, on the same farm. This repeated and consistent use of the same area suggests a high level of site loyalty and local familiarity, even though the landscape of Region 1 is relatively open and permeable.

The farm they occupy covers approximately 4,000 ha (40 km²) and is fenced only with small (2-4-strand) fencing, making it relatively large and easily traversable. In other words, it is unlikely that these males are “trapped”. Yet despite the lack of strong fencing barriers, and the absence of potential mates in the surrounding area (no other individuals have been found in the Northern Cape province), the coalition continued to return.



Fig. 44: Male coalition (FRCC_062 and FRCC_063) in the NC_W8 grid. Male 063 is seen with blood on his face, with male 062 walking in the back.

Their behaviour is also interesting in the context of previous work from central Namibia, where the Leibniz Institute for Zoo and Wildlife Research has shown that male cheetah follow different spatial tactics. The more static males, similar to this coalition, maintain smaller territories of around 380 km², while others can have home ranges up to 1,600 km² [54]. The two males recorded in Region 1 may have been displaying a territorial strategy, but their repeated use of a single area and the lack of other cheetah in the surrounding area makes this behaviour difficult to classify within the typical patterns described elsewhere [21]. It is possible that they are older males, already having mated, that have settled into a low-conflict, relatively tolerant area with sufficient prey and safe access. Regardless, their use of the landscape stays unusual compared to what would normally be expected for a coalition.

A total of 22 scat samples were collected in the area, all attributable to these two males specifically, marking the area as an important communication hub. While the owner of this specific farm, together with the landowners

of the surrounding farms (N = 4), report that the area is largely used for livestock farming and only some game farming, DNA analysis found **no livestock in their diet**. Instead, the samples contained mostly small game species such as springbuck and steenbok. This is consistent with the camera-trap records within this grid, which also showed frequent marking and defecation events, as well as footage of the males with bloodied faces (Fig. 44), suggesting hunting and repeated use of the area as part of a core movement route or hunting ground.

The farm owner indicated that while predators were not preferred, cheetah were tolerated if they simply passed through the area rather than causing damage. Other questionnaire data, including the landowners in the surrounding area, show that overall tolerance for cheetah was high and no cheetah conflict was reported (Fig. 30). This is important as it indicates that the social environment may have contributed to the coalition's continued use of the area.

Since the landowners in this area have reported no loss of livelihood, and faecal analysis has proven that no livestock has been depredated, there appears to be a form of peaceful coexistence between people and cheetah in this area, where the species is tolerated rather than persecuted. This case study exemplifies the kind of human-wildlife coexistence that needs to be fostered through conservation efforts, where tolerance and minimal conflict can safeguard cheetah populations for the future.

8.4 Persecution without prosecution: tolerance and enforcement gaps in a human-dominated landscape.

In 2021, a year before the start of the census fieldwork, COT obtained camera trap images of a coalition of two male cheetah in grid LP_I4, in Limpopo, Region 2. It was later reported that one of the coalition mates had been shot by a local farmer, though the farmer remained unidentified at the time. During the first year of our census, in September 2022, the surviving male reappeared as our first identified individual in the same grid, earning the name FRCC_001. This individual exhibited strong site loyalty within LP_I4, moving between three sentinel sites on two different farms. He showed a clear preference for one site, revisiting it on average every four days (Fig. 24B), compared to much less frequent revisits to the other two (with averages of 94 days and 143 days), resulting in being captured on camera 1,643 times.

On the 21st of February in 2024, this lone male was fitted with a satellite collar and monitored for a total of 137 days until his death on the 7th of July 2024. The collar data helped with the determination of the cause of death, concluding that this male had also been shot, like his coalition mate, by a local farmer. As outlined in the policy chapter (section 5), cheetah are protected under South Africa's Threatened or Protected Species Regulations due to their IUCN Vulnerable status and CITES Appendix I listing. Killing or harming a cheetah without a permit constitutes a serious offence, punishable by fines up to three times the animal's commercial value and imprisonment for up to five years. Yet, prosecuting such cases remains exceedingly challenging, most likely due to low priority given to conservation cases. In this instance, the farmer openly admitted to the shooting, but no penalties were enforced due to a lack of evidence for "ill intent". When even an admission of killing a protected species fails to trigger prosecution, conservationists are left powerless, and legal protections that are intended to safeguard the species do not provide protection at all.

Following this incident, COT adopted a more proactive approach upon learning of another cheetah mortality event. A coalition of four males had been frequently detected on camera traps across grids LP_E7 and LP_F7 in Limpopo, Region 2, spanning three farms. One male from this coalition was collared on the 27th of August in 2024 and recollared on the 3rd of June in 2025, only to die three weeks later. Collar data again pinpointed the cause, confirming that the individual had been hit by a vehicle, as had two of his coalition mates, all three killed in the incident. A local informant contacted COT, reporting that the act appeared deliberate, with the vehicle intentionally aiming for the cheetah (Fig. 45). Due to the previous negative experience of following formal legal channels, COT offered a R100,000 (~6,100 USD) reward instead, funded by private donors, for information identifying the perpetrator. However, this strategy backfired, eliciting complaints from farmers who questioned why substantial funds existed for cheetah investigations but not for their own livelihood losses due to depredation.



Fig. 45: One of the males, FRCC_050, from the four male coalition. This image was sent to COT by an informant after the vehicle collision.

These cases expose an important issue in human-cheetah conflict resolution. Prosecution fails to deter offenders, while reward schemes for mortality investigations foster resentment among farmers. These dynamics decrease tolerance towards both predators and conservationists. The path forward demands robust, enforceable rules paired with governmental support, which does not have to directly involve financial compensation, but could also provide conflict preventing interventions (i.e. subsidized guard dogs or partially financed fencing) to foster a higher tolerance towards predatory species like the cheetah.

8.5 Rare king cheetah sighting in the study landscape

A rare phenotypic variant (i.e. physical characteristic) mutation in cheetah is known as the king or tabby phenotype which results in a unique coat pattern of blotchy connected spots and dark stripes that run across its back. Once two individuals with the mutated gene have been identified and paired, their offspring has a one-in-four (25%) chance of being born a king. It can however also skip generations. The genes that cause this mutation are recessive genes, meaning that they only come to expression when the individual inherits the recessive allele from both parents. King cheetah have been recorded sporadically over the past 100 years [40] in southern Africa and was unfortunately first identified by the western world by being shot at. Initially the mutation was thought to be a hybrid of leopard and cheetah, or hyaena and cheetah, by mistaken locals. Later the mutation was wrongly assigned as a new species, *Acinonyx rex*, until it was eventually corrected in 1939 when the blotched pattern was ascribed to genetic variation.

Considering this, we were unprepared to see a king cheetah on camera, which to our knowledge, is the first credible sighting since 1986 in Kruger NP and according to unpublished reports, again in the mid-2000's. (Fig. 46; Appendix VI). This implies important genetic implications for the broader population as its expression indicates that this rare allele is still present and being successfully transmitted.



Fig. 46: King cheetah individual captured on camera-trap during the census in 2023. Location will not be disclosed.

However, recessive traits may become more frequently expressed in small or partially inbred populations as inbreeding increases homozygosity (carrying two identical alleles of a gene), allowing alleles that are normally masked in heterozygous individuals to be expressed visually [10]. This finding reinforces the fact that maintaining numbers alone is not enough to conserve the last free-roaming cheetah in South Africa, but that the underlying genetic diversity that enables populations to persist and adapt over time must be safeguarded.

Special Acknowledgements

The FRCC reflects a moment in time, built on the substantial efforts of Deon Cilliers (COT) over the years. COTs continued support of the free roaming cheetah population and the farming community raised awareness of the conflict and habitat threats this population is facing. This highlighted the urgent need for a precise census. Although the FRCC is now completed, COT will continue with their conservation efforts for this species.

Project innovators, main funding and drivers of the census

- Chantal Rischard & Stephan Illenberger— Founders/Directors, Ashia Cheetah Conservation
- Marna Smit — Director, Ashia Cheetah Conservation

Writing and coordination

- Marna Smit — Project management, field coordination, report writing and scientific analysis
- Dr. Nynke Wemer — Field coordination, report writing and scientific analysis

Field team members

- Kagiso Masinge — Field team member, Ashia Cheetah Conservation
- Louis Heyns and Benji — Field team member with trained scat dog, Ashia Cheetah Conservation
- Leslie Slabbert — Field team member, Ashia Cheetah Conservation
- Deon Cilliers — Project Manager, Cheetah Outreach Trust
- Cyril Stannard — Project Manager and Senior Field Officer, Cheetah Outreach Trust
- Dylan Dobbins — Field team member, Cheetah Outreach Trust
- Dr. Nynke Wemer — Field team member, University of Groningen
- Maria Beaumont — Student supervisor, Alldays Wildlife and Communities Research Centre; camera checks in the Alldays area
- Morena Rodriguez — Student supervisor, Alldays Wildlife and Communities Research Centre; camera checks in the Alldays area
- Chanelle Becker — Operations Manager, Bushveld Biodiversity Research Centre; camera checks in the Zingela area

Academic support

- Prof. dr. ir. Jan Komdeur — Professor, University of Groningen
- Dr. Vincent Naude — Postdoctoral Researcher, African Parks
- LNVH Advancing Women in Biology Fund
- Dr. D.L. Dobberke Foundation (Dobberke/2229/202225)

Software and laboratory support

- Dr. Nicholas Osner — Technical Director, WildEye Conservation; TrapTagger support
- Marguerite Robinson — Development team, TrapTagger support
- Dr. Joseph Craine — Co-owner and Co-founder, Jonah Ventures; DNA sequencing of scat samples
- Dr. Benjamin Sacks — Adjunct Professor and Director, Mammalian Ecology and Conservation Unit, UC Davis Veterinary Genetics Lab; DNA analysis
- Charné Claassens – Unistel Medical Laboratory; DNA analysis

Veterinary support

- Dr. Peter Caldwell — Veterinary support
- Dr. Ean van der Berg — Veterinary support
- Dr. Jan-Karl Limbach — Veterinary support

Collaring support

- Nico Jacobs — Rhino 911 NPO
- Rox Brummer — Green Dogs Conservation
- Joep Maree — local farmer
- Hennie Pienaar — Mabelingwane Wild
- Manketti Game Reserve
- Thungela Wildlife Estate

Field logistics support

- Nathan Bezuidenhout — Capture cage construction and camera repairs, Ashia Cheetah Conservation
- Brendan Dijkstra — Camera repairs during fieldwork, University of Groningen
- GDP Batteries – camera trap battery donations for COT
- Rare Species Fund – camera trap donations for COT
- Idea Wild – camera trap donations for COT

Social media, outreach and admin

- Kate Lindop — Social media manager, Ashia Cheetah Conservation
- Charmaine Bester – Accounting and financials, Ashia Cheetah Conservation
- Marinda Cilliers — Social media volunteer, Cheetah Outreach Trust
- Sophie Bland — Social media volunteer, Cheetah Outreach Trust
- Toerbroers — Travel and prize logistics from the questionnaire

Data Sharing

- SA Hunters and Game Conservation Association
- The Phasa Foundation
- Bushveld Biodiversity Research Centre

Accommodation and local support

- Gielie Jones Oberjones
- Manna Vorster
- Fernando du Preez
- Leigh Fletcher
- Nick van Rensburg
- Riaan van Rensburg
- John Mackie
- Gerrie Venter
- Morne Brummer
- Marlize Booysen
- Adri Marx
- Rieker Botha
- Christo Vorster Snr & Jnr
- Zingela Nature Reserve
- Insimbi Legacy Projects
- Limpokwena Nature Reserve
- Lalibela Kalahari
- Molopo Nature Reserve
- All Days Wildlife and Communities Research Center
- ACC & COT Donors

Special thanks

We also extend our heartfelt thanks to all farmers and landowners who completed surveys and generously granted access to their properties during the study.

References

- [1] Alberts, C. C., Saranholi, B. H., Frei, F., & Galetti Jr, P. M. (2017). Comparing Hair-Morphology and Molecular Methods to Identify Fecal Samples from Neotropical Felids. *PLoS ONE*, 12(9). <https://doi.org/10.1371/journal.pone.0184073>
- [2] Allendorf, Fred & Luikart, Gordon. (2006). *Conservation and Genetics of Populations*. Blackwell Publishing.
- [3] Anthony, B. P., & Swemmer, L. (2015). Co-defining Program Success: Identifying Objectives and Indicators for a Livestock Damage Compensation Scheme at Kruger National Park, South Africa. *Journal for Nature Conservation*, 26, 65–77. <https://doi.org/10.1016/j.jnc.2015.05.004>
- [4] Balint, P., Billerbeck, R., Bright, P., Egner, C., Gnade, T., Houle, C., Lacoss, R., Lake, R., Latchis, I., Lyke, J., McAllister, N., & Steinberg, J. (1997). A New Conservation Strategy for the Namibian Cheetah (*Acinonyx jubatus*). Report: 1-20. The 1997 Problem Solving Team, Graduate Program in Sustainable Development and Conservation Biology, University of Maryland.
- [5] Barr, S., Chang, Y., Verstege, L., & Díez-León, M. (2025). What Makes a Mother? Investigating Maternal Success in Ex Situ Cheetahs. *Zoo Biology*, 44(4), 332–344. <https://doi.org/10.1002/zoo.21894>
- [6] Bartels, P.; Bouwer, V.; Crosier, A.; Cilliers, D.; Durant, S. M.; Grisham, J.; Marker, L.; Wildt, D. E.; Friedmann, Y., editors. 2002. Global Cheetah Action Plan Review Final Workshop Report. Global Cheetah Conservation Action Plan - Workshop held at Shumba Valley Lodge in South Africa from the 27th to the 30th of August 2001 Apple Valley, MN: IUCN / SSC Conservation Breeding Specialist Group; 78 p.
- [7] Behrens, K. G., Broadbent, N., Galgut, E., Gardner, J., & Molefe, M. (2018). Ethical Considerations in the Management of Livestock Predation. In: Livestock predation and its management in South Africa: a scientific assessment. *Centre for African Conservation Ecology*, 82–105. ISBN 978-0-620-78764
- [8] Belbachir, F., Pettorelli, N., Wacher, T., Belbachir-Bazi, A., & Durant, S. M. (2015). Monitoring Rarity: The Critically Endangered Saharan Cheetah as a Flagship Species for a Threatened Ecosystem. *PLoS ONE*, 10(1), 1–15. <https://doi.org/10.1371/journal.pone.0115136>
- [9] Bergman, D. L., Avenant, N. L., Bodenchuk, M. J., & Steenkamp, E. (2020). Developing Alternatives to Protect Domestic Sheep from Predation in South Africa. *Proceedings of the Vertebrate Pest Conference*, 29(29), 1–7. <https://escholarship.org/uc/item/58r1g4wj>
- [10] Bittles, A. H. (2001). Incest, Inbreeding, and Their Consequences. *International Encyclopedia of the Social & Behavioral Sciences*, 7254–7259. <https://doi.org/10.1016/B0-08-043076-7/03383-0>
- [11] Boast, L., Houser, A. M., Horgan, J., & Reeves, H. (2016). Prey Preferences of Free-Ranging Cheetahs on Farmland: Scat Analysis Versus Farmers' Perceptions. *African Journal of Ecology*, 54(4). <https://doi.org/10.1111/aje.12296>
- [12] Boyle, Sarah & Lourenço, Waldete & Silva, Livia & Smith, Andrew. (2009). Home Range Estimates Vary with Sample Size and Methods. *International journal of primatology*, 80. 33-42. 10.1159/000201092.
- [13] Buk, K. G., van der Merwe, V. C., Marnewick, K., & Funston, P. J. (2018). Conservation of Severely Fragmented Populations: Lessons from the Transformation of Uncoordinated Reintroductions of Cheetahs (*Acinonyx jubatus*) into a Managed Metapopulation with Self-sustained Growth. *Biodiversity and Conservation*, 27(13), 1–31. <https://doi.org/10.1007/s10531-018-1606-y>
- [14] Cafaro, P., Hansson, P., & Götmark, F. (2022). Overpopulation is a Major Cause of Biodiversity Loss and Smaller Human Populations are Necessary to Preserve What is Left. *Biological Conservation*, 272. <https://doi.org/10.1016/j.biocon.2022.109646>
- [15] Calenge, C. (2006). The package "adehabitat" for the R software: A Tool for the Analysis of Space and Habitat Use by Animals. *Ecological Modelling*, 197(3–4), 516–519. <https://doi.org/10.1016/j.ecolmodel.2006.03.017>
- [16] Carneiro, L. R. A., Lima, A. P., Machado, R. B., & Magnusson, W. E. (2015). Limitations to the Use of Species-Distribution Models for Environmental-Impact Assessments in the Amazon. *PLoS ONE*, 11(1), e0146543. <https://doi.org/10.1371/journal.pone.0146543>
- [17] Carroll, C., Lacy, R. C., Fredrickson, R. J., Rohlf, D. J., Hendricks, S. A., & Phillips, M. K. (2019). Biological and Sociopolitical Sources of Uncertainty in Population Viability Analysis for Endangered Species Recovery Planning. *Scientific Reports*, 9, 1–12. <https://doi.org/10.1038/s41598-019-45032-2>

- [18] Carruthers, J. & Nattras, N. (2018). History of Predator-Stock Conflict in South Africa. In: Livestock predation and its management in South Africa: a scientific assessment. *Centre for African Conservation Ecology*, 30–52. ISBN 978-0-620-78764
- [19] Clements, H. S., Child, M. F., Lindeque, L., Lunderstedt, K., & De Vos, A. (2022). Lessons from COVID-19 for Wildlife Ranching in a Changing World. *Nature Sustainability*, 5(12), 1040–1048. <https://doi.org/10.1038/s41893-022-00961-1>
- [20] Cornhill, K. L., & Kerley, G. I. H. (2020). Cheetah Communication at Scent-Marking Sites can be Inhibited or Delayed by Predators. *Behavioral Ecology and Sociobiology*, 74(2), 21. <https://doi.org/10.1007/s00265-020-2802-9>
- [21] Cornhill, K. L., & Kerley, G. I. H. (2020). Cheetah Behaviour at Scent-Marking Sites Indicates Differential Use by Sex and Social Rank. *Ethology*, 126(10), 976–986. <https://doi.org/10.1111/eth.13071>
- [22] de Castro-Arrazola, I., Andrew, N. R., Berg, M. P., Curtsdotter, A., Lumaret, J., Menéndez, R., Moretti, M., Nervo, B., Nichols, E. S., Sánchez-Piñero, F., Santos, A. M. C., Sheldon, K. S., Slade, E. M., & Hortal, J. (2022). A Trait-Based Framework for Dung Beetle Functional Ecology. *Journal of Animal Ecology*, 92, 44–65. <https://doi.org/10.1111/1365-2656.13829>
- [23] Diemont, M., Glazewski, J., & Monaledi, D. F. (2018). Legal Considerations in the Management of Predation on Livestock. In: Livestock predation and its management in South Africa: a scientific assessment. *Centre for African Conservation Ecology*, 106–124. ISBN 978-0-620-78764
- [24] Dondi, L., Chaudhari, R., Schmitt, N., Poissant, J., Musiani, M., Filipe, C. D. M., & Li, Y. (2026). Field-Ready DNA Extraction from Scat using Magnetic Nanoparticles for Non-Invasive Wildlife Monitoring. *Scientific Reports*, 16(6733), 1–11. <https://doi.org/10.1038/s41598-026-37759-6>
- [25] Durant, S. M., Mitchell, N., Groom, R., Petteorelli, N., Ipavec, A., Jacobson, A. P., Woodroffe, R., Böhm, M., Hunter, L. T. B., Becker, M. S., Broekhuis, F., Bashir, S., Andresen, L., Aschenborn, O., Beddiaf, M., Belbachir, F., Belbachir-Bazi, A., Berbash, A., De Matos Machado, I. B., ... Young-Overton, K. (2017). The Global Decline of Cheetah *Acinonyx Jubatus* and what it Means for Conservation. *Proceedings of the National Academy of Sciences*, 114(3), 528–533. <https://doi.org/10.1073/pnas.1611122114>
- [26] Durant, S.M., Groom, R., Ipavec, A., Mitchell, N., & Khalatbari, L. (2024). *Acinonyx Jubatus*. The IUCN Red List of Threatened Species 2024. <https://dx.doi.org/10.2305/IUCN.UK.2024-1.RLTS.T219A259025524.en>
- [27] Edwards, S., Mueller, R., Roeder, R., Melzheimer, J., & Wachter, B. (2022). Cheetah Marking Sites are Also Used by Other Species for Communication: Evidence from Photographic Data in a Comparative Setup. *Mammalian Biology*, 102, 1345–1356. <https://doi.org/10.1007/s42991-022-00284-w>
- [28] ESRI. (2021). South African Farm Portions. ArcGIS. <https://www.arcgis.com/apps/webappviewer/index.html?id=3deecd45c0374cafa70af8273d8dd8b9>
- [29] Endangered Wildlife Trust (2025). 2025 Redlist. <https://ewt.org/2025-red-mammal-list/>
- [30] Ferreira, J. C., & Patino, C. M. (2015). What Does the P Value Really Mean? *Brazilian Journal of Pulmonology*, 41(5). <https://doi.org/10.1590/S1806-37132015000000215>
- [31] Fleming, C. H., Fagan, W. F., Mueller, T., Olson, K. A., Leimgruber, P., & Calabrese, J. M. (2015). Rigorous home-range estimation with movement data: A new autocorrelated kernel density estimator. *Ecology*, 96(5), 1182–1188. <https://doi.org/10.1890/14-2010.1>
- [32] Friedmann, Y., & Daly, B. (2004). Red Data Book of South African Mammals: A Conservation Assessment. Endangered Wildlife Trust. www.redlist.org
- [33] Frankham, R., Ballou, J. D., & Briscoe, D. A. (2010). Introduction to Conservation Genetics (2nd ed.). Cambridge: Cambridge University Press.
- [34] Garant, D., & Kruuk, L. E. B. (2005). How to Use Molecular Marker Data to Measure Evolutionary Parameters in Wild Populations. *Molecular Ecology*, 14(7), 1843–1859. <https://doi.org/10.1111/j.1365-294X.2005.02561>
- [35] Georank. (2026). Georank: compare 197 countries across 8 topics. <https://www.georank.org>
- [36] Getz, W. M., & Wilmers, C. C. (2004). A Local Nearest-Neighbor Convex-Hull Construction of Home Ranges and Utilization Distributions. *Ecography*, 27(4), 489–505. <https://doi.org/10.1111/j.0906-7590.2004.03835.x>

- [37] Gusha, B., Palmer, A. R., & Zondani, T. C. (2023). Assessing Livestock Grazing Distribution in Communal Rangelands of the Eastern Cape, South Africa: Towards Monitoring Livestock Movements in Rangelands. *Land*, 12(4), 1–15. <https://doi.org/10.3390/land12040760>
- [38] Hauser, S., Galla, S. J., Putnam, A. S., Steeves, T. E., & Latch, E. K. (2022) Comparing Genome-Based Estimates of Relatedness for Use in Pedigree-Based Conservation Management. Preprint: *Molecular Ecology Resources*. <https://doi.org/10.1101/2021.07.08.451704>
- [39] Hernández-Hernández, T., Miller, E. C., Román-Palacios, C., & Wiens, J. J. (2021). Speciation across the Tree of Life. *Biological Reviews*, 96, 1205–1242. <https://doi.org/10.1111/brv.12698>
- [40] Hills D. M. and Smithers R. H. N. (1980). The "King Cheetah": a Historical Review. *Arnoldia Rhodesia* 9, 1–23. In Skinner J. D. and Smithers R. H. N. 1990. The mammals of the Southern African sub-region.
- [41] Hofmann, Tim & Marker, Laurie & Hondong, Hermann. (2021). Detection Success of Cheetah (*Acinonyx jubatus*) Scat by Dog-Human and Human-Only Teams in a Semi-Arid Savanna. *Namibian Journal of Environment*, 5. 10.64640/7q2rtk86.
- [42] Houser, A., Somers, M. J., & Boast, L. K. (2008). Home Range Use of Free-Ranging Cheetah on Farm and Conservation Land in Botswana. *South African Journal of Wildlife Research*, 39(1), 11–22. <https://doi.org/10.3957/056.039.0102>
- [43] Jori, F., Brahmabhatt, D., Fosgate, G. T., Thompson, P. N., Budke, C., Ward, M. P., Ferguson, K., & Gummow, B. (2011). A Questionnaire-Based Evaluation of the Veterinary Cordon Fence Separating Wildlife and Livestock along the Boundary of the Kruger National Park, South Africa. *Preventive Veterinary Medicine*, 100(3–4), 210–220. <https://doi.org/10.1016/j.prevetmed.2011.03.015>
- [44] Kerley, G. I. H., Behrens, K. G., Gerruthers, J., Diemont, M., du Plessis, J., Minnie, L., Somers, M. J., Tambling, C. J., Turpie, J., Wilson, S. L., & Balfour D. (2018). Summary for Policymakers. In: Livestock predation and its management in South Africa: a scientific assessment. *Centre for African Conservation Ecology*, 7–14. ISBN 978-0-620-78764
- [45] Kierepka, E. M.; Unger, S. D.; Keiter, D. A.; Beasley, J. C.; Rhodes, O. E. Jr.; Cunningham, F. L.; & Piaggio, A. J. (2016). Identification of Robust Microsatellite Markers for Wild Pig Fecal DNA. *Journal of Wildlife Management*, 80(6). <https://doi.org/10.1002/jwmg.21102>
- [46] Kuperinen, A., Keith, D. M., & Hutchings, J. A. (2014). Allee Effect and the Uncertainty of Population Recovery. *Conservation Biology*, 28(3). <https://doi.org/10.1111/cobi.12216>
- [47] Larsen, P. B., & Chanthavisouk, C. (2024). Free, Prior, and Informed Consent, Local Officials, and Changing Biodiversity Governance in Hin Nam No, Laos. *Conservation Biology*, 38(6). <https://doi.org/10.1111/cobi.14388>
- [48] Le Clercq, L., Kotzé, A., Grobler, J. P., & Dalton, D. L. (2024). Methylation-Based Markers for the Estimation of Age in African Cheetah, *Acinonyx jubatus*. *Molecular Ecology Resources*, 24(4). <https://doi.org/10.1111/1755-0998.13940>
- [49] Lee, E., Choi, T., Woo, D., Min, M., Sugita, S., & Lee, H. (2014). Species Identification Key of Korean Mammal Hair. *The Journal of Veterinary Medical Science*, 76(5), 667–675. <https://doi.org/10.1292/jvms.13-0569>
- [50] Leibniz-IZW Cheetah Research Project. (2020). Spatial Ecology and Distribution of Free-Ranging Cheetahs. <https://www.cheetah-research.org/spatial-ecology-and-distribution>
- [51] Loarie, S. R., Duffy, P. B., Hamilton, H., Asner, G. P., Field, C. B., & Ackerly, D. D. (2009). The Velocity of Climate Change. *Nature*, 462, 1052–1055. <https://doi.org/10.1038/nature08649>
- [52] Marker, L. L., Dickman, A. J., Jeo, R. M., Mills, M. G. L., & MacDonald, D. W. (2003). Demography of the Namibian cheetah, *Acinonyx jubatus jubatus*. *Biological Conservation*, 114(3), 413–425. [https://doi.org/10.1016/S0006-3207\(03\)00069-7](https://doi.org/10.1016/S0006-3207(03)00069-7)
- [53] Marker, L. L., & Dickman, A. (2010). Human Dimensions of Wildlife Human Aspects of Cheetah Conservation: Lessons Learned from the Namibian Farmlands. *Human Dimensions of Wildlife*, 9(4), 297–306. <https://doi.org/10.1080/10871200490505729>
- [54] Marker, L. (2019). Cheetahs Race for Survival: Ecology and Conservation. In: Wildlife population monitoring, 51–65. <https://doi.org/10.5772/intechopen.82255>
- [55] Marnewick, K. A., du Bothma, J., & Verdoorn, G. H. (2006). Using Camera-Trapping to Investigate the Use of a Tree as a Scent-Marking Post by Cheetahs in the Thabazimbi District. *South African Journal of Wildlife Research*, 36(2), 139–145. eISSN: 2410-8200

- [56] Marnewick, K., Beckhelling, A., Cilliers, D., Lane, E., Mills, G., Her-Ring, K., Caldwell, P., Hall, R., & Meintjes, S. (2007). The Status of the Cheetah in South Africa. *CAT News*, 3, 22–31
- [57] Marnewick, K., & Somers, M. J. (2015). Home Ranges of Cheetahs (*Acinonyx jubatus*) Outside Protected Areas in South Africa. *African Journal of Wildlife Research*, 45(2), 223–232. <https://doi.org/10.3957/056.045.0223>
- [58] Marnewick, K., & Page-Nicholson S, Roxburgh L, Somers MJ. Tracking Data from Nine Free-Roaming Cheetahs (*Acinonyx jubatus*) Collared in the Thabazimbi Area, Limpopo Province, South Africa. *Biodiversity Data Journal*, 5. <https://doi.org/10.3897/BDJ.5.e11323>.
- [59] Melzheimer, J., Heinrich, S. K., Wasiolka, B., Mueller, R., Thalwitzer, S., Palmegiani, I., Weigold, A., Portas, R., Roeder, R., Krofel, M., Hofer, H., & Wachter, B. (2020). Communication Hubs of an Asocial Cat are the Source of a Human-Carnivore Conflict and Key to its Solution. *Proceedings of the National Academy of Sciences*, 1–9. <https://doi.org/10.1073/pnas.2002487117>
- [60] Miller, J. R. B. (2015). Mapping Attack Hotspots to Mitigate Human-Carnivore Conflict: Approaches and Applications of Spatial Predation Risk Modeling. *Biodiversity and Conservation*, 24, 2887–2911. <https://doi.org/10.1007/s10531-015-0993-6>
- [61] Muposhi, V. K., Gandiwa, E., Chemura, A., Bartels, P., Makuza, S. M., & Madiri, T. H. (2016). Habitat Heterogeneity Variably Influences Habitat Selection by Wild Herbivores in a Semi-Arid Tropical Savanna Ecosystem. *PLoS ONE*, 11(9). <https://doi.org/10.1371/journal.pone.0163084>
- [62] Nampa, W. I., Mudita, W. I., Kaho, N. P. L. B. R., Widinugraheni, S., & Natonis R. L. (2020). The KoBoCollect for Research Data Collection and Management (An Experience in Researching the Socio-Economic Impact of Blood Disease in Banana). *Journal of Social and Agricultural Economics*, 14(3), 545–556. <https://doi.org/10.24843/SOCA.2020.v14.i03.p15>
- [63] Nyhus, P. J. (2016). Human-Wildlife Conflict and Coexistence. *Annual Review of Environment and Resources*, 41, 143–171. <https://doi.org/10.1146/annurev-environ-110615-085634>
- [64] Parliament of the Republic of South Africa. (1944). Magistrates' Courts Act 32 of 1944, 1–59.
- [65] Parliament of the Republic of South Africa. (1991). Adjustment of Fines Act, 1–3.
- [66] Parliament of the Republic of South Africa. (2020). Non-Detrimental findings for *Acinonyx jubatus* (cheetah), 5.
- [67] Parliament of the Republic of South Africa. (2023). National Environmental Management: Biodiversity Act, 10 of 2004. Department of Forestry, Fisheries and the Environment, 1–43.
- [68] Pérez-Pereira, N., Wang, J., Quesada, H. (2023). Prediction of the Minimum Effective Size of a Population Viable in the Long Term. *Biodiversity and Conservation*, 31(3), 2763–2780. <https://doi.org/10.1007/s10531-022-02456-z>
- [69] Pirie, T. J., Thomas, R. L., & Fellowes, M. D. (2017). Game Fence Presence and Permeability Influences the Local Movement and Distribution of South African Mammals. *African Zoology*, 52(4), 217–227. <https://doi.org/10.1080/15627020.2017.1410074>
- [70] Portas, R., Wachter, B., Beytell, P., Uiseb, K. U., Melzheimer, J., & Edwards, S. (2022). Leopard *Panthera pardus* Camera Trap Surveys in the Arid Environments of Northern Namibia. *Mammalian Biology*, 102, 1185–1198. <https://doi.org/10.1007/s42991-022-00237-3>
- [71] Ramírez-García, J. G., Maciel-Torres, S. P., Hernández-Rodríguez, M., Arenas-Báez, P., Orzuna-Orzuna, J. F., & Granados-Rivera, L. D. (2025). Non-Invasive Sampling for Population Genetics of Wild Terrestrial Mammals (2015–2025): A Systematic Review. *Diversity*, 17(11). <https://doi.org/10.3390/d17110760>
- [72] Review of the Regional Conservation Strategy for the Cheetah and African Wild Dog in Southern Africa (2015). IUCN/SSC Gland, Switzerland and Range Wide Conservation Program for Cheetah and African Wild Dogs, www.cheetahandwilddog.org
- [73] Republic of South Africa. (2025). Inside the Numbers: SA Population Trends for 2025. <https://www.statssa.gov.za/?p=18613>
- [74] Ripple, W. J., Estes, J. A., Beschta, R. L., Wilmers, C. C., Ritchie, E. G., Hebblewhite, M., Berger, J., Elmhagen, B., Letnic, M., Nelson, M. P., Schmitz, O. J., Smith, D. W., Wallach, A. D., & Wirsing, A. J. (2014). Status and Ecological Effects of the World's Largest Carnivores. *Science*, 343(6167), 151–152. <https://doi.org/10.1126/science.1241484>

- [75] Ripple, W. J., Newsome, T. M., Wolf, C., Dirzo, R., Everatt, K. T., Galetti, M., Hayward, M. W., Kerley, G. J. H., Levi, T., Lindsey, P. A., Macdonald, D. W., Malhi, Y., Painter, L. E., Sandom, C. J., Terborgh, J., & van Valkenburgh, B. (2015). Collapse of the World's Largest Herbivores. *Science Advances*, 1–12. <https://doi.org/10.1126/sciadv.1400103>
- [76] Rondinini, C., Di Marco, M., Chiozza, F., Santulli, G., Baisero, D., Visconti, P., Hoffmann, M., Schipper, J., Stuart, S. N., Tognelli, M. F., Amori, G., Falcucci, A., Maiorano, L., & Boitani, L. (2011). Global Habitat Suitability Models of Terrestrial Mammals. *Philosophical Transactions of the Royal Society B*, 366(1578), 2633–2641. <https://doi.org/10.1098/rstb.2011.0113>
- [77] Schober, P., Boer, C., & Schwarte, L. A. (2018). Correlation Coefficients: Appropriate Use and Interpretation. *Anesthesia & Analgesia*, 126(5), 1763–1768. <https://doi.org/10.1213.ANE.0000000000002864>
- [78] Selebatso, M., Moe, S. R., & Swenson, J. E. (2008). Do Farmers Support Cheetah *Acinonyx jubatus* Conservation in Botswana despite Livestock Depredation? *Oryx*, 42(3), 430–436. <https://doi.org/10.1017/S0030605308001154>
- [79] Shams, A., Farhadinia, M. S., O'Riain, M. J., Gaylard, A., Smit, M., Fraticelli, C., Koutou, M., Clement, K. B., Durant, S. M., Melzheimer, J., & Naude, V. N. (2024). Perilous State of Critically Endangered Northwest African Cheetah (*Acinonyx jubatus hecki*) across the Sudano-Sahel. *Animal Conservation*, 28, 208–223. <https://doi.org/10.1111/acv.12974>
- [80] Shikwambana, L., Xongo, K., Mashalane, M., & Mhangara, P. (2023). Climatic and Vegetation Response Patterns over South Africa during the 2010/2011 and 2015/2016 Strong ENSO Phases. *Atmosphere*, 14(416), 1–14. <https://doi.org/10.3390/atmos14020416>
- [81] SICK AG. (2023). Into the wild: Species conservation with sensors from SICK. <https://www.sick.com/be/nl/into-the-wild-species-conservation-with-sensors-from-sick/w/blog-momentum-cheetah-live-trap>
- [82] Smit, K.L., Sievert, O.; Smit, M., Ramcharan, A. (2026). South African Metapopulation: Population Viability Analysis (PVA) & Annual Harvest Model (2026/2027). Unpublished data report.
- [83] Stark, D.J., Vaughan, I.P., Ramirez Saldivar, D.A., Nathan SKSS, Goossens B (2017) Evaluating methods for estimating home ranges using GPS collars: A comparison using proboscis monkeys (*Nasalis larvatus*). *PLoS ONE*, 12(3). <https://doi.org/10.1371/journal.pone.0174891>
- [84] Statista (2026). Forecast of the Total Population of Africa from 2020 to 2050. <https://www.statista.com/statistics/1224205/forecast-of-the-total-population-of-africa>
- [85] Strampelli, P., Searle, C. E., Smit, J. B., Henschel, P., Mkuburo, L., Ikanda, D., Macdonald, D. W., & Dickman, A. J. (2021). Camera Trapping and Spatially Explicit Capture–Recapture for the Monitoring and Conservation Management of Lions: Insights from a Globally Important Population in Tanzania. *Ecological Solutions and Evidence*, 1–13. <https://doi.org/10.1002/2688-8319.12129>
- [86] South African National Biodiversity Institute. (2025). NDF Assessment for *Acinonyx jubatus* (cheetah). Department of Forestry and Fisheries and the Environment. <https://www.sanbi.org/wp-content/uploads/2026/03/Acinonyx-jubatus-NDF-supporting-document.pdf>
- [87] Sousa, L. L., Silva, S. M., & Xavier, R. (2019). DNA Metabarcoding in Diet Studies: Unveiling Ecological Aspects in Aquatic and Terrestrial Ecosystems. *Environmental DNA*, 1(4). <https://doi.org/10.1002/edn3.27>
- [88] Souza, F. C., & Azevedo, F. C. C. (2021). Hair as a Tool for Identification of Predators and Prey: a Study Based on Scats of Jaguars (*Panthera onca*) and Pumas (*Puma concolor*). *Biota Neotropica*, 21(1), 1–10. <https://doi.org/10.1590/1676-0611-BN-2020-1044>
- [89] Tagwireyi, P., Wenga, T., Ndaimani, H., & Mpakairi, K. S. (2020). Environmental Correlates of Cheetah (*Acinonyx jubatus*) Space-Use in a Savanna Landscape. *African Journal of Wildlife Research*, 50(1), 157–166. <https://doi.org/10.3957/056.050.0157>
- [90] Tambling, C. J., Avenant, N. L., Drouilly, M., & Melville, H. (2018). The Role of Mesopredators in Ecosystems: Potential Effects of Managing their Populations on Ecosystem Processes and Biodiversity. In: Livestock predation and its management in South Africa: a scientific assessment. *Centre for African Conservation Ecology*, 205–227. ISBN 978-0-620-78764

- [91] Thuo, D., Furlan, E., Broekhuis, F., Kamau, J., Macdonald, K., & Gleeson, D. M. (2019) Food from Faeces: Evaluating the Efficacy of Scat DNA Metabarcoding in Dietary Analysis. *PLoS ONE*, 15(2). <https://doi.org/10.1371/journal.pone.0225805>
- [92] Turpie, J. K., & Akinyemi, B. (2018). The Socio-Economic Impacts of Livestock Predation and its Prevention in South Africa. In: *Livestock predation and its management in South Africa: a scientific assessment. Centre for African Conservation Ecology*, 53–81. ISBN 978-0-620-78764
- [93] Van der Meer, E. (2018). Carnivore Conservation under Land Use Change: the Status of Zimbabwe's Cheetah Population after Land Reform. *Biodiversity and Conservation*, 27(3), 647–663. <https://doi.org/10.1007/s10531-017-1455-0>
- [94] Vargas, O. M., Madriñán, S., & Simpson, B. (2023). Allopatric Speciation is More Prevalent than Parapatric Ecological Divergence in a Recent High-Andean Diversification. *PeerJ*, 11. <https://doi.org/10.7717/peerj.15479>
- [95] Verschueren, S., Hofmann, T., Kakove, M., Bauer, H., Cristescu, B., & Marker, L. (2024). High Carnivore Richness despite Human Pressure and Prey Depletion in the South-West of the Kavango–Zambezi Transfrontier Conservation Area. *Oryx*, 1–9. <https://doi.org/10.1017/S0030605324000024>
- [96] Viollaz, J. S., Thompson, S. T., & Petrossian, G. A. (2021). When Human–Wildlife Conflict Turns Deadly: Comparing the Situational Factors That Drive Retaliatory Leopard Killings in South Africa. *Animals*, 11(3281). <https://doi.org/10.3390/ani11113281>
- [97] Weise, F. J., Vijay, V., Jacobson, A. P., Schoonover, R. F., Groom, R. J., Horgan, J., Keeping, D., Klein, R., Marnewick, K., Maude, G., Melzheimer, J., Mills, G., Van Der Merwe, V., Van Der Meer, E., Van Vuuren, R. J., Wachter, B., & Pimm, S. L. (2017). The Distribution and Numbers of Cheetah (*Acinonyx jubatus*) in Southern Africa. *PeerJ*, 5. <https://doi.org/10.7717/peerj.4096>
- [98] Wild, M. A., Hobbs, N. T., Graham, M. S., & Miller, M. W. (2011). The Role of Predation in Disease Control: a Comparison of Selective and Nonselective Removal on Prion Disease Dynamics in Deer. *The Journal of Wildlife Diseases*, 47(1), 78–93. <https://doi.org/10.7589/0090-3558-47.1.78>
- [99] Wildeye. (2023). Traptagger [Computer software]. <https://wildeyeconservation.org>
- [100] WWF. (2024). Living Planet Report 2024: A System in Peril. WWF, Gland, Switzerland. ISBN: 978-2-88085-319-8[98]

Appendices

Appendix I – Free-Roamer Cheetah Census Questionnaire

Appendix II - Predator Recognition Kit

Appendix III – Camera Trapping and Scat Collection Procedures

Appendix IV – Site Operations

Appendix V – Camera Trap Report

Appendix VI – FRCC ID Kit

Appendix VII – Unistel Genetics Report