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Ecology of Angolan giraffe (*Giraffa giraffa angolensis*) in the NamibRand Nature Reserve, southwestern Namibia

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Abstract

Understanding how giraffe (*Giraffa* spp.) persist in arid and resource-limited environments is critical for informing conservation strategies in the face of climate change and habitat fragmentation. Yet, little is known about the ecology of Angolan giraffe (*Giraffa giraffa angolensis*) in the pro-Namib sub-biome of southwest Namibia. This study investigated the population structure, spatial ecology, feeding ecology, and social dynamics of a free-ranging Angolan giraffe population in the NamibRand Nature Reserve (NRNR) – a hyper-arid landscape with minimal anthropogenic disturbance. Over 13 months the NRNR giraffe population remained small and stable, consisting of 13 individuals with a relatively even sex ratio and predominantly adult age structure. Herd sizes ranged from one to ten individuals (mean ± SD: 3.8 ± 2.6), comparable to other arid-adapted giraffe populations. Individuals allocated most of their daily activity budget to feeding and locomotion, consistent with the demands of a low-productivity environment. Diet analysis revealed a strong reliance on *Vachellia erioloba*, approximately 53% of all observed foraging events. Mean home range sizes were 342.2 ± 63.4km² for females and 265.8 ± 168.5km² for males, with one male ranging up to 521km², likely in response to mate-searching and low conspecific density. Despite the extreme conditions of the pro-Namib, the Angolan giraffe in NRNR displayed ecological and behavioural traits comparable to other populations in arid regions, underscoring the species' remarkable adaptability. These findings contribute to a growing understanding of *Giraffa* spp. resilience in marginal habitats and insights for conservation planning in arid ecosystems.

Introduction

The changing global climate, combined with anthropogenic activities such as large-scale land clearance and fragmentation for human development and agriculture, infrastructure development, and resource overexploitation, is degrading natural ecosystems and rapidly imperilling biodiversity (Obari 2014, Tilman et al. 2017). This rapid development has resulted in the decline or extirpation of many species. In Namibia, where arid environments exacerbate the negative impacts of these environmental changes, the agricultural sector is one of the major contributors to the economy, including intensive crop and livestock farming in arid and hyper-arid areas (Humavindu & Stage 2013). The majority of Namibian properties are fenced to demarcate boundaries, control access, limit animal movements and exclude some wildlife to reduce potential disease transmission and predation (Boone & Hobbs 2004, Taylor & Martin 1987). Fences also restrict many non-target wildlife species that require seasonal migratory patterns and access to suitable forage (Taylor & Martin 1987). This is of particular concern to gemsbok (*Oryx gazella*) and springbok (*Antidorcas marsupialis*) in the pro-Namib Desert as they move east-west between the Great Escarpment and Namib Desert in response to increased rainfall and food availability (Scott & Shaw 2017, Urban 2021). Understanding the spatial ecology, resource use, and social dynamics of large mobile wildlife in this arid environment is therefore essential for informing conservation management.

Giraffe (*Giraffa* spp.) are iconic taxa which have recently undergone significant range-wide declines in abundance and distribution, largely due to human activities (e.g. intensive agriculture that leads to habitat loss and fragmentation, poaching, civil unrest) and natural threats (e.g. predation, disease) (Muller et al. 2018, Wong 2020). Combined giraffe species' populations significantly declined from an estimated 150,000 to 140,000 individuals over the past 35 years (O'Connor et al. 2019, Brown et al. 2021, Marneweck et al. 2025). Additionally, their geographic range has substantially decreased, and they are locally extinct in at least seven African countries (Brown et al. 2021). Therefore, studying their ecology across diverse habitats is essential to understand how these iconic animals adapt to varying environmental conditions, especially as habitat fragmentation and climate change increasingly threaten their survival and limit their movement and resource access.

Studying Angolan giraffe (*Giraffa giraffa angolensis*) ecology in arid environments such as Namibia's pro-Namib Desert is essential for understanding how this taxon persists in some of the most marginal habitats across its range. Contrasting demographic trends exist throughout sub-Saharan Africa, with some – like the southern (*G. giraffa*) and West African (*G. camelopardalis peralta*) giraffe – experiencing growth (Suraud 2011, Brown et al. 2021), while other (sub)species have declined (O'Connor et al. 2019, Brown et al. 2021). These divergent patterns highlight the need to investigate the ecological and behavioural traits that enable them to survive in different environments, especially those that are harsh and resourcelimited. As population data still sparse in many regions, especially in arid zones, understanding *Giraffa* population dynamics and the drivers of change is critical for evidence-based conservation (Ogutu et al. 2014, Kasiringua et al. 2019).

Across their range, *Giraffa* spp. play vital ecological roles as browsers, seed dispersers, and stimulators of plant regrowth (Du Toit 1990, Du Toit et al. 1990, Hofmeyr 2003, Muller 2019), and their flexible diet – which predominantly includes, but is not limited to, *Vachellia* and *Senegalia* species (e.g. Parker & Bernard 2005, Brand 2007, Anyango & Were-Kogogo 2012, Cornelius et al. 2012, Deacon 2015, Cubas 2022) – supports their expansive distribution. In hyper-arid settings, such adaptability may be particularly important for navigating seasonal and spatial variability in forage availability. Yet, we lack detailed knowledge of how their diet and foraging strategies shift under these conditions. Understanding these ecological adjustments is key to predicting their resilience in the face of climate change and habitat degradation.

Social behaviour adds another layer of complexity. All giraffe species are non-territorial and exhibit fission-fusion social dynamics – frequently changing group sizes and composition depending on environmental conditions (Fennessy et al. 2022). These dynamics likely evolved as adaptive responses to variable food availability and predation risk (Clausen 2013, Van der Waal et al. 2013, Bond et al. 2019). Group living can enhance survival through increased vigilance, social learning, and mating opportunities (Sueur et al. 2011, Bond et al. 2020, 2021) but may also impose costs such as resource competition and disease transmission (Bercovitch & Berry 2009, Clausen 2013). In arid systems like the pro-Namib, where predation pressure is lower and resources more patchily distributed, their sociality may follow unique patterns that are not well captured by studies in more productive environments.

Furthermore, studies of spatial ecology – such as movements and home range size – are particularly valuable in defining the spatial requirements of giraffe in landscapes where resources are scarce and unpredictable (Zimmermann et al. 2001, Obari 2009, D'haen et al. 2019, Tucker et al. 2018). Such data can inform reserve design, corridor planning, and management interventions. Behavioural studies, often based on direct observations, reveal how giraffe allocate time to activities like feeding, walking, and social interactions, which are shaped by sex, season, and environmental context (Fennessy 2004, Obari 2009, McQualter 2018). For example, lactating females may reduce nursing in predator-rich areas (Gloneková et al. 2017), while in areas of low predator density, behaviour may be more influenced by resource distribution than by predation risk.

Given the ecological differences observed among giraffe populations across Africa, this study aimed to investigate the unique adaptations of Angolan giraffe inhabiting one of the most arid and understudied parts of their range – the NamibRand Nature Reserve (NRNR) in Namibia's pro-Namib Desert. Specifically, we assessed population structure and social dynamics, spatial ecology, activity budgets, and diet composition to better understand how they persist in this resource-scarce environment. The NRNR offers a rare opportunity to study them in the absence of key predators, under extreme climatic conditions, and with minimal anthropogenic disturbance – providing a natural setting to examine how behaviour and ecology are shaped by aridity. These data contribute to a growing body of literature on *Giraffa* ecology, filling a critical knowledge gap for arid environments and enhancing our understanding of the species' ecological flexibility. Importantly, our findings offer evidence-based insights to inform local Angolan giraffe conservation management strategies and support broader regional efforts to safeguard populations facing increasing environmental pressures in marginal habitats.

Materials and Methods

Study area

The NRNR in southern Namibia's Hardap Region lies in the pro-Namib Desert, a transitional area between the Namib Desert and the Nama Karoo biomes (Scott & Shaw 2017) (Figure 1). The ~205,000ha NRNR is in the Greater Sossusvlei-Namib Landscape (GSNL), between 24.82˚S and 25.58˚S latitudes, and 15.79˚E and 16.23˚E longitudes. The NRNR shares a 100km-long border with the Namib-Naukluft NP to its west (Scott & Shaw 2017) and borders the ProNamib Nature Reserve on the eastern side.

The pro-Namib Desert climate is arid, with characteristically low, highly variable and patchy rainfall mostly falling during the summer months (Scott & Shaw 2017, Jarvis et al. 2022). The average annual rainfall recorded in the NRNR from 2000 to 2023 was 88mm, with minimum and maximum being 12mm and 337mm, respectively. Since 2000, only three years had a mean annual rainfall above 150mm. Fog sometimes occurs but is uncommon. Temperatures are highly variable, with a record low of -11°C and high of 48°C (Scott & Shaw 2017). Three different seasons are defined based on ambient temperature: the cold-dry (May to August); hot-dry (September to December); and wet (January to April) season (Scott & Shaw 2017).

The vegetation of NRNR is characterised by a variety of growth forms, all of which are specially adapted to survive the arid conditions of the pro-Namib sub-biome. Nine different vegetation types occur: dune grassland, hill shrubland, losberg shrubland, mountain and inselberg shrubland, nubib footslope shrubland, nubib mountain shrubland, pans, western plain grassland, and river shrubland (Burke 2022), and 240 plant species have been recorded (Scott & Shaw 2017). The dominant grass species are *Schmidtia kalahariensis, Stipagrostis ciliata, S. obtusa* and *S. uniplumis,* and the woody vegetation is dominated by *Rhigozum trichotomum, Boscia foetida, Calicorema capitata* and *Lycium bosciifolium* (Burke 2022). Key tree species include *Vachellia erioloba* and the threatened quiver tree (*Aloe dichotoma*). The !Nara melon (*Acanthosicyos horridus*), a near-endemic species to Namibia, also occurs.

The most commonly occurring large mammals are gemsbok and springbok, seasonally fluctuating in numbers and distribution in response to rainfall patterns and the resultant food availability (Scott & Shaw 2017). Other large mammals include red hartebeest (*Alcelaphus caama*), Hartmann's mountain zebra (*Equus zebra hartmannae*), plains zebra (*E. burchellii*), cheetah (*Acinonyx jubatus*), leopard (*Panthera pardus*), and spotted hyaena (*Crocuta crocuta*). Following re-introduction in 2003, Angolan giraffe numbers on the NRNR have increased from an initial founder population of three individuals (Lenssen 2003) to ten individuals in 2019 (Tindall 2019).

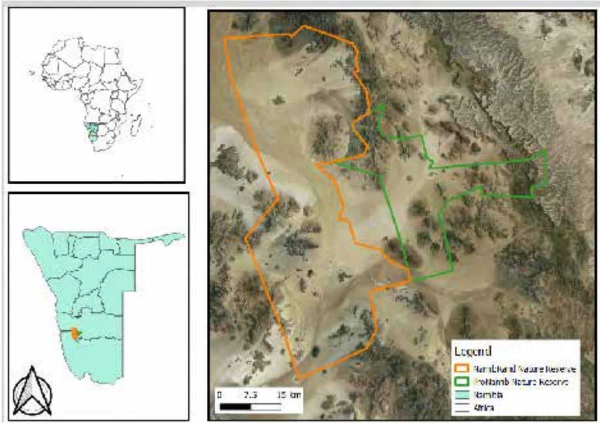

Figure 1: The location of the NamibRand Nature Reserve, Hardap Region, Namibia.

Data collection and analysis

Data collection on Angolan giraffe ecology was conducted over a period of 13 months, from 7 April 2021 to 15 April 2022. All individuals were actively located and observed on average five days per month by driving on the reserve's tracks and traversing potential habitats using a four-wheel drive vehicle. Opportunistic sightings were also provided by the NRNR field rangers and wardens.

Population and social dynamics

To assess their population and social dynamics, we used individual-based survey methods since all giraffe have unique pelage patterns that do not change through their life (e.g. Leuthold & Leuthold 1978, Fennessy 2004, Brand 2007). During each survey, upon encountering an individual, photographs of both right and left sides were taken for each, as well as individually identified distinctive features noted (e.g. sex, age, pelage pattern, prominent scars, and ossicone shape and size). Additionally, GPS location of each herd was recorded. We categorised individuals into three age classes – juvenile, subadult, or adult – based on size and secondary sex characteristics (Strauss et al. 2015).

To determine the social dynamics, all individuals and their herd structure were assessed at each observation (McQualter 2018). Individuals were considered to be associated when they were observed in the same herd at the same time (McQualter 2018). Herd structure data and the frequency of co-occurrence between two or more individuals were used to construct social networks, and to evaluate the relative strength of social interactions within the surveyed population. Their social structure was determined through Social Network Analysis (SNA) performed in R software, version 4.3.1, using the igraph package. SNA investigates complex social and ecological interactions in animal communities, and provides a flexible framework for analysing association (individuals' co-occurrence) and/or interaction (Farine & Whitehead 2015).

Table 1. Herd structure (annual and seasonal herd sizes) of Angolan giraffe on the NamibRand Nature Reserve, Namibia.

Season	Number of giraffe in a herd														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Total herd no.**	**Mean herd size** ±SD
Cold-dry (%)	6.3	28.1	40.6	9.4	0	3.1	12.5	0	0	0	0	0	0	32	3.3 ± 1.7
Hot-dry (%)	28.9	21.1	10.5	0	0	0	5.3	18.4	5.3	10.5	0	0	0	38	4.4 ± 3.5
Wet (%)	28.2	10.3	0	33.3	5.1	12.8	10.3	0	0	0	0	0	0	39	3.6 ± 2.1
Total annual (%)	22	19.3	15.6	14.7	1.8	5.5	9.2	6.4	1.8	3.7	0	0	0	109	
Total herd no.	24	21	17	16	2	6	10	7	2	4	0	0	0	109	3.8 ± 2.6

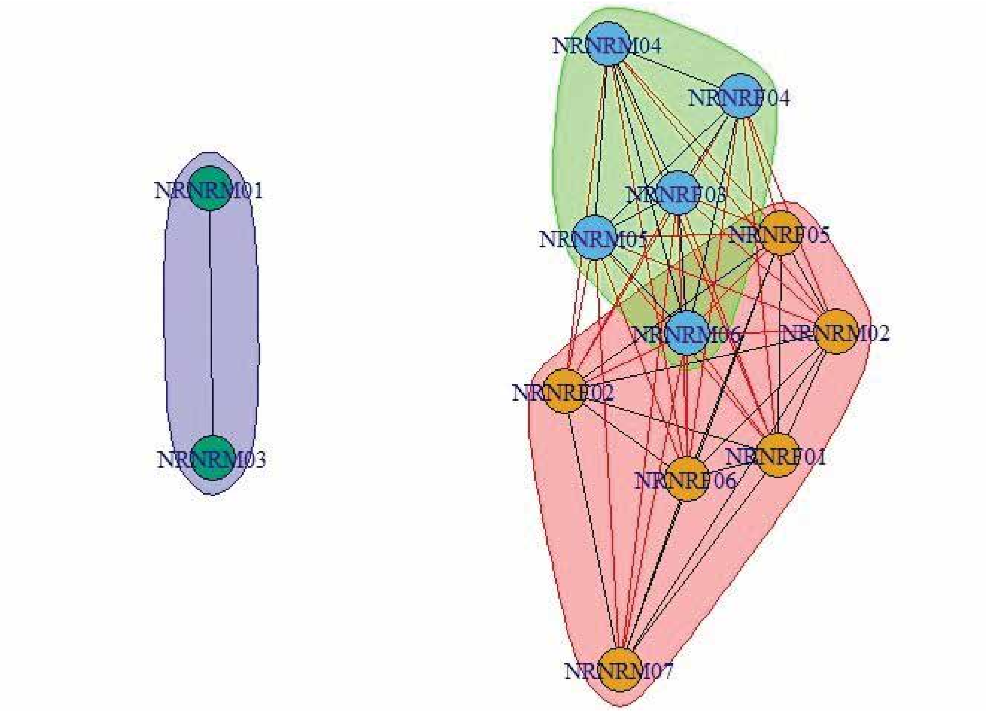

Figure 2: Social structure of Angolan giraffe on the NamibRand Nature Reserve, Namibia assessed using Social Network Analysis method. Each polygon indicates a separate social group. Each circle in the network represents a giraffe with its nomenclature on it and the lines represent an association (co-occurrence) between individuals. Note: circles with the same colour indicate individuals belonging to the same social group.

Behavioural activity budget

We assessed Angolan giraffe diurnal activity patterns over three different daily time periods and throughout the study period: morning (7–11am), midday (11am–3pm), and afternoon (3–7pm). Each individual in a herd was scan sampled and observations of its daily activities (e.g. feeding, walking, etc.) were recorded at five-minute intervals. Their behaviours were categorised based on Fennessy (2004) and Brand (2007) into the following activities: drinking, feeding, grooming, lying down, nursing/suckling, necking, playing, ruminating, sexual behaviour, standing, vigilance, and walking. When a herd consisted of two or more individuals, the following scan sampling method was used: if giraffe 1 and 2 were respectively the first and last giraffe to be scan sampled during the first observation session, then ongoing observations were maintained in that order for the period to avoid bias to a certain behavioural activity. Observations were always made at a distance sufficient to clearly see the individual's activities, yet without disturbing and influencing their normal behaviour. The observed activities of each sex and age class were recorded separately but those of adults and subadults were later combined for each sex for analysis. Data on juveniles for both sexes were also combined.

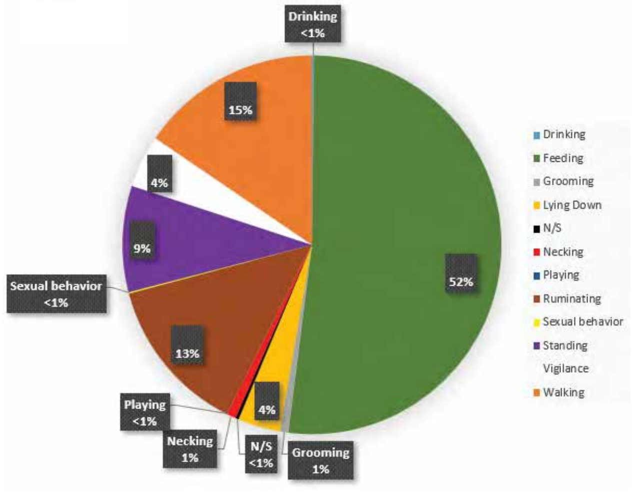

Figure 3: Diurnal activity budgets of Angolan giraffe on the NamibRand Nature Reserve, Namibia expressed as a percentage of annual recordings (n=24,194). N/S stands for nursing or suckling.

Diurnal activity budget was then determined for each behaviour, as the percentage of daytime allocated to each activity. Thereafter, the annual, seasonal, and time of the day activity budgets were compared across behaviours. We tested for variation in activity budgets between males, females, and juveniles. Activity budget data were tested for normality with a *Shapiro-Wilks* test and were not normally distributed. A *Kruskal-Wallis* test was performed in STATISTICA software, and used to compare and test for significant difference in time budget between different behavioural activities.

Spatial ecology

To assess their space use, we estimated home and seasonal ranges by recording GPS coordinates, using a Garmin eTrex 10, every time individuals were encountered. Throughout the day, while collecting behavioural activity data, their GPS coordinates were recorded four times: at first encounter and at the end of each of the three daily time periods. To determine individual home and seasonal ranges, both minimum convex polygon (MCP) and kernel density estimation (KDE) methods were applied. Although the MCP method is largely criticised for being inaccurate (e.g. Flanagan et al. 2016, Knüsel et al. 2019, Hamutenya 2021), it allows direct comparison with previous home range studies. The KDE, which is appropriate for smaller sample sizes (Knüsel et al. 2019), was used to augment MCP home range estimates. Each individual's year-round home and seasonal ranges were calculated using 95% of its location points, to exclude outliers, and 50% which equates to their core area or the area of high utilisation. The MCP analysis was performed using the Animove plug-in tool within QGIS, version 2.18.9, and KDE was calculated in R using adehabitatHR package. Since the KDE was only used as a supplement to MCP, only home ranges estimated with MCP were statistically tested with the *Kruskal-Wallis* test for significant differences.

Diet composition and selection

Data on forage species were gathered concurrently with behavioural observations. Every time an individual was observed feeding, the species on which it foraged was recorded. If unknown, it was photographed or a specimen collected for identification by experts at the Namibia University of Science and Technology (NUST). The feeding observations for both sexes and all age-classes were combined, and the frequency of utilisation of each plant species was expressed as a percentage of the feeding records for that species out of the total feeding records for all utilised plant species. To determine the preferred forage species, Ivlev's Index based on the equation: $E = (r_i – p_i)/(r_i + p_i)$ was used to calculate the selectivity index (E) (Cubas 2022). In the equation, r_i is the relative proportion or use of a particular plant species in their diet obtained by expressing its feeding records as a percentage of the total feeding records of all food plants, and p_i is the relative proportion or availability of the same species in the reserve obtained from its percentage cover out of the total vegetation cover. Relative availability of plant species in the reserve was determined by assessing vegetation in the NRNR. The *Random Points Inside Polygons* research tool within QGIS was used to randomly select 50 sampling points within NRNR's riverbeds and tributaries–preferred habitats in the Namib Desert (Fennessy 2004, 2009, Hamutenya 2021, Z. Hange pers. obs. 2022). The minimum distance between two points was set at 500 m. Following methods by Hamutenya (2021), a circular plot with a 20m radius, was laid at each sampling point. Vegetation cover within each plot was estimated by estimating percentage cover of all grass and forb species, while the cover estimate of each woody species was recorded separately. Selectivity (E) index value > -0.25, but < +0.25 indicates non-selective feeding. E value > +0.25 indicates a preference for a particular forage species, and E < -0.25 indicates avoidance of that forage species (Cubas 2022). Seasonal shift in forage use was assessed by separating the feeding records of each plant species by season and expressing as a percentage of the total feeding records for each season separately.

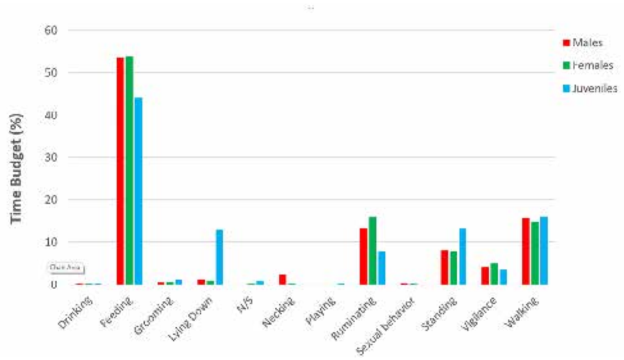

Figure 4: Comparison of diurnal activity budgets between males (n=8,027), females (n=11,059), and juvenile Angolan giraffe (n=5,108) on the NamibRand Nature Reserve, Namibia.

Results

Population and social dynamics

A small population of 13 Angolan giraffe were identified in the NRNR. Of these, 54% (n=7) were adult, 23% (n=3) each subadult and juvenile; two calves born during the cold-dry and hot-dry seasons. The ratio of male to female was 1: 0.86, with juvenile male to female ratio being 1: 0.5.

A total of 109 different herd combinations were encountered over the study period varying from one to ten individuals, with the mean herd size being 3.8 ± 2.6 (Table 1). The most frequently encountered herd size was that of a lone giraffe (22%), followed by two (19.3%), three (15.6%), and four (14.7%) individuals. Herds of five and nine were encountered infrequently (1.8% each).

Herd structures and mean herd sizes varied between the seasons. The smallest mean herd size (3.3 ± 1.7) was observed during the cold-dry season, while the largest was in the hot-dry season (4.4 ± 3.5) (Table 1). During the cold-dry season, groups of three were most encountered, while groups of six were least encountered (40.6% vs 3.1%, respectively). Lone individuals were mostly observed in the hot-dry season (28.9%), whilst the most frequently sighted herd size in the wet season was four individuals (33.3%).

Two subpopulations were observed in the NRNR, consisting of two isolated adult males (NRNRM01 and NRNRM03), and eleven interconnected mixed individuals (Figure 2). The two isolated adult males showed a relatively weak association with each other and never associated with the others. The mixed herd all associated with each other, subdivided into two social groups with varying levels of associations. Each juvenile showed a strong social association to its mother, and the most frequent and strongest associations were between adult females and their calves (1. Adult female NRNRF03 and a subadult male NRNRM05, 2. Adult female NRNRF03 and its calf NRNRM06, and 3. Adult female NRNRF01 and its calf NRNRF06) (Figure 2). The juvenile NRNRM07 had weaker associations with most others, except for its mother NRNRF02, and the adult female NRNRF01 and its calf. The juvenile NRNRM06 was highly associated with most others within its social group, as well as those in the other social group. A subadult male (NRNRM04) infrequently associated with the adult male (NRNRM02) in the group.

Behavioural activity budget

Overall, the NRNR Angolan giraffe spent more than half (52%, n=12,537) of their diurnal hours feeding, followed by walking (15%, n=3,746), ruminating (13%, n=3,250), and then standing (9%, n=2,197) (see Figure 3). They spent the least amount of time (<1%) either nursing (n=69), drinking (n=44), sexual behaviour (n=26), or playing (n=4). A Kruskal-Wallis test revealed a significant difference in time allocations between the different behavioural activities ($p<0.05$).

Similar daytime feeding allocation (54%) and walking time (15-16%) was observed for males (n=4,310 and n=1,275 respectively) and females (n=5,969 and n=1,649 respectively) (Figure 4). Both males and females also spent similar proportions of their daytime standing (8%, n=646 and n=879, respectively), whilst rumination time was marginally higher for females (16%, n=1,770) than males (13%, n=1,081). With respect to juveniles, they spent less daytime feeding (44%, n=2,258) than subadults and adults, yet similar time walking (16%, n=822). Rumination time for juveniles (8%, n=399) was half that of subadults and adults, whereas the time spent lying down (13%, n=658) or standing (13%, n=672) was more than double that of subadults and adults.

Cumulatively, they increased feeding during the hot-dry season (55%, n=5,676), while decreasing their walking (13%, n=1,396) and ruminating (11%, n=1,135) activities. Walking was highest during the cold-dry season (17%, n=987), whilst rumination was highest in the wet season (16%, n=1,308). They spent more time standing during the wet season (10%, n=804), yet lay down more during the hot-dry season (4%, n=460) than during either of the other seasons.

Feeding was the dominant activity throughout the day. Foraging was similar throughout the day: morning (52%, n=3,434), midday (51%, n=4,372), and afternoon (53%, n=4,731), as was walking (15-16%) (morning n=1,044, midday n=1,346, and afternoon n=1,356). Rumination decreased from the morning (18%, n=1,216) to the afternoon (6%, n=766), and standing increased throughout the day - morning (6%, n=426), midday (9%, n=781) and afternoon (11%, n=990). In the morning, individuals lay down less frequently (2%, n=128).

Spatial ecology

Home range sizes varied from 71 to 521km^2, with both the smallest and largest home range sizes being those of males (95% MCP; Table 2). Their core areas varied from nine to 243km^2 (50% MCP). The mean home range size of females was 342.2 ± 63.4km^2, with smaller mean home range sizes for males (265.8 ± 168.5km^2) and juveniles (205.7 ± 41.5) (95% MCP; Table 2). Although their individual home range sizes differed, this was not statistically significant (H= 18.498; P>0.05).

With the KDE analysis, home ranges were substantially larger than for MCP (Table 2). The largest home range size of 1377.8km^2 was of a male, and the second largest 949.7km^2 a female (95% KDE). The mean home range size (95% KDE) of females was 780.4 ± 108.8km^2, ranging from 652.6 to 949.7km^2; males 811.2 ± 305.4km^2, ranging from 510 to 1377.8km^2; and juveniles 546.6 ± 83.5km^2, ranging from 470.8 to 662.9km^2 (95% KDE). The core areas were much smaller: females 190.3km^2, males 214.6km^2, and juveniles 120.4km^2 (50% KDE).

The adult males in the northern NRNR moved differently from those in the south, although all predominantly used riverbeds and tributaries. There was a high degree of home range overlap between individuals despite those in the northern and southern NRNR never meeting (Figure 5). Seasonal mean home range sizes (95% MCP) were larger in the dry seasons than the wet season, but not statistically significant (H=1.4623; P>0.05). Their mean core areas (50% MCP) were larger during the cold-dry season, but not significantly different (H=0.039; P>0.05). Core area sizes in the hot-dry season were similar to those in the wet season.

Diet composition and selection

Angolan giraffe on the NRNR fed on 18 identified plant species (Figure 6). Of those, 16 were woody species, and two herbaceous. Approximately 53% (n=2,899) of their annual diet comprised *V. erioloba*, whilst the second most foraged species was *Parkinsonia africana* (13%, n=730), followed by *B. foetida* (6%, n=356) and *Senegalia mellifera* (6%, n=337) (Figure 6). Interestingly, the herbaceous tsamma melon *Citrullus lanatus*, and particularly its fruit, was consumed in quantities larger than many of the woody species (3%, n=184) (Figure 6). *Ziziphus mucronata, S. galpinii, V. karroo, V. hebeclada,* and the alien invasive *Prosopis* spp., were all consumed in smaller proportions.

Across all seasons *V. erioloba* was the most consumed, ranging from 46% (n=893) in the wet to 59% (n=705) in the cold-dry season. The use of *P. africana* was inverse to *V. erioloba,* with largest proportions contributed during the wet season (19%, n=361), and smallest in the cold-dry season (8%, n=95). Similarly, the largest proportion of *S. mellifera* in their diet was during the wet season (8%, n=154). Both *B. foetida* and *C. lanatus* were consumed in a pattern like *V. erioloba,* contributing largest and smallest proportions of diet in the cold-dry (8%, n=95; 7%, n=86) and wet seasons (5%, n=99; <1%, n=7), respectively. *Commiphora tenuipetiolata* was only consumed during the wet season.

With regards to forage preference, *Adenolobus garipensis, C. tenuipetiolata, P. africana, Phaeoptilum spinosum, S. mellifera, V. erioloba,* and *Z. mucronata* were preferentially selected (Table 3). *Boscia albitrunca, B. foetida,* forbs (including *C. lanatus* and *Kissenia capensis*), *Prosopis spp., S. galpinii, V. hebeclada,* and *V. karroo* were only utilised in proportions relative to their availability in the environment, and *Calicorema capitata, Pechuel-Loeschea leubnitziae,* grasses, and *Rhigozum trichotomum* were avoided (Table 3).

Discussion

Population and social dynamics

Located on the edge of the Namib Desert (Scott & Shaw 2017), the NRNR is marginal habitat with a small population of 13 Angolan giraffe comprising seven (54%) adults, three (23%) subadults, and three (23%) juveniles. Albeit small, the adult-dominated population structure is consistent with many elsewhere (e.g. Angolan giraffe in northwest Namibia: Fennessy 2004, Masai giraffe in Tanzania: Reich 2015, and Kordofan giraffe *G. c. antiquorum* in Democratic Republic of Congo (DRC): D'haen et al. 2019). An adult-biased population exhibits characteristics of a stable population, with low fecundity, and likely related to the limited food supply (Fennessy 2004, Muller 2018).

Most herds observed consisted of the same individuals but in different dynamics, with two subpopulations identified. The mean herd size and numbers fall within previous studies' means, which varied from 2.2 (Masai giraffe, Marealle 2016) to 11.8 (Angolan giraffe, Cubas 2022), with some populations having herds with >100 individuals (Nubian giraffe *G. c. camelopardalis,* Angolan giraffe: Fennessy et al. 2022). In general, herd size is regulated by ecological, social, anthropogenic, and spatio-temporal factors (Fennessy 2004, Hart et al. 2019, Bond et al. 2019), with food availability and predation risk being important ecological regulators (Le Pendu et al. 2000).

As elsewhere, the NRNR males adopted a solitary roaming reproductive strategy by which they search for receptive females to mate with, as well as potentially avoiding their rivals (Bercovitch & Berry 2009). The mixed NRNR herds were mostly small in number (e.g. Fennessy 2004, Bercovitch & Berry 2009, Bond et al. 2019), forming stronger social bonds with conspecifics. Interestingly, the only female encountered alone during this study gave birth soon after. Similar encounters of lone females in pre-partum isolation have previously been reported throughout their range (e.g. Angolan giraffe, Fennessy 2004; West African giraffe, Gloneková et al. 2017).

Although the population was too small for statistical analyses, the mean herd size of those in the NRNR was largest during the hot-dry season, and slightly larger in the wet season than the cold-dry season. This is similar to the desert-dwelling Angolan giraffe in arid northwest Namibia (Fennessy 2004), aggregating seasonally in the main riverbeds mainly to utilise moisture and protein-rich *C. lanatus* fruit. The SNA revealed two isolated subpopulations, one larger in the south further subdivided in two subgroups, each consisting of strongly associated individuals, and connected by weaker ties to members of the other subgroup. Such social division amongst giraffe has been reported elsewhere (e.g. southern giraffe, Clausen 2013; reticulated *giraffe G. reticulata,* Van der Waal et al. 2013; South African giraffe *G. g. giraffa,* McQualter 2018), which indicate a multilevel and very flexible fission-fusion social organisation.

All but two individuals were interconnected and showed a level of association, with association strengths varying between individuals. Such a high level of connectedness is typical of fission-fusion species, resulting from frequent movements of individuals between groups (Clausen 2013). These results are likely exacerbated as the giraffe numbers were low and they shared the same space. Other studies have highlighted that associations between individuals are determined by home range overlaps (Angolan giraffe, Carter et al. 2013; reticulated giraffe, Van der Waal et al. 2013; South African giraffe, McQualter 2018), with female giraffe and their young males often more social, gregarious, and actively choosing to associate with other members of the population (Clausen 2013, Van der Waal et al. 2013, Castles et al. 2019).

The strongest bonds were formed between adult females and their calves. Such mother-calf bonds are well noted (e.g. West African giraffe, Le Pendu et al. 2000; Angolan giraffe, Fennessy 2004; South African giraffe, Malyjurkova et al. 2014) and in some populations these bonds were found to endure for up to ten years (reticulated giraffe, Van der Waal et al. 2013). Stronger associations exist between calves and their mothers, as calves need to be nurtured and protected, and are reported to continue into adulthood (Angolan giraffe, Fennessy 2004, Carter et al. 2013; reticulated giraffe, Van der Waal et al. 2013). Similar bonding was also observed, which is likely also reinforced by the low population numbers. As expected, the two adult males in the north

Table 2. Total home range sizes of females, males, and juvenile Angolan giraffe on the NamibRand Nature Reserve, Namibia estimated with Minimum Convex Polygon (MCP) method (50% and 95%) and Kernel Density Estimation (KDE) method (50% and 95%).

	Giraffe ID	50% KDE km^2	95% KDE	50% MCP	95% MCP
Female	NRNRF01	144.1	674.3	75	261
	NRNRF02	219.2	833.3	123	318
	NRNRF03	175.6	652.6	143	347
	NRNRF04	239.1	949.7	172	455
	NRNRF05	173.6	791.9	80	330
	Mean ±SD	**190.3 ± 34.2**	**780.4 ± 108.8**	**118.6 ± 37.0**	**342.2 ± 63.4**
Male	NRNRM01	169.2	596.5	56	104
	NRNRM02	124.2	510	42	255
	NRNRM03	175.3	726.4	9	71
	NRNRM04	376.8	1,377.80	243	521
	NRNRM05	227.4	845.2	155	378
	Mean ±SD	**214.6 ± 87.5**	**811.2 ± 305.4**	**101 ± 86.1**	**265.8 ± 168.5**
Juvenile	NRNRF06	98.2	470.8	60	188
	NRNRM06	105.8	506.1	68	263
	NRNRM07	157.3	662.9	43	166
	Mean ±SD	**120.4 ± 26.3**	**546.6 ± 83.5**	**57 ± 10.4**	**205.7 ± 41.5**

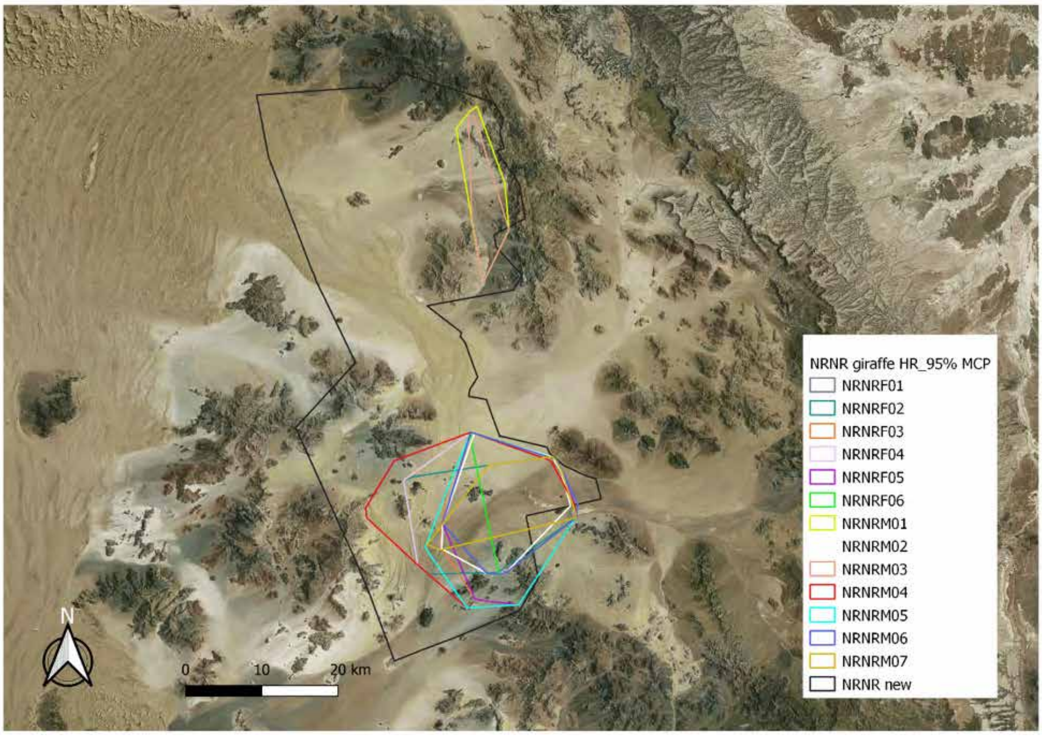

Figure 5: Total home range overlap of Angolan giraffe on the NamibRand Nature Reserve, Namibia estimated using 95% MCP.

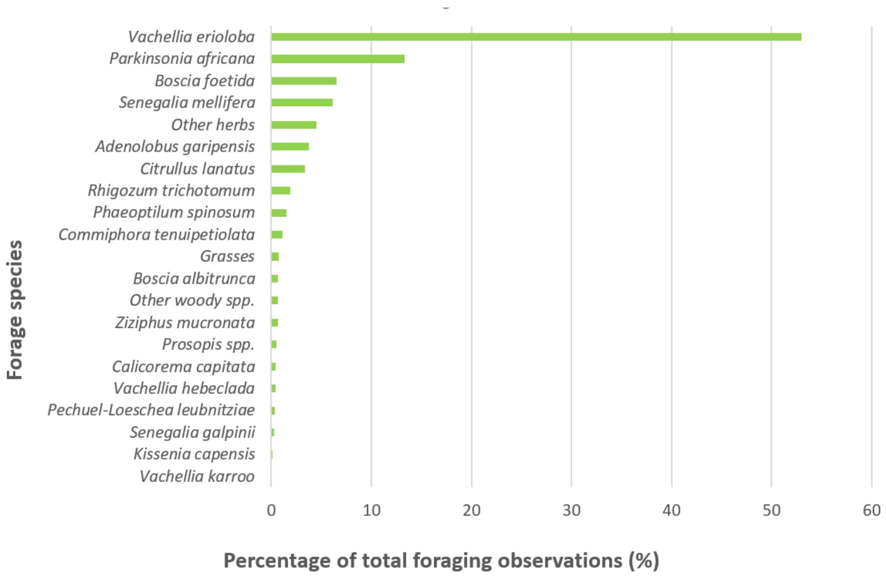

Figure 6: Plant (forage) species eaten by Angolan giraffe on the NamibRand Nature Reserve, Namibia and the relative use (%) of each species (n=5,470).

Table 3. Giraffe food preference and selectivity (E) on the NamibRand Nature Reserve, Namibia. E value > -0.25, but < +0.25 indicates non-selective feeding. E value > + 0.25 indicates a preference for a particular forage species, and E < -0.25 indicates avoidance of that forage species.

Species	**relative use (r_i)**	**relative availability (p_i)**	**Selectivity (E)**
Adenolobus garipensis	0.04	0*	1
Boscia albitrunca	0.01	0.01	0
Boscia foetida	0.07	0.05	0.17
Calicorema capitata	0*	0.05	-1
Commiphora tenuipetiolata	0.01	0*	1
Forbs	0.08	0.19	-0.41
Grasses	0.01	0.45	-0.96
Parkinsonia africana	0.13	0.02	0.73
Pechuel-Loeschea leubnitziae	0*	0.04	-1
Phaeoptilum spinosum	0.02	0**	1
Prosopis spp.	0*	0**	0
Rhigozum trichotomum	0.02	0.10	-0.67
Senegalia galpinii	0*	0**	0
Senegalia mellifera	0.06	0*	1
Vachellia erioloba	0.53	0.03	0.89
Vachellia hebeclada	0*	0**	0
Vachellia karroo	0*	0**	0
Ziziphus mucronata	0.01	0**	1

Please note * indicates the relative use or availability of a species is zero (0) as a result of using only two decimal places. ** indicate that the species occurs on NRNR and was observed eaten by giraffe, but absent from sampling plots due to limited distribution.

of the reserve were weakly associated with each other. Although adult males are known to adopt a more solitary roaming strategy (Luangwa giraffe *G. tippelskirchi thornicrofti*, Bercovitch & Berry 2009), they do associate casually, especially where the population is male dominated and competition for mating is reduced (Angolan giraffe, Fennessy 2004).

Behavioural activity budget

Throughout their range the NRNR giraffe displayed a variety of diurnal behavioural activities, including osteophagia or the eating of bones (Deacon 2015). Unsurprisingly, feeding was the dominant behaviour, absorbing a little more than half their day. Together with walking, ruminating, and standing, approximately 90% of their daytime was spent on these activities. The higher proportion of time allocated to feeding is necessary to maximise an animal's net energy intake, and to enhance fitness, especially in arid environments where forage quality is generally lower (Fennessy 2004, Joel 2017). Feeding time was lower for populations in more temperate environments, such as Masai giraffe in Kenya (36–39%, Adolfsson 2009), Angolan giraffe in Namibia's Etosha NP (32–47.7%, Brand 2007), and South African giraffe in Botswana's Chobe NP (41.57–47.7%, McQualter 2018).

The reduced feeding time in juveniles was a result of the nursing behaviour of dependent-calves (Saito & Idani 2020). Elsewhere, females have allocated higher proportions of their daytime to feeding due to higher nutritional and metabolic requirements (Masai giraffe *G. t. tippelskirchi*, Sinnary 1998; Angolan giraffe, Fennessy 2004; South African giraffe, McQualter 2018). Male Angolan giraffe in Etosha NP increased feeding during the dry season, when food quality and quantity was scarcer (Brand 2007). Lactating and pregnant females have higher nutritional requirements (Fennessy 2004), feeding time in browsers often increase with body mass and size (Du Toit & Yetman 2005), and male giraffe have larger food bulk requirements (Adolfsson 2009).

Feeding behaviour increased during the hot-dry season, following a pattern similar to other Angolan giraffe populations in Namibia (Fennessy 2004, Brand 2007) and South African giraffe in Botswana (McQualter 2018). High quality forage is most abundant in the wet season, with animals able to optimise their energy intake and acquire the required daily nutrients, even with reduced feeding time (Brand 2007). The NRNR individuals utilised *V. erioloba* trees, especially the highly nutritious pods, and moisture-rich *C. lanatus* fruit the most during the cold-dry season (e.g. Mannheimer & Curtis 2018, Scott & Shaw 2017). The increased use of this highly nutritious forage during the cold-dry season likely provided sufficient nutrients over a short period of time.

Walking is an important activity for survival, reproduction, and avoiding predators (Fennessy 2004, McQualter 2018, Joel 2017), especially in an arid and patchy vegetation environment like NRNR (Scott & Shaw 2017). Males and juveniles allocated similar proportions of their daytime to walking, and more than that by females. Similarly, Angolan giraffe males in northwest Namibia and South African giraffe in South Africa spent more time walking than females, 17.4% vs 15%, respectively (Fennessy 2004), and 20% vs 18% for males and females in South Africa, respectively (Deacon 2015). In the Masai Mara NR Masai giraffe calves spent significantly more time walking than adult giraffe (Adolfsson 2009).

The relatively high proportion of rumination observed was directly linked to feeding, as reported elsewhere (e.g. South African giraffe in Botswana, McQualter 2018). We observed males ruminating less than females. This contradicted most of the literature which highlights the increased need for males to further process the ingested less-digestible and fibre-rich forage that they tend to consume (South African giraffe, McQualter 2018). It is possible that the NRNR males ingested relatively more highly nutritious and digestible plant materials at canopy heights beyond the reach of the relatively shorter females.

The relatively small percentage of vigilant behaviour was triggered by movements of other animals, human activities at homesteads, tourists, and to a lesser extent by the researchers. Females were more vigilant, possibly because of their dependent calves which, being more vulnerable to predation, require enhanced protection. Unsurprisingly, drinking in the NRNR was infrequent, as Angolan giraffe have been shown to be water independent in the northern Namib Desert (Fennessy 2004).

As expected, juveniles spent a greater proportion of their time lying down than adults, similar to that observed in desert-dwelling Angolan giraffe in northwestern Namibia (Fennessy 2004) and Masai giraffe in Katavi NP, Tanzania (Saito & Idani 2020). Recumbency is used as an antipredator strategy, as calves tend to be clearly visible to predators when they walk and stand (Saito & Idani 2020). Interestingly, standing increased throughout the day, a result that departs from reports of standing reaching a peak in the middle of the day. However, the findings are not the first to depart from the reported resting behaviour displayed mostly in the middle of the day (Masai giraffe, Adolfsson 2009).

Spatial ecology

The year-round home range (HR) sizes of the NRNR Angolan giraffe varied from 71 to 521km^2 (95% MCP), with larger means recorded during the dry seasons. Both the smallest and largest HRs were those of males. The mean HR of females was larger than that of males and juveniles, however this difference was not statistically significant. These findings support the social network analysis which indicated great variation in herd sizes and associations, animals sometimes moving together and at other times apart. A young male (NRNRM04) had the largest HR on the NRNR, possibly seeking to avoid the dominant adult male (e.g. Bercovitch & Berry 2009, Malyjurkova et al. 2014).

When compared with giraffe across Africa, the mean HR was relatively large, yet smaller than that of the Angolan giraffe in the northern Namib Desert. Home ranges vary greatly, from as little as 3.03km^2 for Masai giraffe in the mesic environments of Kenya (Anyango & Were-Kogogo 2013) to 2,072.4km^2 for the desert-dwelling Angolan giraffe in the arid northwest Namibia (Hamutenya 2021). Although Flanagan et al. (2016)

estimated a home range of 9,565.2km^2 for Angolan giraffe in north-eastern Namibia, it was considered as linear, long-distance exploratory movements, rather than a well-established home range. Variation in HRs arise from a complex relationship between rainfall, forage availability, giraffe population density, predator density, and the size of the study area (Brown et al. 2023). In low rainfall areas, where forage is patchy and limited, the HRs are typically larger, as the animals need to obtain sufficient food and satisfy their bioenergetic requirements through increased travel (e.g. Brand 2007, McQualter et al. 2015, Fennessy 2009, Knüsel et al. 2019, Hamutenya 2021, Brown et al. 2023).

Angolan giraffe in the northern NRNR moved and used the habitat differently from those in the south, although all predominantly used riverbeds and tributaries. The males in the north predominantly used relatively densely vegetated tributaries and ranged east and southwards along the western edge of the Nubib Mountains. Narrow, elongated home ranges are similarly reported in populations where movements and distribution are predominantly along forage-rich riverine ecosystems (e.g. Luangwa giraffe, Berry 1978; Angolan giraffe, Fennessy 2009). The giraffe predominantly used the relatively densely vegetated tributaries in the far north east, and frequently moved southwards along the western edge of the Nubib Mountain to utilise riverine vegetation. On several occasions they traversed tributaries on neighbouring property.

Those in the southern NRNR used nearly the entire area, expanding their home ranges slightly beyond the boundaries of NRNR to a neighbouring property. They mainly utilised riparian vegetation as well as the *V. erioloba*-dominated shallow-dunes in the north east, but generally ranged as far as the south-eastern corner and tributaries in the south west. Angolan giraffe's preference for riparian ecosystems is typical in the arid environments of the northern Namib Desert, as limited woody vegetation grows along river channels (Fennessy 2009, Hamutenya 2021).

No individuals from either NRNR subpopulation intermingled, or were sighted in the thick sand dunes, which create a barrier. Although this dune area carries *V. erioloba* trees, it is a challenge for giraffe with their larger body mass to move on the thick, soft sand. Fennessy (2009) also observed that in northwestern Namibia the giraffe did not use the entire HR area, as some parts consisted of inhospitable, sandy terrain.

In line with the population dynamics SNA findings, home ranges overlapped substantially, with no individual having an exclusive home range. However, the males in the northern NRNR were independent of those in the south. In the Amboseli ecosystem, Kenya, where forage is limited and patchy, Masai giraffe core areas overlapped extensively, as different herds recurrently foraged in the same habitat patches (Obari 2014). Anyango and Were-Kogogo (2013) reported a very high level of home range overlap between individuals, up to 100 per cent, as the Nubian giraffe were confined by a fence in a smaller area within the park and, therefore, shared the few suitable food patches. In line with Anyango and Were-Kogogo (2013), the high degree of HR overlap on the NRNR could possibly be explained by fencing and dunes restricting their movements in the east, which resulted in their sharing of the only suitable habitat patches.

Diet composition and selection

Angolan giraffe on the NRNR fed on 18 different plant species. Their diet was more diverse than that of giraffe in the Kuzikus Wildlife Reserve in the Kalahari Desert, Namibia (Cubas 2022) but similar to that of giraffe in the Etosha NP, Namibia (Brand 2007).As with the diet of South African giraffe in the Eastern Cape, South Africa, (Parker & Bernard 2005) a small proportion of their diet could not be precisely identified.

In the NRNR they predominantly browsed on *V. erioloba, P. africana, B. foetida,* and *S. mellifera,* comprising almost 80 per cent of their diet. Of these, *V. erioloba, P. africana,* and *S. mellifera* were used disproportionally more than their availability, and *V. erioloba* was the most important year-round browsing species. Both Deacon (2015) and Cubas (2022) observed *V. erioloba* to be the most dominant year-round forage species in the southern giraffe's diet. Other species of the genus *Vachellia* form the bulk of their diets across Africa, e.g. *V. nilotica* for reticulated giraffe in Kenya (Gill & Kartzinel 2018), *V. drepanolobium* for Nubian giraffe in Kenya (Anyango & Were-Kogogo 2012), *V. nebrownii* for Angolan giraffe in Namibia (Brand 2007), *V. tortilis* for Masai giraffe in Tanzania (Levi 2022), and *V. karroo* for South African giraffe across South Africa (Souter 2015, Parker & Bernard 2005, Cornelius et al. 2012). *Vachellia* species have high protein, water, and fat content (e.g. Sauer et al. 1982, Sauer 1983, Pellew 1984, Caister et al. 2003, Parker & Bernard 2005) which, along with its wide distribution, made it a favoured choice in the NRNR.

Despite their marginal contribution to the diet, due to reduced abundance and limited distribution across NRNR, *A. garipensis, C. tenuipetiolata, P. spinosum,* and *Z. mucronata,* were preferred. The alien invasive *Prosopis* spp. were also eaten, similarly by West African giraffe in Niger (Ciofolo & Le Pendu 2002). The feeding on *C. lanatus* is rare in literature, with the only other report from Niger (Ciofolo & Le Pendu 2002). Giraffe on the NRNR also fed on the *C. lanatus* fruit only during the dry seasons, likely because of its high moisture content (Sauer et al. 1982, Sauer 1983).

The decreased use of *V. erioloba* during the wet season coincided with increased foraging on *V. hebeclada* and *C. tenuipetiolata,* which were fed upon only during the wet season, and a substantial increase in the use of *P. africana* and *P. spinosum,* and a slight increase in the use of *S. mellifera* and *Z. mucronata.*

The proportion of *S. mellifera* in their diet was greatly reduced during the cold-dry season to an extent that species that were relatively less important overall, e.g. *R. trichotomum, A. garipensis, C. lanatus,* and grasses, became more important. Both *V. hebeclada* and *C. tenuipetiolata* were utilised only during the wet season, with *C. tenuipetiolata* appearing to grow leaves only during the wet season (Z. Hange, pers. obs. 2022), which is probably why they began to feed on it. In general, seasonal shifts in the NRNR Angolan giraffe diet was largely attributed to seasonal variation in the availability of preferred forage (e.g. Fennessy 2004, Brand 2007, Deacon 2015).

Conclusion

The small stable NRNR Angolan giraffe population comprised individuals from all age and sex classes, dominated by adult giraffe with low fecundity and even sex ratio. The population was highly social and interconnected, yet females and their dependent calves were more strongly associated than other relationships. This association pattern subdivided the population into smaller communities of connected animals.

Angolan giraffe on the NRNR behaved similarly to those observed in other arid populations, spending most of their diurnal time feeding or in search of forage by walking between patches in the sparse habitat. This is unsurprising, given the arid conditions and need to compensate for reduced energy and nutrient intake rates from the limited food supply in the pro-Namib sub-biome. Rumination was also one of their dominant behaviours, a mechanism directly linked to feeding, which is necessary to extract essential nutrients from less digestible, dietary fibre-rich forage. Interestingly, and as observed elsewhere across their range, juveniles spent more time resting (standing and lying down) and less time feeding, as nursing plays a more critical role in satisfying their nutritional requirements.

The home ranges varied between individuals, with males on average travelling longer distances, within and beyond the boundaries of the reserve, possibly in search of receptive females and to avoid rivals. However, and in contrast to other arid populations, females ranged over larger areas, and collectively occupied relatively larger home ranges than giraffe in mesic environments. The area utilised should be regarded as a minimum, since movement is restricted by fences; potentially, their range could equal or exceed that of the Angolan giraffe in the open northwestern Namibia conservancy area.

The NRNR Angolan giraffe foraged on a wide variety of plant species, the most important year-round being *V. erioloba.* This species is highly nutritious, and widely distributed across the reserve, making it a key forage species. Other important forage species eaten in large quantities were *P. africana* and *S. mellifera.* Although not abundant, *A. garipensis, C. tenuipetiolata, P. spinosum,* and *Z. mucronata* were also favoured. Surprisingly, the fruit of *C. lanatus* was consumed, especially during the dry seasons, most likely because of its high water content.

This small population of Angolan giraffe in the southern Namib Desert provides a foundation for better understanding other giraffe populations, which can help guide their conservation management in the increasingly fragmented wildlife landscape of southern Africa.

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About the authors

Zazapamue Hange is a qualified environmental biologist and/ or natural resources manager, who is greatly passionate about nature conservation. He is particularly interested in terrestrial ecology, with keen interest in restoration ecology. In an attempt to pursue his passion, he first worked as worked as a research intern at Gobabeb Research and Training Centre, and participated in various long-term monitoring research project, while studying the water potential of camelthorn tree along a water gradient from the Kuiseb River banks to gravel plains of the Namib Desert. Thereafter, he moved on to work as a ranger at the NamibRand Nature Reserve. As a ranger, he played a critical role in anti-poaching patrols and contributed to wildlife protection through law enforcement. His passion for restoration ecology developed to advanced level during his time at NamibRand. A golden opportunity to witness and partake in the rehabilitation of a degraded land surfaced, and when he had to pursue a masters degree, and conduct a feasibility study of the recently established ProNamib Nature Reserve for the re-introduction of Angolan giraffe. During this time, he was not only conducting a giraffe research project, but involved in other rehabilitation works e.g. the removal of fences, and alien invasive plants. All these got him to gain experience on how to manage a protected area, and earned his the current position and serves as research coordinator at the ProNamib Nature Reserve.

Education

1. Master of Natural Resources Management
   Namibia University of Science and Technology

2. Bachelor of Science in Environmental Biology (Honours)
   University of Namibia

3. Namibia Senior Secondary Certificate
   Eldorado High School

Working Experience

1. ProNamib Nature Reserve
   Research Coordinator (2024 – present)
   Researcher (2021–2023)

2. NamibRand Nature Reserve
   Ranger (2019–2020)

3. Gobabeb Research and Training Centre
   Research Intern

Julian Thomas Fennessy is a well-respected conservation scientist and manager who has worked across Africa and Australia, and with a range of local and international partners. Julian has strong and transferable programmatic, research, writing, fundraising and management skills. Combined with his ability to integrate and manage programmes from grass roots to continental scale, his excellent interpersonal skills facilitate good working relationships in multidisciplinary teams and with partners (government and non-government) alike. While working for and managing conservation organisations across Africa and Australia, Julian has developed a solid understanding of policy needs, strategic planning, project management and fundraising requirements, which he can adapt to new situations and needs.

Adittional

- Board Member, Wild Africa Conservation
- Board Member, Programme Advisory Board for PhD in Natural Resources & Spatial Sciences, Namibia University of Science & Technology
- National Giraffe Working Group, Uganda Wildlife Authority

Awards

- International Association of Giraffe Care Professionals (IAGCP) 2010 – *Conservation and Research Award*
- International Association of Giraffe Care Professionals (IAGCP) 2012 – C*amelopardalis Innovation Award*

Reviewer

- National Geographic Society Grants
- IUCN Save Our Species Initiative
- Various scientific journals (e.g. African Zoology, Biology, African Journal of Ecology, etc.)
- Go Green Fund, Namibia

Prof. Morgan Lindo Hauptfleisch holds the position of Director of Research at NNF and am an associate at the Namibia University of Science and Technology and Extraordinary Professor at North West University's Unit for Environmental Science and Management. He has over 20 years of experience in conservation, natural resources and environmental management as practitioner and scientist. His current research focus areas are Environmental Impact Assessment, Conservation Management, Human-Wildlife Conflict, Rural Livelihoods and Ecological Corridors.

He was awarded the BR Oppenheimer Fellowship in People and Wildlife in early 2024 in order to further cross- land-use cooperation for wildlife related livelihoods and conservation, and reduction of human-wildlife conflict (2024–2029)

Work Experience

June 2024 – present: Director of Research Namibia Nature Foundation, Windhoek, Namibia [http://www.nnf.org.na], Developing an applied research programme within NNF to support sustainable development agencies and actors.

April 2012 – May 2023: Associate Professor, Namibia University of Science and Technology (NUST), Founder of the NUST Biodiversity Research Centre,

March 2007 –March 2012: Principal Scientist Southern African Institute for Environmental Assessment [https://www.saiea.com] Providing capacity building and technical expertise in the field of Environmental Impact Assessment and Management across Africa.

January 2002 – February 2007: Biodiversity Resources manager and environmental manager, De Beers Limited, Management of conservation projects and a collection of private reserves, technical management on biodiversity to the mining operations.

Education & Training

2014: PhD in Environmental Management, University of the Free State, South Africa, Environmental Management
2000: MSc in Plant Ecology and Wildlife Management, University of Pretoria , South Africa
1996: BSc (Hons) Ecology, University of Pretoria, South Africa

Other

2021–present: IUCN Giraffe and Okapi Working Group
2015–2022: Board Member of the Namibian Chamber of Environment
2015–2019: Board Member of the International Association for Impact Assessment
2016–present: Ministry of Environment Forestry and Tourism Research Ethics Committee
2023–present: Carnivore Working Group

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Education

DARTMOUTH COLLEGE; Hanover, New Hampshire ~ 2014-2019

PhD in Ecology, Evolution, Ecosystems and Society Department of Biological Sciences ~ Graduate Program in Ecology, Evolution, Ecosystems and Society

Dissertation: From Leaves to Lambda: Bottom-Up Effects on Giraffe Foraging Behavior, Movement Ecology, and Population Dynamics

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK; New York City, New York ~ 2010-2012

Master of Arts in Conservation Biology, 2012 Department of Ecology, Evolution and Environmental Biology Thesis: Animal Movement in a Dynamic Environment: A Study of Grevy's Zebra (Equus grevyi) in Semi-Arid Savannahs of Northern Kenya

UNIVERSITY OF MARYLAND; College Park, Maryland ~2005-2009
Bachelor of Sciences in Biology, 2009
Honors College ~ Presidential Scholar

SCHOOL FOR FIELD STUDIES; Center for Wildlife Management, Tanzania ~2008

Wildlife Management~ Environmental Policy~ Wildlife Ecology ~ Swahili Language Studies Experimental Design and conservation-based field research ~ Research: Tourist Satisfaction in Relation to Wildlife and Other Attractions in the Northern Circuit of Tanzania: Implications for Tourism Planning and Wildlife Management.

Professional Appointments

Giraffe Conservation Foundation Windhoek, Namibia
Conservation Science Coordinator October 2022 – Present

Giraffe Conservation Foundation and Smithsonian National Zoo and Conservation Biology Institute ~ Front Royal, Virginia, USA
Conservation Science Postdoctoral Fellow October 2019 – October 2022

Princeton University ~ Laikipia Zebra Project Mpala Research Centre, Kenya
Project Manager April 2013 – September 2014

MedAdvocacy LLC. Kulpsville, Pennsylvania, USA
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