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Examining rural livelihoods relevant to human-lion conflict interventions within the communal conservancies of the Kunene Region, Namibia

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ABSTRACT

In the Kunene Region of northwest Namibia, desert-adapted lion (*Panthera leo*) numbers increased from the late 1990s to 2015. They have since declined by as much as two-thirds. This is primarily as a result of lions killed following human-lion conflict (HLC) incidents, within communal conservancy lands. HLC and conflict with other predators threatens pastoralists' already-tenuous livelihoods, eroding the economic instrumentalism pillar of the conservancy system. Our survey quantitatively and qualitatively examined pastoralists' livelihoods, perceptions of lions, and the efficacy of recently implemented HLC interventions in core lion range conservancies; it is a follow-up to a previous survey (Heydinger *et al.* 2019). Results show that livestock losses over the past decade likely exceed 80%. These losses are overwhelmingly attributed to the effects of drought and predators. Lions are considered the most problematic species, with 57% of respondents holding negative attitudes towards lions, while 84% say they do not benefit from having lions in their conservancy. Yet, problems with other predators, such as spotted hyaena (*Crocuta crocuta*) and black-backed jackal (*Canis mesomelas*), are more widespread. The effects of HLC interventions, including Lion Rangers, human-wildlife conflict Rapid Response Teams, an early-warning system, and predator-proof livestock enclosures (kraals), are not uniformly experienced and show no unequivocal improvement in respondents' attitudes towards lions. Results are discussed in the context of supporting pastoralists' livelihoods, and as part of an ongoing process for strengthening HLC interventions for the conservation of lions and other carnivores on communal lands.

Keywords: conservancies; desert-adapted lions; human-wildlife conflict; lion rangers; livelihoods; Namibia; social survey

INTRODUCTION

African lion (*Panthera leo*) populations living outside of fenced protected areas are an important part of the continent-wide conservation of the species (Jacobson & Riggio 2018; IUCN 2018). Even though lion populations within fenced protected areas are denser than those in unfenced territories, Africa's protected areas face dramatic funding shortfalls, exacerbated by the COVID-19 crisis and structural economic challenges (Packer *et al.* 2013; Lindsey *et al.* 2018, 2020). During the twenty-first century, lions' range has contracted to an estimated 10% of their historically recorded range (IUCN 2018). Free-ranging lion populations, particularly outside fenced protected areas, may prove more resilient if broad-based local support for their persistence can be achieved (Packer *et al.* 2013; Creel *et al.* 2013). Such populations may not be as susceptible to inconsistent governance or funding shortfalls.

One example of sustained lion population growth and recent range expansion comes from the desert-adapted lion population of the Kunene Region, in northwest Namibia. Currently covering a core range of approximately 40 000 km^2, up from approximately 7 000 km^2 in the 1990s (GRN 2017), the desert-adapted lions primarily inhabit communal conservancy lands which they share with semi-nomadic pastoralists and their livestock. Since the late 1990s, this lion population has rebounded from an estimated low of 20 individuals (Stander 2018), to an estimated 180 individuals in 2015 (GRN 2017). This period of recovery coincided with the growth of Namibia's communal conservancy system, a form of community-based natural resource management (CBNRM) where local people maintain qualified rights to manage and benefit from certain natural resources, including wildlife (Jones & Murphree 2001; Owen-Smith 2010). Since 2015, however, the population has declined to an estimated 57–60 individuals in 2022 (Heydinger *et al.* 2024).

The proximate driver of this decline has been lions killed in response to human-lion conflict (HLC). When lions invade conservancy farms, they are often killed in retaliation to preying upon and/or injuring livestock. No human deaths or life-threatening injuries have been recorded from lions in the region since 1982. Even as the lion population was rebounding from 2000–2010, HLC incidents were responsible for 80% of (non-cub) lion mortalities (Stander 2018). This trend continued through the 2010s to the present. From 2021 through mid-2023, HLC has been responsible for at least 27 of 30 lions either being killed or permanently removed from conservancy lands (Heydinger unpublished data). At the same time lions have been responsible for at least 512 livestock deaths, including cattle, sheep, goats, donkeys (Lion Rangers unpublished data).

The ultimate driver of HLC is likely the dramatic decline in wildlife numbers coinciding with reduced rainfall and available vegetation for livestock and wildlife grazing and browse during the past decade. Since 2010, indicator prey species (gemsbok (*Oryx gazella*), springbok (*Antidorcas marsupialis*), and mountain zebra (*Equus zebra*)) numbers have declined by as much as 69–96% (NACSO 2023). Lion survival appears to have been similarly affected by the declining prey base (Heydinger *et al.* 2024), which may also have driven lions to increasingly switch to livestock as prey.

Increasingly erratic rainfall and rising daytime temperatures (Atlas of Namibia Team 2022) are beyond the control of local people, while high rainfall variability will likely remain a feature of this region's ecology. In contrast, HLC incidents can be minimised, provided lion movements are monitored, and proactive steps are taken to limit contact between lions, pastoralists, and livestock. In 2017, Namibia's Ministry of Environment, Forestry and Tourism (MEFT) published the Human Lion Conflict Management Plan for North West Namibia (NW Lion Plan, GRN 2017), a policy document outlining interventions for addressing the related challenges of reducing HLC and supporting pastoralists' livelihoods in the Kunene Region. Among the recommendations within this plan was activating and upscaling four HLC interventions. These include: a Lion Rangers programme (lionrangers.org), five Human Wildlife Conflict Rapid Response Teams, an early-warning system providing stakeholders with relevant lion movement information, and the construction of predator-proof kraals (details below).

Human social factors are increasingly acknowledged as an important part of fostering durable programmes aimed at conserving lions and other potentially dangerous wildlife (Dickman 2010; Hazzah *et al.* 2017). Though HLC may never be fully preventable, securing the future of lions on communal lands includes assessing what drives negative retaliation to HLC incidents by local pastoralists and working to transform these drivers. As part of ongoing efforts to limit HLC, we performed social surveys to ascertain the costs and benefits of living in conservancies in northwest Namibia, and local perceptions of desert-adapted lions as well as experiences of interventions aimed at limiting HLC. These surveys had four objectives:

1. Record the effects of recent drought-like conditions on livestock ownership among communal farmers within core lion-range conservancies by quantifying livestock ownership trends in these areas.
2. Record the effects of predation on livestock by predators during the same period in these areas.
3. Assess attitudes towards living with lions among survey respondents.
4. Assess attitudes towards, and the effectiveness of, human-lion conflict interventions, among respondents.

This effort is a follow-up to a 2017 study (Heydinger *et al.* 2019). The prior survey found large-scale livestock losses due to drought, the magnitude of which had been exacerbated by large carnivores. Lions were responsible for livestock losses averaging approximately NAD 53 070 (USD 2 900, 2022 value; CPI 2023) per household during preceding years. While most respondents (84%) stated they do not benefit from living with lions, 76% maintained it is important to continue to share communal lands with lions (Heydinger *et al.* 2019).

Our current survey adopts objectives from this prior survey, as well as focusing on the effectiveness of alternative HLC interventions, within areas suffering high levels of HLC. We also examine the interface of local livelihoods with the costs and benefits accruing to conservancy residents, as well as perceptions relevant to conservancies' effectiveness in helping mitigate the costs of living with potentially dangerous wildlife, focusing on lions and other large predators. The resulting picture suggests the conservancy system is struggling to deliver on aspects of its founding principles (Jones & Murphree 2001). Our analysis is based on the perspective that societal norms and values fostering pro-environmental behaviour may be just as important as ecological factors (Ostrom 2000; Muntifering *et al.* 2015). This work contributes to existing literature on the effectiveness of CBNRM structures to address the costs incurred by rural residents being charged with managing large, potentially dangerous wildlife. Specific to the context of northwest Namibia, this study provides a contemporary picture of rural livelihoods in a livestock-based economy following years of drought-like conditions. It provides practitioners and researchers with a case study which can contribute to managing and mitigating human-wildlife conflict in rural communities.

Study Area

The core range of the desert-adapted lions encompasses approximately 40 000 km^2 of unfenced communal conservancies and government-managed lands. This includes 11 communal conservancies, three tourism concessions, and a portion of the Skeleton Coast National Park (Figure 1; Table 1). We surveyed a subset of households within each conservancy in this landscape. In comparison, Heydinger *et al*. (2019) surveyed only three communal conservancies (Anabeb, Puros, and Sesfontein) totalling 7 597 km^2. Our expanded survey is due to a broader mandate for limiting HLC across the landscape, as well as the greater reach of our research team and the Lion Rangers. Our broadened scope therefore provides a more comprehensive picture of livelihoods and HLC in core lion range conservancies.

Table 1: *Communal conservancies and government-managed areas that were surveyed during this study (NACSO 2020).*

Conservancy	**Human population**	**Area (km^2)**
Anabeb	1 402	1 570
Doro !Nawas	1 242	3 978
Ehi-rovipuka	1 846	1 980
≠Khoadi-//Hôas	4 308	3 364
Omatendeka	1 985	1 619
Orupupa	2 024	1 234
Puros	641	3 562
Sesfontein	1 941	2 465
Sorris-Sorris	950	2 290
Torra	1 064	3 493
Tsiseb	2 415	7 913

Core desert-adapted lion range is dominated by the Namib Desert, running along the Atlantic coast, merging into the Nama Karoo biome along the western African escarpment, transitioning into the highland savanna further east, and bisected by ephemeral riverbeds running east to west. The soil is typically basaltic, shallow, rocky, and unproductive (Atlas of Namibia Team 2022). Rainfall is patchy and generally occurs during the wet season (January–May), increasing from west to east. The entire area falls within the ≤ 200 mm isohyet with high annual rainfall variability (≥ 60%). Prey species, including

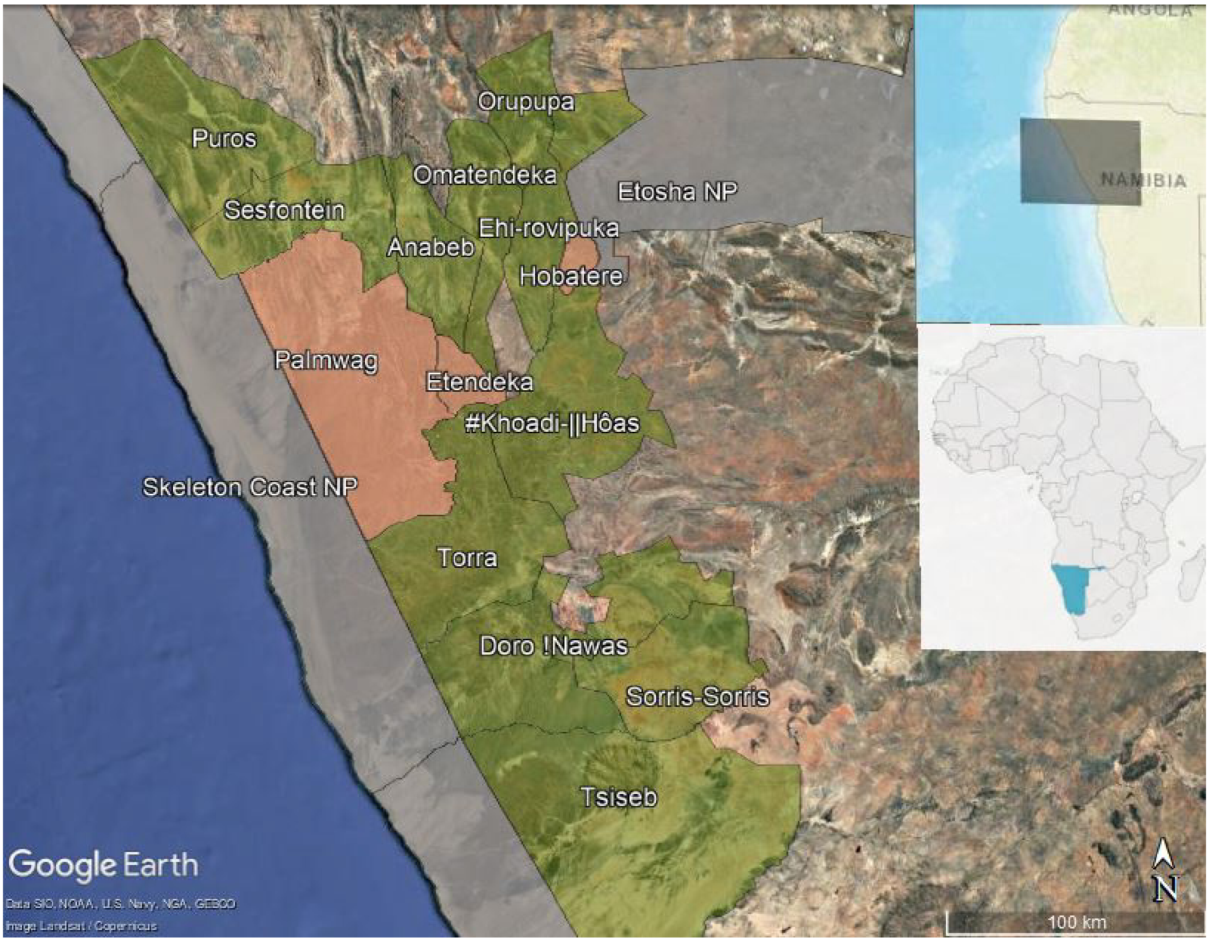

Figure 1: *Map of core lion range with conservancy and government-managed area boundaries within the Kunene Region. Communal conservancies are depicted in green; neighbouring concessions in beige; national parks in grey.*

gemsbok, springbok, mountain zebra, giraffe (*Giraffa camelopardalis*), and kudu (*Tragelaphus strepsiceros*), maintain seasonal movements, responding to localised rainfall and subsequent availability of grasses and browse. During the dry season (June–December), prey and livestock often congregate in ephemeral riverbeds.

Core lion range is home to approximately 19 800 rural residents, primarily Otjiherero- and Damara-speaking peoples whose primary source of income is derived from livestock farming of cattle (*Bos taurus*), sheep (*Ovis aries*), goats (*Capra aegagrus hircus*), and donkeys (*Equus asinus*). Households within the region typically suffer from low and uncertain incomes and limited financial opportunities (Mendelsohn *et al.* 2002; Collins *et al.* 2009). By Namibian standards, 38% of residents in Kunene are considered impoverished, while 24% are considered severely impoverished, based upon the cost of basic food needs (NNPC 2015), and 31% of residents report no sources of income, while fewer than 35% have access to electricity for lighting at home (NSA 2024). Livelihoods have been further hampered by a downturn in tourism-based income stemming from the COVID-19 pandemic (Lendelvo *et al.* 2020). Social prospects are also limited: Kunene has Namibia’s highest primary school drop-out rates, with only 55% of residents completing primary school by age seventeen (UNICEF 2013).

Kunene is one of Namibia’s most heavily degraded and drought-prone regions; over-utilisation of rangelands is caused by high concentrations of livestock in specific areas (NNPC 2015). Due to an intensive government borehole-drilling programme during the 1970s, much of the region is considered to be limited by available grazing rather than water (Bollig 2020). From 2000 to 2010, the region experienced a relatively wet period, resulting in wildlife and livestock increases (Owen-Smith 2010; NACSO 2020). From 2011 to 2017, extensive drought caused the decline of livestock numbers by as much as 67% (Heydinger *et al.* 2019), as well as indicator prey species (above). These challenges are likely to be exacerbated in coming years, as Kunene is projected to experience a 2–3°C temperature increase by 2060 (Atlas of Namibia Team 2022).

Background – Communal Conservancies and HLC Interventions

Following independence in 1990, Namibia’s Nature Conservation Amendment Act (No. 5/1996) empowered communal area residents to form conservancies. These are gazetted institutions managing natural resources within a defined, community-agreed-upon jurisdiction, where residents may receive monetary benefits from natural resources. Based upon the tenets of CBNRM, communal conservancies stand upon four conceptual pillars: i) sustainable use as a conservation paradigm; ii) market-based valuing of resources (economic instrumentalism); iii) locals empowered with decision-making rights (devolutionism); and iv) local, collective proprietorship of natural resources (Jones & Murphree 2001). Though the intent of the legislation was to provide residents with ownership rights to wildlife, there remains a dearth of research examining the effectiveness of conservancies in Kunene for reconciling rural livelihoods with wildlife conservation.

Among the challenges facing core lion range conservancies has been persistent HLC. As many Kunene conservancies secured tenure to their wildlife, prey species numbers increased; so too did the number of lions and HLC numbers (Stander 2010; GRN 2017). Since 2009, the Namibian government has provided limited financial offsets to communal residents in the form of cash payments through a Human Wildlife Conflict Self Reliance Scheme (HWC SRS) (GRN 2018). Implemented by government, the HWC SRS devolves responsibility to conservancies to report human-wildlife conflict and disperse payments to affected residents. However, the funds made available through this programme only partially offset the cost of livestock losses and 92% of surveyed lion range conservancy members are dissatisfied with the programme (Heydinger *et al.* in press; Heydinger unpublished data).

Endorsed by government in 2017, MEFT’s NW Lion Plan provided a series of interventions in addition to the existing HWC SRS. First was re-activating the local Lion Rangers programme, a CBNRM initiative whereby community-appointed conservationists are employed, trained, and equipped to monitor lions and limit HLC within their conservancies (Heydinger 2023). There are currently 49 Lion Rangers across all 11 core lion range conservancies. Based upon other successful CBNRM programmes in Kunene (Hearn 2003; Jacobsohn & Owen-Smith 2003; Muntifering *et al.* 2015), as well as on the Lion Guardians in Kenya and Tanzania (Hazzah *et al.* 2014; Dolrenry *et al.* 2016), Lion Rangers serve as liaisons between their communities and lions inhabiting communal areas.

Second was activating and capacitating five Human-Wildlife Conflict Rapid Response Teams (RRT). Employed by local NGOs, each RRT receives annual Lion Ranger training and is further capacitated with full-time use of a 4x4 vehicle. The primary responsibility of RRTs is to transport Lion Rangers across the landscape, respond to HLC in far-flung areas, and safely chase lions away from farms when other conflict prevention and mitigation measures fail.

Third was up-scaling an existing early-warning system. With the increasing availability of GPS/satellite and VHF collars at relatively affordable prices, research teams and MEFT have collared more than 45 of the region's estimated 57–60 adult lions. These collars provide location fixes relayed via the iridium satellite network to a secure online interface. Lion Rangers, RRTs, permitted researchers, and key government staff receive automated notifications by SMS when collared lions enter designated farming areas. On the ground, collar locations are also communicated to early-warning towers, which have been deployed in key HLC-hotspot farms. Standing 4–5 m tall, these towers alert farmers via bright lights and sirens when lions are within line of sight and are active round-the-clock. There are currently 14 early-warning towers across the landscape.

Finally, predator-proof livestock enclosures (kraals) have been deployed at approximately 120 farms in core lion range conservancies. These kraals are constructed with chain-link fencing and aluminium poles, wrapped in semi-transparent shade-netting, topped with barbed wire at three meters height, all cemented one-half meter into the ground. Predator-proof kraals are a proven method of deterring lions from attacking livestock when livestock are inside, with only one recorded incident of lions penetrating a poorly sited predator-proof kraal since the programme's inception. These kraals serve as a last line of defence, when monitoring and early-warnings fail to alert farmers to lions' presence.

Following the guidelines of the NW Lion Plan, the four interventions began in 2018. From 2016–2021, HLC incidents declined by 33% (MEFT unpublished data). However, early data from 2023 show a 38% *increase* in livestock losses compared to the 2021–2022 average. Our surveys are part of an ongoing effort to assess the reach and effectiveness of HLC interventions and the extent to which they have succeeded in fostering community tolerance of living alongside lions.

MATERIALS AND METHODS

Semi-structured surveys eliciting both quantitative and qualitative information were performed *in situ* at 323 farming homesteads (farms) across 11 communal conservancies in the Kunene Region from November 2021 to February 2022. Survey execution and ethical research practices replicate those previously approved by the University of Minnesota Institutional Review Board ensuring confidentiality and informed consent (see Heydinger *et al.* 2019). Surveys were primarily conducted with the heads of livestock-owning households, in the preferred language of the respondent, including English, Afrikaans, Otjiherero, and Khoekhoegowab. Sampling was limited to one respondent per household, though other family and community members were frequently present, provided input and were encouraged to participate. Surveys typically took 35–45 minutes. Topics included (i) demographic information; (ii) coarse-grain employment and income-source information; (iii) experiences regarding conservancy membership; (iv) household livestock data focusing on quantitative trends; (v) experiences and perspectives of predator species, emphasising lions; (vi) experiences and perspectives of HLC interventions. Responses were quantitative or categorical – e.g. when asked "what type of important benefits are you receiving from your conservancy" – responses were grouped where possible, such as "meat," "money," or "seeds for gardens." For livestock numbers, respondents were encouraged to provide precise quantitative values. However, if respondents were unsure about numbers they were asked to estimate. When a list of possible responses was available – e.g. "how common are lions in your conservancy": a) very common; b) common; c) rare; or d) absent – respondents were given the chance to answer freely. Where responses were categorised – e.g. "how would you describe the problems you have with lions: none, low, moderate, or serious?" – levels for none, low, etc., were not predefined, allowing respondents to use their personal discretion. Attitudes towards lions and HLC interventions were surveyed using a series of Likert Scale responses adapted from Heydinger *et al.* (2019) and were categorised based upon surveyors' discretion. Our approach facilitated open dialogue: whenever possible, comments were used to clarify responses and respondents were encouraged to elaborate. We believe respondents felt empowered to answer each question honestly. Survey protocols, including eliciting informed consent, replicated those previously approved (see Heydinger *et al.* 2019). All responses were recorded on standardised survey forms and captured in Microsoft Excel.

Summary statistical analyses were performed to describe the data. Pearson's second skewness coefficient was used to assess asymmetries in the probability distribution of the data:

$$Sk_2 = \frac{3(\bar{x} - Md)}{s}$$

where $\bar{x}$ = the mean of the sample, Md = the median, and s = the standard deviation. This measure was used due to its robustness in the face of outliers and ability to detect asymmetries in the data (Bruce & Bruce 2017). The coefficient of variation was used to test the relative variability of responses to survey questions:

$$CV = \frac{\sigma}{\mu}$$

where σ = the standard deviation of responses within a conservancy, and μ = the mean of responses within the conservancy. This measure is widely recognised for its versatility in comparing variability in data sets with different scales (Whitehead 2008). Pearson's correlation coefficient was used to test the strength of association between variables as their difference from the expected distribution:

$$r = \frac{\Sigma\,(x_i-\bar{x})\,(y_i-\bar{y})}{\sqrt{\Sigma(x_i-\bar{x})^2\,(y_i-\bar{y})^2}}$$

where x_i = the values of the x-variable in the sample, $\bar{x}$ = mean of the values of the x-variable, y_i = the values of the y-variable in the sample, $\bar{y}$ = mean of the values of the y-variable (Bruce & Bruce 2017). Correlations $0.10 \le |r| < 0.30$ are considered weak; $0.30 \le |r| < 0.50$ are considered moderate; $|r| \ge 0.50$ are considered strong. Data were analysed and visualised using Microsoft Excel. Analysis was performed at the landscape and at a conservancy-by-conservancy level. Supplementary analyses are freely available online (Heydinger 2022).

RESULTS

Demographics and Income Sources

A total of 323 respondents from 110 different farming areas were surveyed. Basic demographic information is available in the supporting information (Appendix A). All respondents self-identified their cultural identity. More than 50% of respondents were age 50 or older: this is reflective of targeting the household head or person who could provide the most information about livestock.

Of the 171 people reporting consistent income, only 55 (17% of all respondents) receive consistent income that is primarily derived from sources other than government programmes (i.e. pension or subsidies for children). When only non-salaried or inconsistent incomes were reported, these were classified as occasional income. 95% of respondents (n = 306) reported at least one source of income, 25% (n = 82) reported at least two sources, and 3% (n = 10) reported three or more sources of income. Selling livestock was the most consistently reported source of income (52%; n = 167); an additional 11% (n = 37) reported selling livestock without listing it as an income source, likely indicating money from sale did not meaningfully contribute to a family's livelihood.

Livestock

Overall Trends

Among respondents, 91% (n = 294) reported currently keeping livestock. Summary statistics of livestock ownership are given in Appendix B. The rightward skew of all livestock species indicates livestock ownership is concentrated in certain households. To assess recent changes in livestock numbers, respondents were asked to compare current ownership of each species with the number owned three years ago. For cattle, no one reported an increase, 83% (n = 264) reported a decrease, and 16% (n = 51) reported no change. For sheep, 2% (n = 5) reported an increase, 82% (n = 259) reported a decrease, and 16% (n = 52) reported no change. For goats, 3% (n = 11) reported an increase, 93% (n = 297) reported a decrease, and 4% (n = 12) reported no change. For donkeys, 1% (n = 3) reported an increase, 82% (n = 260) reported a decrease, and 16% (n = 52) reported no change. When asked about the greatest threats to their livestock, the most frequently identified were drought (95%; n = 300) and predators (93%; n = 296).

Declining Numbers

Surveys in Anabeb, Puros, and Sesfontein conservancies (Heydinger *et al.* 2019) serve as a basis of comparison for changes in livestock ownership. Within these conservancies, ownership of cattle, sheep, and donkeys is skewed, being more concentrated within a few wealthier households (Appendix B). Livestock losses over the past decade have exacerbated this concentration. Since the early 2010s, mean cattle numbers have decreased by 97% (87% since 2017), sheep by 89% (72% since 2017), goats by 79% (56% since 2017), and donkeys by 84% (47% since 2017; Figure 2).

Diminished Herd Value

Heydinger *et al.* (2019) asked respondents to estimate the monetary value (in Namibian dollars; NAD) of an average-sized adult female for each livestock species. Based upon these estimates, the median value of a household livestock herd (all species combined) has decreased (Table 2). In 2017, the value of a median livestock herd was NAD 168 091 (USD 9 185; 68% decrease since the early 2010s), and by 2021/2 the value of a median livestock herd was NAD 58 560 (USD 3 200; 89% decrease since the early 2010s; 65% decrease since 2017). The total value of livestock lost across all households is approximately NAD 64.9 million (USD 3.5 million) since the early 2010s, and NAD 16.2 million (USD 883 317) since 2017. Again, these values represent only three of eleven surveyed conservancies.

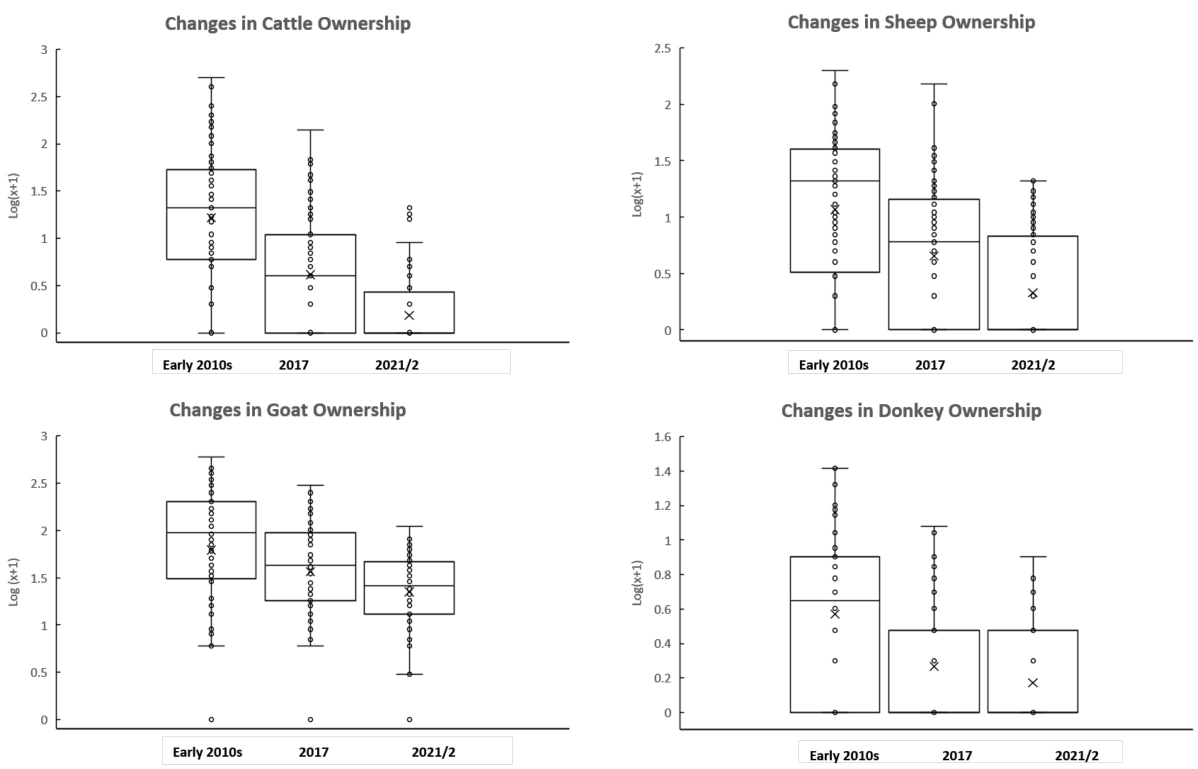

Figure 2: *Changing household-level ownership for each species for Anabeb, Puros, and Sesfontein, comparing 2021/2 ownership with previous survey results (Heydinger* et al. *2019). Responses as to number of relevant species owned have been log(x+1)-transformed for ease of visualisation, where x is the raw value. Boxes indicate interquartile range. Solid horizontal lines within the box visualise median response, while 'X' within the box visualises mean response.*

Table 2: *Changes in livestock ownership for Anabeb, Puros, and Sesfontein conservancies. Mean and median number of livestock owned per household; Skew, Pearson's second skewness coefficient, positive values indicate rightward skew among responses; Min, minimum number owned; Max, maximum number owned; Total, total number owned by all respondents; Responses, number of respondents for each specific type of livestock; Median NAD, the value of the median size herd for that species (cattle = NAD 10,048/head, sheep NAD 1852/head, goats NAD 2,342/head, donkeys = NAD 1519/head; 2022 values, CPI 2023; Oanda 2024).*

Cattle	Early 2010s	2017	2021/2
Mean	48.2	10.3	1.3
Median	25	4	0
Skew	3.622	4.041	3.925
Min	0	0	0
Max	500	140	20
Total	4,003	854	117
Responses	83	83	88
Median NAD	251,204	40,192	0

Sheep	Early 2010s	2017	2021/2
Mean	28.7	11	3.1
Median	20	5	0
Skew	2.430	4.718	1.675
Min	0	0	0
Max	200	150	20
Total	2,381	911	270
Responses	83	83	88
Median NAD	37,075	9,260	0

Goats	Early 2010s	2017	2021/2
Mean	143	71	30.7
Median	100	50	25
Skew	1.253	1.503	0.897
Min	0	0	0
Max	600	300	110
Total	11,867	5,894	2,698
Responses	83	83	88
Median NAD	234,222	117,120	58,560

Donkeys	Early 2010s	2017	2021/2
Mean	5.1	1.6	0.8
Median	4	1	0
Skew	1.731	2.058	1.955
Min	0	0	0
Max	25	11	7
Total	415	129	72
Responses	82	82	88
Median NAD	6,076	1,519	0

***Table 3:** Frequency of responses to survey question "what predators do you have the most problems with, starting with the worst" by conservancy. Up to three responses were recorded per respondent. Percentages are relevant to the proportion of responses within a conservancy. Shaded cells indicate which predator species are considered most problematic within each conservancy.*

Conservancy	Lion		Leopard		Spotted hyaena		Black-backed jackal		Cheetah		Number of respondents
	%	n	%	n	%	n	%	n	%	n	
Anabeb	57	17	53	16	67	20	73	22	40	12	30
Doro !Nawas	28	5	67	12	67	12	61	11	33	6	18
Ehi-rovipuka	94	29	42	13	68	21	71	22	6	2	31
≠Khoadi-//Hôas	82	40	22	11	51	25	51	25	24	12	49
Omatendeka	50	16	53	17	72	23	53	17	56	18	32
Orupupa	23	5	45	10	91	20	64	14	23	5	22
Puros	68	21	42	13	81	25	65	20	6	2	31
Sesfontein	48	13	7	2	78	21	59	16	26	7	27
Sorris-Sorris	20	3	40	6	53	8	87	13	13	2	15
Torra	78	36	61	28	41	19	50	23	17	8	46
Tsiseb	5	1	59	13	59	13	59	13	36	8	22
Number of responses		186		141		207		196		82	323

Conservancy Challenges

Lack of Benefits

When asked whether they had received important benefits from their conservancy, 41% (n = 132) replied affirmatively, while 59% (n = 191) said they had not. Positive responses ranged from a low of 18% in ≠Khoadi-//Hôas (n = 9) and Orupupa (n = 4) to a high of 77% (n = 24) in Puros. Conservancy-by-conservancy responses differed from the expected distribution, ($\chi^2 = 50.9$, $p < 0.001$, df = 10, n = 323), indicating a respondent's conservancy was correlated with whether they reported receiving important benefits. When asked to specify benefits, the most frequent response was meat (67%; n = 89) from own-use hunting, followed by food parcels (31%; n = 41), employment (17%; n = 22), and access to water (16%; n = 21). When asked to identify the biggest challenges facing conservancy residents, the most frequent response was drought (51%; n = 165), followed by human-wildlife conflict (32%; n = 104), and predators (29%; n = 93). Though human-wildlife conflict encompasses a wider range of challenges than predators, there may have been overlaps in what respondents sought to convey in these responses – i.e. those responding human-wildlife conflict may have been including problems with predators in their response.

Predator Conflict

Livestock losses

When asked, "how often are you losing livestock to predators" 84% (n = 262) reported "at least a few times per year," while 66% (n = 207) reported a near-monthly basis. 99% (n = 310) reported having lost livestock to predators at some point. When asked whether they had ever received financial offsets for lost livestock through the HWC SRS, 37% (n = 112) of respondents stated yes, 51% (n = 166) have not, and a further 7% (n = 24) were unsure of receiving offsets or unaware of the programme.

Problematic Predators

When respondents were asked, "what predators do you have the most problems with, starting with the worst" lions were the species most frequently identified as the most problematic (38%; n = 123), spotted hyaena (*Crocuta crocuta*) were second (26%; n = 82), and black-backed jackal (*Canis mesomelas*) were third (15%; n = 48). When respondents were given the opportunity to name up to three problematic species, spotted hyaena were the most frequently identified (64%; n = 207), followed by black-backed jackal (61%; n = 196), and lion (58%; n = 186). Table 3 summarises conservancy-by-conservancy response frequency, when up to three responses were included. Answers differed between conservancies ($\chi^2 = 130.97$, $p < 0.001$, df = 10, n = 323), indicating a significant relationship between a respondent's conservancy and which predators they considered among the most problematic. Assessed on a species-by-species basis, there was an association between a respondent's conservancy and whether they considered lions ($\chi^2 = 38.44$, $p < 0.001$, df = 10, n = 323), leopard (*Panthera pardus*) ($\chi^2 = 21.09$, $p = 0.02$, df = 10, n = 323), and cheetah (*Acinonyx jubatus*) ($\chi^2 = 26.87$, $p < 0.01$, df = 10, n = 323) among the most problematic. For other species, the association between conservancy and species did not differ significantly from expected.

Respondents differ as to how common they believe lions are within their conservancy (Table 4). Conservancy-by-conservancy, responses differed from the expected distribution ($\chi^2 = 250.6$, $p < 0.001$,

Table 4: *Summary of responses to survey question: "how common are lions in conservancy". Values are the percentage of respondents stating lions are Very common, Common, Rare and Absent in their conservancy.*

Conservancy	**Very common %**	**Common %**	**Rare %**	**Absent %**	**Number of respondents**
Anabeb	63	27	10	0	30
Doro !Nawas	0	17	61	22	18
Ehi-rovipuka	58	19	23	0	31
≠Khoadi-//Hôas	31	52	17	0	48
Omatendeka	22	31	41	6	32
Orupupa	0	0	32	68	22
Puros	45	26	29	0	31
Sesfontein	73	27	0	0	26
Sorris-Sorris	0	21	57	21	14
Torra	20	47	33	0	45
Tsiseb	5	5	24	67	21
Number of responses	102	92	86	38	318

df = 10, n = 318). Though respondents were not asked to define what was meant by "very common," "common," etc., previous research indicates current lion prevalence is considered relative to past lion prevalence (Heydinger *et al.* 2019, Heydinger *et al.* in press).

Respondents differ as to how common they believe lions are within their conservancy (Table 4). Conservancy-by-conservancy, responses differed from the expected distribution ($\chi^2 = 250.6$, $p < 0.001$, df = 10, n = 318). Though respondents were not asked to define what was meant by "very common," "common," etc., previous research indicates current lion prevalence is considered relative to past lion prevalence (Heydinger *et al.* 2019, Heydinger *et al.* in press).

Lack of Benefits

When asked, "do you benefit from having lions in your conservancy" 76% (n = 248) responded "no". When asked, "how would you describe your attitude towards lions" 17% (n = 58) responded positively, while 57% (n = 190) described their attitude as negative. From conservancy to conservancy, responses differed significantly from the expected distribution ($\chi^2 = 104.11$, $p < 0.001$, df = 10, n = 321). There was a moderate positive correlation between whether or not a respondent reported benefiting from lions and their attitude towards lions ($r = 0.44$, $p < 0.001$, n = 312). When asked, "how serious a problem are lions in your conservancy" 54% (n = 175) considered lions to be a serious problem, 14% (n = 44) considered lions a moderate problem, while 30% (n = 98) considered lion problems to be low, or stated there were no lions in their conservancy. Responses differed significantly from conservancy to conservancy ($\chi^2 = 223.8$, $p < 0.001$, df = 10, n = 317). When asked, "is it important for there to continue to be lions in your conservancy" 60% (n = 187) of respondents stated "no," 28% responded "yes," and 12% described their feelings as neutral or were unsure. There was a moderate correlation between whether a respondent benefited from having lions in their conservancy and whether they felt it was important for lions to persist in their conservancy ($r = 0.41$, $p < 0.001$, n = 302).

Knowledge and Perceived Effectiveness of HLC Interventions

Responses varied by conservancy as to respondents' level of engagement by, and attitudes towards HLC interventions (Figure 3; Table 5). Respondents differed across conservancies as to whether the Lion Rangers ($\chi^2 = 58.45$, $p < 0.001$, df = 10, n = 323) or RRTs ($\chi^2 = 70.05$, $p < 0.001$, df = 10, n = 320) had visited a respondent's farm, or whether a respondent had the early-warning system ($\chi^2 = 28.89$, $p < 0.01$, df = 10, n = 321) or a predator-proof kraal ($\chi^2 = 46.24$, $p < 0.001$, df = 10, n = 321) at their farm, signalling an association between a respondent's conservancy and the presence of that intervention (Figure 3). There was a strong positive correlation between positive attitudes towards the Lion Rangers and whether Lion Rangers had visited a respondent's farm ($r = 0.59$, $p < 0.001$, n = 320). There was a moderate positive correlation between positive attitudes towards the RRTs and whether RRTs had visited a respondent's farm ($r = 0.39$, $p < 0.001$, n = 317). By comparison there was a small but significant positive correlation between attitudes towards the early-warning system and whether respondents had the system installed at their farm ($r = 0.19$, $p < 0.001$, n = 306) and a non-significant correlation between attitudes towards predator-proof kraals and whether a respondent had a predator-proof kraal at their farm ($r = 0.002$, $p = 0.96$, n = 306).

***Table 5:** Extension and perceived effectiveness of HLC interventions by conservancy. Values given indicate percent response.*

Conservancy	Have you heard of the Lion Rangers?			Have the Lion Rangers ever visited your farm?			What is your attitude towards the Lion Rangers?			Have you heard of the HWC Rapid Response Teams?			Have the HWC Rapid Response Teams ever visited your farm?			What is your attitude towards the HWC Rapid Response Teams?*		
	Yes	No	Unsure	Yes	No	Unsure	Pos	Neg	Unsure	Yes	No	Unsure	Yes	No	Unsure	Pos	Neg	Unsure
Anabeb	93	3	3	73	27	0	69	3	28	97	3	0	97	3	0	77	10	13
Doro !Nawas	78	22	0	61	39	0	61	0	39	61	39	0	33	67	0	17	17	67
Ehi-rovipuka	90	6	3	71	23	6	55	6	39	52	42	6	39	52	10	29	6	65
≠Khoadi-//Hôas	65	35	0	27	73	0	29	4	67	82	16	2	49	49	2	35	31	35
Omatendeka	88	9	3	50	41	9	50	6	44	56	34	9	38	53	9	38	6	56
Orupupa	32	59	9	9	82	9	9	0	91	5	90	5	0	95	5	5	0	95
Puros	100	0	0	48	52	0	71	10	19	87	13	0	43	57	0	65	6	29
Sesfontein	96	4	0	63	37	0	56	7	37	59	37	4	42	54	4	41	15	44
Sorris-Sorris	60	40	0	40	60	0	47	0	53	60	40	0	40	60	0	47	0	53
Torra	85	15	0	52	46	2	54	13	33	78	22	0	46	50	4	42	7	51
Tsiseb	59	41	0	45	55	0	55	0	45	18	82	0	18	82	0	23	0	77
Mean	79	20	2	49	49	2	50	6	44	64	33	2	43	53	3	40	11	50
Standard dev	0.198	0.187	0.027	0.181	0.175	0.037	0.169	0.042	0.189	0.265	0.257	0.031	0.223	0.218	0.035	0.195	0.087	0.219
Number of responses	255	63	5	158	157	8	161	18	143	206	107	8	138	171	11	127	34	160
Total responses	323			323			322			321			320			321		

Conservancy	Have you heard of the Early-Warning System?			Do you have the Early-Warning System at your farm?			What is your attitude towards the Early-Warning System?			Have you heard of predator-proof kraals?			Do you have a predator-proof kraal at your farm?			What is your attitude towards predator-proof kraals?*		
	Yes	No	Unsure	Yes	No	Unsure	Pos	Neg	Unsure	Yes	No	Unsure	Yes	No	Unsure	Pos	Neg	Unsure
Anabeb	83	13	3	20	77	3	76	0	24	100	0	0	30	70	0	90	7	3
Doro !Nawas	61	39	0	0	100	0	56	0	44	83	17	0	11	89	0	61	6	33
Ehi-rovipuka	58	42	0	19	77	3	62	0	38	97	3	0	55	45	0	83	3	14
≠Khoadi-//Hôas	36	62	2	6	91	2	28	2	70	88	13	0	31	67	2	53	19	28
Omatendeka	53	44	3	0	97	3	58	0	42	100	0	0	28	72	0	97	3	0
Orupupa	10	90	0	0	100	0	21	0	79	32	68	0	0	100	0	64	0	36
Puros	84	16	0	29	71	0	68	6	26	100	0	0	19	81	0	94	0	6
Sesfontein	56	44	0	7	93	0	52	0	48	96	4	0	19	81	0	85	7	7
Sorris-Sorris	40	60	0	13	87	0	40	0	60	87	13	0	14	86	0	73	0	27
Torra	52	48	0	15	83	2	26	7	67	96	4	0	53	47	0	73	12	15
Tsiseb	41	59	0	18	77	5	59	0	41	64	36	0	18	82	0	73	0	27
Mean	53	46	1	12	86	2	48	2	50	88	12	0	29	71	0	77	7	17
Standard dev	0.201	0.205	0.013	0.093	0.098	0.017	0.174	0.026	0.17	0.199	0.199	0	0.160	0.161	0.006	0.134	0.058	0.122
Number of responses	170	147	3	39	276	6	149	6	153	283	38	0	93	226	1	238	21	52
Total responses	320			321			308			321			320			311		

* Pos = positive; Neg = negative; Unsure = neutral/unsure.

For all HLC interventions, there was a weak positive or non-significant correlation between a respondent's attitude towards lions and whether an intervention had been or was currently present at their farm. There was a small but significant positive correlation between whether a respondent stated they were benefiting from having lions in the conservancy and whether they had an early-warning tower ($r = 0.23$, $p < 0.001$, $n = 312$), or predator-proof kraal at their farm ($r = 0.14$, $p < 0.05$, $n = 311$).

DISCUSSION

The overall picture emerging from these surveys is one in which CBNRM's economic instrumentalism is struggling to deliver. Livestock losses, diminished prey numbers, inadequate financial offsets following human-wildlife conflict, and inconsistent benefit distribution each undermine the economic pillar of the conservancy system (Jones & Murphree 2001). This appears to be negatively affecting not only livelihoods, but attitudes towards certain wildlife and the conservancy system.

Livelihood Effects of Livestock Losses

Livestock losses across core lion range conservancies have dramatically compromised the livelihoods and household wealth of farmers. Respondents point to the effects of drought and predators as the drivers of such losses. Such losses appear to be concentrated:

effectively exacerbating inequalities between relatively poor and well-to-do households. Because selling livestock is the most common source of income, livestock deaths compromise human wellbeing. Such losses seem to coincide with diminished rainfall since 2011. Our field work indicates that these losses are typical across Kunene's communal lands, while declines in prey species have been region-wide over the same period. In a country-wide analysis of human-wildlife conflict impacts within Namibia's communal conservancies, Tavolaro *et al*. (2022) found a strong negative correlation at the conservancy level between annual reports of livestock depredation and estimated ungulate abundance. In the context of northwest Namibia's decreased rainfall since the mid-2010s, drought may both be limiting livestock numbers and increasing the risk to livestock from predators as they struggle to secure enough wild prey to meet their energetic requirements. As Tavolaro *et al*. (2022) found no predictor variable for reported livestock depredation by lions, further research is needed to ascertain the linkages between livestock depredation by lions and decreased prey numbers during drought. Additionally, decreased ecosystem productivity affects not only wildlife, but livestock ranging patterns. By deploying GPS/satellite collars on livestock herds, Muzuma (2024) reveals how shared "lion-goat" space may be driving conflict in proposed wildlife movement corridors. As elsewhere in Africa, increased human population growth may further exacerbate human-lion interactions. The recently completed Namibia national census reveals a nearly 40% human population increase in the Kunene Region from 2011 to 2023 (NSA 2024).

Livestock losses to predators have affected 99% of households, including two-thirds on a near-monthly basis. Yet, financial offset payments from the HWC SRS are not reaching most pastoralists, and those that do reach the ground are often inadequate to replace the value of livestock lost (Heydinger *et al*. 2019). Comments from respondents indicate that offsets are rarely delivered, and that even when payments are made, they are too little and too late in coming, sometimes years late. Among those respondents

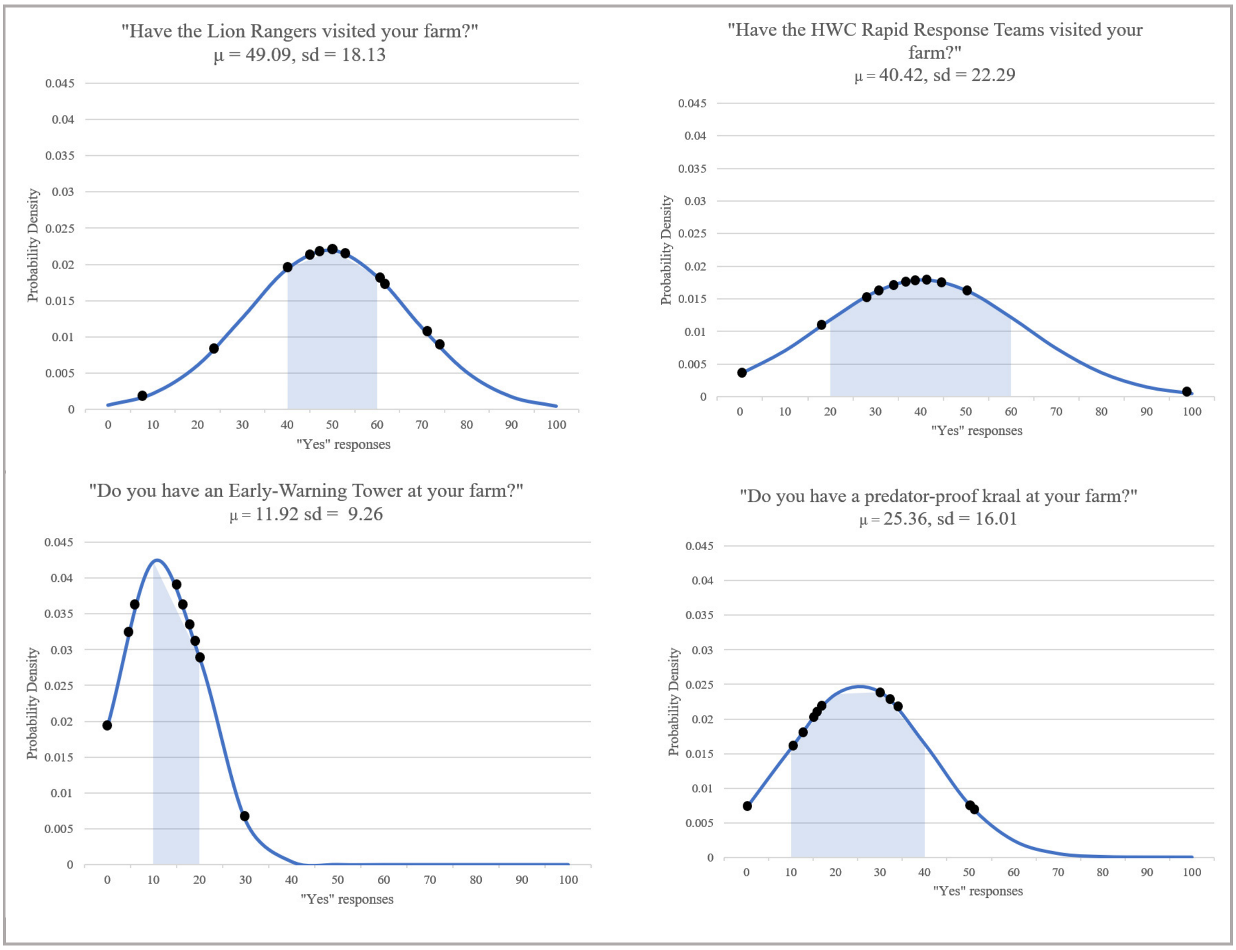

Figure 3: *Presence of HLC interventions across the landscape, by conservancy. Each point represents percentage of "yes" responses by conservancy, while the apex of the curve represents the mean. The blue line shows normalised distribution of responses and the shaded area indicates one standard deviation from the mean.*

critical of the offset payment system, many deemed the process by which claims are recorded, submitted, assessed, and potentially paid out as driven by local politics and favouritism. Problems surrounding power-sharing and equitability bedevil conservancy politics in northwest Namibia, including those inhabited by survey respondents (Heffernen 2022). While the structures of HWC SRS are meant to depoliticise offset payments at a national level, local power structures and management difficulties can undermine the programme's effectiveness.

Inadequate Conservancy Benefits

Livelihood challenges are further exacerbated by a lack of conservancy benefits. Those receiving benefits most frequently cited meat or food distribution, though many stated such benefits have declined since the drought and COVID-19 pandemic. Hunting by conservancies, whether for own-use and shoot-and-sell, or for trophy-hunting quotas, has also been greatly curtailed in recent years due to declining wildlife numbers (NACSO 2020), meaning that just as livelihoods are suffering from declining livestock numbers, conservancy benefits have also ebbed. Even so, the extent to which benefits (e.g. from hunting) had previously reached conservancy residents was already limited. A case study by Turpie and Letley (2021), emphasised accountable payment mechanisms within Namibian conservancies as an important part of ensuring residents were responsive to potential incentives stemming from natural resources. They show that inadequate internal oversight of financial systems compromises residents' trust in conservancy structures.

While CBNRM programmes have had mixed success in delivering benefits to participants (Dressler *et al.* 2010), it is logical that conservancy structures undermining participants' existing financial prospects, such as the keeping of livestock, will generate negative local attitudes. The misalignment of the costs incurred by conservancy members and the benefits accruing at the conservancy level, or to private firms such as tourism operators, calls into question whether conservancies are appropriate for housing potentially dangerous wildlife (Jones & Murphree 2004). The realisation of benefits, whether monetary or non-monetary, are part of the conceptual foundations upon which conservancies are built (Murphree 2008). Where monetary benefits are lacking, feelings of ownership leading to effective stewardship may provide an emotive foundation for communities to conserve, but communities must then be even *more empowered* to manage wildlife (Murphree 1989), rather than being constrained by external social and political forces. Whether conservancies were ever intended to provide meaningful rural socio-economic development has been called into question (Murombedzi 2012). The forthcoming Wildlife and Protected Areas Management Bill aims to devolve greater authority over wildlife use and clarity on land-use designations within communal areas, while promoting sustainable resource use and management, though this legislation has been under discussion for some time (Odendaal 2024).

Challenges from Predators

Challenges presented by predators reveal subtle differences across the survey landscape. Lions are considered the most problematic predator by the greatest number of respondents (38%). This may be due to a culturally mediated fear of lions (Heydinger *et al.* in press). It may also be due to lions killing multiple livestock per HLC incident. In recent years such 'mass-casualty' events have received nation-wide news coverage (Hartmann 2017, 2018). However, when respondents were asked to name up to three problematic predators, more respondents identified spotted hyaena (64%) and black-backed jackal (61%) than lions (58%). The association between a respondent's conservancy and whether they considered lions among the most problematic predators indicates that lion problems are spatially heterogeneous. No such association exists for spotted hyaena and jackals. The conservancies in which lions are considered most problematic are also those conservancies in which they are said to be the most common. Though spotted hyaena and jackal conflict receive less attention, more households might potentially benefit from interventions relevant for limiting human-hyaena and human-jackal conflict.

Attitudes Towards Lions

Perceptions of lions' occurrence coincide with lion monitoring data. Results from a lion population survey (Muzuma & Heydinger 2024) completed nearly one year after these social surveys, found lions were absent from Doro !Nawas, Orupupa, Sorris-Sorris, and Tsiseb conservancies. These are the only conservancies in which > 50% of respondents considered lions to be rare or absent – suggesting local pastoralists maintain some understanding of lion movements and prevalence. Though population surveys of other predators have not been attempted, local perceptions of, e.g., leopard, hyaena, or cheetah might be a useful starting point for estimating their population sizes.

Examined attitudes towards lions are most strongly correlated to whether respondents reported benefiting from them; this suggests a foundation for more proactive interventions focusing on financial benefits, rather than only limiting conflict. A recently implemented Wildlife Credits programme, whereby conservancies receive monetary benefits for living alongside lions based upon lion movement data (Heydinger *et al.* 2022; Conservation Namibia 2023), may increase the number of respondents receiving benefits from lions. However, elsewhere in Namibia and neighbouring countries, increased tolerance for wildlife has been primarily linked to nonmonetary, rather than monetary benefits within CBNRM settings (Kansky *et al.* 2020). Why lions persist in certain conservancies may be driven by local tolerance for their presence, as well as by ecological conditions: lions have been shown to be adept at identifying and navigating through "corridors of [human] tolerance" (Dolrenry *et al.* 2020).

While our previous survey found 76% of respondents felt it was important for lions to continue to exist in their conservancy, 60% of respondents to our current survey felt it was *not* important for lions to continue to exist. The number of respondents stating they do not benefit from lions mirrors the previous survey (84%). We cannot attribute the difference in these results to changed geographic scope of our survey versus the previous one. Instead, the decline may have resulted from the added harms from livestock predation on top of the continued impacts of prolonged drought. An alternate possibility is that the existence of HLC interventions has raised the profile of HLC as a local issue with sociopolitical valence: in effect making people more critical of lion presence because they know HLC receives government and NGO attention (Heydinger *et al.* in press). Negative responses by people to human-wildlife conflict often reflect human-human relationships, such as political and socio-economic inequalities, or contrasting values, beliefs, or attitudes (Dickman 2010; Redpath *et al.* 2015). Follow-up surveys will be needed to further interrogate drivers of human attitudes towards lions and other potentially dangerous wildlife (Dickman *et al.* 2014). Among other topics these will include how respondents' sources of information are changing: e.g. our on-the-ground work increasingly finds social media to be a fount of, often inaccurate, information.

Extent of HC Interventions

HLC interventions appear to have had an uneven effect. While respondents generally viewed HLC interventions – the Lion Rangers, RRTs, early-warning system, and predator-proof kraals – favourably, many respondents were unaware of their existence. For the Lion Rangers (44%), RRTs (50%), and early-warning system (50%), approximately half of respondents stated a neutral or unsure attitude towards them – primarily because the respondent felt uninformed of their existence. While much of this can be attributed to interventions being spatially concentrated within HLC 'hotspots,' increasing deployment of these interventions, and better communication regarding their purposes, is needed. Interventions were not evenly distributed across conservancies, though it is worth noting these interventions have continued over the ensuing two-plus years. Simultaneously, attention should be paid to how the implementation of HLC interventions have transformed the social and political contexts of HLC (Jones & Murphree 2004). The existence of a strong positive correlation between attitudes towards the Lion Rangers and whether Lion Rangers had visited a respondent's farm suggests that greater landscape coverage by the Lion Rangers will improve not only awareness but attitudes. Yet, with no correlation between the presence of interventions and attitudes towards lions, simple proximity may not foster tolerance of lions.

To date approximately 120 predator-proof kraals have been erected at conservancy farms, free of charge to the livestock owners. These kraals have been provided specifically as a remedy to HLC. Yet, few pastoralists connect predator-proof kraals with the presence of lions within the landscape or connect predator-proof kraals with benefits from the presence of lions. Lion Rangers and other conservation personnel can engage with pastoralists to facilitate greater understanding of conservation benefits due to lions. Because predator-proof kraals are so positively received, their provision might best foster improved attitudes towards living with lions.

Supporting Livelihoods for Conservation

The overall picture is one in which pastoralists' livelihoods are in trouble in core lion range conservancies; echoing similar economic findings within the region (NNPC 2015; NSA 2021; IFRC 2022). While livelihoods have unquestionably been hampered by the recent drought, conservancies and supporting organisations are also not providing meaningful benefits to many residents. By eroding the economic instrumentalist pillar of the conservancy system, a lack of monetary benefits is already forcing many residents to question each conservancy's purpose. These challenges are exacerbated by HLC and conflict with other carnivore species. The current challenge is how to increase benefits without further sacrificing already degraded environments (NNPC 2015; Inman 2020a, 2020b) and diminished wildlife numbers, all under the shadow of environmental transformations stemming from climate change (Atlas of Namibia 2022). HLC interventions may provide limited mitigation, but these approaches require further refining, including strengthening of conservancy structures. More work and greater creativity will be needed to simultaneously support local livelihoods while fostering positive attitudes towards lions by limiting the negative outcomes of HLC.

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Appendix A: *Summary of demographic and livelihood information for respondents.*

Conservancy	**Number of respondents**	**% of respondents**
Anabeb	30	9.3
Doro !Nawas	18	5.6
Ehi-rovipuka	31	9.6
≠Khoadi-//Hôas	49	15.2
Omatendeka	32	9.9
Orupupa	22	6.8
Puros	31	9.6
Sesfontein	27	8.4
Sorris-Sorris	15	4.6
Torra	46	14.2
Tsiseb	22	6.8
TOTAL	323	100
Sex	**Number of respondents**	**% of respondents**
Male	210	65.6
Female	110	34.4
TOTAL	320	100
Cultural identification	**Number of respondents**	**% of respondents**
Herero	112	34.7
Himba	68	21.1
Damara	111	34.4
Riemvasmaker	14	4.3
Nama	5	1.5
Other	9	2.8
No response	4	1.2
TOTAL	323	100
Family size (median)		**Median**
Number of children		5
Number of grandchildren		2
Age range	**Number of respondents**	**% of respondents**
20–29	20	6.2
30–39	61	18.9
40–49	56	17.3
50–59	72	22.3
Pensioner*	104	32.2
Not recorded	10	3.1
TOTAL	323	100
Do you have income?	**Number of respondents**	**% of respondents**
Yes	179	55.8
Occasional	127	39.6
No	15	4.7
TOTAL	321	100
Sources of livelihoodǂ	**Number of respondents**	**% of respondents**
Pension	110	34.1
Selling livestock	167	51.7
Subsidies for children	27	8.4
Conservancy employee	21	6.5
Government salary	7	2.2
Tourism employee	12	3.7
Other (e.g. selling crafts)	33	10.2
TOTAL	377	

*Respondents either stating they were over 60 years of age or stating they did not know their age but estimated to be over 60, were recorded as pensioners.

ǂNumerous respondents indicated multiple livelihood sources.

Appendix B: *Summary statistics of livestock ownership for all respondents. Mean and median number of livestock owned; skew, Pearson's second skewness coefficient, positive values indicate rightward skew among responses; min, minimum number owned; max, maximum number owned; total, total number owned by all respondents; count, number of respondents.*

Parameter [1]	**Cattle**	**Sheep**	**Goats**	**Donkeys**
Mean	4.5	8.2	38.3	0.9
Median	0	0	25	0
Skew	3.98	3.15	3.14	2.41
Min	0	0	0	0
Max	94	110	361	11
Total	1 460	2 646	12 329	276
Count	322	322	322	322

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Drinking and bathing behaviour of raptors in an arid, warm environment: Insights from a long-term camera trapping study in Namibia

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ABSTRACT

Raptors are thought to obtain much of their water from their food as pre-formed and metabolic water, and therefore not by drinking. However, there are few publications about their behaviour at waterholes to test this idea. This study analysed 6 291 camera trap observations of raptors over 11 years at waterholes in a game reserve located in the warm, arid environment of north-central Namibia. Of 45 species recorded in the area, 12 were never recorded at water, whereas another 13 species were recorded 100 or more times at water. While there, raptors spent most time drinking, standing in the water, or bathing. Diurnal raptors usually visited water in the middle – and heat – of the day while owls were present throughout the night. Most visits to water were between May and November which were the driest months of the year. We found a strong inverse correlation ($p < 0.0001$) between the number of visits and the relative humidity in that month, suggesting that water balance is an important factor driving this behaviour. In general, these findings indicate that many raptors make much greater and seasonally changing use of water than is commonly assumed and appear to do so to help meet their physiological needs for water and thermoregulation. Many other raptors, including most falcons and kestrels, however, have little or no need for drinking or bathing, begging answers to questions about why and how these differences and variations exist. This paper also raises questions about how raptors that visit water frequently will respond to increasing heat and aridity.

Keywords: aridity; bathing; birds of prey; cooling; drinking; heat; Namibia; rainfall; raptors; water requirements

INTRODUCTION

Most terrestrial vertebrates obtain water by drinking or from their food. The majority of raptors are thought to use the latter strategy, using pre-formed water in their food and water produced by the metabolism of food (Houston *et al.* 2007). The general paucity of observations of drinking by birds of prey (Boal *et al*. 2023) supports this assumption. Other than Boal *et al.* (2023), we know of only three substantive papers on drinking by raptors, each focused on one species (Haak *et al.* 2013, Kassara *et al.* 2023, Schoenjahn *et al.* 2024). Slightly more has been published on bathing by raptors; in addition to information on bathing in Boal *et al.* (2023), Haak *et al.* (2013) and Kassara *et al.* (2023) there are studies on bathing by Ristow *et al.* (1980), Holthuijzen *et al.* (1987), Schmidl (1988), Eisermann (2005) and Sazima (2018). Other anecdotal mentions of drinking and bathing are to be found in natural history studies, and falconry handbooks often describe the need to supply captive raptors with drinking and bathing water (e.g. Chitty 2008).

While raptors of some species very seldom or perhaps never visit surface water to drink, bathe or cool themselves (e.g. Schoenjahn *et al.* 2024), other raptors that make frequent use of free water may face challenges in arid environments where surface water from rain is generally seasonal and ephemeral, and access to artificial and modern water sources (such as waterholes) is often compromised, for example by the presence of congregations of larger animals. Water intake is crucial for homeostasis and animals living in these arid environments therefore need reliable strategies to acquire water. These needs may become more critical as arid parts of the earth become hotter and drier.

This paper provides information from a substantial volume of data on the daily and seasonal timing of drinking and bathing by a community of 33 raptor species in an arid environment. Another 12 species of birds of prey recorded in our study area were never recorded at water. The information presented here was recorded from images taken by camera traps placed at 12 waterholes over 11 years in northern-central Namibia, in southern Africa.

METHODS

The data were collected on the 30 000 hectare Ongava Game Reserve (or just Ongava) on the southern boundary of Etosha National Park (the centre of Ongava is roughly at 19.36 South, 15.84 East). Ongava lies about 1 100 masl in a mosaic of flat ground and gently sloping dolomite hills. About 70% of the reserve consists of shrubland and woodland dominated by mopane (*Colophospermum mopane)*, purple-pod terminalia (*Terminalia prunioides)*, sicklebush (*Dichrostachys cinerea)*, trumpet-thorn (*Catophractes alexandri)* and red bushwillow (*Combretum apiculatum)*. Grass cover dominates the remaining 30% of Ongava (Figure 1).

Ongava's climate is semi-arid with an average annual rainfall of 380 mm, most of it falling in summer thunderstorms at irregular intervals between December and March (Figure 2). During these wetter months some surface water may be available in short-lived pools of rainwater and dams which soon evaporate or seep into the soil. During the dry season (May–November) surface water is only available at artificial waterholes. At Okaukuejo, 25 km north and at the same elevation as Ongava, average relative humidity at 14h00 ranges between 22% in the dry season and 44% during the wet season (Figure 2). Air temperatures are highest between September and December with average daily highs of 35˚C. June is the coolest month of the year when average daily maxima are around 25˚C, and night temperatures can drop to freezing point.

We collected data at 12 artificial waterholes distributed between largely open, grass covered areas and light bush and wooded areas elsewhere (Figure 1). Images were captured by Reconyx cameras (RC-55 and HC-500 models) deployed at the waterholes to record visits of mammals. Typically, several cameras were stationed to monitor each waterhole simultaneously. The cameras were generally placed between 5 and 20 metres from the water. Two sets of data collected between July 2009 and October 2019 were available for analysis. The first was from cameras deployed periodically, but more often between May and October than in other months. The second set was collected from cameras deployed continuously over longer periods of up to 20 months at five waterholes (Appendix 1). Both sets provided information on the species visiting water, but analyses of diurnal variance were limited to the 13 species recorded over 100 times at waterholes (Table 1). Information on seasonal changes in behaviour and frequency of visits were derived from the second set but limited to nine species with over 50 independent observations collected at the five waterholes and normalised by the number of days that were monitored by camera traps (Appendix 2).

The data from the camera traps were extracted using the Ongava Research Centre Geo Data Management System (GDMS) camera trap analysis software which processes image sequences collected simultaneously by several cameras and collates data on the species, numbers of individuals and activities seen during discrete bouts of activity (Zett *et al.* 2023). We configured the camera traps to record a burst of 10 images, separated by 1–3 seconds, for each motion-triggered sequence. We set a minimum delay interval of 30 seconds between bursts. All images and their meta-data (dates, times, locations, etc.) were then stored in a database which could be analysed using a range of filters and sorting criteria. For our raptor data set, all relevant images were exported for further analysis with their meta-data. Times reported in this paper are in the GMT + 2 time zone.

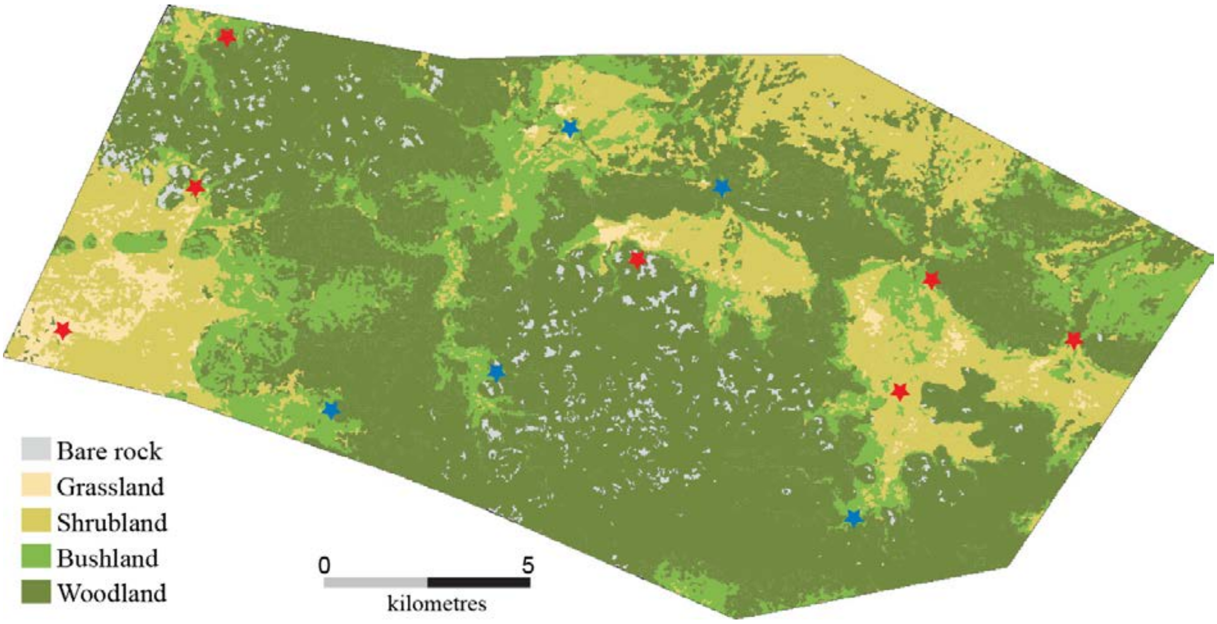

Figure 1: *The vegetation structure (de Cauwer* et al. *2024) of Ongava Game Reserve and the 12 waterholes at which camera traps were deployed. Intensively monitored waterholes are shown by blue stars while red stars mark those which were less intensively monitored.*

The original dataset often contained multiple images from the single visit of a raptor, usually of images taken each time the bird's movement triggered one or more of the cameras. The data from images of the same species with the same age at the same waterhole within a 30-minute period were assigned to a single independent *observation*. We recorded four types of activity or behaviour during each *observation*: drinking, bathing, standing in water, and standing nearby. During any single *observation* each of these activities was recorded once only, regardless of the number of times a bird performed them; four was thus the maximum number of different activities recorded during an *observation*.

Our data are subject to several biases and constraints which we cannot control, and which limited options to test certain ideas. For example, we have no measure of bias due to the sizes of raptors, since larger birds with bigger wings (such as eagles) would activate and be recorded more consistently by camera traps than smaller birds (goshawks and falcons, for instance). Similarly, drinking and bathing involve motion which camera traps would record more often than comparatively motionless standing in water. Whether the cameras were equally sensitive during the days and nights, respectively to diurnal and nocturnal birds, is not known. To what degree the frequency that raptors visit surface water reflects their use of water or their local abundance can't be tested. Of necessity, some cameras were placed closer to waterholes than others, likely increasing the chance of them being triggered by smaller birds at the water. Some independent observations may have been lost by filtering the data into discrete observations with a maximum duration of 30 minutes, but filtering was necessary due to the large number of images that would otherwise have been treated as independent visits. It is also not known what proportion of images were triggered by movements of raptors or coincidentally by larger mammals within view of the same cameras. Thus, for example, the number of birds recorded at water during the heat of the day may be inflated by the heightened presence of large mammals drinking in hot weather. Because motion triggered the cameras, bathing and splashing (see Figure 2) could be recorded more often than drinking when birds simply dipped their beaks briefly into the water, for example. Similarly, the proportion of behaviour recorded will have been biased by the duration of that behaviour relative to the sampling frequency of the camera. Finally, access to surface water varied between waterholes; some with large expanses and margins of water within easy reach of perches that birds could use as they approached the water, but other waterholes were smaller, more often crowded with large mammals, and perhaps less accessible to birds.

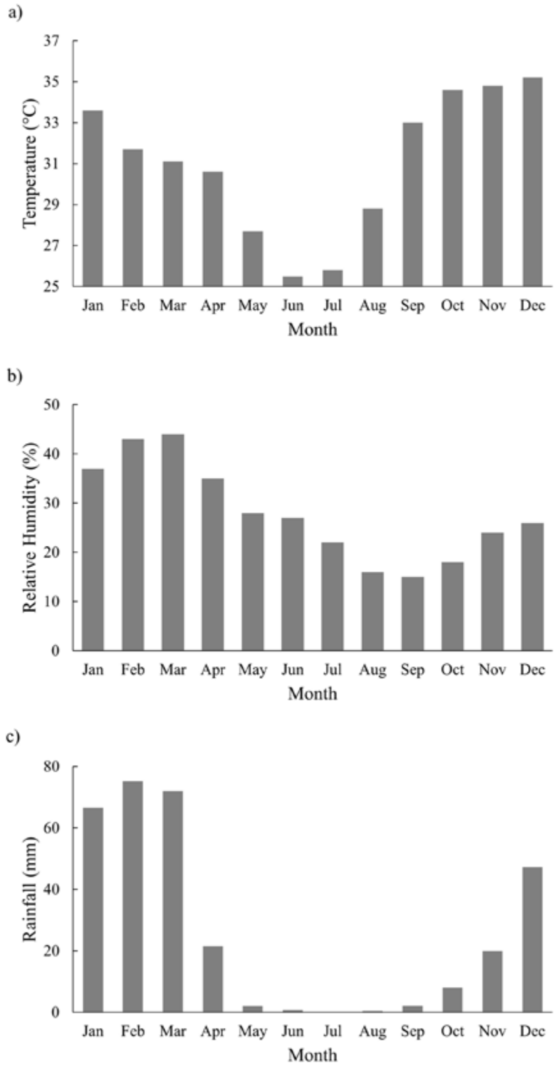

Figure 2: *(a) Average monthly maximum temperature and (b) relative humidity at 14h00 at Okaukuejo recorded by Namibia Meteorological Services http://www.meteona.com, and (c) average monthly rainfall at Ongava for 1981–2021 from https://www.chc.ucsb.edu/data/chirps.*

Sightings of raptors between 1987 and 2024 submitted to the Southern African Bird Atlas Projects (https://sabap2.birdmap.africa/) provided a measure of the presence of different raptors in the Ongava area against which records of raptors at waterholes in the reserve could be compared (Table 1). The SABAP data were limited to quarter-degree squares and pentads that overlie Ongava Game Reserve, each pentad covering an area of 5 x 5 minutes of latitude and longitude. Reporting Rate is a measure of the relative abundance of the species, given here as the percentage of times the species was recorded on full protocol cards.

These data also suffer from biases. For example, raptors vary in how easily they are identified, the times of day they and/or observers are active, the degree to which birds are easily sighted (or heard) or often inconspicuous, and how long different species are present during the year. The frequencies with which

Table 1: *Numbers of records and reporting rate of raptors in the SABAP1 (1986 to 1997) and SABAP 2 survey (2007–2024)*[1] *and photographed at waterholes by the Ongava camera traps. Records of the ten most frequently recorded species in each dataset are in bold.* migrant, ** vagrant.*

Common name	**Scientific name**	**SABAP records**	**SABAP reporting rate %**	**Records at water**
Pale-chanting goshawk	*Melierax canorus*	**116**	41.1	144
Tawny eagle	*Aquila rapax*	**89**	31.6	**524**
Bateleur	*Terathopius ecaudatus*	**61**	21.6	77
Secretary bird	*Sagittarius serpentarius*	**55**	19.5	**289**
Pearl-spotted owlet	*Glaucidium perlatum*	**54**	19.1	0
Lanner falcon	*Falco biarmicus*	**49**	17.4	2
Barn owl	*Tyto alba*	**47**	16.7	**324**
Greater kestrel	*Falco rupicoloides*	**45**	16	1
Gabar goshawk	*Micronisus gabar*	**42**	14.9	**395**
White-backed vulture	*Gyps africanus*	**39**	13.8	**353**
Lappet-faced vulture	*Torgos tracheliotos*	32	11.3	**196**
Black-chested snake-eagle	*Circaetus pectoralis*	26	9.2	**161**
Black-winged kite**	*Elanus caeruleus*	25	8.9	1
Red-necked falcon	*Falco chicquera*	19	6.7	1
Martial eagle	*Polemaetus bellicosus*	16	5.7	48
African harrier-hawk**	*Polyboroides typus*	15	5.3	15
African hawk-eagle	*Aquila spilogaster*	15	5.3	**2 928**
Shikra	*Accipiter badius*	14	5	100
Spotted eagle-owl	*Bubo africanus*	14	5	**148**
African scops owl	*Otus senegalensis*	11	3.9	0
Rock kestrel	*Falco rupicolus*	11	3.9	2
Common buzzard*	*Buteo buteo*	10	3.5	12
Black kite/yellow-billed kite*	*Milvus migrans/parasitus*	8	2.8	5
Brown snake-eagle	*Circaetus cinereus*	8	2.8	41
Pygmy falcon	*Polihierax semitorquatus*	8	2.8	0
Southern white-faced scops owl	*Ptilopsis granti*	6	2.1	1
Verreaux's eagle	*Aquila verreauxii*	6	2.1	**355**
Little sparrowhawk**	*Accipiter minullus*	5	1.8	2
Bat hawk**	*Macheiramphus alcinus*	2	0.7	0
Cape vulture**	*Gyps coprotheres*	2	0.7	2
Ovambo sparrowhawk	*Accipiter ovampensis*	2	0.7	2
Wahlberg's eagle*	*Hieraaetus wahlbergi*	2	0.7	0
White-headed vulture**	*Trigonoceps occipitalis*	2	0.7	8
Booted eagle**	*Hieraaetus pennatus*	1	0.4	0
Dark chanting goshawk**	*Melierax metabates*	1	0.4	0
Giant eagle-owl	*Bubo lacteus*	1	0.4	7
Hooded vulture**	*Necrosyrtes monachus*	1	0.4	0
Lesser kestrel*	*Falco naumanni*	1	0.4	0
Lizard buzzard**	*Kaupifalco monogrammicus*	1	0.4	0
Marsh owl**	*Asio capensis*	1	0.4	7
Peregrine falcon**	*Falco peregrinus*	1	0.4	0
Red-footed falcon*	*Falco vespertinus*	1	0.4	0
Augur buzzard	*Buteo augur*	0	0	139
Lesser spotted eagle*	*Clanga pomarina*	0	0	1
Steppe eagle*	*Aquila nipalensis*	0	0	1
TOTAL		865		6 292

[1] SABAP1 quarter-degree squares covering the Ongava Game Reserve were 1915BD and 1915BC for which 142 cards were submitted. For SABAP2 140 cards were submitted for the pentads covering the same area: 1915_1540, 1915_1545, 1915_1550, 1915_1555, 1920_2040, 1920_2045, 1920_2050, 1920_2055. The SABAP2 data were retrieved from https://sabap2.birdmap.africa/ on 10 August 2024.

different species were recorded (Table 1) thus only provide an approximation of their abundance in and around Ongava.

We used simple linear regression to test for relationships between selected dependent and independent variables. In each case we checked that the dependent variable was continuous and then normally distributed using the Shapiro-Wilk test (shapiro.test, R, V4.0.0, R Core Team, 2024). If this test showed that the distribution of the dependent variable was not significantly different from a normal distribution ($p > 0.05$), we used the Regression tool in Microsoft Excel to calculate correlation coefficients (r^2) and p-values; p-values < 0.05 were considered to indicate a significant linear relationship.

RESULTS

A total of 6 291 observations of raptors were recorded from 3 868 trap days (24h period) between July 2009 and October 2019. Of the 45 species recorded in and around Ongava, 34 were recorded at water and 13 of them were recorded 100 or more times at water (Table 1).

There was a considerable disparity between the species recorded by the SABAP surveys and those recorded at waterholes in the same area at Ongava (Table 1). We found no correlation between SABAP reporting rate (%) and our record counts ($r^2 = 0.0006$, $p > 0.5$). For example, African hawk-eagles and Verreaux's eagles were frequent visitors to water but seldom recorded by SABAP observers. Augur buzzards were recorded at water in 139 separate camera trap observations but were never reported in the SABAP data. Augur buzzards and Verreaux's eagles usually nest on tall cliffs, of which there are none in the Ongava area, but both are known to nest in trees (Hockey *et al.* 2005), as did at least one pair of Verreaux's eagles at Ongava (personal observations). We also found no correlation between the average mass for a raptor species (see Table 2) and our record counts ($r^2 = 0.0034$, $p > 0.5$, $n = 21$ for species counted more than 5 times).

The predominance of African hawk-eagles, which were recorded during 2 928 separate observations – or 46.5% of all the observations of raptors at water – was perhaps partly due to their relative abundance, there being three or four African hawk-eagle pairs resident on the Ongava Game Reserve, compared to one pair of martial eagles and secretary birds, and one or two pairs of Verreaux's eagles and black-breasted and brown snake-eagles (personal observations). Gabar and pale-chanting goshawks and barn owls were recorded at water relatively infrequently but were the most abundant raptors on Ongava (personal observations).

By contrast, 22 raptor species recorded in the SABAP data were seldom (3 or fewer times) recorded drinking, bathing or standing in water. Ten of these species were never recorded at water. Of eight species of falcons and kestrels reported in the area, four were never recorded at water while the other four were recorded just once or twice at water, suggesting that this group of raptors obtain all or the great majority of their water from prey (Table 1). Migrant and vagrant raptors were seldom recorded at water.

Table 2: *Percentages of different behaviours or activities in waterholes recorded in the camera trap images for 13 species recorded 100 or more times at waterholes. The raptors are grouped according to their preferred prey*[1]*. Records of birds standing away from water are not included. Average mass is from AVONET (Tobias* et al. *2022) which in turn derives mass data from Dunning (2008). Entries for African hawk-eagle and gabar goshawk are indexed in AVONET by their synonyms* Hieraaetus spilogaster *and* Melierax gabar *respectively.*

Species	Drinking (%)	Standing in water (%)	Bathing (%)	Prey group	Average mass (g)
African hawk-eagle	48.7	43.6	7.7	1	1 466
Verreaux's eagle	70.7	21.4	7.8	1	4 195
Tawny eagle	59.0	36.2	4.8	2	2 236
White-backed vulture	76.7	9.5	13.7	3	5 433
Lappet-faced vulture	86.8	2.8	10.4	3	6 969
Black-chested snake-eagle	81.2	17.8	1.0	4	1 500
Secretary bird	89.0	10.1	0.9	5	4 017
Augur buzzard	42.3	39.7	18.1	5	1 099
Pale chanting-goshawk	69.4	26.1	4.5	5	663
Spotted eagle-owl	56.4	38.3	5.4	5	645
Barn owl	72.5	25.7	1.8	5	403
Gabar goshawk	72.4	22.2	5.4	6	169
Shikra	75.0	22.6	2.4	6	131

[1] Prey groups: 1 – large birds and mammals; 2 – carrion, mammals and birds; 3 – carrion; 4 – snakes and small mammals; 5 – small animals; 6 – small birds.

a) Verraux’s eagle bathing

b) Pale chanting goshawk bathing

c) Shikra standing in water

d) African hawk-eagle standing in water

e) Secretary bird drinking

f)Tawny eagle drinking

g) Augur buzzard landing

h) Barn owl standing at edge of waterhole

Figure 3: *Examples of images recorded at waterholes of birds of prey at Ongava Game Reserve, Namibia.*

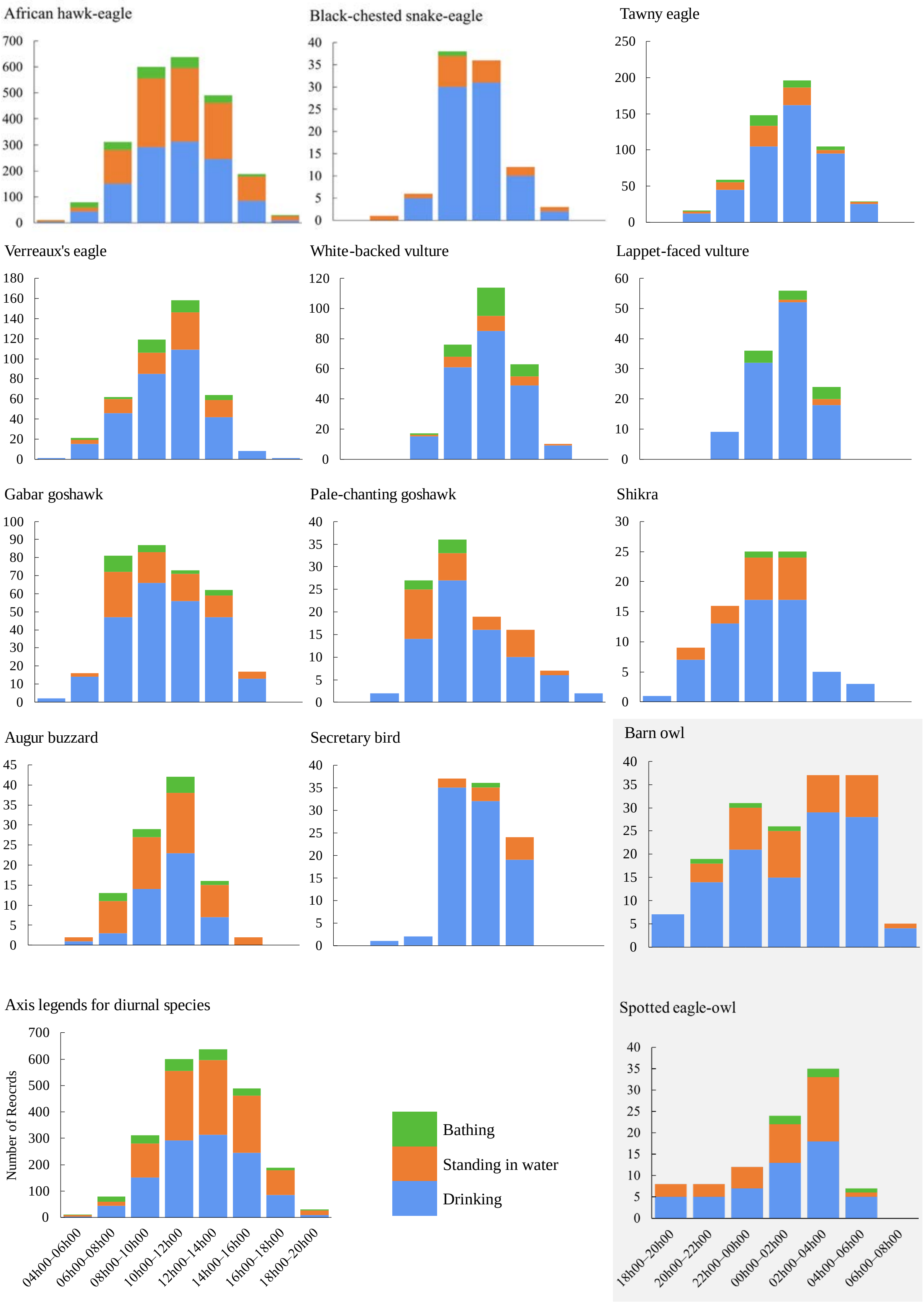

Figure 4: *Numbers of records of drinking (blue), standing in water (orange) and bathing (green) during the day for the 13 raptor species most frequently recorded at waterholes. Note that the x-axis is different for diurnal (white background) and nocturnal (shaded background) species.*

Nine other species were recorded between 5 and 99 times using water, and 13 more species were recorded 100 or more separate times at waterholes (Table 1).

Secretary birds and vultures were only observed at waterholes in open, sparsely vegetated areas. By contrast, sparrowhawks, goshawks and owls were more frequently recorded in wooded areas. Eagles were observed regularly in both wooded and open areas but were absent from waterholes in densely wooded areas.

Drinking usually occurred when a bird perched on the lip of a waterhole or stood in shallow water at its edge (Figure 3). While standing in water birds typically stood motionless, often with their bellies submerged. To bathe, all species usually waded into deeper water where they would splash water over their feathers and then preen before leaving the water. Behaviour recorded as ‘standing nearby’ normally referred to birds perched on a branch or on the ground near the waterhole edge. Two or more of these behaviours were often recorded during an observation. For example, a bird would first drink, then stand in the water for a while, then bathe, and later stand nearby on the ground, perhaps to dry off.

We could not measure the duration of bathing, standing in water and drinking, but the frequencies reported in Table 2 provide approximations of the proportions of times spent engaged in the three activities. Drinking predominated, for most species making up 70% or more of the recorded behaviour. Exceptions are the even higher frequencies of drinking records by secretary birds, lappet-faced vultures and black-chested snake-eagles, but lower frequencies of drinking by augur buzzards, and African hawk-eagles (Table 2).

After drinking, standing in water accounted for the majority of other records for most species. Exceptions were the short times spent standing in water by lappet-faced and white-backed vultures and secretary birds. African hawk-eagles, augur buzzards, tawny eagles and spotted eagle-owls were recorded standing in water most often.

Ten of the 13 species listed in Table 2 were recorded bathing less than 10% of the time, and for most species bathing was noted in 5% or less of the records. Exceptions were higher frequencies of bathing by the two vultures and augur buzzards. By contrast, black-chested snake-eagles, barn owls and secretary birds seldom bathed.

Datasets for proportion of time spent drinking, standing in water and bathing were all found to be normally distributed (Shapiro Wilk $p > 0.5$ in each case. We found no significant correlation between either drinking or bathing (%) and the average mass of a species ($r^2 = 0.2265$, $p > 0.1$ and $r^2 = 0.1259$, $p > 0.2$ respectively). However, there was a significant inverse correlation between the percentage of time spent standing in the water and average mass ($r^2 = 0.4618$, $p < 0.02$) – larger species spent less time standing in the water.

Table 3: *Mean and standard deviation of the times that raptors arrived at waterholes. Times are expressed using the 24-hour clock starting at midnight (GMT + 2 hrs). The standard deviations and means are in hours and minutes.*

Species	Mean time of day	Standard deviation
Spotted eagle-owl	00h13	2h 58m
Barn owl	01h26	3h 19m
Shikra	11h15	2h 26m
Gabar goshawk	11h51	2h 35m
Verreaux’s eagle	11h57	2h 12m
Pale chanting goshawk	12h17	2h 54m
Black-chested snake-eagle	12h25	1h 44m
Lappet-faced vulture	12h26	1h 32m
Augur buzzard	12h28	2h 07m
African hawk-eagle	12h31	2h 39m
Tawny eagle	12h42	2h 12m
Secretary bird	12h45	1h 55m
White-backed vulture	13h09	1h 55m

Table 4: *Mean and standard deviation of the time of day when African hawk-eagles were recorded arriving at waterholes each month, and the time of solar noon at Okaukuejo in Etosha National Park (on the 15th of each month in 2013, GMT + 2hrs). Sample sizes were very small in February, March, April and December thus standard deviations were not calculated for those months.*

Month	Mean time of day	Standard Deviation	Mid-month solar noon
January	12h53	2h 30m	13h05
February	13h41		13h10
March	10h23		13h04
April	11h45		12h56
May	12h29	2h 38m	12h52
June	12h38	2h 43m	12h56
July	12h37	2h 36m	13h01
August	12h55	2h 38m	13h00
September	12h03	2h 38m	12h51
October	12h25	0h 39m	12h41
November	12h45	2h 39m	12h40
December	13h09		12h51

Several species spent considerable time perched in nearby trees or standing a few meters from waterholes, such as the two owls, black-chested snake-eagles and secretary birds, while others seemed not to dally much near water, such as tawny eagles, Verreaux’s eagle, shikras and gabar goshawks.

Diurnal raptors usually visited waterholes during the middle of the day (Table 3 and Figure 4). The smallest of them – shikras and gabar goshawks –

often visited waterholes earlier in the morning than other diurnal raptors. African hawk-eagles were observed at waterholes on average at 12:31 (standard deviation 2 hours 39 minutes). The averages for each month were usually between 12:00 and 13:00, but somewhat later in February and earlier in March (Table 4).

Secretary birds, white-backed and lappet-faced vultures concentrated their visits during the middle of the day between 10h00 and 16h00, whereas visits to water by other diurnal species increased gradually from about 07h00 until midday and then declined until about 18h00. Most visits by diurnal raptors were thus during the heat of the day. Owls visited water throughout the night, with the frequency of their visits increasing from dusk until one or two hours before dawn (Figure 4).

Bathing occurred most often in the first half of the day or night; indeed, bathing by diurnal raptors was seldom recorded after 15h00. Drinking was recorded throughout the day, and the proportion of drinking and standing in water varied in approximate unison during the day (Figure 4), perhaps because it was easier to drink while standing in the water than from the edge of a waterhole.

African hawk-eagles visited waterholes most frequently during the driest months of the year (May to November) (Figure 5). The same pattern held for an aggregation of other species, including owls. Of visits to water by barn owls, 67% were in August, September and October, and 75% of observations of spotted eagle-owls were in September and October. Among some exceptions were Verreaux's and tawny eagles which were recorded at water only in the hottest months of October, November and December.

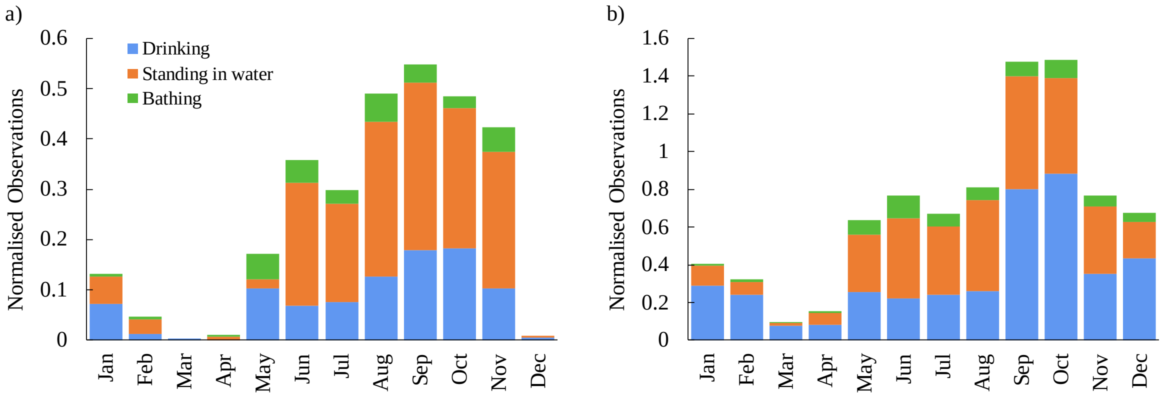

Figure 5: *Numbers of observations of raptors drinking (blue), standing in water (orange) and bathing (green) each month divided by the number of days per month monitored with camera traps (Appendix 2) for (a) African hawk-eagles and (b) the eight other raptors most frequently recorded at waterholes.*

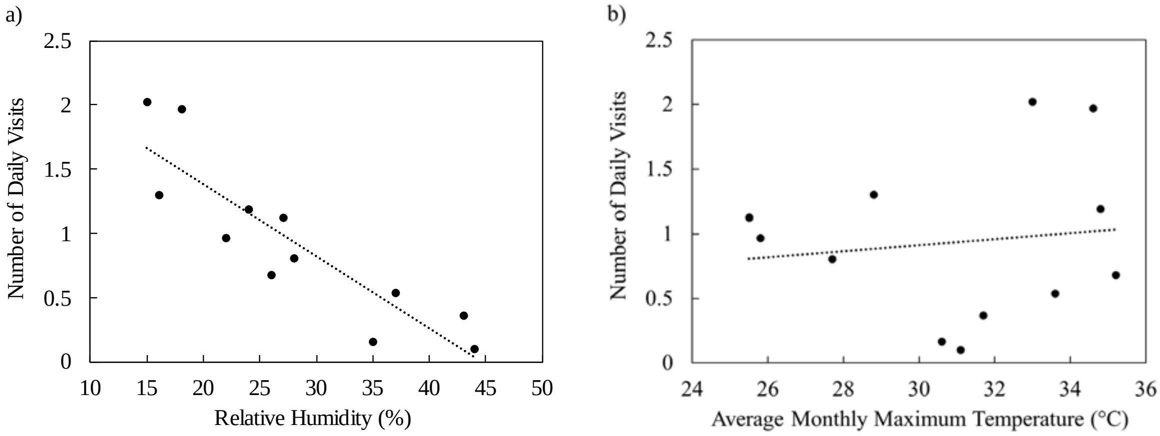

Figure 6: *The correlation between (a) average relative humidity at 14h00 per month and (b) average monthly maximum temperatures with the number of visits to water by all raptors per day divided by the number of days per month monitored with camera traps (Appendix 2, Shapiro-Wilk W = 0.941, p = 0.511). For humidity there is a significant inverse correlation (r^2 = 0.7831, p < 0.0001), but there is no significant correlation for temperature (r^2 = 0.0161, p > 0.5).*

While waterhole visits were generally most frequent in the coolest and driest months, the strongest (inverse) correlation with waterhole visits was relative humidity (Figure 6), with an r-squared value of 0.78 ($p = 0.00013$) between the frequency of waterhole visits per month and relative humidity. Indeed, waterhole visits were several times more frequent in in the driest months than in the wetter and hotter months.

DISCUSSION

The findings presented here indicate that many raptors make more use of standing surface water than implied by the paucity of published information. This is true for the 11 diurnal raptors and two owls that were recorded 100 or more times using surface water. However, comparisons of the frequency of records at water and field sightings indicate that many species make little or no use of surface water.

Some differences between species were likely due to their respective sizes, larger birds being more likely to trigger camera traps than smaller ones (Glen *et al.* 2013; Mills *et al.* 2019). However, small gabar goshawks, barn owls and shikras were also often recorded by the camera traps and much more often than many larger raptors in the area. Indeed, we found no correlation between average adult raptor mass and frequency of drinking. Taken together, these data and observations indicate that there is a great deal of variation in the use of surface water between species and at different times of the year and day. Very small raptors, such as pygmy falcons, pearl-spotted owlets and African scops-owls, may just be too small to trigger cameras reliably. From the list of species recorded in the Ongava area and at waterholes, we detected no obvious patterns between the frequencies with which different raptors used surface water and their phylogeny, habitat, or food preferences.

However, among species that made frequent use of surface water their visits to waterholes were most frequent during the hottest times of the day and during the driest times of the year than during the most humid and rainy months. Those patterns together with their frequent drinking, bathing and standing in water behaviour suggest that the maintenance of water balance and, to a lesser extent, direct cooling are important motives for visiting water holes. It is also possible that raptors had been attracted to waterholes to hunt, as reported by Cade (1965) and Jenkins & Davies (2005) and had then stopped incidentally to drink, bathe or stand in the water. Our camera traps recorded several images of prey being caught at waterholes in Ongava.

Possible interspecific differences in needs for surface water are also reflected by the different frequencies with which they were recorded drinking, standing in water and bathing. For instance, drinking and standing in water might have been most important for African hawk-eagles, while the two vulture species and augur buzzards bathed more frequently than other species. And several species first bathed before drinking and standing in water, suggesting a different ordering of apparent priorities.

But some – such as martial eagles, augur buzzards, black-chested snake-eagles, barn owls and secretary birds – seldom bathed and thus perhaps had little need to bathe. Most of these are large birds with little risk of drowning or attack by other predators while being waterlogged in shallow waterholes, reasons that have been advanced by Anderson (2000), Anderson *et al.* (1999) and Peeters & Peeters (2005) to explain the relative infrequency of bathing by other species. Our results show that larger birds spend relatively less time standing in the water which supports this reasoning. While drinking and cooling may be important uses of surface water during the heat of the day and in the driest months, other species-specific factors may be at play. For example, gabar and pale chanting goshawks usually visited waterholes earlier than other diurnal raptors, and Verreaux’s eagles were only recorded at water in December. Most species also began making frequent visits to waterholes in the coolest winter months of May, June and July, just a few months after the summer rains.

Our findings suggest that some raptors make frequent use of water, perhaps even relying on surface water to help meet their physiological requirements for water and temperature regulation, and perhaps to maintain their plumage. Moreover, this reliance seems to be driven by relative humidity, rather than temperature. Other raptors have little or no such need for standing or surface water, which raises questions around water balance maintenance and cooling – noting the high metabolic costs of thermoregulation that accompany hot conditions (Gerson *et al.* 2014; Van Dyk *et al.* 2019). We wonder too about the value and use of water by raptors to counter the hotter and drier weather that southern Africa can expect in the future (Engelbrecht *et al.* 2024). To what degree these birds will require greater use of surface water for cooling remains unknown. We encourage studies to investigate these and other questions. Camera-trap and video monitoring (e.g. Smit *et al* 2019) together with computer-based processing to identify birds and their behaviour should make these studies easier and more enlightening.

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Appendix 1: *Dates and days of camera trap deployment at waterholes in Ongava monitored over long periods in 2012-2015. All recordings made from 01/01/2012 to 31/12/2014 were used in the monthly behavioural analysis.*

Waterhole	Start	Stop	Duration in days
Margo	10/01/2012 24/04/2013	05/11/2012 30/12/2014	300 615
Onduri	17/07/2012 27/04/2013 05/03/2014	01/11/2012 28/09/2013 04/01/2015	107 154 305
Roland's Pos	05/01/2012 04/05/2013	03/11/2012 05/01/2015	303 611
Suiderkruis	01/01/2012 30/04/2013 10/03/2014	02/11/2012 24/09/2013 18/10/2014	306 147 222
Tiervlei	30/04/2012 24/04/2013	31/10/2012 29/12/2014	184 614
Total			3 868

Appendix 2: *The number of days each month that waterholes were monitored in Ongava over long periods between 2012 and 2015.*

Month	Days monitored
January	182
February	171
March	235
April	260
May	431
June	420
July	449
August	465
September	442
October	390
November	222
December	214

A preliminary botanical assessment of an isolated inselberg archipelago in the Namib Sand Sea, Namibia

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Abstract

The inselbergs of the Namib Desert serve as biodiversity refugia in a matrix of largely depauperate gravel plains or sand dunes. Despite their ecological importance and expected species richness, the biota of most Namib inselbergs has not been surveyed. An isolated and previously unexplored inselberg archipelago in the northeastern corner of the Namib Sand Sea was visited in December 2023. A preliminary botanical assessment recorded 42 plant species across three inselberg sites. The floristic survey was conducted by walk-over assessments and capturing photographic records that were uploaded to iNaturalist for public access. Euphorbia Koppie exhibited the highest diversity at 38 species, attributed primarily to its larger size and habitat heterogeneity, while the smaller Commiphora Koppie and Owl Koppie recorded 16 and 14 species respectively. Frequently recorded species across all three sites include *Commiphora saxicola*, *Cleome angustifolia* subsp. *diandra*, *Caroxylon* sp., *Euphorbia glanduligera*, *Tephrosia dregeana*, *Tetraena cylindrifolia* and *Stipagrostis ciliata*. This survey contributes valuable baseline data for future biodiversity assessments and conservation efforts in the Central Namib Desert at a time of increasing threat from tourism, infrastructure development, mineral prospecting, poaching and mining activities.

Keywords: Central Namib, inselberg, floristic diversity, Namib Desert, Namib Sand Sea, Namibia

Introduction

The Namib Sand Sea lies on the coastal plain in the Namib Desert, Namibia, between the Khoichab Depression in the south and the Kuiseb River in the north, reaching inland as far as the base of the Great Escarpment (Lancaster 1989, Stone 2013). Inselbergs of varying size and geology are found across the Namib Desert (Jürgens & Burke 2000) and represent islands of biodiversity that provide refuge habitats in a landscape that largely consists of open plains (Larson 2001). Despite their ecological significance, only a small number of inselbergs in the Namib Desert have been extensively floristically surveyed (Nordenstam 1974, Burke *et al.* 1998); the majority lack inventories for any biota.

Most inselbergs within the extensive dune fields of the Namib Sand Sea are located in its southern half (Namibia National Committee for World Heritage 2012), with the exception of a small archipelago in the northeastern corner. This archipelago is surrounded by a relatively narrow sequence of dunes that run parallel to the Kuiseb Canyon in the north, Tsondabvlakte in the south, and terminate near Saagberg in the east. The inselbergs are the southwestern-most outcrops of the Mahonda and Haris Formations of the Hakos Group along the southern margin of the Damara Supergroup, consisting of quartzites, amphibolites and mica schists that are well exposed in the Kamsberg (Hoffmann *et al.* 1994). As far as the authors are aware, these inselbergs have never received a biodiversity assessment of any kind. Furthermore, sites 1 and 2 (Figure 1) showed no evidence of having ever been visited by motor vehicles.

Unlike other inselbergs in the Central Namib Desert that are surrounded by gravel plains, this archipelago is surrounded by dunes. Sand dunes can change formation and position quite considerably over the course of even a few thousand years (Bristow *et al.* 2007). This suggests that the inselbergs, particularly the lower ridges, are likely to have been repeatedly submerged by encroaching dunes and re-exposed over time. Therefore, these inselbergs may provide a rare opportunity to study plant succession dynamics on recently exposed habitable substrate in an otherwise inhospitable matrix. Extensive exposures of the Tsondab Sandstone Formation around these inselbergs, gullies in Kamberg Calcrete Formation abutting Euphorbia Koppie along its southeastern side, and the relatively low dunes and absence of steep sand ramps suggest that these inselbergs have never been totally submerged by dunes, that would have ensured the extirpation of all lithophilic or petrophilic biota.

This survey forms part of a wider effort to document the flora of the Central Namib, in particular inselberg diversity, at a time when much of the Namib Desert is at risk of destruction from increasing tourism (Tay 2013), exploration and mining concessions (Wassenaar *et al.* 2013), poaching (The Namibian 2020) and infrastructure installations such as communication towers. As this is the first publication to document these inselbergs in any form, we additionally include *ad hoc* observations about fauna, geology and archaeology.

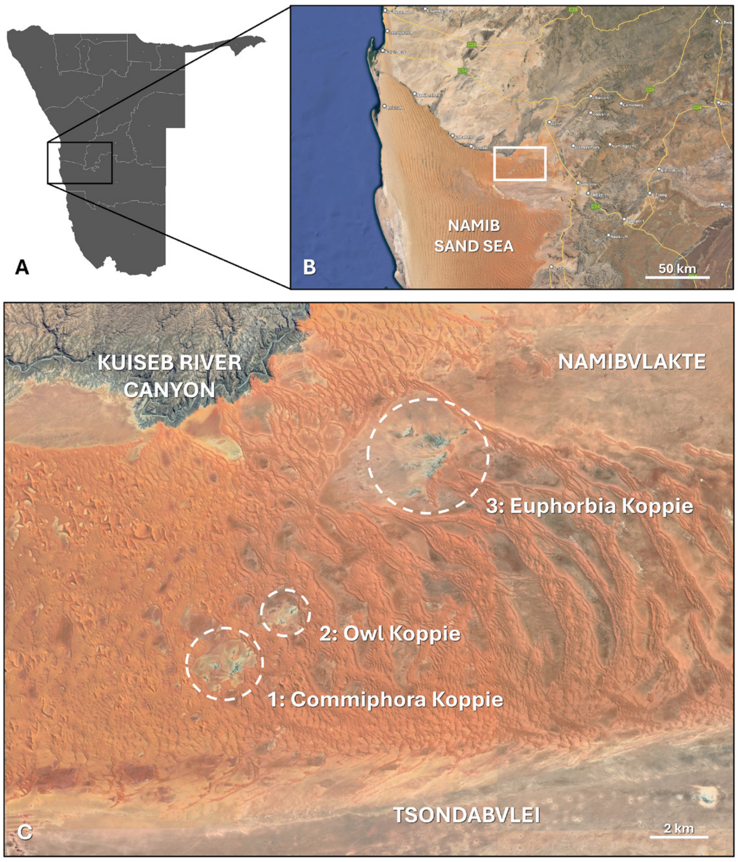

Figure 1: *The location of the inselberg sites. A) The position of (B) within Namibia is indicated by the black square. B) The position of (C) is indicated by the white square. C) The three sites inselberg sites are circled and named: Site 1 (Commiphora Koppie), Site 2 (Owl Koppie) and Site 3 (Euphorbia Koppie).*

Materials and Methods

The authors visited the three inselberg sites in a single trip over three days (4th–6th December 2023). Plant diversity was assessed on each inselberg by a thorough walk-over survey, with photographic observations made of each new plant species record at each site. Photographic observations were selected in place of collecting herbarium specimens to minimise disturbance to the site. Furthermore, the abundance of already dead and dried plant matter would prove unsuitable for the pressing of specimens. The three inselberg sites were considered as distinct because they were separated by at least a 1 km belt of dunes or sand plains from another rocky outcrop. Species inventories were generated for each of the three sites. Although it would have been optimal to conduct the survey following rains, precipitation in the Central Namib is extremely infrequent and difficult to predict (Seely & Louw 1980). Therefore this is considered to be a preliminary survey, with the intention of returning for a follow-up survey after considerable rainfall. Additional informal notes were made on fauna, geology and archaeology of interest.

Both recent and historic maps were thoroughly searched to find existing names for these inselbergs but, with the exception of Site 3, no names were located. Discussions with nearby residents and past associates of Gobabeb also yielded no results. Therefore, we have provided suggested names for the inselberg sites, in each case named after a prominent or remarkable natural feature of the site. Site 1 is named 'Commiphora Koppie' after the large and old *Commiphora saxicola* encountered here. Site 2 is named 'Owl Koppie' after the two individuals of *Bubo* sp. encountered here. Site 3 had informally been labelled 'Euphorbia Hill' by former staff at Gobabeb - Namib Research Institute; a name that has been used in at least one published paper (Wenndt *et al.* 2021). This name is conserved here with Site 3 referred to as 'Euphorbia Koppie' after the abundance of *Euphorbia virosa* across the rocky slopes and surrounding washes.

Photographic observations were accompanied with a date, time and geographic coordinates. Photographic observations were uploaded to iNaturalist (iNaturalist.org 2024), where they can be accessed following the reference numbers cited in Appendix 1. Species identifications were carried out by Sebastian Hatt and Gillian Maggs-Kölling at Gobabeb - Namib Research Institute, with consultation of taxonomic revisions, floras, and herbarium specimens and catalogues at GBB, WIND, PRE and K. Herbaria abbreviations follow Index Herbariorum (Thiers 2024). Species classification and nomenclature follows Plants of the World Online (POWO 2024) and APG IV *et al.* (The Angiosperm Phylogeny Group 2016) for angiosperms. Names may deviate from these resources where expert opinion suggests otherwise. Abundance of each species was recorded by sight and subjectively assigned to the A.C.F.O.R. scale (Morris & Therivel 1995).

Results

A total of 42 plant species was recorded across the three inselberg sites, each vouchered as a photographic observation uploaded to iNaturalist (iNaturalist.org 2024). Figure 2 illustrates a selection of the flora and fauna species recorded. An annotated checklist is presented in Appendix 1, with notes on habitat and abundance.

Inselberg Site 1: Commiphora Koppie

Site 1 (Figure 3A) consists of an approximately rectangular interdune plain, c. 3 x 2.5 km, at an elevational range of c. 760–820 m, lying adjacent and connected to a plain about half this size to the north. Site 1 is separated from Site 2 by c. 1 km of uninterrupted sand dunes. The dominant inselberg (Figure 3B) at this site, c. 1.6 x 0.4 km, lies at the eastern edge of the plain and at its peak reaches an elevation of c. 80 m above the surrounding terrain. The southwestern tip of this ridge becomes gradually submerged by sand dunes, with occasional areas of bare rock until the edge of the plain. Running parallel at c. 0.75 km to the northeast is a string of three exposed outcrops, each no more than 300 m across. The inselbergs are predominantly Damara sequence quartzite and mica schist, while the surrounding plains are dune sands of the Sossus Sand Formation, and weathered remnants of Kamberg Calcretes and the Karpfenkliff Conglomerate Formation that overlie exposed patches of Tsondab Sandstone.

A total of 16 species was observed at this site. The inselbergs form the primary habitat for plants, followed by the dunes themselves, which harbour dune-adapted specialists. *Stipagrostis ciliata* (Desf.) De Winter is dominant across the inselberg surface, apparently suited to every available niche from rocky crags to dune sands. Also abundant across most rocky surfaces is *Cleome angustifolia* subsp. *diandra* (Burch.) Kers, readily identified in its dried state by the distinctive bristle-like glands on the basal stem. Several species frequently observed across most of the rocky slopes at this site include: *Caroxylon* sp. (Figure 3C), the taxonomy of which is in urgent need of revision, *Tetraena cylindrifolia* (Schinz) Beier & Thulin, *Tephrosia dregeana* E.Mey. (Figure 3D), *Euphorbia glanduligera* Pax (Figure 2C) and *Commiphora saxicola* Engl. Individuals of *Commiphora saxicola* were relatively young (< 0.5 m tall, stems to 100 mm thick) across the inselbergs, with the exception of a small rocky outcrop on the northeastern edge of the plain where several individuals had attained considerable size and age (Figure 3E), reaching over 1.5 m in diameter with stems to 300 mm thick. Both the rocky outcrop and the basal stems of several *Commiphora* were considerably submerged in sand. The age of the *Commiphora* here may

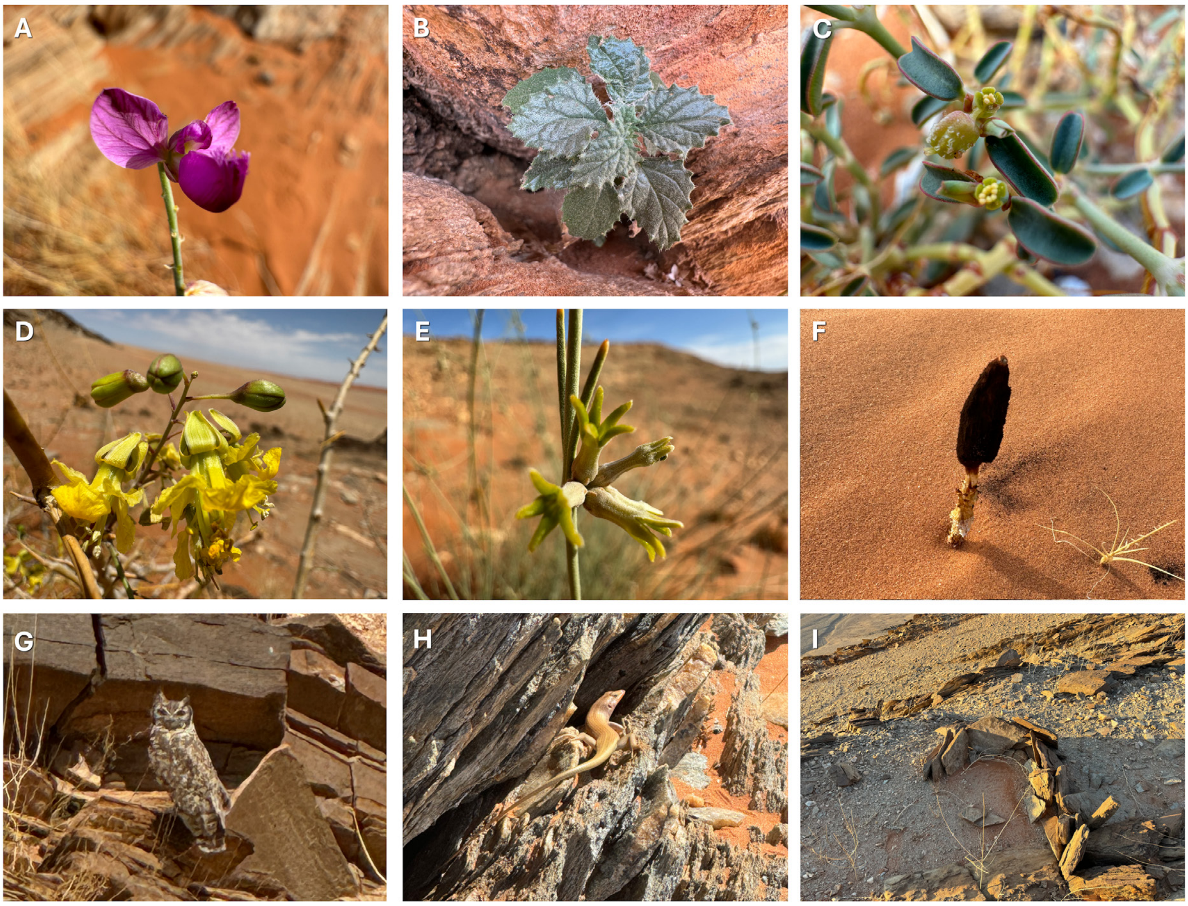

Figure 2: *Characteristic flora and fauna of the inselberg archipelago. A)* Polygala guerichiana. *B)* Forsskaolea candida. *C)* Euphorbia glanduligera. *D)* Parkinsonia africana. *E)* Orthanthera albida. *F)* Podaxis *sp. G).* Bubo *sp. H)* Trachylepis sulcata. *I) Suspected stone circle at Site 1. All photos by Sebastian A. Hatt.*

indicate that this is one of the older exposed rocky areas at this site, but is now in the process of being submerged by the surrounding dunes.

Polygala guerichiana Engl. (Figure 2A) and *Orthanthera albida* Schinz (Figure 2E) were infrequent and only found on the larger inselberg. *Osteospermum microcarpum* (Harv.) Norl. and a single *Trichodesma africanum* (L.) Sm. were located at the base of a small valley, where rain run-off from the mountain presumably concentrates water and nutrients. Two live and apparently healthy *Acacia erioloba* E.Mey. trees were located at the southeastern tip of the larger inselberg (Figure 3F), on a rocky area partially submerged by sand, while an additional dead trunk was located nearby. Dried stem remnants of *Sarcocaulon* aff. *marlothii* Engl. were located near one of the smaller inselbergs, but no live or intact individual was found.

The dune sands immediately surrounding the plain were dominated by *Stipagrostis sabulicola* (Pilg.) De Winter hummocks and *S. ciliata*. Less frequently scattered amongst these are *Stipagrostis seelyae* De Winter and *Kohautia ramosissima* Bremek. However, it important to note that this survey did not extensively cover the adjoining dunes and instead focused on the inselbergs and plains. Thus, other common dune specialists such as *Hermannia minimifolia* E.Holzh., *Cladoraphis spinosa* (L.f.) S.M.Phillips and *Stipagrostis lutescens* (Nees) De Winter are likely found here but were not observed.

Inselberg Site 2: Owl Koppie

Site 2 (Figure 4A) consists of an approximately triangular interdune plain, c. 2.4 x 2.2 km, at an elevational range of c. 800–830 m. Site 2 is separated from Site 3 by c. 6.5 km of sand dunes interrupted with occasional interdune plains. An inselberg-ridge (Figure 4B–D), briefly interrupted in the middle by a small area of flat ground, lies roughly in the centre of the plain, measuring c. 1.4 x 0.2 km and reaching an elevation of c. 40 m above the surrounding terrain. The southwestern tip becomes gradually submerged by sand dunes, with occasional areas of bare rock until the edge of the plain. This ridge forms a continuation of the ridges in Site 1, and thus shares its geology. An extensive area of exposed Tsondab sandstone ridges occurs along the outer margin of the plain to the southwest of Site 2 (Figure 4F). A number of animal-dug

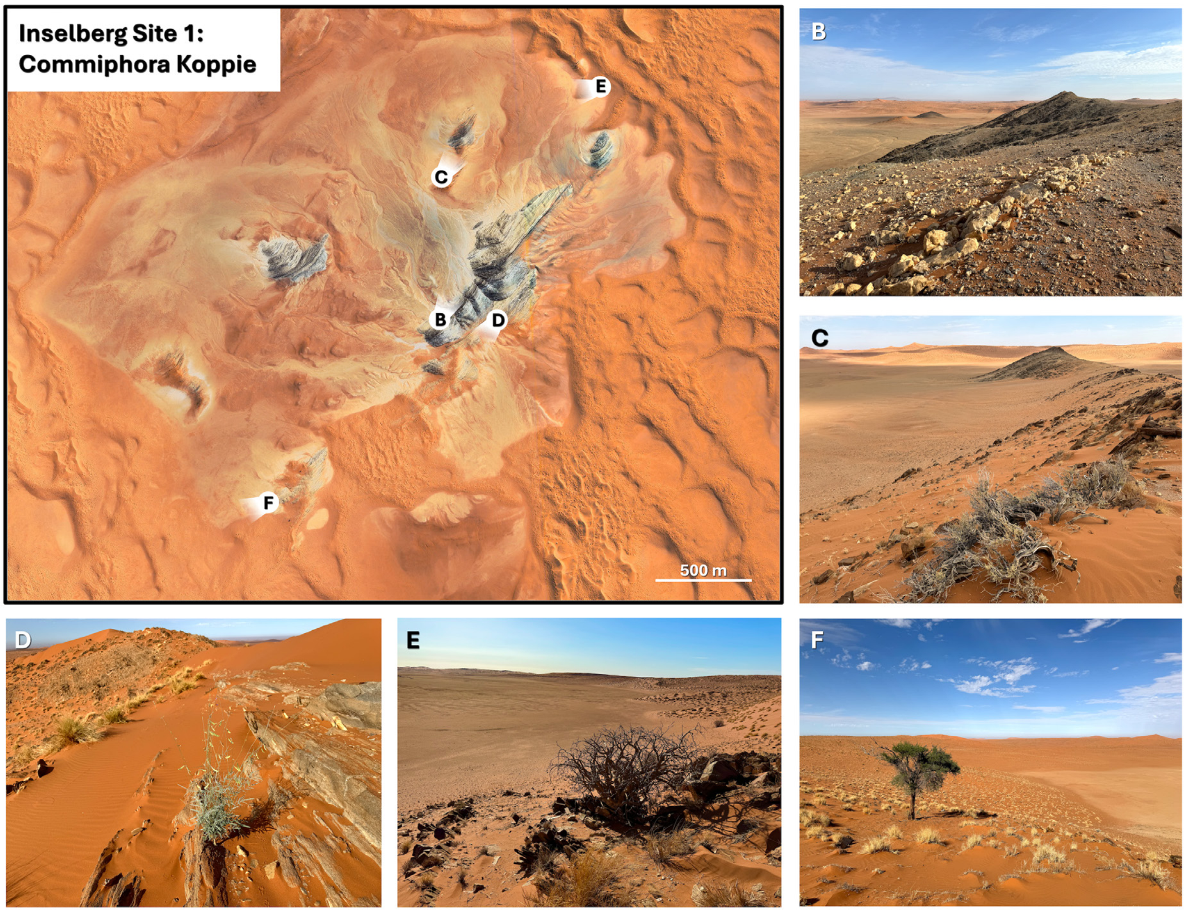

Figure 3: *Map and some notable features of Inselberg Site 1: Commiphora Koppie. A) Map of Site 1. The letters correspond to pictures B–F, and the direction of the white spotlight indicates the direction of the photograph. B) A view along the main ridge. C)* Caroxylon *sp. on partially sand-submerged rock. D)* Tephrosia dregeana *on partially sand-submerged rock. E) A large and established* Commiphora saxicola *on a partially sand-submerged rocky outcrop north of the main inselberg. F) One of* two Acacia erioloba *trees found at this site. All photos by Sebastian A. Hatt.*

depressions, or *gorras*, and green shoots on closely-cropped cushions of *Stipagrostis ciliata* at the base of the sandstones and in adjacent gullies hints at the presence of ephemeral seeps after wet spells. At least one historical map suggested a seep or spring in the area where the inselbergs occur.

A total of 14 species was recorded from this site. Floristic composition was mostly the same as at Site 1, with a few notable exceptions. *Orthanthera albida*, *Polygala guerichiana* and *Sarcocaulon* aff. *marlothii* were not observed at Site 2. Species not observed in Site 1 include *Forsskaolea candida* L.f. (Figure 2B) in rocky crags, a few dried individuals of *Pogonospermum genistifolium* (Engl.) I.Darbysh. & Kiel in a wash at the base of the inselberg, and a single *Parkinsonia africana* Sond. (Figure 2D) in flower on the brief plain between the ridges. While no tree-sized *Acacia erioloba* were observed at this site, two small shrub-sized (c. 1 m tall) individuals (Figure 4E) were observed growing in the plain to the north of the inselberg, near some exposed Tsondab sandstone (Figure 4F).

Inselberg Site 3: Euphorbia Koppie

Site 3 (Figure 5A) consists of an irregularly shaped interdune plain, c. 8 x 6 km, at an elevational range of c. 800–870 m. Site 3 is separated from the adjacent Namibvlakte to the northeast by a thin strip of continuous sand dunes c. 400 m across. An arrowhead-shaped set of rocky hills lie in the centre of the plain (Figure 5B). Several washes drain from the hills into the central plain, forming a clearly defined network of channels. The lower parts of the eastern slopes of the hills are partially submerged under sand ramps. As with Sites 1 and 2, the inselberg ridges consist predominantly of quartzite and mica schist, but with exposed amphibolite outcrops along the lower elevations on the western sides.

A total of 38 species was observed at this site; twice the number of species observed at the other two sites combined. All species observed at Sites 1 and 2 were also observed here, except for *Parkinsonia africana*, *Pogonospermum genistifolium* and *Forsskaolea candida*. *Euphorbia virosa* is common on the rocky slopes (Figure 5C), and individuals are visible from a great distance as dark spots on the hill. They are also abundant in the washes and plains enclosed by the inselbergs (Figure 5D), where they are surrounded by scattered *Blepharis obmitrata* C.B.Clarke, *Blepharis grossa* (Nees) T.Anderson, *Trichodesma africanum* and *Stipagrostis ciliata*.

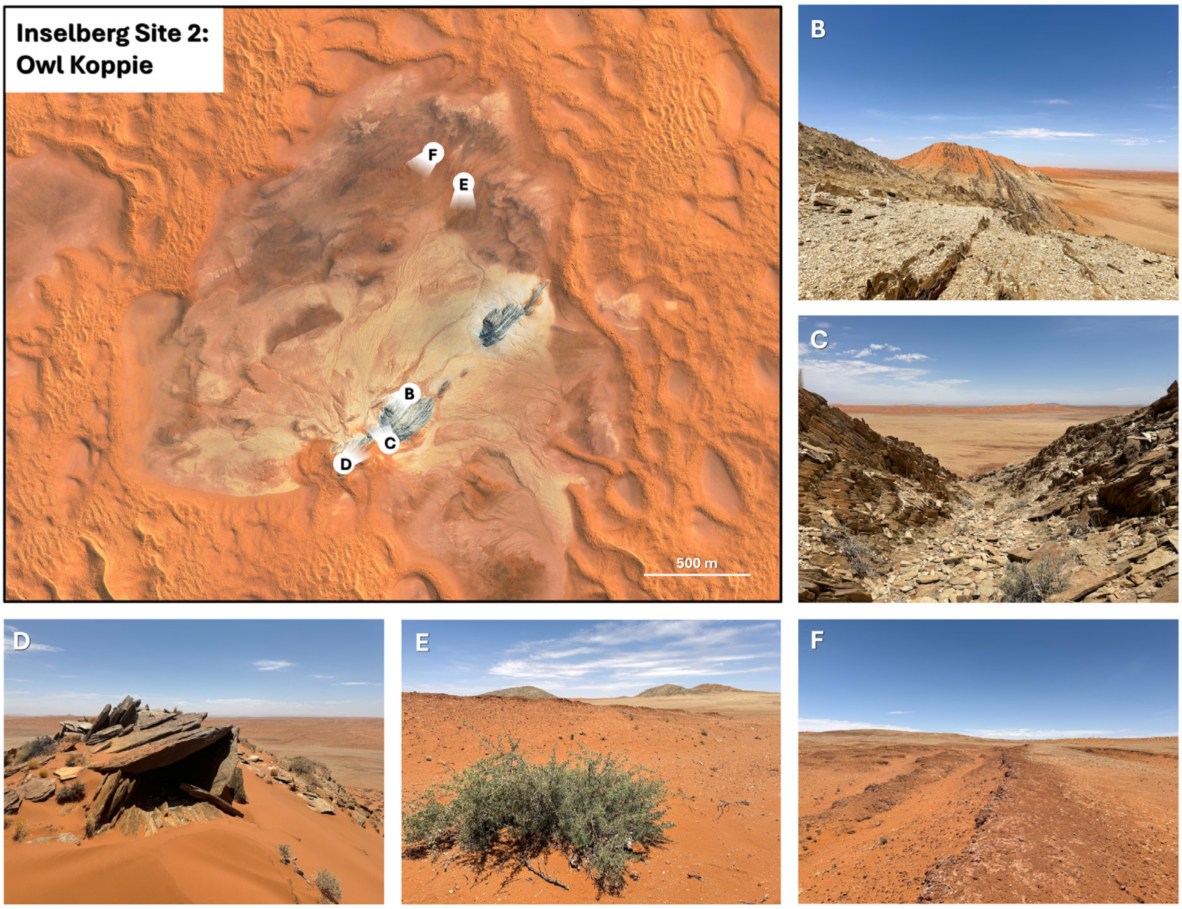

Figure 4: *Map and some notable features of Inselberg Site 2: Owl Koppie. A) Map of Site 2. The letters correspond to pictures B–F, and the direction of the white spotlight indicates the direction of the photograph. B) A view along the main ridge. C) A view down the valley between the two hills. D) A small cave or den along the crest of the ridge. E) A small shrub of* Acacia erioloba *near exposed Tsondab sandstone in the interdune plain. F) Exposed Tsondab sandstone in the interdune plain. All photos by Sebastian A. Hatt.*

The inselbergs featured several small valleys where the following species were commonly observed: *Sesamum marlothii* Engl. (Figure 5E), *Polygala guerichiana*, *Tribulus* sp., *Orthanthera albida*, *Roessleria gazanioides* (Harv.) Stångb. & Anderb. and *Cleome* aff. *suffruticosa* or *foliosa*. Subshrubs and shrubs frequently observed across the rocky slopes include *Euphorbia lignosa* Marloth, *Jamesbrittenia maxii* (Hiern) Hilliard, *Cryptolepis decidua* (Planch. ex Benth.) N.E.Br. and *Pogonospermum cleomoides* (S.Moore) I.Darbysh. & Kiel. Less frequently observed shrubs include *Barleria merxmuelleri* P.G.Mey. and *Commicarpus squarrosus* (Heimerl) Standl. Additional herbs observed on the rocky slopes include *Chascanum garipense* E.Mey., *Emilia marlothiana* (O.Hoffm.) C.Jeffrey, *Pegolettia senegalensis* Cass. and *Forsskaolea hereroensis* Schinz.

Larger shrubs such as *Kissenia capensis* Endl., *Boscia foetida* Schinz and *Acacia erioloba* were infrequently observed on rocky slopes, particularly on the eastern faces. Several dense populations of *Acanthosicyos horridus* Welw. ex Benth. & Hook.f. were observed on the sand-covered eastern slopes of the inselberg (Figure 5F), presumably tapping into groundwater deep beneath the sand. A further population was observed mounting the dune on the northern edge of the plain.

Ad hoc *Observations*

We did not attempt any intensive surveys to supplement the floristic inventory, but recorded *ad hoc* observations of life associated with the inselbergs. Western rock skinks (*Trachylepis sulcata*) (Figure 2H) and plain sand lizards (*Pedioplanis inornata*) were observed infrequently on the rocky slopes. Cape hares (*Lepus capensis*) were observed on the inselbergs and surrounding plains. Two large owls (*Bubo* sp.) were observed around noon on the rocky valley at Site 2 (Figure 2G). Oryx (*Oryx gazella*) were frequently observed crossing the dunes surrounding the inselbergs, while droppings of Hartmann's Zebra (*Equus zebra hartmannae*) were frequently observed on the outcrops. Peringuey's adder (*Bitis peringueyi*), a wedge-snouted desert lizard (*Meroles cuneirostris*) and evidence of the Namib golden mole (*Eremitalpa granti namibensis*) were observed in the dunes surrounding the inselbergs. At least one spotted hyaena (*Crocuta crocuta*)

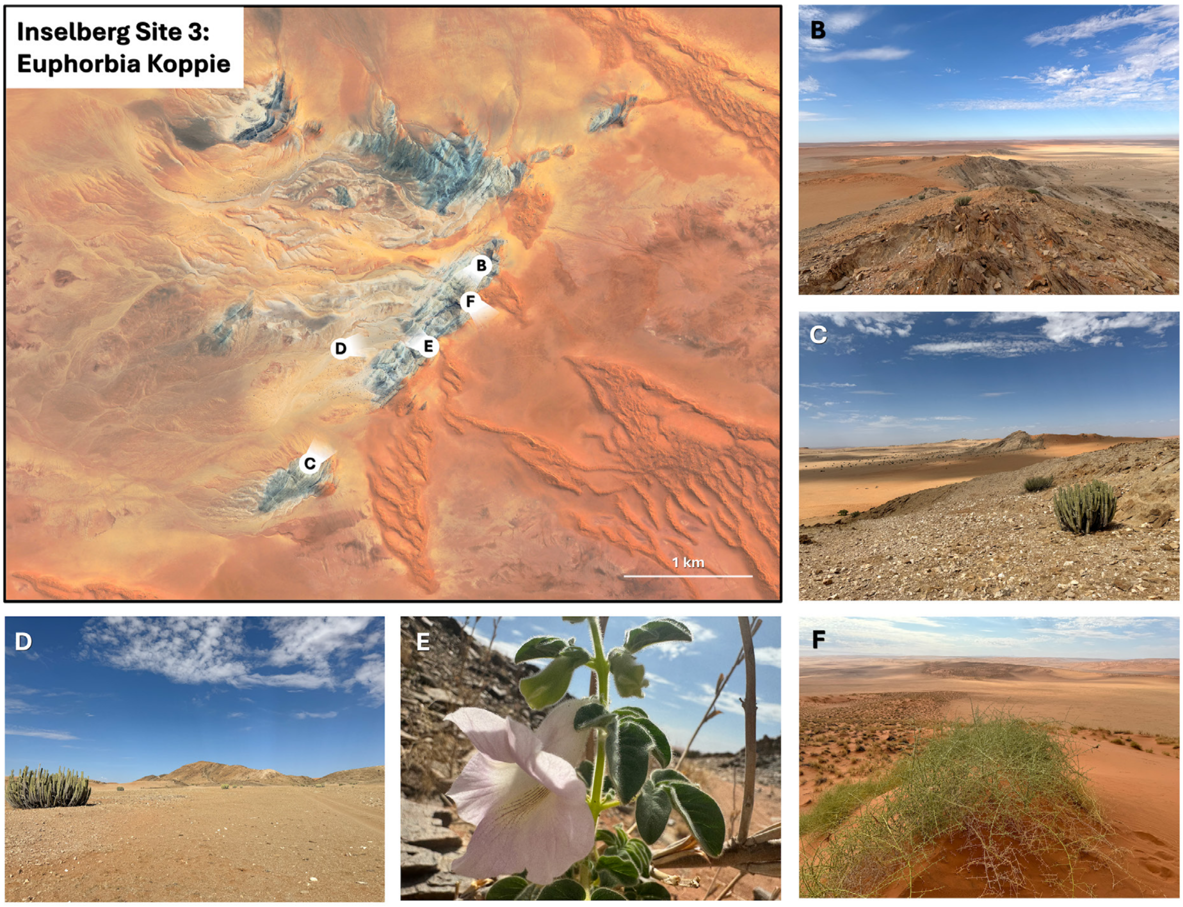

Figure 5: Map and some notable features of Inselberg Site 3: Euphorbia Koppie. A) Map of Site 3. The letters correspond to pictures B–F, and the direction of the white spotlight indicates the direction of the photograph. B) A view along the main ridge. C) Euphorbia virosa *on the rocky slopes. D)* Euphorbia virosa *on the sandy washes surrounding the inselberg. E)* Pedalium marlothii *in flower in a small valley. F) A sandy hummock of* Acanthosicyos horridus. *All photos by Sebastian A. Hatt.*

was observed entering and leaving a rocky den at Site 3. Speckled pigeons (*Columba guinea*) were observed feeding on *Boscia foetida* fruit on the rocky slopes at Site 3, and an ostrich (*Struthio camelus*) egg was observed in the plains surrounding Site 3. Lappet-faced vultures (*Torgos tracheliotos*) were observed in the plains at Site 2, where the fresh remains of an Oryx calf occurred near the ephemeral seeps at the base of a Tsondab sandstone ridge. Cocoons of the African silk moth (*Gonometa postica*) were found on the *Acacia erioloba* at Site 1. Termite inkcaps (*Podaxis* aff. *pistillaris*) were infrequently observed in the dune sands surrounding the inselbergs (Figure 2F).

A suspected stone circle, similar to those at Rooikamer (Shackley 1985), was observed along a game trail near the apex of the ridge at Site 1 (Figure 5I), with slate stones arranged in a circle about 1 m in diameter. Some Early Stone Age bifaces were observed along the route between the sites and on the plains at Site 3.

Discussion

The inselbergs display floristic affinity with the Kuiseb Canyon and Mt Kamberg to the northeast, according to existing plant records from these areas (GBIF.org 2024). They also share a common geology as the same metamorphic rocks, predominantly schists, quartzites and amphibolites (Hoffmann *et al.* 1994) occur at the Kamberg. As the observations were made after many years of scanty rain, the list presented here is certainly not exhaustive – returning after good rains of > 10 mm would likely reveal several more annuals or geophytes that are not detectable in drier years (Seely & Louw 1980, Günster 1994, Huntley 2023). The majority of perennials observed were alive but not in flower. Annuals that were visible were represented only by dead remains.

Site 3 was the most biodiverse of the three sites (38 species) and was at least four times larger by surface area than Site 1 or 2 (16 and 14 species, respectively). Most species at Site 1 and 2 could also be found at Site 3, but many species at Site 3 could not be found at Site 1 or 2. This result primarily reflects the greater size and habitat heterogeneity at Site 3. The floristic composition of Sites 1 and 2 may also be influenced by their greater isolation afforded by their position deeper in the dunes, coupled with their lower elevation making them potentially more readily affected by shifting windblown sand over time. *Euphorbia virosa*, a long-lived perennial, is abundant at Site 3, forming a dominant part of the vegetation on both the rocky slopes and surrounding washes. Despite its abundance at Site 3, it is entirely absent from Sites 1 and 2, which may suggest the recent partial emergence of these inselbergs from the dunes. However, this is not supported by the observation of two other long-lived perennial species at Sites 1 and 2: *Commiphora saxicola* and *Acacia erioloba*.

Despite their isolated location, there are several potential threats to the biodiversity of the inselberg sites. Sites 1 and 2 are not accessible by any established track, but a tourist 4x4 track runs through Site 3. Off-road driving is illegal in the Namib-Naukluft National Park (Ministry of Environment, Forestry and Tourism 2021) yet remains extremely common and is often committed by poachers (pers. obs.). There are also sustained pressures by tourism operators and entrepreneurs for access and sites to develop visitor accommodation facilities (pers. obs.), where inselbergs offer scenic landscapes and stable surfaces to develop infrastructure. The accessibility of Site 3 makes it vulnerable to development and destructive driving. Poaching remains a serious problem in the Namib-Naukluft National Park and has decimated the population of many large mammals, notably Oryx and Zebra (Clements *et al.* 1984, Namibian 2020). Such disturbance to the ecosystem will likely have an indirect impact on the flora of these inselbergs (Whitford & Duval 2020).

These inselbergs lie within the Namib Sand Sea World Heritage Site, which has been withdrawn from any prospecting and exploration that may lead to mining. Despite being a designated protected area and the focal area for Namibia's only Strategic Environmental Management Plan, other areas within the Namib-Naukluft National Park are not as fortunate as new prospecting and mining licences continue to be granted (Mulonga *et al.* 2017). Disruption of ecological processes from mining operations can be devastating to biodiversity in and around the affected areas. (Wassenaar *et al.* 2013), particularly where dispersal resilience and population recovery are as vulnerable to landscape fractionation as in the Namib Desert.

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Appendix 1: Annotated checklist of the plants of the three inselberg sites.

A complete list of species recorded are described here, arranged by plant family. Habitat notes are recorded according to where the species were observed. Abundance is assigned to either Abundant (A), Common (C), Frequent (F), Occasional (O) or Rare (R) depending on their perceived abundance by the authors, recorded separately for each of the three inselberg sites, indicated by (1-3). Vouchers are provided for observations of each species at each of the three inselberg sites: Site 1 (Commiphora Koppie), Site 2 (Owl Koppie) and Site 3 (Euphorbia Koppie). The 9-digit number of the reference ID for the associated iNaturalist observation, accessed online by prefixing the code with 'https://www.inaturalist.org/observations/'. n/s = not seen.

FAMILY	SPECIES	HABITAT	ABUNDANCE	SITE 1	SITE 2	SITE 3
Poaceae	*Cladoraphis spinosa* (L.f.) S.M.Phillips	Dunes	C (3)	n/s	n/s	194703466
Poaceae	*Stipagrostis ciliata* (Desf.) De Winter	Rocky slopes, plains, dunes	A (1,2,3)	194679214	194701136	194702194
Poaceae	*Stipagrostis lutescens* (Nees) De Winter	Dunes	F (3)	n/s	n/s	193937203
Poaceae	*Stipagrostis sabulicola* (Pilg.) De Winter	Dunes	A (1,3)	194679586	n/s	193937205
Poaceae	*Stipagrostis seelyae* De Winter	Dunes	C (1,3)	193936968	n/s	193937202
Zygophyllaceae	*Tetraena cylindrifolia* (Schinz) Beier & Thulin	Rocky slopes	C (1,2,3)	194679254	194680895	194704038
Zygophyllaceae	*Tribulus* sp.	Rocky washes, rocky slopes	O (3)	n/s	n/s	194704006
Fabaceae	*Parkinsonia africana* Sond.	Rocky washes	R (2)	n/s	194691532	n/s
Fabaceae	*Tephrosia dregeana* E.Mey.	Rocky slopes	C (1,2,3)	194680545	194680817	194702336
Fabaceae	*Vachellia erioloba* (E.Mey.) P.J.H.Hurter	Dunes-covered rocks	R (1, 2); O (3)	194679824	194701175	193210008
Polygalaceae	*Polygala guerichiana* Engl.	Rocky slopes	O (1,3)	194679624	n/s	194702060
Urticaceae	*Forsskaolea candida* L.f.	Rocky slopes	R (2)	n/s	194700827	n/s
Urticaceae	*Forsskaolea hereroensis* Schinz	Rocky slopes	O (3)	n/s	n/s	194702124
Cucurbitaceae	*Acanthosicyos horridus* Welw. ex Benth. & Hook.f.	Dunes, dune-covered rocks	F (3)	n/s	n/s	194703497
Euphorbiaceae	*Euphorbia glanduligera* Pax	Rocky slopes	C (1,2,3)	194680583	194700857	194703768
Euphorbiaceae	*Euphorbia lignosa* Marloth	Rocky slopes	O (3)	n/s	n/s	194703319
Euphorbiaceae	*Euphorbia* virosa Willd.	Rocky slopes, plains	C (3)	n/s	n/s	194703155
Geraniaceae	*Sarcocaulon* aff. *marlothii* Engl.	Rocky slopes	R (1); O (3)	194680624	n/s	194703846
Burseraceae	*Commiphora saxicola* Engl.	Rocky slopes	F (1,2,3)	194680597	194701072	194704050
Malvaceae	*Hermannia minimifolia* E.Holzh.	Dunes	C (3)	n/s	n/s	194702513
Capparaceae	*Boscia foetida* Schinz	Rocky slopes	F (3)	n/s	n/s	194703270
Cleomaceae	*Cleome* aff. *suffritucosa/foliosa*	Rocky slopes	O (3)	n/s	n/s	194703700
Cleomaceae	*Cleome angustifolia* subsp. *diandra* (Burch.) Kers	Rocky slopes	A (1,2,); F (3)	194679913	194700998	194704095
Amaranthaceae	*Caroxylon* sp.	Rocky slopes	C (1,2,3)	194680510	194700868	194703603
Nyctaginaceae	*Commicarpus squarrosus* (Heimerl) Standl.	Rocky slopes	R (3)	n/s	n/s	194703370

Loasaceae	*Kissenia capensis* Endl.	Rocky slopes	O (3)	n/s	n/s	194703345
Rubiaceae	*Kohautia ramosissima* Bremek.	Dunes	F (1,2)	194679548	194701191	n/s
Apocynaceae	*Cryptolepis decidua* (Planch. ex Benth.) N.E.Br.	Rocky slopes	O (3)	n/s	n/s	194704012
Apocynaceae	*Orthanthera albida* Schinz	Rocky slopes	O (1); C (3)	194679171	n/s	194703253
Boraginaceae	*Trichodesma africanum* (L.) Sm.	Rocky washes	R (1); O (2,3)	194676349	194700903	194701864
Scrophulariaceae	*Jamesbrittenia maxii* (Hiern) Hilliard	Rocky slopes	F (3)	n/s	n/s	194703535
Pedaliaceae	*Sesamum marlothii* Engl.	Rocky washes	F (3)	n/s	n/s	194701819
Acanthaceae	*Barleria merxmuelleri* P.G.Mey.	Rocky slopes	O (3)	n/s	n/s	194703144
Acanthaceae	*Blepharis grossa* (Nees) T.Anderson	Plains	F (3)	n/s	n/s	194703807
Acanthaceae	*Blepharis obmitrata* C.B.Clarke	Rocky slopes, plains	F (3)	n/s	n/s	194703824
Acanthaceae	*Pogonospermum cleomoides* (S.Moore) I.Darbysh. & Kiel	Rocky slopes	F (3)	n/s	n/s	194703220
Acanthaceae	*Pogonospermum genistifolium* (Engl.) I.Darbysh. & Kiel	Rocky washes	R (2)	n/s	194700676	n/s
Verbenaceae	*Chascanum garipense* E.Mey.	Rocky slopes	F (3)	n/s	n/s	194703110
Asteraceae	*Emilia marlothiana* (O.Hoffm.) C.Jeffrey	Rocky slopes	O (3)	n/s	n/s	194703680
Asteraceae	*Osteospermum microcarpum* (Harv.) Norl.	Rocky slopes, rocky washes	R (1); C (2,3)	194676406	194700878	194703054
Asteraceae	*Pegolettia senegalensis* Cass.	Rocky slopes	R (3)	n/s	n/s	194701462
Asteraceae	*Roessleria gazanioides* (Harv.) Stångb. & Anderb.	Rocky washes	R (3)	n/s	n/s	194703961

Homeward bound: post-translocation homing behaviour of an Angolan giraffe in Namibia

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Abstract

Measuring the short- and long-term success of a translocation is challenging but critical. With increasing artificial movements of wildlife within and between African countries, understanding the results of such translocations is valuable. Translocations are an increasingly common conservation management tool to reverse biodiversity loss through re-populating, augmenting and/or expanding populations, especially for giraffe (*Giraffa* spp.). In southern Namibia, we used GPS satellite tags to monitor the movement of six Angolan giraffe (*G. giraffa angolensis*) post-translocation. We report the first known 'homing behaviour' of a giraffe post-translocation (155 days and 893.65 km). We hope our results will help guide future large-mammal translocation strategies. Decision making should be based on shared knowledge, and increasing our understanding of translocation efforts is key.

Keywords: fences, Giraffa, giraffe, home range, homing, movement, Namibia, translocation

Introduction

Animal movement is a fundamental driver of evolutionary and ecological processes (Berdahl *et al*. 2018). Some species have a 'built-in' homing behaviour which researchers have studied for almost a century, in predominantly smaller terrestrial vertebrate species – both domesticated and non-domesticated (e.g. Leuthold 1966; Dell'Ariccia *et al*. 2008; Berdahl *et al*. 2016). More recently, increased attention has been given to homing behaviour, including that of African carnivores and eutherians.

For conservation management, it is crucial to understand whether animals 'return home' following translocations or introductions and why. Are such movements random, a result of navigation, or guided by a sense of familiarity? Additionally, it is useful to consider the possible roles of olfaction (familiar odours, scent gradients) and acoustic aid orientation in influencing these homing behaviours (Jorge 2011).

In Africa, homing behaviour has been reported in Ugandan kob (*Kobus kob thomasi*) males after a translocation of 5-23 km to a new area (Leuthold 1966), in both sexes of African savanna elephant (*Loxodonta africana*) after moves of up to > 150 km (Pinter-Woolman 2009; Fernando *et al*. 2012; Goldenburg *et al*. 2019), and in various large African predators including cheetah (*Acinonyx jubatus*), leopard (*Panthera pardus*), and lion (*Panthera leo*, e.g. Linnell 1997; Weise 2016).

Historically, homing studies have often been limited to capture-recapture events (e.g. Leuthold 1966; Dell'Ariccia *et al*. 2008; Berdahl *et al*. 2016). However, the use of GPS satellite technology has provided a better understanding of exact movements and has helped to assess if the homing behaviour was truly navigational (direct) or somewhat random (e.g. Marneweck *et al*. 2023). A high percentage of herbivores are reported to settle near release sites in unfamiliar ranges which would indicate a poor homing ability (Rogers 1988). However, where larger numbers of animals were translocated, this has not always been the case (Rogers 1988).

Red deer (*Cervus elaphus*) homed over relatively short distances when moved up to 11 km, with 88% of translocations resulting in successful homing, with a median time of 4.75 days (range 1.23–100 days, Silovsky *et al*. 2024). In 2008, Hartmann's mountain zebra (*Equus zebra hartmannae*) were translocated approximately 300 km (direct line) to a communal conservancy in northwest Namibia, and within a week returned to the capture site with the GPS satellite collar recording an almost direct navigational movement (Jago pers. com. 2024). On the other hand, for cheetah that were translocated > 137 km away from their capture site, no homing behaviour was observed (Weise 2016).

Whilst spatial movements of large non-migratory African mammals have been subjected to far fewer experimental investigations, largely for practical reasons, aspects such as partial and seasonal migrations have been reported. In ungulates, including giraffe (*Giraffa* spp.), such migrations are not uncommon within ecologically distinct seasonal ranges, whilst other animals in the population remain resident (Brown & Bolger 2020). Seasonal long-distance movement and non-migratory movements have been reported in various giraffe taxa, including the Angolan (*G. giraffa angolensis*, Fennessy 2009; Flanagan *et al*. 2016), Masai (*G. tippelskirchi*, Pellew 1984), Nubian (*G. c. camelopardalis*, Brown & Bolger

2020), and West African giraffe (*G. c. peralta*, Le Pendu & Ciofolo 1999). However, no systematic investigation into how giraffe navigate at both individual and population levels has been conducted so far.

Species translocations are a valuable and increasingly common conservation management tool used to reverse biodiversity loss through re-establishing, augmenting and/or expanding populations. Most translocations aim to establish viable populations at the release site (Fischer & Lindenmayer 2000) or permanently remove animals from the source site (Richard-Hansen *et al*. 2000). However, failures have been reported (e.g. Linnell *et al*. 1997; Fischer & Lindenmayer 2000; Massei *et al*. 2010; Fontúrbel & Simonetti 2011). One such impediment to success is post-release hyper-dispersal, which is the long-distance movement of individuals post-translocation (any direction) rather than homing to their original location. Bilby and Moseby (2024) reviewed 151 conservation translocations (reinforcements and reintroductions) with hyper-dispersal reported in 52.1% of them. Interestingly, hyper-dispersal was relatively consistent across taxa (42.9–60%), with eutherians exhibiting a higher average incidence.

In the case of giraffe, deliberate conservation translocations continue to benefit all four species across their range by re-establishing populations in areas where they were formerly extirpated and augmenting small, dwindling populations (e.g. Flangan *et al*. 2016; Brown *et al*. 2023). Therefore, putting this into context, it is critical to monitor the post-translocation movement patterns of wild giraffe to ensure they settle as much as to observe if they exhibit any unconventional behaviour. In the long-term, such monitoring will help assess and improve translocation tools in a species or population’s conservation. This report highlights recent observations of a female Angolan giraffe which exhibited homing behaviour in southern Namibia. This is the first time such behaviour has been reported.

Study Area and Methods

Since its conversion from livestock farming, the ProNamib Nature Reserve (PNNR) in southwestern Namibia has sought to aid the restoration of wildlife habitat and migratory routes. The initial rehabilitation included the removal of fences and the re-introduction of Angolan giraffe to the territory (Zazapamue 2023).

On 26 April 2022, six sub-adult Angolan giraffe (3 females, 3 males) were individually captured on Farm Nomtsas (FN) in southern Namibia by chemical immobilisation with a combination of the ultra-potent opioids etorphine and thiafentanil (Fennessy *et al.* 2022). The opioids were immediately reversed with the full antagonist naltrexone, when the giraffe were in lateral recumbency. Once secured and stable, the giraffe were fitted with Ceres GPS satellite ear tags that were set to record four GPS coordinates per day to monitor translocation success. The giraffe were subsequently loaded onto a game capture truck, transported ~165 km southwest by road to PNNR, and released the following morning (Figure 1).

We calculated the home range (50% and 95%) of each giraffe using adaptive Local Convex Hull (*a*-LoCoH) in the R package *adehabitatHR* (Calenge 2006). For each individual giraffe, the value of *a* was calculated as the largest distance between any two points. To calculate the net daily distance moved by each giraffe, we calculated the distance between two consecutive points using the Vincenty ellipsoid formula and summed for each day. For both above calculations, we used R version 4.2.1 (R Core Team 2022).

The homing behaviour was assessed using package Circular v.0.4-7 (Agostinelli & Lund 2013) in R by calculating bearing angles and distances between a subject's last known location and release location relative to the capture site. Bearing angles were adjusted to set an individual's 'home' direction (i.e. the original capture site) to 0°. All distances were normalised on a scale from zero to one, representing the distance between a subject’s capture and release sites. Fies *et al*. (1987) considered that an animal was homing if it returned to its capture property or moved its entire translocation distance towards the capture location within 22.5° on either side of the true ‘home’ direction (Fies *et al*. 1987). In addition, successful homing was defined to include the animal returning to the capture site.

Results and Discussion

On average, the GPS satellite ear tags recorded 2.69 locations/day (Table 1). All but one of the translocated giraffe established their home ranges around the release site on PNNR. One female giraffe (GCF00935_0787) lost her ear tag tracking device soon after release, and as a result we were unable to calculate home range estimates for this individual.

For the giraffe that remained on the release site, the average daily movements varied between 3.61 and 8.50 km per day and the home ranges between 17.70 and 31.29 km^2 (Table 1). One of the female giraffe movements, Jinjeh (GCF00938_1123), were within this same range with an average of 6.34 km moved per day when travelling and 4.17 km per day once settled back at the original capture site. Her home range at the original capture site was estimated at 138.70 km^2. Similar variation in home ranges has been reported for all four giraffe species across their geographical distribution and habitat types (e.g. Flanagan *et al*. 2016; Brown *et al*. 2023). As PNNR is a fenced environment, giraffe display smaller home range sizes for such an arid environment, compared to giraffe in the open communal area of northwest Namibia, where some of the largest home ranges of all (> 1,900 km^2) have been reported (Fennessy 2009). Considering FN is

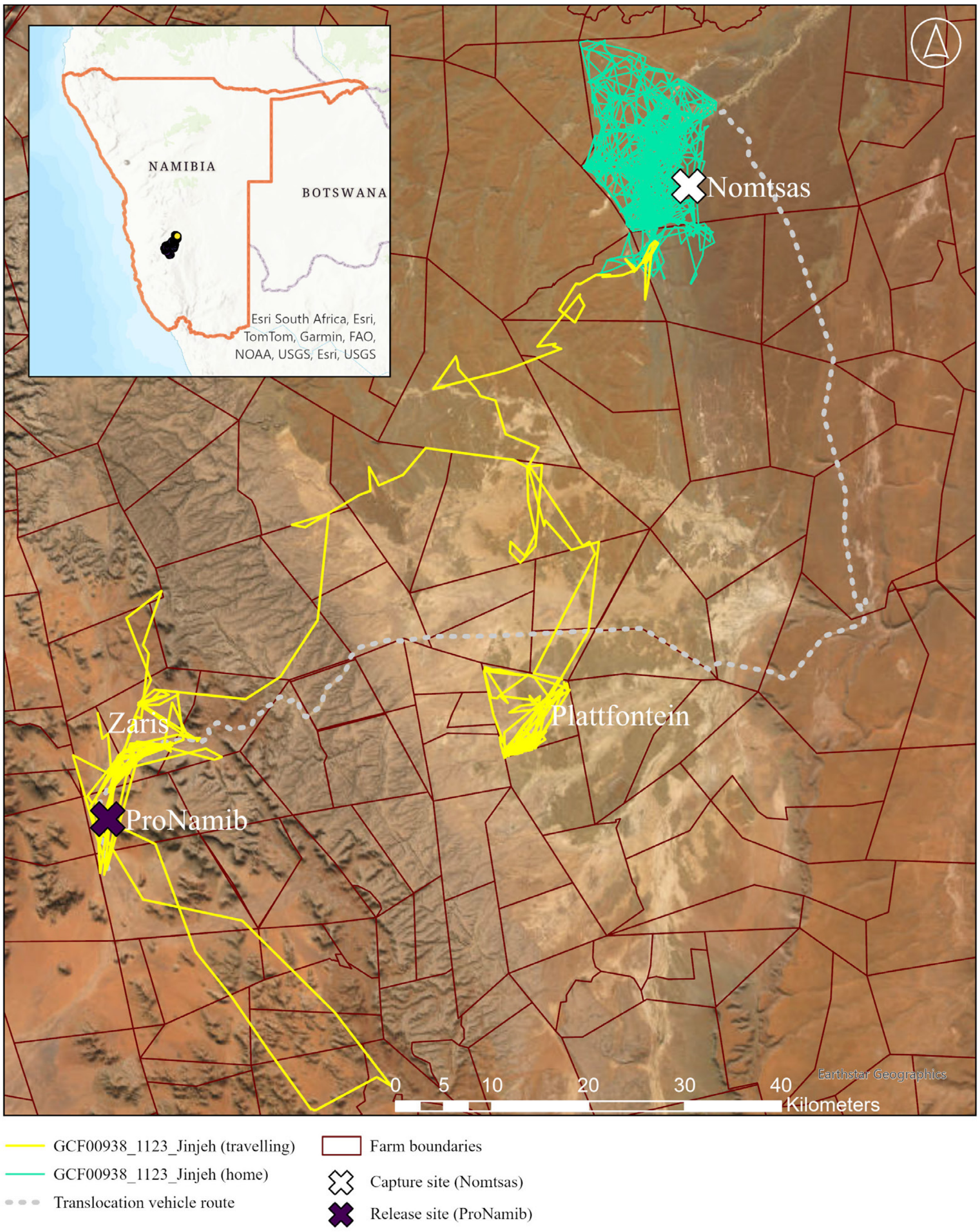

Figure 1: *The movements of a female Angolan giraffe GCF00938_1123_Jinjeh from the release site at ProNamib Nature Reserve (PNNR; purple 'X') returning home to the capture site (Farm Nomtsas; white 'X') between April and September 2022.*

Table 1: *Data summary, a-LoCoH home ranges and mean daily distance moved estimates of the GPS satellite tagged giraffe translocated to ProNamib Nature Reserve in 2022, including the female giraffe (GCF00938_1123_Jinjeh) who homed back to Farm Nomtsas (capture site), highlighted in bold.*

Giraffe ID	Sex	Tag start	Tag end	Days	Mean (± SE) locations/day	95% a-LoCoH (km²)	50% a-LoCoH (km²)	Mean (± SE) net daily km moved
GCF00823_0741_Landy	M	09/05/2022	22/04/2024	715*	3.15 (0.03)	23.37	4.16	4.43 (0.09)
GCF00853_1079_Fred	M	10/05/2022	22/04/2024	714*	2.69 (0.04)	21.66	3.64	4.14 (0.09)
GCF00935_0787_Verdane	F	27/04/2022	04/05/2022	7	2.33 (0.33)	-	-	8.50 (1.89)
GCF00937_1092_Genny	F	24/04/2022	26/06/2022	63	2.87 (0.14)	17.70	2.71	3.61 (0.32)
GCF00938_1123_Jinjeh	**F**	**09/05/2022**	**28/03/2024**	**690**	**2.77 (0.04)**	**138.70**	**23.17**	**6.34 (0.44); travelling** **4.17 (0.11); home**
GCF00940_1235	M	09/05/2022	22/04/2024	715*	2.32 (0.03)	31.29	4.85	4.19 (0.11)

*denotes tag still active with the deployment end indicating the date of data extraction (22/04/2024).

200 km^2 and PNNR is 890 km^2, it is not surprising that Jinjeh's FN home range was larger than those that remained on PNN.

After the release of Jinjeh into PNNR on 26 April 2022, she immediately headed north. On 17 June 2022, after spending 52 days on the Zaris farm, Jinjeh started to move south again. Three days later she turned north and arrived back at PNNR on 23 June 2022. After a further ten days she left PNNR again and headed northeast before turning south. On 8 July 2022 she turned south and arrived at Plattfontein farm four days later where she stayed for 63 days. On 13 September 2022, she headed north again (along the same pathway that she arrived on), and on 19 September 2022 she turned northeast. On 28 September 2022, she arrived back on FN, where she was initially captured and where she has remained until today. Her ear tag fell off on 28 March 2024, and she cannot be tracked remotely anymore. However, personal observation using individual pelage coat pattern identification confirmed her current location on FN in June 2024. Ultimately, it took Jinjeh 155 days and 893.65 km to find her way back home. During her travels, she utilised various habitats, including riverine systems to the east of PNNR, along the escarpment, and moved further north-east of the escarpment.

Jinjeh did not exhibit homing behaviour as per the definition of Fies *et al*. (1987) i.e. moving the entire translocation distance towards the capture location within 22.5° on either side of the true 'home' direction. Of all 1,881 'steps' (i.e. a consecutive pair of coordinates), only four fitted the definition of homing (i.e. within 22.5° of home direction; 23:43:14 on 11/05/2022, 05:47:29 on 12/05/2022, 17:40:00 on 29/05/2022, and 21:49:20 on 04/06/2022). However, as she returned to the capture site, we do consider her behaviour as homing. Several natural and anthropogenic barriers exist in this landscape, such as fences, roads and the Khomas Hochland mountain range, all of which will have affected her route home. Despite this, she was still able to navigate the ~894 km journey (~155 km in a straight line). Interestingly, the homing behaviour of Jinjeh is the first time such behaviour has been reported for giraffe. It is unknown how she truly homed and what navigational senses were used. In homing pigeons, a single demonstration of a route is insufficient, with robust learning requiring repeated trips (Banks & Guilford 2000; Petit *et al*. 2013). The homing behaviour observed loosely fits the findings of Silovsky *et al*. (2024), who described an 'exploratory', then 'homing', and finally an 'arrival' phase. However, it was noted that the longer an animal needs to reach home, the more unlikely it is they ever enter an observed 'homing phase' – as observed by Jinjeh's movements which did not transition into a single fast and straight movement.

Gussett (2009) measured the short-term success of a translocation by the survival rate. Other than Jinjeh's return home, the translocation of Angolan giraffe was successful in the short-term, with all individuals surviving (Gussett 2009). However, due to the long gestation time of giraffe, the long-term success could not yet be established (i.e. in terms of both survival and reproduction; Gussett 2009).

Understanding and sharing findings like these can be valuable for conservation managers and researchers. They could help predict possible movements of translocated animals after their release and as such, inform the planning of future conservation interventions. From an applied management perspective, it is important to be realistic about possible outcomes of translocations and key to their success is the development of species- and site-specific translocation strategies. Moreover, assessing pros and cons of hard (immediate release) and soft releases (using a boma) should be further studied, while acknowledging that limitations for both methods exist. Decision-making in wildlife translocations should also be based on experience and situational knowledge, rather than purely on academic findings and assumptions.

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Community-Based Natural Resource Management (CBNRM) in southern Africa: history, principles, evolution and contemporary challenges

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Abstract

Community-Based Natural Resource Management (CBNRM) is arguably the most important tool for simultaneously driving rural development and improving community livelihoods and biodiversity conservation in Southern Africa. However, persistent challenges prompt a crucial inquiry: what strategies can ensure CBNRM's relevance in reconciling the competing demands of development and conservation while guaranteeing fair benefit-sharing among local communities and achieving sustainable conservation outcomes?

If the region is to continue its success story as an African anomaly, it will have to (i) close the gaps in digital access and readiness which threaten to hold it back; (ii) skilfully manage its transition to sustainable local funding mechanisms, alternative biodiversity markets and robust equitable benefit distribution schemes; (iii) adeptly navigate power dynamics and cultural sensitivities on the global stage; and, in its avant-gardist and pioneering spirit, (iv) boldly address critically overlooked mental health aspects within conservation in rural settings. This essay, therefore, explores the evolution, principles, and application of CBNRM across the region, set against a backdrop of historical exploitation and exclusionary practices. By examining the roots of CBNRM in indigenous stewardship, its development through colonial and post-colonial periods, and its contemporary challenges and opportunities, the paper argues for a shift from the traditional dichotomous view of natural resource management to an alternative perspective encompassing the dynamic and complex nature of managing natural resources in a way that is socially equitable, economically viable, and ecologically sustainable.

Drawing on previous studies and recent interviews conducted in Southern Africa, this paper adopts a methodological approach that combines critical discourse analysis with a thorough review of the literature to highlight the connection between CBNRM and formal (state apparatus) and informal (Web 3.0, social media) institutions and their role in shaping modern rural development. The analytical framework of the paper is firmly anchored in the Common Property Resource (CPR) theory. Overall, I contend that the goals of biodiversity conservation, poverty alleviation, rural development, and sustainable natural resource use are intertwined and mutually reinforcing in the quest to improve community well-being and protect biocultural heritage. Central to the analysis is the hypothesis that communities will actively manage their environment when the benefits outweigh the costs, suggesting that devolving management rights and responsibilities to local communities leads to better conservation outcomes because of their direct interest in the sustainability of resources. The future of CBNRM in southern Africa is presented as promising yet contingent on embracing innovations such as the utilisation of artificial intelligence, and the potential of social media for policy decision-making. To achieve its full potential, CBNRM must be supported by strong legal and policy frameworks, greater community engagement, and international partnerships that foster knowledge exchange and resource mobilisation. Ultimately, findings indicate that, despite its challenges, CBNRM offers a sustainable pathway for reconciling conservation and community development, underscoring the importance of continued exploration, support, and refinement of this model to ensure its success in fostering an equitable and sustainable present and future for southern Africa's socio-economic and ecological landscape.

Keywords: AI-powered conservation, CBNRM, conservation and the digital wild, Common Property Resource (CPR) Theory, Intersectional Conservation Paradigm (ICP), learning-by-doing approach, mental health in conservation, social media, southern Africa

Introduction

Brief overview of natural resource management in southern Africa

The vast and diverse landscapes of southern Africa are rich in natural resources, including wildlife, fisheries, forests, grazing lands, irrigation waters, and mineral deposits. These resources are not only crucial for the ecological balance and biodiversity of the region but also form the foundation of the livelihoods, cultures, and economies of its people. Historically, natural resource management in southern Africa has traversed various models and philosophies, from indigenous community stewardship to colonial exploitation, and post-independence state-centric conservation efforts. These approaches have often oscillated between the extremes of unrestricted use and strict preservation, leading to numerous challenges in balancing human needs with environmental sustainability.

CBNRM as a concept and its relevance to southern Africa

In this context, CBNRM emerges as a transformative concept that seeks to reconcile these challenges by involving local communities in the stewardship of their natural resources. CBNRM is grounded in the understanding that communities living closest to natural resources are the most affected by their management outcomes and, therefore, have a vested interest in their sustainable use. Following the hypothesis that 'people seek to manage the environment when the benefits of management are perceived to exceed its costs' (Murphree 1991), this approach represents a radical departure from traditional top-down management models, advocating for the devolution of management rights and responsibilities to local communities. It operates on the premise that when communities benefit directly from the sustainable management of (authority to use, benefit from, sell, and manage) natural resources, they are more likely to invest in long-term conservation efforts (Muyengwa, Child & Lubilo 2014). CBNRM in southern Africa is not a monolithic concept but a dynamic and evolving practice, shaped by the unique socio-political, cultural, and ecological contexts of the region. It encompasses a wide range of initiatives, from wildlife conservation and forestry management to fisheries and water resources, each adapted to local conditions and needs. The principles of benefit, empowerment, and conservation are central to CBNRM, aiming to ensure that communities not only have a say in resource management decisions but also share in the economic benefits derived from these resources. This participatory approach seeks to build local capacity, foster environmental stewardship, and promote socio-economic development, all within the framework of sustainable resource use (Ngwira, Mbaiwa & Kolawole 2013).

Thesis statement

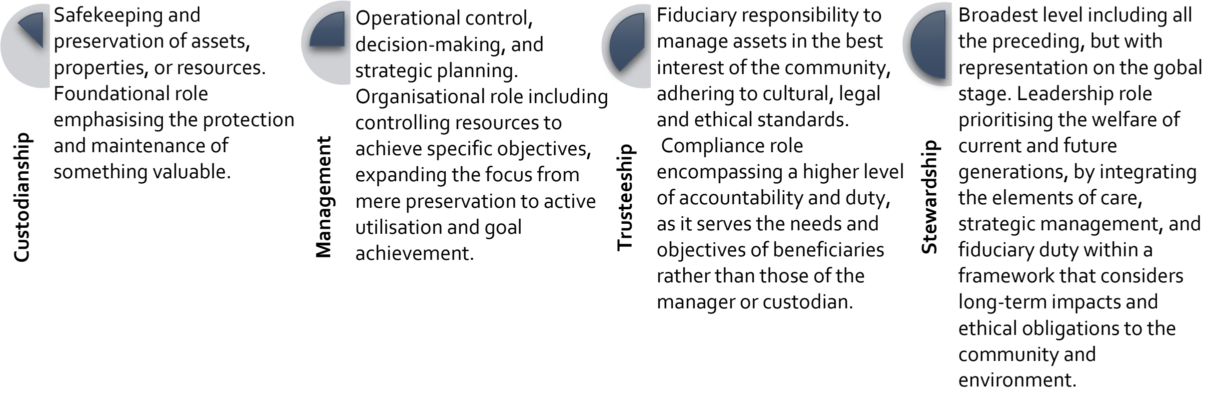
CBNRM represents a pivotal shift from traditional conservation approaches towards more inclusive, sustainable, and locally driven resource management practices—supported by principles of benefit, empowerment, and conservation—that aim to reconcile human livelihood needs with biodiversity conservation, making it more equitable, resilient, and sustainable for current and future generations. It challenges the historical paradigms of exclusion and control, offering a pathway to reconcile the often-competing demands of development and conservation. This essay draws upon the foundational principles, history, and insights from pivotal works in the field, particularly those by Marshall Murphree and the contributions of the Southern Africa Sustainable Use Specialist Group (SASUSG) and Brian Child, among others.

Historical context and evolution of CBNRM in southern Africa

The history of natural resource management in southern Africa is a tale of transformation, rooted in indigenous practices, reshaped by colonial policies, and reimagined in the post-colonial era through CBNRM (USAID undated). This evolution reflects broader socio-political changes and the search for models that balance conservation with human development. CBNRM's roots in southern Africa can be traced back to the early recognition of the limitations and failures of exclusionary conservation models that restricted local community access to natural resources. The economist Marshall W. Murphree highlights the "mixed profile of success and failure" in CBNRM, attributing much of its complexity to the challenge of implementing community-based approaches within a politico-legal framework that was often indifferent, if not outright hostile to communal resource management (Murphree 1995). This historical backdrop sets the stage for understanding CBNRM not just as a conservation strategy, but as the foundation of an indigenous socio-political movement aimed at redefining the rights and roles of local communities in the custodianship, management, trusteeship, and stewardship of their natural resources (Table 1).

Table 1: *Role of local communities in CBNRM.*

Role	Focus	Usage
Custodianship (cultural)	- primarily emphasises safekeeping and preservation. - responsible for looking after something or someone but not necessarily for making strategic decisions about its future.	- term used in contexts involving the protection and maintenance of physical (e.g. wildlife, forest, etc.) and abstract (e.g. cultural symbols, rituals, etc.) properties, artifacts, or even digital assets [e.g. indigenous non-fungible tokens (NFT), etc.].
Management (managerial)	- involves planning, organising, leading, and controlling resources and operations to achieve specific goals. - action-oriented and focuses on efficiency, effectiveness, and achieving objectives.	- used in business, organisational, and project contexts, management encompasses a broad range of activities, including financial management, human resources, and operational management for physical [e.g. Namibian Association of CBNRM Support Organisations (NACSO), etc.] and virtual [e.g. cultural decentralised autonomous organisations (DAOs), etc.] institutions and systems [e.g. CBNRM, community-based decentralised finance (DeFi), etc.]. - have authority over their domain and are expected to make decisions that influence outcomes.
Trusteeship (legal)	- about holding and managing assets on behalf of others. - have a fiduciary duty, which means they must act in the best interest of the beneficiaries, often with a legal or moral obligation to do so.	- used in legal, financial, and charitable contexts. - manage trusts, estates, or act on behalf of nonprofit organisations, ensuring that resources are used according to the trust's terms or the organisation's mission (e.g. conservancies, conservation metaverse, etc.).
Stewardship (cautionary)	- emphasises responsible overseeing and protection of something considered worth caring for and preserving. - involves a broader sense of duty that includes ethical considerations, sustainability, and the welfare of future generations.	- used in a variety of contexts, including environmental, corporate, and financial. - suggests a commitment to managing resources wisely, ethically, and sustainably, often with a long-term perspective. - may not own the resources they oversee but are tasked with ensuring their wellbeing and responsible use.



Custodianship
Safekeeping and preservation of assets, properties, or resources. Foundational role emphasising the protection and maintenance of something valuable.

Management
Operational control, decision-making, and strategic planning. Organisational role including controlling resources to achieve specific objectives, expanding the focus from mere preservation to active utilisation and goal achievement.

Trusteeship
Fiduciary responsibility to manage assets in the best interest of the community, adhering to cultural, legal and ethical standards. Compliance role encompassing a higher level of accountability and duty, as it serves the needs and objectives of beneficiaries rather than those of the manager or custodian.

Stewardship
Broadest level including all the preceding, but with representation on the gobal stage. Leadership role prioritising the welfare of current and future generations, by integrating the elements of care, strategic management, and fiduciary duty within a framework that considers long-term impacts and ethical obligations to the community and environment.

Figure 1: *Difference between local communities' roles in CBNRM.*

While all these roles involve some form of care and oversight, custodianship focuses on safeguarding; management emphasises operational skills; trusteeship involves legal or ethical obligations to others, and stewardship encompasses a broad leadership attribute (Figure 1).

It can thus be inferred from the above that the roles of local communities in CBNRM are a movement from direct care and preservation of assets (custodianship), through the strategic and operational decision-making involved in their use (management), to a responsibility for managing on behalf of others with their best interests in mind (trusteeship), and a comprehensive ethical obligation to safeguard resources for the broader good and future sustainability (stewardship).

Pre-colonial resource management practices and community stewardship

Before the advent of colonialism, southern African societies had established intricate systems of resource management, characterised by communal stewardship, rotational farming, seasonal hunting bans, and sacred groves (Foyet & Louis 2023). These practices were governed by traditional laws and cultural norms, ensuring sustainability and equitable access (Foyet & Mupeta-Munyama 2023). Communities lived in harmony with their environment, utilising resources judiciously and maintaining ecological balance through indigenous knowledge systems (Louis 2024).

Impact of colonialism on traditional resource management and community rights

The colonial period marked a significant disruption to these traditional practices. European powers imposed new land tenure systems, reallocating communal lands to settlers and introducing commercial farming and mining. Another novelty was introduced: fortress conservation. It involved creating protected areas such as national parks and wildlife reserves from which local people were excluded. Rooted in the early national park movements of the United States, notably marked by the establishment of Yellowstone National Park in 1872, the fortress conservation model was popularised by Gifford Pinchot, John Muir and Theodore Roosevelt in the early 20th century and influenced by the notion of preserving nature in its pristine state, free from human interference (Marsh 2003). This reallocation often led to the eviction and displacement of local communities and the erosion of traditional management practices (Carruthers 1989), without compensation or alternative livelihoods. Furthermore, the establishment of protected areas and game reserves, under the guise of environmental protection, restricted local access to vital resources and hunting grounds, severing the deep-seated connection between communities and their natural environment (Suich & Child 2008).

Post-colonial shifts and the emergence of CBNRM as a response to the failures of top-down conservation models

The post-colonial period saw a gradual recognition of the limitations and failures of state-centric, top-down conservation models. In the 1980s, these models were criticised for excluding local communities and often leading to conflicts, poaching, environmental degradation – factors that all contributed to worsening poverty conditions and erupting from social fragmentation (e.g. resentment, distrust, economic injustice, disintegrated family units). In response, the late 20th century witnessed the emergence of CBNRM as a paradigm shift towards more inclusive and sustainable resource management approaches. CBNRM sought to re-engage local communities in conservation efforts, recognising their rights, knowledge, and vested interest in the sustainability of resources.

However, CBNRM early initiatives were supported by large organisations. The Natural Resource Management Project (NRMP) funded by the USAID provided technical assistance and financial support to Governments, NGOs and communities until the late 90s (Jones 1999). Working with NORAD and the World Bank, CBNRM practitioners reduced poaching in Zambia's Kafue National Park by 80% in three months using data (operational research) and participatory governance rather than guns, helicopters and human rights abuses, leading to a US$45 million investment (Child 2023). In Botswana, the IUCN and the SNV— both organisations which supported CBNRM stakeholders in mapping out post-NRMPs—backed the establishment of the Botswana Community-Based Organization Network (BOCOBONET), an advocacy group and platform for communication among community organisations involved in CBNRM activities (Jones 1999). Nevertheless, in the early 21st century, academic criticism of the donor-designed CBNRM model led to a renewed interest in previously neglected oral and grey literature, as well as in the insights gathered by committed rural practitioners in southern Africa and economists, who, over time through practical application, argued that: "all people affected by the rules should participate in making them" (Ostrom 1990, Hulme & Murphree 2001).

CBNRM the people's way

The aspiration to amplify community voices has been a longstanding one. Unlike previous initiatives directed by larger NGOs, today's CBNRM in southern Africa is a more localised approach, propelled by local actors themselves, under an umbrella movement known as Community Leaders Network (CLN). This self-driven movement has established a robust platform for communities to advocate for common interests across the region and globally, underscoring the strength of a united community voice. The distinct impetus for the current movement is the shift towards self-representation (Louis 2024). This journey from a vision to a tangible, impactful organisation, initiated and driven by the community itself, marks a significant departure from externally led initiatives, highlighting a new era of grassroots empowerment and solidarity (Lubilo 2024).

Principles of CBNRM

The optimal principles of CBNRM are deeply rooted in the recognition of the rights of local communities to manage and benefit from the natural resources upon which they depend. These principles are encapsulated in the legislation and policies that govern communal lands in countries like Zimbabwe and Namibia, where CBNRM prototypes were established. Murphree highlights the critical role of "strong property rights" over wildlife and other natural resources as foundation for sustainable community-based management (Murphree 1995) and emphasises the integration of financial benefits, authority, and responsibility (as strategic pillars) to generate significant increments in social capital (Bowles & Gintis 2002, Murphree 2009).

The Southern Africa Sustainable Use Specialist Group (SASUSG) further elaborates on these principles, emphasising the importance of tenure, economic benefits, ecological sustainability, and participatory and adaptive management. SASUSG argues for a model of resource management where use and conservation are not mutually exclusive but are integrated into a sustainable land-use framework that benefits both people and ecosystems (SASUSG 1996). Berkes identifies these principles within the context of southern Africa's particular brand of community conservation, which integrates economic, political, and organisational strategies within a devolutionary framework (Berkes 2010). This rights-based approach is instrumental in ensuring that communities are not merely participants but have substantial control and stake in resource management outcomes (Suich & Child 2008).

"For wildlife and protected areas to survive on a significant scale, they must be socio-politically acceptable, economically viable and ecologically sustainable" (Child 1955). This statement by Graham Child, one of Africa's premier wildlife conservationists, succinctly summarises CBNRM principles detailed as follows:

- **Benefit sharing (price)** refers to the distribution of the gains from natural resource management among local communities. CBNRM emphasises the importance of tangible benefits to local communities from the sustainable use of natural resources. By pricing products and services derived from natural resources, communities are able to receive tangible and measurable value in the form of financial income, improved living conditions, or access to resources. The benefits derived from guarding and managing wild resources need to be concrete and substantial enough to motivate community involvement and support for sustainable practices.

- **Community empowerment (governance)** translates into enhancing the capacity of local communities to manage their natural resources effectively. Strengthening local governance structures and systems, decision-making processes, ownership, accountability, and leadership over natural resources implies a shift towards local autonomy, where (a) communities have authority, knowledge, and skills to make decisions that affect their environment and well-being; and (b) their sovereignty over their land and resources is acknowledged and respected.

- **Sustainable conservation (tolerance and inclusion)** refers to aligning conservation efforts with community development and livelihood activities. Recognising the interconnectedness of ecological health and human prosperity, CBNRM advocates for solutions that serve both environmental and socio-economic objectives. Integrating conservation and sustainability objectives with livelihood enhancement strategies guarantees that initiatives aimed at restoring and protecting natural habitats and biodiversity simultaneously reflect the interests and needs and bolster the well-being of communities co-existing with wildlife and living alongside areas rich in biodiversity and vulnerable to climate change.

- **Ownership (proprietorship)** translates into ensuring the active involvement of community members in the management and decision-making processes of their natural resources. CBNRM, a model that emerged from the new conservation movement centred on the notion of new institutionalism or institutional economics (North 1986, Williamson 2000, Child *et al*. 2012), emphasises moving from participation (passive involvement) to active engagement. This profound empirical difference between participatory and representational governance at community level (Child 2012, Child 2019, Child 2023) marks the major intellectual contribution to CBNRM of wildlife economist Brian Child: "When community members own the resources and are co-creators of the initiatives undertaken, they have a stake in the outcome of resource management processes, boosting their commitment to sustainable management practices".

Implementation of CBNRM across southern Africa

Several countries in southern Africa have been pioneers in adopting and shaping CBNRM frameworks, each tailoring the concept to fit their unique environmental, social, and political landscape, concurrently contributing to its evolution as a recognised management model (Muyengwa, Child & Lubilo 2014). This widespread yet varied implementation of CBNRM attests to the region's innovative approach to conservation and community development (Smith 2019). This section discusses the diverse experiences of CBNRM programmes, the enabling or restrictive role of legal and policy frameworks, and the challenges faced in the implementation process.

Early development of CBNRM in southern Africa

Zimbabwe's CAMPFIRE (Communal Areas Management Programme for Indigenous Resources), initiated in the 1980s, became one of the earliest and most celebrated examples of CBNRM (Taylor 2009). It focused on wildlife management and revenue sharing with rural communities, enhancing conservation and providing economic benefits from trophy hunting and tourism (Bond 2001). Namibia's Conservancy Programme, established post-independence in the 1990s, enabled communities to (a) create over 80 conservancies and (b) sustainably manage and benefit from wildlife on their lands, contributing significantly to the recovery of wildlife populations (Nuding 2002), enhanced community incomes and community development (Jones & Weaver 2009) through ecotourism and sustainable use (conservation hunting, also known as sustainable hunting). Botswana's CBNRM Programme has successfully integrated community participation in wildlife tourism, crafts, and veld products (Mbaiwa 2004), demonstrating the economic and conservation viability of community-led conservation efforts (Mbaiwa 2014). In Zambia's CBNRM, communities earn through conservation hunting, tourism, or carbon projects (Lubilo 2024). These milestones, among others, illustrate the region's leadership in adapting CBNRM to diverse ecological and social contexts. They demonstrate a collective move towards rectifying historical injustices and recognising the indispensable role of communities in conservation and sustainable development.

To circumvent political challenges, pioneering countries had to employ pragmatic strategies, focusing on ground-level implementation and leaving unresolved many of the broader political battles surrounding community rights and resource tenure (Murphree 1995). Such strategies are grouped under "social expediency", a term referring to actions or policies that are chosen or implemented because they are deemed beneficial or practical in terms of social outcomes, rather than based on principles or ethical considerations. Often applied in contexts where immediate, pragmatic solutions are prioritised to address social issues, challenges, or needs, this concept emphasises the usefulness or effectiveness of decisions in achieving desired social results, particularly focusing on the greatest good for the greatest number of people or the smooth functioning of social systems. This expediency-based conservation approach—focusing on policy and practice rather than addressing politico-legal challenges upfront—while yielding notable successes, has also set forth the need for a more concerted effort to tackle underlying politico-legal issues to ensure the long-term sustainability of CBNRM initiatives.

The role of legal and policy frameworks in facilitating or hindering CBNRM

CBNRM has shaped and been influenced by policy reform in the region. The recognition of community rights in legislation, such as land and forest laws, reflects a shift towards more inclusive governance of natural resources. The role of CBNRM in promoting local democratic governance through policy reform (Nelson & Agrawal, 2008), underscores the need for policies that support community participation and benefit-sharing to ensure the sustainability of conservation efforts (Nelson 2010).

Given that the primary challenge lies in the ability to persuade central wildlife authorities to relinquish control over wildlife and its associated benefits to local communities, the success of CBNRM in southern Africa is closely tied to the existence of supportive legal and policy frameworks (Chishakwe, Murray & Chambwera 2012). These frameworks provide the foundation for community rights to manage and benefit from local resources. CBNRM programmes in Zimbabwe and Namibia, where devolution was legislated in the primary wildlife legislation in 1982 and 1996 respectively, did achieve some success (Muyengwa, Child & Lubilo 2014); For example, Namibia's CBNRM policy and the Nature Conservation Amendment Act empower communities to form conservancies with legal rights to use and manage wildlife. Another example is the Makuleke Contractual Park in South Africa, a landmark case where the Makuleke community regained land rights within the Kruger National Park and has since engaged in successful CBNRM public private partnerships (Foyet & Louis 2023) such as ecotourism ventures, balancing conservation and development.

Conversely, in places where legal frameworks are weak or non-inclusive, CBNRM initiatives have struggled to gain traction, facing challenges in securing land rights, accessing resources, and achieving formal recognition. Two decades ago, in Botswana where communities were granted land leases, and in Zambia where contestation over who gets the benefits from wildlife were an ongoing issue, CBNRM witnessed less success (Muyengwa, Child & Lubilo 2014).

Nevertheless, recent developments signal positive progress. In Zambia, the failing South Luangwa National Park was brought to sustainability by establishing it as a devolved cost centre that retained its income, and by outsourcing all commercial activities to the private sector (Dalal-Clayton & Child 2003). The country's national CBNRM policy advancements have actively been advocated for throughout the years and are on the verge of being implemented (Lubilo 2024). The forthcoming launch of the CBNRM policy in the country was driven by an indigenous-led movement known as Community Leaders Network (CLN) and exemplifies how grassroots demands can shape government policy (Homer-Dixon, 1996). Members of CLN's Zambia Chapter equally advocated for the review of the Wildlife Act and spearheaded the establishment of a zero draft bill. Zambia's rural actors played a central role in the policy's development by rallying resources, engaging with stakeholders, advocating nationwide and placing the government at the heart of the initiative, given the latter's formal hold of the policy-making apparatus. This collaborative effort, sparked by the demand of the country's local communities for clear operational guidelines, has led to a policy that not only the government will take pride in but also marks a significant achievement for the communities. Given the country's historical feud between the government and local communities, which escalated during the 2016 series of disputes and again in 2023 when Zambia's CBNRM Association took the government to court, such positive progress observed in 2024 are all the more remarkable. It is a testament to community-driven advocacy, and it reflects the drive of Zambia's CBNRM actors for a framework that enhances their interaction with the government and industry stakeholders, highlighting the instrumental role of CBNRM's institutions in fostering conservation policies.

Historically a frontrunner in CBNRM initiatives (Jones 1999) that experienced setbacks (Chevallier & Harvey 2016), Botswana is now revitalising its CBNRM policies (Stone *et al*. 2020). Also inspired by CLN's initiatives, Botswana expressed interest in revising its CBNRM policy and sought insights from Namibia. This represents a form of cross-pollination, where successful strategies and policies from one country can inform and improve practices in another. Through such exchanges, CBNRM actors from both countries analyse policies to understand what makes them successful or where they fall short. These activities underscore the importance of creating strong connections with governments to influence policy and political discourse positively. This has resulted in ongoing discussions with the government aiming to improve governance and engagement strategies, exemplified by a recent formal petition by hunting communities to the British High Commission. Malawi has seen the establishment of a national CBNRM forum, while South Africa has initiated a community conservation network to address CBNRM-related issues. Similar efforts in Lesotho have led to the formation of a national working group for CBNRM, with plans to replicate these successes in Eswatini and Madagascar, following their request for assistance to bolster their local conservation strategies. In Tanzania, CLN members have engaged with the government on benefit sharing and funding distribution. Additionally, the Kruger border in Mozambique has recently been serving as a demonstration teaching site for a novel learning-by-doing CBNRM programme (Merz 2014, Vundla 2019). Accordingly, by facilitating community stewardship of natural resources through the implementation of community-led governance and management structures, CBNRM embodies the common property resource (CPR) theory.

CBNRM and the Common Property Resource (CPR) theory

CPR theory addresses how communities manage natural resources that are accessible to all members of the community but are susceptible to overuse and depletion. Contrary to the "tragedy of the commons" narrative, which predicts that individual self-interest would lead to the overexploitation and degradation of shared resources, CPR theory explores how groups can develop collective arrangements that allow for the sustainable management and conservation of these resources. It focuses on the rules, norms, and institutions that communities establish to regulate access to and use of shared resources. These arrangements are often complex, reflecting the ecological characteristics of the resource, the socio-economic needs of the community, and historical and cultural factors. The theory underscores the importance of local governance, the participation of community members in decision-making processes, and the enforcement of agreed-upon rules to prevent resource degradation.

CPR theory has been significantly influenced by the works of Elinor Ostrom and other scholars, who have documented cases around the world where communities have successfully managed common resources over long periods without depleting them. Ostrom identified several design principles common to successful CPR management, including clearly defined boundaries, collective-choice arrangements, monitoring and sanctioning mechanisms, and conflict resolution processes. The theory challenges the assumption that centralised government control or privatisation are the only effective means to manage natural resources, highlighting the potential of community-based management approaches.

By aligning with CPR's emphasis on local governance, CBNRM empowers communities to establish their own rules and norms for resource management, ensuring that decision-making reflects the community's socio-economic and cultural contexts. Moreover, in line with CPR's collective participation tenet, CBNRM promotes the active participation of all community members in managing shared resources, fostering a sense of ownership and responsibility towards sustainable use. Also, by reflecting CPR's principles on monitoring and sanctioning, CBNRM involves local surveillance of resource use and adherence to community-established regulations, helping to maintain resource sustainability. Finally, consistent with CPR's emphasis on conflict resolution processes, CBNRM provides mechanisms for addressing disputes within the community, ensuring equitable access and use of resources.

By applying these CPR principles, CBNRM effectively demonstrates how community-led approaches to resource management can overcome the challenges of overuse and depletion, offering a sustainable alternative to centralised control or privatisation. The success of CBNRM initiatives, as seen in various case studies similar to those documented by Elinor Ostrom, underscores the viability and effectiveness of applying CPR theory in real-world contexts, highlighting the critical role of community governance in the sustainable management and conservation of natural resources.

Challenges in implementing CBNRM

Despite these successes, CBNRM's journey in southern Africa has also encountered a range of challenges and criticisms that question its efficacy, equity, and sustainability. Some of these challenges include:

a) **Legal barriers:** In some cases, such as that of Angola, national laws and regulations have not fully supported community ownership and management rights, limiting the scope of CBNRM initiatives (Saruchera & Manzana 2013).

b) **Governance issues:** Effective CBNRM requires strong local governance structures. In some instances, as depicted in the case of Zambia, weak institutional capacity, lack of transparency, and internal conflicts have undermined community management efforts.

c) **Economic viability:** Ensuring that CBNRM contributes to tangible economic benefits for communities is crucial. However, the economic sustainability of some initiatives remains a concern, particularly in areas with limited wildlife such as island countries within or neighbouring southern Africa (Kull 2002) or nations with low tourism potential such as Lesotho (Makwindi & Ndlovu 2021).

d) **External pressures:** Land grabbing, resource competition, and external investment interests can threaten the integrity of CBNRM areas, requiring robust legal protections and community advocacy. Such is the case of the Democratic Republic of Congo (DRC), where rural members of CBNRM associations (Lubilo 2024) work with communities around Virunga National Park amidst political unrest (Bickford 2016). In scenarios where a country may be under authoritarian rule or experiences a coup, the dilemma arises whether to continue operations.

One of the core critiques of CBNRM is its variability in ensuring equitable distribution of benefits among community members. In some instances, the benefits accruing from CBNRM initiatives have been unevenly distributed, favouring local elites or those in governance structures over the wider community (Jones & Murphree 2013). Such disparities in benefit distribution can erode the legitimacy of CBNRM projects and diminish support within communities, highlighting a significant challenge in implementing these initiatives in a way that is both inclusive and fair.

Furthermore, economic sustainability also poses a dilemma, as CBNRM projects often rely on external funding and are subject to the vicissitudes of tourism markets and the challenge of developing local and/or regional sustainable income streams. The surge and continuous push from Western-initiated anti-trophy hunting legislation endanger aspects of CBNRM and necessitate the exploration of new markets, such as Asia, or the development of intra-continental trade within Africa.

Moreover, criticism regarding the lack of digital literacy among rural populations in the conservation sector, as well as the digital unpreparedness of government officials and institutional actors in the field, highlights a significant challenge facing contemporary conservation efforts. On one hand, the concern over digital literacy in biodiversity-rich rural communities touches on a crucial gap in empowering key populations to participate effectively in conservation initiatives at the local, national, regional and global levels. Digital tools and technologies have become central to modern conservation strategies, from data collection and monitoring of biodiversity to community engagement and education. The absence of digital skills not only sidelines rural communities from actively engaging in these modern conservation practices but also limits their access to information, resources, and networks crucial for sustainable management and advocacy of natural resources. On the other hand, the lack of digital readiness of government officials and institutional actors exposes a broader issue of adaptability and responsiveness within the conservation sector. Digital readiness is not merely about the adoption of technology but also reflects an institution's ability to leverage digital tools for better policy formulation, enforcement, and engagement with stakeholders. This lack of preparedness can result in inefficient conservation practices, missed opportunities for innovation, and a disconnect between conservation policies and the on-ground realities they aim to address.

Together, these criticisms suggest a pressing need for targeted digital education and capacity-building initiatives in conservation finance, local resource mobilisation, and digital conservation within the conservation sector. By enhancing these skills among rural communities and government and institutional actors, there's an opportunity to bridge critical gaps in conservation efforts. Such advancements would not only enable more inclusive and participatory conservation strategies but also foster a more dynamic and effective use of technology and finance in protecting natural resources and improving livelihoods.

The future of CBNRM in southern Africa: strategies to ensure CBNRM's relevance in reconciling development and conservation

The experience of implementing CBNRM has underscored the need for a supportive politico-legal environment, clear property rights, and effective governance structures at the community level. Murphree (1995) and SASUSG (1996) both point to the essential role of adaptive management, where decisions are informed by ongoing monitoring and engagement with the communities involved. Furthermore, there is a call for broader integration of CBNRM principles into national and regional policies, underscoring the need for political advocacy and the mobilisation of rural communities to demand stronger tenurial rights and a greater say in how natural resources are managed. Despite these growth areas, the future of CBNRM in southern Africa holds promise, with several innovations and trends poised to enhance its impact and sustainability.

Innovations and emerging trends

Intersectional Conservation Paradigm (ICP)

Coined by legal scholar Kimberlé Crenshaw in the late 80s, intersectionality is a conceptual framework that analyses how various social and cultural identities—such as race, gender, class, sexuality, ability, language, and more—intersect and overlap to create unique modes of discrimination and privilege. Generally, it highlights that social inequalities are not experienced in isolation. They are interconnected and therefore cannot be examined separately from one another. It emphasises the need to consider multiple facets of identity when understanding social issues, policies, and the lived experiences of individuals, arguing that traditional approaches to social justice and anti-discrimination, which focus on single categories of identity, are inadequate (Crenshaw 2013). I could argue that although this framework has significantly impacted numerous disciplines such as sociology, feminist studies, critical race theory, and beyond, its application within the conservation field has yet to be observed. But I would frame it differently: our failure, as conservation scholars, to closely look at intersectionality has limited our ability to see the framework in places in which it is already doing work and to imagine other places to which it might be taken. Intersectionality is particularly relevant to conservation, especially from an institutional perspective, where it can (and already has) profoundly inform(ed) and transform(ed) institutional paradigms in natural resource management, offering a distinct understanding of the complexities of power, oppression, and privilege both within the miso (rural), in the meso (national) and across the macro (global) discursive geographies of conservation.

While climate change adaptation in CBNRM is trendy, the concept is not new, as CBNRM promotes solutions that are inherently climate resilient. However, lately, a heightened emphasis has been placed on the global dimension of CBNRM. Predominantly analysed as a domestic policy for conservation, scholars have underestimated CBNRM's global power dynamic (Swatuk 2005) and oversimplified dichotomy between consumptive (e.g., trophy hunting) and non-consumptive (e.g., photographic tourism) uses of natural resources. Nevertheless, CBNRM is increasingly being understood as a global assemblage in which competing actors exercise various forms of power that are at times synergistic and at other times in opposition to one another (Heffernan 2022). Between the localisation of global norms and the globalisation of local norms discourse (Madzwamuse 2010, Acharya 2011), CBNRM has evolved into a discursive junction where various stakeholders employ distinct power/knowledge disparities to advance specific agendas. While CBNRM's components such as trophy hunting are generally framed in contrast to photographic tourism, seen widely as a 'non-consumptive' form of conservation, recent literature challenges this conventional classification by demonstrating that all forms of tourism are in fact consumptive and that all variables need to be accounted for in labeling practices as either consumptive or non-consumptive (Heffernan 2022). This approach, which can be coined as the intersectional conservation paradigm, promotes a non-dichotomous view of conservation that acknowledges the complexities of global influences and power imbalances.

Wildlife economy

Traditionally, wildlife, among other natural resources, has been viewed merely as an input rather than an asset in a national economy. This perspective has resulted in minimal government investment in the wildlife sector and insufficient resource allocation of resources to support wildlife conservation. Reversing this position requires an illustration to state and non-state actors using compelling evidence about the economic contribution of wildlife resources to local, national and regional economies (ALU/AWE-COP 2023). Should the preservation of biodiversity hinge on our ability to actively enhance conservation initiatives (ranging from protected areas to land-use policies) across 44% (64 million square kilometres/home to over 1.8 billion people) of the world's terrestrial regions (Allan *et al.* 2022), Namibia stands at the forefront of this endeavour. With the world's most effective conservation programme already safeguarding significantly more than the international target of at least 30% of its land, Namibia is uniquely equipped to lead the way in these efforts. The theory of change is that southern Africa is the only place on the planet where wildlife is increasing, as a result of policy experiments that have deliberately (but partially) replaced exclusionary, non-economic conservation models with inclusionary market-led conservation (Child 2023).

This new paradigm of inclusive, market-led wildlife governance in southern Africa, a global outlier where the expansion of wildlife and wildlife-based livelihoods contrasts starkly to the global loss of 84% of mammal biomass under a business-as-usual paradigm, remains unripe. The wildlife economy is operating at about 10% of its potential, with considerable scope to expand wildlife numbers and habitats through community empowerment and poverty reduction (Snyman *et al.* 2021). There are many talented Africans who are well-placed and eager to unlock this potential (ALU/AWE-COP 2023). By consolidating the knowledge that led to the rewilding of southern and eastern Africa's drylands, and by developing a quantitative vision of the status and potential of the wildlife economy, wildlife economist Brian Child and his collaborators are building an emerging community of practice, through the establishment of an adaptive research-into-practice programme aiming to (a) transform the regional wildlife economy from US$3 to US$30 billion and (b) develop demonstration sites for participatory governance across the southern African region. Some outputs include the establishment of village based PEESG monitoring (policy barriers – economic/livelihood performance and impact; environment; social; governance) based on monitoring tools such as hunting management systems (Child 1995), investor performance systems (WWF/SARPO 1997, Child & Weaver 2006, Child & Wall 2009), governance dashboard (Child, Muyengwa, Lubilo & Mupeta-Muyamwa 2014), livelihoods survey (Mulindahabi 2017) administered by national and regional CBNRM associations and supported by technical training based on key books (Child 2019, Child & Wojcik 2014). Another area for development is the establishment of real time feedback mechanisms providing data to develop a financial topography map/model of the wildlife economy (US$/ha) to benchmark current performance, envision potentials, and identify barriers, as the foundation for selling a "regional wildlife economy vision and strategy" to key decision-makers (Child 2023). This process of co-learning by co-doing – with an emphasis on empowering communities to enter the wildlife economy as participatory village companies – requires an African conservation scholarship and leadership armed with theoretical and practical experience and proficient in navigating the digital wild.

Social media and the digital wild

Although data-driven approaches (i.e. remote sensing) have enhanced the precision of policy decisions (Vinuesa 2020), they do not always enable more effective allocation of resources for conservation initiatives, due to factors often overlooked such as social media influence. Conservation messaging has often faced gaps, not only in effectively engaging wider and more diverse audiences but also in effectively reaching and resonating with specific, targeted audiences. While valuable, traditional methods, such as print media or in-person campaigns may not always resonate with digitally savvy generations and, arguably, policy and law makers (Louis 2024), for whom social media has evolved into a crucial component of political discourse (Straus 2018) - enabling them to voice their perspectives (Devlin, Widjaya & Cha 2020), disseminate information (Knight First Amendment Institute 2020), and engage with constituents (Van Kessel & Hughes 2018) online – a revamp in conservation communication is necessary.

In this era of computational public policy (Solo 2011), there is a growing need for wildlife conservation efforts to adopt virtual strategies, to better align with the evolving landscape of policymaking and stakeholder engagement (Miao, Holmes, Huang & Zhang 2021). Features are embedded in social media platforms for a reason, and leveraging them and others social media hacks – responsibly - can serve conservation efforts effectively (Foyet 2024). Also, harnessing digital technologies, such as culturomics (e.g. social media data analytics) in the conservation field will allow policymakers to gather real-time, comprehensive data on sentiments, wildlife populations and ecosystems (Foyet 2024).

AI- powered conservation

AI is emerging as a powerful ally for communities engaged in conservation efforts — and it is coming at a time in which we face increasingly complex ecological challenges (Potts 2017) and the urgent need to protect our natural world (Martin, Maris & Simberloff 2016) and respective biocultural heritage (UNESCO 2023). The synergy between AI and conservation has the potential to enhance our ability to monitor and safeguard ecosystems, mitigate human-wildlife conflicts (RESOLVE 2020), optimise resource management and foster sustainable coexistence between people and wildlife. Despite these myriad uses of AI in conservation, its integration in conservation citizen science and engagement remains relatively new. There is a pressing need for more professionals in the fields of conservation culturomics and computational sustainability who possess local knowledge to establish the linkages between semantics, social behaviour and conservation patterns (Foyet 2024). Additionally, several urgent areas within conservation are expected to undergo significant developments, including technology-driven advancements in conservation planning and decision support (Justeau-Allaire 2023), the tourism, hospitality, and event management industry (Foyet 2024), AI-powered Natural Language Processing (NLP) and Communication, public engagement, and education: AI-powered chatbots and virtual assistants will be used to engage the public (Khan *et al.* 2024) and answer conservation-related questions (Chi 2022). Leveraging AI tools to facilitate interactive learning experiences (Reyhani Haghighi, Pasandideh, & Johnson 2023) and disseminate accurate information (Egon & Rosinski 2023) about conservation issues will lead to a more informed and engaged public, freeing up resources for addressing other pressing human-centred concerns (Gomes *et al.* 2019).

Mental health in conservation – generational burdens

Acknowledging that environmental challenges like drought can significantly impact behaviours is crucial. For instance, in Namibia, drought conditions compel people to undertake activities they wouldn't normally consider, driven by the need to secure their livelihoods. The emotional toll on those working in conservation, such as rangers, is profound, illustrating the mental and emotional challenges faced in balancing human needs with wildlife preservation. This highlights the broader, often overlooked, mental health aspects within conservation, suggesting a need for greater empathy and understanding in addressing both human and environmental needs.

"People's behaviours are shaped by their environments, isn't it? For instance, in Namibia, if there is the drought, people start moving and doing things that they are not supposed to do because they need to survive. It's like, me not having food in my house. I will do anything to put food on the table for my family and my children. Sometimes, when you are desperate, your behaviour also changes. And it's not because you wanted to change, but because you are forced by circumstances to change. So we do have some of those behaviours. But as I said, and that's where [CBNRM] comes in, to address those livelihood issues, otherwise behaviours will change. Some of it is not just because of certain external factors. Some of them, sometimes it's also just greed. People poaching that for me is greed, a behaviour that needs to change. You know, if I was a psychologist, I would probably give you 100 reasons. There's a big debate now, people are saying that we need more psychologists and anthropologists in conservation because people are mentally affected. **We need anthropologists to understand the history, psychologists to understand behaviours, economists to create the market, and social marketing to market. The world of conservation is not managed by a computer. We sit here, we make decisions. That's the real difference. So because it is still very heavily dependent on people, mentally it gets to you. You don't want to be in the unsafe shoes of a ranger, but you want to save the elephant. So when you see the elephant dying, you get so angry, it gets mentally to you, but you don't want to be there physically.** There's a lot of these issues mentally that is making people mad, both in the West and here."

Maxi Pia Louis, 2024

Generational burdens refer to the various challenges and conditions passed from one generation to the next, significantly impacting lives and futures. These burdens are (a) **economic and financial** [debts, unfunded liabilities (i.e. pension obligations and healthcare benefits), and the overall economic conditions inherited by the affected generation], limiting their economic opportunities and standard of living and affecting their ability to achieve economic stability, afford education, or access housing; (b) **environmental** [consequences of previous generations' environmental beliefs, policies and practices, and long-term effects of pollution, climate change, loss of biodiversity and natural resource depletion], posing significant challenges to their future prosperity and well-being: affected generations inherit a planet that requires immediate and substantial action to mitigate environmental crises, often without the necessary resources or political will from preceding generations; (c) **social and psychological pressures** (i.e. societal expectations, cultural norms and taboos, notions of weakness, shame, curse, silence and unspoken truths) shaping how a generation lives, works, and engages with society. Added to it is the mental health impact of facing uncertain futures, higher rates of anxiety and depression, and the pressure to solve complex global issues left by previous generations; (d) **technological and employment shifts**: rapid technological advancement and changes in the job market mean a generation must adapt to a world vastly different from their parents'. They face the challenge of navigating the gig economy, automation, and the digital transformation of the workplace, often without the security of traditional employment models; (e) **political and institutional legacy** (i.e. political systems, structures, and policies) inherited and which may no longer be effective in addressing contemporary challenges. This includes outdated educational systems, healthcare, and governance models that do not meet the needs or values of current generations. Generational burdens thus encapsulate a wide range of issues, demanding innovative solutions and a collaborative approach across ages to ensure a sustainable and equitable future for all.

The complexity of human behaviour in conservation underscores the growing call for a multidisciplinary approach I call human-centred conservation. This approach incorporates insights from anthropology, psychology, economics, computer science and social marketing. This diversity of perspectives is essential for understanding the multifaceted relationship between humans and their environment, from the historical context of communities to the cultural values that underpin people's interactions with nature, the economic drivers of conservation efforts, the technological innovations that can support sustainable practices, and the mental models and cognitive biases that influence individual and collective decisions regarding environmental stewardship and conservation actions. The necessity for mental health support services in conservation has become as fundamental as other basic needs, such as water, in our communities and even within our own homes. Mental health care should be integrated into conservancies' daily activities, programmes, and household routines. This approach is becoming increasingly important as we recognise the significant impact of societal stresses on well-being, especially in rural areas where such pressures are often unseen or disregarded.

In the past, African culture may have viewed the expression of psychological distress as a sign of weakness. However, there's a growing recognition of the deep-seated effects of stress on rural individuals. The daily lives of rural dwellers are marked by rigorous physical tasks, and they bear and transmit to their offspring the weight of scarcely examined burdens, rooted in historical, cultural, and family legacies. These inherited challenges significantly impact this marginalised population in manners yet to be fully comprehended. Addressing these needs involves acknowledging and addressing the psychological support required by rural individuals, thereby enriching the well-being of entire communities. This shift towards recognising and treating mental health issues in rural settings as an integral part of overall health and wellness, and an integrated part of One Health initiatives marks a significant step forward in how we care for ourselves and each other through a "leaving no one behind" policy of human-centred conservation.

Finally, international support and partnerships play a vital role in advancing CBNRM. This includes technical assistance, capacity building, and financial support from development agencies, conservation organisations, and research institutions in support of CBNRM goals, among others. Such partnerships can facilitate knowledge exchange, promote best practices, and provide the resources necessary for scaling successful CBNRM models (Foyet 2023).

As CBNRM in southern Africa evolves, addressing its critiques and challenges while leveraging emerging opportunities and innovations will be key to its future success. By strengthening policy frameworks, enhancing community engagement and economic viability, and fostering international support, CBNRM can continue to offer a sustainable pathway for conservation and community development in the region.

Brief critical analysis of CBNRM discourse

Critical Discourse Analysis (CDA) is a methodological approach to studying language in its social context, focusing on the ways that discourse (written, spoken, or visual communication) shapes and is shaped by power relations within society. It examines how language is used to construct social identities, dominate or marginalise certain groups, and influence beliefs and behaviours. CDA goes beyond the textual analysis of language to include consideration of the cultural, political, and historical contexts in which discourse occurs, aiming to uncover the underlying power dynamics and ideological processes at play. An examination of the language, power dynamics, and social practices within understandings of CBNRM in southern Africa reveal the following key themes:

- **Power and ideology in language usage**: CBNRM literature repeatedly emphasises *empowerment, benefit-sharing*, and *community participation* as central to CBNRM. This choice of language promotes an ideology where local communities are not just beneficiaries but also active participants in resource management. This reflects a shift from traditional, top-down conservation approaches to more inclusive strategies that recognise the rights and knowledge of local communities.

- **Discursive construction of social identities**: CBNRM discourse constructs a positive identity for local communities by highlighting their roles as custodians, managers, trustees, and stewards of natural resources. This portrayal challenges historical narratives that marginalised these communities from conservation efforts, presenting them instead as key actors in sustainable resource management.

- **Representation of social practices**: CBNRM is represented as a practice that integrates conservation with socio-economic development. The discourse constructs a narrative where conservation and community development are not only compatible but mutually reinforcing, thus challenging traditional conservation practices that often excluded human needs and rights from environmental protection efforts.

- **Mental health and conservation**: The inclusion of mental health aspects introduces a novel dimension to the discourse on conservation, advocating for a holistic approach that considers the well-being of those involved in conservation efforts. This reflects an expanding understanding of conservation that encompasses human well-being alongside environmental sustainability.

Overall, the primary difference between local and external views of CBNRM lies in the emphasis on community empowerment, cultural integrity, and economic development versus a primary focus on biodiversity conservation and

Table 2: *Contrasting CBNRM perspectives between local and external actors.*

Aspect	Local Actors' View (Within)	External Actors' View (The West)
Objective	Conservation for local benefits (improving livelihoods, preserving biocultural heritage).	Conservation of biodiversity for global environmental benefits. Improvement of local livelihoods is seen as a beneficial outcome but not the primary goal.
Benefit sharing	Prioritisation of equitable distribution of benefits among community members to ensure livelihood improvements.	Emphasis on effectiveness of conservation outcomes, with benefit sharing seen as a means to incentivise local conservation efforts.
Governance	Advocacy for locally driven governance structures reflective of community needs and contexts.	Advocacy for governance models supporting centralised oversight & international standards unsuited to local realities.
Economic Development	CBNRM as poverty alleviation tool (broader economic need).	View CBNRM as a tourism enhancer / investor vs community oriented (narrow economic goal).
Cultural Practices	Integration of traditional knowledge and cultural practices in natural resource management = biocultural protocols.	Interest in cultural practices to the extent that they contribute to or do not hinder conservation objectives.
Legitimacy and Rights	Assert legitimacy of rights to manage and benefit from local resources as fundamental to sovereignty and cultural identity = principled.	Recognition of local rights as important for gaining community buy-in and support for conservation initiatives = instrumental.
Perception of challenges and solutions	Concerns over governance issues focusing on solutions enhancing local capacity and securing legal rights.	Concerns around scalability of CBNRM; focus on solutions involving technical assistance, capacity building, monitoring and funding.

global environmental benefits (Table 2). Local actors view CBNRM as an integral part of their socio-economic fabric and cultural identity, whereas external actors often approach it from a conservation-centric perspective, sometimes underestimating the complex interplay of local social, economic, and cultural factors. Applying CDA, it's evident that the discourse on CBNRM in southern Africa reflects shifts in power dynamics towards more inclusive and participatory approaches. The text uses language and legitimation strategies that promote an ideology of empowerment, sustainability, and integration of human and environmental well-being, challenging traditional conservation narratives and practices.

Conclusion

In this essay, we have journeyed through the historical evolution, principles, and contemporary implementation of CBNRM in southern Africa, highlighting its role in bridging and reconciling conservation with community development. From its roots in pre-colonial stewardship practices, through the dislocations of colonialism, to its emergence as a counterpoint to top-down conservation models in the post-colonial era, CBNRM has evolved as a critical framework for sustainable natural resource management globally and holds profound significance for southern Africa's socio-economic and environmental landscape in particular. It represents a paradigm shift towards more inclusive, democratic, and sustainable approaches to natural resource management. By foregrounding the rights and knowledge of local communities, CBNRM offers a model for managing the region's rich natural resources in a way that respects cultural heritage, promotes social equity, and preserves ecological integrity. The principles of CBNRM—benefit sharing, community empowerment, conservation, and participation—provide a foundation for initiatives that aim to enhance both environmental sustainability and socio-economic development. Programmes like Zimbabwe's CAMPFIRE, Namibia's conservancies, and Botswana's CBNRM projects exemplify the diverse applications of these principles, demonstrating the potential for CBNRM to deliver tangible conservation and community benefits.

However, the implementation of CBNRM is not without its challenges. Experimenting with adaptively improving community governance necessitates a combination of information technology and peer review, while issues of equity, economic sustainability, legal and digital barriers, and mental health remain significant hurdles. Balancing conservation objectives with community development needs requires careful negotiation and adaptive management, highlighting the complexity of CBNRM as a practice. Despite these challenges, the future of CBNRM in southern Africa is ripe with opportunity. Innovations in climate change adaptation, social media, AI, and CBNRM PPPs, supported by robust policy frameworks and international partnerships, present pathways for strengthening CBNRM.

Looking ahead, the prospects for CBNRM in fostering sustainable development and conservation are promising. As the region faces increasing environmental pressures and socio-economic challenges, the need for integrated, community-driven resource management strategies has never been greater. With continued innovation, support, and commitment from all stakeholders, CBNRM can play a pivotal role in shaping a sustainable and equitable future for southern Africa. The journey of CBNRM is far from complete, but its contributions to the region's socio-economic and environmental well-being are undeniable, marking a path forward that merits continued exploration, support, and refinement.

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Freshwater fish as a potential nutritional gap-filler in combating malnutrition in Namibia

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Abstract

With Namibia exporting up to 97% of the catch from marine capture fisheries, the small-scale inland fisheries resources have been touted as the community-centred solution towards ensuring food security and alleviating malnutrition in the country. Although efforts have been made over the years to address malnutrition, especially among children, nearly 90% of children under the age of five do not receive the minimum acceptable diets with adequate dietary diversity and meal frequency. Consequently, one in every five children has stunted growth. With monotonic energy-based diets prioritising caloric input over balanced nutrition, Namibian children are often deficient in micronutrients such as vitamins B2, B3, B9, calcium, and iron, all of which are found in high concentrations in freshwater fish. Additionally, fish provide other essential micronutrients such as vitamin B12, zinc, selenium, and omega-3 fatty acids that support overall health and growth. Small-sized fish or juveniles of large fish have high concentrations of these essential micronutrients, underscoring the need for further research on fisheries resource utilisation and the nutritional composition of local fish resources which hold significant potential for addressing dietary micronutrient deficiencies. This article aims to discern the potential contribution of freshwater fish in addressing malnutrition, especially amongst vulnerable groups such as children.

Keywords: diets, freshwater fish, inland fisheries, micronutrients, Namibia, stunted growth, undernourishment, wasted growth

Introduction

Namibia is a sparsely populated country in south-western Africa, with a population of 3.02 million inhabiting 826 000 km² – an average population density of 3.7 persons per km² (NSA 2024). The low population density is partly due to Namibia being the driest country in sub-Saharan Africa, with only 5% of the country receiving more than 500 mm of rainfall annually and 92% of the land classified as either semi-arid, arid or desert (Sweet & Burke 2006). Yet, agriculture remains an important sector in the country's formal and informal economy, supporting up to 70% of the population (Shiimi *et al.* 2012). Despite this, 70% of the required staple food in Namibia (maize and pearl millet) is imported from neighbouring countries like South Africa, Zambia and Angola; highlighting the difficulties of agricultural food production in dry climatic conditions (Shifiona *et al.* 2016, Mupambwa *et al.* 2019). As such, Namibia faces a dire malnutrition situation and is not on course to attain most of its global sustainable development goals related to nutrition (GNR 2022). It was envisaged that by March 2024, about 26% of the Namibian population will be facing high levels of acute food insecurity and will require urgent government intervention (IPC 2023). The World Health Organization (WHO) defines malnutrition as a "deficiency or excessive intake, imbalance of essential nutrients or impaired nutrient utilisation resulting in insufficient dietary energy levels to maintain a normal active and healthy life" (WHO 2023). In developing countries like Namibia, malnutrition (which includes all forms of poor nutrition such as undernutrition and overnutrition) is a big concern. Undernutrition (deficiency in important nutrients) is typically the most common form of malnutrition, and primarily expresses itself in the form of stunted growth (children being too short for their age) and/or wasted growth (children's weight being too low for their height, WFP 2024).

Capture fisheries in Namibia are essential sectors with the potential to improve food security and economic growth. In 2020, the marine sector contributed NAD 6.86 billion of the NAD 10.58 billion (65%) Gross Domestic Product (GDP; MFMR 2021). However, the market is predominately international, with as much as 97% of the marine capture exported in 2020, contributing 14.3% of the total country export (MFMR 2021). Freshwater inland fisheries and aquaculture have been regarded as the community-centred solution towards ensuring food security and alleviating malnutrition in the country (GRN 2002, Hackenberg *et al.* 2022, Iitembu *et al.* 2022). The north-eastern part of the country has a greater concentration of perennial rivers and high rainfall compared to the rest of the country, with three of the five Namibian perennial rivers (Kavango, Zambezi and Kwando), and over 100 000 people depending on inland fisheries activities (Sweet & Burke 2006, Tall & Failler 2012). Yet, a considerable portion of the population in each of the north-eastern regions of Kavango East and Kavango West are classified as stage 4 under the Integrated Food Security Phase Classification, indicating an urgent need for intervention to recover from food insecurity (IPC 2023). With the reported high concentration of essential micronutrients, the adaptive management and sustainable utilisation of freshwater fish could be pivotal in counteracting malnutrition through increased freshwater fish consumption (Gronau *et al.* 2018, Nölle *et al.* 2020, Hackenberg *et al.* 2022).

This review aims to pinpoint the potential contribution of freshwater fish in helping combat malnutrition in Namibia, especially among children - a group very vulnerable to undernourishment.

Overview of malnutrition in Namibia

Malnutrition in Namibia has only started gaining scholarly attention in recent years, with studies directed towards describing the prevalence of this condition (NAFIN 2010, Mwilima 2018, GNR 2022, Johannes 2024). Much of the earlier estimates of both poverty and malnutrition were based on the Institute for Public Policy Research's (IPPR) research into the trends of poverty and inequality in post-independence Namibia. This was published in a series of surveys called the Namibia Household and Income Expenditure Survey (NPC 1994) - updated in 2015 - and the National Demographic and Health Survey (MoHSS & ICF International 2014). In addition to these, Misihairabgwi and Rennie (2012) documented the reports on nutritional inequality in Namibia and abroad. Overall, the prevalence of malnutrition in Namibia was found to be high among both the younger and older age groups, with 45% of the 12–18 years and 32% of the 46–66 years being undernourished as of 2012 (Misihairabgwi & Rennie 2012). Amongst children less than five years of age, nearly one in three children (28%) in Namibia had stunted growth, whilst 9% were physically wasted in their growth. Similar statistics were also reported by Mwilima (2018) and these prevalences had been increasing since 1992 (Mwilima 2018).

Despite important progress in efforts to eradicate malnutrition in Namibia, recent estimates indicate that further interventions are necessary to effectively address this issue (Misihairabgwi & Rennie 2012, Johannes 2024). In 2019, it was reported that about 288 840 (87%) of the children in Namibia under the age of five did not receive the minimum acceptable diets with adequate dietary diversity and meal frequency (Shikongo 2019). Most recently, a systematic review of the prevalence of malnutrition among Namibian children revealed an improvement from historical highs. The prevalence of malnutrition declined to 17.1% in 2021 for the whole population, whilst one in five (approximately 72 000) children in Namibia are stunted, with 43% of the current adults having been stunted in their earlier development and therefore unlikely to attain their full growth potential (Johannes 2024).

Geographically, the prevalence of malnutrition in Namibia varies among the 14 administrative regions of the country. Regions with low social and economic indicators such as low income, low level of education and high population density, especially in northern to north-eastern Namibia tend to have a higher prevalence of malnutrition (Misihairabgwi & Rennie 2012). In relation to the prevalence of stunting, Ohangwena (36.5%) and Omusati (39.4%) regions, which are among the north-central regions where 43% of the country's population occupies only 7% of the total land area, often record the highest levels of stunting among children under the age of five (Mwilima 2018, Fujimura *et al.* 2022, Johannes 2024). Similarly, vulnerability to food shortages is highest in Kavango East and Kavango West regions, where 92% and 89% of the population per region is facing food shortages, respectively (Mwilima 2018). Likewise, these two regions are also associated with a high prevalence of both stunting (19.5% and 15.9%) and wasting (5.7% and 6.2%, Fujimura *et al.* 2022).

The prevalence of undernourishment in Namibia also varies among gender groups. The prevalence of stunting is 23.6% and 18.1% among Namibian male and female children under the age of five (Fujimura *et al.* 2022). Among the whole population at large, Misihairabgwi and Rennie (2012) reported fewer females (25%) to be underweight compared to males (32%) based on their Body Mass Index (BMI; Misihairabgwi & Rennie 2012). However, among children under the age of five in Namibia, female children (4.6%) experienced lower weight for their height (wasted growth) compared to male children (3.8%; Fujimura *et al.* 2022). However, broad generalisation of prevalence data should be done with some levels of caution, as different estimation methods may yield different values, especially in developing countries such as Namibia where the quality of the estimation data often is of poor quality, when available (Fujimura *et al.* 2022).

Nutritional composition of staple food in Namibia

A typical Namibian diet is mainly composed of cereal grains like pearl millet (locally known as mahangu) and maize, which are often consumed with red meat and seasonally with leafy greens such as wild spinach, and milk (Vähätalo *et al.* 2005, Singlinger *et al.* 2019). On average, the commercial per capita consumption of maize, which is used to supplement mahangu when preparing meals, is 44 kg per year, whilst mahangu is 29 kg per year – resulting in mahangu accounting for only 20% and maize 33% of the national cereal consumption (Shifiona *et al.* 2016). Mahangu is chiefly produced on a subsistence level for human consumption across the country (hence low importation), whilst the local subsistence production of maize is low, frequently necessitating commercial importation to satisfy local demands (NAB 2023).

As a collective, Namibia can be described as a meat-eating nation, with a per capita consumption of around 50–60 g/day, well above both the WHO-recommended level of 15 g/day and the world average of 41.8 g/day (Table 1; Singlinger *et al.* 2019). In addition, due to unfavourable climatic conditions and the relative unaffordability of imported products, Namibians generally have limited access to fruits and vegetables (Vähätalo *et al.* 2005, Singlinger *et al.* 2019).

Table 1: *Consumption levels of various Namibian food groups and their recommended levels by the World Health Organization (WHO).*

Food Groups	**WHO Recommended Levels**	**Namibian Levels [a]**	**Status**
Whole grains	125 g/day	50-199 g/day	Equal
Meat	15 g/day	50-60 g/day	Excess
Vegetables	400 g/day	40 g/day	Deficit
Fruits	300 g/day	30-74 g/day	Deficit

[a] Namibian consumption level adopted from Singlinger *et al*. (2019).

Mahangu and maize are among the most common crops in the country (climate permitting). Both predominantly contain high carbohydrate content, making them an ideal source of dietary energy. The considerable carbohydrate levels in these staple grains contribute significantly to their gross energy values, with mahangu providing around 1 700 kJ/kg and maize providing between 1 398 and 1 477 kJ/kg (Okoruwa & Kling 1996, Bathla *et al.* 2020, Hassan *et al.* 2021). Meat is chiefly a protein-dense food, providing around 23 g of protein per 100 g (Williams 2007, Wyness 2016). Availability and nutritional efficiency have made porridge (made from a mixture of maize and sometimes mahangu) and meat a mainstay in the diets of especially children as it is used primarily for the growth, repairs and maintenance of body tissues (Endrinikapoulos *et al.* 2023). This makes them essential in the Namibian diets where caloric intake seem to be prioritised over balanced nutrition.

As a result of the monotonic energy-based diets, there have been key findings highlighting the dire lack of essential nutrients in Namibian diets, especially among children – a group with a high prevalence of malnutrition. In a study that employed various observational and biochemical methods, Jooste *et al*. (1994) investigated the nutritional status of 380 school-going children in north-eastern Namibia. Overall, it was reported that their diet lacked sufficient calories, as it often only fulfilled 39% and 45% of the recommended daily intake by the WHO, for girls and boys, respectively (Jooste *et al.* 1994). Furthermore, their diets were deficient in essential micronutrients and minerals such as vitamin A, riboflavin (B2), nicotinic acid (B3), vitamin B6, folic acid (B9), ascorbic acid (vitamin C), vitamin E, iron (Fe), calcium (Ca) and iodine (I) (Jooste *et al.* 1994, Vähätalo *et al.* 2005).

Although the available nutritional data as discussed in Jooste *et al*. (1994) and Vähätalo *et al*. (2005) are from the mid-1990s and 2000s, contemporary social and environmental issues do not provide a positive outlook, suggesting little improvement, or a worsened situation. For instance, the Namibian population more than doubled from 1.40 million in 1991 to 3.02 million in 2024 (NSA 2024). Yet, in the context of climate change, there has been an increased intensity, frequency and duration of drought events in Namibia over the last decade, further constraining the sustenance of an already-dry country (Liu & Zhou 2021). Currently, Namibia is experiencing one of its worst droughts in recent memory, which has resulted in country-wide crop failures, severe food insecurity and the declaration of a nationwide state of emergency. Nutrient sources that could be relied upon in the 1990s are becoming increasingly vulnerable to the pressures of climate change and population growth, suggesting the need for nutritional alternatives.

Persistent environmental factors (droughts and floods that disrupt agricultural production) and socio-economic factors (high unemployment rate) limit access to diverse food sources, which further exacerbates undernutrition in Namibia (NPC & WFP 2021). The deficiency in micronutrients is not always easily measured, and when they become clinically evident it is often too late and accompanied by disturbances in physical growth, intellectual development and immunological functions (NAFIN 2010). Namibian population suffers from various diseases caused by micronutrient deficiencies, such as goitre (caused by iodine deficiency), xerophthalmia (vitamin A deficiency), anaemia (iron deficiency), and pellagra (vitamin B3 deficiency; FSNC 1995). Although the government has taken significant strides to increase the consumption of deficient micronutrients, such as through salt iodisation programs and the distribution of vitamin A supplements at primary health care centres – other deficiencies are more complex in their origin, making them difficult to address individually. Animal food sources, such as freshwater fish, often have a variety of micronutrients in forms readily available for human absorption, making them ideal for combating micronutrient deficiencies as a whole, rather than individualised supplementation programs in non-endemic parts of the country.

Nutritional value of fish and contribution towards mitigating undernutrition

The high concentration of essential nutrients in fish, coupled with the high availability and accessibility in natural and rural systems all around the world, makes fish a key asset in combating nutritional ailments worldwide (McIntyre *et al.* 2016). Although the nutritional profiling of freshwater fishes is entirely lacking in Namibia, a study has been done in neighbouring Zambia where the composition of common freshwater fishes of different sizes and preparation and consumption methods was profiled (Table 2; Nölle *et al.* 2020). Freshwater fish were found to often contain high protein and moderate fat contents, around 17.38 g per 100 g and 3.52 g per 100 g, respectively, with small fish generally having higher fat content than large fish. Fish are also known for their high fatty acid composition, especially the long-chain polyunsaturated omega-3 fatty acids that have a low synthesis in the human body, hence their supplementation is often recommended as the body cannot sufficiently manufacture them. These essential long-chain polyunsaturated fatty acids such as eicosapentaenoic

Table 2: *Common nutrients found in freshwater fish, along with their recommended daily intake (RDI) for children (1-3 years) and pregnant and lactating women (PLW).*

Nutrient	Units	Recommended Daily Intake (RDI) [a]		Content per 100 g edible portion [b]			Mean content
		1–3 years	PLW	Small fish (3.7–10.0 cm)	Medium fish (10.3–18.7 cm)	Big fish (20.9–46.1 cm)	
Proximate							
Protein	g/day	13	71	18.9	17.8	17.5	18.1
Fat	g/day	–	–	4.2	5.1	2.8	4.0
Fatty acid composition							
EPA	%	–	–	1.3	0.4	0.6	0.8
DHA	%	0.1	0.2	2.8	1.6	3.1	2.5
Vitamin composition							
Vitamin B2 (Riboflavin)	mg/day	0.5	1.4–1.6	0.1	0.2	0.1	0.1
Vitamin B3 (Niacin)	mg/day	6	18–17	2.5	2.7	2.92	2.7
Vitamin B6 (Pyridoxine)	mg/day	0.5	1.9–2.0	–	–	–	–
Vitamin B9 (Folates)	µg/day	160	600–500	15.5	11.9	12.9	13.4
Vitamin B12	µg/day	0.9	2.6–2.8	10.6	2.7	2.7	5.3
Mineral composition							
Calcium (Ca)	mg/day	500	1 200–1 000	1 029.6	250.9	31.8	437.4
Iron (Fe)	mg/day	5.8	15	5.9	0.9	0.5	2.4
Zinc (Zn)	mg/day	4.1	5.5–9.5	5.2	1.5	0.8	2.5
Potassium (K)	mg/day	–	–	265.1	260.4	279.3	268.3
Magnesium (Mg)	mg/day	60	–	44.2	26.2	24.3	31.5
Selenium (Se)	µg/day	17	28–35	36.4	53.2	35.8	41.8

[a] Derived from FAO and WHO (2001) and WHO *et al*. (2002).
[b] Derived from Nölle *et al*. (2020).

acid (EPA) and docosahexaenoic acid (DHA) play a critical role in the cognitive abilities and brain development of a child, especially during the first 1 000 days of life (Longley *et al.* 2014). In Zambian freshwater fishes, the concentration of the EPA ranged from 0.05% in tilapias to 2.79% in small-sized fishes such as kapenta, while the DHA ranged between 0.16% in S*ynodontis* species to 13.39% in cichlids (Nölle *et al.* 2020, Estiasih *et al.* 2021).

Fish also have a high concentration of essential minerals such as calcium (304 mg per 100 g), iron (1.76 mg per 100 g), and zinc (1.9 mg per 100 g); with these concentrations typically being highest in smaller-bodied fishes which are consumed whole, with bone, scales, viscera and head intact (Larsen *et al.* 2000, Nölle *et al.* 2020). In essence, much of these minerals are often lost as by-products when only the preferred parts (often fillets) of large fish are consumed. In Zambia, which shares similar river systems and fish communities with north-eastern Namibia, freshwater fishes contain high volumes of micronutrients such as vitamin B2 (Riboflavin, providing 24% of the recommended daily intake [RDI] per 100 g edible portion), vitamin B3 (niacin, 45% RDI), vitamin B9 (folate, 8% RDI), calcium (87% RDI), and iron (42% RDI); which are all deficient in the diets of malnourished children in Namibia (Jooste *et al.* 1994, Vähätalo *et al.* 2005, Nölle *et al.* 2020), underscoring the potential of freshwater fish in combating malnutrition.

Conclusions and recommendations

Although Namibia is a large country with a relatively small population, alarming statistics paint a worrying picture of the current and future nutritional status of the population, especially among vulnerable groups such as children where one in five are experiencing stunted growth. About 26% of the Namibian population is food insecure and needs rapid intervention from the government for assistance (IPC 2023). With diverse freshwater resources, including fish, particularly in north-eastern Namibia, this should not be the case if the fish resources are sustainably managed. Yet, up to 79% of communities in north-eastern Namibian are unable to afford and access nutritious and daily survival diets (NPC & WFP 2021). The current drought (2023/4), and its impact on depleting the resource base relied upon by Namibians, might make a bad nutritional situation even worse (Brown & Thomson 2024). As we have outlined above, the consumption of freshwater fish, especially the smaller-sized fish, has huge potential in providing key nutrients that are currently deficient in staple foodstuffs, hence lacking in diets.

Efforts to address the nutritional deficiencies in Namibian diets should be coupled with the comprehensive nutritional profiling of local freshwater fish species from Namibian rivers. Specifically, further research should prioritise the quantification of the nutrients prevalent in freshwater fish but deficient in the diets of Namibian children. Additionally, attention should be given to nutrients found in fish in high concentrations that are not reported to be deficient in diets but are recognised for their beneficial effects on human health.

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Lesser Grey Shrike *Lanius minor* Gmelin 1788 on its non-breeding grounds: comparative biometrics, moult data and criteria to determine age and sex

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CONTENTS

ABSTRACT

In this study we present measurements, moult data and related observations for 356 Lesser Grey Shrikes *Lanius minor* ringed during their non-breeding season in Namibia. Our research focuses mainly on addressing critical gaps in knowledge about the species' plumage. We describe non-breeding plumage features that have been omitted in the southern African bird books, and thus provide essential information for accurate ageing. It is noteworthy that birds lacking a black forehead (frontal mask) and those with an incompletely black bill are not necessarily juveniles or immatures, as asserted in the literature and identification guides. These same plumage features are signs of moulting adults and can be observed particularly on the non-breeding, but at times already on the breeding-grounds. Additionally, we offer photographic evidence of the head moult, loss of black forehead and changes in bill colour during the non-breeding season. We discuss the timing and progress of primary moult in adults and first-year birds, along with plumage features for age determination. The study also examines the increase of mass, site fidelity, bird numbers responding to rainfall, and short and long-term fluctuations of population numbers. Our findings contribute insights into the ecology and behaviour of Lesser Grey Shrikes in the non-breeding grounds. Finally, we propose potential subjects for further research to enhance conservation and management efforts.

Keywords: Africa; age; bird ringing; errata in literature; *Lanius minor*, Lesser Grey Shrike, misidentification; moult; Namibia; non-breeding grounds; plumage; SAFRING; sex

1. INTRODUCTION

Species and subspecies of Namibian birds are underrepresented in research and literature of southern African birds, still showing huge gaps of knowledge. This lack of data refers also to the moult process of migrants on their non-breeding grounds. We have been ringing birds in southern Africa for more than twenty years and are evaluating our data to expand the knowledge about less researched species and subspecies in the region (Bryson & Paijmans 2021, 2022, 2023a, 2023b; Bryson *et al.* 2023; Paijmans & Bryson 2023).

In this paper, we present our observations, measurement data and moult data from 356 Lesser Grey Shrikes *Lanius minor* that we ringed in their austral migratory territories in Namibia. Our main focus was on the changes that Lesser Grey Shrikes undergo during their yearly complete moult, especially the moult of the head and the colour-change of the bill, and how this allows for more precise age determination. The lack of the frontal black mask or its mottled appearance, together with a bill not fully black, serves in the southern literature as a criterion for the young age of the Lesser Grey Shrike. As described in the northern literature (Cramp & Perrins 1993, p. 482; Shirihai & Svensson 2018, p. 192; see also Lefranc & Worfolk 2022, p.118), the black front of the mask is being moulted during the complete moult to a variable extent and the area can turn all grey. Then only the stripe of the lore and the ear coverts remain black (Figure 1).

Figure 1: *Adult Lesser Grey Shrike at the begin of the migration time. The black forehead is being replaced by grey feathers during the yearly complete moult. Suffolk, Great Britain, July 2006. Photo courtesy of Steve JM Gantlett.*

Many of the birds identified in the southern hemisphere as first-year are therefore adults. This leads to the need to re-evaluate the age of birds seen and captured and sheds new light on the numbers of young birds occurring in the area and the age ratio between them and adults.

The annual complete moult mainly takes place on the non-breeding grounds in southern Africa beginning to little explored degree with body, head and tertial moult already in the breeding grounds (see Section 10, Moult).

2. DISTRIBUTION AND SITES

The Lesser Grey Shrike is a migratory species. The whole world population, breeding from Spain to China, with an extent of about 6,000 km west to east and about 2,000 km north to south, spend the non-breeding season in the southern part of Africa in an area which encompasses little more than a tenth of the breeding range (Dowsett 1971, p. 263; Herremans 1998b, p. 588; see also insert in Figure 2).

We ringed Lesser Grey Shrikes in Namibia (Figure 2): in the western arid savanna at the edge of the Namib-Naukluft Park (Farm Sphinxblick 22°29'S, 15°27'E, Figures 3 and 4), south of the Waterberg (Farm Hamakari 20°36'S, 17°20'E), in the central eastern bushland near Witvlei (Farm Okatjerute 22°21'S, 18°31'E, Figure 5), near Otavi (19°37'S, 17°11'E), in the Erongo mountains (21°29'S, 15°52'E), in Omaruru (21°20'S, 16°04'E) and at Spitzkoppe (21°50'S, 15°09'E).

3. METHODS

3.1 Bird ringing

Our catching tools were mainly clap traps baited with mealworms and set up around perches (in the pre-Namib, Figure 3) or along fence-lines (on the

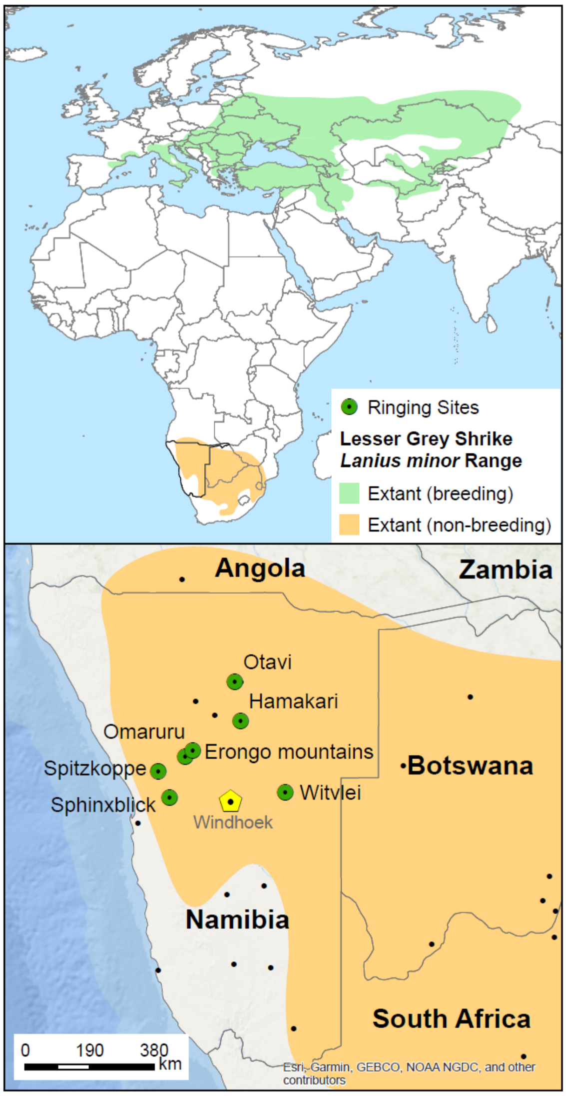

Figure 2: *Distribution map for the Lesser Grey Shrike, downloaded from www.iucnredlist.org on 3 August 2023. The upper map shows the boreal breeding grounds, the lower map the non-breeding grounds in Africa and its occurrence in Namibia. Green dots designate sites where the data were gathered in the current study.*

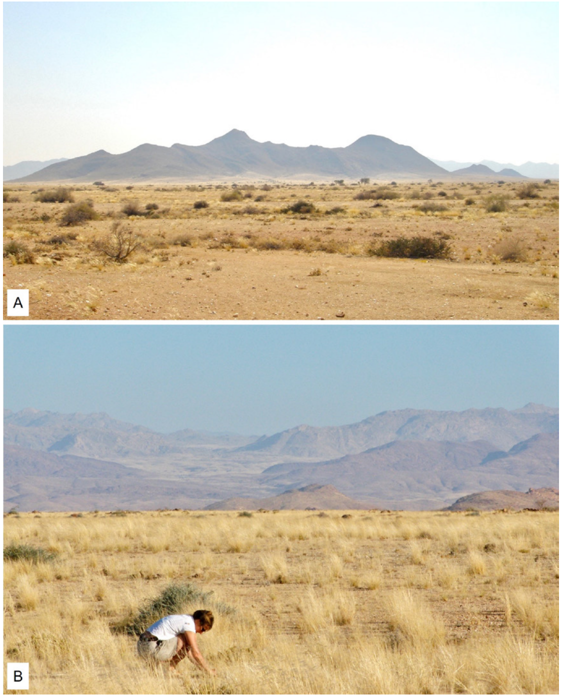

Figure 3: *(A) Typical study site in the pre-Namib desert of western Namibia with small trees and bushes. Farm Sphinxblick, 19 June 2005. (B) Setting up traps near the perches on low bushes. 23 November 2009.*

Figure 4: *About a week after the rain the land turns green, still showing bare patches. Farm Sphinxblick, 22 January 2004.*

Figure 5: *Our traps along a farm road in the savanna of eastern Namibia. Near Witvlei, January 2019.*

farmland in the savanna, Figure 5). In some cases, we found Lesser Grey Shrikes also in mist-nets set up for a general bush-bird survey. The birds were ringed and measured and moult scores were taken in accordance with the guidelines of the South African Bird Ringing Unit's (SAFRING) Bird Ringing Manual (de Beer *et al.* 2001, based on Svensson 1984). All photographs were taken by the authors if not stated otherwise.

3.2 Determination of sex

We determined the sex of Lesser Grey Shrikes as far as possible, by plumage, following the phenotypical characteristics described in the common and specialised European literature (i.e. Blasco-Zumeta & Heinze 2023; Bub 1981, p. 120; Cramp & Perrins 1993, pp. 482–483; Pearson 2000, p. 359; Shirihai & Svensson 2018, pp. 193–194; Yosef *et al.* 2020) and reconfirmed it, when possible, by shape of the two pubic bones and their distance from each other (Schwichtenberg 1973, p. 45). The paper by Krištín *et al.* (2007) on tail patterns as a further supportive criterion to determine the sexes came to our attention only after finishing this study. We revised all our photographs, were able to confirm most of our decisions and add further determinations of the sex.

3.3 Determination of age

The age groups from areas with well-defined breeding seasons can generally be well differentiated into first-year and older birds. We determined the age by a combination of plumage features such as colour, markings, quality, abrasion and contrast of old and fresh plumage, especially during the moult process, changing shape of primaries with ageing, and by the colouration of the bill and the occurrence of a gape flange. We followed mainly Bub (1981), Fry *et al.* (2000), Herremans (2005), del Hoyo *et al.* (2008), Shirihai & Svensson (2018) and Blasco-Zumeta & Heinze (2023).

3.4 Measurements

Table 1 presents the measurements of our sample of Lesser Grey Shrikes. The culmen was measured to the indentation on the front of the skull following the convention for the measuring of passerines (Demongin 2016, p. IX). For the general description of methods and measurements see Bryson & Paijmans (2021, 2022).

There are no significant differences between the sexes or the ages. Head, culmen and mass of the first-year birds correspond with those of the adults, although first-year birds of age group 5 are slightly lighter than those of the other age groups.

Young birds were caught far more often than adults (285:65, equivalent to 4.38:1). It is unclear to what extent this is due to the higher number of individuals in the new brood, and/or first-year birds occupying lower-grade areas than adults. Herremans (2003 in litt., pers. comm.) points out a possible interaction with body condition and proneness to become trapped as young birds in less optimal territories, with lower weight, may be more likely to be caught.

Table 1: *Measurement data from this study. Average measurements (including standard deviation, minimum and maximum measurements) of adult and first-year Lesser Grey Shrikes. We followed the convention of marking young individuals in the first calendar year with SAFRING Code 5 (until 31 December), and in the second calendar year until the first northern migration with SAFRING Code 6 (from 1 January), which enables us, with some uncertainty, to determine the age more precisely.*

Grouping	Parameter	Wing (mm)	Tail (mm)	Tarsus (mm)	Culmen (mm)	Head (mm)	Mass (g)
All Adults SAFRING Code Age 4	Mean ± SD	115.8 ± 3.2	91.8 ± 4.4	25.2 ± 0.9	23.1 ± 1.6	42.9 ± 1.2	45 ± 4.2
	Min–max	109–123	80–104	23–27.7	21.4–32	40.4–46	37.5–61.2
	n	65	59	61	61	61	65
Adult Unknown Sex	Mean ± SD	115.8 ± 2	90.4 ± 3.4	25.1 ± 1	23.4 ± 2.4	42.4 ± 1.3	44.3 ± 5
	Min–max	111–119	84–96	23.3–27.7	21.4–32	40.4–46	37.5–61.2
	n	21	17	19	19	19	23
Adult Females	Mean ± SD	115.7 ± 3.5	92 ± 3.6	25.3 ± 1	23.3 ± 1	42.7 ± 0.9	45 ± 4.1
	Min–max	110–122	83–98	23.6–27.3	22–26.2	41.2–44.7	39.2–58
	n	22	20	21	21	21	22
Adult Males	Mean ± SD	115.8 ± 3.9	92.6 ± 5.5	25.3 ± 0.9	22.7 ± 1.2	43.5 ± 1.1	45.7 ± 3.3
	Min–max	109–123	80–104	23–26.8	21.4–25.1	41.7–45.6	40.7–55.5
	n	22	22	21	21	21	20
All 0 to 6 months SAFRING Code Age 5	Mean ± SD	113.8 ± 3.9	89.1 ± 3.2	24.8 ± 0.8	22.8 ± 1.1	42.6 ± 1.5	42.2 ± 2.2
	Min–max	107–119	81–94	23.8–26.1	21.3–25.5	39.9–46.8	38.8–45.9
	n	15	14	14	14	15	15
All 0 to 6 months SAFRING Code Age 6	Mean ± SD	114 ± 4	89.8 ± 4.2	25.1 ± 0.8	22.7 ± 1	42.5 ± 1	44.5 ± 4.1
	Min–max	96–123	80–105	21.9–28.1	19.9–26.2	39.8–46.2	31.8–67.4
	n	270	251	255	254	254	270

Both sexes of adults were represented in equal numbers, although for one third of the adults sex could not be determined.

4. TAXONOMY

Some authors (Clancey 1980; Vaurie 1955 in Lefranc & Worfolk 2022) recognised two subspecies: *L. m. minor* Gmelin 1788 and *L. m. turanicus* Fediushin 1927. The variation has been discussed controversially and a subspecies-split was not always recognised (Cramp & Perrins 1993, Shirihai & Svensson 2018). Nowadays, the species is considered monotypic (Yosef *et al.* 2020; Lefranc & Worfolk 2022) since the "differences, if any, appear very slightly and are probably negligible" (ibid. p. 118).

5. CHALLENGES

5.1 Basic errata in the southern literature

Existing differences between breeding and non-breeding plumage and bare parts are well described in most of the relevant northern-hemisphere publications (Bub 1981; Pearson 2000 in Fry *et al.* "The Birds of Africa"; Cramp & Perrins 1993). Unfortunately, these facts have not found entry into the southern literature of field guides and bird books that depict only adult Lesser Grey Shrikes during the breeding season without considering a plumage change. This results in the perpetuated misidentification of adult moulting birds as first-year individuals, with consequences for the relation of numbers of first-year and adult birds and the determination of wintering grounds of the different age groups.

We had relied on this literature in the early years of data collection (Harris & Arnott 1988; Maclean 1993; Hockey *et al.* 2005; Chittenden *et al.* 2016) which show the adults always with black forehead and black bill and identify birds with grey forehead and paler bill as first-year birds.

While working on this paper it quickly became evident that the wing moult observed in adults and the head colouration described in the southern literature did not match. We finally found in the northern literature a bird with non-breeding head and bill colouration (Shirihai & Svensson 2018, p. 193; see Figure 17). As a next step, we reviewed our age determination of the individuals we had taken photos of after ringing. We could specify about two-thirds of all of our data, while for the other records unfortunately the age had to be revised due to lacking pictures to be "unknown".

5.2 Random use of terms for age description

Another challenge is the random use of terms when the age of a not fully developed adult bird is designated. In general, the terminology to describe the age of birds is far from consistent or clearly defined. Several core terms are used arbitrarily in both a general and a restricted sense. It is hence not standardised and differs within Africa and also widely between the continents (see Schulze-Hagen 2019). We tried to be consistent in the use of terms and as clear as possible, mainly following Harris & Franklin (2000, pp. 50–51), Shirihai & Svensson (2018, p. 17) and Jenni & Winkler (2020a, b).

We want to point out especially the use of the term "juvenile" that is used in a wider sense for any kind of young bird and creates much confusion when a precise and differentiated determination of age is demanded. We used the term "juvenile" in the restricted sense. It describes the first-year bird until the time of its post-juvenile moult, which sets in latest at three months and ends at about four to six months. With very few exceptions, all our first-year Lesser Grey Shrikes arrived on the non-breeding grounds in their post-juvenile plumage, at times with first signs of the complete moult on median coverts, one tertial or one or two primary feathers with corresponding greater coverts. For age terms see the Glossary for Ageing in Bryson & Paijmans (2021, pp. 21–22).

6. LESSER GREY SHRIKES ON THE BREEDING GROUNDS

6.1. Timing of breeding

Lesser Grey Shrikes breed in the northern hemisphere. Eggs are laid mainly from May to June (range of April to July). The young fledge about 32 days later i.e. mainly June to July (15–16 days for incubation and 16–18 for nestling period) (Cramp & Perrins 1993) and stay with their parents for at least another two weeks (Lefranc & Worfolk 2022, p. 124).

We have not found any published records of breeding Lesser Grey Shrikes in southern Africa. Other migratory species like White Storks *Ciconia ciconia* (Cape Town, pers. obs.) or European Bee-eater *Merops apiaster* (for example Török 1999; pers. obs. near Cape Town) are known to have turned into resident breeding species in southern Africa with inner-African migratory patterns. For one member of the *Laniidae*, the Red-backed Shrike *Lanius collurio*, there are repeated claims of breeding but these assertions have not been substantiated (see discussion in Bryson & Paijmans 2023a).

6.2. Juveniles on the breeding grounds

Three plumages have been described during the first half year of life: a first juvenile plumage, a second generation of juvenile plumage and the plumage after the post-juvenile moult (Bub 1981, p. 119;

Figure 6: *Juvenile with bars on upperparts and flanks. The chest is already becoming light-coloured. Spain, July 2018. Photos courtesy of Marc Gálvez.*

Figure 7: *Two first-year Lesser Grey Shrikes in transitional plumage in July. (A) The very first plumage is pale brownish-grey above, still finely barred on the head and on the back. The bird is in the process of its post-juvenile moult: the dark medium coverts have already been replaced. The brownish-black mask does not extend onto the forehead. The gape flange is still pink and prominent. Spain, 21 July 2015. (B) This individual has replaced the barred, drab body feathers with more uniform grey ones of a second generation of juvenile plumage that grows at the age of 3-4 weeks. Spain, 18 July 2018. Photos courtesy of Marc Gálvez.*

Cramp & Perrins 1993, p. 498). These plumages are not clearly recognisable from each other, as there is, as in all bird species, a continuing transition in addition to a considerable variability in time.

The plumage of juveniles is “brown-grey from crown to mantle (...) overlaid with fine ... brown-grey bars” (Cramp & Perrins 1993, p. 482) of varying extent. Wing and tail are duller than in adults and, as a useful tool for determining the age of the bird, the coverts and flight feathers show white tips (Figure 6).

Some of the features appear in first-year birds on the non-breeding grounds.

Fully grown juveniles replace in parts the barred feathers with more uniform grey ones of a second generation of juvenile plumage at the age of three to four weeks (Cramp and Perrins 1993, p. 498). (Figure 7A). Post-juvenile head and body moult (i.e. partial moult) begins soon after fledging (Figure 7B) and is completed in 10–11 weeks by August to September.

7. GENERAL CRITERIA OF SEX AND AGE ON THE BREEDING AND NON-BREEDING GROUNDS

Several features of the plumage are described as sex-related and give cues for the distinction between the sexes: the colouration of the upper-parts and of the breast, the colouration and width of the black forehead and the black markings on the tail. These characteristics are subject to variations and may undergo a change with age.

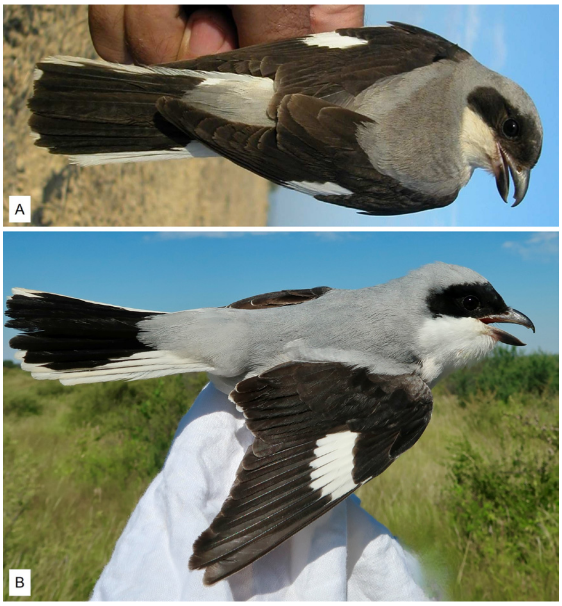

Figure 8: *Upper-parts of adults. (A) Female with dull grey upper-parts and brownish wing. Spain, 11 July. Photo courtesy of Javier Blasco-Zumeta. (B) Male with blue-grey upper-parts and black shafts on white T6 and T5. 2 April 2021.*

Individuals can be positively assigned to an age group on the non-breeding grounds based on characteristics of the plumage and presence of an existing gape flange. First-year birds, hatched in the boreal summer, arrive at about half a year of age, adults at about one and a half years of age or older.

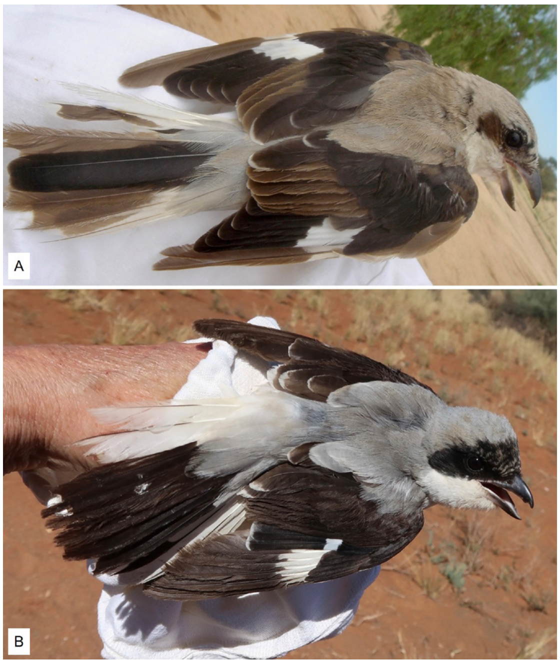

Figure 9: *(A) First-year female with post-juvenile brownish mantle and head and first new dull-grey feathers on the back and on the upper-tail coverts. The central tail feathers are brownish-black, the markings on T5 are longish. 11 February 2009. (B) Male with two white outer tail feathers. 10 December 2022.*

Figure 10: *Tail of (A) adult male with asymmetric, small black spots and dark shafts on T5. 11 March 2023. (B) Tail of a first-year male with still dark brown tail pattern and barred, blurred spots on T5. 17 March 2023.*

All pictures of the distinguishing features were taken in Namibia by the authors, if not stated otherwise.

7.1 Colouration of the upper-parts

Ages differ clearly in the (boreal) autumn, sexes usually in the (boreal) spring, sometimes all year round (Shirihai & Svensson 2018, p. 192). The upper-parts of the males are "ashy-blue-grey" (Figure 8B), less so in females (Cramp & Perrins 1993, p. 482) (Figures 8A and 15).

The overall grey colouration of the adult male plumage differs clearly from the first-year plumages of the male and more so of the female (Figure 9).

The dark parts of wings and tails are pitch black in males and browner and slightly lighter in females. It is undetermined if the black colouration of the wing becomes more expressed with age (Bub 1981, p. 123).

7.2 Black markings on the outer tail

As first described by Pajewski (in Iljitshew 1976, in Bub 1981, p. 120) the tail pattern shows a mostly reliable difference between females and males, best used together with other criteria for the determination of the sex (see also Krištín *et al.* 2007). Presumably from the first plumage on (Figure 9), the tail pattern in combination with the overall colouration of the upper-parts allows a clear classification of the sexes.

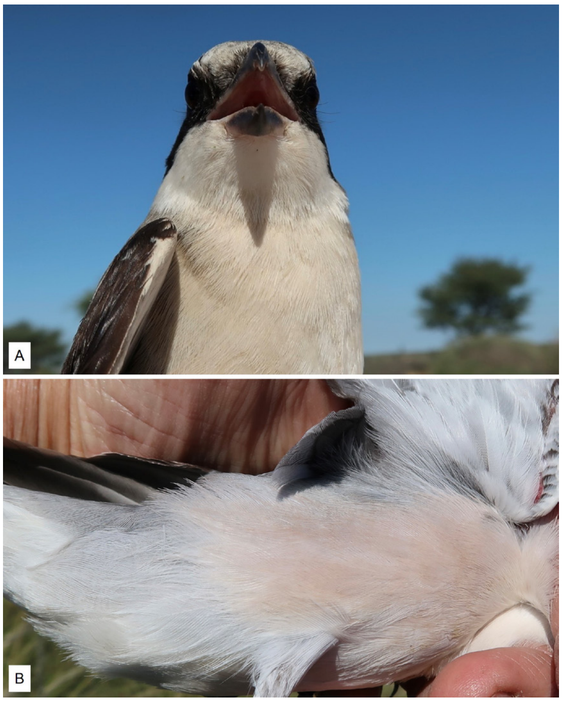

Figure 11: *Adult males. (A) After arrival on the non-breeding grounds with pale pink chest and grey forehead beginning the complete annual moult. 9 December 2022. (B) After his complete moult with typical light vinaceous underparts and whitish hind-flanks and vent. 2 April 2021.*

The outer rectrix T6 is always white in both sexes, while T5 shows a difference. A dark spot > 22mm long allows the determination of a female (Figure 9A). In males T5 is either all-white, with occasional black shafts (Figure 9B), or has spots of variable length and symmetry, which are smaller than those found on females (Lefranc 2022, p. 118; also Bub 1981, p. 122).

Figure 10 shows the varying size of the tail spot in males, (A) all-black in adults or (B) still brown and sometimes blurred in the first year of life.

7.3 Colouration of the breast

7.3.1 Adults

On average, the breast of females shows a lighter salmon pink than that of the male, especially in the breeding plumage. However, there is some overlap (Shirihai & Svensson 2018) (Figure 11). Furthermore, the worn feathers are replaced during the moult on the non-breeding grounds by brighter ones towards the time of departure. Due to extensive variation, the colouration alone cannot be used as reliable feature to determine the sex (Bub 1981, p. 120).

In our observation, males in particular show a wide variation of colouration (Figure 12), possibly due to individuals gathering from a diversity of provenances. The colour extends from the breast and chest to the flanks that can be well seen with the bird in the hand.

7.3.2 First-year Lesser Grey Shrikes

In first-year birds the chest and flanks in both sexes are more drab and tinged grey-brown (Figures 13A and B) and some still show light barring from the juvenile plumage (Figure13C). At this age, the sex can mostly be determined already by the tail pattern.

7.4 Forehead, ear-coverts and bill

The black forehead is a sign of breeding adults only, as is a dark black bill that is becoming paler at the base, of mainly the lower mandible, after breeding. Ear coverts in females are not as richly black as in males (Figure 14).

After the breeding season, adults moult the forehead which then turns grey to varying degrees and the bill becomes paler in both sexes (Figures 15C and D) on the non-breeding grounds. Grey feathers replace the black ones on the forehead in adults as described in detail by Shirihai & Svensson (2018, 193–194) and Cramp & Perrins (1993, pp. 482 and 498). In some early moulting individuals this occurs from June onwards. See Figures 1, 16 and 17 for images of adults photographed in the northern hemisphere. The mask is regained in the process of complete moult, in the early months of the year. (See also Fry *et al.* 2000; Glutz von Blotzheim & Bauer 1993.)

Figure 12: *Adult males, already in fresh, full plumage at the end of the complete annual moult, with - for our research area - (A) exceptionally grey and (B) exceptionally dark underparts. 17 March and 18 March 2023, respectively. (C) Contrasting dark underparts and white throat. Spain, May 2020. Photos courtesy of Marc Gálvez.*

First-year birds develop the black forehead mainly on the non-breeding grounds and the bill turns black only towards the time of the northerly migration.

Observations of Lesser Grey Shrikes kept in captivity for reintroduction in Spain showed that non-breeding adults or those with a failed brood start the complete moult already during the breeding season (Marc Galvéz 2020, pers. comm.; Figure 16; see also Bub 1981, p. 119). This early moult is documented also for Red-backed Shrikes. Heinroth & Heinroth (1924–1926, in Kramer 1950, p. 15) observed it in captive birds in a tame, freely breeding female. See also Bub for further observations (1981, pp. 105–106).

Adult Lesser Grey Shrikes without or with only a minimal frontal mask due to early moult have also been observed in the wild (Figures 1 and 17). (See also a mask-less, female adult bird photographed in Gauteng, South Africa at the end of November: https://macaulaylibrary.org/asset/393495551.) This fact might go undetected or the birds might be interpreted as first-year at a more superficial view.

7.5 Colouration of the head and width of frontal mask

During the non-breeding time the black on the forehead is being replaced to varying degrees by grey feathers. Adults start the post-breeding moult mostly while still on the breeding grounds and by the time they arrive in Namibia (or the non-breeding region at large), will have largely replaced the black forehead feathers with grey ones (Figure 18A). First-year Lesser Grey Shrikes arriving on the non-breeding grounds mostly show no black on the forehead (Figure 18B) which will develop into a compact mask before returning to the breeding grounds (Figure 19).

In breeding plumage, the width of the black forehead indicates the sex only in its most extreme measurements. It has been documented as 7–12 mm wide in females and 9–15 mm in males (Bub 1981, p. 119–120, see there also the photographic series of both sexes; Shirihai & Svensson 2018, p. 193, give 6.5–11.5 mm and 10.5–17 mm, respectively; Lefranc & Worfolk 2022, p. 218, 7–12 and 10–15 mm, respectively). Rarely, females show an expressive male-like black forehead, whereas some females have a primarily grey forehead.

The width of the black forehead alone is a "poor indicator of sex" (Shirihai & Svensson 2018, p. 192). We used it as a supporting criterion for sexing individuals towards the end of the head moult. The measurement was taken from the base of the exposed bill (at feathering) to the furthest black feather on top of the head.

Figure 13: *First-year birds at the beginning of the complete moult. (A) Male still with buff underparts lacking the warm tone of adults and greyish hind-flanks. 20 December 2021. (B) Male with even all-grey underparts without any pink tinge. 15 January 2011. (C) Mainly on arrival some individuals still show slight barring on the flanks. Thin body feathers with fewer barbs points out residual, still unmoulted, juvenile plumage, here of a female. 14 November 2017.*

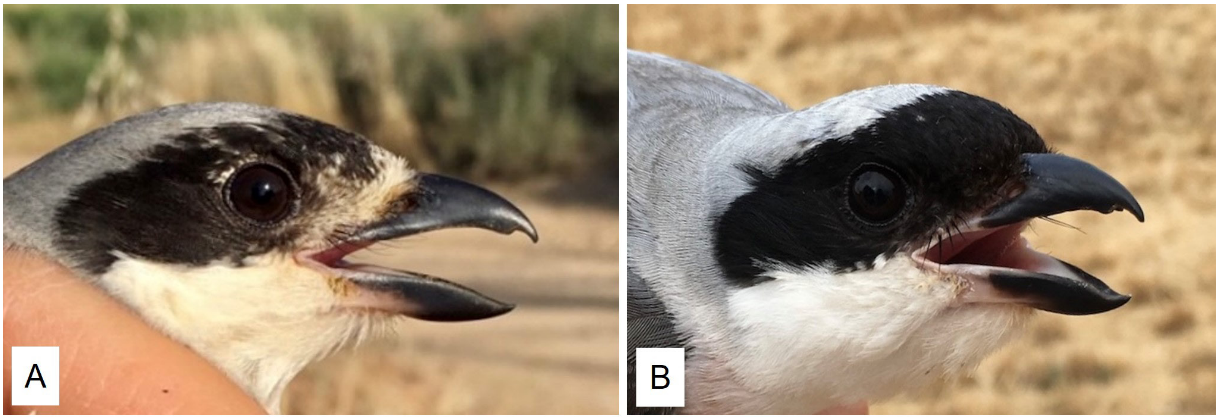

Figure 14: *Frontal mask and bill colouration of adults on the breeding grounds. (A) Female and (B) male. After breeding, the bill is becoming paler at the base, mainly of the lower mandible. Note also the darker grey-tone on the head of the female. 21 August 2017 and 22 July 2017, respectively. Photos courtesy of Marc Gálvez.*

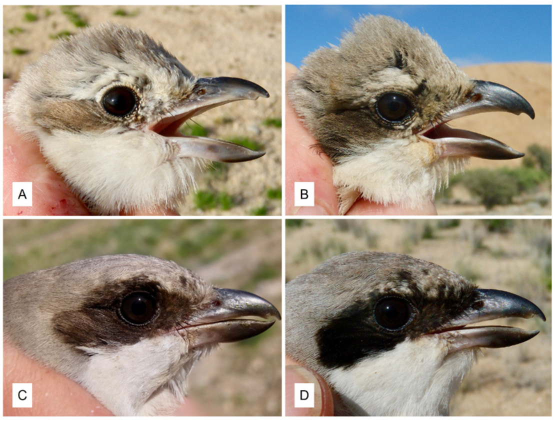

Figure 15: *Comparison of different age and sex in January. The pictures show the head of Lesser Grey Shrikes on the non-breeding grounds in Namibia: (A) Unsexed first-year bird; "babyface" with pale crown, pale brown ear coverts, pinkish gape, horn-coloured beak with growing "tooth", 9 January 2011. (B) First-year of life, presumably second calendar year, ringed at the same day as (A). Overall, this bird is further developed: very first black feathers above the eye; beak tip, "tooth" and colour more advanced. 9 January 2011. (C) Adult female in non-breeding plumage with only single black feathers on the forehead. The colour of the ear coverts are here exceptionally brown, possibly due to the age. In most females they are sub-black. 13 January 2011. (D) Adult male in non-breeding plumage with deep black mask reaching the beak, and few black feathers on the forehead. 15 January 2011.*

Figure 16: *Non-breeding, adult female in complete moult during the boreal summer. The forehead has turned grey. The age is well known since this bird is kept in captivity in a reintroduction program in Spain. 22 July 2015. Photo courtesy of Marc Gálvez.*

Figure 17: *Adult with grey forehead and still black bill; exceptionally early moult of forehead; presumably a female by brownish-grey rather than black ear coverts and primaries. Norfolk, June 2008. Published in Shirihai & Svensson (2018, p. 193). Photo courtesy of Steve JM Gantlett.*

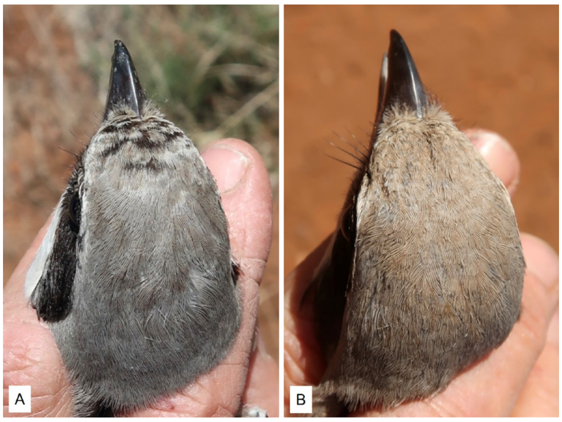

Figure 18: *(A) Grey head of adult with growing black feathers. 29 December 2021. (B) Brown head of first-year individual still without black forehead. Note the short, abraded feathers. 10 December 2022.*

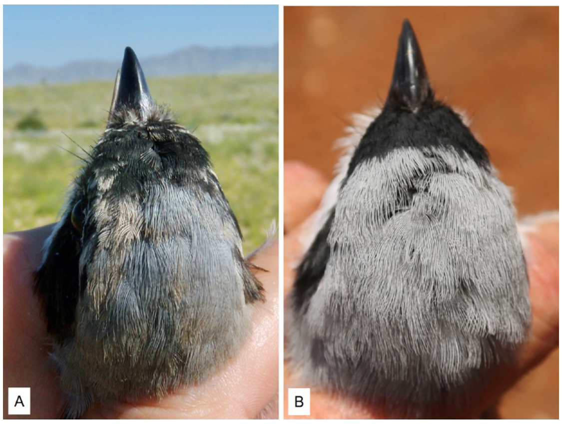

Figure 19: *First-year individuals in transition. (A) Head partially moulted with short brown abraded feathers and fresh long blue-grey feathers. 18 February 2011. (B) Before migration to the boreal breeding grounds the moult comes to completion. 11 March 2023.*

8. ARRIVAL TIME AND YEARLY COMPLETE MOULT IN NAMIBIA

Both adult and young Lesser Grey Shrikes appear in our study area in western Namibia in the area of 22°29'S, 15°27'E from January onwards when the beginning of the rainy season is expected. In the east, though, at 22°21'S, 18°31'E, arrival occurred earlier, with a low number mid and end of November and rising in December (see Tables 2 and 3).

This matches the observations in Namibia of the first arrivals further north from 3 November 1957 along the Omuramba Omatako southwards (Sauer & Sauer 1960, p. 71). In Botswana to the east, the median of first arrivals in 1992 was 2 November (n = 6), 18 November in 1993 (n = 18), the overall median 10 November (n = 44), of which 75% arrived in 26 days, from 31 October to 27 November (Herremans 1994, p. 60).

8.1 Moult

The annual complete moult mainly takes place on the non-breeding grounds in southern Africa, while body moult already starts in the breeding-grounds, involving one or more tertials and is probably suspended during migration. (See Lesser Grey Shrikes with one freshly moulted tertial from August in Greece: https://macaulaylibrary.org/asset/363846201 or from September in Finland: https://macaulaylibrary.org/asset/482872001.)

Table 2: *Extent of primary feather moult (P1 to P10) of adult Lesser Grey Shrike. Values are average moult scores of each primary for the n birds per month sampled. The colour gradient is shown on the side. The tail (t), head (h) and body (b) moult are expressed as a percentage of birds assessed showing signs of moult. No data were collected for the months marked in grey.*

Month	n	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	t	h	b
Jul	0													
Aug	0													
Sep	0													
Oct	0													
Nov	3	0	0	0	0	0	0	0	0	0	0	0%	0%	0%
Dec	11	4	4	3	2	0	0	0	0	0	0	0%	18%	27%
Jan	24	5	5	4	4	3	2	1	0	0	0	65%	10%	50%
Feb	3	4	3	3	3	3	3	3	1	1	1	100%	100%	100%
Mar	23	5	5	5	5	5	5	5	5	4	3	20%	29%	0%
Apr	3	5	5	5	5	5	5	5	5	5	5	0%	0%	0%
May	0													
Jun	0													

Moult Score

0
1
2
3
4
5

Table 3: *Extent of primary feather moult (P1 to P10) of first-year Lesser Grey Shrike (age group 5 and 6 in Safring code, corresponding to first-year birds: code 5 until 31 December, code 6 from 1 January on). Values are average moult scores of each primary for the n birds per month sampled. The colour gradient is shown on the side. The tail (t), head (h) and body (b) moult are expressed as a percentage of birds assessed showing signs of moult. No data were collected for the cells marked in grey.*

Month	n	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	t	h	b
Jul	0													
Aug	0													
Sep	0													
Oct	0													
Nov	7	1	1	0	0	0	0	0	0	0	0	0%	0%	0%
Dec	10	4	4	2	1	0	0	0	0	0	0	11%	0%	22%
Jan	140	4	4	4	3	2	1	0	0	0	0	63%	28%	44%
Feb	82	5	5	5	4	4	4	3	1	0	0	89%	65%	62%
Mar	50	5	5	5	5	5	5	4	4	4	3	39%	50%	59%
Apr	0													
May	0													
Jun	0													

Moult Score

0
1
2
3
4
5

At times, an early body and head moult (Figure 1) has been described in the northern hemisphere, especially in non-breeding adults or after failed brood. New observations point towards moult on stop-over sites in northern Africa where two tracked individuals spent nearly two months before continuing their migration south (Adamik *et al.* 2023).

Our findings on moult (Tables 2 and 3) generally match the data of Dowsett (1971, pp. 264–265) collected from 36 museum specimens from Botswana, Zambia and Zimbabwe. The Lesser Grey Shrikes he assessed did not start moulting until the second half of December (ibid., p. 265); our data from this month were captured at the end of December.

The replacement of the flight feathers proceeds quickly from January to early February and slows afterwards, while the body moult continues until late March or early April (ibid., p. 265). The moult advance (expressed in the moult score) in our sample from Namibia was 13 for the whole of December (no sample in Dowsett). For the whole of January our moult score reached 23, while Dowsett (1971) recorded 24 in the first half and 31 in the second half of the month.

In February our sample was too small (moult score for the two halves 38 and 40 respectively in Dowsett), but overall in March our adults had the primary score of 47, with Dowsett recording 41 for the first half only. In April, we recorded only two birds in the first days and one on 18 April.

Although one of our first-year birds (CV38330) already had a moult score of 9 in mid-November, most were in moult process only at the end of the month - none of the adults though.

In December the average score for first-year birds (11) fell behind that for adults (13). One female had an exceptionally advanced score of 22 on 29 December (CV39526).

The moult score in January for immatures (first year of life) was 18, and 24 for adults. In February it rose to 31 for immatures, compared to 25 for our minute sample of three adults. In March the primary moult of young and adults came close to completion with a moult score of 45 and 47, respectively.

Most birds, young and adult, complete their moult before departing for their breeding grounds again.

8.2 Adults

Adults can clearly be distinguished from young until the end of the first year of life by the overall colouration and more advanced moult of the primaries and tail (Figure 20).

Figure 20: *Grey, black and white plumage are features of adults. The moult of this adult is much further advanced than that of a first-year individual (Figure 21) with more brownish plumage. Primary moult score 28 (5555530000). 18 January 2009.*

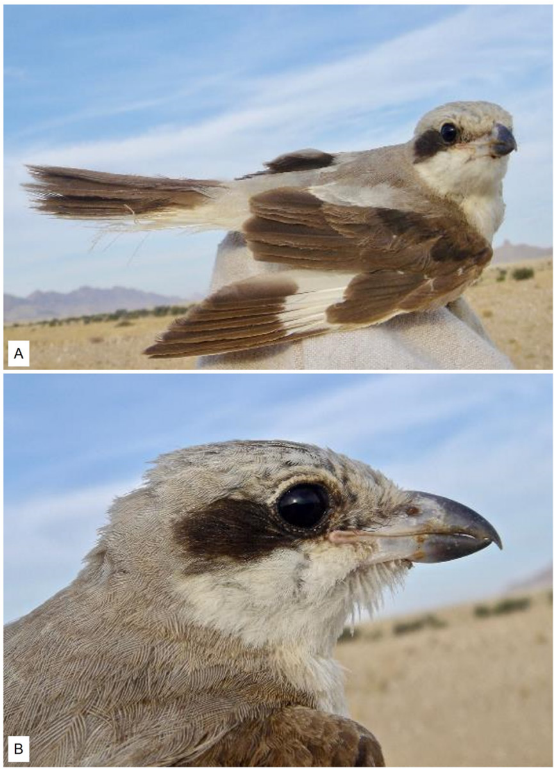

Figure 21: *First-year Lesser Grey Shrike, about half a year old. (A) In the typical arid savanna habitat of the pre-Namib, it is starting its first moult at the beginning of January, with pale and worn tail, primaries and coverts. The gap on the wing indicates three sprouting inner primaries. The only new, dark feathers are some median coverts; moult score 4 (2110000000). (B) Close-up of the head with a fast grown, not yet well matured bill with a small "tooth", a pale basis and a pink fleshy gape flange, yet quite dark ear coverts. Note the loose barbs of feathers on the mantle, as sign of a fast grown plumage. 5 January 2007.*

It is unexplored how the plumage changes throughout the first years: “Ringing must clarify whether the black colouration of the wings becomes more pronounced with increasing age, so that one-, two- and three-year-old birds (and older) can be distinguished” (Bub 1981, p. 123). Unfortunately, no further explanation or context is given.

8.3 First-year Lesser Grey Shrikes

The term “first-year” could mean a bird in the first calendar year (until 31 December of the year in which the birds was hatched), but in other publications it covers the first year of life, i.e. before adulthood. This includes the time in the second calendar year (from 1 January onwards of the year after hatching until approximately the breeding time of the adults). We specify the age for clarification when needed.

The extent of the moult progress in arriving birds is highly variable. Some first-year birds arrive in brownish, moderately abraded plumage with worn tail, brown remiges, fleshy gape and without black forehead. First fresh feathers sprout on the coverts, the first primaries are being shed. The mantle, rump and head as well as the less visible body feathers on the underside are being moulted in much varying degrees (Figure 21).

We observed another, well-stocked group of more worn individuals in the first months after arrival. They show several new primary feathers, coverts and tertials in mid-January (Figure 22) together with dramatically worn tails, but no frontal mask or only a few black feathers. It is unknown if these massive differences are due to different hatching dates and/or different provenances.

***Figure 22:** First-year bird with light brownish head and mantle, pale, brown ear coverts, primaries and alula, this with white edges. The primary moult of this individual from mid-January was well advanced compared to the one of Figure 21, ringed in the begin of January. Primary moult score 23 (5555300000). 18 January 2009.*

9. EXCEPTIONAL PLUMAGES OF LESSER GREY SHRIKES

Unlike Red-backed Shrikes that are subject to a wide variety of plumage colouration (Bryson & Paijmans 2023a), Lesser Grey Shrikes in our research area were quite homogenous in their phenotype. During our studies, we encountered only a few Lesser Grey Shrikes with unusual features.

9.1 Juvenile plumage in southern Africa

Juveniles have normally completed their post-juvenile head and body moult by September. Due to this timing, individuals in juvenile plumage have not been recorded in southern Africa (Herremans 2005, p. 727), although “often some juvenile feathers [are] retained on arrival in [the] Afrotropics” (Stresemann 1920, p. 99, translated in Cramp & Perrins 1993, p. 499) and “some birds probably even [arrive] still largely in juvenile plumage” (Cramp & Perrins 1993, p. 499). We observed one individual arriving early in mid-November, still in the process of post-juvenile body moult. It showed brown, white-tipped remiges and coverts and barring on the rump, upper-tail coverts and flanks (Figure 23).

9.2 Residual feathers in March

We ringed a single individual in mid-March with numerous residual brownish feathers on the mantle while the head was still moulting and the underparts, wings and coverts were in fresh plumage (Figure 24).

For Lesser Grey Shrikes it has been described in the northern literature that “very occasionally [boreal] spring birds have one or two bleached and worn unmoulted” secondaries which “may be second-year birds, judging from the often brown colour and heavy abrasion of these retained feathers” (Svensson 1984, p. 212). Also Bub (1981, p. 124) mentions individuals returning to the breeding grounds with one to three bleached and worn, and thus unmoulted, coverts and one bird with the innermost tertial from the second-last plumage.

9.3 Unusual colouration

One individual (CV38329, Figure 25) showed an unusual colouration, which is unique for our studies. It was ringed in November and was very pale and sand-coloured for an adult. It had no signs of a juvenile though, like residual barring on the rump, fleshy gape flange or white tips on the remiges and coverts. The primaries are worn like in other adults, and the bill is horn-coloured and lighter at the base. While the second generation of the juvenile plumage as described in Cramp & Perrins (1993, p. 498) does not match this description, a picture in Cramp & Perrins (1993, Figure 4 on Plate 23, opposite p. 353) shows a similar Lesser Grey Shrike from central Asia in a (fresh) first adult non-breeding plumage (in

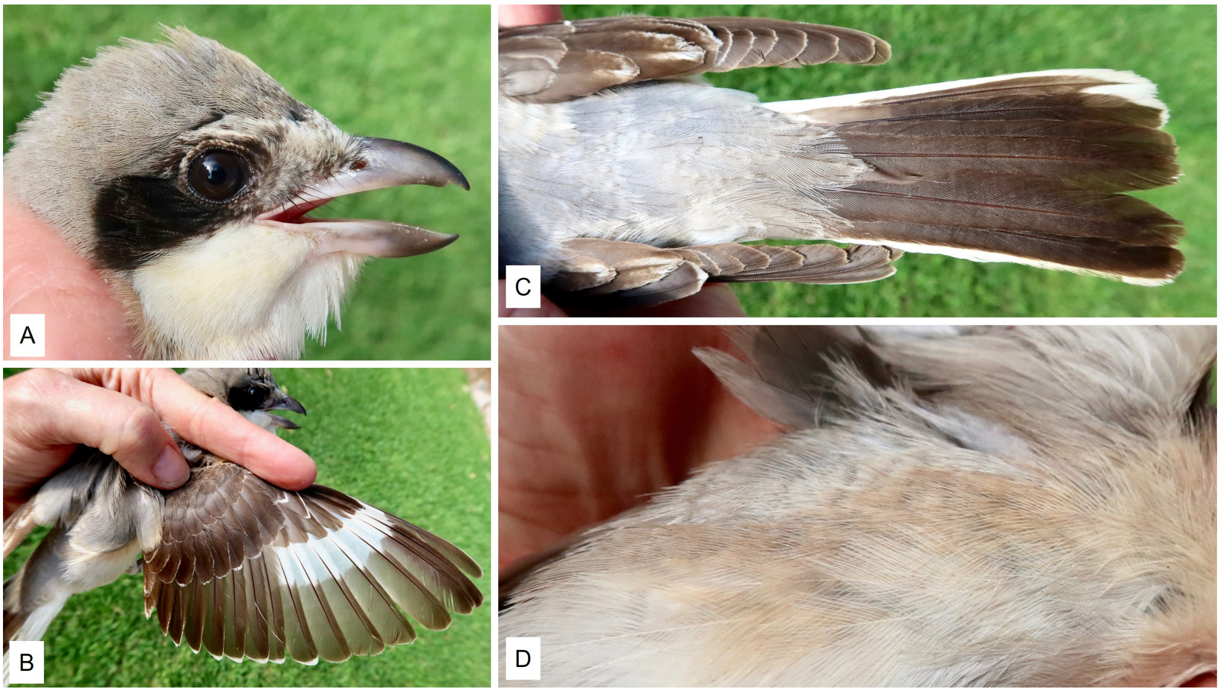

Figure 23: *Lesser Grey Shrike still exhibiting juvenile features. (A) A pink gape flange, horn-coloured beak with broad pinkish base, buffish fringes on the ear coverts and mixed old pale-brown and fresh grey feathers on the head (no black forehead, no dark colouration between eye and beak). (B) White fringes and tips on the wing: on alula and coverts, wide on pointed secondaries, finer on primaries. (C) Barred rump, tips of tertials with buff subterminal marbling (see Cramp & Perrins 1993, p. 498). (D) Barring on flanks with buff-rufous tinge. 14 November 2017.*

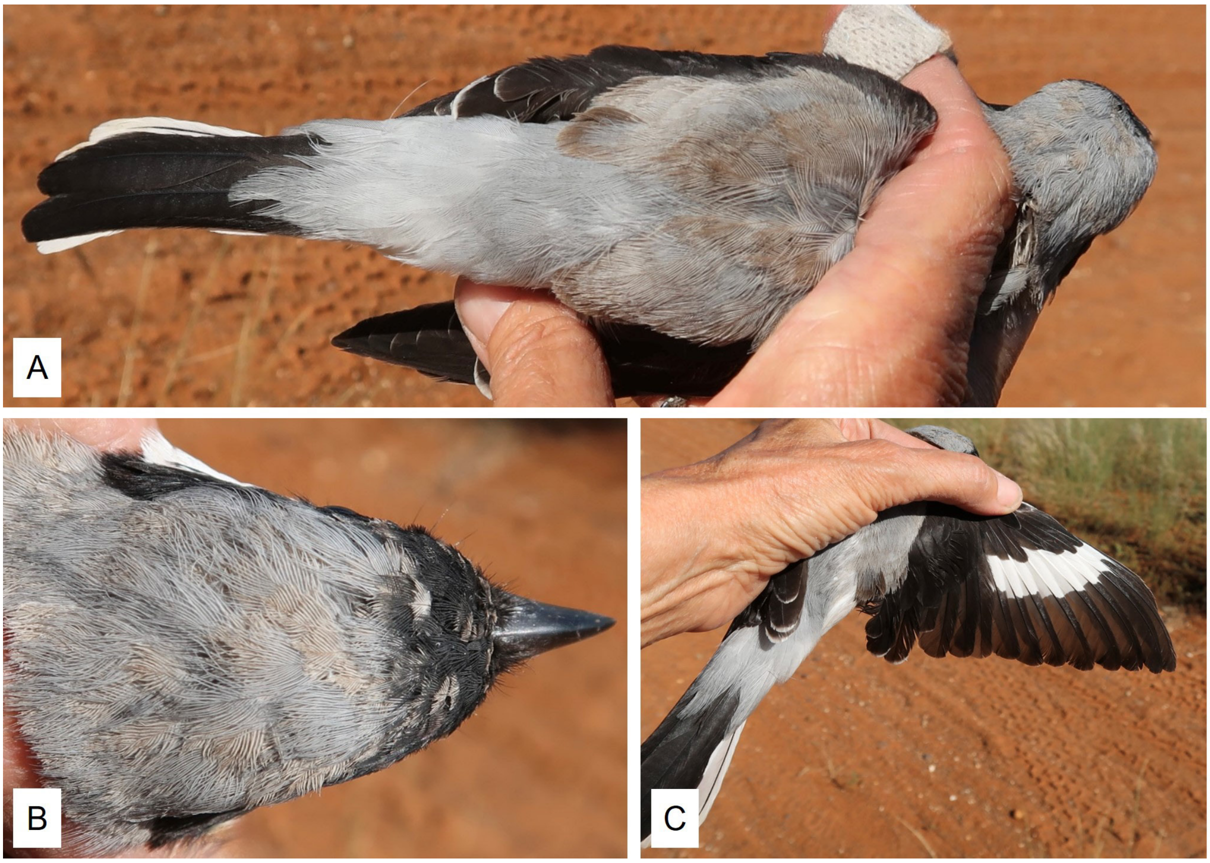

Figure 24: *An uncommon late moult of the mantle that might not be completed until migration (A) while on the head (B) and the wing (C) moult is almost finished. 11 March 2023.*

the boreal autumn) of the formerly *L. m. turanicus,* subspecies characterised by a larger wing. The measurements, though, were in the middle range of our sample, and the question remains inconclusive (see also the discussion in Clancey 1980, p. 161).

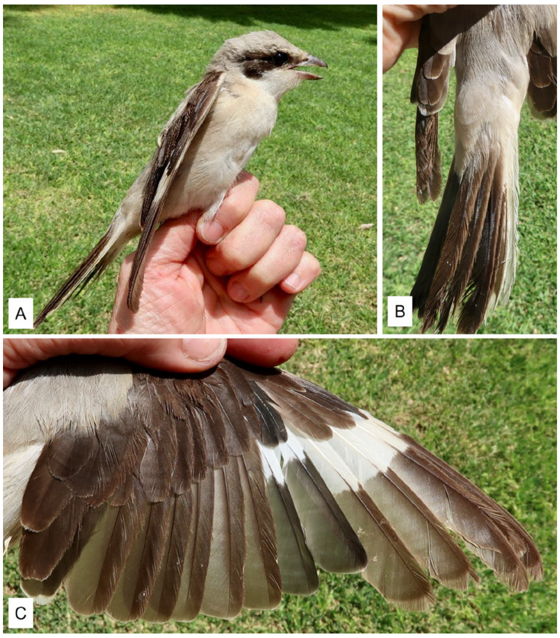

Figure 25: *Sandy coloured female with (A) pale underparts and (B) light buffy rump. (C) By the moult state the age was determined as adult. 16 November 2016.*

10. NOTES

10.1 Retraps and site fidelity

Despite continuous ringing efforts in the same months over many years, we could not find any site fidelity on the non-breeding grounds. However, we had four short-term retraps out of 356 birds: after one day (CV35746), after four (CV38330) and after eight days (CV38328 and CV39683) at the very same location of first capture. Within our sample, we could not confirm the site fidelity expectations reported for Red-backed Shrikes, as expressed in Herremans (1998a, p. 491).

10.2 Mass gain from arrival to departure

Lesser Grey Shrikes in our study area experienced a considerable mass change per month. In adults we measured an increase in body mass in the months leading up to the impending migration cycle (Figure 26). The mean body mass showed a steady and significant increase from 41.6 (± 2.2) g in November to 55.7 (± 6.9) g in April, with a corresponding median rise from 41.4 g to 5 g. These trends are indicative of migratory birds' documented pre-migration fattening strategy, which requires increased foraging activity and metabolism changes to accumulate energy reserves (Baierlein 2003). Please note that the sample sizes of observed adults were relatively small for each month, with counts ranging from 3 to 24.

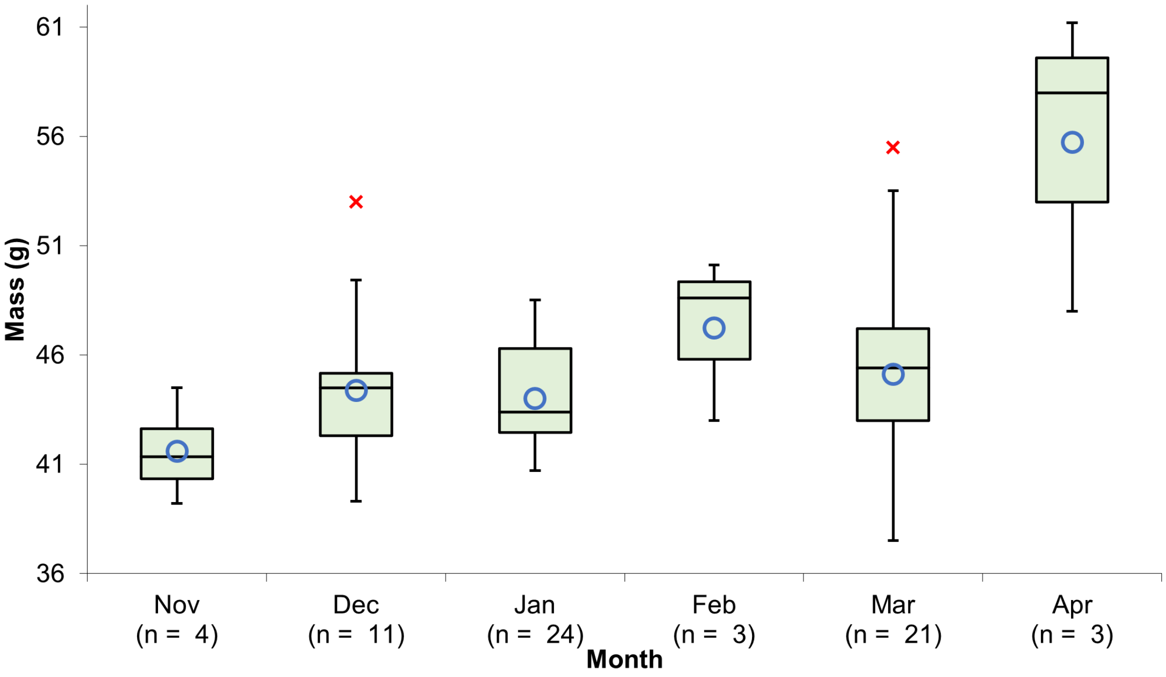

Figure 26: *The average mass (g) of adult (age code 4) Lesser Grey Shrikes in Namibia by month between the migrations. Each box represents the interquartile range (IQR) between the first (Q1) and third (Q3) quartiles, with a central horizontal line indicating the median. Whiskers extend to the maximum and minimum values within 1.5 times the IQR from the box. Outliers are depicted as individual data points beyond the whiskers (red X). The blue circle indicates the mean mass of the birds sampled each month.*

Sampled juvenile Lesser Grey Shrikes had a notable and consistent increase in body mass over the months leading up to the migration period (Figure 27). Specifically, the mean body mass showed a steady and significant increase from 41.5 (± 2.9) g in November to 45.8 (± 5.9) g in April, with a corresponding median rise from 41.9 g to 44.7 g.

10.3 Interaction with the Southern Fiscal *L. collaris*, Red-backed Shrike and Fork-tailed Drongo *Dicrurus asimilis*

We cannot confirm competition between Lesser Grey Shrike and Southern Fiscal (*L. collaris*) and the domination of the latter, as described by Ferret (in Dowsett 1971, p. 264) for our study area in western Namibia. In more than 20 years of observation, we never saw a similar event, despite the observation of hundreds of individuals of both species.

Loske (1985, p. 31), though, twice observed a Lesser Grey Shrike displacing a Red-backed Shrike from a perch, and "several times" being displaced by a Fork-tailed Drongo *Dicrurus asimilis* from an exposed look-out on a telephone pole or a tree top.

10.4 Precipitation and fluctuation of bird numbers

Unlike the more stable numbers of sedentary Southern Fiscals, the numbers of migratory Lesser Grey Shrike and Red-backed Shrike fluctuated over the years in response to substantial rainfall arriving from the north and (especially) the east in 2009, 2011 and 2014 (Figure 28, as published in Bryson & Paijmans 2021, p. 15).

10.4.1 Rain patterns in the pre-Namib

Namibia as a semi-arid country is said to have had a seven-year cycle of good and little rain (farmers GK, WR, 2003, pers. comm.) with an outstanding annual variation in rainfall (Moreau 1972, p. 134). In our western research area at the border of the Namib-Naukluft Park, total annual rainfall between 2002 and 2014 varied from 15 mm to 650 mm. Figure 29 shows some changes of the vegetation and landscape during the time of our research.

10.4.2 Relation between numbers of shrikes and rainfall

We started our consistent studies in the western research area in the pre-Namib in 2002 and concluded during a year-long drought in 2014 near Witvlei in the east. Until 2009, we had caught only one or two Lesser Grey Shrikes per year.

From our farmers (pers. comm.) we know about a long drought in the time before 1999 which made sheep farmers give up their farms for lack of vegetation. Maybe the low numbers of Lesser Grey Shrike and other species in the first years after the millennium resulted from this poor rainfall condition and had turned habitual, with birds not visiting or exploring the area after it had been unsuitable for a long time. From 2009 onwards, with

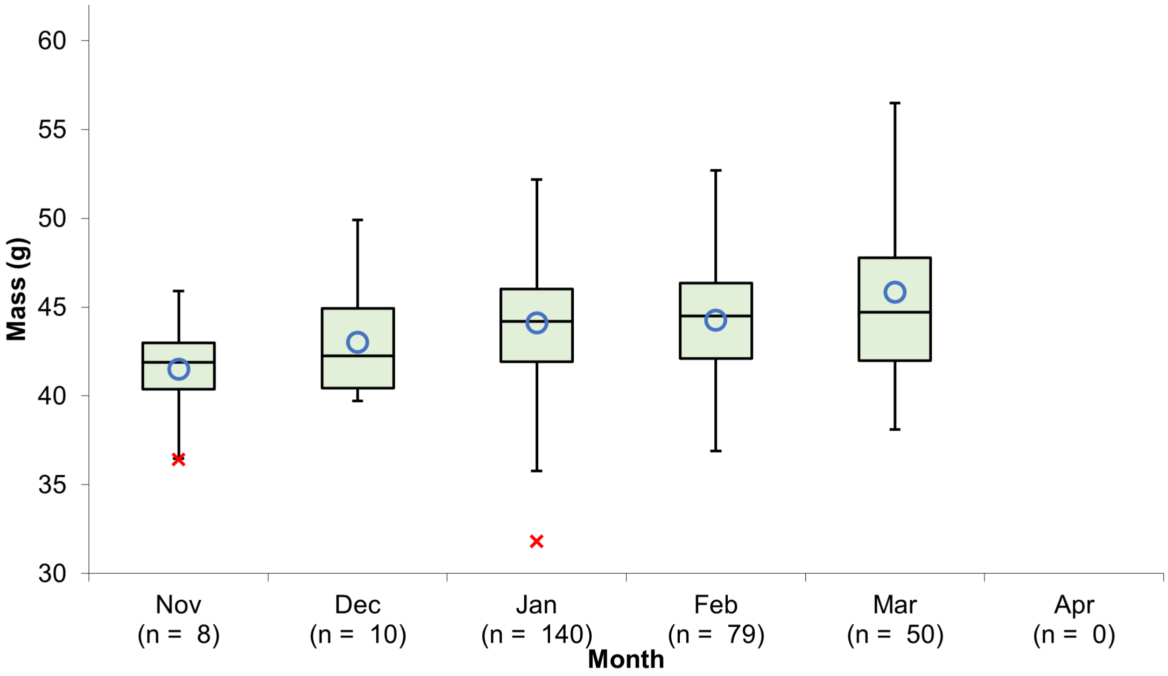

Figure 27: *The average mass (g) of first-year (age code 5 and 6) Lesser Grey Shrikes by month. Each box represents the interquartile range (IQR) between the first (Q1) and third (Q3) quartiles, with a central horizontal line indicating the median. Whiskers extend to the maximum and minimum values within 1.5 times the IQR from the box. Outliers are depicted as individual data points beyond the whiskers (red X). The blue circle indicates the mean mass of the birds sampled each month.*

the second peak of good rain after a wet 2006 when we ringed one single bird, Lesser Grey Shrikes were at least present (see Bryson & Paijmans 2021, p. 15, Figure 19). The excellent rain of 2011 reflected in an enormous increase of birds, numbers and species, arriving at the now suitable habitat. During this peak, we could observe literally one Lesser Grey Shrike on each bush, and through our binoculars we could see in the field of view about 20 birds at once. After having ringed almost 100 Lesser Grey Shrikes, we decided to focus on other species, although we could have caught many more. During this influx in 2011, Red-backed Shrikes also took advantage of higher food availability and increased in numbers, an event that occurred again in 2014.

We have discussed different variables: more favourable conditions further east or north, from where the rain and the birds come to the arid savanna, which might have satisfied the needs of the species; slow or definite withdrawal from a formerly visited non-breeding area due to drought and thus

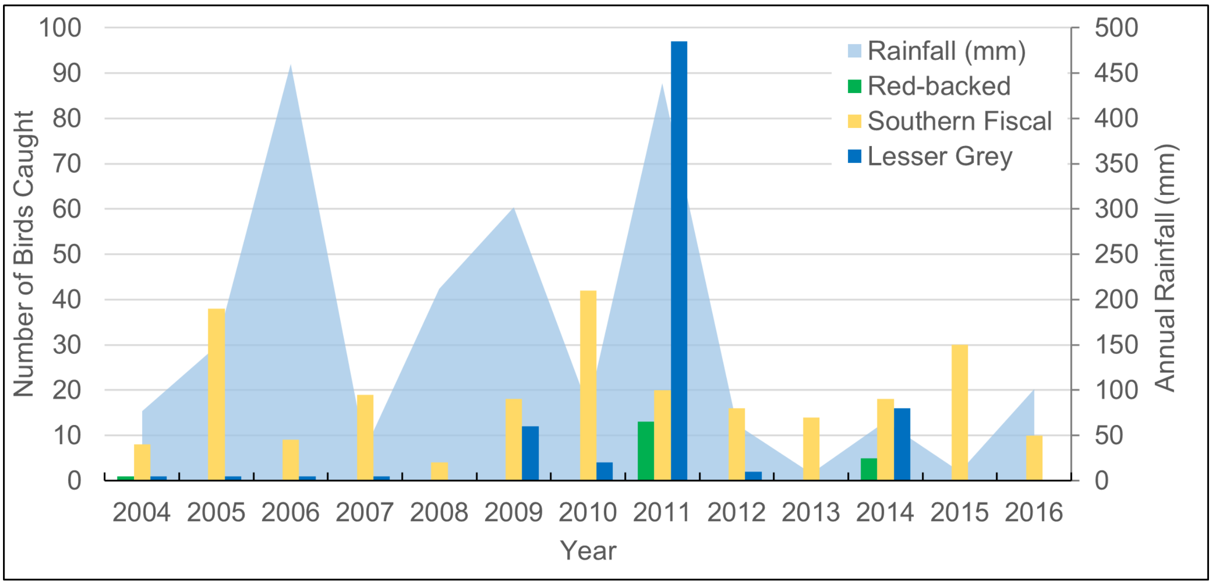

Figure 28: *The numbers of Lesser Grey Shrike, Red-backed Shrike and Southern Fiscal ringed per year in the pre-Namib savanna (22°25'S, 15°25'E) in relation to annual rainfall fluctuations as published in Bryson and Paijmans (2021). Rain data extracted by Tony Robertson from: http://earlywarning.usgs.gov/fews/product/48#download.*

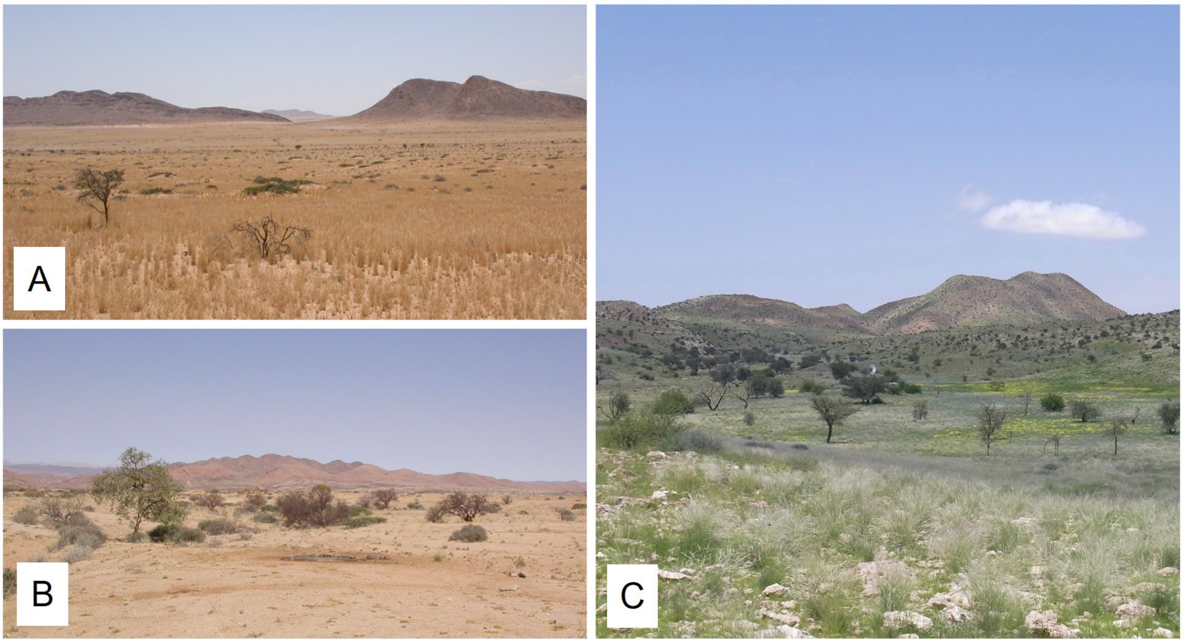

Figure 29: *Changing vegetation in the arid savanna at Farm Sphinxblick at the edge of the pre-Namib. (A) During the dry season, 26 November 2002, (B) during drought years, 3 September 2003, and (C) after exceptionally good rains. 3 February 2011.*

unfavourable conditions; and/or low overall numbers of migratory individuals due to possible factors in breeding grounds or on the migration route. See also the discussion on site fidelity, punctuality of arrival in relation to rainfall and drought and the range extension of migrants in the Kalahari basin (Herremans 1998b).

10.5 Numbers in the literature

For Namibia, several road counts of Lesser Grey Shrikes have been published. The variation of numbers indicates a relation to precipitation.

Considerable fluctuations in Lesser Grey Shrikes numbers have been observed using road counts across years, and intervals of days, weeks and months. On two occasions, more than two birds per kilometre were counted.

On 27 March 1970, Tree (A. J. Tree, pers. comm., in litt. 2020; Tree 1998) counted 11 Lesser Grey Shrikes along the stretch of 30 km of the main road between Karibib and Usakos and almost thirty years later, on 21 January 1998, around 2.5 times more (27 individuals). On the same days the numbers observed between Okahandja and Karibib (a distance of 115 km) were 148 (27 March 1970) and 218 (21 January 1998) individuals respectively, thus an average of one shrike every 527 metres.

Later in 1970, surveys along the road between Windhoek and Rehoboth (93 km) recorded 9 individuals on 8 February, 8 on 16 February, 17 on 18 February, 31 on 4 March and 72 on 1 April 1970 (ibid.).

On 23 March 1984, Loske (1985) counted 145 birds along 75 km of the road from Otjiwarongo to Okahandja which results in 1.9 birds per km, or one bird every 526 m. Becker (1975) registered a similar value: On 18 March 1975 he found one bird every 500 m between Usakos and Karibib (Loske 1985, p. 31), while along the coast, in the Namib and the pre-Namib the species was almost completely absent linking the occurrence of the species to rainfall in the assessed areas (ibid.).

In his “Monitoring of the world population of the Lesser Grey Shrike on the non-breeding grounds in southern Africa” Herremans (1998a) collected ample comparative material in Botswana, Namibia and South Africa. The survey covered an area of 43,125 ha and produced an average of 1.12 to 1.5 birds per km, corresponding to a distance of 666 m to 893 m between individuals.

10.6 Parasites

Contrary to our expectations and the usual occurrence in the field we observed only three individuals hosting mites. No ticks were found.

11. FURTHER RESEARCH

We recommend further research regarding the non-breeding grounds on:

- the site fidelity of the Lesser Grey Shrike,
- the function of rainfall as recommended by Herremans et al. (1995, p. 66) and
- the overall ratio of age groups and possible reasons thereof.

In terms of plumage, research is required to:

- explore the change of the colouration throughout the ageing of adult Lesser Grey Shrikes, and
- monitor the progress of moult processes throughout the months in different regions on the non-breeding grounds.

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We want to thank Javier Blasco-Zumeta, Spain, and Rob Bijlsma, Netherlands, for their invaluable personal and professional support. Our gratitude goes to Tony Tree and Marc Gálvez for open-handedly sharing their experience of shrikes on the non-breeding and breeding grounds, and helping with comments, discussion and photos. We thank Pascal Eckhoff from the Humboldt Museum for Natural History, Berlin, for discussions on moult, Steve Gantlett for kindly letting us use his photos and Janine Dunlop from the Niven Library in the FitzPatrick Institute of African Ornithology at the UCT for her reliable and courteous service as librarian. We are also grateful to Norbert Lefranc for his gentle support, to Ken Stratford for revision and encouraging feedback and to Marc Herremans for discussion on moult, rich information and the generous scientific upgrade of this text. Much appreciated! Our thanks also go to the editorial team of the NJE, especially to Alice Jarvis, for their patience and support. We also want to express our gratitude to the Namibian Ministry of Environment, Forestry and Tourism for granting the ringing permit and to the Namibian farmers who kindly hosted us during our studies, allowing us to move and catch freely on their properties, especially D. and G. Kleemann from the Farm Sphinxblick, N. and K. von Kühne from the Farm Okatjerute, B. and W. Ritzdorf from the Farm Dabib, S. and W. Diekmann from the Farm Hamakari. And my gratitude goes to my ringing assistants Corné van der Merwe and Petrus Karwapa for easing the days in the field. The research was conducted under the South African Bird Ringing Unit (SAFRING) permit number 1240 and all birds were captured and handled under a ringing license issued by the Namibian Ministry of Environment, Forestry and Tourism (Enquiries: Holger Kolberg holgerk@afol.com.na).

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Burchell's Courser *Cursorius rufus*, Gould 1837, in Namibia: biometric and moult data, plumage and criteria for the determination of age

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CONTENTS

ABSTRACT

This is the first comprehensive study on moult and plumage of Burchell's Courser (*Cursorius rufus*). Biometric measurements are few, the moult strategy is undocumented and detailed depiction is scarce. As bird ringers, we have the unique opportunity to observe these aspects closely while handling live birds, providing valuable insights. We add the measurements from our study to other available measurements and present moult observations of seven Burchell's Coursers from Namibia, of two age groups. Drawing on our own observations, existing literature, and public photographs, we aim to improve the understanding of plumage characteristics crucial for age determination during observation and ringing activities. We provide detailed descriptions of the plumage and moult variability across different age groups, highlighting similarities with the closely related Temminck's Courser (*Cursorius temminckii*) and the Cream-coloured Courser (*Cursorius cursor*). We illustrate non-described features of the juvenile and the post-juvenile plumage and discuss the challenging aspects, mainly of primary moult of adults and first-year birds, emphasising the need for further research in this area.

Keywords: bird ringing; Cream-coloured Courser (*Cursorius cursor*); determination of age; juvenile plumage; Namibia; plumage development; post-juvenile moult; post-juvenile plumage; primary moult; SAFRING; serial descendent moult; Temminck's Courser (*Cursorius temminckii*)

1. INTRODUCTION

Burchell's Coursers (*Cursorius rufus*) (Figure 1) are medium-sized birds of open, sparsely vegetated habitats of western southern Africa. As nomads and local migrants, their movements follow apparently the rainfall, but regular or long-distance movements have not been recorded. The distribution range is mainly in Namibia and South Africa, with records from southern Angola and Botswana. Over the last 200 years, its abundance and range have decreased rapidly and considerably in the southern range which is cause for conservation concerns. In Namibia, the habitat preferences are for the Namib desert and the Namibian escarpment. The protected and less disturbed areas seemed to provide stable numbers. (Maclean & Herremans 1997, p. 444; Maclean & Kirwan 2020; Urban *et al. 1*986).

Of nine courser species, seven occur in Africa. Burchell's Coursers remain understudied, with data lacking for areas like population size, longevity, breeding facts like mate fidelity, incubation period and breeding success, and especially moult, with measurements of individuals in the low digits (Hockey 2005, p. 425). We conducted this very detailed research to clarify the unexplored moulting strategy and to accumulate data of measurements of Burchell´s Coursers to fill these gaps of knowledge in the new edition of Roberts Birds of southern Africa (https://www.robertsbirds.co.za/).

Figure 1: *Adult Burchell's Courser. 15 June 2012. © Tom Heijne.*

Only limited data are available in the database of the South African Bird Ringing Scheme (SAFRING) and in the published literature. According to the SAFRING database, 38 Burchell's Coursers have ever been ringed (SAFRING 2024), and no individuals have been retrapped so far.

We searched the literature for data on moult and biometry and included unpublished SAFRING data. We illustrate with photographic evidence the development from hatchling to adult as well as the juvenile and undescribed post-juvenile features of the plumage. Furthermore, we discuss the observation that juveniles seem to grow a second set of body feathers which is unexplored, as is the occurrence of three feather generation in immature birds.

The information in this paper helps conservation efforts by improving how we monitor populations with more accurate age determination, and showing how environmental factors affect birds' life stages. In doing this, it provides clearer guidelines to citizen scientists to identify the different life stages, resulting in improved quality data. This may further improve collection methods and allow comparisons with other species, revealing bigger ecological trends. We describe our observations and recommendations for further research in the field and of museum specimens.

2. METHODS OF DATA COLLECTION

2.1 Timing and location

We caught the birds from our sample between December and February from 2009 to 2015 on the farm Sphinxblick, Erongo Region (around 22°29'S, 15°27'E). The habitat in the pre-Namib is arid savanna of sandy or gravelly plains with mostly sparse vegetation (Figure 2).

The photographs were taken by the authors unless specified otherwise. The number of and the link to their location in the publicly accessible Macaulay Library of the Cornell University are given, when accessible, in the caption of every photograph (e.g., ML619126968). For numbers and links without depiction the authors could not be reached.

2.2 Taxonomy, bird ringing, measurements and determination of age

The species is considered to be monotypic.

Birds were trapped in clap traps with mealworm bait or, occasionally, in mist-nets.

A ring with a unique number engraved was applied. Measurements of wing, tail, head, bill and mass were taken, as well as moult codes, in accordance with the guidelines of the SAFRING Bird Ringing Manual (de Beer et al. 2001, based on Svensson 1984). We determined the age primarily on plumage characteristics. Additional data for comparison were gathered from both published and unpublished sources, including the SAFRING database.

2.3 Moult and moult codes

When recording moult, we considered the ten functional primaries and did not include the tiny eleventh primary. In the common code for recording moult, 5 stands for a new, fully grown, code 0 for an old primary, while 1 to 4 correspond with the growing size of each feather. Code 1 represents a feather in a still closed pin, code 2 a feather sprouting through the pin and up to 1/3 of the final length, code 3 stands for a growing feather of 1/3 to 2/3 of the final length and code 4 for 2/3 to final length, when still in the blood sheath.

This coding was applicable only in the case of the clearly descendent moult in first-year birds, since the moult strategies of adults, namely the serial descending moult, proved to be too complex to be covered by the standard coding. The codes 0 to 5 do not reflect the age relation between the ten functional primaries, originating from up to three different growth waves. It is furthermore unclear if *Cursorius* species are subject to one single annual moult wave or if two or even three can start per year.

__Figure 2:__ Namibian habitat of our study of Burchell's Courser: sandy and gravel plains in an arid open landscape. ML619126968.

For moult strategies we referred to the publications on the Cream-coloured Coursers (*C. cursor*) since Burchell's Coursers 'have much in common' in size and structure with the East African races of this species (Cramp 1983, p. 97).

3. MEASUREMENTS

For Table 1, we gathered the measurements of five adults and two first-year Burchell's Coursers from our study and, to our knowledge, all the published measurements from the literature.

4. MOULT AND BREEDING

In Namibia, active nests have been recorded during all months with exception of November and December; peaks are from April and July, but the sample of 30 records is small (Figure 3; Brown *et al.* 2015). During our study between November and March, we did not record any breeding activity and did not observe brood patches in the birds ringed.

The only mention of moult in Burchell's Coursers in the literature is from Macdonald who observed in Namibia 'north-east of Kleinkaras a few birds, probably a family party'. Most of his five specimens, shot between 10 and 27 of January in southern Namibia, 'were in various stages of post-breeding moult' since it was 'clearly evident that the new feathers are darker and more richly coloured than the old' (1957, p. 67).

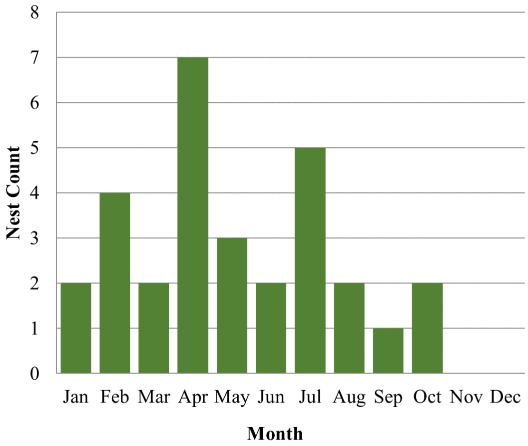

__Figure 3:__ Nest count records of egg-laying months of Burchell's Coursers in Namibia (Brown et al. *2015).*

Table 1: *Measurement data for Burchell's Courser* Cursorius rufus. *Average measurements (including standard deviation, minimum and maximum measurements) of adult birds from our study and from Hoesch & Niethammer (1940, p. 126), Macdonald (1957, p. 67-68), Urban* et al. *(1986, p. 212), and Pearson & Ash (1996, p. 226) and Kok & Van Zyl (1996, p. 161), both in Hockey (2005, p. 425). Furthermore, we include unpublished data from SAFRING (2024).*

Grouping	**Parameter**	**Wing (mm)**	**Tail (mm)**	**Tarsus (mm)**	**Culmen* (mm)**	**Head (mm)**	**Mass (g)**
Current study							
Adults	Mean ± SD	135 ± 3	51.8 ± 3.6	47.2 ± 1.7	28 ± 3.2	50.8 ± 1.1	75.5 ± 8.7
	Min–max	130–138	49–58	44.7–49.4	24.4–33	49–51.8	66.1–86.8
	n	5	5	5	5	5	5
Adults, sex unknown	Mean ± SD	135 ± 3.5	50.3 ± 1.3	47.9 ± 1.1	27.9 ± 3.7	50.6 ± 1.1	75.7 ± 10.1
	Min–max	130–138	49–52	46.7–49.4	24.4–33	49–51.6	66.1–86.8
	n	4	4	4	4	4	4
Adult female	Mean	135	58	44.7	28.7	51.8	75.1
	n	1	1	1	1	1	1
First–year	Mean ± SD	130.5 ± 3.5	52.5 ± 4.9	45.2	28.9 ± 0.1	53.4 ± 1.7	76.2 ± 8.3
	Min–max	128–133	49–56	45.2–45.2	28.8–29	52.2–54.6	70.3–82
	n	2	2	1	2	2	2
SAFRING Database 2024**							
Adults, sex unknown	Mean ± SD	136 ± 3.7	62.3 ± 17.9	49.5 ± 4	23.7 ± 4.6	52.4 ± 2.3	83 ± 2.5
	Min–max	129–143	51–89	45–52.4	17.9–28.4	50.6–55	78–85.4
	n	9	4	3	4	3	8
Macdonald 1957, pp. 67–68							
Adult females	Min–max	133–142	52–55		25–28		
	n	5	5		5		
Adult males	Min–max	133–140	50–57		27–29		
	n	3	3		3		
Urban *et al.* 1986, p. 212							
Adults, sex unknown	Mean ± SD	135	51.2	48	22.9		75 (Namibia)
	Min–max	132–138	48–53	46.5–51	21–25.5		
	n	13	13	13	13		unknown
Hockey 2005, p. 425							
with reference to		Pearson & Ash 1996, p. 226		Pearson & Ash 1996, p. 226	Pearson & Ash 1996, p. 226 to feathering		Kok & Van Zyl 1996, p. 161
Adult females	Mean ± SD	135.3		47	20.7		80.2 ± 2.9
	Min–max	131–138		44–48	20–21		61–90
	n	6		6	6		9
Adult males	Mean ± SD	139.2		47.6	20.6		94.3 ± 3.3
	Min–max	136–143		47–49	20–21		76–112
	n	5		5	5		11
Hoesch 1940, p. 126							
Adult female	Mean	135					82.5
	n	1					1

* The measurements of the culmen were taken to the skull, i.e. to the indentation on the front of the skull (Demongin 2016, p. IX). In two individuals, additionally the culmen was measured to the feathering (Demongin 2016, p. IX). It amounted to 20.7 mm (adult) and 21.4 mm (first-year).

** Of the 38 data sets in the SAFRING database, seven are from our studies, 15 are from small chicks, and of nine adults with measurements of wing and mass, only four have the remaining measurements of tail, tarsus, culmen and head recorded.

5. PLUMAGE AND AGE

In our research area in the arid savanna of the pre-Namib, small flocks of three to seven Burchell's Coursers would arrive overnight, and in the mornings, we would find groups of first-year birds in transition to adult plumage, obviously well able to fly, and adults. Due to the sporadic and erratic appearance of the birds, we could not observe a continuous development of moult.

The lifespan of Burchell's Coursers is unknown. One captive Cream-coloured Courser was at least seven years old (Glutz von Blutzheim 1986, p. 844). The age of Burchell´s Coursers can roughly be determined by different plumage expressions described in the literature and documented by photographs: those of freshly hatched young, downy young, juveniles, immatures and adults. Here we give a short general overview and discuss details of the wing, its flight feathers and the primary moult in greater depth below.

The determination of age by plumage features must be considered a rough estimation. In contrast to migratory wader species, no clear seasonal allocations seem possible, frequently feathers are retained, even for longer periods, and breeding and the subsequent age development can occur throughout the year. Approximate fixed points are given when adults and non-adults show active primary moult at the same time.

5.1 Adults

Small and medium-sized birds are generally considered adults when they have completed one year of ageing. In Burchell's Courser, adults can be recognised by a plumage without markings: plain upperparts, a rufous crown with a grey hind-crown ending in a black triangle and a black stripe behind the eye, located below a bright white band. Also, the underparts are plain, brown on the chest and separated from the white belly and vent by a black band, darkening towards the belly (Figure 4).

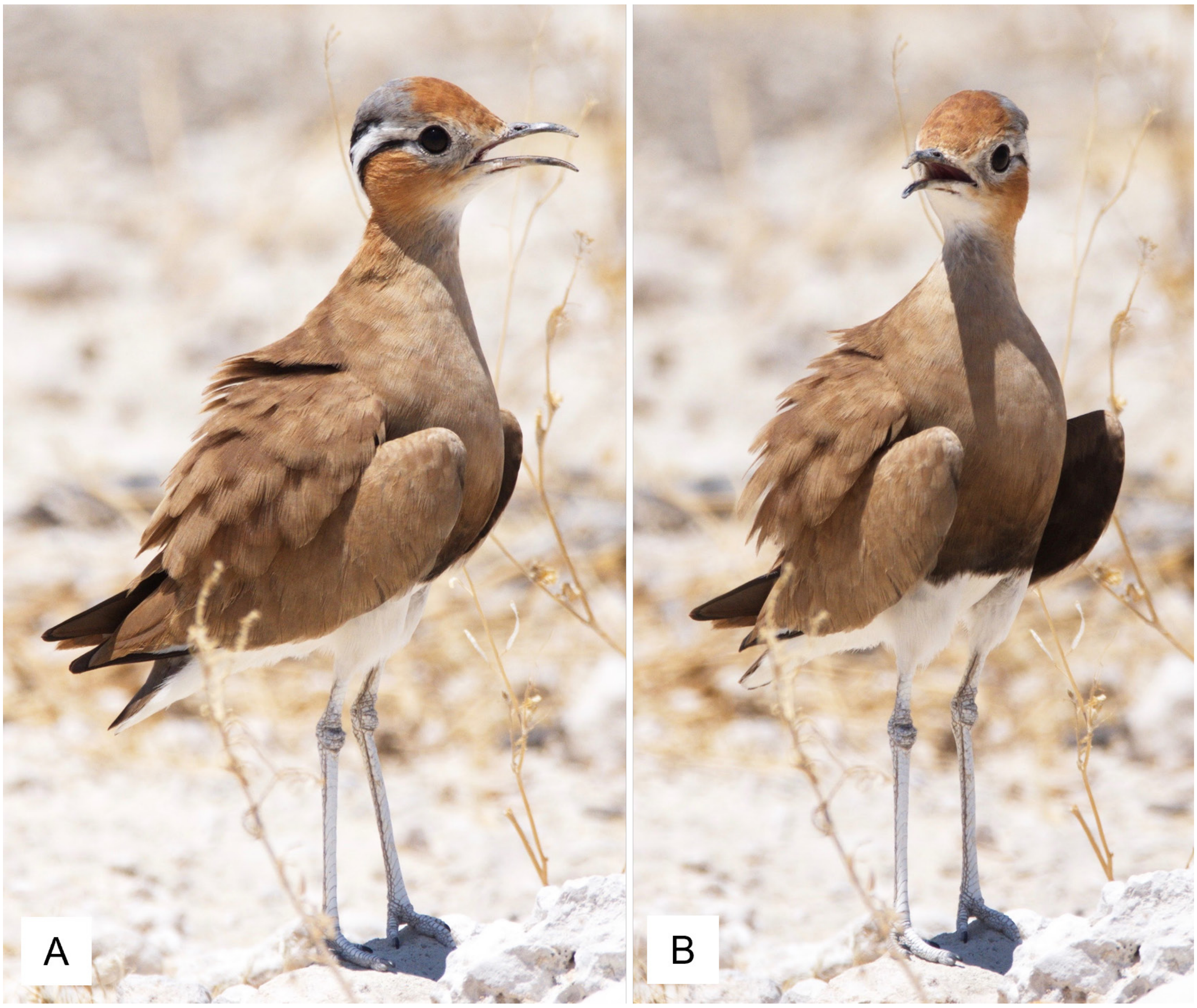

Figure 4: *Burchell's Courser in adult plain plumage showing: (A) the distinct head markings of the adult and (B) the brown chest divided from the white underbelly by a dark line. Omusati, Namibia, 2 November 2018. © Dominic Standing. ML217492281 and ML217492271.*

However, this seems to occur earliest in the second year.

We found broad, round rectrices, a shape commonly associated with the adult age, which had non-adult markings (see 5.5.2; Figure 13C), and several visible moult waves of primaries concurrent with retained coverts of a former plumage (Figure 19). It is unexplored if these features are related to a slow progress over more than one year to reach full adult plumage or if they are moulted off in the next 'complete' moult. It has also not been confirmed if the primary moult waves are started once a year or more frequently.

Presumably, there are no seasonal variations in the plumage of Burchell's Coursers and no significant sex differences, equal to the Cream-coloured Courser (Cramp 1983, p. 91 and p. 97 respectively).

5.2 Development of first-year to adult plumage

After egg-laying which can take place in almost any month (see Figure 3; Brown *et al.* 2015), the juvenile and post-juvenile, immature plumage consequently can be found throughout the year. Juveniles seem to grow a second set of body feathers which is unexplored - as is the occurrence of three feather generations in immature birds.

Full body size is reached after a few months, possibly only two (see 5.2.1), while the post-juvenile moult stretches over many months. We defined first-year birds as such by the abundance of markings of the plumage, mainly on the head, belly, rump and tail while taking into consideration that full adults possibly show residual feathers from an earlier plumage. For the determination of young age we also considered:

- the lack of the black line behind the eye,
- the lack of the black triangle on the neck,
- the leg colour changing from dark grey to whitish,
- the pointed shape of primaries and outer secondaries,
- the occurrence of only one moult wave of the primaries (or none in early young),
- the colouration of the axillaries (dark in younger and light in adults)
- and the combination of these features.

5.2.1 Freshly hatched and downy young

The freshly hatched young (Figure 5A) is described with down of a 'creamy stone colour, with a fair number of black markings on the crown and a few black markings on the back' (Bromley 1952, p. 61).

The only picture of a downy young we found was in Dixon (1975, p. 64) and shows light and dark markings all over the upperparts (Figure 5B). The growth of the young and with it the feather development progresses quite quickly. Lane (1933, pp. 73) observed two chicks in Potchefstroom, South Africa, following an adult in mid-September and resighted them 'a month later when they were almost fully grown'.

5.2.2 Juvenile plumage

Juveniles change their appearance in a few weeks from pale and faintly patterned (Figure 6A and 6B) to distinctly marked and rich in contrast (Figure 6C).

This points towards an additional set of body feathers, similar to that of most passerine species (described by Bub 1981, p. 119; Jenni & Winkler 2020b, pp. 61-62).

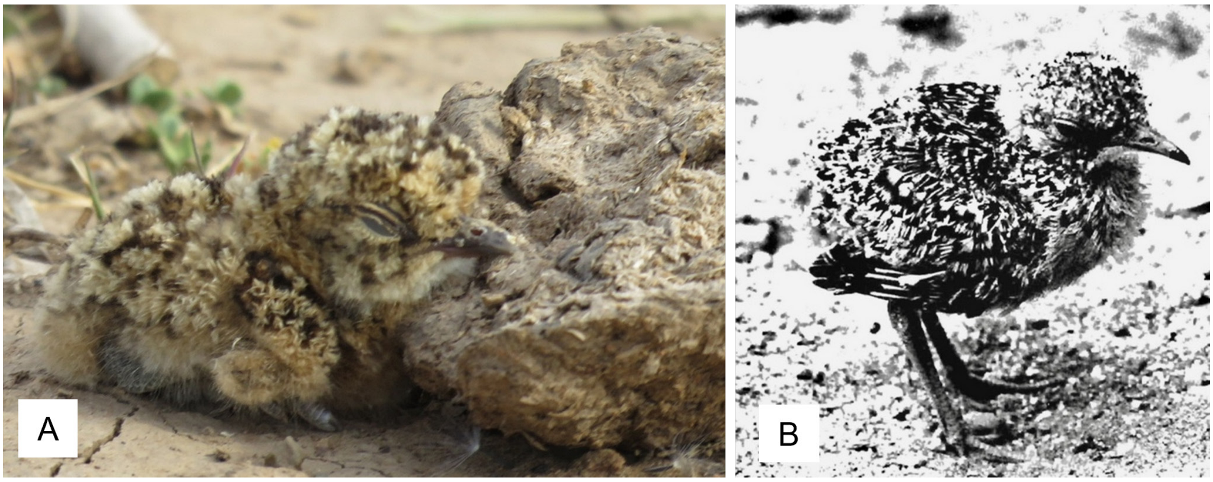

Figure 5: *(A) Hatchling resting on dry animal droppings. Northern Cape. 21 October 2020. © Riëtte Griesel. (B) Downy young of the Burchell's Courser. The blood sheaths show the growing primaries. Namib Desert Park. Photo in Dixon (1975, p. 64).*

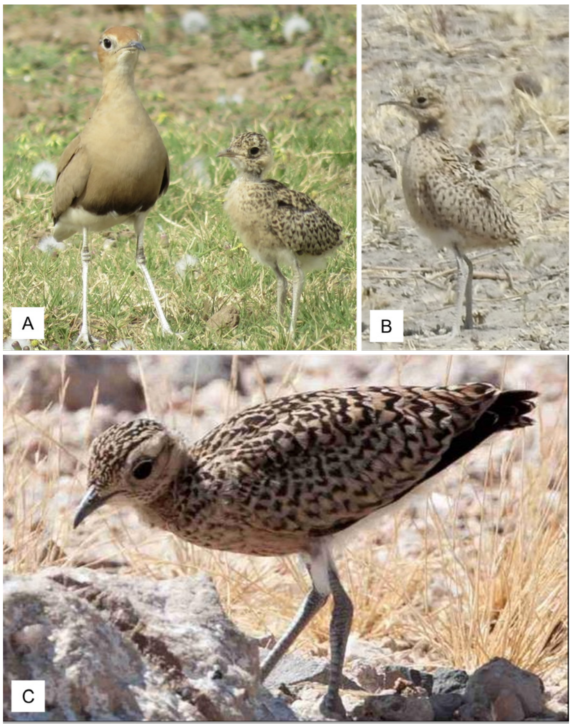

Figure 6: *Juvenile plumage in progress. (A) Chick with adult for comparison of size. Northern Cape, 21 October 2020. © Riëtte Griesel. (B) Young chick with lesser marked plumage, but older than (A), determined by comparison with (non-depicted) parent. Etosha NP, Namibia, 1 September 2019. © Marti Ikehara. ML223744091. (C) 'Half-grown chick', so-called by the photographer, in juvenile plumage with distinct markings. Spitzkoppe, Erongo, Namibia, 2 September 2008. © Dorothee Suter. ML368614011.*

Furthermore, despite both being from September, one (Figure 6C) is further developed in size and plumage than the other (Figure 6B), pointing towards an early hatching. Generally darker legs are also observable in juveniles compared to the pale white of the adult.

Figure 7: *Immature Burchell's Courser in transition to adult plumage. 4. February 2012. SAFRING 4H46518. ML619128077.*

5.2.3 Post-juvenile plumage

During the post-juvenile moult, the adult-looking plumage is acquired progressively and marked feathers of the first year are frequently retained into the second year (Figure 7). For a detailed discussion see Section 7.

5.3 Head markings

Two features stood out as far as the head markings are concerned. Firstly, the black triangle in the neck develops fully with age during several years (Figure 8).

Secondly, in some individuals, the grey area starts behind the eye (Figure 8A), in others between the eyes (Figure 8B; see also ML596222591). It is unknown if the size of the brown frontal patch is a sign of sex. It is not a sign of age as we can confirm after reviewing all the photographs available in the Macaulay Library (https://birdsoftheworld.org/).

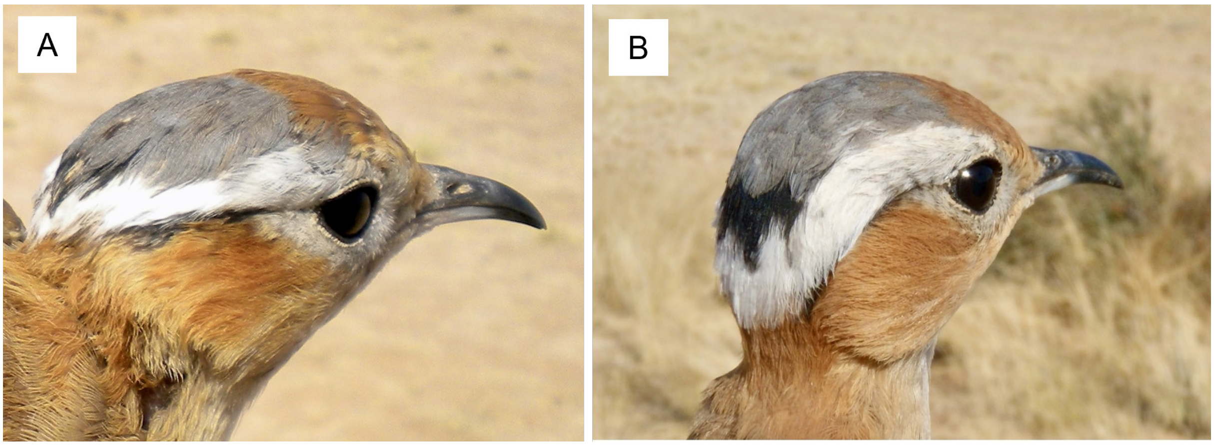

Figure 8: *Comparison of the head markings of first-year (A) and adult (B) Burchell's Courser. (A) 27 December 2009. SAFRING 497781, ML619127150; (B) 4 February 2012. SAFRING 4H46516, ML619127571.*

5.4 Colouration of chest and belly

In our research area, we found that the colouration of the upper- as well as the underparts is variable, as is the colour and the width of the dividing line between the brown chest and the white belly. Birds at the end of their first year still might retain a central area of vermiculated juvenile feathers (Figures 9A and 10A).

Figure 9: *Comparison of the underparts of a first-year (A) and an adult (B) Burchell's Courser. (A) The markings on the belly and the wing are from the juvenile plumage. 4 February 2012, SAFRING 4H46517, ML619128812. (B) Unmarked underparts of an adult with a washed blackish dividing line between chest and belly. 27 December 2009, SAFRING 497782, ML619128435*

Figure 10: *Comparison of the colouration of the dark dividing line between chest and belly. (A) Blackish tinge in a first-year bird. 27 December 2009, 497781, ML619127145. (B) Brown tinge in an adult. 28 February 2015, SAFRING CC79107, ML619128272*

The dividing line may be of a pale blackish or dark-brown colouration (Figures 9B and 10B). The black tinge can already show in first-year birds (Figure 10A). It is thus not a sign of age but may differ between the sexes or be a population or an individual feature.

Furthermore, this dividing line can be almost absent (ML220679131), a few millimetres wide (ML596222571) or well over a centimetre wide (ML611229139). More research is needed to clarify if these differences relate to progressing age and maturity, sex or seasonal changes in plumage.

5.5 Tail

The tail consists of 12 rectrices. The moult strategy of the tails is unexplored and not fully understood. The description of the appearance of the rectrices of adults as well as of young birds is multiform and even contradictory. This is possibly due to variability of the plumages based on age, wear and individual variation, and also to imprecise age labelling, especially the use of the term 'juvenile' for any young bird. In addition, coursers are known to retain their feathers for up to two years (and perhaps more) and a full adult plumage might take even

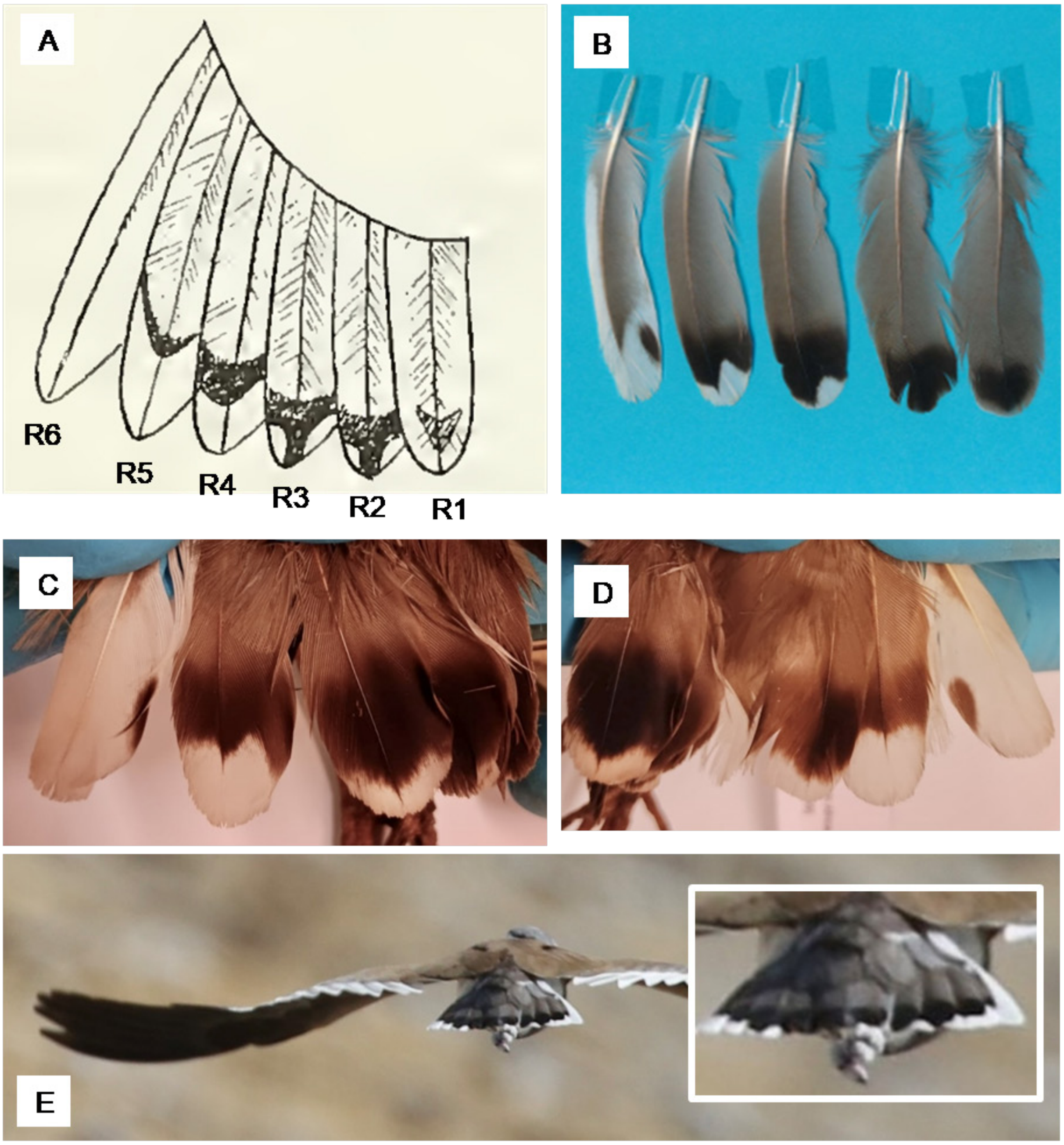

Figure 11: Variation of the patterns on the upper tail of adults: (A) drawing from Pearson & Ash (1996, p. 228). (B) Skin with one missing rectrix (R3?). February 1967, Namibia. Private scientific collection. © Pascal Eckhoff. (C) Left and (D) right tail of a mount. Museum of Natural History, Berlin, Inv. Nr. ZMB 12932. Collected between 1820 - 1839. © Anna Kowalczewska. (E) Etosha NP, Namibia, 1 November 2020. © Steve James. ML276365951.

longer to reach completion. Photographs providing detailed information of age are scarce. Beyond our own pictures (of poor quality), of adults we found only one depiction from a collection, one of a museum specimen and one drawing, and two drawings of a then called ‘juvenile’.

5.5.1 Tail of adults

None of the descriptions of the pattern of the rectrices found in the literature fully matches the drawing or the photographs from Figure 11 (Mackworth-Praed & Grant 1962, p. 330; Maclean & Urban 1986, p. 211; Pearson & Ash 1996, p. 227; Stark & Sclater 1906, p. 324).

All mostly have the ‘outer tail feathers increasingly tipped white with subterminal dusky bar’ in common (Hockey 2005, p. 424). The (sub-)terminal bar, the amount and pattern of white at the tip, the colour and markings on the outer rectrix R6 and the colour of tail and bar are all variable. The different descriptions are not only due to individual emergence in the plumage. We hypothesise that they might describe age- and possibly sex-related differences, like tail patterns in Lesser Grey Shrikes (*Lanius minor*) (Krištín *et al.* 2007). However, more material is needed for clarification.

The depictions of Figure 11 show tail feathers of different individuals. Noteworthy is the variation of the outer tail feather R6, either plain white (A), white with a small dark sub-terminal patch on the inner vane (C and D) or grey with white outer vane and tip and dark patch (B); the variation of the extent and the contour of the white tips; and of the width of the dark (sub-)terminal band. See also Figures 21B and 22B with two tails from December in different wear.

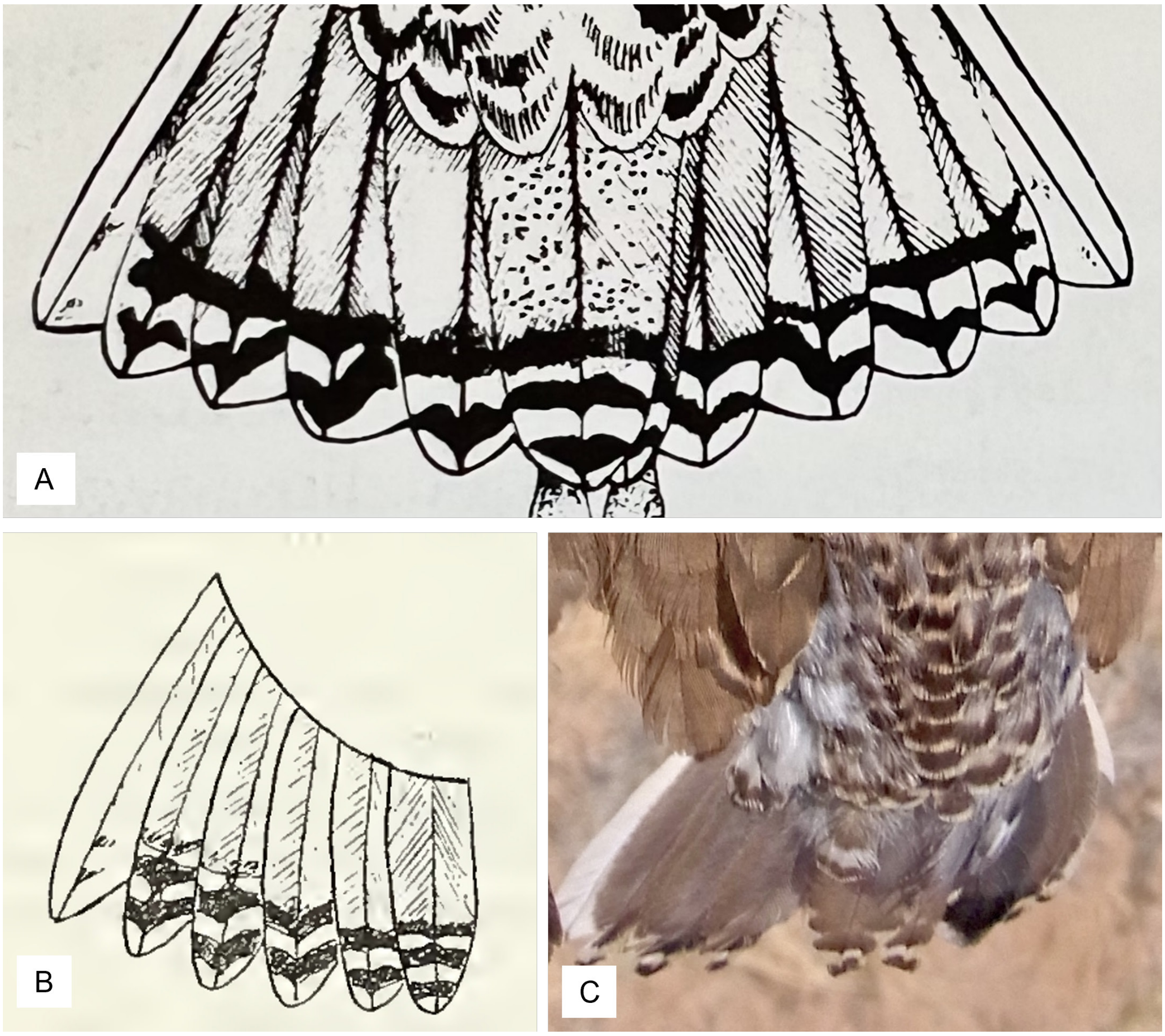

Figure 12: *Upper tail of young birds: (A) Juvenile from South Africa (from Hayman et al. 1987, p. 250); (B) Determined as ‘juvenile’ by Pearson & Ash (1996, p. 228). The rectrices will be replaced only in the second year of life, and the very same feathers will thus also be found in immatures. (C) Immature (same individual is in Figure 17). 4 February 2012. SAFRING 4H46518, ML619128073.*

5.5.2 Tail of first-year birds

There is no precise and consistent description of the tail feathers of the juvenile, nor of the immature Burchell´s Coursers. First-year, thus non-adult birds include juveniles (until their post-juvenile moult) and immatures. Stark & Sclater (1906, p. 324) described for 'young birds: the tail is ashy, the tips of the feathers black with sandy spots along both webs'. Since the term 'juvenile' is used randomly in the literature for both ages, the value of the data is lost. Maclean & Urban (1986, p. 212) found immatures with 'tail mottled with tawny' (sic) which in the literature turns into juveniles with 'upper tail mottled tawny, with 2-3 subterminal dark bars and white tip on all except outer rectrices, which only have subterminal bars on inner web, otherwise predominantly white' (Hockey 2005, p. 424).

Apart from Figure 12, there are no images for either this age or the transition in the first year available. The tail markings on Figures 12A and 12B are quite well resemblant, although the shape of the tips is more pointed in B, as generally common in first-year birds. Figure 12C shows abraded tips in an immature from early February of about one year of age.

Figure 13A shows an immature from December where the tail (Figure 13B) still wears markings also on the central feathers. In contrast, Figure 12C depicts the tail of an adult (from the same flock as Figure 12C) with broad round rectrices and with two non-adult feathers of the same shape (presumably R4 and R5 with white R6 missing). All rectrices are subject to the same modest abrasion, which points towards simultaneous growth.

The latter feature led us to the hypothesis that possibly some individuals replace some of their rectrices during the post-juvenile moult with round but marked new feathers or produce feathers with non-adult markings moulting into the adult plumage or grow them as adults.

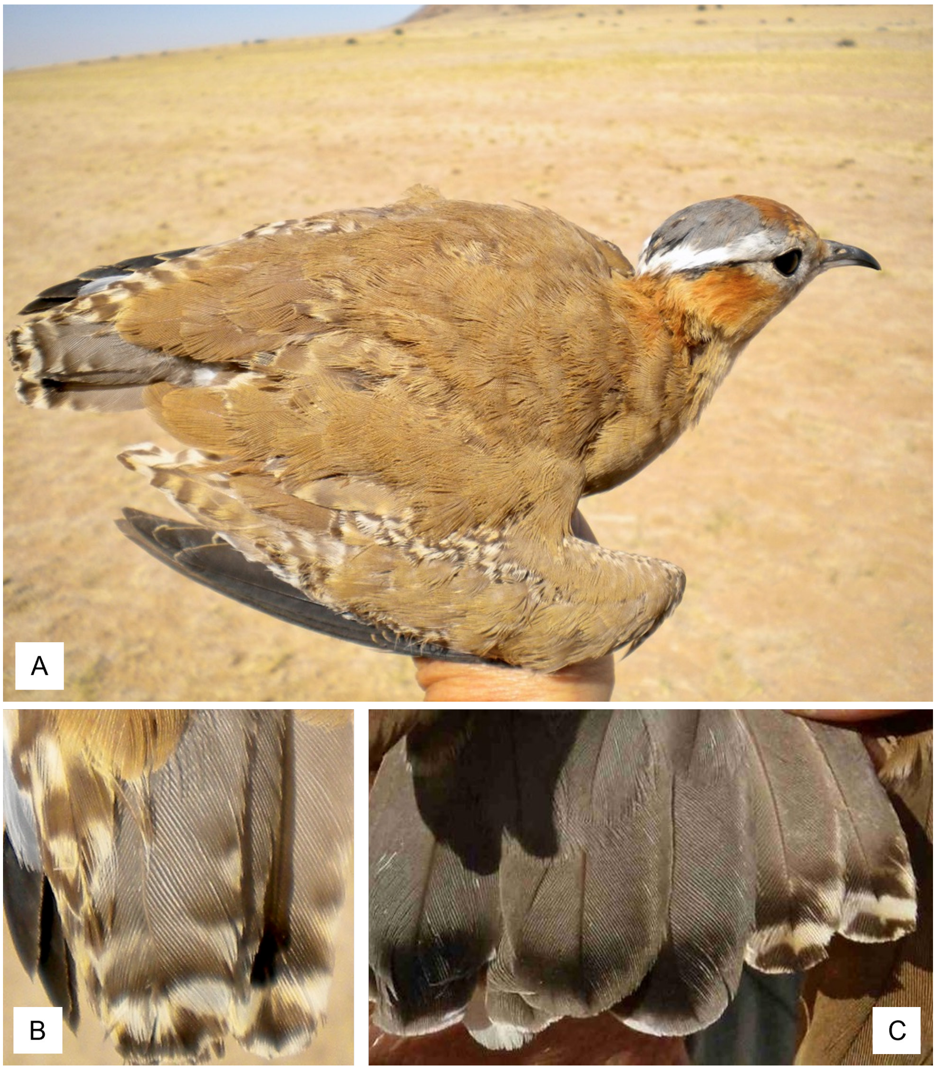

Figure 13: *(A) Immature in transition to adult plumage and (B) corresponding tail. 27 December 2009. SAFRING 497781. (C) Tail of an adult (individual from Figure 20) with two retained, marked rectrices. Compare the round shape of the tips with 12A, 12B and especially 12C. 4 February 2012. SAFRING 4H46516, ML619127568.*

5.6 Secondaries, tertials, axillaries and underwing coverts

The shape of several feather groups is generally different between the first and the following plumages which gives an additional tool for determining the age of a feather and with this, of the bird (Baker 1993, p. 16). In our sample, this also concerns the secondaries with apparent differences on the tips and of the width. In first-year Burchell´s Coursers, we found pointed outer secondaries, while in adults the outer secondaries have rounded tips.

It is unrecorded at what stage of moult and in which age the inner secondaries are replaced by round ones. We observed one individual in adult plumage with sharply pointed, possibly abraded secondaries (Section 9.3, Figure 21A). See also Section 7.3.

The tertials of a first-year plumage bear markings and correspond with the length of the secondaries (Figure 14A and 14B), those of adults are much longer and reach the end of the tail (Figures 20 and 22B). Furthermore, for more precise age determination you can draw on the colouration of the proximal part of the axillaries which are dark in younger birds (Figure 14A) and light grey in adults (Figure 14C).

6. MOULT

Beyond the most common strategy of simple descendent moult, various other general and frequent strategies have been described linked to the orders, but also to the size of the species and corresponding with their biological necessities. These include the frequent arrested moult with interrupted and suspended growth, a serial descendent moult (Jenni & Winkler 2020b) and

Figure 14: *(A) Immature with brown, marked feathers on tail, rump and tertials, dark proximal axillaries and underwing coverts and white fringes on the primaries. The inner secondaries are pointed, the parting line between chest and belly is indistinct. Sesriem, Namibia, August 2022. © Jacques de Spéville. (B) Marked tertials and belly of an immature. 4 February 2012, SAFRING 4H46517, ML619128810. (C) Adult with light grey-brown proximal axillaries and ashy brown underwing coverts. The black line behind the eye turns more distinct. Central Namibia. © Paul Donald.*

other types like 'slow continuous moults' (Rogers 1990, p. 144). For *Cursorius* species, a 'seemingly serial descendent moult' (Cramp 1983, p. 97) has been described (discussed in Section 8.4*)*.

6.1 Annual Moult

It is generally agreed that in the annual cycle of adult small- and medium-sized birds, a complete moult usually occurs after the breeding season; variations occur (Jenni & Winkler 2020b, p. 220). Differences in timing may arise depending on the bird family or order. In small and medium-sized first-year birds, the timing of the first complete moult, which includes remiges and rectrices, is generally established at the time of the moult of adults throughout the families (Jenni & Winkler 2020b, pp. 231 and Figure 148 on p. 232), while Hayman *et al.* (1987, p. 20) allocate the moult of adult waders as 'usually later than that of first-year birds'.

We found in our sample that both age groups moulted the primaries at the very same time. Out of a flock of seven birds, we ringed one adult (Figure 20) and two non-adults (Figures 13 and 17). All three had progressed approximately evenly in their primary moult.

6.2 General moult strategies of Burchell's Coursers

Neither for the post-juvenile moult nor for the primary moult of the first and subsequent years in southern African *Cursorius* species, data about the exact duration are available. We observed that the process is extended and that it might take several years for the wing, especially for the primaries, to be completely renewed (Figures 21 and 22).

7. MOULT IN FIRST-YEAR BIRDS

Shorebirds, which coursers are allocated to, start their post-juvenile moult with a few weeks, until, exceptionally late, with up to three months, and at large, the phenotype of the adult plumage in courser family of *Glareolidae* is acquired at the age of several months to just over one year (Cramp 1983, p. 84). Like other *Cursorius* species and waders in general, juvenile feathers are usually retained (Hayman *et al.* 1986, p. 20) into the second-year plumage and possibly even longer.

Glutz von Blotzheim (1986, p. 839) remarks that the closely related Cream-coloured Coursers replace the innermost primaries and rectrices during the post-juvenile moult. In our study we could not confirm this for the tail of Burchell's Coursers but found a possible realisation in the wing of a first-year bird. See also Section 7.3.

The comparison with the moult strategy of the Cream-coloured Coursers, which is helpful as a starting point for the moult description in Burchell's Coursers, comes to its limits when studying that of the first year. Cream-coloured Coursers begin their post-juvenile moult within a few weeks of fledging. As a partly migratory species they adjust to the necessities of being able to migrate and this moult is partial or complete, dependent on the time of fledging (Cramp 1983, p. 97).

For Burchell's Coursers, no long-distance movements are recorded (Maclean & Kirwan 2020; also Sclater 1906, p. 22) and hence the strategy of a complete post-juvenile moult lacks a functional basis. We observed the beginning of the first primary moult in February, when the moult of body and median coverts was almost completed (if not for residual feathers).

In our sample of two immatures, the rectrices and remiges were not included in the post-juvenile moult. Their first moult process occurred at the beginning of the second year of life when adults undergo their annual post-breeding moult (Figures 17 and 18).

In most, if not all, (non-passerine) species, juvenile feathers, mostly detectable in outer primaries, secondaries, tertials and greater-coverts, are narrower and the tips are more angled and wear more rapidly to a pointed shape (Baker 1993, p. 16; Hayman *et al.* 1987, p. 20). We found this in the outer primaries and in the secondaries, which confirm the young age of the feathers and thus of the birds (Figure 18 vs. adults in Figures 21 and 22).

7.1 Unexplored features of the post-juvenile plumage

In the first-year plumage, we found unaccounted differences in colour, and markings of the post-juvenile plumage that cannot be explained by retained feathers (Figures 15A and B). Both immatures are from the end of the calendar year: Figure 15A from 2 November from northern Namibia and Figure 15B from 28 December from the northern Cape in South Africa. They show a varying degree of the zigzag pattern: thin and pale in Figure 15A, well distinct, broad and warm brown in Figure 15B.

The intensity of the plumage colouration may be faded by the sun, and other factors may play a role: clinal variations or regional differences, although subspecies are not recognised. More material is needed to test our hypotheses that either the immature grows a specific set of coverts and body feathers, or that there is a unlikely specific post-juvenile plumage. This is possibly a general feature of coursers. In the Temminck's Coursers, we found likewise two different generations of coverts (Figure 16). See also Bryson and Paijmans (2024, in press).

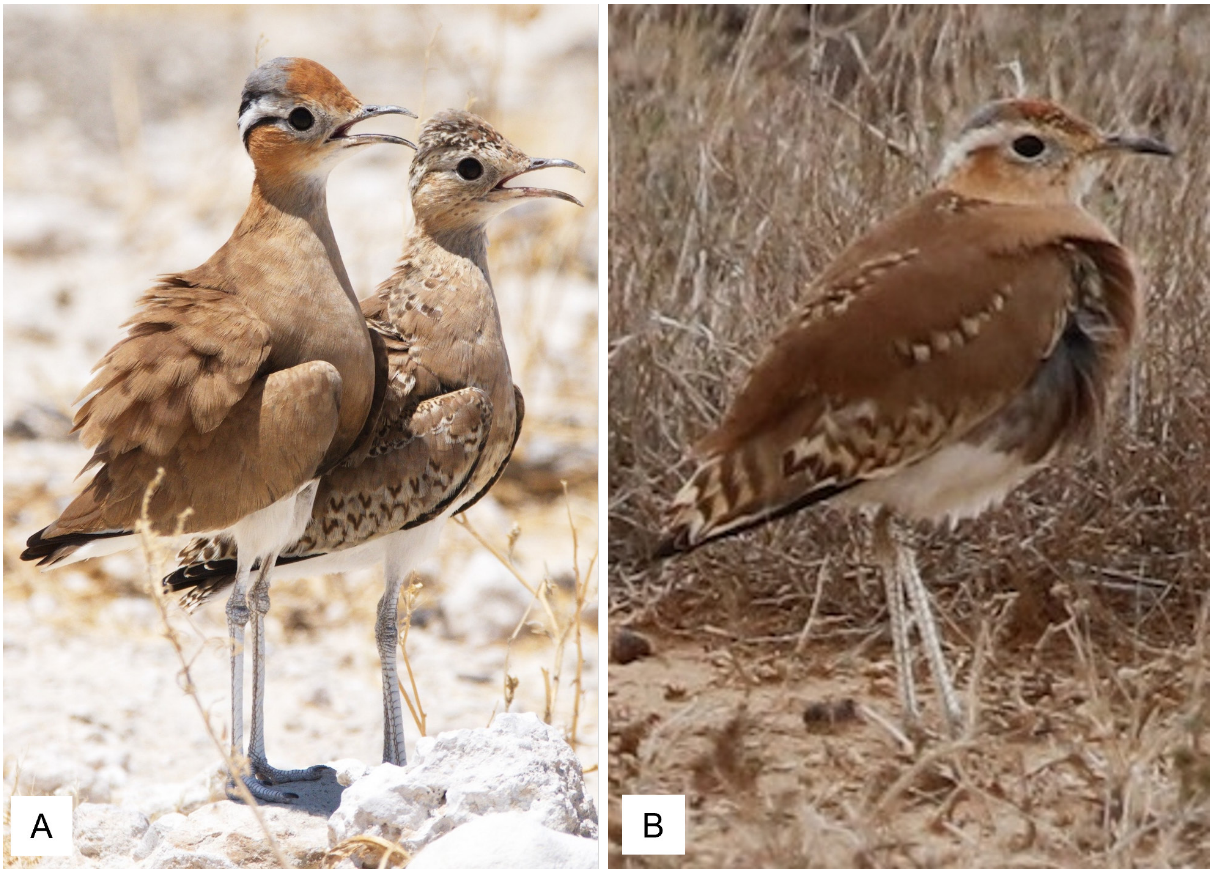

Figure 15: *(A) Adult Burchell's Courser and young during its post-juvenile moult. Omusati, Namibia, 2 November 2018. © Dominic Standing. (B) Immature completing its first adult plumage. Only a low number of coverts remain from the juvenile plumage. The head shows the adult supercilium, the rufous cheek and the grey hind crown, while the black stripe behind the eye still is in development. Northern Cape, South Africa, 28 December 2023. © Jason Fidorra. ML614135534.*

Figure 16: *Residual coverts of two non-adult feather generations in Temminck's Courser. Okavango, Botswana, December 2019. © Luboš Mráz*

.

Figure 17: *Burchell's Courser in transition: The difference between marked juvenile and plain adult plumage is quite obvious. While most of the head, mantle and of the median coverts is moulted, the rump and the lesser and greater coverts are still in process. In the left tail one fresh, grey rectrix has grown. 4 February 2012. SAFRING 4H46518, ML619128076.*

7.2 First complete moult

The primaries of first-year birds generally look uniform since they have grown at about the same time. Their replacement starts during the first complete moult. In the Cream-coloured Courser, advanced first-year birds look 'like adults, but all primaries [are] equally new, rather than showing suspended moult as in many adults; occasionally, a few juvenile wing-coverts or scapulars are retained' (Cramp 1983, p. 97).

7.3 The moult of two different first-year birds

In the same small flock, we observed two first-year birds in similar transitional plumage (Figure 17). Both birds were at the beginning of their second year of life, determined by the beginning primary moult with approximately the same moult sequence 3000000000 (Figure 18A) and 4100000000 (Figure 18B; but see Glutz von Blotzheim 1986, p. 839, on the replacement of the innermost primary during the otherwise partial post-juvenile moult).

When comparing the two wings, they seem homologous at first glance. At closer inspection, the differences of colour, shape and markings of primaries, secondaries and the different groups of coverts are so pronounced that they even appear to represent two different age groups. Figure 18A

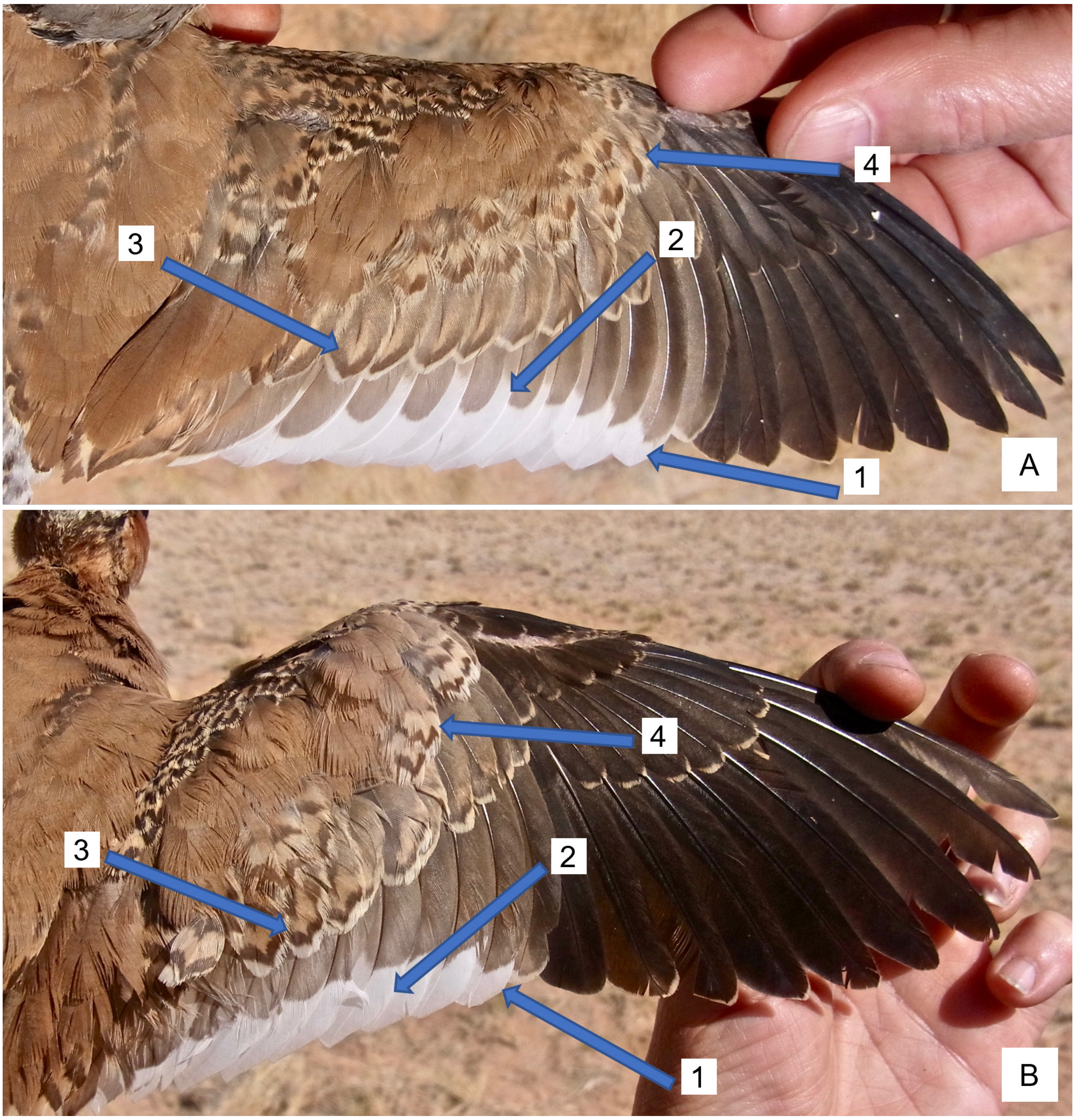

Figure 18: *The wings of two first-year birds of one group from 4 February 2012. On the first view the two wings look similar but on closer inspection they seem to represent two different age groups. Note the differences in colour, shape and markings of primaries, secondaries (1 and 2) and coverts (3 and 4). (A) SAFRING 4H46518, ML619128078. Moult sequence 3000000000. (B) SAFRING 4H46517, ML619128809. Moult sequence 4100000000.*

shows features of a younger age. The overall wing is paler. The inner primaries in Figure 18A have a juvenile pointed tip, those in Figure 18B round ones with small buff fringes. The outer secondaries (1) are pointed in Figure 18A vs. round in Figure 18B. The white edge (2) stretches far up the outer vane in Figure 18A, but not in Figure 18B. It is possibly an individual and not an age-related feature. The greater coverts (3) in Figure 18A are pointed vs. rounded in Figure 18B, have a straight subterminal bar along the white edges vs. a darker vermiculation, and dark shafts, often a sign of early feathers, whereas Figure 18B does not show them. The median coverts (4) in Figure 18A are almost transparent of poor quality with thin fringes, and show paler, undefined markings vs. distinct, vermiculated markings in Figure 18B.

Unfortunately, we were not able to find detailed photographic material or descriptions that could explain these differences. Hypotheses to be tested are a distinct immature generation of plumage of higher feather quality and more distinct markings. We can only speculate about the underlying patterns and hope that with this observation and description other researchers will help us out with more data and explanations.

8. MOULT IN ADULTS

8.1 Primary moult of Burchell's Coursers

The primary moult in the *Cursorius* family is highly complex with numerous variations and is not fully understood (Cramp 1983, p. 97). The primary moult, as in all *Charadriidae*, is descendent (Stresemann & Stresemann 1966, p. 217) as also documented in Temminck's Coursers (Bryson & Paijmans 2024, in press, and as in ML616708191). In Cream-coloured Coursers, the primaries take about six months to be replaced (Cramp 1983, p. 97). For the southern African species, the duration of the primary moult is unknown. In some individuals, we found a white tip on the inner primary (Figures 20 and 21).

8.2 Determination of age

We could not find any information in the literature on whether (Burchell's) Coursers start one or more primary moult waves during one calendar year or during a moulting season. The *Sternidae,* the sub-family of terns, of the same order of *Charadriiformes* as the *Glareolidae*,which the coursers are allocated to, can undergo three or even four moult waves per year (Demongin 2016, pp. 151). This concerns the inner primaries that are moulted twice or even three times a year, a process which is then called *repeated moult* (Jenni & Winkler 2020b, p. 211) and is different from the moult strategy of the coursers. For the Burchell's Courser, the extent of the wear and abrasion makes one yearly moult wave more likely (Figure 19), although solid data are lacking.

If Burchell's Coursers are subject to one single wave or moult series per year, the number of waves in a wing will indicate the minimum age of this individual. The following discussion is based on the assumption of one wave per year.

8.3 Serial descendent moult

The moult strategy of the Burchell´s Coursers is basically a serial descendent moult, although not all requirements are fully met. 'In a serial descendent moult, a moult wave starts at P1 and is suspended whenever the moult period ends, even though only some of the primaries have been moulted. At the next moult period, the suspended moult wave is resumed at the point of interruption and carried on for a few more primaries or until it is completed' (Jenni & Winkler 2020b, p. 222).

Every year (or in large birds every second or third year), 'a new wave starts at the innermost primary concurrently with the resumption of previously suspended moult waves.

Depending on the number of primaries moulted per year and the frequency of starting a new moult wave, the number of concurrent moult waves varies, and so the number of *concurrently* [highlighted by UB] growing feathers too. ... This results in a very complex mixture of primaries of three or four generations' (ibid.).

Young (Burchell's) Coursers can be recognised as such by the occurrence of one single moult wave which is their first and until then only primary moult event.

8.4 Seemingly serial descendent moult in *Cursorius*

Jenni and Winkler determine as a serial moult strategy when moult starts in 'a new wave before the previous one has ended', and thus one or several feathers are in active growth (2020b, p. 228). The adult Burchell´s Coursers in our sample had only one active centre of moult, conforming with Cramp's description of the Cream-coloured Coursers: 'Apparently, two moult series [are] never active at the same time'. He thus called the strategy 'seemingly (but actually not) serially descendent.' He also ascertained that the innermost primary 'perhaps does not start before the outer one has finished' its growth or that the outer series temporarily stops when the innermost starts. Some primaries are probably replaced only every second year (1983, p. 97).

9. DISCUSSING THE MOULT OF FOUR DIFFERENT ADULTS

Below we discuss the moult phenology of four different adult Burchell´s Coursers ringed in December, February and March and one wing from

February. We were not able to establish a general pattern in the primary moulting process in this species during our studies. We describe and comment in detail some features to summarise the actual knowledge of the moult strategies. It is unexplored to what extent the findings can be transferred to the moult of other *Cursorius* species like the Temminck's Courser. (But see the scarce records of moult of the Double-banded Courser *Rhinoptilus africanus* in Bryson & Engelbrecht 2023, and compare with the common, regular progression in passerines Bryson & Engelbrecht 2024; Bryson & Paijmans 2022, 2023; Bryson *et al*. 2023).

9.1 Adult 1 from 1 March 2015

'A ... new series [of moult] may start with [the] innermost [primary], but this does not always happen: apparently, two moult series are never active at the same time, and the innermost primary perhaps does not start before the outer ones are finished, or the outer series temporarily stops when the innermost starts' (Cramp 1983, p. 97 on the moult of the Cream-coloured Courser).

In Figure 19 the different generations of primaries in an individual from March are well distinct. By that, the age of the individual can be determined approximately. If it was known if single residual feathers can remain unmoulted for more than two seasons, the determination of age could be even more precise.

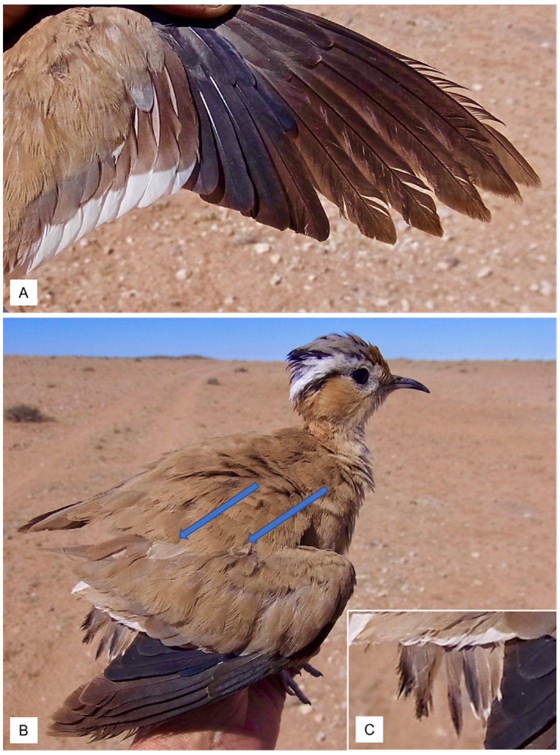

Figure 19: *Adult in its third year during primary moult. (A) Wing with three or possibly four different generations of primaries. ML619128271. (B) The blue arrows indicate residual feathers: right from the juvenile, left from a post-juvenile plumage. The remaining upperparts have undergone (at least) one complete moult. ML619128270. (C) Tail feathers of different age groups. 1 March 2015. SAFRING CC79107.*

On the upperparts, three generations of feathers are recognisable. The upperparts are plain, if not for one single marked, thus juvenile feather (from 2013, blue arrow on the right in Figure 19B) and a plain but pale feather from a post-juvenile plumage, older than the surrounding feathers (left arrow).

The inner primaries P1 to P4 have moulted in a first wave of a complete moult (2014), now the inner three primaries belong to a second moult wave (2015), while P5 is resuming the first wave from 2014. The primary coverts are simultaneously moulted with the primaries.

The pointed, very abraded outer primaries P6 to P10 are older than P4, thus from 2013. The outer secondaries have rounded tips which is a sign for at least the second plumage. Compare the pointed secondaries of first-year birds in Figures 18A and 18B.

Based on these criteria, we preliminarily concluded that this individual is in its third year, during its second complete moult although the temporal relation between the growth of P3 and P5 is unclear. Do they belong to the growth of the same season or to two consecutive ones? In the latter case, the primaries would belong to four generations.

The tail includes at least two generations of feathers: two pale rectrices with white tips (presumably R4 and R5, following the white, here missing R6), a growing, grey one with blackish terminal spot, and darker inner rectrices with undefined brown terminal patches, probably the central pair which differs in colour. Compare with the full adult tail in Figures 11 and 21B.

This leads us to the hypothesis that it can possibly take up to four years for a Burchell's Courser to acquire an entirely adult plumage without residual body feathers from the first year.

9.2 Adult 2 from 4 February 2012

Primary 'moult starts with the inner primaries ... shortly after the eggs hatch ... but the primary moult is suspended.... A few individuals moult some more primaries after that, occasionally reaching completion, but the outer primaries usually are retained until next year and some primaries are probably replaced only every two years' (see Figure 19) (Cramp 1983, p. 97 on the moult of the Cream-coloured Courser).

On the wing of this adult (Figure 20) from February, two moult waves and three generations of primaries

Figure 20: *Adult in at least third year. Primary moult with P1 and P2 growing, P3 to P5 from a former generation and P6 to P10 oldest. A white tip shows on the innermost primary. Long tertials indicate adult plumage. 4 February 2012. SAFRING 4H46516, ML619127414.*

are visible, with P2 as the only active moulting one. The first wave stopped with P5, now the next wave comprises growing P1 and P2, and P6 to P10 are older but in good condition: dark, dense and hardly abraded (compared to Figure 19A) which makes it likely that they already have been moulted after the juvenile plumage.

The adult age is also evident by the rather long tertials that reach the end of the tail, rounded, not pointed outer secondaries and the lack of residual juvenile feathers on the upperparts. On the other hand, for a younger adult speak the rudimentary black triangle at the neck (compare to Figure 8); the shape of the outer primaries which are narrower and more pointed than in the older adult with uniform grey tail with white tips from Figure 21B in December; the outer coverts with pale tips and the tail with barred tips of a juvenile plumage (Figure 13C).

Figure 21: *Adult. (A) The wing shows different moult waves (P1 to P3 with not visible P4 moulting), P5 to P7, and P8 to P10. The innermost primary has a small white tip. The three outer secondaries have round, i.e. adult, tips, the remaining secondaries are sharply pointed. ML619128436. (B) The tail shows an adult, fully black sub-terminal band, white tips. 27 December 2009. SAFRING 497782, ML619128438.*

9.3 Adult 3 from 27 December 2009

The birds from Figures 21 and 22 are both from December which allows a comparison in moult progress. The individual from Figure 21 is a fully grown adult from December with at least four years of age. The wing shows three moult waves, the outer one being from an adult. Brown P1 is from a former wave with the actual continuation of darkest P2 and P3, and P4 as a growing pin; fully grown P5 to P7 as

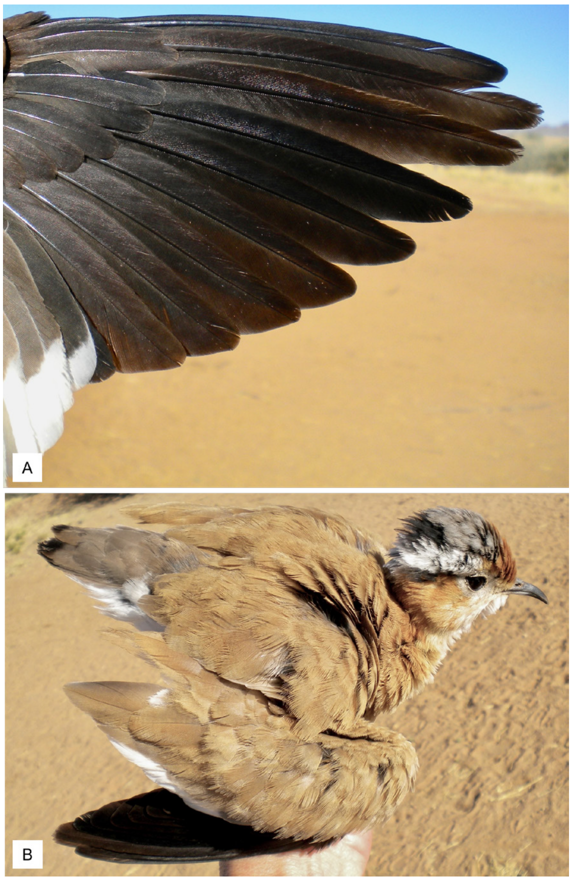

Figure 22: *Adult. (A) Wing in primary moult; no white tip on inner primary. Three dark new feathers stand out: fully grown P1 and P7 and growing P10. ML619129152. (B) Uniformly coloured wing, back, rump and tail, the latter having the tips abraded. 12 December 2009. SAFRING 4H35568, ML619129150.*

the last feathers from a former wave, seemingly older than P1, but possibly from the same season; and fully grown P8 to P10 as a continuation and completion of this wave.

A white tip shows on the innermost primary (as the individual in Figure 20). Also, the secondaries are moulting. The three outer secondaries are darker, and have round, i.e. adult, tips. The remaining secondaries are sharply pointed, whereby it is not clear if this is a normal adult shape, since these tips are not described.

It is undetermined if the description of Jenni and Winkler (2020b, p. 222) about the serial descendent moult of large raptors and storks can be applied here, too. The 'time taken for one wave to reach its end at P10 increases with age... With age, the serial moults develop irregularities, such as asymmetries between left and right wing, longer or shorter intervals between the shedding of adjacent feathers'.

9.4 Adult 4 from 12 December 2009

The adult from Figure 22 is a fully grown adult. The wing shows three moult waves ending with P1, P7 and P10, the latter being the only actively growing primary in the wing. It is, though, obviously resuming the outer wave from an earlier year, taking it to completion. P7 is fully grown, the corresponding primary covert is completing its growth, as is the outermost secondary. With three moult waves and P8 and P9 with rounded tips, we hypothesise that the age of this bird is at least four years.

Cramp describes this strategy as a 'seemingly (but actually not) serially descendent' moult (1983, p. 97), since at the end of the three waves not all but only one, P10, is in active moult. No white of the tips of the rectrices is visible, in contrast to the other adult from December (Figure 21).

9.5 Adult 5, wing

This said and concluding our research and the photographic evidence of the 'seemingly serial descendent moult' of Burchell's Coursers, we discovered in a private collection a wing from February of a fully grown adult with a de facto serial descending, bi-focal moult with primaries and one corresponding covert growing in both moult centres (Figure 23). This strategy is an addition to the strategy described by Cramp (1983) and our observations.

This variability reminded us of the statement by Jenni and Winkler in their book about the passerine moult: 'Although most species cluster into distinct moult categories ..., moult strategies can be highly variable within species ... and also between years and within individuals …, and are apparently adapted to the ecological conditions specific to the population or individual' (2020a, p. 47).

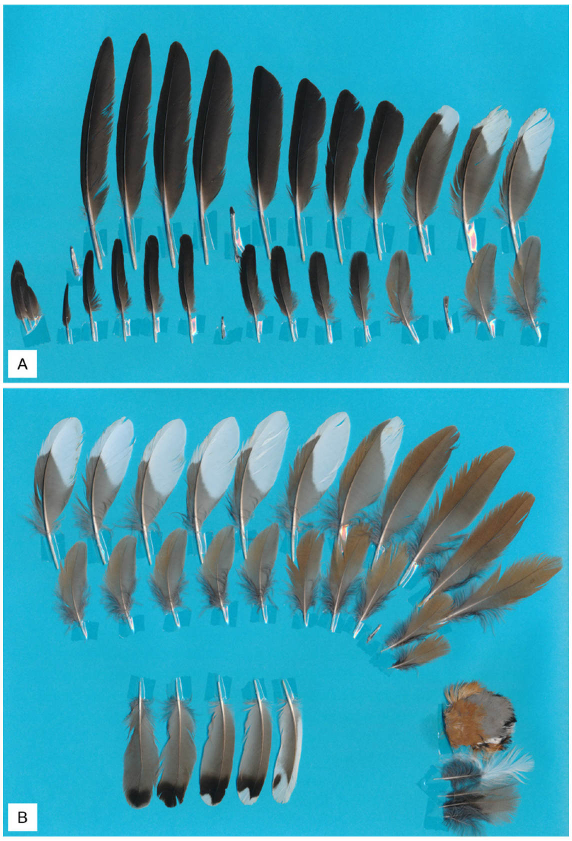

Figure 23:*A wing of an adult Burchell's Courser. (A) Primaries with two active moult centres and three secondaries with corresponding coverts and alula. The outer primaries seem slightly paler and browner, although hardly more abraded than the inner ones. This difference would not justify a whole year of wear. (B) Continuation of the secondaries, tertials, tail, head and body feathers. One tertial and one rectrix (R5?) are missing. February 1967, Namibia. Private scientific collection. © Pascal Eckhoff.*

9.6 Further moult data

Beyond our own data captured, only two sets of moult data are recorded by SAFRING (2024, unpublished data), both from adults ringed in the Northern Cape in South Africa; one ringed on 23 March 2024 with arrested moult (moult sequence 5555555000) and one from 6 September 2023 displaying ten new primaries (moult sequence 5555555555). Neither of these two individuals had a broodpatch. Considering the complexity of the moult strategy and the similarity in colouration of feathers from different generations (for example in Figures 13 and 15), it seems appropriate to reconsider at least the moult sequence from the March individual. Possibly the moult waves were not recognised as such, as happened to us at the beginning of our studies.

10. FURTHER RESEARCH

Overall, the basic documentation of detailed plumage features, the age development and the physical moult process of the Burchell's Courser shows many gaps or is non-existent.

Following subjects need further exploration and precise description.

Plumage

A detailed description and photographic documentation of the plumage and the changes throughout all ages is needed, including features of a plumage in the second and third year and older, like residual feathers on body, tail and wing. Also, the question of seasonal changes is not yet explored.

Body

Variations in the colouration and the size of the dividing line on the belly should be examined, based on age, sex, season and geography, as well as the overall colouration and progressive darkening of the feathers during the first year.

Head

The size of the brown and the grey area on the crown and the relation to sex should be addressed.

Tail

A detailed description of the variations in tail shape and pattern throughout the first-year and ageing adulthood.

A detailed description of the variations in shape and tail pattern over time and the moulting process should be explored, including a description and comparison of the colouration of the different rectrices.

Wing and moult

Special attention should be directed to the moult progress, including:

- the sequence of the overall moult progress on body and wing,
- the moult strategy during the post-juvenile and adult moult,
- the process of primary moult, including symmetry of both wings, also with progressing age,
- the frequency of primary moult waves, also depending on the age of the birds,
- the duration of the individual moult waves and
- and the duration of the complete replacement from P1 to P10.

Of interest is also how long individual feathers can be retained, especially of coverts and tail, and if the post-juvenile moult process advances slowly and continuously, or if all residual feathers are moulted during the second complete moult.

The understanding of the moult processes allows conclusions about the annual life cycle of the species and the family group. It is a tool for scientific researchers and citizen scientists alike to determine more precisely of age during field observation, as well as in captured individuals and museum skins. Discerning age groups gives insight into the ecology of population. Observing and predicting trends of population dynamics are crucial for the conservation, especially in little known species in decline.

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