**Chapter 18**

# Integrating Remote Sensing with CBNRM for Desert-Adapted Lion Conservation

John Heydinger

## 1) Introduction

The desert-adapted lions (*Panthera leo*) of northwest Namibia's Kunene Region are iconic, demonstrating unique grouping patterns[1] and movements[2] within a 'one-of-a-kind' landscape. Inhabiting unfenced lands designated primarily as communally-managed conservancies, the desert-adapted lion population is relatively small, though stable. From 1997-2015 the population recovered from ~20 to ~180 individuals.[3] This conservation success story is unique: these are among the only African lion populations to have grown over the last 25 years outside fenced protected areas.[4] Since the mid-2010s, however, the population has declined to an estimated 57-60 adult (non-cub) individuals[5] and from an estimated density of 0.28-0.35 lions/100 km$^2$ [6] to 0.1 lions/100 km$^2$.[7] This decline has been driven by retaliatory lion killing following human-lion conflict (HLC) – occurring because lions threaten farmers' safety and livelihoods via livestock destruction.[8] Since 2000, retaliatory killings of lions following HLC incidents have accounted for 89% of recorded lion (non-cub) mortalities in Kunene.[9] HLC thus poses a serious threat to the viability of the desert-adapted lion population.

Lion presence on conservancy lands is something of a paradox: conservancy legislation was implemented to enable rural Namibians to benefit from wildlife within communal, multi-use landscapes.[10] Yet, HLC imposes significant costs upon farmers in Kunene conservancies. Recent surveys of communal farmers inhabiting three core lion-range conservancies reveal livestock losses from HLC estimated at US$ 2,985 per household, and losses from all predators at US$ 10,151 over a three-year period, based on surveys of approximately 90% of livestock-owning households.[11] Such losses can be life-altering. Day-to-day household needs may be compromised while funds for emergencies become scarce. HLC and subsequent lion killing is thus both a wildlife conservation and human wellbeing challenge. Furthermore, communal area farmers overwhelmingly (84%) feel they do not benefit from lions inhabiting their

[1] Stander (2018)
[2] GRN (2017)
[3] GRN (2017)
[4] Packer et al. (2013)
[5] Heydinger & Muzuma (2023)
[6] Stander (2010)
[7] Heydinger & Muzuma (2023))
[8] Sullivan (2016)
[9] GRN (2017); Tavolaro et al. (2022)
[10] Jones (2001)
[11] Heydinger et al. (2019)

conservancy. Even so 75% want lions to continue to inhabit their conservancy, with the primary reason given that they want future generations to be able to see wild lions.

Strengthening lion monitoring in Kunene is important for limiting HLC and supporting farmers' livelihoods. However, Kunene's vast and rugged landscapes create considerable difficulties for monitoring lions. Not only is much of the area difficult to access, but because desert-adapted lions cover such expansive territories, monitoring efforts must be highly-mobile and flexible. Furthermore, because lions in Kunene primarily inhabit communal land, lion monitoring must also engage local communities. Without community participation, lion monitoring and conservation risks alienating conservancy rights over wildlife, with the potential downstream effect of lion management being considered an external imposition. This may engender antagonism towards lion conservation activities, leading to lion-killing as a form of protest.[12]

The challenge facing Community-Based Natural Resource Management (CBNRM) of lions in Kunene is how to simultaneously limit HLC while building tolerance of lions among farmers. Doing so requires synthesizing inclusive, locally-centered efforts with available technologies for monitoring lion movements. This chapter examines how the Lion Rangers program[13] is actualizing community-centered monitoring and conservation of the desert-adapted lions. Building on lion ecologist Philip 'Flip' Stander's work, the Lion Rangers are using cutting-edge remote sensing technologies, including GPS/satellite collars with VHF and early-warning capabilities affixed to lions (lion collars), and an extensive array of motion-activated cameras taking high-quality photographs (camera traps) deployed across the landscape along key movement corridors and areas where lions concentrate. Using these methods, Lion Rangers program researchers are developing an increasingly comprehensive picture of lion movements in Kunene. Yet, the program is truly centered on the Lion Rangers themselves. Composed of 49 conservancy members from 11 lion-range conservancies, the Lion Rangers are employed by their conservancies and capacitated by the Lion Rangers program to monitor lions, provide information to other farmers and key conservancy personnel regarding lion movements and behavior, while supporting farmers' livelihoods by limiting HLC, thereby increasing local tolerance for living alongside lions. The integration of lion collars and camera traps with the locally-centered work of the Lion Rangers is promoting the active mitigation, management, and prevention of HLC in Kunene.

This chapter examines how the Lion Rangers program integrates remote sensing technologies with community-centered monitoring and HLC interventions for desert-adapted lion conservation. I begin by introducing the core desert-adapted lion landscape and providing a brief history of the lion population. This includes an overview of historical and ongoing lion conservation efforts in Kunene, including an examination of the effects of CBNRM on the lion population as well as an introduction to the Lion Rangers program. Remote sensing technologies have been an important part of lion monitoring in Kunene for years, but recent

[12] Heydinger & Muzuma (in press)
[13] Lion Rangers (2023)

advances are enabling such tech to also be an important part of limiting HLC. GPS/satellite collars and camera traps are proving to be invaluable tools for monitoring lions and limiting HLC. I close with a case study illustrating how these approaches are limiting HLC and supporting lion survival. I close with a case study of a conflict-causing male lion known as NPL-27, which illustrates how these remote sensing and community-centered methods are being integrated for effective desert-adapted lion conservation.

## 2) Kunene core lion-range

The core of desert-adapted lion range in Kunene is an area of approximately 40,000 km$^2$. This area encompasses 11 communal area conservancies (Anabeb, Doro !Nawas, Ehi-rovipuka, ǂKhoadi-ǁHoas, Omatendeka, Orupupa, Puros, Sesfontein, Sorris Sorris, Torra and Tsiseb) as well as the Hobatere, Etendeka, and Palmwag tourism concessions, and part of the Skeleton Coast National Park running approximately from the Hoaruseb riverbed in the north to the Ugab riverbed in the south.[14] Dominated by the northern Namib Desert, primarily composed of sandy dunes pocked by small oases in the west, the area also includes rugged mountains and gravel plains bisected by east-to-west ephemeral riverbeds. The area's basaltic soil is shallow, rocky, and relatively unproductive.[15] Other iconic desert-adapted species include black rhinoceros (*Diceros bicornis*), elephant (*Loxodonta africana*), gemsbok (*Oryx gazella*), and mountain zebra (*Equus zebra*). Rainfall is generally low (50-250 mm per year) and erratic, increasing from west to east. During the wet season (January-May) rains fall in brief, localized downpours. Prey species, including gemsbok, mountain zebra, and giraffe (*Giraffa camelopardalis*), follow the rains to fresh grass and often congregate in riverbeds during the dry season (June-December). Springbok (*Antidorcas marsupialis*) generally stay on the plains, while kudu (*Tragelaphus strepsiceros*) reside in stands of trees and cliffsides. Surface water is sparse. During the 1970s, however, a government borehole-drilling program greatly increased year-round water availability. Since that time livestock and wildlife are generally grazing-, not water-limited.[16] Boom-and-bust rainfall patterns cause prey numbers to fluctuate widely. Beginning in 2000 the region experienced a relatively wet period, resulting in wildlife and livestock increases. From 2011 to 2017, extensive drought caused the decline of indicator prey species by as much as 60% and livestock by as much as 67%.[17] Since 2020, early indications are that a modest increase in rainfall is leading to recovering wildlife numbers.[18]

This area includes approximately 19,300 rural residents, who primarily identify as Damara/ǂNūkhoen, or Herero/Himba. Most are small-scale pastoralists for whom livestock has significant economic and cultural value. Drought and predation are the main threats to these farmers' livelihoods, with lions accounting for approximately 20% of livestock losses. Though the Namibian government provides limited annual funding to each conservancy to compensate

[14] Stander (2007)
[15] Mendelsohn et al. (2002); Stander (2018)
[16] Bollig (2020)
[17] Heydinger et al. (2019)
[18] NACSO (2022)

for livestock lost to human-wildlife conflict, 92% of farmers surveyed are dissatisfied with the program because the compensation money does not equal the monetary value of livestock lost.[19] While pastoralism comprises most household incomes, these are often low and insecure.[20] Forty percent of Kunene residents earn ≤ US$1/day, while twenty-three percent earn ≤ US$0.73/day (NNPC 2012). Livelihoods have been further hampered by a downturn in tourism receipts stemming from the COVID-19 pandemic.[21] Additionally, Kunene has Namibia's highest primary school drop-out rates; only fifty-five percent of residents complete primary school by age seventeen.[22] Such social and economic vulnerability exacerbated by HLC not only worsens livelihood prospects, it may also be straining the conservancy system[23] – also see **Chapters 3** and **5**.

## 3) Lions and CBNRM in Kunene

Since the inauguration of Namibia's communal area conservancy system in 1998, Kunene has become a wellspring of community conservation. During this same period lion numbers rebounded. While lions have long inhabited Kunene, likely in low densities, from the 1980s to 1990s they were nearly eradicated on communal lands.[24] Speaking of this period, one Kunene pastoralist remembers that "[i]n olden days lions were being killed and they were manageable."[25] The growth of the conservancy system in this century has created a new wildlife conservation paradigm, one in which colonial-era government staff have been replaced by locals as the custodians of wildlife; although legal enforcement, e.g. of anti-poaching, remains with the government.

Beginning in the late 1990s, Namibian Flip Stander undertook intensive monitoring of the desert-adapted lions, focusing on individuals and groups in the Palmwag Concession and western areas of Puros, Anabeb, Sesfontein, and Torra conservancies.[26] Already experienced monitoring lions in Etosha and Nyae Nyae, Stander's focus on lions in Kunene coincided with the development of the conservancy system. Simultaneously, the region received relatively good rainfall leading to growing prey populations in the early 2000s. During this period lion numbers rose and lions began re-occupying their former range across Kunene (Figure 18.1). In 1999 and 2000, lion numbers in Kunene grew by 22% and 23% respectively, slowing to about 15% from 2001-2004.[27] In 2006, Stander hypothesized a significant linear relationship between the number of lions in Kunene and the size of the range they occupy.[28] More lions moving within communal farming areas coincided with increasing HLC incidents.

[19] Heydinger et al. (2019)
[20] Mendelsohn et al. (2002)
[21] Lendelvo et al. (2020)
[22] UNICEF (2013)
[23] Bollig (2016)
[24] Heydinger (2021)
[25] Sesfontein Pastoralist #4, Personal Communication, 23 November 2017.
[26] Stander (1999, 2000); Stander & Hanssen (2003)
[27] Stander (2004)
[28] Stander (2006)

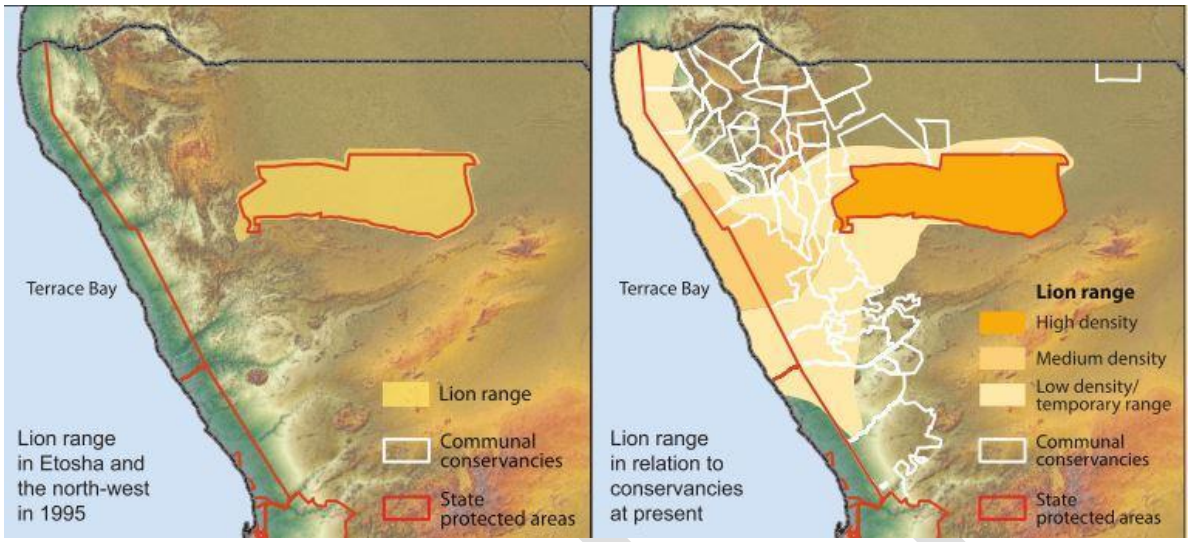



Figure 18.1. Lion range expansion in northwest Namibia, 1995-2015. Reprinted from NACSO (2016: 40).

The institutional context of this lion recovery is important for understanding the challenge of HLC. Desert-adapted lions range mostly within communal conservancy lands. As part of a counter-hegemonic conservation movement that gained momentum in the late 1980s to early 1990s, communal conservancies aim to overcome some of the social, political, and economic injustices stemming from wildlife conservation-oriented interventions during Africa's colonial era.[29] Much is written about the history and implementation of communal conservancies in this volume (see Chapters 3, 5, 12 and 14). Pertinent to lion conservation, under Namibia's Nature Conservation Amendment Act (No. 5/1996), communal area residents may secure limited rights to 'huntable game' species via their conservancy. As institutions for securing benefits stemming from wildlife, conservancies may engage in or contract for trophy-hunting based on government-approved quotas, can apply to hunt protected species such as lions, and can trade and sell wildlife products with government approval. Conceptually based upon the CBNRM framework and Nobel Prize winning economist Elinor Ostrom's Design Principles for Common-Pool Resources,[30] communal conservancies use processes of consultation, engagement, and empowerment[31] to facilitate collective proprietorship of wildlife for simultaneous conservation and community benefit (although see Chapter 5 for review of how this institutional structure is playing out in practice).

Lions, however, prove an awkward fit with the CBNRM paradigm. Lions are a protected species (Nature Conservation Act No. 4/1975), and thus not subject to normal hunting regulations. Heydinger and Muzuma have examined how conservancies constrain residents' ability to manage and benefit from lions.[32] In brief, while conservancy farmers maintain

[29] Dressler et al. (2010); Owen-Smith (2010)
[30] Ostrom (1990); Jones (2010)
[31] Jacobsohn (2019)
[32] Heydinger & Muzuma (in press)

economic and wellbeing risks from living alongside lions, they are unable to directly benefit from lion hunting without government approval. A lack of benefits to match the costs of living with lions is considered a key driver in lion killing. In effect, for many conservancy farmers lion killing is a rational economic response to HLC.

In 2017, Namibia's Ministry of Environment, Forestry and Tourism (MEFT) released the *Human-Lion Conflict Management Plan for North West Namibia* (NW Lion Plan).[33] By providing a framework for addressing HLC while supporting the rights and development needs of local communities, the NW Lion Plan emphasizes the importance of community-centered action and decision-making relevant to lion conservation. Objectives include creating a standardized monitoring system, establishing best practices for HLC mitigation, and creating mechanisms to reduce HLC. Following a regional planning meeting held in September 2017, government, researcher, and conservancy stakeholders agreed to activate and capacitate a group of Lion Rangers.

### *3.1 Lion Rangers*

The Lion Rangers are conservancy employees, receiving specialized training and equipment to lead conservancy-level efforts in lion monitoring and limiting HLC. Based on successful CBNRM programs such the Conservancy Game Guards and Save the Rhino Trust trackers in Kunene,[34] and the Lion Guardians in Kenya and Tanzania,[35] the Lion Rangers are nominated by their conservancies to serve as custodians of lions on communal lands. As a CBNRM program, tasked with unifying conservation and rural development,[36] the Lion Rangers program aims at providing lion-centered benefits to conservancies while reducing the costs associated with HLC. This approach is based upon local historical experiences of living with lions[37] and contemporary perspectives of HLC.[38]

From its inception, the Lion Rangers program goal has been the long-term sustainable management of HLC in Kunene, centering the work of local conservationists, to ensure the survival of the desert-adapted lions as well as community benefit from their presence. Because Lion Rangers operate within communal conservancies, the program structure and objectives are founded upon the four conceptual pillars of CBNRM. Adapted from Jones and Murphree, these are:[39]

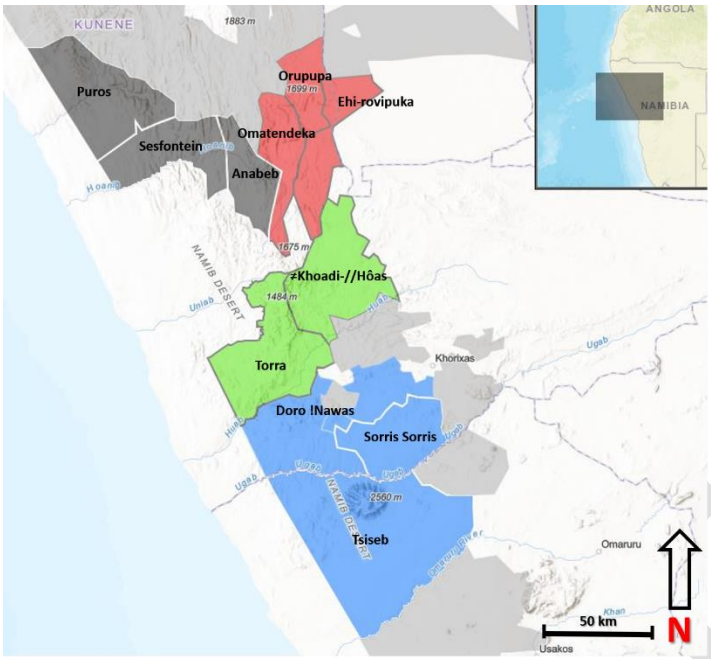
- *Sustainable use as conservation paradigm* – As the premier threat to natural habitats and resources, landscape transformation necessitates creating incentives for sustainable resource use, rather than technical interventions or compulsion to limit appropriation.

[33] GRN (2017)
[34] Hearn (2003); Owen-Smith (2010); Rhino Ranger Incentive Programme (2014); Muntifering et al. (2017)
[35] Lion Guardians (2023)
[36] Jones (2001)
[37] Heydinger (2021)
[38] Heydinger et al. (2019); Heydinger & Muzuma (in press)
[39] Jones & Murphree (2001)

Lion monitoring and conservation are linked to the possibility of conservancy residents potentially benefiting from lion presence.

- *Economic instrumentalism* – Economic considerations are seen to drive resource decisions. Resource provision and appropriation must be economically competitive or else landscape transformation may occur. This includes the creation of supporting structures and access to markets. By providing employment, the Lion Rangers program links lion presence to household level benefits and the local economy. Sustainable management of lions may lead to both consumptive (e.g. trophy hunting) and non-consumptive (e.g. tourism and Wildlife Credits) benefits.
- *Devolution* – Responsibility for resources is supported by the authority and entitlement necessary to generate stewardship. Local control enables rights to manage, benefit from, and dispose of resources. Empowered by their conservancy management and trained by program leadership and other experts, Lion Rangers participate in lion monitoring and HLC interventions and play an active role in decision-making relevant to lion management.
- *Collective proprietorship* – Communities of collective interest are the locus for rights-devolution. Internal legitimacy comes from communities whose membership, boundaries, and constitution are self-defined. External legitimacy comes from legislation. As community members and part of a broader set of stakeholders, Lion Rangers are responsible for representing their conservancy in lion monitoring and management operations.

Operating with government approval, Lion Rangers are the conduit between pastoralists, the conservancy, government, and NGOs concerning HLC. Most Lion Rangers are also pastoralists. They embody the experience of living with lions and are charged to faithfully represent the challenges surrounding HLC. Prior to the activation of the Lion Rangers there was limited monitoring of lions in many lion-range conservancies. The Lion Rangers are the first platform to demonstrate that communities can be trusted to sustainably manage ‘their’ lions. By merging the Lion Rangers’ field deployment with cutting-edge monitoring technologies already in use by area researchers, an emphasis is being placed on devolving responsibility to select community members, without sacrificing high-quality data collection for evidence-based lion conservation. This empowers local people with the responsibility of lion monitoring and conservation.




| CONSERVANCY | HUMAN POPULATION | AREA (KM²) |
|---|---|---|
| Anabeb | 1402 | 1570 |
| Puros | 641 | 3562 |
| Sesfontein | 1491 | 2465 |
| Ehi-rovipuka | 1846 | 1980 |
| Omatendeka | 1985 | 1619 |
| Orupupa | 2024 | 1234 |
| ǂKhoadi-‖Hôas | 4308 | 3364 |
| Torra | 1064 | 3493 |
| Doro !Nawas | 1242 | 3978 |
| Sorris Sorris | 950 | 2290 |
| Tsiseb | 2415 | 7913 |

Figure 18.2. Core lion-range conservancies, separated into Lion Blocks. The Black Block consists of Anabeb, Puros, and Sesfontein; the Red Block of Ehi-rovipuka, Omatendeka, and Orupupa; the Green Block of ǂKhoadi-‖Hoas and Torra; and the Blue Block of Doro !Nawas, Sorris Sorris, and Tsiseb. Each conservancy gazette number and year of formation is given.

In Kunene, core lion-range conservancies are grouped into "Lion Blocks" (Figure 18.2). Because lions move freely in this mostly unfenced landscape, it is logical for neighboring conservancies to partner for monitoring and managing lions. This approach seeks to overcome some of the existing shortfalls related to the conceptual pillars of CBNRM. By linking conservancies together, the justification for and effectiveness of collective proprietorship are strengthened; this supports devolution of decision-making to the Lion Block, if not the conservancy, level. Through a forthcoming Wildlife Credits projects,[40] which is paying Lion Block conservancies for lion presence.[41] Lion Blocks are also forging economic links between lion presence and lion conservation by providing community-level monetary benefits.

Within their Lion Blocks, Lion Rangers are deployed on joint-patrols, whereby conservancies pool their resource to get Lion Rangers into the field. Generally, Lion Rangers are deployed to field camps neighboring HLC hotspots, usually for 10-14 days per patrol shifts. Lion Rangers are responsible for performing foot- and vehicle-based patrols. These emphasize monitoring lion and other carnivore movements, as well as livestock movements around nearby farms. In the field Lion Rangers collect environmental data using the Spatial Monitoring and Reporting Tool (SMART) mobile app.[42] This enables environmental data collected by the Lion Rangers to be quickly exported (via either a cellular network or through Wi-Fi) for use by researchers

[40] Wildlife Credits (2023)
[41] Heydinger et al. (2022)
[42] SMART (2023)

and wildlife managers. Built upon the successful model of the Event Books System,[43] SMART limits the time between data collection and analysis, making the management of lions and other wildlife more responsive to changing circumstances on-the-ground. By putting the power of high-tech data collection and communication directly in the hands of the Lion Rangers, the SMART program enables Rangers to play a greater role in both monitoring and conservation of the desert-adapted lions. Because these data are digitized and up-to-date, high-quality maps of HLC and lion sightings are made readily available. As I will show below, these data are playing an important role in managing HLC. In **Chapter 19** Brassine provides an in-depth review of the use and usefulness of the SMART program for the Lion Rangers.

Figure 18.3. Lion Rangers Rinoveni Tjauira (Omatendeka), Matarakuani Kavetu (Ehi-rovipuka), and Richard Katira Zaako (Orupupa) on patrol in the "Red" Lion Block, 2022.

## 4) Names, collars and cameras

Within the text of the NW Lion Plan, the Namibian government affirmed the importance of collecting data on the spatial and temporal patterns of lion movements. These data are an important part of not only responding to and mitigating, but possibly preventing HLC incidents.

### *4.1 Names*

Limiting HLC starts with knowing which lions inhabit the area. Beginning in 1999, very-high frequency (VHF) collars were deployed by Stander on lions in Kunene, primarily for studying their movements and grouping patterns. Building on his experience in Etosha during the 1980s and 1990s, Stander also began giving lions in Kunene unique identifiers in the form of alpha-numeric names. Whereas the convention in western Etosha had been to name lions WPL-# ('W' for western Etosha, 'PL' for *Panthera leo*, plus a unique number to identify the individual), in Kunene, individual lions were named according to an XPL-# system ('X' for the Xhorixas district where the study was taking place).[44]

[43] Stuart-Hill et al. (2005)

[44] Stander (2018)

Naming individuals, in this case nonhumans, is itself a monitoring and governance technology. Individually identifying lions by name, though not unique at the time, was important, both for building a coherent picture of lion movements and grouping patterns, and for creating a discourse in which lions became increasing known, knowable, and, potentially, manageable.[45] Much as the process of mapping a landscape, including the creation of boundaries and assigning names to certain features, increases humans' ability to govern and manage that landscape, naming individual lions reinforces researchers, government staff, and the Lion Rangers' ability to speak with specificity about different lions, in turn enabling us to tailor monitoring and management to lions as individuals. Human-animal historian Etienne Benson has shown that naming research animals is not only useful for differentiating among them, but is also associated with a variety of moral commitments from the researcher towards the subject.[46] Heydinger has incorporated this understanding into the history of human-lion relationships within Etosha.[47] Among park staff and tourist visitors to Etosha during 1950s and 1960s, lions became conceptually transformed from fearsome pests into cosseted individuals who were individually known and in certain cases provisioned with carcasses during drought and to provide tourist viewing opportunities.

Naming lions in Kunene is indicative of an increased concern for their wellbeing among conservation elites. Beginning with XPL-1 and XPL-2 in 1999, to date more than 140 lions in Kunene have received unique alpha-numeric identifiers. To the roster of XPL-# lions have been added OPL-#, for lions inhabiting the greater Ombonde catchment landscape, and NPL-#, for lions monitored by the Namibian Lion Trust (NLT 2023), a local NGO which is also part of the Lion Rangers program. Coinciding with the work of Stander and his NGO Desert Lion Conservation Trust,[48] the first two decades of the twenty-first century brought increasing attention to the desert-adapted lions, in the form of research reports and publications, semi-popular articles in conservation magazines, and full-length documentaries focusing on the lives and survival prospects of certain lions.[49]

### *4.2 Collars*

Iterative of Cold War-era technologies developed primarily for military purposes, VHF and later GPS/satellite collaring of elusive, wide-ranging wild animals has been an important part of population biology since the 1960s. Benson provides a thorough and insightful examination of this history.[50] From the 1960s, lions were being collared on a small scale in East Africa.[51] Beginning in 1984, Craig Packer and his team of researchers began fitting VHF collars to lions in Serengeti. Over the next 30 years they collared more than 300 lions, with 18-24 lions collared

[45] Scott (1998)
[46] Benson (2016)
[47] Heydinger (2021)
[48] DLCT (2023)
[49] Vanishing Kings (2015)
[50] Benson (2010)
[51] Schaller (1972)

at any one time.[52] This research revealed ground-breaking insights into lion movement patterns and spatial ecology. By the time Stander began working in Kunene, collaring of lions and other similarly elusive and wide-ranging large carnivores was commonplace elsewhere.

Collars enable lions to be monitored remotely. While VHF frequencies are still used, GPS/satellite collars are now available at relatively affordable prices. These have become central to lion research, monitoring, and HLC prevention in Kunene. Once fitted to an individual through a standard process of chemically-induced immobilization under the supervision of a licensed veterinarian or para-vet,[53] GPS/satellite collars begin transmitting location fixes, first to a satellite array, which relays the location fix to a secure online interface. (Elsewhere collars have additional technologies for collecting other data such as respiration and heart rate – these have not been used to-date in Kunene.) Collars can be programmed to transmit location fixes at different intervals. Currently lion collars in Kunene transmit location fixes every four hours during the day, and every two hours at night; these intervals can be reprogrammed, for example when a lion enters a known HLC area. Collars enable researchers and government staff to monitor collar locations online and communicate movements to Lion Rangers and other staff on-the-ground. These collars are also part of an "early-warning system." When lions cross a geofence boundary, automated messages in the form of SMSs, go out to area Lion Rangers and farmers alerting them to lions' presence within the area. As of January 2023, there are 35 active GPS/satellite collars fitted to lions in Kunene. This represents approximately 65% of adult lions which, as a percentage of the total population, is the highest for a free-ranging lion population in Africa.

Collar data provide a dynamic picture of lion movements across Kunene. Not only can current movements be tracked, but as the number of location fixes grows, these locations can be compared to a lion's historical movements. Over time, a home range for each lion becomes visible. Figure 18.4 is a visualization of the movements of the lioness OPL-4. Collared on 22 May 2021, over the ensuing 16 months, she maintained a home range of approximately 1,140 $km^2$, centered around the Otjiapa-Okavariona-Otjejekupe waterhole complex in the Omatendeka conservancy. Given that the core of her home-range is far from established farms, and largely contained within a mountainous area, this lioness is normally not considered at high-risk of HLC. However, during March 2021, one can see that OPL-4 did move as far northwest as the mountains south of the Mbakondja farming area in Anabeb (furthest northwest points) – perhaps in search of prey that had dispersed during the rainy season. This was an aberration compared to her regular movements. When such lions venture beyond the core of their home ranges, potentially into areas they are less familiar with, researchers and the Lion Rangers will pay extra attention to incoming collar data, with the goal of preventing HLC before it occurs.

[52] Packer (pers. comm.)
[53] Stander & Morkel (1991); Kock & Burroughs (2012); Donaldson et al. (2023)

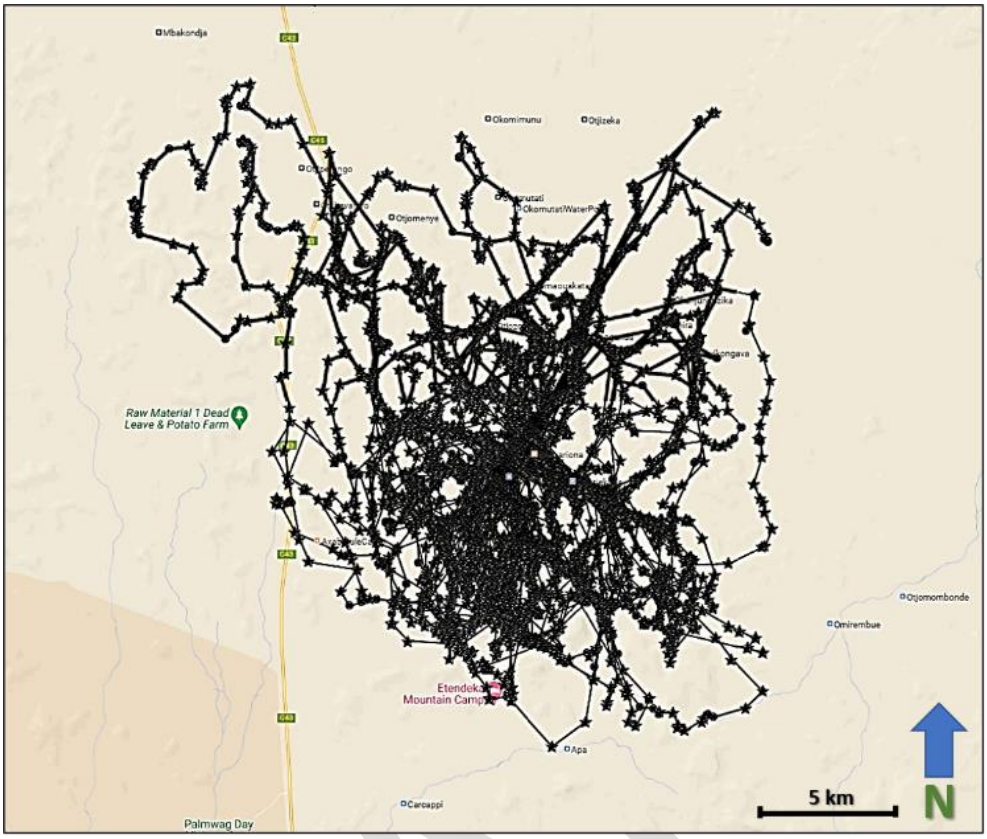



Figure 18.4. Visualized GPS/satellite collar locations of OPL-4 in the Anabeb and Omatendeka conservancies, from 22/5/21 to 27/9/22.

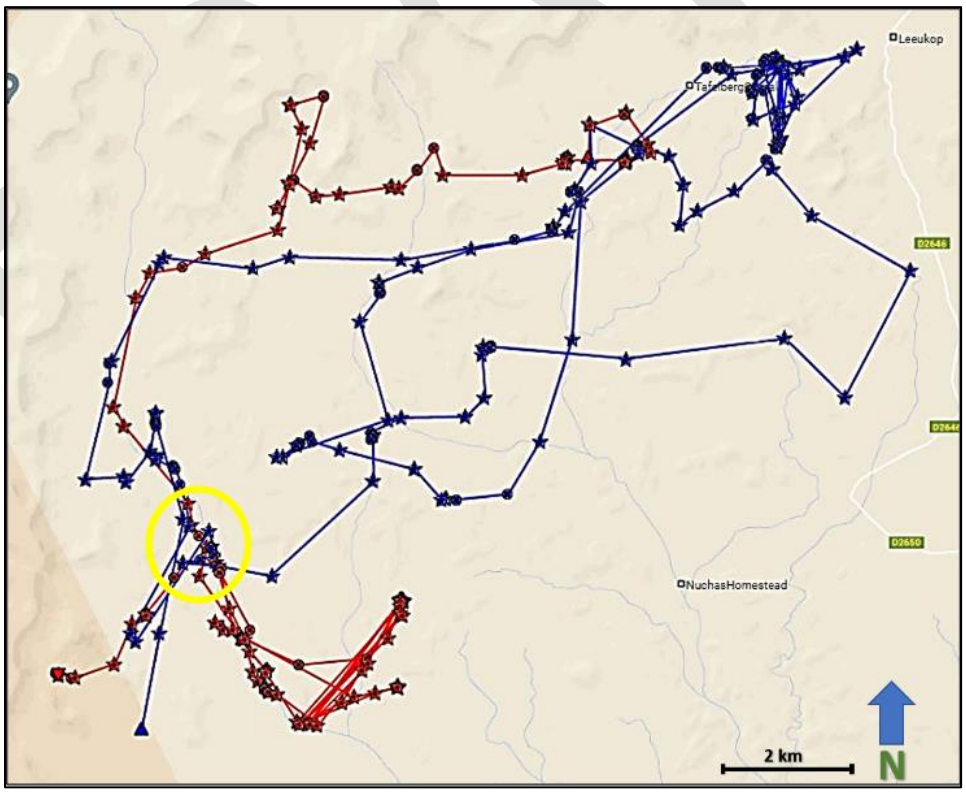



Figure 18.5. Visualized GPS/satellite collar locations of OPL-3 and NPL-28 in ǂKhoadi-ǁHoas Conservancy, from 23/12/22 to 16/1/23. Yellow circle indicates the area enlarge in Figure 6.

When collared lion movements are viewed in relation to one another, new insights into lion sociality emerge. It is generally understood that male lions will defend their territory against other males. How these interactions occur at the landscape level can be visualized through available collar data. Figure 18.5 shows the movements of two males, OPL-3 (red fixes) and NPL-28 (blue fixes) over a 25-day period from December 2022 to January 2023 in the Klip River/Tafelberg area of ǂKhoadi-ǁHoas Conservancy. Looking across the 25 days it may seem these two lions are sharing this approximately 800 km$^2$ landscape.

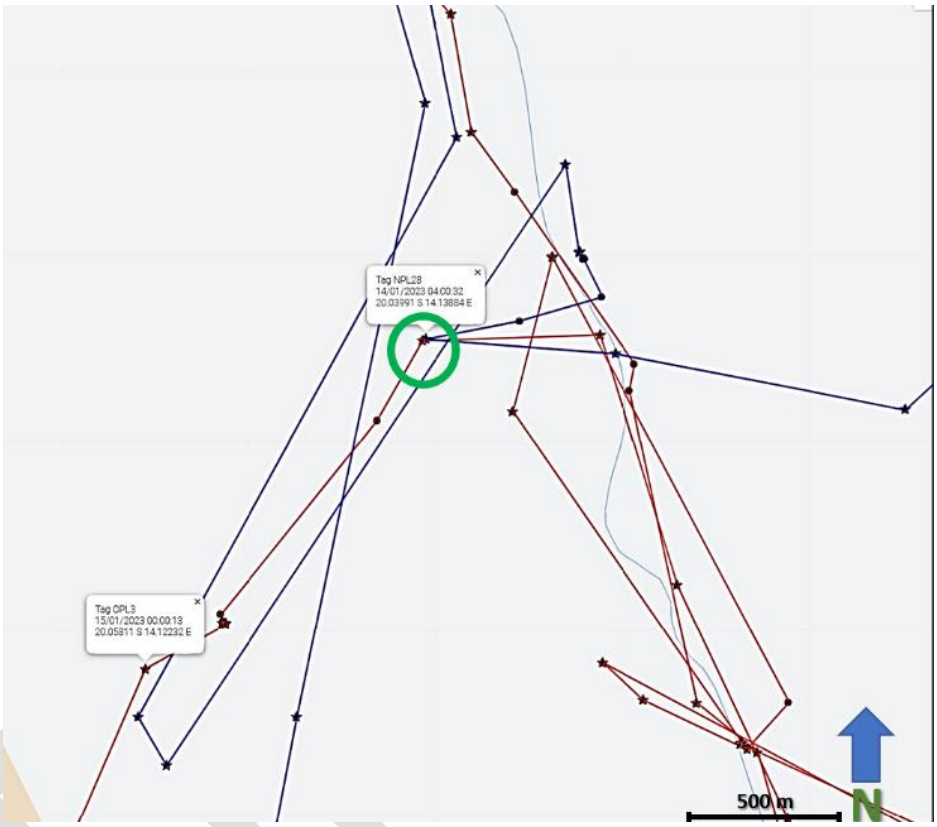



Figure 18.6. Visualized GPS/satellite collar locations of OPL-3 and NPL-27 in ǂKhoadi-ǁHoas Conservancy, from 23/12/22 to 16/1/23. Area enlarged to emphasize movements from 14-16 January. Green circle indicates likely conflict event.

Zooming into specific GPS points, however, reveals interaction dynamics (Figure 18.6). At approximately 0400 on the night of 14 January 2023 [green-circled fixes], OPL-3 and NPL-28 came into close contact about 500 meters west of the Klip riverbed. An apparent altercation resulted in OPL-3 moving further southwest, while NPL-28 briefly returned towards the core of his territory. Less than 24 hours later, NPL-28 appears to have pursued OPL-3, pushing him further southwest while NPL-28 once again returned towards the core of his territory. During the next week, OPL-3 traveled nearly 50 kms north out of the area, while NPL-28 returned to the core of his territory to the northeast. It is noteworthy that while OPL-3 is estimated at between 5-6 years old and 140 kgs, and has struggled to maintain a consistent home range, NPL-28 is estimated at between 7-8 years old and 180 kgs, and has been residing in the area since at least October 2022, when he was collared. From this interaction, combined with demographic and physiological data as well as historical collar data from these two lions, and

an absence of other known males in the area, we can infer that while NPL-28 maintains a relatively stable territory in the Klip River/Tafelberg landscape – one that he will defend against potential competitors – OPL-3 does not enjoy similar territorial dominance. Indeed, the recorded home range of each lion since NPL-28 was collared on 10 October 2022 further reveals aspects of each lions' spatial ecology. While NPL-28 has occupied a range of approximately 900 km$^2$ during this period, OPL-3 has covered an area spanning more than 3,200 km$^2$ during that same time. This further reveals the social and spatial dynamics at work among lions. OPL-3 is considered a nomad in search of a stable territory. His wanderings frequently bring him near to farming areas, increasing the likelihood of HLC. His movements are therefore closely monitored by the Lion Rangers. By comparison, NPL-28 is still considered a relatively low HLC risk because he inhabits an area with no currently established farms or livestock outposts.

Figure 18.7 shows the movements of nine collared male lions over only a two-week period in January 2023. This indicates the challenge of monitoring and limiting HLC, even over this approximately 7,600 km$^2$ portion of the landscape. Though these males generally maintain distinct territories, these can overlap, increasing the prospect of HLC at nearby farms. As more lion collar data become available, researchers and Lion Rangers have more information for limiting HLC.

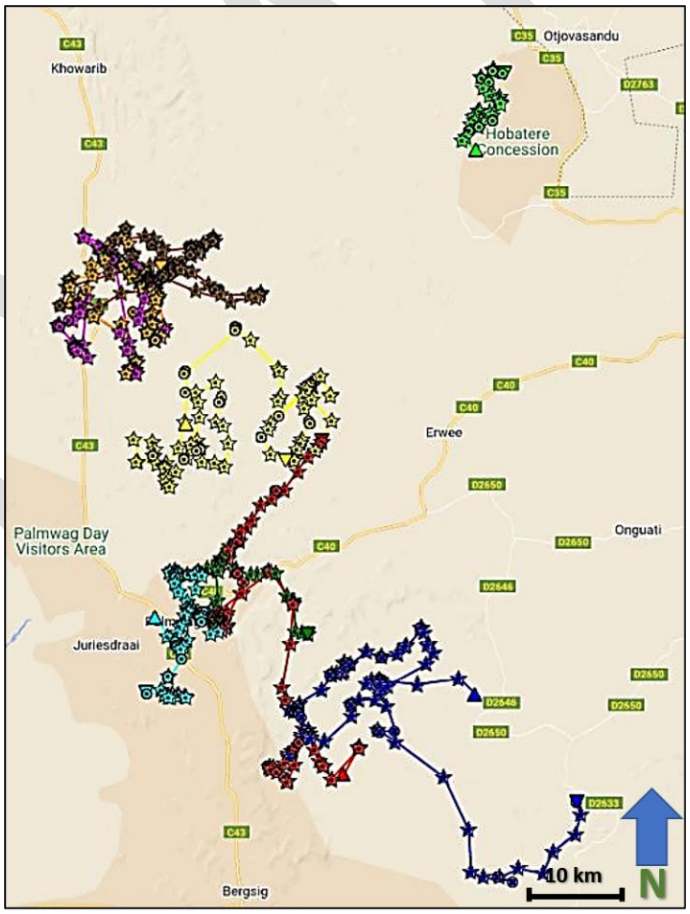



Figure 187 Visualized GPS/satellite collar locations of nine male lions across Kunene, from 10-24/1/2023. Approximate size of areas is 7,600 km$^2$.

### *4.3 Camera traps*

Motion-activated cameras taking high-quality pictures (camera traps) enable researchers and Lion Rangers to intensively monitor key areas where lions are likely present. First developed as a method of estimating tiger population size by Karanth and Nichols, camera traps are an increasingly popular tool for monitoring and estimating the abundance of large-bodied species when individuals are identifiable.[54] Large terrestrial carnivores generally demonstrate secretive behavior and nocturnal habits, existing at low densities while having broad spatial requirements that may cross physical, administrative, and political boundaries.[55] This combination of factors presents challenges to intensive monitoring. Camera traps allow for passive collection of presence and abundance data as well as identification of individuals within key areas. When repeated over time, camera traps have been shown to be a useful method for achieving both precise and accurate population estimates for large carnivores.[56] Other non-invasive approaches such as track counts have been shown to be less accurate[57] and may even be too imprecise for implementing effective management.[58] The predominantly rocky substrates of Kunene also make tracking of lions difficult, and in many areas make it near impossible to use tracks as a measure of abundance.

Beginning in May 2021, we deployed camera trap arrays around key waterpoints and lion movement corridors, centered around the Ombonde river landscape in Anabeb, Omatendeka, and Ehi-rovipuka conservancies and Etendeka and Hobatere tourism concessions (Table 18.1). Using a 'camera blitz' approach[59] we sought to record lion presence where possible with the intended result of collaring key individuals, such as males and pride females. Secondary objectives were to assess presence of other large carnivores in the landscape, as well as landscape-use overlap among large carnivores. Key individuals were then targeted for collaring primarily based on HLC considerations, with research data considered a useful by-product.

We used Panthera V7 camera traps[60] for all photographic 'captures.' Camera placement emphasized capturing images of lions, other large carnivores, and prey species along known movement corridors, primarily between or surrounding natural springs. Target areas were identified based upon local knowledge of lion movements, coming either from the Lion Rangers or local tourism operators. Cameras were generally mounted on trees or rocky outcrops, between 80-200 cm high, 2-3 meters from game trails or 4x4 tracks, and were positioned to record images at approximately the flank height of an adult lion (70-90 cm high). Specific camera placement along trails and near waterpoints was based on reading tracks and expert assessment of wildlife movement by the Lion Rangers and researchers. Camera deployment prioritized capturing as many images of lions and other large carnivores as possible. Therefore, cameras were not uniformly distributed in target areas. During our first

[54] Karanth & Nichols (1998)
[55] Williams (2021)
[56] Portas et al. (2022); Williams et al. (2021); Balme et al. (2009)
[57] Balme et al. (2009)
[58] Droge et al. (2020); Belant et al. (2019)
[59] Balme et al. (2009)
[60] Panthera (2023)

three deployments (Etendeka, Omatendeka 1, and Omatendeka 2) cameras were checked after approximately 2-3 weeks and batteries were changed where they registered below 50% remaining. In all other areas cameras were deployed and remained in the field until it was likely that batteries had completely discharged (approximately 3-5 weeks). Each photographic capture of lions, other large carnivores, and prey species, was categorized according to date, time, and location. Forthcoming publications are examining likelihood of photographic capture for lions and other large carnivores given different site covariates.

| Deployment | Location Details | Capture Period | # Cameras | Effort (trap-days) | Target Species Images | Lion Images |
|---|---|---|---|---|---|---|
| Etendeka | Etendeka Concession: Upper Uniab Corridor | May 21 - July 21 | 42 | 1633 | 1045 | 150 |
| Omatendeka 1 | Omatendeka Conservancy: Otjiapa-Okavariona-Otjejekupe Waterhole Complex | Oct. 21 - Dec. 21 | 80 | 4085 | 14949 | 365 |
| Omatendeka 2 | Omatendeka Conservancy: Otjomombonde-Omirembue Waterholes Corridor | Dec. 21 - Mar. 22 | 81 | 4203 | 23611 | 12 |
| Hobatere | Hobatere Concession: Treehouse Waterhole Area | July 22 - Sept. 22 | 76 | 1498 | 4132 | 64 |
| Anabeb-Palmwag | Anabeb: Waterholes south of Mbakondja; Palmwag: Okamakuara Waterhole area | Jan. 2023 | 68 | 1378 | 3405 | 100 |

Table 18.1 of camera trap deployments since May 2021. 'Capture period' indicates the dates which camera arrays were deployed;' # of cameras' is the number of individual camera traps deployed and retrieved for each area; 'effort (trap-nights)' is the sum total number of days cameras were deployed at any area (# of cameras x # of days); 'target species images' is the total number of all images of large-bodied mammals photographed during deployment period; 'lion images' is the number of captures containing lions.

Scrutiny of camera trap images allows us to identify lion presence and individuals for collaring operations. While lions have been shown to have near-unique vibrissae (whisker spot) patterns,[61] these are rarely visible on camera trap images. However, given the low overall

[61] Pennycuick & Rudnai (1970)

population (56-60 individuals) and extremely low density (0.2 lions/100km$^2$),[62] time and location of each photographic capture, along with demographic markers such as sex and age, as well as diagnostic markings such as ear tears, scars, and whether or not the lion is collared, enable us to differentiate among individuals with a high degree of confidence; this may contribute to lion abundance and density estimates going forward. Figure 18.8 shows photos of three collared adult females (OPL-4, OPL-5, and OPL-15) one collared adult male (NPL-27), two uncollared subadult males, and one uncollared adult female.

Figure 18.8 Selection of camera trap images from Omatendeka 1 deployment Oct.-Dec. 2021, showing the type of quality of lion photos from camera traps.

Camera trap data are enabling researchers and Lion Rangers to make more informed decisions regarding lion monitoring and HLC interventions. Below, I present a brief case study of how collars, camera trap images, and the Lion Rangers' field monitoring combined to limit HLC, resulting in the translocation of the lion NPL-27 away from a HLC area.

[62] Heydinger & Muzuma (unpublished data)

## 5) Case study: translocation NPL-27

Combined with the field expertise of the Lion Rangers, lion collar and camera trap data provide an increasingly comprehensive picture of lion movements within Kunene communal areas. The case of NPL-27, an adult male lion estimated at 7-8 years of age, vividly illustrates how these data can be combined to increase the effectiveness of HLC management.

Figure 18.9. Camera trap photo of NPL-27 taken near Okavariona waterhole, 13/11/21.

NPL-27 was first collared by the Namibian Lion Trust on 30 August 2020 in Omatendeka Conservancy. From then until 1 May 2022, he maintained a relatively stable home range of approximately 850 $km^2$, with most of his time spent along a river corridor northeast of the Otjiapa-Okavariona-Otjejekupe waterhole complex. Numerous photos and videos taken by researchers during this period show him enjoying dominance in the area, including fathering at least two litters of cubs.

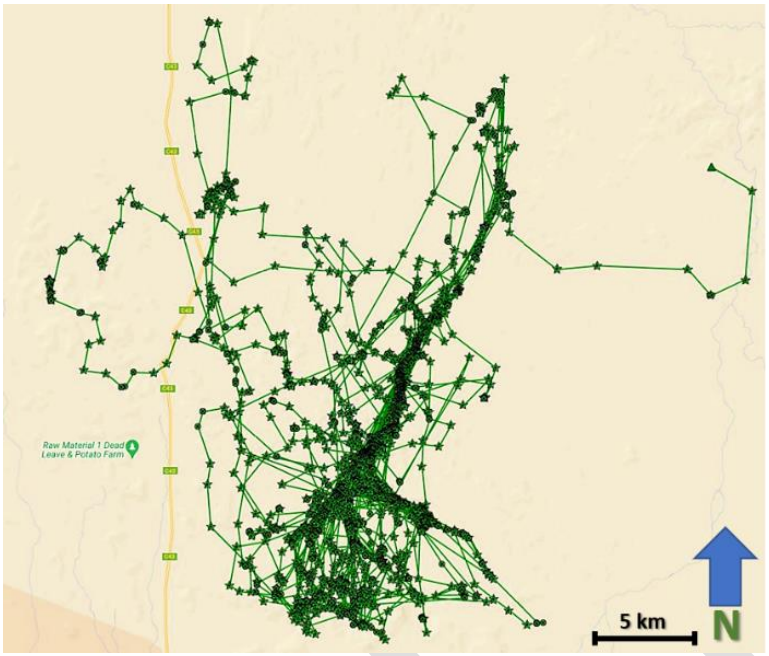



Figure 18.10. Visualized GPS-satellite collar data illustrating NPL-27 home range in Anabeb and Omatendeka conservancies from 30/8/2019-1/5/2022.

From 14 October – 15 December 2021, the Lion Rangers research team deployed 80 trail cameras within the waterhole complex area. During this period, equivalent to 4,085 "camera trap-days," 365 images of lions were captured. NPL-27 appears in 90 of these images. Only one other adult male was captured during this period, in three photos from 14 October. Additionally, NPL-27 was frequently captured in photos with area females, who showed signs of pregnancy during this time. These images supported our conclusion that NPL-27 was effectively maintaining a territory in the area, from which he was largely excluding other males.

Abruptly in May 2022, NPL-27's movements changed dramatically. Between 2 May and 13 June 2022, he covered an area encompassing more than 1,000 $km^2$. An area distinctly different from his previous range (Figure 12). During this period, NPL-27 was responsible for three separate HLC incidents, during which he killed three donkeys in Omatendeka and two cattle in ǂKhoadi-ǁHoas conservancies. His movements also brought him into the ǂKhoadi-ǁHoas farming area, where HLC incidents have previously resulted in numerous retaliatory killings of lions by farmers. Following these incidents, the decision was taken by MEFT and the conservancies to have NPL-27 translocated from the ǂKhoadi-ǁHoas farming area and hopefully away from further HLC trouble.

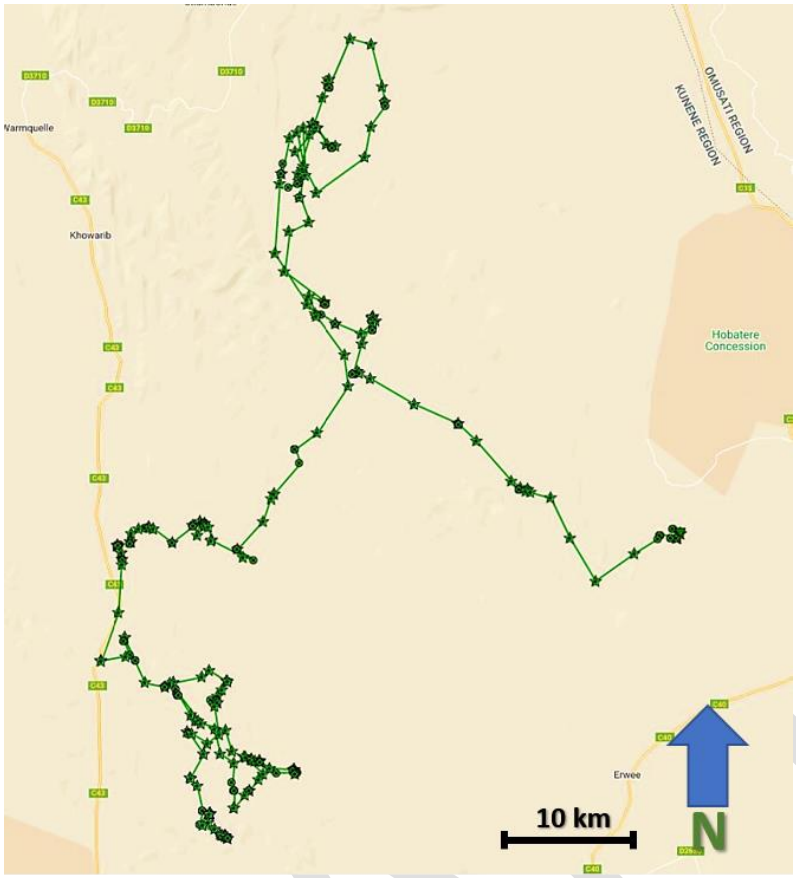



Figure 18.11. Visualized GPS-satellite collar data illustrating NPL-27 movements in Anabeb, Omatendeka, Ehirovipuka, and ǂKhoadi-ǁHoas conservancies, from 2/5/2022-13/10/2022.

Figure 18.12. Cow killed by NPL-27 in ǂKhoadi-ǁHoas farming area, 13 June 2022.

Normally this translocation would have emphasized returning NPL-27 to his previous home-range. However, his sudden departure raised questions as to whether the Otjiapa-Okavariona-Otjejekupe area remained a suitable destination. Neither rainfall data nor movements of other collared females in the area provided insight as to the cause of NPL-27's seemingly sudden decision to leave the area. If NPL-27 would not re-settle here, it was considered likely that he would continue to be a source HLC.

A first clue as to NPL-27's departure came from the collar data of two other males, who had recently moved their ranges further west, into the Otjiapa-Okavariona-Otjejekupe area. OPL-8 was first collared by MEFT and the Lion Rangers in the Hobatere Tourism Concession on 6 October 2021 along with his likely brother OPL-7: both were estimated between 4.5-5 years old at the time. Collar data from OPL-8 and OPL-7 indicated the two were closely bonded, rarely spending more than a day or two apart. From October 2021 until late April 2022, these two lions primarily resided within the Hobatere Tourism Concession – some 60 kms from the Otjiapa-Okavariona-Otjejekupe area and separated by a rugged mountainous area. Perhaps in search of mating opportunities, in May 2022 OPL-8, and likely OPL-7 (whose collar had ceased to function), departed Hobatere, making their way south and west. These two males, moving into their prime years, would have been imposing adversaries for other male lions. Further data came from the Lion Rangers' SMART patrols. These showed that, simultaneously, another male, OPL-3, spotted by the Lion Rangers on numerous occasions, was moving into the area just south of Otjiapa-Okavariona-Otjejekupe. Although he was without a functioning collar at the time, OPL-3 was monitored by Rangers in the area, leading to him being collared in partnership with Desert Lion Conservation Trust on 2 June 2022.

Figure 18.13. Male lions OPL-7 and OPL-8 shown resting south of Otjiapa-Okavariona-Otjejekupe area, December 2022.

On the night of 28 May 2022, NPL-27 came into close contact with OPL-8 (and likely OPL-7) north of Otjiapa-Okavariona-Otjejekupe. Whether a direct altercation took place is unknown, however, NPL-27 and OPL-8's collars recorded locations less than 200 meters from each other at both 0600 and 0800. The result of this close encounter was NPL-27 being pushed further north, more than 40 kms in the next three days, to an area he was not previously recorded in. By comparison, in the following two weeks OPL-8 resided in the area where the conflict took place, eventually settling into a home-range centered around Otjiapa-Okavariona-Otjejekupe, which he and OPL-7 have maintained as of this writing. These two males have also taken over the pride privileges of the females OPL-4, OPL-5, and OPL-15, who previously moved primarily with NPL-27.

The conflict leading to NPL-27's departure, visible through available collar data, in combination with Lion Rangers' ongoing work and SMART reports tracking available prey and lion movements, made the Otjiapa-Okavariona-Otjejekupe area a poor prospect for successfully translocating NPL-27. It was considered highly likely that NPL-27 would either be quickly chased out of the area, or killed in conflict with the other males.

Camera trap data suggested a viable alternative. From December 2021 to March 2022, the Lion Rangers research team deployed 81 camera traps to the Otjomombonde-Omirembue waterholes area in Omatendeka Conservancy. This mountainous and hard-to-reach area east of Otjiapa-Okavariona-Otjejekupe is considered something of a refuge for wildlife away from farming areas. Most crucially, trail camera images indicated minimal presence of lions. During the recent camera deployment, covering 4,203 "trap nights," of more than 23,000 images containing carnivore or prey species, only 12 images contained lions (by comparison 72 images contained spotted hyena (*Crocuta crocuta*) and 162 contained brown hyena (*Hyaena brunnea*)). Five of these captures showed a male lion, known as NPL-33. Although considered to be resident within the Otjomombonde-Omirembue area, when the translocation of NPL-27 was being considered, NPL-33 was approximately 15 km to the north. Trail camera images also showed ample numbers of mountain zebra (*Equus zebra*), giraffe (*Giraffa camelopardalis*), (springbok (*Antidorcas marsupialis*), and even black-faced impala (*Aepyceros melampus petersi*) in the area. Ongoing Lion Ranger work in the area indicated prey species were still inhabiting the area.


Figure 18.14. Visualized GPS/satellite collar data of NPL-27 translocation from ǂKhoadi-ǁHoas farming (top right) to Otjomombonde-Omirembue waterholes area (bottom left), 16-21 June 2022.

Relying on the combination of collar data, trail camera images, and Lion Ranger reports around NPL-27's former range of Otjiapa-Okavariona-Otjejekupe, as well as surrounding Otjomombonde-Omirembue, the decision was taken by MEFT translocate NPL-27 to Otjomombonde-Omirembue. During the early morning hours of 17 June 2022, NPL-27 was successfully immobilized and translocated from the ǂKhoadi-ǁHoas farming area. An approximately 30-hour operation was completed when NPL-27 was revived near the Omirembue waterhole. Follow-up monitoring by the Lion Rangers and via collar data indicated that he resided in the area through the end of the month, making no attempt to return to either Otjiapa-Okavariona-Otjejekupe or the farming areas where he previously caused conflict.

Figure 18.15. Lion Rangers, MEFT staff, and NPL-27 during translocation operation, 17 June 2022.

***Translocation postscript***

Leading lion researchers are divided on the effectiveness of translocation.[63] Translocated lions tend to return to their points of departure, sometimes with surprising speed, as our team has seen on numerous occasions. When it is used, translocation may simply be the best available option. Though NPL-27 would later be removed for encroaching on a separate farming area further south, the work of the Lion Rangers and researchers, under the supervision of MEFT, minimized remaining conflict and contributed to NPL-27 not being destroyed.

Because NPL-27 did not return to his previous range, risking near-certain conflict with OPL-8 and OPL-7, nor did he return to the ǂKhoadi-ǁHoas farming area, his translocation is considered a qualified success. In such a massive, unfenced landscape, there is no guarantee that lions will not encroach on human settlements. Rather the combination of remote sensing data and on-the-ground work of the Lion Rangers contributed to the conclusion that NPL-27 was failing to maintain a territory sufficiently distant from farming areas. He was now considered a "problem-causing" lion in need of removal. As it became apparent that other alternatives had been exhausted, NPL-27's movements were monitored closely, leaving sufficient time to plan and execute a follow-up operation whereby NPL-27 was safely removed from the area. As of this writing he survives in his new location.

## Conclusion

The combination of the Lion Rangers work and remote sensing data is pushing forward the prospect of lion monitoring and conservation based upon CBNRM principles in Kunene. The monitoring and translocation of NPL-27 provide a series of important insights for integrating technological and community-based approaches.

First, Kunene communal conservancies are farming areas. While conservancies have been gazetted to provide limited rights to wildlife for conservancy residents; potentially dangerous animals such as lions cannot too greatly negatively affect human lives and livelihoods. When

[63] ALWG (African Lion Working Group) pers. comms. (2022)

this occurs action must be taken to secure human wellbeing, but also to ensure continued support among conservancy residents for wildlife conservation. In the case of NPL-27, once he became a problem-causing lion it was necessary for him to be removed away from causing possible HLC, to ensure human wellbeing and continued support of lion conservation in the area. Through the work of the Lion Rangers, the conservancies took an active leadership role in monitoring the movements of NPL-27, limiting further HLC, and undertaking his translocation. These operations were performed in partnership with the local communities.

Second, the emphasis on remote sensing should not minimize the foundation of CBNRM upon which these specialized techniques become meaningfully operational in limiting HLC. The translocation of NPL-27 was able to take place because of the work of the Lion Rangers in monitoring wildlife, responding to and recording HLC, working with conservancy members to gauge their reactions, and providing on-the-ground information to researchers and government managers to make informed decisions. Remote sensing technologies can help researchers and Lion Rangers understand which lions are moving in which areas. But they cannot anticipate the likely effects of these movements, collect data on the human and more-than-human effects of these movements, nor forecast the response of locals. The interpretive element rests with researchers and the Lion Rangers, to not only monitor and understand lion spatial ecology, but to be able to react to HLC and potentially prevent conflict before it occurs. By providing more information to communities through remote sensing technologies, the Lion Rangers research team is helping grow the capacity of locals managing HLC. Accordingly, by working with the Lion Rangers, researchers are better able to contextualize how certain types of data collection and analysis can support CBNRM. Much has been and will continue to be written about the challenges and successes of CBNRM in Kunene (e.g. Sullivan 2003; Hoole 2008; Bollig 2020). The usefulness of lion collars, camera traps, and certainly the SMART program, rely on community tolerance of living with lions as well as local conservationists' monitoring of the landscape for potential drivers of HLC, such as changing rainfall patterns, encroachment on farming areas by uncollared lion and other large carnivores, and prey and livestock movements. In **Chapter 20** of this volume Muzuma explores another side of HLC: livestock movements across the landscape and how these can also drive HLC. Gaining as comprehensive a picture as practicable of the variables contributing to HLC refines the ability of the MEFT, the Lion Rangers, and researchers, to mitigate, manage, and even minimize HLC. This reinforces livelihoods as well as the survival of the desert-adapted lions.

As noted by Garth Owen-Smith and Margaret Jacobsohn, who helped found Namibia's communal conservancy movement, CBNRM must be a bottom-up approach in which process is also product (Owen-Smith 2010; Jacobsohn 2019). Caution should be the operative word when incorporating new technologies into community conservation. Remote sensing technologies such as lion collars and camera traps risk distancing the viewer from the real-life consequences of living with lions. As technological theorist and human-animal studies scholar Donna Haraway has noted, "situated knowledges," those that are specifically relevant and forged by their time and place, are particularly powerful because they recognize the connectivity between actors, factors, and forces in each time and place (Haraway 1990). Remote sensing techniques should not replace, but augment, existing expertise of those living

alongside lions. We have experienced numerous instances where lion collars have failed or been damaged, or trail cameras have malfunctioned, or even disappeared. People, and their knowledge of the landscapes they inhabit, are far more durable. Desert-adapted lion conservation will continue to rely primarily on the willingness of conservancy residents to live alongside lions. The techniques outlined here merely support CBNRM of lions.

## References

(ALWG) African Lion Working Group, 2022. https://www.africanliongroup.org/ Accessed 7 February 2023.

Balme, G.A., Hunter, L.T.B. & Slotow, R., 2009. Evaluating Methods for Counting Cryptic Carnivores. *J. Wildl. Manage.* 73: 433–41. https://doi.org/10.2193/2007-368

Belant, J.L., Bled, F., Mkasanga, I.J., Wilton, C.M., Mwampeta, S.B., Beyer, D.E., Mwakilema, W., & Fyumagwa, R. 2019. Track surveys do not provide accurate or precise lion density estimates in serengeti. *Glob. Ecol. Conserv.* 19, e00651.

Benson, E., 2010. *Wired Wilderness: Technologies of Tracking and the Making of Modern Wildlife*. Johns Hopkins University Press, Baltimore. https://doi.org/10.1353/tech.2012.0028

Benson, E., 2016. Naming the Ethological Subject. *Sci. Context* 29: 107–28.

Bollig, M., 2016. Towards an Arid Eden? Boundary-making, Governance and Benefit Sharing and the Political Ecology of the New Commons of Kunene Region, Northern Namibia. *Int. J. Commons* 10: 771–799.

Bollig, M., 2020. *Shaping the African Savannah: From Capitalist Frontier to Arid Eden in Namibia.* Cambridge: Cambridge University Press.

(DLCT) Desert Lion Conservation Trust, 2023. https://www.desertlion.info/ Accessed: 7 February 2023.

Donaldson, A.C., Carl, L., Meyer, R., Fuller, A. & Buss, P.E. 2023. Comparison of the Cardiovascular Effects of Immobilization with Three Different Drug Combinations in Free-ranging African Lions. *Conserv. Physiology* 11: 1–11. https://doi.org/10.1093/conphys/coac077

Dressler, W., Busher, B., Schoon, M., Brockington, D., Haynes, T., Kull, C.A., McCarthy, J. & Shrestha, K. 2010. From Hope to Crisis and Back Again? A Critical History of the Global CBNRM Narrative. *Environ. Conserv.* 37: 5–15.

Dröge, E., Creel, S., Becker, M.S., Loveridge, A.J., Sousa, L.L. & Macdonald, D.W. 2020. Assessing the Performance of Index Calibration Survey Methods to Monitor Populations of Wide-ranging Low-density Carnivores. *Ecol. Evol.* 1–17. https://doi.org/10.1002/ece3.6065

(GRN) Namibia Ministry of Environment and Tourism, 2017. *Human-Lion Conflict Management Plan for North West Namibia*. Windhoek, Namibia.

Haraway, D.J., 1990. *Simians, Cyborgs, and Women: the Reinvention of Nature*. New York and London: Routledge.

Hearn, M. 2003. *Assessment of Biological and Human Factors Limiting the West Kunene Rhino Population*. Report for the SADC Regional Programme for Rhino Conservation.

Heydinger, J., 2021. Human-Lion Conflict and the Reproduction of White Supremacy in Northwest Namibia. *Afr. Stud. Rev.* 64: 909–37. https://doi.org/10.1017/asr.2021.72

Heydinger, J., Muzuma, U. 2023. Report on the Population Survey of the Free-ranging Lions of Northwest Namibia, with Results and Recommendations, 2022. Namibia Ministry of Environment, Forestry and Tourism. Windhoek, Namibia.

Heydinger, J., Diggle, R., Stuart-Hill, G., Dierkes, K. & Packer, C. 2022. Differentiated Payments for Ecosystem Services Based on Estimated Prey Consumption by Lions Within Communal Conservancies in Northwest Namibia. *Ecosyst. Serv.* 53: 101403. https://doi.org/10.1016/j.ecoser.2021.101403

Heydinger J., Muzuma U. & Tsaneb J. in press. CBNRM and the Desert-Adapted Lion: Centering Local Perspectives to Limit Human-Lion Conflict. In Anderson D. & Bollig M. eds. *Conservation in East and Southern Africa: People, Policy, Practice*. Cambridge University Press. URL: http://lionrangers.org/wp-content/uploads/2022/09/HeydingerMuzumaTsaneb_CBNRMandDesertAdaptedLions.pdf

Heydinger, J., Packer, C. & Tsaneb, J., 2019. Desert-adapted Lions on Communal Land: Surveying the Costs Incurred by, and Perspectives of, Communal-area Livestock Owners in Northwest Namibia. *Biol. Conserv.* 236: 496–504.

Hoole, A., 2008. *Community-Based Conservation and Protected Areas in Namibia: Social-Ecological Linkages for Biodiversity*. Unpublished PhD Thesis, University of Manitoba.

Jacobsohn, M., 2019. *Life is Like a Kudu Horn*. Cape Town: Jacana.

Jones, B.T.B., 2001. The Evolution of a Community-based Approach to Wildlife Management at Kunene, Namibia. In Hulme, D. & Murphree, M.W. eds. *African Wildlife & Livelihoods: The Promise and Performance of Community Conservation*. Oxford: James Currey, 160–76.

Jones, B.T.B. 2010. Ostrom and Namibian conservancies. *Curr. Conserv.* 4: 21–23.

Jones, B.T.B. & Murphree, M.W. 2001. The Evolution of Policy on Community Conservation in Namibia and Zimbabwe. In Hulme, D. & Murphree, M.W. eds. *African Wildlife & Livelihoods: The Promise and Performance of Community Conservation*. Oxford: James Currey, 38–58.

Karanth, K.U., Nichols, J.D., 1998. Estimation of Tiger Densities in India Using Photographic Captures and Recaptures. *Ecology* 79, 2852–62. https://doi.org/10.1890/0012-9658(1998)079[2852:EOTDII]2.0.CO;2

Kock, M.D. & Burroughs, R. 2012. *Chemical and Physical Restraint of Wild Animals: A Training and Field Manual for African Species*. Greyton: International Wildlife Veterinary Services.

Lendelvo, S., Mechtilde, P. & Sullivan, S. 2020. A Perfect Storm? COVID-19 and Community-based Conservation in Namibia. Namibian Journal of Environment 4(B): 1–15.

Lion Guardians, 2023. http://lionguardians.org/ Accessed 7 February.

Lion Rangers, 2023. http://lionrangers.org/. Accessed 7 February.

Mendelsohn, J., Jarvis, A., Roberts, C. & Robertson, T. 2002. *Atlas of Namibia: a portrait of the land and its people*. David Philip, Cape Town.

Muntifering, J.R., Linklater, W.L., Clark, S.G., !Uri-ǂKhob, S., Kasaona, J.K., |Uiseb, K., Du Preez, P., Kasaona, K., Beytell, P., Ketji, J., Hambo, B., Brown, M.A., Thouless, C., Jacobs, S. & Knight, A.T. 2017. Harnessing Values to Save the Rhinoceros: Insights From Namibia. *Oryx* 51(1): 98–105.

(NACSO) Namibian Association of CBNRM Support ORganizations, 2016. *The State of Community Conservation in Namibia: A Review of Communal Conservancies, Community Forests and other CBNRM Initiatives; Annual Report 2016*. Windhoek, Namibia.

NACSO, 2022. https://www.nacso.org.na/sites/default/files/North%20West%20Game%20Count-Regional%202022%20final.pdf Accessed: 7 February.

(NLT) Namibian Lion Trust, 2023. https://namibianliontrust.org/ Accessed: 7 February.

Ostrom, E., 1990. *Governing the Commons. The Evolution of Institutions for Collective Action.* Cambridge: Cambridge University Press.

Owen-Smith, G., 2010. *An Arid Eden: A Personal Account of Conservation in the Kaokoveld*. Johannesburg and Cape Town: Jonathan Ball.

Packer, C., et al. 2013. Conserving Large Carnivores: Dollars and Fence. *Ecol. Lett.* 16: 635–41.

Panthera, 2023. https://panthera.org/conservation-technology/poachercam Accessed: 7 February.

Pennycuick, C.J. & Rudnai, J. 1970. A Method of Identifying Individual Lion with an Analysis of the Reliability of Identification. *J. Zool.* 160: 497–508.

Portas, R., Wachter, B., Beytell, P., Uiseb, K.H., Melzheimer, J. & Edwards, S. 2022. Leopard *Panthera pardus* Camera Trap Surveys in the Arid Environments of northern Namibia. *Mamm. Biol*. https://doi.org/10.1007/s42991-022-00237-3

Republic of Namibia National Planning Commission, 2012. *Namibia Poverty Mapping*. Windhoek, Namibia.

Rhino Ranger Incentive Programme 2014. *Rhino Ranger Incentive Programme – 2014 Progress Report*. http://www.savetherhinotrust.org/uploads/4/5/0/5/45057859/rhino_ranger_2014_update.pdf, accessed 5 April 2021.

Schaller, G.B., 1972. *The Serengeti Lion: A Study in Predator-prey Relations*. Chicago and London: University of Chicago Press.

Scott, J.C., 1998. *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed*. New Haven and London: Yale University Press.

(SMART) Spatial Monitoring and Report Tool, 2023. https://smartconservationtools.org/ Accessed: 7 February.

Stander, P.E., 1999. Conservation of lions and other large carnivores in Etosha National Park and Khorixas District, Namibia. Windhoek. http://www.the-eis.com/viewfile.php?pth=data/literature/Conservation of lions and other large carnivores in Etosha National Park and Khorixas District.pdf

Stander, P.E., 2000. Conservation of lions and other large carnivores in the Kunene Region, Namibia: Population ecology and long term monitoring of free-ranging populations in a marginal and arid environment. http://www.the-eis.com/viewfile.php?pth=data/literature/Conservation of lions and other large carnivores in the Kunene Region.pdf

Stander, P.E., 2004. Population ecology and distribution of lions in the Kunene and Erongo Regions, Namibia. Windhoek, Namibia. http://www.the-eis.com/viewfile.php?pth=data/literature/Population ecology and distribution of lions in the Kunene and Erongo Regions.pdf

Stander, P.E., 2006. Population ecology and demography of Kunene Lions, January 2006. Windhoek, Namibia. http://www.the-eis.com/viewfile.php?pth=data/literature/Population ecology and demography of Kunene Lions_2006.pdf

Stander, P.E., 2007. Behaviour-ecology and Conservation of desert-adapted Lions; 2007 Progress Report of the Kunene Lion Project, Namibia. Windhoek. http://www.the-eis.com/viewfile.php?pth=data/literature/Behaviour_ecology and Conservation of desert_adapted Lions.pdf

Stander, P.E., 2010. The impact of male-biased mortality on the population structure of desert-adapted lions in Namibia. http://www.the-eis.com/viewfile.php?pth=data/literature/The impact of male_biased mortality on the population structure of desert_adapted lions in Namibia.pdf

Stander, P.E., 2018. *Vanishing Kings: Lions of the Namib Desert*. Johannesburg: HPH Publishing.

Stander, P.E. & Hanssen, L. 2003. Population ecology of desert-adapted lions in the Kunene Region, Namibia. Windhoek, Namibia.

Stander, P.E. & Morkel, P. vdB. 1991. Field Immobilization of Lions Using Disassociative Anaesthetics in Combination with Sedatives. African *Journal of Ecology* 29: 137–48.

Stuart-Hill, G., Diggle, R., Munali, B., Tagg, J. & Ward, D. 2005. The Event Book System: A Community-based Natural Resource Monitoring System From Namibia. *Biodivers. Conserv.* 14: 2611–31. https://doi.org/10.1007/s10531-005-8391-0

Sullivan, S., 2003. Protest, Conflict and Litigation: Dissent or Libel in Resistance to a Conservancy in North-west Namibia. In Anderson, D.G. & Berglund, E. (Eds.), *Ethnographies of Conservation: Environmentalism and the Distribution of Privilege*. London: Berghahn Books, 69–86.

Sullivan, S. 2016. Three of Namibia's Most Famous Lion Family have been Poisoned – Why? The Conversation 23 August https://theconversation.com/three-of-namibias-most-famous-lion-family-have-been-poisoned-why-64322

Tavolaro, F.M., Woodgate, Z., Brown, C., Redpath, S.M. & O'Riain, M.J. 2022. Multispecies Study of Patterns and Drivers of Wildlife Impacts on Human Livelihoods in Communal Conservancies. Conservation Science and Practice 2022; e12773, https://doi.org/10.1111/csp2.12773

UNICEF, 2013. Regional Education Analysis for Namibia.

*Vanishing Kings: Lions of the Namib*, 2015. https://vanishingkings.org/ Accessed: 7 February 2023.

Wildlife Credits, 2023. https://wildlifecredits.com/ Accessed: 7 February.

Williams, K.S., Pitman, R.T., Mann, G.K.H., Whittington-Jones, G., Comley, J., Williams, S.T., Hill, R.A., Balme, G.A. & Parker, D.M., 2021. Utilizing Bycatch Camera-trap Data for Broad-scale Occupancy and Conservation: A Case Study of the Brown Hyaena *Parahyaena brunnea*. Oryx 55: 216–26. https://doi.org/10.1017/S0030605319000747