Namibian Journal of Environment

Environmental Information Service, Namibia for the Ministry of Environment, Forestry and Tourism, the Namibian Chamber of Environment and the Namibia University of Science and Technology.

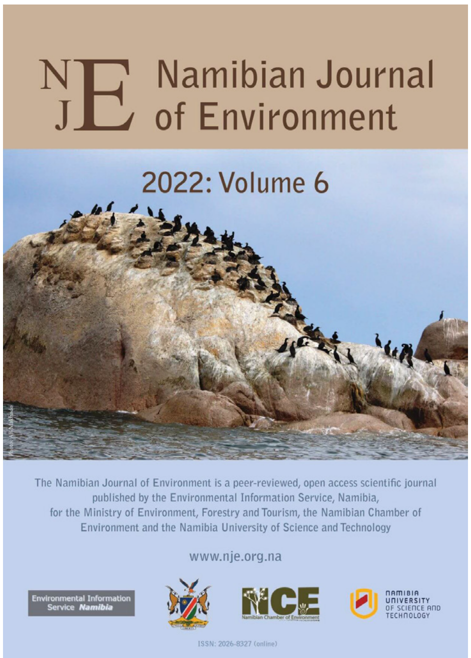
The *Namibian Journal of Environment* (NJE) covers broad environmental areas of ecology, agriculture, forestry, agro-forestry, social science, economics, water and energy, climate change, planning, land use, pollution, strategic and environmental assessments and related fields. The journal addresses the sustainable development agenda of the country in its broadest context. It publishes four categories of articles: **Section A: Research articles**. High quality peer-reviewed papers in basic and applied research, conforming to accepted scientific paper format and standards, and based on primary research findings, including testing of hypotheses and taxonomical revisions. **Section B: Research reports**. High quality peer-reviewed papers, generally shorter or less formal than Section A, including short notes, field observations, syntheses and reviews, scientific documentation and checklists. **Section C: Open articles**. Contributions not based on formal research results but nevertheless pertinent to Namibian environmental science, including opinion pieces, discussion papers, meta-data publications, non-ephemeral announcements, book reviews, correspondence, corrigenda and similar. **Section D: Monographs and memoirs**. Peer-reviewed monographic contributions and comprehensive subject treatments (> 100 pages), including collections of related shorter papers like conference proceedings.

NJE aims to create a platform for scientists, planners, developers, managers and everyone involved in promoting Namibia's sustainable development. An Editorial Committee ensures that a high standard is maintained.

ISSN: 2026-8327 (online).

Chief Editor: K STRATFORD

Editor for this paper: S PÉRIQUET



SECTION B: RESEARCH REPORTS

Recommended citation format:

Fischer H, Portas R & Edwards S (2022) A preliminary comparison of brown hyaena activity patterns at den sites located within a protected reserve and a commercial farmland. *Namibian Journal of Environment* 6 B: 1-5.

Cover photo: AB Makhado

A preliminary comparison of brown hyaena activity patterns at den sites located within a protected reserve and a commercial farmland

H Fischer[1], R Portas[2], S Edwards[1]

URL: https://nje.org.na/index.php/nje/article/view/volume6-fischer

Published online: 7th September 2022

[1] Capel Manor College, Bullsmoor Lane, Waltham Cross, Enfield, UK EN1 4RQ. sledwardsuk@gmail.com
[2] University of Lubljana, Biotechnical Faculty, Dept. for Forestry, Večna pot 83, SI-1000 Ljubljana, Slovenia; Cheetah Research Project, Department of Evolutionary Ecology, Leibniz Institute for Zoo and Wildlife Research of Berlin, Alfred-Kowalke-Straße 17, 10315 Berlin, Germany

Date received: 1st November 2021; Date accepted: 13th June 2022.

Abstract

Wildlife activity patterns reflect both internal biological rhythms and adaptations to environmental factors. Studies examining the impact of anthropogenic activities on wildlife, including land-use, have frequently found changes in activity patterns in response to these activities. One species often found in human-dominated landscapes is the brown hyaena (*Parahyaena brunnea*), a large, nocturnal carnivore, endemic to southern Africa, which lives in societal clans that use a communal den. This study compared brown hyaena activity patterns at two den sites: a protected nature reserve and a non-protected commercial farmland in north-central Namibia. Activity curves produced by camera trap monitoring of the two den sites were significantly different and showed a coefficient of overlap of 0.21 (95% confidence intervals 0.19-0.25). Brown hyaena den activity at the protected site was mainly diurnal, whilst activity at the non-protected site showed a higher degree of nocturnal activity. Several potential reasons may explain the differences in den activity between the two sites, including environmental conditions and anthropogenic influences. More studies are needed with larger sample sizes to further investigate the impact of these factors.

Keywords: activity patterns, brown hyaena, Namibia, protected area

Introduction

Wildlife activity patterns, also referred to as diel activity patterns, reflect both internal biological rhythms and adaptations to environmental factors experienced by an individual, which may vary on a daily and/or seasonal basis (Kolowski *et al*. 2007; Ordiz *et al*. 2017). The period of day in which an individual is active can be adapted to exploit their environment, and major drivers of activity patterns include resource availability, predator avoidance and intraspecific interactions (Kitchen *et al*. 2000), and as such, changes to activity patterns may incur indirect fitness costs for a species (Kolowski *et al*. 2007; Kruuk 2014). Documenting wildlife activity patterns can therefore provide valuable ecological insights as well as helping to reveal the impact of anthropogenic activities on wildlife populations (Frey *et al*. 2017). Studies examining the impact of anthropogenic stress on wildlife have frequently found that wildlife modified their activity patterns (Di Bitett *et al*. 2008; Gaynor *et al*. 2018a; Morales-Gonzalez *et al*. 2020). More specifically, human activity has been suggested to be the cause of decrease in diurnal activity (Shamoon *et al*. 2018); for example, elephants (*Loxodonta africana*) have been found to restrict diel activity in areas with higher levels of human disturbance (Gaynor *et al*. 2018b).

Given the current increasing rate of anthropocentric land-utilisation across Africa, which has led to the conversion of natural habitats into heterogenous agricultural landscapes, documenting the impact of land-use on wildlife activity patterns is likely to be important for conservation management of endangered species. Studies have shown that wildlife species alter activity patterns in response to human land-use (Gaynor *et al*. 2018a). Several African ungulate species, including sable (*Hippotragus niger*) were found to increase their nocturnal use of waterholes in response to human hunting pressure (Crosmary *et al*. 2012). Similarly, serval (*Leptailurus serval*) have been recorded to increase nocturnal activity levels on farmlands which is suggested as a mechanism to avoid daytime activity of humans (Ramesh & Downs 2013).

In addition to being sites of increased human activity, farmlands may also represent areas where carnivore persecution takes place. This is because of the real or perceived threat carnivores pose towards livestock and/or human life (Kent & Hill 2013; Ramesh & Downs 2013). Human persecution imposes a stimulus to which an individual animal cannot become habituated, and wild carnivores often respond to anthropogenic activity by avoidance (Gaynor *et al*. 2018a; Kitchen *et al*. 2000). Previous studies have shown that human disturbance can cause an increase in nocturnal activity in diurnal carnivore species such as brown bear (*Ursus arctos,* Morales-Gonzalez *et al*. 2020) and nocturnal and crepuscular carnivore species such as serval (Kitchen *et al*. 2000).

Brown hyaena (*Parahyaena brunnea*) is a species commonly found on farmland, and therefore its sympatric overlap with humans may impact its activity pattern (Mills & Hofer 1998; Owens & Owens 1978; Wiesel 2015). The brown hyaena is a large-sized (~45 kg) mammalian carnivore endemic to southern Africa with an estimated total population size of < 10,000 individuals and is listed as Near Threatened by the International Union for Conservation of Nature (Wiesel 2015). The species experiences deliberate or incidental persecution in the form of shooting, trapping, and poisoning. This is usually due to farmers perceiving brown hyaenas to be a threat to livestock despite them rarely preying on livestock, being primarily a scavenger (Kent & Hill 2013; Mills 1990; Wiesel 2015; Winterbach *et al*. 2017). As a consequence, human persecution has led to the local extinction of brown hyaenas in southern parts of Namibia (Wiesel 2015).

Within protected areas of the southern Kalahari, brown hyaenas are predominantly nocturnal, with activity peaks observed after sunset and just before sunrise (Mills 1990). The species is social and lives in clans of up to 13 individuals, consisting of related females, their offspring of both sexes and non-natal males. Approximately 8% of the population consists of nomadic individuals which have no lasting relationships with conspecifics (Mills 1990). Although clan members forage solitarily, individuals within a clan share the same home range and communal dens, which function as the centres of social activity and are visited by all clan members (Mills 1990). Cubs are raised at a communal den, from three months old, with the involvement of all clan members (Mills 1990). Communal denning, given that food availability is sufficient, provides several benefits: clan members cooperate in ways that appear to increase the direct and indirect fitness of individuals, including increased food supply by several individuals, which in turn enhances breeding and cub survival rates (Alcock & Rubenstein 2019; Mills 1990; Owens & Owens 1978). Dens also function as protection for the cubs during periods when adults are absent (Mills 1990; Owens & Owens 1978).

In this study, we compared the activity patterns of two brown hyaena clans at their communal den sites located in areas differing in level of formal protection to investigate the potential anthropogenic impact on activity patterns. We predicted that den activity at the protected site would show a higher degree of nocturnality compared to the non-protected site due to the higher risk of persecution on farmlands.

Materials and Methods

Study sites

The protected site, Okonjima Nature Reserve (ONR) is a privately-owned reserve, situated 50 km south of Otjiwarongo, north-central Namibia. The 200 km^2 reserve is fully enclosed by a 2.4 m-high electrified fence of 7-10 kilovolt, erected in 2010 and comprises a 180 km^2 area reserved for wildlife and a 20 km^2 area containing buildings for human activity, such as non-consumptive tourism. Brown hyaena density within ONR was estimated at 24.01 brown hyaena/100 km^2 (Edwards *et al*. 2019). ONR also contains a leopard (*Panthera pardus*) population estimated at a density of 14.51 leopards/100 km^2 (Noack *et al*. 2019). No active carnivore management has taken place since the establishment of the fence. The brown hyaena den on ONR was monitored as part of an ongoing study.

The farmland site, Gross Okandjou Farm (GOF) is a commercial farm totalling 90 km^2, situated 30 km west of the town of Omaruru in central-western Namibia. The farm is divided into camps where a total of 80-120 cattle (*Bos taurus*) and 60 horses (*Equus caballus*) graze. Farm activities include non-consumptive tourism (horse-riding) and sustainable hunting of antelope for meat production, predominantly kudu (*Tragelaphus strepsiceros*) and gemsbok (*Oryx gazella*). No carnivore persecution takes place directly at the farm; however, large carnivores in the area are likely to range over several neighbouring farms, which may differ in tolerance towards carnivores, due to their perceived or real threat to livestock. The brown hyaena den was located inside a cave within mountainous habitat and was found and monitored opportunistically.

Data collection

A brown hyaena clan, consisting of a collared female with three 7-month-old cubs, two adults and one sub-adult was monitored using a camera trap at ONR. A single Cuddeback X-change 11339 infra-red camera trap (Non Typical Inc., Wisconsin, USA), housed in a 'Cuddesafe' protective housing was mounted approximately 50 cm from the ground on a metal pole, focused on the main den entrance. The camera trap was programmed to take three images per trigger, with no delay between triggers and an image quality of 20 mega-pixels and the sensor set to high sensitivity (Edwards *et al*. 2020). On GOF, the den, used by a clan consisting of two adults and one cub estimated to be nine months old, was monitored using a Reconyx PC900 HyperFire (Reconyx Inc, Holeman, Wisconsin, USA) motion sensor camera trap, positioned to capture all den entrances. The motion sensor was set to high sensitivity, with three image per trigger and no delay interval between triggers.

Adults often stayed for prolonged periods of time at the dens (maximum time = 5 h 28 min). Thus, to ensure that time stamps were temporally independent, a random sub-sample comprising 50% of the records from each den was selected and included in the analysis (c.f. Edwards *et al*. 2021). The time stamps of independent events were then used to produce activity curves. Data used for this study were collected from 21 June 2020 to 22 July 2020, with a total of 24 and 25 active camera trap nights achieved for ONR and GOF respectively. To avoid temporal bias, days where the camera trap was not active for the entire 24-cycle (due to batteries running out of power) were removed from the analysis.

Data analysis

Camera trap data from each site were filtered to remove any images not showing brown hyaena presence; these may have been triggered by unrelated movements such as other species or wind-related movements (Trolliet *et al*. 2014). The package 'overlap' (Ridout & Linkie 2009) in statistical program R (R Development Core Team 2014) was used to non-parametrically estimate and plot the probability function of the time distribution for each site, producing a visual representation of the activity pattern, the 'activity curve'. In this approach, events (time stamps from camera traps), were viewed as a random sample taken from an underlying continuous temporal distribution, describing the probability of an event occurring at any given time (Ridout & Linkie 2009).

The 'overlap' package was also used to calculate coefficients of overlap between the activity curves produced, using estimator Δ, a continuous variable between 0 and 1, where 0 indicates no overlap, and 1 indicates total overlap. The coefficient is defined as the area under the curve formed by taking the minimum of each density function of the two compared cycles at each time point (Monterroso *et al*. 2014). Estimator Δ_4 was used as this is suggested the most applicable for sample sizes of > 75 (Ridout & Linkie 2009). Confidence intervals for coefficients of overlap were calculated using 1 000 bootstraps. A Watson Wheeler test in R package 'circular' (Lund & Agostinelli 2013) was used to test for homogeneity in the two activity patterns. The test detects differences in the mean angle of the circular temporal data indicative of differences in activity peaks (Batschelet 1981).

Results

After filtering of images not showing brown hyaena presence and removal of incomplete camera trap nights, a total of 897 image files from ONR and 18 161 image files from GOF were obtained. This resulted in a random sub-sample of 50% of each data set of n = 448 from ONR and n = 9 080 from GOF being used for analysis. The probability overlap plot showed a clear peak in brown hyaena den activity at ONR during the mid-afternoon, which corresponded to a mean activity period of 14h56, whilst at GOF, a bimodal activity curve was seen with peaks around 05h00 and 22h00 (Figure 1, Table 1). The coefficient of overlap between the two sites was 0.21 (95% confidence intervals 0.19-0.25). The Watson-Wheeler test indicated a significant difference in the activity patterns between each site ($W = 714$, d.f. = 2, $p < 0.001$).

Table 1: *Circular descriptive statistics for brown hyaena den activity at Okonjima Nature Reserve (ONR) and Gross Okandjou Farm (GOF).*

Variable	ONR	GOF
Sample size	448	9 080
Mean vector	14h52	01h23
Length of mean vector	0.77	0.45
Circular variance	0.21	0.54
Circular standard deviation	02h43	04h46
Standard error of mean	00h05	00h02
95% confidence interval	14h45-15h07	01h28-01h38

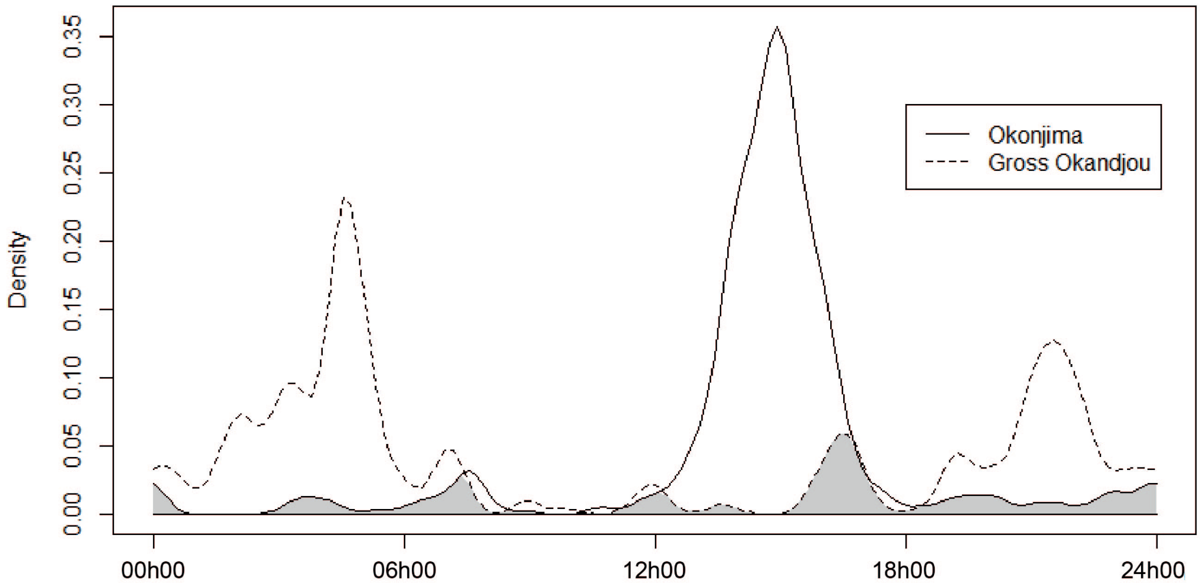


Figure 1: *Overlap plot showing the activity curves for brown hyaena at den sites on Okonjima Nature Reserve and Gross Okandjou Farm. Grey area represents the overlap in activity.*

Discussion

Wild carnivores have been recorded shifting diel activity patterns and increasing nocturnal activity in response to human activity both in the form of land-use, and the corresponding increases in human activity, and direct persecution (Gaynor *et al*. 2018a). Given the increase in human land-utilisation in Africa, interactions between humans and wildlife are likely to occur more frequently, thus understanding the outcomes of such interactions is important for conservation management (Kolowski *et al*. 2007; Wiesel 2015). We compared brown hyaena den activity at two sites in Namibia and found a significant difference in activity patterns between a protected reserve and a non-protected farmland. Brown hyaenas at the protected site displayed higher levels of diurnal den activity than those in farmland, with a peak in activity during mid-afternoon at the protected site, in comparison to activity peaks around 05h00 and 22h00 in farmland. Although data collection was limited to one den per site, these results may suggest that differences in the environmental conditions between the two sites may be causing brown hyaenas to change their den activity patterns.

The potential persecution of carnivores across the larger farmland landscape is a possible reason for the differences in activity patterns seen between the two sites. A study examining the impact of persecution on coyotes (*Canis latrans*) found nocturnal activity increased when persecution was present compared to no persecution (Kitchen *et al*. 2000). The same study also showed that eight years after anthropogenic persecution had ceased, coyotes adopted a more diurnal activity pattern, indicating that anthropogenic persecution influenced coyote diel activity pattern, and was able to conclude that nocturnal activity of coyotes increased with the presence of persecution (Kitchen *et al*. 2000). Furthermore, a study focusing on sika deer (*Cervus nippon*) found a higher degree of nocturnality during a culling program than prior to its start (Ikeda *et al*. 2019). Additionally, a study found that red brocket deer (*Mazama americana*) were more nocturnal in areas with persecution compared to areas with higher level of protection (Di Bitett *et al*. 2008). However, given the unknown levels of persecution on the farmlands surrounding the GOF, further research would be needed to investigate how persecution of brown hyaena and/or sympatric carnivores impacts brown hyaena activity patterns across Namibian farmlands.

Another potential factor which may explain the differences in brown hyaena den activity seen between the two sites is differences in activity patterns of sympatric apex predators. Brown hyaenas are a scavenging species and comparison of brown hyaena and leopard diet via scat analysis on Namibian farmlands found a high degree of overlap, suggesting the species may benefit from the presence of leopard (Stein *et al*. 2013). Indeed, brown hyaenas on ONR have frequently been observed scavenging from leopard kills, and even kleptoparasitising leopard kills (Edwards *pers. obs*.). Scavengers may benefit from being sympatric with efficient predators (Creel *et al*. 2001) and, to maximise this benefit, brown hyaenas may align their activity patterns with leopards to access their kills before other scavengers such as vultures (*Accipitridae* species) do, although this could also increase interference competition (Creel *et al*. 2001). However, activity patterns of leopards on both farmlands and protected areas also containing brown hyaenas would need to be compared in order to fully examine if differences in apex predator activity patterns could explain the differences in brown hyaena activity patterns observed in this study.

This study is limited to just one den at each study site, between which differences in cub age and clan structure were seen, which may have impacted how often and when adults visited the den. The three cubs on ONR were seven months old, compared to a single cub of nine months old on GOF. Mills (1990) observed an increase in the time spent suckling as cubs grew, however between four and nine months old mothers visited cubs at the den once per 24 hours during the night. Brown hyaena cubs receive solid food at the den from four months of age, which is brought back by clan members, but are not weaned until 12-16 months of age (Mills 1990). Therefore, cubs at both dens were in similar phases of development regarding their diet. The single cub at GOF was provided food by two adults, in comparison to the three cubs on ONR which had two adults and a sub-adult within their clan. The three cubs at ONR may have required more frequent food deposits from adults than the single cub at ONR, which may explain the increased diurnal activity at the site. In addition, prey density and food availability may differ in both study sites, which may also affect the activity patterns of brown hyaenas. Future studies which include a range of sites, clan sizes and cub ages are needed to fully assess the impact of clan size and cub age on timing of visits to the den under different environmental conditions.

Conclusion

Although limited to a small sample size, the findings of this study suggest that the brown hyaena den site within a commercial farmland had higher levels of nocturnal activity and a significantly different activity pattern to a den within a protected reserve. These findings are consistent with several former studies showing an increased nocturnal activity due to anthropogenic activity and/or persecution on other carnivore and prey species such as coyotes, servals, bears and red brocket deer. The consequences of higher levels of brown hyaena nocturnal den activity at GOF compared to ONR are currently unclear. More studies are needed to understand the specific implications of higher nocturnal den activity at the farmland site compared to the protected site on brown hyaena populations and fitness of individuals on a long-term basis.

Acknowledgements

We would like to thank the Ernest Kleinwort Charitable Trust, the Namibian Wildlife Conservation Trust, Varta Consumer Batteries, the AfriCat Foundation, AfriCat UK and Okonjima Lodges CC for supporting the project. We thank the Vogel family from the farm Gross Okandjou for their interest and support in wildlife research and conservation. We also thank the Ministry of Environment, Forestry and Tourism in collaboration with the National Commission on Research, Science and Technology for granting the relevant permits for this research. Thank you to Nikolaos Karantanis and Thomas Logan for their input on the design of this study.

References

Alcock J, Rubenstein DR (2019) *Animal Behaviour* (Eleventh edition). Oxford University Press, Oxford

Batschelet E (1981) *Circular statistics in biology.* Academic Press, London

Creel S, Spong G, Creel NM (2001) Interspecific competition and the population biology of extinction-prone carnivores. In Gittelman JL, Funk SM, MacDonald D, Wayne R (ed) *Carnivore Conservation*, pp. 35–60. Cambridge University Press, Cambridge.

Crosmary WG, Valeix M, Fritz H, Madzikanda H, Côté SD (2012) African ungulates and their drinking problems: Hunting and predation risks constrain access to water. *Animal Behaviour* 83(1): 145–153. https://doi.org/10.1016/j.anbehav.2011.10.019

Di Bitetti MS, Paviolo A, Ferrari CA, De Angelo C, Di Blanco Y (2008) Differential responses to hunting in two sympatric species of brocket deer (*Mazama americana* and *M. nana*). *Biotropica* 40(5): 636–645.

Edwards S, Noack J, Heyns L, Rodenwoldt D (2019) Evidence of a high-density brown hyaena population within an enclosed reserve: The role of fenced systems in conservation. *Mammal Research* 64(4): 519–527.

Edwards S, Noack J, Heyns L, Rodenwoldt D (2021) Are camera traps a reliable method for estimating activity patterns? A case study comparing technologies for estimating brown hyaena activity curves. *Remote Sensing in Ecology and Conservation* 7(2): 129–138.

Frey S, Fisher JT, Burton AC, Volpe JP (2017) Investigating animal activity patterns and temporal niche partitioning using camera-trap data: challenges and opportunities. *Remote Sensing in Ecology and Conservation*: 1–10. https://doi.org/10.1002/rse2.60

Gaynor KM, Hojnowski CE, Carter NH, Brashares JS (2018a) The influence of human disturbance on wildlife nocturnality. *Science* 360(6394): 1232–1235.

Gaynor KM, Branco PS, Long RA, Gonçalves DD, Granli PK, Poole JH (2018b) Effects of human settlement and roads on diel activity patterns of elephants (*Loxodonta africana*). *African Journal of Ecology* 56: 872–881. https://doi.org/10.1111/aje.12552

Ikeda T, Takahashi H, Igota H, Matsuura Y, Azumaya M, Yoshida T, Kaji K (2019) Effects of culling intensity on diel and seasonal activity patterns of sika deer (*Cervus nippon*). *Scientific Reports* 9(1): 1–8. https://doi.org/10.1038/s41598-019-53727-9.

Jacobson AP, Gerngross P, Lemeris JR, Schoonover RF, Anco C, Breitenmoser-Würsten C, Durant SM, Farhadinia MS, Henschel P, Kamler JF, Laguardia A, Rostro-Garcia S, Stein AB, Dollar L (2016) Leopard (*Panthera pardus*) status, distribution, and the research efforts across its range. *PeerJ* 2016 4:e1974. https://doi.org/10.7717/peerj.1974. PMID: 27168983

Kambongi T, Heyns L, Rodenwoldt D, Edwards S (2021) A description of daytime resting sites used by brown hyaenas (*Parahyaena brunnea*) from a high-density, enclosed population in north-central Namibia. *Namibian Journal of Environment* 5: B1-6.

Kent VT, Hill RA (2013) The importance of farmland for the conservation of the brown hyaena *Parahyaena brunnea*. Oryx 47(3): 431–440.

Kitchen AM, Gese EM, Schauster ER (2000) Changes in coyote activity patterns due to reduced exposure to human persecution. *Canadian Journal of Zoology* 78(5): 853–857.

Kolowski JM, Katan D, Theis KR, Holekamp KE (2007) Daily patterns of activity in the spotted hyaena. *Journal of Mammalogy* 88(4): 1017–1028.

Lund U, Agostinelli C (2018) *CircStats: circular statistics, from Topics in Circular Statistics*, R package version 0.2-6. https://CRAN.R-project.org/package=CircStats

Mills G, Hofer H (1989) *Hyaenas. Status Survey and Conservation Action Plan.* IUCM/SSC Hyaena Specialist Group. IUCN, Cambridge. http://www.carnivoreconservation.org/files/actionplans/hyaenas.pdf

Mills MGL (1994) *Kalahari hyaenas: Comparative behavioural ecology of two species.* The Blackburn Press, New Jersey.

Monterroso A, Conde C, Gay C, Gómez D, López J (2014) Two methods to assess vulnerability to climate change in the Mexican agricultural sector. *Mitigation and Adaptation Strategies for Global Change* 19(4): 445–461.

Morales-Gonzalez A, Ruiz-Villar H, Ordiz, A, Penteriani V (2020) Large carnivores living alongside humans: Brown bears in human-modified landscapes. *Global Ecology and Conservation* e00937. https://doi.org/10.1016/j.gecco.2020.e00937

Ordiz, A, Sæbø S, Kindberg J, Swenson JE, Støen, O (2017) Seasonality and human disturbance alter brown bear activity patterns: implications for circumpolar carnivore conservation? *Animal Conservation* 20: 51–60. https://doi.org/10.1111/acv.12284

Owens MJ, Owens DD (1978) Feeding ecology and its influence on social organization in brown hyaenas (*Hyaena brunnea*, Thunberg) of the Central Kalahari Desert. *African Journal of Ecology* 16(2): 113–135.

R Development Core Team (2014) *R: a language and environment for statistical computing; Version 3.1.1*. R Foundation for Statistical Computing, Vienna.

Ramesh T, Downs CT (2013) Impact of farmland use on population density and activity patterns of serval in South Africa. *Journal of Mammalogy* 94(6): 1460–1470.

Ridout MS & Linkie M (2009) Estimating overlap of daily activity patterns from camera trap data. *Journal of Agricultural, Biological, and Environmental Statistics* 14(3): 322–337.

Shamoon H, Maor R, Saltz D, Dayan T (2018) Increased mammal nocturnality in agricultural landscapes results in fragmentation due to cascading effects. *Biological Conservation* 226: 32–41. https://doi.org/10.1016/j.biocon.2018.07.028

Stein AB, Fuller TK, Marker LL (2013) Brown hyaena feeding ecology on Namibian farmlands. *African Journal of Wildlife Research* 43(1): 27–32. https://doi.org/10.3957/056.043.0115

Trolliet F, Huynen MC, Vermeulen C, Hambuckers A (2014) Use of camera traps for wildlife studies. A review. *Biotechnology, Agronomy and Society and Environment* 18(3):446-454

Wiesel I (2015) Parahyaena brunnea: Wiesel I.: The IUCN Red List of Threatened Species 2015: e.T10276A82344448 [Data set]. *International Union for Conservation of Nature.*

Winterbach CW, Maude G, Neo-Mahupeleng G, Klein R, Boast L, Rich LN, Somers MJ (2017) Conservation implications of brown hyaena (*Parahyaena brunnea*) population densities and distribution across landscapes in Botswana. *Koedoe* 59(2) a1441.