Received: 27 May 2022 | Revised: 7 September 2022 | Accepted: 3 October 2022

DOI: 10.1111/aje.13078

SHORT COMMUNICATION

African Journal of Ecology WILEY

Count me in: Leopard population density in an area of mixed land-use, Eastern Cape, South Africa

Safia Bouderka[1] | Travis W. Perry[1,2] | Daniel Parker[2,3] | Maya Beukes[2] | Nokubonga Mgqatsa[2]

[1]Department of Biology, Furman University, Greenville, South Carolina, USA

[2]Wildlife and Reserve Management Research Group, Department of Zoology and Entomology, Rhodes University, Makhanda, South Africa

[3]School of Biology and Environmental Sciences, University of Mpumalanga, Mbombela, South Africa

Correspondence
Daniel Parker, Wildlife and Reserve Management Research Group, Department of Zoology and Entomology, Rhodes University, Makhanda, South Africa.
Email: daniel.parker@ump.ac.za

Funding information
Furman University's Office of Undergraduate Research

1 | INTRODUCTION

Although the leopard (*Panthera pardus*) has the widest range of any felid in the world is designated as a vulnerable species, mainly because of human-induced conflict (Jacobson et al., 2016). Our study focuses on a population of leopards on privately owned, mixed-use farmland (Baviaanskloof Hartland – BH hereafter) which is adjacent to the Baviaanskloof Mega Reserve (BMR) in the Baviaanskloof UNESCO World Heritage Site of the Eastern Cape, South Africa. Given the unique make-up of the region, with sometimes conflicting management objectives, the status of leopards in the broader Baviaanskloof is of particular interest to a range of stakeholders. However, despite the need for management decisions to be based on reliable and regular population monitoring efforts (Elliot et al., 2020), the last formal assessment of the leopard population in the Baviaanskloof was performed in 2011/2012 but published 9 years later (Devens et al., 2018). The only other assessment of the status of leopards in the region was an unpublished Master's project (McManus, 2009). Here, we use photographic captures of leopards and a Spatially Explicit Capture Recapture (SECR) analytical framework in the mixed-use BH region of the Baviaanskloof to generate an up-to-date leopard population density estimate that can inform conservation management of the species in this important World Heritage Site.

2 | MATERIALS AND METHODS

2.1 | Study area

The Baviaanskloof World Heritage Site falls within the Cape Floristic Region, recognised for its extraordinary biodiversity (Myles, 2018). The landscape consists of a central valley and its tributary valleys and floodplains, dominated by steep, mountainous terrain. The area hosts an array of unique vegetation biomes including Albany Thicket, Fynbos, Succulent Karoo, Nama-Karoo, Grassland, Savannah and Forest (Skowno et al., 2021). The BMR is a roughly 500,000 ha area of protected land consisting of the 200,000 ha Baviaanskloof Nature Reserve (BNR), under the management of the Eastern Cape Parks and Tourism Agency (ECPTA), and several state-owned protected areas and privately owned lands under conservation stewardships (Rapeneau, 2015). The BH falls within the greater BMR and is situated west of the BNR (Figure 1). The BH is a cooperative of privately owned agricultural lands (Rapeneau, 2015). Specific camera locations with a minimum convex polygon area of 75 km^2 were placed in the BH (Figure 1) in four of the Bavianskloof's major vegetation biomes: Fynbos, Albany Thicket, Savannah and Forest (Appendix 1).

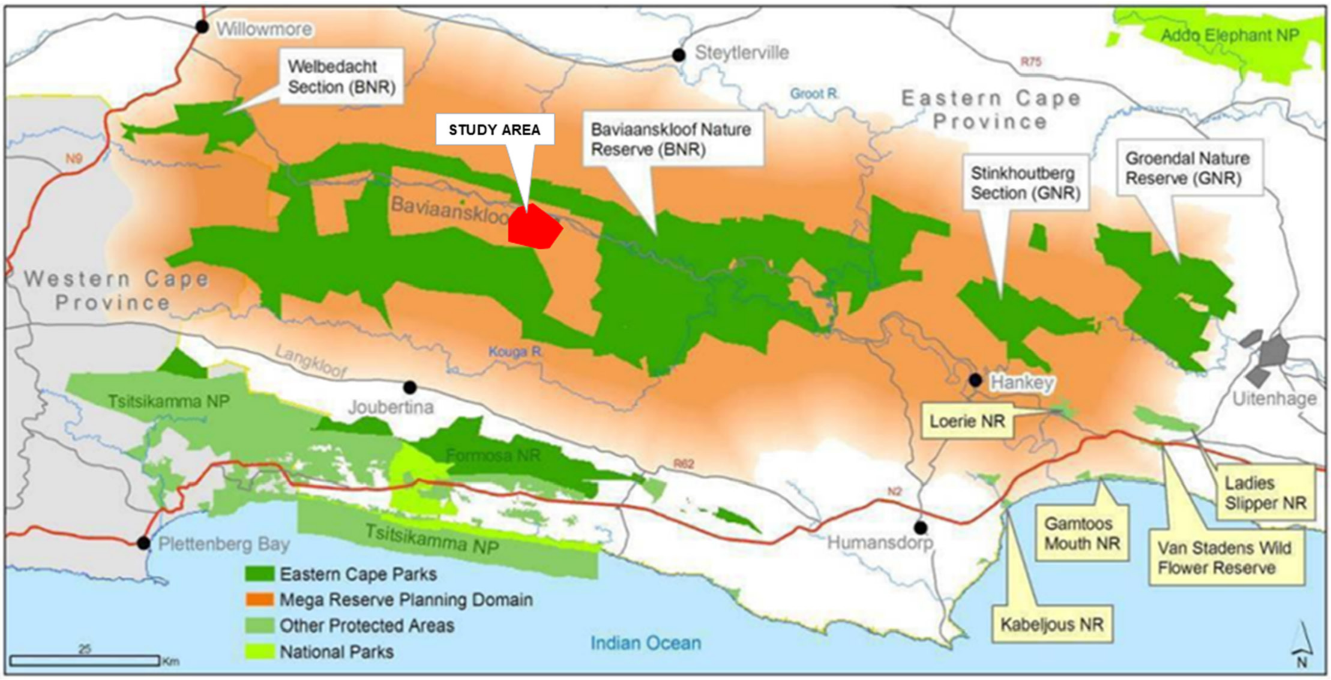

FIGURE 1 A map of the protected areas in the Baviaanskloof region, Eastern Cape, South Africa with our study area (without buffer) added and highlighted in red (*source*: ECPTA).

2.2 | Methods

We deployed 28 un-baited motion-activated camera traps across the study area, from 28 January 2020 to 5 February 2020 and monitored them for 7 months. We placed one Cuddeback X-Change™ Color Model 1279 camera per site (Figure 2). Cameras were placed to be representative of the variations in vegetation type in the study area and spaced close enough together such that no individual leopard present could be missed (Figure 2). This camera spacing was aligned with known leopard home range sizes for the area (females = 106–130 km^2; males = 85–498 km^2) (McManus, 2009). Cameras were placed in areas where there were two or more signs of animal activity (i.e., tracks, scat or signs of foraging), and were positioned in such a way as to minimise false triggers, over-exposure, and interference from sun and vegetation. Cameras were visited every 30–45 days to download photos, replace batteries, ensure continued camera functionality and remove any obstructions that may have appeared, such as vegetation that had grown in front of the camera and obscured its view. Some traps were affected by camera or battery malfunctions, as well as interference from animals. These issues were corrected and recorded during camera checks. During checks, photos were downloaded directly from the cameras' SD cards, and then uploaded to PhotoGoFer (Rapid Imaging, Inc.), a photo data capture program that securely stores image files and associated data in a secure database. In PhotoGoFer, relevant data for each photo, such as species, sex, age, unique attributes and individual ID, were associated with the image file in a process called tagging. Individual leopards were identified by matching their unique spot patterns between photos. Photos were manipulated in Google Slides to align photos of spot patterns directly on top of one another and to confirm identifications. All leopard identifications were made by SB and cross-checked by TWP and MB.

We generated leopard population density estimates independently for left-side and right-side captures in R (R Core Team, 2021) using the 'secr' package (Efford, 2021). We used the first 60 days of our sampling period for our estimates to address the assumption of a closed population (Karanth & Nichols, 1998). We defined our camera traps as 'count' detectors to account for their ability to capture an individual several times at the same occasion. We selected a buffer of 20 km and used a half-normal detection function following Devens et al. (2018). The addition of the 20 km buffer to our study area made our total effective area sampled 2643 km^2.

3 | RESULTS AND DISCUSSION

Of 13,819 photographic capture events over a period of 7 months and 5012 camera trap days, we captured 89 photos of leopards. We identified a total of six adult leopards from the left side and five adult leopards from the right side. During the initial 60-day period with 4740 camera trap days, four adult leopards were identified from the left side and the right-side photos respectively. From these data, we generated population density estimates of 0.74 leopards/100 km^2 for left-side photos and 1.4 leopards/100 km^2 for right-side, resulting in a mean estimate of 1.07 leopards/100 km^2 (Table 1). Additionally, we captured photos of two reproductive females. The first was sighted with

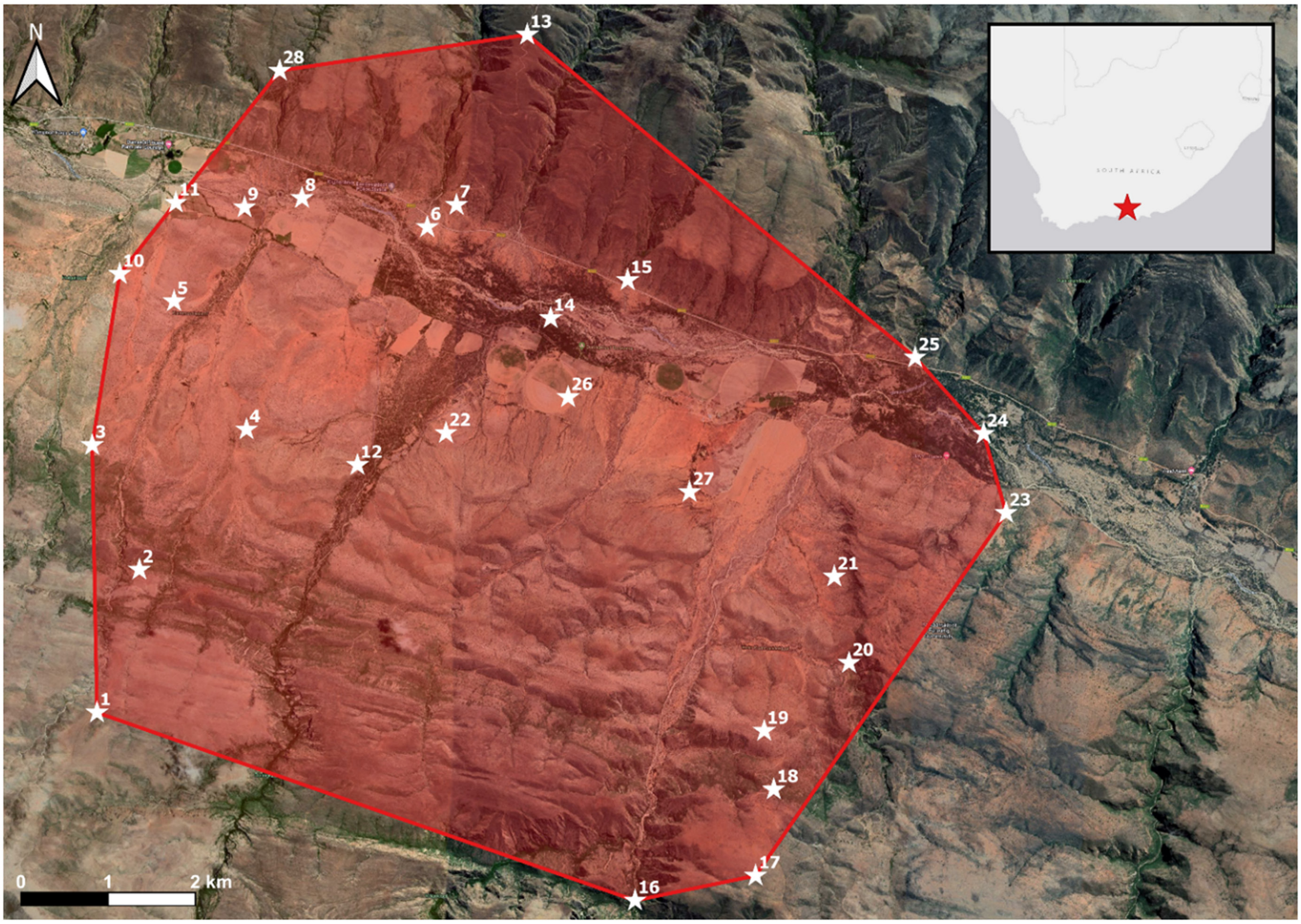

FIGURE 2 The layout of 28 single-camera traps placed in the Baviaanskloof Hartland study area (75 km^2), and a demonstration of the relative location of our study area in South Africa (top right).

TABLE 1 Estimated leopard population density per 100 km^2 (with sample size and upper and lower confidence limits shown) in the Baviaanskloof, for adult leopards captured and identified from the left and right side during a 60-day period in 2020.

Side	Density/100 km^2	Lcl	Ucl	*n*
L	0.74	0.23	2.3	4
R	1.40	0.45	4.5	4
Mean	1.07			

a single cub on 5 February 2020 and 21 February 2020. We positively identified the cub on 21 February 2020 sighting to be one of two cubs we frequently sighted together; therefore, we reasonably assume this leopard to be the mother of two cubs. The other reproductive female was sighted with a single cub on 5 March 2020.

Our estimate of 1.07 leopards/100 km^2 is comparable to the first population estimate generated in the region (McManus, 2009), but higher than the later assessment (Devens et al., 2018). McManus (2009) produced a population density estimate of 1.1 leopards/100 km^2 and 1.3 leopards/100 km^2 using camera traps and GPS data, respectively, for the entire Baviaanskloof. Devens et al. (2018), using the SPACECAP package, and an SECR framework, reported a much lower estimate of 0.24 leopards/100 km^2. Differences in methodology between our study and Devens et al. (2018) may have resulted in this disparity. For example, Devens et al. (2018) generated their estimates using a 90-day sample period (Karanth & Nichols, 1998) and Bayesian SECR modelling. Fine scale differences in photo-capture success across different camera sites between the two studies is also possible. The disparity in estimates may, of course, also be because of changes in the leopard population in the intervening decade between the two studies. Indeed, we know leopard population densities and their estimates can fluctuate dramatically over time and/or depending on the field techniques and analytical framework used (Amin et al., 2022).

Nevertheless, our estimate of 1.07 leopards/100 km^2 likely reflects our study area being situated on non-protected farmland and its proximity to a large, protected area with abundant natural prey and one that provides a mosaic of suitable habitat types for leopards (*cf.* Amin et al., 2022). The density of leopards on farmlands has been found to be much lower than adjacent protected areas, and human–farmer conflict resulting in edge effects that may seriously weaken the effectiveness of reserves to conserve species like leopards (Balme et al., 2010; Marker & Dickman, 2005). Even in areas like the Phinda-Mkhuze Complex in KwaZulu-Natal, South Africa, which has shown consistently high leopard population densities averaging around 7 leopards/100 km^2, leopards show much greater mortality rates near the borders of the protected area compared to the central areas (Balme et al., 2010). Although the BNR prohibits hunting or capturing of any animals on the reserve, leopards can move freely in and out of the reserve, increasing their potential to come into conflict with farmers (Balme et al., 2010).

The status of leopards in the Baviaanskloof is of great economic and socio-political relevance to the farmers of the BH, who are under significant stress due to the reduced profitability of agriculture in an unfavourable economic environment and on lands degraded due to past unsustainable agricultural practices (Kerley et al., 1995). The majority of agricultural production in the Baviaanskloof is small livestock, for which farmers suffer losses due to depredation (Rapeneau, 2015). Actual or perceived threats of loss to carnivores has been shown to prompt farmers to resort to lethal protection of their livestock using traps, poison, hunting dogs, and often direct hunting and killing of perceived or potential offenders (Minnie et al., 2015). In addition, 67% of Baviaanskloof farmers harboured negative attitudes towards leopards, despite leopards only being responsible for 0.7% of livestock losses per year (Minnie et al., 2015). By killing leopards on their land, farmers not only threaten the leopard population but also their own livelihoods in an already unfavourable economic environment. Balme et al. (2010) recommend mitigating conflicts along reserve borders by implementing strategies on both sides of the borders, including systems for the regulation of problem animal control and community interventions to reduce human–leopard conflicts. We believe that such interventions should at least be attempted in the Baviaanskloof to reduce human–leopard conflict.

Our leopard population estimate provides up-to-date insight on the status of leopards in an important mixed land-use part of the Baviaanskloof World Heritage Site. However, to be relevant and useful for all stakeholders in the region, it is vital that up-to-date leopard population monitoring be conducted, and suitable human–leopard conflict mitigation measures put in place.

ACKNOWLEDGEMENT

Funding for this project was provided by Furman University's Office of Undergraduate Research. Our research was performed in association with Furman Cougar Project and the Baviaanskloof Wildlife Project. We thank the Eastern Cape Parks and Tourism Agency, Rhodes University, the National Research Foundation, Living Lands, and the landowners of the Baviaanskloof Hartland for their support of this project.

CONFLICT OF INTEREST

The authors confirm that they have no interests to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ORCID

Daniel Parker https://orcid.org/0000-0001-7555-5674

REFERENCES

Amin, R., Wilkinson, A., Williams, K. S., Martins, Q. E., & Hayward, J. (2022). Assessing the status of leopard in the cape Fold Mountains using a Bayesian spatial capture–recapture model in just another Gibbs sampler. *African Journal of Ecology*, *60*, 299–307. https://doi.org/10.1111/aje.12944

Balme, G. A., Slotow, R., & Hunter, L. T. B. (2010). Edge effects and the impact of non-protected areas in carnivore conservation: Leopards in the Phinda-Mkhuze complex, South Africa: Impact of edge effects on carnivore conservation. *Animal Conservation*, *13*(3), 315–323. https://doi.org/10.1111/j.1469--1795.2009.00342.x

Devens, C., Tshabalala, T., McManus, J., & Smuts, B. (2018). Counting the spots: The use of a spatially explicit capture-recapture technique and GPS data to estimate leopard (*Panthera pardus*) density in the eastern and Western cape, South Africa. *African Journal of Ecology*, *56*(4), 850–859. https://doi.org/10.1111/aje.12512

Efford, M. G. (2021). *Secr: Spatially explicit capture-recapture models*. R package version 4.4.5. https://CRAN.R-project.org/package=secr

Elliot, N. B., Bett, A., Chege, M., Sankan, K., Souza, N., Kariuki, L., Broekhuis, F., Omondi, P., Ngene, S., & Gopalaswamy, A. M. (2020). The importance of reliable monitoring methods for the management of small, isolated populations. *Conservation Science and Practice*, *2*(7), e217. https://doi.org/10.1111/csp2.217

Jacobson, A. P., Gerngross, P., Lemeris, J. R., Jr., Schoonover, R. F., Anco, C., Breitenmoser-Würsten, C., Durant, S. M., Farhadinia, M. S., Henschel, P., Kamler, J. F., Laguardia, A., Rostro-García, S., Stein, A. B., & Dollar, L. (2016). Leopard (*Panthera pardus*) status, distribution, and the research efforts across its range. *PeerJ*, *4*, e1974. https://doi.org/10.7717/peerj.1974

Karanth, K. U., & Nichols, J. D. (1998). Estimation of tiger densities in India using photographic captures and recaptures. *Ecology*, *79*(8), 2852–2862. https://doi.org/10.1890/0012-9658(1998)079[2852:EOTDI I]2.0.CO;2

Kerley, G. I. H., Knight, M. H., & de Kock, M. (1995). Desertification of subtropical thicket in the eastern cape, South Africa: Are there alternatives? *Environmental Monitoring and Assessment*, *37*(1–3), 211–230. https://doi.org/10.1007/BF00546890

Marker, L. L., & Dickman, A. J. (2005). Factors affecting leopard (*Panthera pardus*) spatial ecology, with particular reference to Namibian farmlands. *South African Journal of Wildlife Research*, *35*(2), 105–115.

McManus, J. S. (2009). *The spatial ecology and activity patterns of leopards (Panthera pardus) in the Baviaanskloof and Greater Addo Elephant National Park (GAENP), Eastern CAPE Province, South Africa* [MSc thesis]. Rhodes University.

Minnie, L., Boshoff, A. F., & Kerley, G. I. H. (2015). Vegetation type influences livestock predation by leopards: Implications for conservation in agro-ecosystems. *African Journal of Wildlife Research*, *45*(2), 204. https://doi.org/10.3957/056.045.0204

Myles, P. B. (2018). Towards a governance model for a biosphere mega Reserve in South Africa. *International Journal of Research in Tourism and Hospitality.*, *4*(2), 1–17.

R Core Team. (2021). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. https://www.R-project.org/

Rapeneau, C. (2015). *Human-wildlife conflict and involvement of the local population: A case study of the Baviaanskloof*. [Unpublished master thesis]. Utrecht University.

Skowno, A. L., Jewitt, D., & Slingsby, J. A. (2021). Rates and patterns of habitat loss across South Africa's vegetation biomes. *South African Journal of Science*, *117*(1-2), 1–5. https://doi.org/10.17159/sajs.2021/8182

How to cite this article: Bouderka, S., Perry, T. W., Parker, D., Beukes, M., & Mgqatsa, N. (2023). Count me in: Leopard population density in an area of mixed land-use, Eastern Cape, South Africa. *African Journal of Ecology*, *61*, 228–232. https://doi.org/10.1111/aje.13078

APPENDIX 1 THE COORDINATES OF OUR 28 CAMERA TRAPS, SETUP AND REMOVAL DATES, AND VEGETATION TYPE AT EACH TRAP SITE

Camera	Y coordinate	X coordinate	Setup	Removed	Vegetation type
1	33.6111224	24.02963	01/28/2020	08/08/2020	Fynbos
2	33.59623	24.03435	01/28/2020	08/08/2020	Thicket
3	33.5835	24.02807	02/05/2020	08/07/2020	Thicket
4	33.58141	24.04707	01/28/2020	08/07/2020	Thicket
5	33. 56,839	24.03766	02/04/2020	08/03/2020	Thicket
6	33.55995	24.06865	01/30/2020	08/05/2020	Thicket
7	33.55757	24.07217	01/29/2020	08/05/2020	Thicket
8	33.55733	24.05308	01/31/2020	08/04/2020	Savannah
9	33.558469	24.04603	01/30/2020	08/03/2020	Savannah
10	33.56573	24.03085	02/052020	08/03/2020	Thicket
11	33.5582	24.03752	02/05/2020	07/25/2020	Thicket
12	33.58475	24.0609	02/05/2020	08/07/2020	Thicket
13	33.53976	24.08028	01/28/2020	07/06/2020	Fynbos
14	33.56898	24.08421	01/31/2020	08/04/2020	Savannah
15	33.56482	24.09358	01/31/2020	05/26/2020	Savannah
16	33.6289	24.09679	02/01/2020	07/24/2020	Forest
17	33.62596	24.11158	02/03/2020	08/04/2020	Fynbos
18	33.61699	24.11351	02/03/2020	08/04/2020	Thicket
19	33.61097	24.11211	02/03/2020	08/04/2020	Thicket
20	33.60368	24.12234	02/03/2020	08/06/2020	Forest
21	33.59481	24.12019	02/04/2020	08/06/2020	Thicket
22	33.58117	24.07171	02/04/2020	06/29/2020	Thicket
23	33.5877	24.14117	02/04/2020	08/06/2020	Thicket
24	33.57958	24.1381	02/04/2020	08/06/2020	Savannah
25	33.57192	24.12936	01/31/2020	08/06/2020	Savannah
26	33.5771	24.08666	01/31/2020	08/04/2020	Savannah
27	33.58652	24.102	02/05/2020	08/04/2020	Thicket
28	33.54423	24.04986	01/30/2020	08/07/2020	Forest