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A description of daytime resting sites used by brown hyaenas (*Parahyaena brunnea*) from a high-density, enclosed population in north-central Namibia

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Abstract

Successfully conserving large carnivores requires an in-depth understanding of their habitat requirements. Ideally this includes a knowledge of the habitat types and features used as resting sites. Resting sites are an important requirement for many species, as they have the potential to influence species distribution and density. We examined the daytime resting sites used by brown hyaenas, a large carnivore endemic to southern Africa and classed as Near Threatened by the IUCN, within an enclosed reserve in north-central Namibia. Using historical spatial data from GPS collars we analysed 1 582 resting sites from nine adult brown hyaenas and classified them according to their location relative to the home range of each hyaena. We also visited a randomly chosen sub-set (n = 123) of these resting sites in the field and recorded habitat types and microhabitat features for each. Our results showed that brown hyaenas most frequently rested within the core area of their home range, most frequently in riverine habitat, followed by bush encroached habitat, and most frequently used microhabitat under a tree or bush. The fact that bush encroached habitat is being frequently used for resting is an important consideration for brown hyaena conservation. Bush encroached areas are often cleared by debushing projects in Namibia and the practice may negatively impact brown hyaenas.

Keywords: brown hyaena, carnivore, Namibia, *Parahyaena brunnea,* resting site

Introduction

The conservation management of large carnivores requires a thorough understanding of their habitat requirements to be successful (Doncaster & Woodroffe 1993, Gess *et al*. 2013). Resting sites are an important requirement for many species as sleeping can be considered one of the most dangerous states of an animal's life (Lima *et al*. 2005). Animals decrease the risk of threats such as predation whilst sleeping by choosing suitable resting sites (Chutipong *et al*. 2015). The availability of sites used for resting has the potential to influence the distribution and density of a species (Doncaster & Woodroffe 1993), therefore species management plans should ensure the availability of such sites, especially for species of conservation concern.

Previous studies have shown that the selection of resting sites is far from random (Freire 2011); resting sites should provide thermoregulatory benefits, protection from the weather and protection from both parasites and predators (Endres & Smith 1993). For example, American eastern spotted skunks (*Spilogale putorius*) were found to select resting sites that had increased vegetation cover and that were structurally complex, which is believed to aid with thermal regulation and predator avoidance (Lesmeister *et al*. 2008). Similarly, American mink (*Mustela vison*) select above-ground resting sites with dense vegetation for cover (Zabala *et al*. 2007).

Larroque *et al*. (2017) found European stone martens (*Martes foina*) selected buildings for resting sites whereas sympatric pine martens (*Martes martes*) selected forest patches, while both species avoided open areas for daytime resting sites. African spotted hyaenas (*Crocuta crocuta*) were found to prefer to rest in woodland habitat with low visibility and vegetation structure which provided both shade and safety (Kushata *et al*. 2017).

Brown hyaenas (*Parahyaena brunnea*) are found throughout the southern African sub-region and are currently the rarest Hyaenidae, with fewer than 10,000 adult individuals remaining. As a result they are listed as Near Threatened by the International Union for the Conservation of Nature (IUCN) (Wiesel 2015). Threats to the species include human-wildlife conflict following real or perceived livestock predation, eradication as part of predator control programs, and to a lesser degree road traffic collisions and body parts being used for traditional medicine (Wiesel 2015). Brown hyaenas are found across a range of habitat types including savanna, scrubland, grassland, wetlands, desert and coasts (Wiesel 2015) and have been found to be flexible within their habitat use at a landscape scale (Welch *et al*. 2016). Depending on the area, brown hyaenas may be considered apex predators, for example on the coastline of southern Namibia (Wiesel 2010), or as a subordinate competitor to lions (*Panthera leo*) and spotted hyaenas in areas with an intact carnivore guild (Mills 2015).

In order to understand the habitat requirements of brown hyaenas within an inland system we examined the daytime resting sites used by a high-density brown hyaena population in an enclosed reserve in north-central Namibia. The brown hyaenas at the study site were part of an ongoing study and included nine adult individuals monitored with GPS collars. Using historical GPS data, we analysed the location of previous resting sites in relation to their home ranges, classifying them as occurring within the core area, low use area or overlap areas used by two clans. We expected that brown hyaenas would not rest within overlap areas, in order to avoid direct encounters with neighbouring clan members. We also visited a randomly chosen sub-set of resting sites in the field to record habitat and microhabitat features. Because competitively dominant spotted hyaenas are also present at the study site, we expected brown hyaenas to favour habitat and microhabitat features that provide concealment.

Methods

Study site

The study was carried out on the Okonjima Nature Reserve (ONR), a 200 km² privately owned nature reserve located approximately 50 km south of Otjiwarongo, north-central Namibia (Figure 1). The reserve is fully enclosed by an electrified perimeter fence. It receives an average annual rainfall of 450 mm that falls during the hot wet season from October to March. The vegetation is predominantly tree and scrub savanna interspersed with silver terminalia (*Terminalia sericea*) and several *Acacia* species. Perennial water is provided by a total of 18 artificial waterholes across the reserve. The ONR perimeter fence was erected in 2010 around a naturally occurring brown hyaena population that was recently estimated to occur at a density of 24.01 brown hyaenas/100 km² (Edwards *et al*. 2019). Spatial data from monitored brown hyaenas has shown the perimeter fence to be impenetrable to hyaenas (Edwards *et al*. 2020). No species management has taken place since the erection of the fence. Leopard (*Panthera pardus*) density within the reserve is relatively high, having been estimated at 14.51 adults/100 km² during a 2015-2016 density survey (Noack *et al*. 2019), compared to an estimated density of 3.60 leopards/100 km² on commercial farmlands bordering the Waterberg Plateau Park (Stein *et al*. 2011), approximately 100 km from the study site.

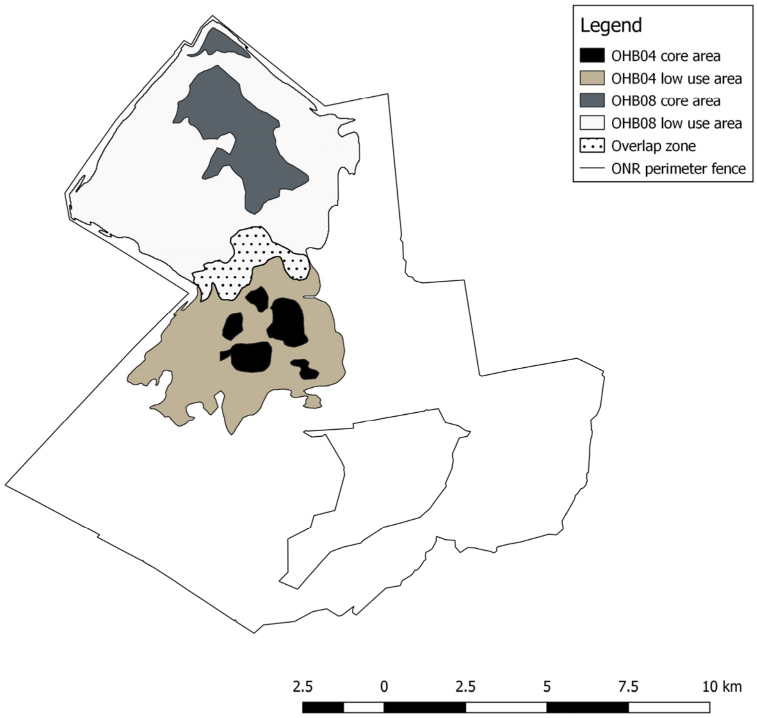

Figure 1: *The Okonjima Nature Reserve study site and two example individual brown hyaena home ranges showing the core area, low use area and overlap between the adjacent home ranges. OHB-numbers refer to individual hyaenas as described in the text.*

GPS collars

Between January and November 2018 a total of nine adult brown hyaenas were sedated to fit global positioning system (GPS) collars sourced from Wireless Wildlife, Potchefstroom, South Africa. For collar fitting, hyaenas were either free darted (n = 6) or captured (n = 3) in a large (approx. 2 m x 3 m) wire box trap, fully lined with industrial conveyor belt rubber to prevent the hyaena injuring itself by attempting to dig or bite at the wire. The trap was fitted with both an internal and external live feed camera and a remotely triggered door. Brown hyaenas were darted using a Pneudart projector using an average weight of 50 kg per animal for dose calculation. A combination of 125 mg Ketamine (sourced from Intersana, Windhoek, Namibia), 2.5 mg Medetomidine and 12.5 mg Butorphanol 12.5 mg (both latter sourced from Kyron Laboratories, Johannesburg, South Africa) was used. When sedation was not deep enough Ketamine at a dose of 0.5 mg/kg (approx. 20-25 mg) was intravenously injected via the saphenous vein. A minimum time of 45 minutes elapsed before the antidotes 'Antisedan' (sourced from Zoetis, Sandton, South Africa) was given at a dose of 2.5 mg intravenously and 5 mg intramuscularly, and 'Trexonil' (sourced from Wildlife Pharmaceuticals, White River, South Africa) at 12.5 mg intravenously and 25 mg intramuscularly. Because brown hyaenas are mainly nocturnal (Mills 1990) the GPS collars, from which data was remotely transferred via ultrahigh frequency (UHF) base stations and repeaters, were scheduled to provide one fix every 30 minutes at night (19h00 to 07h00 local time) and one fix every two hours during the day. Analysis of spatial data along with camera trap data from den sites revealed that individuals OHB01, OHB03 and OHB11 belonged to the same clan, and OHB07 and OHB08 to another (Table 1).

Brown hyaena GPS data; resting sites and home ranges

Following Kushata *et al*. (2017) a daytime resting site, hereafter referred to as a resting site, was defined as the GPS position recorded at 13h00 on days where there was a net displacement of less than 50 m between 09h00 and 16h00. Sites were recorded between January 2018 and January 2019. As brown hyaena movement was restricted by the impermeable perimeter fence, home ranges were estimated using Permissible Home Range Estimation (PHRE) (Tarjan & Tinker 2016); for more detail see Edwards *et al*. (2020). Individuals were defined as belonging to the same clan by the repeated presence of an individual at the same communal den; for more information on communal den site monitoring see Edwards *et al*. (2020). Core areas were defined by the 50% probability kernel, and low use areas were defined as the 95% probability kernel outside of the core area kernel. Overlap areas were defined as those areas where the home ranges of two or more clans overlapped, see Figure 1 for an example. No core areas occurred in overlap zones. A total of 1 582 resting sites from nine monitored brown hyaena were analysed and assigned as falling within the core, low use or overlap area of the individual hyaena's home range by plotting resting sites and home range contours with QGIS 2.8.4 Wien software (www.qgis.org). A resting site was determined as being within an overlap zone if it fell into the overlap between an individual's home range and that of a neighbouring individual from a different clan. As home ranges from clan members had a high degree of overlap, only overlap with non-clan members was considered.

Table 1: *Summary of nine individual adult brown hyaenas monitored on Okonjima Nature Reserve using GPS collars.*

Hyaena ID	Sex	Reproductive status*	GPS monitored clan members
OHB01	Male	Unknown	OHB03 & OHB11
OHB02	Female	Confirmed	None
OHB03	Male	Unknown	OHB01 & OHB11
OHB04	Female	Confirmed	None
OHB06	Female	Confirmed	None
OHB07	Male	Unknown	OHB08
OHB08	Female	Confirmed	OHB07
OHB10	Female	Confirmed	None
OHB11	Female	Confirmed	OHB01 & OHB03

**Reproductive status of females only, confirmed by camera trap data of the female suckling cubs at a den site.*

A subset of 123 randomly chosen resting sites from seven monitored brown hyaenas (range 7-20 resting sites per monitored brown hyaena) recorded between January 2018 and January 2019 were visited on foot in the field to assign a habitat and microhabitat type to each. Due to time constraints the initial aim of visiting 20 resting sites for each individual could not be met, explaining the variation between individuals in the number of resting sites visited (Table 3). Resting sites were randomly chosen using the 'Random selection' feature in QGIS. Resting sites were located by loading GPS positions of resting sites into the Avenza maps application (Avenza.com) on a GPS enabled Samsung tablet. The five habitat types used were: bush encroached, mountain, open savanna, riverine and open woodland. Bush encroached habitat was defined as having dense growth of *Acacia mellifera*, *Dichrostachys cinerea* and *Terminalia sericea* with little to no grass coverage. Mountain habitat was defined as rocky areas with a higher elevation than the surrounding area. Open savanna habitat was defined as mixed woodland-grassland with spaced trees and an unclosed canopy. Riverine habitat was defined as riverbeds plus a 50 m buffer on each side. Open woodland was defined as habitat with large trees with a canopy density of 10-40%. Each resting site was also assigned to a microhabitat, these being: burrow (assumed to be originally from aardvark *Orycteropus afer* or warthog *Phacochoerus africanus*), drainage line, riverbank or under a tree/bush. A burrow microhabitat feature was assigned if the GPS position of the resting site fell within 2 m of an established burrow. A drainage line microhabitat was defined as a channel naturally cut into the ground through which water would normally flow during heavy rains. A riverbank microhabitat was defined as the sandy area directly adjoining a riverbed. The tree or bush microhabitat was assigned if the resting site fell within 2 m of the base of a tree or bush.

Figure 2: *Typical riverine habitat brown hyaena resting site.*

Results and Discussion

Resting sites in context of the home range

Of the 1 582 daytime resting sites analysed 55.3% (n = 874) were located within the core area of the home range, 33.4% within the low use area and 11.4% within overlap areas. Although individual brown hyaenas showed differences in patterns of resting site locations, 77.8% (n = 7) used core areas for resting most frequently, with female OHB04 having the majority (69.8%) of resting sites in the low use area, and male OHB03 having 43.1% of resting sites in the overlap areas (Table 2).

Table 2: *Resting site locations of nine individual adult brown hyaenas in relation to their home ranges on Okonjima Nature Reserve.*

Hyaena ID	Number of resting sites	Percentage of resting sites within:		
		Core area	Overlap areas	Low use areas
OHB01	131	40.5	22.9	36.6
OHB02	122	64.8	5.7	29.5
OHB03	102	25.5	43.1	31.4
OHB04	172	27.3	2.9	69.8
OHB06	282	60.3	9.9	29.8
OHB07	49	53.1	0	46.9
OHB08	359	64.9	5.0	30.1
OHB10	194	84.5	5.7	9.8
OHB11	171	44.4	21.6	33.9
Mean (SD, 95% CI)		51.7 (18.2, 39.8-63.6)	13.0 (13.1, 4.5-21.5)	35.3 (15.2, 25.4-45.3)

Resting site habitat choice

Riverine habitat was the most commonly selected habitat for daytime resting (Figure 2), with a total of 41.5% of resting sites located in this habitat (Table 3). Bush encroached habitat was the second most commonly utilised with 33.3% of resting sites, followed by open woodland (10.6%), open savanna (8.9%) and mountain (6.5%) habitats (Table 3).

A one-way analysis of variance (ANOVA) test showed that significant differences existed in the percentage of resting sites found within the different habitat types ($F = 5.87$, d.f. = 4, $p < 0.05$). A Tukey's pairwise multiple comparison test revealed significant differences between the mountain and bush encroached habitats ($p < 0.05$) with significantly more resting sites located in bush encroached habitat; between riverine and mountain habitats ($p < 0.01$) with significantly more resting sites located in riverine habitat; between open savanna and riverine habitats ($p < 0.05$) with significantly more resting sites in riverine habitat; and between open woodland and riverine habitats ($p < 0.05$) with significantly more resting sites in riverine habitat.

Table 3: *Habitat types utilised as resting sites by adult brown hyaenas within the Okonjima Nature Reserve.*

Hyaena ID	Number of resting sites	Percentage of resting sites within each habitat type:				
		Bush encroached	Mountain	Open savanna	Riverine	Open woodland
OHB01	19	15.8	21.1	0	47.4	15.8
OHB02	7	57.1	0	28.6	28.6	0
OHB03	18	11.1	16.7	11.1	38.9	22.2
OHB04	20	55.0	0	10.0	35.0	0
OHB06	19	79.0	0	5.3	0	15.8
OHB10	20	15.0	5.0	5.0	70.0	5.0
OHB11	20	15.0	0	15.0	60.0	10.0
Mean (SD, 95% CI)		35.4 (25.5, 16.5-54.4)	6.1 (8.3, -0.1-22.3)	10.7 (8.6, 4.4-17.1)	40.0 (21.1, 24.5-55.6)	9.8 (7.9, 4.0-15.7)

Table 4: *Microhabitat types utilised as resting sites by adult brown hyaenas within the Okonjima Nature Reserve.*

Hyaena ID	Number of resting sites	Percentage of resting sites within each microhabitat type:			
		Burrow	Drainage line	Riverbank	Tree or bush
OHB01	19	0	15.8	0	84.2
OHB02	7	0	28.6	14.3	71.4
OHB03	18	5.6	16.7	5.6	72.2
OHB04	20	0	0	0	100.0
OHB06	19	5.3	0	0	94.7
OHB10	20	0	0	0	100.0
OHB11	20	5.0	0	5.0	85.0
Mean (SD, 95% CI)		2.3 (2.6, 0.3-4.2)	8.7 (10.8, 0.7-16.7)	3.5 (5.0, -0.1-7.2)	86.8 (11.2, 78.5-95.3)

Microhabitat choice of resting site

For all monitored brown hyaenas, both combined and individually, the tree or bush microhabitat was most commonly utilised as a daytime resting site, with 88.6% of visited resting sites being under trees or bushes (Table 4). A total of 6.5% of resting sites were located in drainage lines, 2.4% in burrows, and 2.4% on riverbanks. A one-way ANOVA showed significant differences in the number of resting sites found in each microhabitat feature category ($F = 138.0$, d.f. = 4, $p < 0.01$). A Tukey's multiple pair-wise comparison test showed that all resting sites under a bush or tree were utilised significantly more than burrows ($p < 0.01$), drainage lines ($p < 0.01$), open areas ($p < 0.01$) or riverbanks ($p < 0.01$).

Conclusion

Understanding the habitat requirements of threatened species is a key component of any successful wildlife management planning. Resting sites are especially important as they are often required to provide protection from predators whilst animals are sleeping and have the capability to influence the distribution and even abundance of a species (Doncaster & Woodroffe 1993). By examining the resting sites used by GPS monitored brown hyaenas within an enclosed reserve we gained a greater understanding of the habitat requirements of this species. Brown hyaenas mainly rested within the core areas of their home ranges, with the exception of a possibly dispersing male who frequently rested in the overlap zones of his and his clan neighbours' home ranges. Riverine habitat, followed by bush encroached habitat were most frequently used for resting, with microhabitat under a tree or bush being most frequently used. However, as the total availability of each habitat type or microhabitat is not known, the results here do not represent habitat preferences. While preliminary, our results can be used to guide habitat management of areas wishing to conserve brown hyaenas.

Although patterns for individual hyaenas varied (range 25.5% to 84.5% of resting sites), 55.3% of all analysed resting sites were found within the core area of hyaena home ranges. Overlap areas were used least as resting sites, with just 11.4% of analysed resting sites being found within these areas. Such a result might be explained by a reduced risk of direct encounters with a neighbouring clan member, which Mills (1990) noted often result in antagonistic interactions for same sex individuals of brown hyaena. Direct encounters between neighbouring individuals on ONR may be more frequent than in open systems due to the high population density (Edwards *et al*. 2019) and the boundary fence constricting hyaena movement (Edwards *et al*. 2020). Therefore resting in core areas, which are unlikely to be used by neighbouring individuals, may decrease the risk of direct encounters or an individual being attacked by a neighbour whilst sleeping.

In contrast to most individuals, male brown hyaena OHB03 was found to frequently rest in overlap areas, with 43.1% of his resting sites found within overlap zones. During the study period this male showed frequent nocturnal excursions far into the territories of neighbouring clans and was recorded on camera traps at the communal den sites of two neighbouring clans (Edwards, in prep). In the Kalahari, Mills (1990) noted that most, if not all, males will leave their natal clan eventually. The behaviour of OHB03 coupled with his age, estimated at age class three (young adult) (Mills 1982), might suggest dispersal behaviour seeking to integrate into a new clan to become a breeding male (Mills 1990). Such behaviour might explain why this individual was frequently found resting outside of his core area.

Riverine habitat was the most frequently used habitat type for resting sites, and was used significantly more often than mountain, open savanna and open woodland. Riverine habitat on ONR typically has a dense network of large trees and bushes adjacent to the riverbed that provides both shade and concealment. Mills (1990) recorded brown hyaenas using the shade of trees and bushes as resting sites particularly in summer, because brown hyaenas with their thick and long hair may suffer from overheating otherwise. Similarly, Kushata *et al*. (2018) found spotted hyaenas selected for woodland daytime resting sites, suggesting these habitats provide the most shade and aid in thermoregulation. Despite brown hyaenas at the study site often selecting mountainous areas for den sites (Edwards, in prep), only 6.5% of resting sites were found in mountain habitat. Stratford and Stratford (2011) found that spotted hyaena on Ongava Nature Reserve, Namibia, avoid resting on hilltops, suggesting the angle of the slopes may provide little protection from the sun and further expose them to the elements. This might also explain why so few brown hyaena resting sites on ONR were located in mountain habitat.

Bush encroached habitat was the second most frequently used habitat for resting sites, being used significantly more often than mountain habitat. In Namibia, bush encroachment is known to lower the economic productivity of commercial ranchland by reducing the carrying capacity for livestock (Quan *et al*. 1994). As a result, 'debushing', the removal of unwanted bush by fire, mechanical, chemical or biological methods, is now commonplace in Namibia in an attempt to open up areas to restore grazing and thus the economic capacity of an area. In ONR debushing has been done over several years in an attempt to facilitate viewing of wildlife for tourists. However, the results of this study show bush encroached areas to be important for brown hyaenas through use as daytime resting sites. As resting site availability is known to be influential in the distribution of species (Freire 2011), it is important to ensure that suitable sites are available for species of conservation concern, therefore debushing projects may wish to consider leaving intact patches of bush encroached habitat within brown hyaena range, especially when other dense habitats are not available. Furthermore, as brown hyaenas were found to rest most often within core areas of their home range, leaving patches of bush encroached habitat within hyaena clan core areas may be especially beneficial.

Microhabitat under a tree or bush was most commonly used for resting, with 88.6% of sites being associated with this microhabitat. Mills (1990) recorded brown hyaenas selecting trees with large branches close to the ground for resting sites in the Kalahari and suggested that such sites, in addition to providing a thermal refuge, offered increased concealment from predators, which in ONR might include spotted hyaena. Spotted hyaenas have been infrequently recorded killing brown hyaenas, and non-food related interactions in the Kalahari usually involved the brown hyaena being harassed (Mills 1990). Therefore, choosing a resting site which provides concealment from spotted hyaenas will be beneficial and potentially explains the frequent use of bushes and trees.

Future studies may benefit from examining seasonal changes in habitat and microhabitat choice of resting site and use, and where possible, use larger sample sizes of brown hyaenas. Furthermore, because the factors relating to sleeping site selection may vary for a species depending on the environmental conditions and community of species in which it resides (Chutipong *et al*. 2018), repeating the study in contrasting habitats and species community assemblages will enable a more in-depth understanding of brown hyaena resting site requirements.

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