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A study on the postrelease behaviour and habitat preferences of black rhinos (*Diceros bicornis*) reintroduced into a fenced reserve in Namibia

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Abstract

Translocations and reintroductions are key elements for the population management of the critically endangered black rhino (*Diceros bicornis*, Linnaeus, 1758). In this study, we investigated the postrelease behaviour and habitat preferences of a black rhino starter group (n = 4) on the individual level. The animals were reintroduced to a fenced game reserve (87 km^2) in North-Central Namibia 1 year prior to our study. We used camera traps and very high frequency (VHF) radiotelemetry to examine the animals' temporal and spatial behaviour over a period of 4 months at transition between wet and dry seasons. Our results underline a peak in drinking activity and waterhole visits occurring between 7 p.m. and 8 p.m. We found a shift in intensity in drinking activity during the period of the study. Satellite-based woody cover estimations only suggest positive correlations between the density of woody cover and favoured black rhino habitat types. Although the area seems suitable to facilitate breeding success of this starter group, it does not support a self-sustaining population. However, black rhinos were already successfully reintroduced to several additional fenced reserves in this region. The selective opening of fences in the future could help to enable genetic exchange between currently isolated groups of rhinos.

Key words: black rhino, camera traps, land use, reintroduction

Résumé

Translocations et réintroductions sont des éléments clés de la gestion de la population du rhinocéros noir (*Diceros bicornis*), en danger critique d'extinction. Dans cette étude, nous avons étudié le comportement d'un groupe de départ de rhinos noirs (n = 4) après leur lâcher et leurs préférences en matière d'habitat au niveau individuel. Les animaux ont été réintroduits dans une réserve de faune clôturée (87 km^2) au centre-nord de la Namibie un an avant le début de notre étude. Nous avons utilisé des pièges photographiques et la radio-télémétrie VHF pour examiner le comportement des animaux dans le temps et dans l'espace, sur une période de quatre mois à la transition entre saison des pluies et saison sèche. Nos résultats mettent en évidence un pic de consommation d'eau et de visites au point d'eau entre 7 et 8 pm. Nous avons trouvé un glissement de l'intensité de la consommation d'eau au cours de l'étude. Des estimations de la couverture ligneuse basées sur des images satellite suggèrent seulement des corrélations positives entre la densité de la couverture ligneuse et les types d'habitats préférés des rhinos. Bien que la région semble de nature à favoriser la reproduction de ce groupe de départ, elle ne satisfait pas les besoins d'une population autonome. Cependant, des rhinos noirs ont déjà été réintroduits avec succès dans plusieurs autres réserves de la région. L'ouverture sélective des enclos pourrait à l'avenir aider à rendre possibles des échanges génétiques entre ces groupes de rhinos isolés jusqu'à présent.

Introduction

Due to effective conservation strategies, including translocations and reintroductions, Namibia currently holds approximately one-third of the black rhino (*Diceros*

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bicornis) *in situ* population (Emslie, 2012). The re-establishment of satellite populations on private land, national parks and conservancies has been one of the most promising conservation strategies in Namibia since the late 1980s (Lindeque, 1990). The Namibian Rhino Custodianship Programme is successfully reintroducing black rhinos from the Etosha National Park (ENP) to freehold game farms and conservancies to establish viable satellite populations. This development went along with landowners successively shifting their focus from livestock farming towards wildlife management and tourism (Göttert & Zeller, 2008). This change of land use provides unique opportunities for studying the black rhinos' adaptability towards novel environments. However, fenced reserves and farms still represent artificially managed systems and are not truly 'natural' conditions. Therefore, it is important to understand the spatial requirements and social factors that influence the postrelease behaviour of black rhinos in fenced reserves.

Guidelines for black rhino reintroductions are established (Emslie, Amin & Kock, 2009; Linklater *et al.*, 2011), and the main focus of previous research has been on successive metapopulation management (Raath & Hall-Martin, 1989) and the associated risks (Hall-Martin & Penzhorn, 1977; Brett, 1998). Translocation or reintroduction success is commonly measured by postrelease survival (Linklater *et al.*, 2012) or reproductive performance. However, little is known about behavioural patterns after reintroductions although this information would contribute to a better understanding of the factors affecting reintroduction success.

Black rhinos occur in a broad variety of habitat types (Dinerstein, 2011). The species' ecological adaptability can be illustrated by the spectrum of the dimensions of home ranges found in different habitat types, varying between 4.3 and 13.8 km^2 in South Africa (Conway & Goodman, 1989) and approximately 440 km^2 in Namibia (Hearn, Loutit & Uri-Khob, 2000). Despite this pronounced variability, there are surprisingly few studies dealing with aspects of postrelease response behaviour on an individual level (Linklater & Swaisgood, 2008; Patton *et al.*, 2010).

The aim of the present study was to investigate the spatial, temporal and social behaviour, as well as the habitat preferences of one male and three female black rhinos 1 year after their reintroduction to a fenced game reserve directly adjacent to the ENP. Our specific objectives were (i) to develop profiles of circadian activity rhythms of rhinos at waterholes (waterhole use over 4 months and drinking times over 24 h), (ii) to characterize aspects of the animals' social organization (rhinos drinking occasionally together, area overlap) and (iii) to investigate habitat use and preferences (activity areas and woody cover estimations).

Materials and methods

Study area, animals and study period

The study was conducted on a private wildlife reserve in northern Namibia's Kunene region (Fig. 1). On its western border, the study area shares a common fence with the ENP. The reserve is completely fenced-in, and the potentially usable black rhino habitat comprises 87 km^2. Between 1953 and 1999, the area was used for livestock farming and afterwards, land use has been shifted towards game farming and ecotourism. The area is situated at an altitude of 1260–1350 m above sea level. It belongs to the Namibian Karstveld, an acacia-tree-and-shrub savannah, characterized by large expanses of grasslands with occasional trees and shrubs. A vegetation survey carried out during our study period revealed that particularly common plant species were mopane [*Colophospermum mopane*, (Kirk ex Benth.) Kirk ex J. Léonard] and false umbrella thorn (*Acacia reficiens*, Wawra).

All four animals, one adult male (15 years) and females Juno (7 years), Gaya (5 years) and Cleo (4 years) were captured in the ENP, and no past associations are known. Rhinos were released into the fenced sanctuary on 31 March 2011 (Anthony and Cleo) and 18 June 2011 (Juno and Gaya).

Data collection took place between 1 March and 30 June 2012.

Camera traps

A total of twenty passive infrared triggered digital camera systems (Moultrie® Game Spy M-100; EBSCO Industries Inc., Birmingham, AL, U.S.A.) were used to record rhino presence and activity. Eight cameras continuously captured images at the seven permanent waterholes of the farm throughout the entire study period (*stationary cameras*). The remaining twelve cameras (*temporary cameras*) were installed at places indicating regular rhino activity. We shifted these cameras at random intervals ranging from 2 to 6 weeks. We used naturally occurring objects (trees or shrubs), as well as self-made mounts, to reach a favourable angle and distance between camera and object of interest.

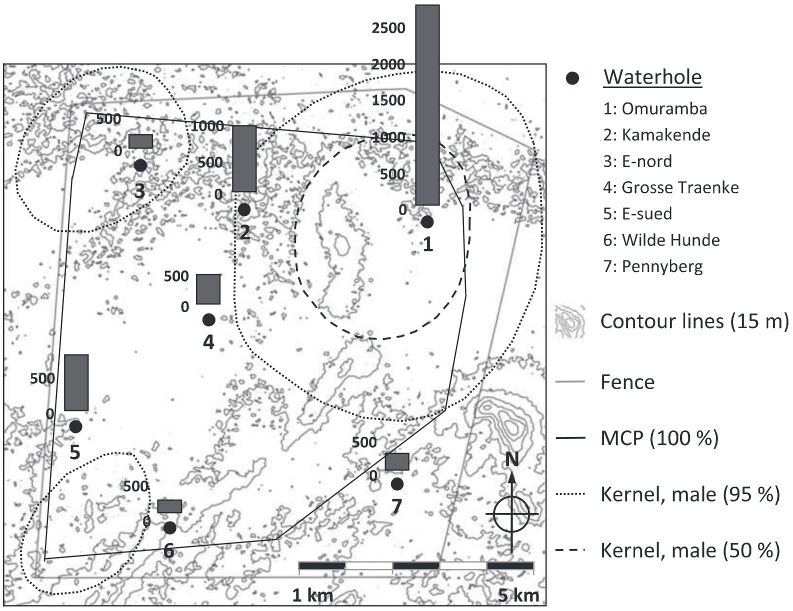

Fig 1 Study area: size, elevation and distribution of waterholes (labelled from 1 to 7). Total number of rhino images per waterhole is given (black bars). Additionally, the male rhino's activity area (100% MCP and 95% Kernel) and core area (50% Kernel) are given

Each identifiable black rhino image sequence was considered an event. An entire 24-h camera trap cycle is referred to as one camera trap day (*CTD*). We used horn curves, ear marks and other individual characteristics (relative size, sexual features) to individually identify the rhinos. We recorded rhino images per particular waterhole, time of day and number of rhino individuals per image. We analysed social interactions (more than one rhino per image) by conducting a single link cluster analysis (Morgan *et al.*, 1976) using a sociometric matrix. Stationary cameras at waterholes consistently captured images suitable for identifying rhinos on an individual level [n = 5302 images (96.7%)]. Temporary cameras captured only few and often blurred images (n = 164 images), from which the majority could not be identified. Thus, the presented results are exclusively based on the stationary cameras.

VHF radiotelemetry

Rhinos were tracked either in the morning hours (7 a.m.–9 a.m.; 50.8% of fixes) or during midday and early afternoon (2 p.m.–3 p.m.; 49.2% of fixes).

Only one position (fix) was recorded per rhino and observation day.

We estimated activity areas of females 'Cleo' and 'Juno' and the male 'Anthony' according to the 100% minimum convex polygon (MCP) method (Mohr, 1947; Southwood, 1966). Data volume allowed the calculation of Kernel polygons (Worton, 1989) to estimate activity area (95%) and core area (50%) of the male animal. We conducted MCP and Kernel analysis using QGIS (QGIS – Quantum GIS Development Team, Ver. 1.8.0, 2013; Open Source, U.S.A.) in combination with the Python plugin AniMove (Ver. 1.3.3) for the QGIS geo-processing platform SEXTANTE (Ver. 1.0.9). We calculated values for the percentage of utilization distribution for 50% and 95% Kernel polygons and used Scott's rule of thumb (Scott, 2010) as bandwidth method. We calculated home range overlaps (*V*) using an index (Lazo, 1994) ranging from 0 (no overlap) to 1 (identical home ranges).

We used QGIS software on the basis of ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer) data to represent the results within detailed maps of the study area.

Woody cover estimation

We used satellite remote sensing to estimate fractional woody cover across the study region. We selected RapidEye® (RapidEye AG, Berlin, Germany) imagery because of the good compromise of spatial, spectral and temporal resolution (RapidEye data provided by the DLR). We used the imagery (Ortho Product Level 3A) to calculate the Red Edge Normalized Diffference Vegetation Index (NDVI), which provides an indication of photosynthetic activity (Peñuelas & Filella, 1998).

$$\text{Red Edge NDVI} = \frac{(\text{Band}\,4 - \text{Band}\,3)}{(\text{Band}\,4 + \text{Band}\,3)}.$$

We selected early dry season imagery to minimize confusion between woody tree cover and herbaceous grass cover in our classification. NDVI values were used to create a mask of woody and nonwoody pixels at the native 5-m resolution of the imagery for further analysis.

A linear spectral unmixing approach (Asner, Levick & Smit, 2010) was applied to the 'woody' pixels masked in the NDVI analysis to derive subpixel proportions of woody cover, grass and soil. We digitalized the three endmembers on screen in Google Earth using a base map of WorldView-2 imagery (DigitalGlobe, Longmont, CO, U.S.A.) with a spatial resolution of 0.5 m. Linear spectral unmixing was performed in ENVI 5.0 (Exelis Inc., Tysons Csorner, VA, U.S.A). We calculated woody cover values of the farm area, waterhole vicinities (using the following parameters: radius = 1 km, area = 3.14 km^2) and the 50% Kernel estimates (core areas) using raster statistics functions in QGIS.

Statistical analysis

We used SigmaStat 3.5 (Systat Software, Inc., Bangalore, Karnataka, India) software to run the statistical analysis for the comparison of camera trap images related to the animal's seasonal and circadian activity patterns. We performed one-way analysis of variance (ANOVA) as well as Kruskal–Wallis one-way ANOVA on ranks whenever the normality test failed. We present the arithmetic mean (AM), the standard deviation (SD) and the standard error of the mean (SEM).

Results

Camera traps

During 752 CTDs (92% of the total CTDs), one or several rhinos were indirectly observed at the different waterholes in contrast to only 72 days (48 in March–April and 24 in May–June), during which no rhinos have been observed. The number of images related to an individual rhino varies between n = 1410 images (female 'Juno') and n = 2127 images [female 'Cleo' (AM: 1579.8, SD: 373.7)].

Preferences for specific waterholes

The number of images taken at the different waterholes is not evenly distributed (Fig. 1). Rhinos (all visits pooled) seem to clearly prefer the waterhole 'Omuramba', where n = 2685 rhino images (48.5%) were captured. The next most frequently visited waterholes were as follows: 'Kamakende' (17.1%), 'E-sued' (14.4%), 'Grosse Traenke' (7.5%), 'Pennyberg' (5.5%), 'E-nord' (3.6%) and 'Wilde Hunde' (3.4%). Mean percentage of images captured is AM = 14.7% (SD = 16%).

Circadian waterhole visits and seasonal responses

Each individual rhino showed increasing frequency of image events over the course of the 4-month study. R^2 varies between 0.05 (female 'Cleo') and 0.11 (female 'Gaya'). Thus, individual data were pooled to obtain a general pattern (Fig. 2). Kruskal–Wallis one-way ANOVA indicates a highly significant increase of rhino images

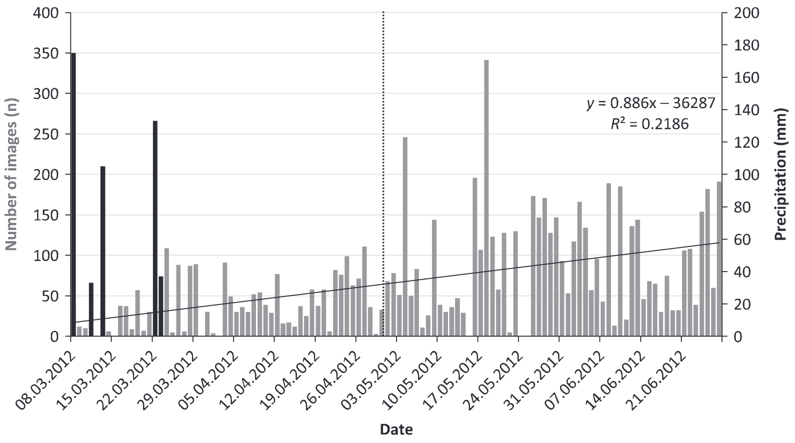

Fig 2 Daily frequency of rhino images (n = 5302) taken at the seven waterholes and precipitation in the study area. There is a significant increase of indirect observations over the course of the study; the function of this linear regression (black line) is also given. Transition from rain to dry season indicated by dotted line, precipitation indicated by black bars

captured during the dry season, when compared to the wet season 2012 ($P = 0.001$, $H = 21.5$, d.f. = 1).

The circadian distribution of images shows that rhinos visited the waterholes only during certain times of the 24-h period (Fig. 3): all animals were exclusively observed during the evening, night and early morning hours, whereas the late morning, midday and afternoon hours of the day were completely avoided. The circadian activity pattern shows a peak of activity between 7 p.m. and 8 p.m. (48.2% of images captured). Kruskal–Wallis one-way ANOVA revealed significantly more rhino images captured between 7 p.m. and 12 p.m., when compared to the time period between 1 a.m. and 6 a.m. ($P = 0.002$, $H = 8.3$, d.f. = 1). We found no obvious indication for a change in this circadian profile over the study period.

Temporal shifts in association indices

The majority (82.7%) of images suggests that the rhinos in the study area are solitary. However, a total of n = 949 images show 2 (16.2%) and n = 58 images (1%) show three animals at the same time. A total of four images (0.1%) are proving that even all four rhinos were gathering at 'Omuramba' during the same time (Fig. 4). Images showing two or more rhinos drinking at the same time were associated with the respective individuals. During the first 2 months of the study, most images of rhinos drinking together show the male rhino and female 'Cleo'. During the following 2 months, by contrast, most images of rhinos drinking together show the male rhino and female 'Juno' (Table 1).

VHF radiotelemetry

The male's activity area (100% MCP) comprised 65.8 km^2 and covered 75.8% of the potentially usable area of 87 km^2 (n = 38 fixes). The activity area of female 'Cleo' comprised 50.2 km^2 (57.7%, n = 10 fixes), and the activity area of female 'Juno' comprised 58.6 km^2 (67.4%, n = 19 fixes). Gaya has not been included into this analysis, as this animal's VHF signal was off since February 2012.

The activity areas of these three rhinos show a high degree of overlap: the males' MCP comprises both of the females' MCPs ($V = 1$) and the MCPs of the two females show an overlap of $V = 0.92$.

Kernel density estimations show that the male rhino established a core area (50% Kernel) in the north-eastern section of the reserve with an area size of 14.1 km^2. The uncorrected and the corrected 95% Kernel covered an area of 64.6 and 52.2 km^2, respectively. The male rhinos' core area comprises the most frequently visited waterhole 'Omuramba' (Fig. 1).

Woody cover estimation

Spectral analysis shows that large proportions of the farm's woody cover were distributed around the farm's hill ridges, the north-eastern section as well as the south-western parts. The south-western corner is situated in a considerably lower altitude than the ridges (Fig. 5). Woody cover of the associated fractions of the south-western corner was among the highest of the area, comparable only to the hill regions. The flat areas, mainly situated in the northern and

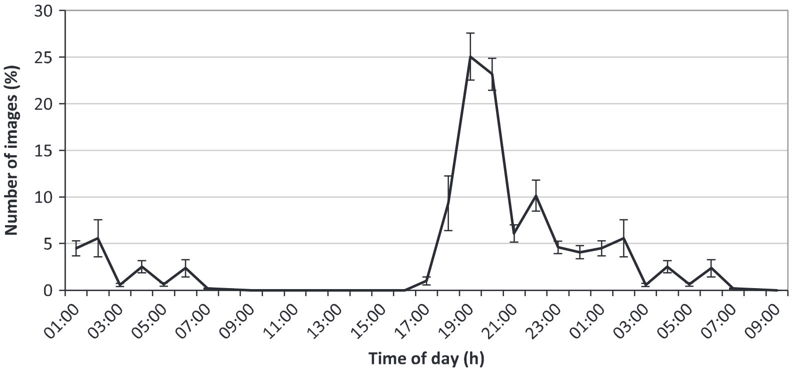

Fig 3 Arithmetic mean (AM) and SEM of the percentage activity per hour calculated from all rhino images per waterhole. For better interpretation, a 32-h interval is displayed. While there is a clear peak of activity between 07:00 p.m. and 08:00 p.m., between 08:00 a.m. and 04:00 p.m. no images were captured at all

Fig 4 ‘Omuramba’ was the most frequently visited waterhole and the site for most of the intraspecific encounters. Moreover, all images displaying more than two rhinos at the same time were taken at this place

Table 1 Table of similarities

	Anthony	Cleo	Juno	Gaya
(1)				
Anthony				
Cleo	**604**			
Juno				
Gaya		463	120	
(2)				
Anthony				
Cleo	126			
Juno	**393**	70		
Gaya	75	200	30	

Coefficients of associations are given for March/April (1) and May/June (2). The higher the coefficient of association, the stronger the particular dyad (bold values emphasise the strongest associations). The data are indicating a dynamic group structure with differently strong pronounced dyadic associations during the study period.

central parts of the farm, were characterized by rather sparse and patchy woody vegetation. These areas were dominated by large, open grasslands and bare soil. The corresponding woody fractions were therefore quite low. Mean woody cover values (%) have been calculated for the farm area (AM = 18.3, SD = 19.8), the male’s core area (AM = 26.8, SD = 19.8) and in the direct waterhole vicinities. ‘Wilde Hunde’ (AM = 24.6, SD = 20.5) and ‘Omuramba’ (AM = 24.3, SD = 18.9) were the most densely covered waterholes with almost equivalent woody cover values. ‘E-sued’ (AM = 23.2, SD = 17.9) and ‘Pennyberg’ (AM = 22.1, SD = 20.7) were slightly less dense covered with similar values. ‘Grosse Traenke’ had a mean cover of AM = 17.3 (SD = 18.6), and the least densely covered waterholes were ‘Kamakende’ (AM = 8, SD = 13.9) and ‘E-nord’ (AM = 5.1, SD = 10.4).

Discussion

Social organization

Black rhinos are described as solitary with only temporary social bonds between females and their offspring or during copulation (Goddard, 1966; Mukinya, 1973). This understanding influences current rhino research and management (Linklater *et al.*, 2012). However, a number of studies highlight the fact that social interactions between individuals do occur beyond the level of reproduction: in Kenya, Tatman, Stevens-Wood & Smith (2000) found groups of females and subadult animals of different sex and age sharing a common home range with one breeding male. Göttert *et al.* (2010) reported rhinos forming social units after their re-introduction in Namibia, and Anderson (2013) stressed the significance of pre-existing social bonds in translocated rhinos in South Africa.

In our study, one male and three females were released into a novel environment 1 year prior to this investigation. The social indices (activity area overlap and multiple occasions at waterholes) illustrate that social interactions between females occurred occasionally and that the dominant breeding male incorporated the areas of two females. The male was in a position with no sources of intraspecific aggression (defence over reproductive resources), and the females were in a reproductive age. This explains the clear shift in the strongest dyadic interactions within the group, given that mature males are known to follow females in oestrus (Goddard, 1966). Moreover, the size restrictions of the fenced area create an artificially induced situation, which might also explain the degree of activity area overlap and multiple occasions at waterholes. However, it is reported that sudden shifts in the social organization of black rhinos are likely to occur (Lent & Fike, 2003; Göttert *et al.*, 2010). Despite the relatively short study period (4 months including fractions of wet and dry season), the study design (stationary camera traps at waterholes) enabled to detect this sudden social shift.

Spatial organization

The largest recorded black rhino home ranges are found in Namibia; maximal home range sizes of 441.2 km^2 (Hearn,

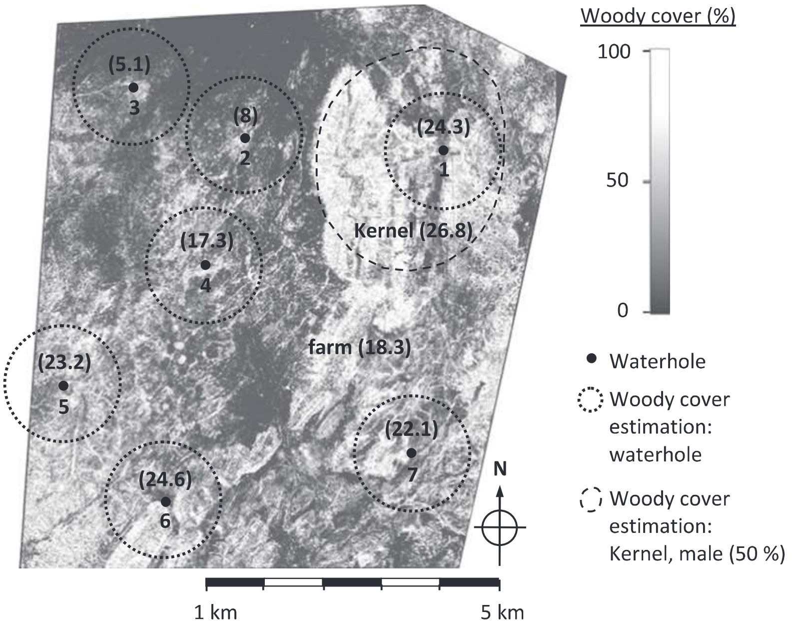

Fig 5 Distribution of woody cover values within the study area as revealed by spectral analysis. Mean values were calculated for the male's core area (dashed line) and in a 1-km radius of each waterhole (dotted line). Woody cover values (AM) are indicated by parenthesized numbers

Loutit & Uri-Khob, 2000) and 243.6 km^2 (Göttert *et al.*, 2010) were reported. With regard to the available size of the study area, the investigated individuals exhibited very large activity areas using most of the available area. This is particularly illustrated by the activity area size (100% MCP) of the females 'Cleo' and 'Juno', when considering the relatively low number of fixes. The combination of camera traps and radiotelemetry (core area of the male rhino) leads to the assumption that spatial dimensions gained from a carefully considered trap design might accurately reflect the true spatial organization of a rhino.

Activity patterns

Estimations based on direct observations at waterholes assume that drinking occurs between 7 p.m. and 10 p.m. (Joubert & Eloff, 1971) and 7 p.m. and 9 p.m. (Mukinya, 1977). Our data are referring to 24-h waterhole monitorings. The results specify drinking behaviour reported in literature, showing that drinking and waterhole visits can occur during the whole night (from 5 p.m. to 9 a.m.) with a main peak from 7 p.m. to 8 p.m.

Seasonal responses

Increasing frequency of photographic events at waterholes from wet to dry season demonstrates a clear seasonal response. This shift in intensity in drinking activity during the period of study can be regarded as a seasonal behavioural change (Fig. 2). High temperatures during the day and the decrease of rainfall by the end of April led to a complete evaporation of surface water in the field. The vegetation dried out and water contents in rhino fodder plants decreased over time. Over the course of the study, demand for water by rhinos increased consistently and waterholes were more frequently visited.

Habitat use and preferences

According to Conway & Goodman (1989) and Berger & Cunningham (1995), the most important black rhino habitat features are as follows: availability of water, availability of food and cover and the absence of human disturbance. The optimum black rhino habitat appears to be dense tree and shrub savannah and open woodland (Hitchins, 1969; Joubert & Eloff, 1971). Our study reveals that rhinos (all visits pooled) showed a clear preference for one specific area ('Omuramba').

Remote sensing analysis and woody cover estimations of direct waterhole vicinities and the male's core area suggest positive correlations between favoured habitat types and the density of woody cover. The area around the most frequently visited waterhole ('Omuramba') was the second most densely covered waterhole. However, three other waterholes ('Wilde Hunde', 'E-sued' and 'Pennyberg') were also characterized by high woody cover values. These areas have, nevertheless, only infrequently been visited by rhinos when compared to 'Omuramba'. This suggests that habitat type and the availability of food and shelter are only some of the criteria leading to the preference for a certain waterhole. These areas play an important role in a black rhino life cycle, and it is very likely that the reasons for an animal to visit these places go beyond simple drinking behaviour.

Conclusion

This study was conducted 1 year after the re-introduction of a black rhino starter group. Our results suggest that the animals acclimatized to this particular area, establishing a social organization prior to the start of our investigation. The spatial dimensions of activity areas correspond with results from other studies in Namibia. All animals used most parts of the 87 km^2 fenced reserve, while preferring certain areas. Although the area may facilitate further breeding success and additional adult rhinos, spatial limitations might cause conflicts when several breeding bulls were present in the area. The area obviously does not facilitate a self-sustaining population. However, re-introductions of black rhinos to fenced reserves along the southern border of the ENP may not only reinforce ecosystem services or economic benefits gained from ecotourism. The sum of all released satellite populations holds important key positions in protecting the metapopulation. The selective opening of fences at strategically sensible locations could help to establish a more connective situation and enable genetic exchange between rhinos from ENP and adjacent reserves.

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