Tierärztliche Hochschule Hannover

Aus dem Deutschen Primatenzentrum Göttingen, Leibniz Institut für Primatenforschung
und dem Institut für Tierhygiene, Tierschutz und Nutztierethologie

On the acclimatisation of African rhinoceros after re-introduction to former livestock farmland in Namibia

INAUGURAL - DISSERTATION
zur Erlangung des Grades eines
Doktors der Naturwissenschaften
- Doctor rerum naturalium -
(Dr. rer. nat.)

vorgelegt von

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Haldensleben

Hannover 2011

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Tag der mündlichen Prüfung: 14.02.2011

It takes a very long period of observing to become really familiar with an animal and to attain a deeper understanding of its behaviour; and without the love for the animal itself, no observer, however patient, could ever look at it long enough to make valuable observations on its behaviour.

Konrad Lorenz

Meinen Eltern

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CHAPTER I: GENERAL INTRODUCTION

African rhino population dynamics

All five extant rhinoceros species are threatened with extinction to varying degrees and have become uncommon outside of reserves (Khan 1989, Gakahu 1993). Throughout their natural range, African rhinos are facing conflicts with humans and will only survive within intensively guarded sanctuaries. From the arrival of European settlers in Africa onwards, anthropogenic influence, more precisely thoughtless and unsustainable hunting, has caused a dramatic decline in rhinoceros numbers.

The black rhinoceros *Diceros bicornis* Linnaeus 1758 population declined from several hundred thousands of animals in the early 20th century to approximately 100,000 individuals left in 1960. With a rising demand for rhino horn in the Middle East and Asia, a period of poaching further reduced the population down to 2,410 animals remaining in the wild in the 1990s (IUCN 2010). This decline in population size has forced conservation authorities to protect remaining animals in relatively small, intensively guarded or fenced key areas and sanctuaries and within breeding programmes in captivity. Despite some recovery in a few countries in recent years, there is still concern that today's small, isolated, and scattered subpopulations are not growing quickly enough to resist poaching effects (Kingdon 2003, Hutchins and Kreger 2006). Often reproductive output of translocated black rhinos is low coupled with high intra-specific fighting mortality (Brett 1998, Du Toit 2002), and it remains uncertain, if the species can withstand the effects of poaching in the future.

The population of the southern white rhinoceros *Ceratotherium simum simum* Burchell 1817 was reduced to one small population of 20 + individuals, located in Kwa Zulu Natal, South Africa by the end of the 19th century (IUCN SSC African Rhino Specialist Group 2008). Only due to intensive conservation efforts, including translocation procedures to small reserves and privately owned land (Pienaar 1970, Emslie and Brooks 1999, Rookmaaker 2000) was the population able to recover to a number of 17,480 individuals living in the wild in 2007 (IUCN SSC African Rhino Specialist Group 2008). Despite this positive development, 93 % of this population is concentrated in South Africa (IUCN SSC African Rhino Specialist Group 2008), with animals having a patchy distribution on isolated areas and in countless relatively small and fragmented subpopulations. These subpopulations are more vulnerable to demographic extinction, diseases, epidemics, genetic drift and inbreeding (Lacy 2000, Reed 2005). In fact, current successful conservation efforts for white rhinos are based on state expenditure, and if conservation budgets would decline, rampant poaching could seriously threaten numbers. Just recently, Damm (2010) reported on the worsening rhino crisis in the southern African subregion, where after over 180 rhino have been killed between January and August 2010 only in South Africa.

The *in-situ* conservation of metapopulations for African rhinos is of major importance because 1) relatively large tracts of habitat still exist, 2) mortality in *ex-situ* populations is high and captive African rhino populations are currently not self-sustaining (Carlstead and Brown 2005), and 3) annual *per capita* cost for *in situ* programmes are consistently lower when compared to budgets for captive African rhino programmes (Balmford et al. 1995).

Namibia's importance for rhino conservation

Namibia looks back to a fairly long history of wildlife conservation initiatives starting during German colonial rule in 1892, when first regulations for hunting were proclaimed. Another important step was a modification of the hunting law in 1967, after which the landowner automatically became owner of wildlife, including all rights of utilisation (Barnard et al. 1998, Göttert and Zeller 2008). That is why numerous farmers changed their strategy and started farming with wildlife instead of small livestock (mainly sheeps and goats) and cattle. The tourism industry within Namibia is the countrie's fastest growing income sector and heavily relies on wildlife. This is one major reason why utilisation of wildlife is becoming more interesting for landowners than the farming with cattle and small livestock (Vorläufer 2003). As a result, quality of vegetation and fauna increased rapidly on former livestock farms.

Namibia has become a stronghold for both African rhino species. The country has today approximately 1/3 of the entire *in-situ* black rhino population. The country includes > 95 % of the desert-adapted, south-western subspecies *Diceros bicornis bicornis* Linnaeus 1758 with the largest subpopulation in the Etosha National Park (ENP) (Stanley-Price and Dublin 2000). After population decline in the 1970s, Namibia's conservation authorities managed to rapidly breed black rhinos to high densities at state protected areas from 300 individuals in 1980

(Emslie and Brooks 1999), 700 individuals in 1999 (Erb 1999) to 1,390 individuals in 2007 (IUCN 2010). Du Preez (2010) even estimated a total of 1,461 individuals in 2007 and 1,694 individuals in 2010. Up until 1985, *Diceros b. bicornis* occurred in only two populations in Namibia (Erb 1999): the Damaraland population and the Etosha population. Since then, rhino have been re-introduced into conservation areas and private land in Namibia. Due to sparse human settlement, usable habitat without resident black rhinos remains in Non Governmental Organization (NGO) areas.

More than 90 % of the southern white rhino population is distributed to South Africa, and only three further countries hold over 300 individuals each: Zimbabwe, Kenya and Namibia. Together, these three countries conserve over 82.5 % of the subspecies outside of South Africa (IUCN SSC African Rhino Specialist Group 2008). Therefore, Namibia plays an important role for development of the southern white rhino population. Before 1900, white rhinos were extinct in present day Namibia. In 1984, a total of 70 individuals were present in Namibia. On July 21, 1995 a total of ten southern white rhino individuals were translocated from Kruger National Park in South Africa to the ENP in Namibia (Mishkin 1995). These were the first white rhino after 100 years in the area of ENP. At this stage, white rhinos had been re-established in Waterberg Plateau Park and on several game farms (Mishkin 1995) in Namibia.

In an effort to establish viable black rhino populations, the Rhino Custodianship Scheme has successfully relocated surplus animals from state to private land since 1993 (B. Kötting, Etosha Ecological Institute, personal communication). Black rhinos were translocated from state protected areas like ENP, Waterberg Plateau Park, Hardap Recreation Reserve and Mangetti Game Camp. Although black rhinos are property of the country, the landowner is responsible for the animals. Between 1993 and 2006, a total of 143 animals were translocated from the above mentioned parks to private areas. A further 25 animals were shifted between private areas sizing between 50 km^2 and 650 km^2, with an average size of 150 km^2. At the south-western border of the ENP, for example, black rhinos were translocated to fenced areas that can be connected in the future, implicating the long term opportunity to allow genetic interactions between individuals from adjacent farms and even the ENP.

The relationship between translocation and acclimatisation: implications for rhino management

Translocation is an invasive procedure that forces rhinos to quickly adapt to a new environment and to locate resources, while simultaneously avoiding predators and interacting with mating competitors. Ideally, translocated rhinos should quickly establish natural, species-specific behaviour, relating to physiological requirements, social status and reproductive activity. Depending on ecological differences between the capture and the release site, rhinos need to acclimate to the new environment to varying degrees. Directly after release, rhinos need to quickly find important resources, such as water, food and shelter. This can, for example, result in increased exploration and movement of great distances in search of appropriate habitat. Jnawali and Wegge 1993 observed wide dispersal (15 - 40 km) of some individuals of an Indian rhino *Rhinoceros unicoris* Linnaeus 1758 founder group after release. In the longer term, rhinos have to establish home ranges and activity patterns according to metabolic requirements and habitat type and quality. Furthermore, rhinos have to organise within a social structure, which is required for reproductive success. Finding adequate food and water, avoiding predators, ultimately fighting over mating opportunities and resisting diseases are likely to be distressing events that can influence animal health and finally translocation success. Such individual responses, which have not been systematically and comprehensively studied, are of considerable importance for the development of improved and more effective conservation strategies. Frequently, however translocation procedures disregard the species-specific requirements, which can cause stress, harm the animals and place the entire procedure at risk for failure (Teixeira et al. 2007).

Although several authors highlighted the importance of post-release monitoring of translocated rhinos for successful metapopulation management (Hutchins and Kreger 2006, Emslie et al. 2009), surprisingly little attention has been given to the post-release acclimatisation processes of translocated rhinos (Göttert et al. 2010). Whereas the word ‘adaptation’ mainly refers to processes occurring at an evolutionary and population level, acclimatisation (or acclimation) refers to potentially beneficial shifts in physiological parameters (physiological acclimatisation), complex perception and cognition (cognitive acclimatisation), and sets of behavioural and physiological correlates (behavioural acclimatisation) of individual organisms with respect to a multistress environment (Hart 1957, Prosser 1958, Eagan 1963, Mazess 1975).

Study objectives

The primary goal of this thesis was to generate data on the acclimatisation response of a six individual black rhino starter group and a seven individual white rhino starter group after release at a specific area (Etosha Heights/Moesamoeroep farm complex) at the direct south-western border of the Etosha National Park in Namibia.

In order to set out the background for this study, the initial objective was to **characterise the habitat** into which the rhinos were released. The specific aims were:

- to characterise general features of the study area (size, climate, geology, land use)
- to systematically monitor the vertebrate fauna at the study area
- to assess the vegetation types of the study area

The second objective was to describe aspects of the post-release **cognitive and behavioural acclimatisation** of the black rhino starter group and a subadult white rhino male after release into the study area. The specific aims were:

- to systematically investigate the ranging behaviour of the rhinos with particular focus on: i) exploration behaviour, ii) establishment of home ranges and activity centres, and iii) settlement patterns and settlement periods
- to investigate the habitat use of the rhinos by complementing movement data with habitat descriptions (plant species richness, composition, height, cover and indices of diversity)
- to describe the establishment of the social organisation of the rhinos (association indices, overlap of home ranges and activity centres)
- to investigate diurnal activity patterns and the response behaviour of the black rhinos towards the observers

The final objective was to generate data on the **physiological acclimatisation** of all studied rhinos. The specific aim was:

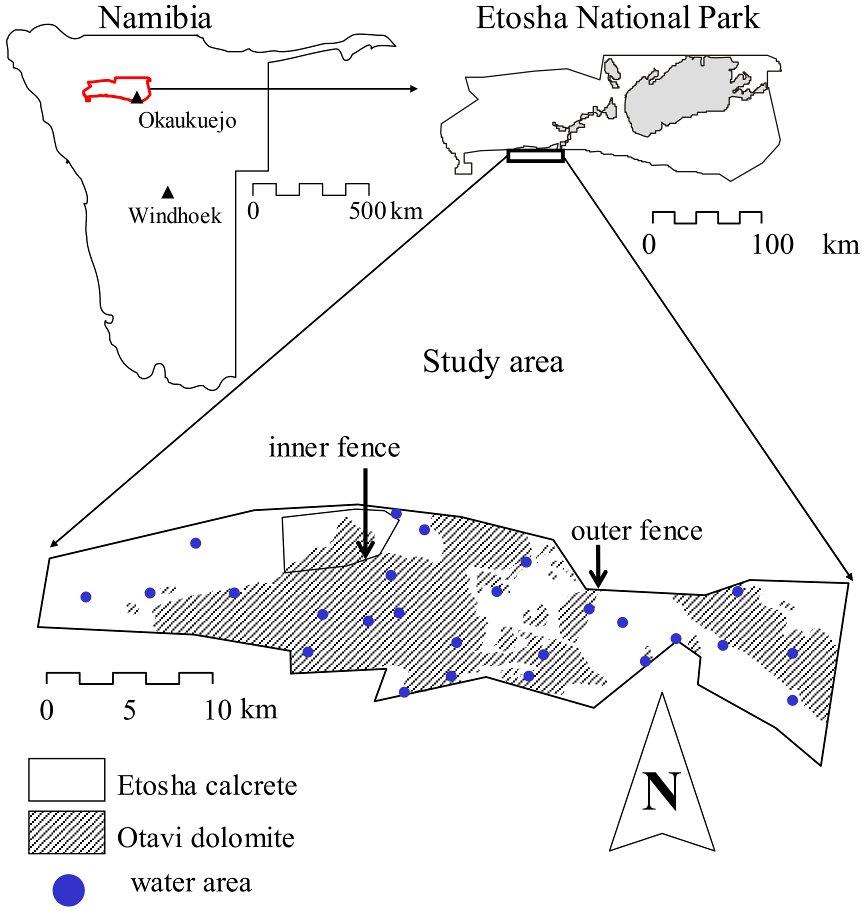
- to evaluate and apply behavioural analyses and faecal hormone metabolite analyses for the assessment of the physiological status

Collectively, these results should provide a framework in part applicable to further studies on acclimatisation responses of relocated African rhinos in Namibia and other countries within the distribution range.

Study area

Position

The study was carried out at the Etosha Heights/Moesamoeroep farm complex in north-central Namibia, approximately 60 km west of the town Okaukuejo and approximately 400 km north-west of the capital city Windhoek. The fenced area of 368 km^2 is situated adjacent to the south-western border of ENP (between 19°12`S and 19°21`S and between 14°54`E and 15°22`E [Map 1]). The study area is relatively large compared to the average areas size of areas participating in the Rhino Custodianship Scheme (150 km^2 [B. Kötting, Etosha Ecological Institute, personal communication]). Excluding 20.4 km^2 of an inner-fenced section leads to a potentially useable area of 347.6 km^2.



Map 1. Etosha Heights/Moesamoeroep farm complex: size, geographic position, geological formations and distribution of water areas.

Geology, soils and vegetation

The area covers an altitude range between approximately 1170 m and 1350 m. It comprises two broad geological substrates: Otavi dolomite (OD) and Etosha calcrete (EC) (Miller 2008). The dolomite hills are dominated by bare dolomite rock at higher altitudes and shallow sandy soil with decreasing elevation. Dolomite hills are characterized by a woodland habitat type with the most diverse community of plants in the area (Mendelsohn et al. 2000). The calcrete substrate features loams, silty loams and clayey loams. It forms a mosaic of different habitat types: Etosha mixed low trees, mopane shrubs and Etosha plains (Mendelsohn et al. 2000). The vegetation ranges from woodland and open tree and shrub savannah (Etosha mixed low trees and mopane shrubs) to fairly open grass- and dwarf scrub savannah (Etosha plains) (Mendelsohn et al. 2000).

Climate

The area is situated in the semi-arid climate zone with rain falling variable and patchy. Precipitation shown below was measured at two cattle farms, which are adjacent to the southern border of the study area: the farm 'Kronendaal' (data: J. Burger) and the farm 'Uitspruit' (data: K. Burger). The mean annual precipitation amount at 'Kronendaal' between 1986 and 2006 was 281.5 mm (SD: 108.8 mm), with exceptionally high precipitation during the study period (2005: 347 mm, 2006: 442 mm). Over this 20 years period there was a significant increase of the annual precipitation value (Figure 1c). Accordingly, it has been noted that especially the 2005/2006 austral summer was anomalously wet over large areas of southern Africa (Muller et al. 2008). As typically for this region, rain falls in the summer month (between October and April) but mainly between January and April (Mendelsohn et al. 2002), as indicated by the monthly precipitation at the farm 'Uitspruit', measured between January 2003 and February 2007 (Figure 1a). The study period was characterised by good rains in 2005, exceptional good rains in 2006 and very little precipitation during the end of the investigation in January and February 2007. Information on temperatures has been obtained from the weather station in Okaukuejo (http://www.weatheronline.co). Mean maximum daily temperatures during the hottest months (October – January) are above 35 °C. The coolest months are June and July with mean lowest night-time temperatures of 7 °C (Figure 1b).

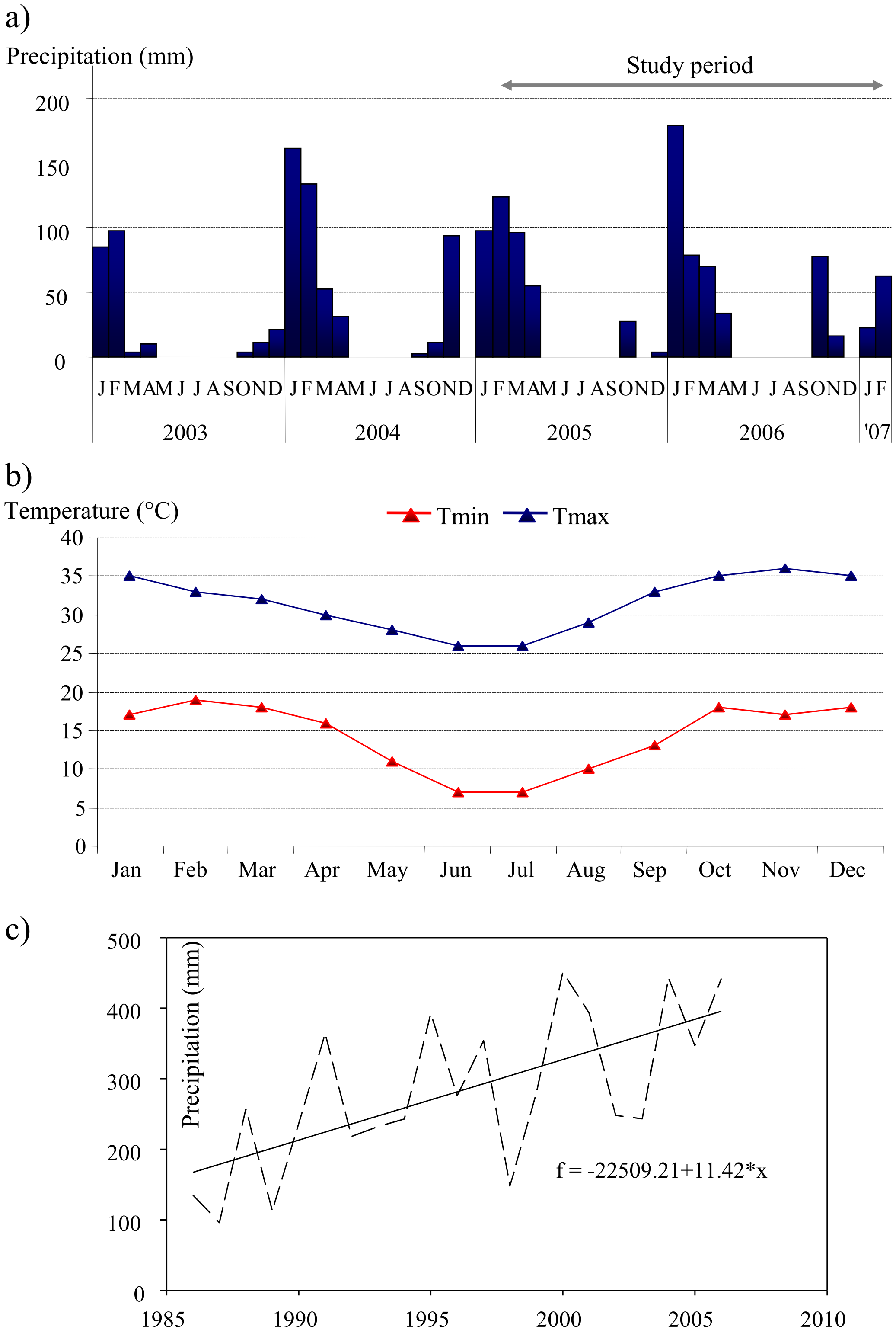
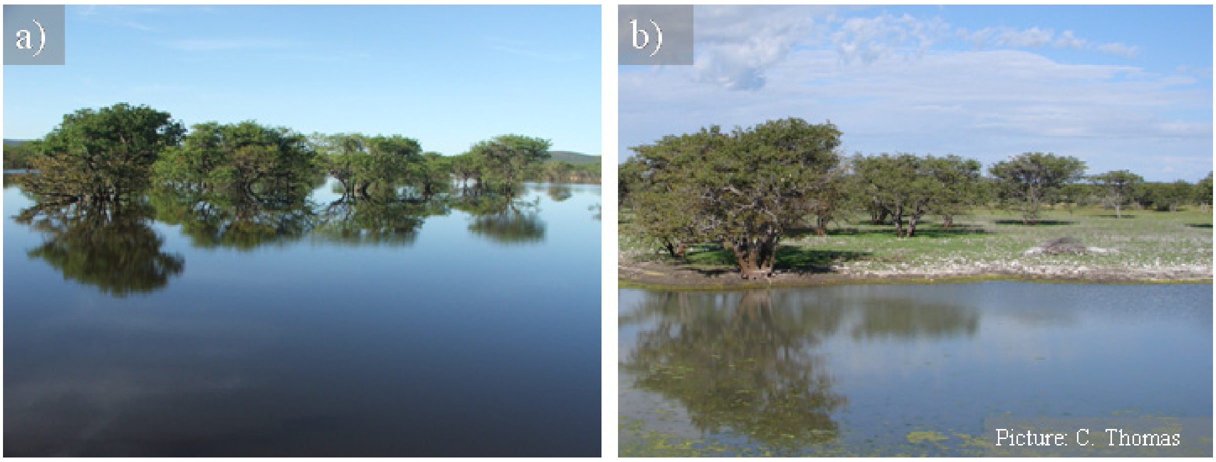


Figure 1. a) Monthly precipitation at the farm 'Uitspruit' between January 2003 and February 2007, b) mean maximum and minimum daily temperatures at the weather station in Okaukuejo, Etosha National Park. Data were obtained from ULR: http://www.weatheronline.co and c) annual precipitation at the farm 'Kronendaal' between 1986 and 2006. The polynomial linear regression model is: f = y0+a*x, R = 0.65, F (ANOVA) = 13.97, p = 0.0014.



Picture 1. Ephemeral water body at the study area. a) photo taken on Jan 08, 2006, b) photo taken on Apr 12, 2006.

Land use

In 1907 the former Game Reserve No. 2 (today Etosha National Park [ENP]) was proclaimed by the governor of *Deutsch-Südwestafrika*, Dr. Friedrich von Lindequist. It covered fairly 80.000 km^2 and incorporated the natural migration patterns of wildlife (Barnard et al. 1998). Between 1947 and the early 1970s, the borders of the park were changed several times and finally, the park was dramatically reduced to its present size of 22.912 km^2. Additionally, the entire park was surrounded by an 850 km game fence.

The study area is part of the 'Gagarus-block', a sector which was cut off from ENP area in 1947 (Ministry of Environment and Tourism 2007). Since the early 1960s the study area was divided into six private fenced livestock farms (from W to E: Grenswag, Eensgesind, Seringetti, Leeurante, Sonderwater, Moesamoeroep), of which each was under the use of livestock farming for approximately 40 years. Between 2001 and 2004, the study area was converted into a wildlife conservancy by removal of livestock and internal fences, drilling for additional perennial waterholes and the relocation of several ungulate species. During the study period there was a density of 0.07 water sites per km^2, and the average human population density was 0.14 inhabitants per km^2. The largest human aggregation was a hamlet of approximately 30 people.

Animals and Translocation procedures

Between November 2004 and April 2005, a six individual black rhino starter population was released into the outer-fenced section of the study area (p. 6). On Jun 11, 2006, one white rhino individual (subadult male 2) was additionally released into the outer-fenced section. Between May and August 2006, a six individual white rhino starter population was released into the inner-fenced section of the study area (p. 6).

Black rhinos

Animals

On Nov 5 and 6, 2004, two subadult males (age: 2.5 and 5 years) were translocated from a NGO area south of ENP (linear distance between capture and release site: 231 km), where they already formed the first generation after reintroduction within the Rhino Custodianship Scheme. The subadult males were translocated four month before data was officially collected and settlement behaviour during that time was not investigated. Introduction of subadult males took place into an area abandoned by rhinos for over 100 years, featuring no intra-specific olfactory cues at all.

Between Apr 7 and 12, 2005, four additional rhinos were translocated from ENP (linear distance between capture and release site: 101 km - 144 km, Table 1). This group consisted of one adult male (age: 11 years), one female adult (age: 12 years) and two subadult females (age: 3 years). Two of these rhinos (female adult and subadult female 2) were captured at the same area in ENP (Rietfontain) on consecutive days. Hence, these rhinos might have been familiar with each other before translocation. The adult male was at an age, when it would normally enter the status of a breeding bull. The adult female was proven to be fertile as it was leading a young when captured. This young was at an age when it was not dependend on its mother anymore. Habitats at capture and release sites were similar for all six black rhinos.

Table 1. Translocation data for the black rhino founder group.

	Subadult ♂1	Subadult ♂2	Adult ♂	Subadult ♀1	Subadult ♀2	Adult ♀
Date of relocation	5/11/04	6/11/04	7/4/05	12/4/05	11/4/05	12/4/05
App. age (years)	2.5	5	11	3	3	12
Shoulder height (m)	1.22	1.43	1.52	1.44	1.52	1.51
Head circumference (m)	1.04	1.24	1.42	1.22	1.25	1.35
Capture site	farm/ Okosongoro	farm/ Okosongoro	ENP/ Gemsbokvlakte	ENP/ Khurus	ENP/ Rietfontein	ENP/ Rietfontein
Site distance (km)[1]	231	231	101	132	137	140
Group composition at capture site	with cow + subadult ♂ 2	with cow + subadult ♂ 1	single	with cow	with cow	with calf

[1] linear distance between capture and release site

Translocation procedures

Hard-release translocation (same day capture release) was carried out by different teams within the Rhino Custodianship Scheme. Rhinos were immobilised from helicopter, using darts rifles with steel barrels (3 cc) and 60 mm barbed stainless steel needles. Black rhinos were knocked down with a mixture of 2-7 mg of the neurolept analgesic Etorphine Hydrochloride (M99), 80-160 mg of sedative Azaperone (Stresnil) and 5000 iu of Hyaluronidase (Hyalase) in order to increase rate of absorption of drugs (Dr. M. Jago, Namibian capture veterinarian, personal communication). After capture, eyes and ears were protected with rags, additional oxygen was given, pulse oximetry was measured (Morkel and Kennedy-Benson 2007) and diurnal active radio-transmitters (frequency range: 148.4 - 150.9 MHz) were inserted into one of the horns.

Black rhinos were ear-marked and age was estimated according to the only available tooth wear method after Hitchins (1978), which is based on the count of cementum lines of the first permanent molar. At the scene, age estimates are very difficult as the animal’s mouth would have to open all the way to look at the entire row of teeth. In animals younger that seven years and older than ± 30 years, age can be determined fairly accurately in the field but between eight and 29 years a lot of wrong estimates (usually underestimates) do occur (B. Kötting, Ethosha Ecological Institute, personal communication). Estimation depends on the experience of the veterinarian mostly and on other ageing experts present.

For loading, rhinos were reversed with a doze of 60-80 mg Nalorphine (Lethidrone) and 0.5-2 mg Diprenorphine (M5050). After the antagonist was administered, rhinos were crated and transported in especially build crates (3m x1.2m x 1.9m) equipped with a special down lifting mechanism. For offloading, rhinos received Diprenorphine (1.5 x bold Etorphine dosage) that were 50-150 mgs of Naltrexone and coaxed out of the crate, just before they got down and the final check up was preceded. Special importance was given to the avoidance of disturbance. All potential sources were carefully removed and only a minimum of people (veterinarian, e. g. farm owner) accompanied the animal when the antagonist was administered. Translocation procedures lasted between six and 12 hours. Rhinos were released single.

White rhinos

Animals

On May 26, 2006, two animals (subadult male 1 and adult female 1) were translocated from a farm, which is directly adjacent to the study area. The adult female that was chosen for translocation was leading a calf that moved away when the female went down as a result of the capture drug. Inguinal mammae of the female were clearly swollen (Picture 3g), indicating the calf was not weaned at this stage.

On Jun 11 and 27, 2006, two rhinos (subadult male 2 and adult female 2) were translocated from the farm Otjiwa in Namibia. On Jun 26, 2006, subadult male 3 was translocated from the farm Otjisemba in Namibia. With an estimated age of 12.5 years, this male was on the brink to reach the adult status. The rhino was released after dusk and after leaving the crate, it performed a charge against the vehicle before trotting off.

Table 2. Translocation data for the white rhino founder group.

	Subadult ♂1	Subadult ♂2	Subadult ♂3	Juvenile ♂	Adult ♀1	Adult ♀2	Adult ♀3
Date of relocation	26/05/06	11/06/06	26/06/06	03/08/06	26/05/06	27/06/06	03/08/06
App. age (years)	8.5	8.5	12.5	2.5	≥15	≥15	≥15
Capture site	Safarihoek (Nam[1].)	Otjiwa (Nam.)	Otjisemba (Nam.)	Stoffberg (RSA[2])	Safarihoek (Nam.)	Otjiwa (Nam.)	Stoffberg (RSA)
Transport duration (h)	1.5	6 - 7	7 - 8	>60	1.5	6-7	>60
Additional information	-	-	-	-	-	-	aborted calf

In June 2006, three animals have been chosen to be translocated from Kwanare Trading Pty Ltd, Stoffberg, South Africa. One male died during the boma adaptation at the area of origin. Remaining two rhinos (juvenile male and adult female 3) were transported in two individual crates. The vehicle left in the morning hours on Aug. 01, 2006 in Stoffberg. Owing to complications at the border between Botswana and Namibia, rhinos arrived at the destination area on Aug 03, 2006 at 21:30 pm. The female that has aborted a high developed foetus during the transport, immediately left the crate, trotted a few meters and spotted into the direction where the juvenile male was offloaded. After release, the juvenile male did not directly retreat from the vehicle but emitted distress calls (squeeling), facing the transport vehicle for several minutes before both rhinos moved away together.

Similar to black rhinos, one white rhino (subadult male 2) was released into the outer fenced section of the study area, whereas all remaining six white rhinos were released into the inner fenced section (p. 6).

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[1] Namibia

[2] Republic of South Africa

Translocation procedures

White rhinos were immobilised with 1.5-2.5 mg Etorphine Hydrochloride (M99) and 50-100 mg Azaperone (Stresnil). Rhinos were ear marked, prepared for crating and the antidote Naloxone was administered. Subadult male 2 received a diurnal active radio-transmitter into the horn. Partly immobilised rhinos were pulled onto the crate (1.5 x 4.6 m), recovered from immobilisation during transport and were released more or less reversed from the action of the drug. In contrast to black rhino procedures, age of white rhinos was estimated by assessment through an experienced veterinarian and knowledge of the previous owners. All translocated females were at an adult stage, which made it impossible to specify their age in greater detail. These females were probably 15 years of age or older. Translocated males were estimated to be 2.5 years (juvenile male), 8.5 years (subadult males 1 and 2) and 12.5 years (subadult male 3) years old.

Picture 2. Black rhino individuals and translocation procedures: a) subadult male 1, b) subadult male 2, c) adult male, d) subadult female 1, e) subadult female 2, f) adult female, g) additional oxygen treatment while processing the dozed animal for crating, h) age estimation according to tooth method.

Picture 3. White rhino individuals and translocation procedures: a) subadult male 1, b) subadult male 2, c) subadult male 3, d) adult female 1, e) adult female 2, f) adult female 3 and juvenile male, g) adult female directly after release, clearly swollen teats indicate that the calf, the female was leading when captured, was not weaned at that time, h) aborted, highly developed foetus of adult female 3, abortion was probably caused by translocation stress.

Management implications

The conservation status of the investigated two African rhino species differs. The south-western black rhino *Diceros bicornis bicornis* is listed as vulnerable, whereas the southern white rhino *Ceratotherium simum simum* is listed as near threatened (IUCN 2010). White rhinos were bought at auctions for prizes between app. € 5,000 and 20,000, and translocation was carried out by private agencies. Contrary, black rhinos were not sold to private persons at the time of this study, but were managed on the basis of a custodianship within a state conservation programme. As a consequence of this, the quality of the black rhino translocation procedures was following very high standards, whereas the observation of the translocation of white rhinos exposed several problems. One reason may be that the translocation of white rhinos today is a business under the rule of economy and financial interest, especially as rhinos are effective public relations for eco- and trophy hunting tourism industry. This may cause negative influences on the animal welfare, as has been observed regarding one adult female (adult female 1) that was chosen for translocation. This female was separated from its calf at a stage when the calf was not weaned. Another drastic mismanagement was the transport of adult female 3 that was soon to conceive a calf and aborted the foetus during transport, probably due to a transport period of more than 60 hours! It therefore appears that the conservation status may affect the quality of translocation standards, influencing the welfare of animals during the translocation procedure. The conservation status should, however, not affect the professionalism of translocation procedures at all.

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CHAPTER II: ASSESSING BIODIVERSITY AND HABITAT QUALITY IN COMBINATION WITH RHINO MONITORING

Introduction

Measuring levels of biodiversity is a common instrument for assessing the quality of areas, selecting reserves and developing conservation strategies (Kirkpartick 1983, Pressey et al. 1993, Witting and Löschke 1995). The methodological approaches for measuring biodiversity indices range from rapid appraisals to all-taxa biodiversity inventories (Sueur et al. 2008). The thesis in hand aims at characterising the acclimatisation of African rhinos after re-introduction to former commercial livestock farmland in Namibia. Between 1907 and 1947, the studied area has been part of the protected area that was later termed Etosha National Park (ENP). Between the 1960s and the beginning of this century, the study area was used for commercial livestock farming, mainly cattle farming, before it was converted into a wildlife conservancy (p. 9). Overgrazing as a result of intensive cattle farming, coupled with episodic droughts, has caused widespread degradation and loss of floristic and faunal diversity which is unlikely to recover to climax conditions (Du Toit and Cumming 1999, Tews et al. 2004a). It is also known that owing to significantly lower stocking rates, commercial farmland supports a larger and more diverse assemblage of birds and mammals when compared to communal rangelands (Joubert and Ryan 1999). The aim of this chapter is to carry out a state description of the study area at the time of investigation. Therefore, a simple method for measuring the number of vertebrate species (species richness) over time was developed in combination with rhino monitoring procedures. Vertebrates were chosen as they can easily be observed and have been most frequently used in biodiversity inventories (Tews et al. 2004b). Data collection started at a stage, when experience and knowledge on the spatial distribution of rhinos has resulted in defined monitoring procedure, which were established by Dr. J. Schöne, who initiated data collection between February and November 2005 (Schöne 2005). Based on the distribution of rhinos among the study area, observers regularly needed to travel long distances between the camp site and rhino core areas. These tours, as well as additional observations made by the author throughout a 16 months non-stop stay at the study area, form the basis of this investigation. By comparing the species richness at the studied area with state protected areas in Namibia, an assessment of the area's quality is proposed. Also, species monitoring, particularly bird species assemblage, allows making indirect assessments about the occurring habitat types and the structural complexity of the area. Such information is needed to answer the first specific objective of this thesis, which is to describe the specific environment to judge on the study area's suitability for re-introduction of both African rhino species.

Material and methods

Data collection

This investigation is based on observations made during a period of 16 months (between Nov 2005 and Feb 2007) during a non-stop stay of the author at the study area. During most of this period (Nov 2005 – Nov 2006), the author was accompanied by a group of students. Using a 4 x 4 vehicle (Nov 2005 – Oct 2006) and a motorbike (Oct 2006 – Feb 2007), driven at a speed of 20 - 60 km * h^{-1}, identical tours on gravel and sandy roads were regularly driven to reach the rhino core areas. During each of 261 observation days, a tour between 50 km and 150 km was driven. Furthermore, observers additionally walked several kilometres every observation day, often in relatively densely structured rhino core area habitat (chapter III), or at the surroundings of the camp site. Also, the author joint more than ten game drives between dusk and dawn using a spotlight, he carried out more than 20 game drives for tourists during the day hours, and he witnessed several hunting sessions (walk and stalk, playback attraction) during day and night. Throughout the study period, the occurrence of vertebrate species was noted when the respective animal was observed for the first time. For identification of species and the use of taxonomical terms, the following literature was considered: amphibians: Channing (2001), reptiles: Branch (1998), birds: Sinclair and Ryan (2003), mammals: Kingdon (2003), IUCN (2009). Whenever possible, a digital photograph of the animal was taken. The author notes that the term 'reptiles' refers to a paraphyletic group (Westheide and Rieger 2010). However, here the term reptile is used as no assumptions on the systematics are made.

Data analysis

To assess the time frame necessary for sampling saturation of species richness, cumulative species curve method (Wethered and Lawes 2003) was applied for reptiles, birds and mammals. Since data collection forms part of a cumulative assessment over time, the sampling unit was each consecutive day on site. Bird species numbers were pooled according to habitat preferences. Information about species-specific habitat types was obtained from Sinclair and Ryan (2003). Based on this information, ten broad habitat types were defined: 1) catholic, 2) associated with rocky areas, 3) associated with water, 4) grassland and desert, 5) grassland, 6) grassland and savannah, 7) savannah and desert, 8) savannah, 9) savannah and woodland, and 10) woodland, and the number of bird species per habitat type was examined.

To look at seasonal patterns of bird diversity, bird species were listed according to habitat types for a collection period during the wet season (Jan 31 – Mar 21, 2006, 26 tours driven) and a collection period during the dry season (Jul 3 – Sep 3, 2006, 43 tours driven). For comparison of seasonal data, the Sørensen similarity index was calculated (Sørensen 1948):

$$\text{Similarity index } (\beta) = \frac{2c}{(S_1 + S_2)}$$

Where: S_1 = the total number of species recorded in the wet season
S_2 = the total number of species recorded in the dry season
c = the number of species common to both seasons

This index may range from 0 (no species overlap) to 1 (the same species found during both seasons).

Results

In total, 218 vertebrate species were found (1 amphibian species, 24 reptile species, 148 bird species and 45 mammal species). The three cumulative species curves for different taxa plateau out at a certain stage of the investigation, indicating sufficient sampling units (time period of data collection) in order to critically assess the species monitoring (Figure 2).

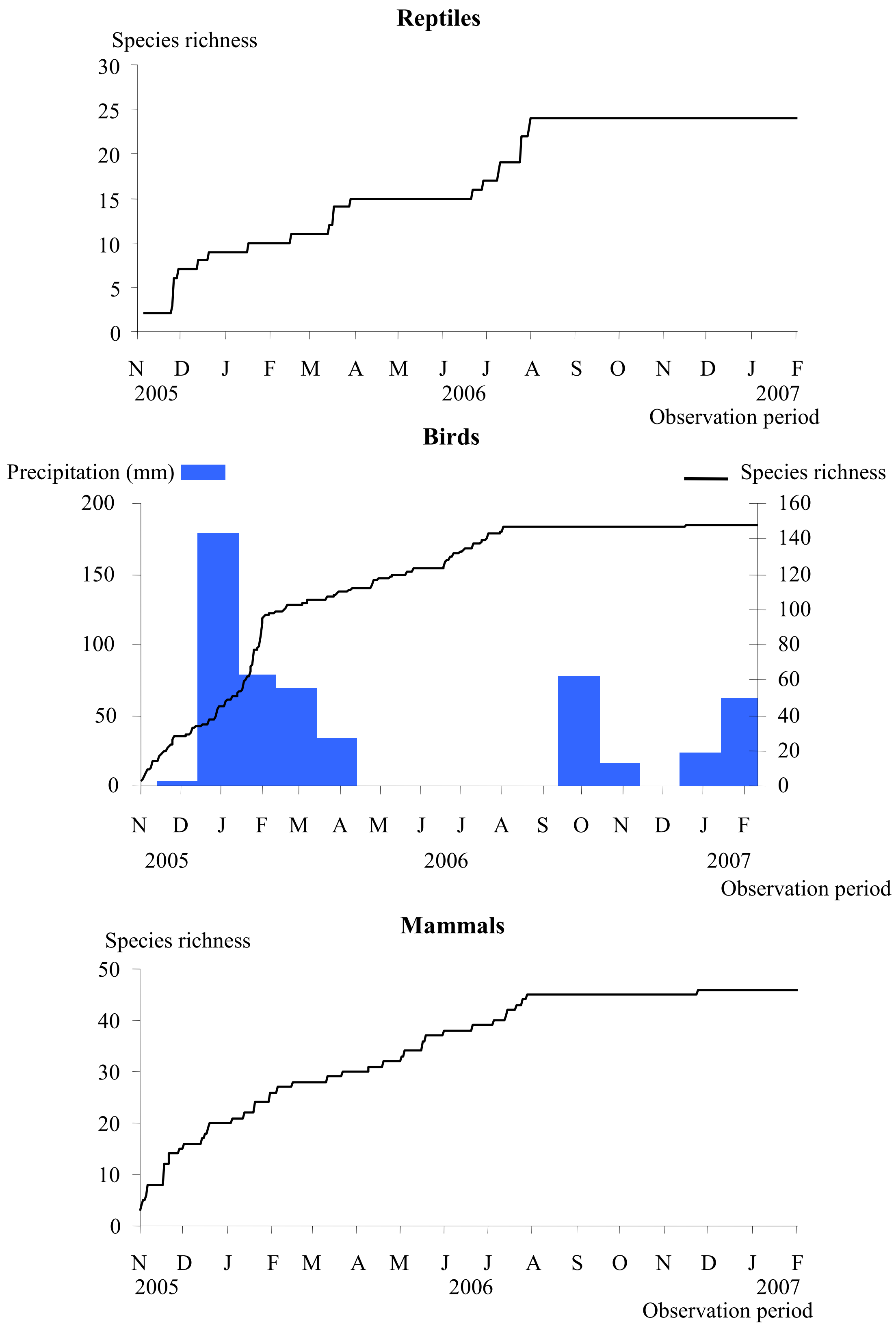

Figure 2. Cumulative species curves of identified vertebrate species over the study period per taxon. Species names according to order of first identification are given in Tables 4-6.

Amphibians

The only observed amphibian species was the African bullfrog *Pyxicephalus adspersus*. The species was proven between January and March 2006, when several ephemeral ponds existed on the plains due to the late and heavy rains at the beginning of the year 2006 (Picture 1, p. 9).

Reptiles

The cumulative species curve for reptiles shows a rather sigmoid progression, indicating the typical asymptotic increase pattern until reaching the 15 species level on Apr 8, 2006 (day 149 after start of the observation). A first plateau phase is reached until the second increase period occurred between Jul 1 and Sep 10, 2006 (233 – 273 days after start of the observation); during this period, 37.5 % of the entire reptile species range was found. The time frame for assessment of the entire species range of 24 species was nine months. All 24 identified species were proven by photographs. Similar to the African bullfrog, the marsh terrapin *Pelomedusa subrufa* was strictly associated with water (found between Jan and Mar 2006) at ephemeral ponds.

Birds

The cumulative species curve for birds is characterised by a rather asymptotic progression. There is a long increase period until the 123 species level (83.1 % of the entire species number) is reached seven months after start of the observation. During this period, there is a sharp increase between Jan 9 and Feb 21, 2006. Following the increase period, there is a short plateau period (between Jun 13 and Jul 5, 2006), after which a second increase period occurred between Jul 6 and Aug 8, 2006, bringing the total to 147 species out of the total 148 bird species that were identified. It took nine months from the start of observation to identify the 147 birds. From the 148 bird species, 66.9 % were proven by photographs. Among others, the following ecological groups of bird species can be identified:

Water associated species

In total, seven water associated species were found (Egyptian goose *Alopochen aegyptaicus*, red-billed teal *Anas erythrorhyncha*, squacco heron *Ardeola ralloides*, blacksmith plover *Vanellus armatus*, three-banded plover *Charadrius tricollaris*, golden bishop *Euplectes afer* and dabchick *Tachybaptus ruficollis*), of which only *V. armatus* and *E. afer* were also found during the dry months of this year (May – Sep). The other five species were strictly linked with water bodies that existed at the study area between Jan and Apr 2006.

Migratory species

From 22 Palaearctic or intra-African migrant species, the following 13 species were only observed during the wet season (Jan – Apr): white stork *Ciconia ciconia*, Abdim`s stork *Ciconia abdimii*, Jacobin cuckoo *Oxylophus jacobinus*, great spotted cuckoo *Clamator glandarius*, European bee-eater *Merops apiaster*, yellow-billed kite *Milvus aegyptius*, black kite *Milvus migrans*, Eurasian hobby *Falco subbuteo*, western red-footed kestrel *Falco vespertinus*, pearl-breasted swallow *Hirundo dimidiate*, plum-coloured starling *Cinnyricinclus leucogaster*, garden warbler *Sylvia borin*, and lesser grey shrike *Lanius minor*.

The following three migrant species were exclusively seen during the dry season (May-Sep): brown snake eagle *Circaetus cinereus*, booted eagle *Hieraaetus pennatus* and Temminck`s courser *Cursorius temminckii*. The following eight migrant species were seen during both seasons: lesser spotted eagle *Aquila pomarina*, tawny eagle *Aquila rapax*, purple roller *Coracias naevius*, rufous-cheeked nightjar *Caprimulgus rufigena*, black-breasted snake eagle *Circaetus pectoralis*, common buzzard *Buteo buteo*, Eurasian hobby *Falco subbuteo* and garden warbler *Sylvia borin*.

Indicators for woodland

Indicators for woodland including old and hollow trees are cave nesting birds, such as barn owl *Tyto alba*, southern yellow-billed hornbill *Tockus leucomelas*, Monteiro`s hornbill *Tockus monteiri*, grey hornbill *Tockus nasatus*, Damara hornbill *Tockus damarensis,* African hoopoe *Upupa africana*, and common scimitarbill *Rhinopomastus cyanomelas*.

Conservation status

Using data presented by Robertson et al. (1998), the bird monitoring revealed four species listed as vulnerable (Marabou stork *Leptoptilos crumeniferus*, lapped-faced vulture *Torgos tracheliotus*, tawny eagle *Aquila rapax* and martial eagle *Polemaetus bellicosus*) and two species listed as endangered (white backed vulture *Gyps africanus* and bateleur *Terathopius* *ecaudatus*). According to Robertson et al. (1998) and Sinclair and Ryan (2003), the following six Namibian endemic species were identified: Rüppel's parrot *Poicephalus rueppellii*, Carp's tit *Parus carpi*, bare-cheeked babbler *Turdoides gymnogenys*, white-tailed shrike *Lanioturdus torquatus*, Monteiro's hornbill *Tockus monteiri* and Damara hornbill *Tockus damarensis*.

Habitat preferences

When looking at the habitat requirements of the bird species inventoried, a clear correlation with savannah and savannah – woodland mixed habitat can be seen (Figure 3). The same pattern comes out when using wet and dry season data only; there is no change in the distribution of bird species per ecological group between seasons. Also, there is no obvious difference in the total number of species per collection period: wet season (Jan 31 – Mar 21, 2006) = 91 species, dry season (Jul 3 – Sep 3, 2006) = 104 species. In contrast, similarity index (β) of the species range between wet and dry season is 0.6, indicating a noticeable change of bird species occurring throughout the seasons.

Mammals

The cumulative species curve for mammals is characterised by a steady increase pattern until Aug. 7, 2006 (nine months after start of the observation), when 44 out of 45 mammal species were observed. Out of these 45 species, 41 species were directly observed (71.4 % were proven by photographs) and further four species were identified by spoor. There was one sighting of a horseshoe bat (*Rhinolophus spec.*) that was identified to the genus level only.

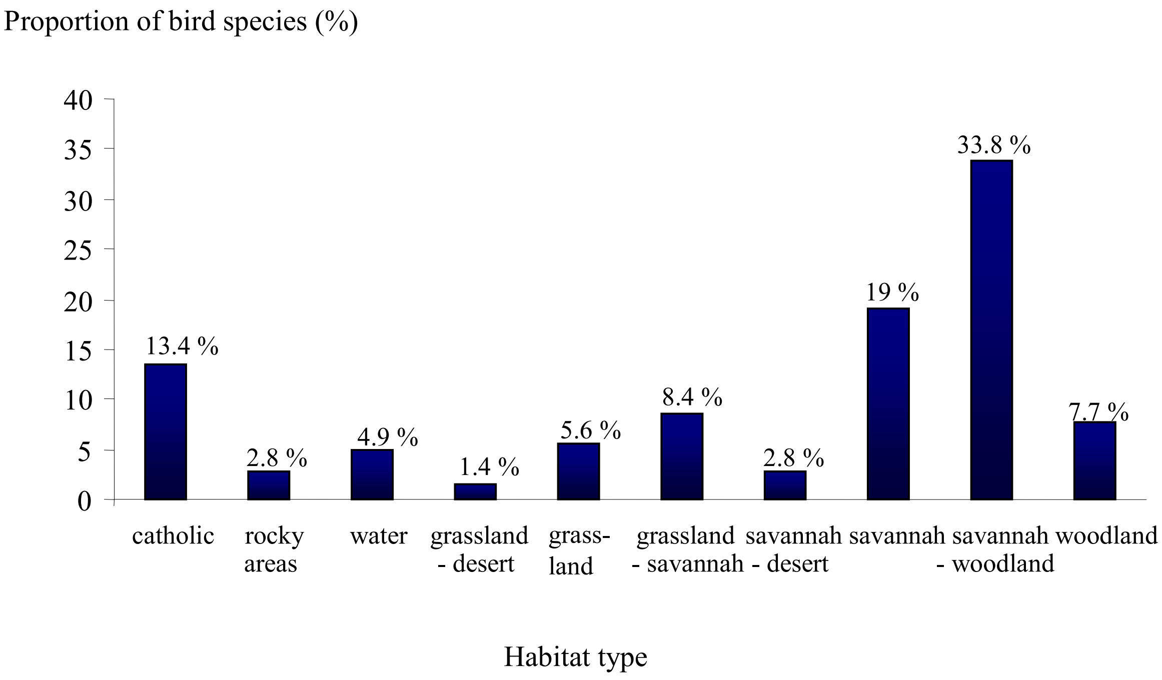

Figure 3. Percentage of bird species richness per habitat type is given. The result is based on all identified bird species over the study period.

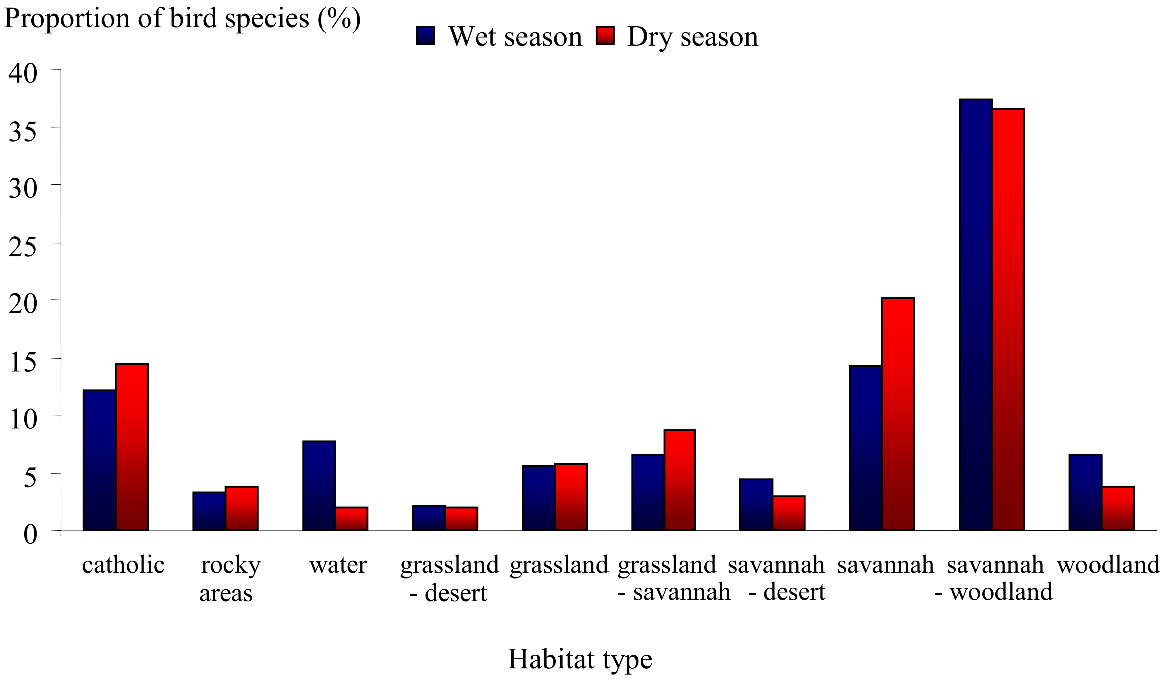

Figure 4. Percentage of bird species richness per habitat type and season is given. Wet season data was collected between Jan 31 and Mar 21, 2006, dry season data was collected between Jul 3 and Sep 9, 2006.

Picture 4. a) coral snake *Aspidelaps lubricus*, b) white tailed shrike *Lanioturdus torquatus*, endemic to Namibia, indicator for savannah habitat, c) Damara hornbill *Tockus damarensis*, endemic to Namibia, indicator for savannah-woodland habitat, d) African wildcat *Felis silvestris* and e) Cape fox *Vulpes chama* were rarely observed, f) aardvark *Orycteropus afer* was proven by spoor only, g) lion *Panthera leo* spoor were increasingly found at later stages of the study, h) fence that was destroyed by a male elephant *Loxodonta africana*.

Discussion

The cumulative species curve method allows for a validation of the methodological approach in this study. Cumulative species curves for birds and mammals show the typical asymptotic progression, that is, as the number of observation days increases, the rate of increase in species identified for the first time decreases, so that an asymptotic curve results. The steep increase phase of cumulative species curve for birds during the wet season may be linked with the change of the bird species assemblage owing to rainfall. The sigmoid pattern of cumulative species curve for reptile is due to artificial reasons. At a later stage of the study (Jul – Sep 2006), observers increased the effort to detect reptiles (e. g. turning of stones). During this period, 37.5 % of the entire reptile species range was found.

Birds

According to Avibase (2010), a total of 690 bird species can be found in Namibia. With a total of 148 identified bird species, the study area of the present investigation consisted of almost one quarter (21.5 %) of all bird species occurring in Namibia. From a total of 60 raptor species (family Accipitridae and Falconidae) that are distributed across Namibia (Avibase 2010), 46.7 % (28 species) were identified on the study area. Raptors are an especially useful indicator for the habitat quality, as they are top predators at the end of the food chain. The bird species monitoring has illustrated the high quality of the study area as it comprised a relevant proportion of the bird species occurring within the country. The relatively high number of bird species can be explained by the different geological formations and associated habitat structures of the study area. Skowno and Bond (2003) carried out a study on bird communities in a comparable ecosystem in KwaZulu-Natal, South Africa. By demonstrating that different habitat types (grasslands, *Acacia* woodlands and broadleaf woodlands) have markedly different bird assemblages, the authors further showed the importance of birds as bioindicators for structural vegetation changes, such as bush encroachment. Joubert and Ryan (1999) used bird and small mammal assemblages to compare commercial and communal rangelands in the Succulent Karoo in South Africa. They found a more diverse assemblage of birds and mammals on commercial rangelands, providing more vegetation structure than communal lands. The present thesis has also proven a significant seasonal influence on the bird species range (water associated species, migratory species). Although the area has been used for several decades as livestock farmland, the bird species monitoring has proven significant numbers of species indicating a savannah-woodland continuum. The occurrence of woodland-associated bird species demonstrates that dead wood for feeding and breeding was available at the study area. Since woodland habitat is associated with rocky areas (chapter III), former influence of livestock (especially cattle) on the habitat may have been less intense at the rocky areas when compared to the grassland on the plains, since cattle would typically prefer the grasslands instead of woodland on rocky outcrops. Another reason for the relative high number of species may be the direct adjacency to the ENP. Since bird occurrence is not hindered by an anthropogenic boundary such as game fence of the National Park, there should be a considerable fringe effect between the study area and the ENP.

Mammals

Griffin (1998) presented data on mammal species numbers in protected areas in Namibia. The number of small mammal species found in the present study is clearly lower than species numbers from protected areas in Namibia (Table 3). Owing to the methodological approach of line-transect sampling with vehicles, the species range detected with the method used in the present study varies from medium-sized to very large mammal species. Small mammals were only observed by chance, or they were eventually caught with traps at the field station to keep away snakes. Thus, the number of detected small mammals is based on sporadic observations and may not reflect the actual situation at the study area at that time. An investigation of these taxa according to appropriate methods (live-trapping of small mammals, netting of bats) would be an important future activity to obtain a more detailed picture of the mammal species diversity at the study area. However, when comparing the number of medium sized or larger mammal species at the study area with state protected areas in Namibia, the study area reveals comparable levels (Table 3).

Table 3. Number of indigenous mammal species in selected formal conservation areas in Namibia and number of identified mammal species from the present study. Taxonomic terms and data for protected areas refer to Griffin (1998).

	Protected area[1]							
Order	1	2	3	4	5	6	This study	Total species in Namibia
Insectivora	4	4	2	3	3	3	1	8
Chiroptera	22	14	18	10	10	14	1	48
Primates	2	2	1	1	1	1	1	4
Carnivora	25	19	26	14	14	21	16	38
Cetacea	-	-	+	-	-	+	-	40
Proboscidea	1	-	1	-	-	-	1	1
Perissodactyla	3	1	2	1	1	1	4	4
Hyracoidea	1	1	1	1	1	1	-	2
Tubulidentata	1	1	1	1	1	1	1	1
Artiodactyla	14	15	8	10	7	8	13	28
Pholidota	1	1	-	1	1	-	-	1
Rodentia	23	22	21	20	18	23	6	53
Lagomorpha	3	1	3	2	2	4	1	5
Macroscelidea	2	1	3	1	1	3	1	6
Total	102	82	87	65	60	80	46	239

This chapter proves the suitability of a method to assess biodiversity levels and habitat quality that was developed in combination with rhino monitoring procedures. The results reveal a state description of the study area at the time of the investigation. Since rhino monitoring was based on regular long-distance tours that needed to be driven, monitoring of the vertebrate fauna has been a cost and time effective approach to describe the study area. Since it took observers more than eight months to detect the entire set of vertebrate species per taxon, the chapter highlights the importance of the time scale for such investigations.

Although the study area has been previously used for commercial livestock farming for more than 40 years, the results of this chapter suggest a relatively high level of habitat heterogeneity and structural complexity at the study area. This description of the study area sets the basis for the analysis of rhino spatial and temporal behaviour and habitat use, and it shows the study area's suitability for the re-introduction of grazers and browsers as well, including both species of African rhinos.

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[1] Protected areas: 1) Etosha National Park (size: 22,270 km^2), 2) Waterberg Plateau Park (size: 405.5 km^2), 3) Skeleton Coast National Park (including Cape Cross Seal Reserve and National West Coast Recreation Area [size: 24,250 km^2]), 4) Daan Viljoen Game Park (size: 39.5 km^2), 5) Von Bach Recreation Resort (size: 42.8 km^2), 6) Namib Naukluft National Park (size: 49,768 km^2).

Management implications

This study has shown the importance of the time scale for the assessment of the species range. It gives a data collection method that was developed in combination with rhino monitoring procedures. When applying VHF radio telemetry at such an area, long distances need to be travelled in order to locate and observe a relatively small group of rhinos at a relatively large area. The study was developed 'along the way' of rhino data collection. Thus, it is a low cost procedure (distances need to be covered anyway) that turned out to reveal useful information to describe habitat features and habitat quality in view of rhino translocations. The value of this specific area can be seen from the results of a simple monitoring of species over time. Despite the former land use of livestock farming, the area can be described as an important habitat for savannah and savannah-woodland species. The study serves as a model for an indirect assessment of the habitat quality. In contrast to many conservation areas that are effectively habitat islands in a 'sea' of agricultural or urban areas (Skowno and Bond 2003), the present study area forms an important additional conservation area for the ENP.

Summary

This chapter characterises the continuous vertebrate species monitoring at the study area over a period of 16 months (Nov 2005 – Feb 2007). It describes a method that was developed in combination with rhino tracking procedures. The cumulative species curve method has been used to validate the methodological approach and stress the importance of the time scale for such investigations. The mammal species richness was compared with several protected areas in Namibia. The seasonal occurrence of amphibian, reptile and bird species is useful to describe seasonal patterns in this particular semi-arid savannah ecosystem. Bird species range is discussed in view of seasonality (availability of water) and additional habitat-related features. Birds were used as bioindicators, and an indirect assessment of the habitat quality was conducted on the basis of the bird monitoring. Based on the study area's proximity to the ENP and the occurrence of two geological formations (with distinct vegetation types), the number of species of birds, as well as medium sized and large mammals indicates a large proportion of species occurring within Namibia present at the study area. Generally, the chapter proves the study area's suitability for the re-introduction of grazers and browsers as well, including both species of African rhinos.

Table 4. Reptile species found over the study period. Order of species is based on first sighting over the study period.

Scientific name	English name
Mabuya sulcata sulcata	western rock skink
Chamaeleo dilepis	flap-neck chameleon
Gerrhosaurus nigrolineatus	black-lined plated lizard
Bitis caudalis	horned adder
Aspidelaps lubricus lubricus	coral snake
Agama aculeata aculeata	ground agama
Mabuya binotata	Ovambo tree skink
Pachydactylus turneri	Turner`s thick-toed gecko
Geochelone pardalis	leopard tortoise
Pelomedusa subrufa	marsh terrapin
Psammophylax rhombeatus	rhombic skaapsteker
Psammophis subtaeniatus subtaeniatus	stripe-bellied sand snake
Varanus albigularis	rock monitor
Python natalensis	Southern African python
Naja nigricollis nigricincta	black-necked spitting cobra
Bitis arietans	puff adder
Mabuya spilogaster	Kalahari tree skink
Pedioplanis namaquensis	Namaqua sand lizard
Lygodactylus lawrencei	Lawrence`s dwarf gecko
Cordylosaurus subtessellatus	dwarf plated lizard
Nucras intertexta	spotted sandveld lizard
Mabuya striata	striped skink
Pachydactylus punctatus	speckled thick-toed gecko
Pachydactylus bicolor	velvety thick-toed gecko

Table 5. Avian species found over the study period. Order of species is based on first sighting

Scientific name	English name	Photo taken	Habitat
Plocepasser mahali	white-browed sparrow-weaver	+	savannah - woodland
Serinus flaviventris	yellow canary	+	savannah - semi-desert
Oena capensis	Namaqua dove	+	savannah - woodland
Lamprotornis nitens	Cape glossy starling	+	savannah - woodland
Lanioturdus torquatus	white-tailed shrike	+	savannah
Pycnonotus nigricans	red-eyed bulbul	+	savannah
Pterocles bicinctus	double-banded sandgrouse	+	catholic
Tockus leucomelas	southern yellow-billed hornbill	+	savannah - woodland
Ardeotis kori	kori bustard	+	grassland - savannah
Quelea quelea	red-billed quelea	+	savannah
Bubo africanus	spotted eagle owl	+	catholic
Torgos tracheliotus	lappet faced vulture	+	savannah
Corvus capensis	black crow	+	grassland - desert
Upupa africana	African hoopoe	+	savannah - woodland
Melierax gabar	gabar goshawk	+	savannah
Melierax canorus	pale chanting goshawk	+	savannah - semi-desert
Monticola brevipes	short-toed rock trush	+	rocky areas
Coracias navae	purple roller	+	savannah - woodland
Merops hirundineus	swallow-tailed bee-eater	+	catholic
Parus carpi	Carp`s tit	+	savannah - woodland
Estrilda erythronotos	black-cheeked waxbill	+	grassland - savannah
Pytilia melba	Melba finch	+	savannah - woodland
Vidua regia	shaft-tailed whydah	+	grassland - savannah
Cercomela familiaris	familiar chat	+	rocky areas
Calendulauda sabota	sabota lark	+	savannah
Emberiza flaviventris	golden-breasted bunting	+	savannah - woodland
Numida meleagris	helmeted guineafowl	+	catholic
Eupodotis ruficristata	red-crested korhaan	+	grassland - savannah
Dicrurus adsimilis	fork-tailed drongo	+	savannah - woodland
Granatina granatina	violet-eared waxbill	+	savannah - woodland
Elanus caeruleus	black-shouldered kite	+	grassland - savannah
Pterocles namaqua	Namaqua sandgrouse	+	grassland - desert
Streptopelia capicola	Cape Turtle Dove	+	catholic
Struthio camelus	common ostrich	+	savannah - semi-desert
Milvus aegyptius	yellow-billed kite	+	catholic
Sagittarius serpentarius	secretarybird	+	savannah - woodland
Polemaetus bellicosus	martial eagle	+	savannah
Philetairus socius	sociable weaver	+	savannah
Pternistes adspersus	red-billed francilin	+	savannah - woodland
Vanellus coronatus	crowned plover	+	grassland
Vanellus armatus	blacksmith plover	+	water
Alopochen aegyptaicus	egyptian goose	+	water
Ciconia abdimii	Abdim`s stork	+	grassland
Coracias caudata	lilac-breasted roller	+	grassland
Leptoptilos crumeniferus	marabou stork	+	grassland - savannah
Milvus migrans	black kite	+	catholic
Tockus monteiri	Monteiro`s hornbill	+	savannah - woodland
Parus cinerascens	ashy tit	+	savannah

Scientific name	**English name**	**Photo taken**	**Habitat**
Falco vespertinus	western red-footed kestrel	+	grassland - savannah
Falco chicqera	red-necked falcon	+	savannah
Anas erythrorhyncha	red-billed teal	+	*water*
Bubalornis niger	red-billed buffalo-weaver	-	savannah - woodland
Urocolius indicus	red-faced mousebird	-	savannah - woodland
Amadina erythrocephala	red-headed finch	+	savannah - woodland
Bubulcus ibis	cattle egret	+	grassland
Eupodotis afraoides	northern black korhaan	+	catholic
Malcorus pectoralis	rufous-eared warbler	-	grassland - savannah
Tricholaema leucomelas	acacia pied barbet	-	savannah - woodland
Tockus nasatus	grey hornbill	+	savannah - woodland
Vidua paradisaea	eastern paradise whydah	+	savannah - woodland
Laniarius atrococcineus	crimson-breasted boubou	+	savannah
Tyto alba	barn owl	+	catholic
Charadrius tricollaris	three-banded plover	-	water
Turdoides bicolor	pied babbler	-	savannah
Ploceus intermedius	lesser masked weaver	-	savannah - woodland
Merops apiaster	european bee-eater	-	catholic
Falco subbuteo	Eurasian hobby	-	savannah - woodland
Buteo buteo vulpinus	common buzzard	+	catholic
Gyps africanus	white-backed vulture	+	savannah - woodland
Caprimulgus rufigena	rufous-cheeked nightjar	-	savannah - woodland
Caprimulgus tristigma	freckled nightjar	-	woodland
Burhinus capensis	spotted dikkop	+	catholic
Euplectes afer	golden bishop	-	water
Hirundo dimidiata	pearl-breasted swallow	-	savannah - woodland
Ploceus velatus	masked weaver	+	grassland - savannah
Terpsiphone viridis	paradise flycatcher	-	woodland
Turdoides gymnogenys	bare-cheeked babbler	+	savannah
Tockus damarensis	Damara hornbill	+	savannah - woodland
Accipiter minullus	little sparrowhawk	-	woodland
Passer motitensis	great sparrow	+	woodland
Cinnyricinclus leucogaster	plum-coloured starling	+	woodland
Serinus atrogularis	black-throated canary	+	savannah - woodland
Cercotrichas paena	Kalahari robin	-	savannah
Namibornis herero	Herero chat	-	savannah - woodland
Serinus mozambicus	yellow fronted canary	-	savannah - woodland
Lanius minor	lesser grey shrike	+	savannah
Passer diffusus	southern grey-headed sparrow	+	woodland
Sylvia borin	garden warbler	+	savannah - woodland
Emberiza tahapisi	rock bunting	+	rocky areas
Tachybaptus ruficollis	dabchick	+	water
Mirafra passerina	monotonous lark	-	savannah - woodland
Ploceus rubiginosus	chestnut weaver	+	savannah - woodland
Cinnyris fusca	dusky sunbird	-	savannah
Calendulauda africanoides	fawn-coloured lark	-	savannah
Ardeola ralloides	squacco heron	+	water
Poicephalus rueppelli	Rüppell`s parrot	+	savannah - woodland
Aquila spilogaster	African hawk eagle	+	savannah - woodland

Scientific name	**English name**	**Photo taken**	**Habitat**
Aquila rapax	tawny eagle	+	savannah - woodland
Streptopelia senegalensis	laughing dove	+	catholic
Accipiter badius	shikra	-	savannah - woodland
Clamator glandarius	great spotted cuckoo	-	savannah - woodland
Myrmecocichla formicivora	ant-eating chat	+	grassland
Terathopius ecaudatus	bateleur	-	savannah
Colius colius	white-backed mousebird	-	savannah-semi-desert
Creatophora cinerea	wattled starling	-	catholic
Eremopterix leucotis	chestnut-backed finchlark	+	savannah
Oxylophus jacobinus	Jacobin cuckoo	+	savannah - woodland
Circaetus pectoralis	black-breasted snake eagle	+	catholic
Prinia flavicans	black-chested prinia	+	savannah
Ciconia ciconia	white stork	+	grassland
Rhinoptilus chalcopterus	bronze-winged courser	+	savannah - woodland
Chalcomitra amethystina	amethyst sunbird	+	woodland
Scleroptila levaillantoides	Orange River francolin	+	grassland - savannah
Aquila pomarina	lesser spotted eagle	+	savannah - woodland
Eremomela icteropygialis	yellow-bellied eremomela	+	savannah - woodland
Anthoscopus minutus	Cape penduline tit	+	savannah
Lagonostica senegala	red-billed firefinch	-	woodland
Rhinopomastus cyanomelas	common scimitarbill	+	savannah - woodland
Bradornis mariquensis	Marico flycatcher	+	savannah - woodland
Tchagra australis	brown-crowned tchagra	+	savannah - woodland
Trigonoceps occipitalis	white-headed vulture	-	savannah
Falco rupicolus	rock kestrel	+	catholic
Turdoides melanops	black-faced babbler	+	woodland
Cinnyris talatala	white-bellied sunbird	-	savannah - woodland
Ardea melanocephala	black-headed heron	+	grassland - savannah
Calamonastes fasciolatus	barred warbler	-	savannah
Sporopipes squamifrons	scaly-feathered finch	-	savannah
Falco biarmicus	lanner falcon	-	catholic
Hirundo fuligula	rock martin	-	rocky areas
Tchagra senegala	black-crowned tchagra	-	savannah
Aquila pennatus	booted eagle	-	catholic
Falco rupicoloides	greater kestrel	+	savannah - semi-desert
Ptilopsus granti	white -faced scops owl	-	savannah - woodland
Anaplectes rubiceps	red-headed weaver	-	savannah - woodland
Turnix sylvatica	small button quail	-	grassland - savannah
Batis pririt	pririt batis	-	savannah - woodland
Passer melanurus	Cape sparrow	-	grassland
Polyboroides typus	gymnogene	-	woodland
Glaucidium perlatum	perl-spotted owlet	-	savannah - woodland
Polihierax semitorquatus	pygmy falcon	+	savannah
Cursorius temminckii	Temminck`s courser	-	grassland
Cisticola aridulus	desert cisticola	-	grassland
Lanius collaris	fiscal shrike	-	catholic
Sylvietta rufescens	long-billed crombec	-	savannah - woodland

Scientific name	English name	Photo taken	Habitat
Circaetus cinereus	brown snake-eagle	-	savannah - woodland
Otus senegalensis	Africa scops-owl	-	savannah - woodland
Falco peregrinus	peregrine falcon	-	catholic
Lophaetus occipitalis	long-crested eagle	+	woodland

Table 6. Mammalian species found over the study period. Order of species is based on first sighting. Index: 1) regularly observed (> 20 sightings throughout the study period), 2) sporadically observed (2-20 sightings throughout the study period), 3) only one sighting throughout the study period, 4) species only proven by spoor.

Scientific name	Authority	English name	Photo taken	Notes
Diceros bicornis	Linnaeus 1758	black rhinoceros	+	1
Herpestes sanguineus	Rüppell 1835	slender mongoose	+	2
Phaecochoerus africanus	Gmelin 1788	warthog	+	1
Kobus ellipsiprymnus	Ogilbyi 1833	waterbuck	+	1
Lepus saxatilis	F. Cuvier 1823	scrub hare	+	1
Hystrix africaeaustralis	Peters 1852	porcupine	+	2
Giraffa camelopardalis	Linnaeus 1758	giraffe	+	1
Tragelaphus strepsiceros	Pallas 1766	kudu	+	1
Antidorcas marsupialis	Zimmermann 1780	springbok	+	1
Xerus inauris	Zimmermann 1780	ground squirrel	+	1
Connochaetes taurinus	Burchell 1823	blue wildebeest	+	1
Equus quagga	Boddaert 1785	common zebra	+	1
Mellivora capensis	Schreber 1776	honey badger	-	2
Gerbilliscus leucogaster	Peters 1852	bushveld gerbil	+	2
Canis mesomelas	Schreber 1775	black-backed jackal	+	1
Raphicerus campestris	Thunberg 1811	steenbok	+	1
Alcelaphus buselaphus	Günther 1884	red hartebeest	+	1
Tragelaphus oryx	Pallas 1766	eland	+	1
Hippotragus niger	Harris 1838	sable antelope	+	1
Crocuta crocuta	Erxleben 1777	spotted hyaena	-	2
Panthera pardus	Schlegel 1857	leopard	-	3
Orycteropus afer	Pallas 1766	aardvark	-	4
Oryx gazella	Linnaeus 1758	oryx	+	1
Petromus typicus	A. Smith 1831	dassie rat	+	2
Equus zebra hartmannae	Matschie 1898	Hartmann`s mountain zebra	+	1
Aepyceros melampus petersi	Bocage 1879	black-faced impala	+	1
Proteles cristata	Sparrman 1783	aardwolf	-	2
Pedetes capensis	Forster 1778	springhare	+	2
Acinonyx jubatus	Schreber 1775	cheetah	-	4
Rhinolophus spec.	-	-	+	
Sylvicapra grimmia	Linnaeus 1758	common duiker	-	2
Loxodonta africana	Blumenbach 1797	African elephant	-	4
Caracal caracal	Schreber 1776	caracal	+	2
Felis sylvestris cafra	Desmarest 1822	African wild cat	+	2
Ceratotherium simum	Burchell 1817	white-rhinoceros	+	1
Otocyon megalotis	Desmarest 1822	bat-eared fox	+	2
Ictonyx striatus	Perry 1810	striped polecat (zorilla)	-	3

Scientific name	Authority	English name	Photo taken	Notes
Elephantulus intufi	A. Smith 1836	bushveld elephant-shrew	+	2
Panthera leo	Meyer 1826	lion	+	2
Vulpes chama	A. Smith 1833	Cape fox	+	2
Mus indutus	Thomas 1910	desert pygmy mouse	+	3
Papio ursinus ursinus	Kerr 1792	Chacma baboon	-	4
Crocidura cyanea	Duvernoy 1838	reddish-grey musk shrew	+	3
Cynictis penicillata	G. B. Cuvier 1829	yellow mongoose	+	2
Hyaena brunnea	Thunberg 1820	brown hyaena	-	4
Genetta genetta	Linnaeus 1758	small spotted genett	-	3

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CHAPTER III: POST-RELEASE EXPLORATION BEHAVIOUR, SOCIAL STRUCTURE AND HABITAT USE OF BLACK RHINOS

Introduction

Although information on the process of acclimatisation is essential for developing and enhancing translocation procedures, surprisingly acclimatisation has not been the focus of much attention in the literature, possibly owing to a lack of interaction between animal welfare researchers and conservation biologists (Teixeira et al. 2007).

Despite the importance of translocation for black rhino *Diceros bicornis* Linnaeus 1758 conservation, there are only a few reports on post-release movements and general behavioural cues of black rhinos available in the literature. Hitchins et al. (1972) and Hall-Martin and Penzhorn (1977) reported on the behaviour of black rhino individuals leaving the enclosure or crate before disappearing from view. Raath and Hall-Martin (1989) described the translocation of six black rhinos from the Etosha National Park (ENP) in Namibia to the Vaalbos National Park in South Africa, witnessing one individual to move up to 24 km during the first day after release. Walker (1992) contributed a pre-release study during 18 weeks boma management of black rhinos in South Africa. Linklater et al. (2006) were the first to systematically study the post-release daily movements of black rhinos. Authors studies 15 black rhinos that were released in Mun-ya-Wana Game Reserve in South Africa. Authors found a maximum first-day travelled distance of 6.7 km. Linklater and Swaisgood (2008) used daily movements to described settlement patterns of 34 black rhinos released into 12 different sites across South Africa, stating that time frame for acclimatisation is 15 – 25 days post-release. Patton et al. (2010) found a time frame of 1- 93 days until settlement of animals. Linklater and Swaisgood (2008) and Patton et al. (2010) reproted that in at least 44 % of cases settlement was not complete after 100 days, indicating ongoing variability in maximal movements.

A special situation can be found in Namibia, where the black rhino explores the limits of its natural distribution. Black rhinos in Namibia are known to establish by far the largest home ranges and move the greatest distances, when compared to further countries within the distribution range of the species (Loutit et al. 1987, Göttert et al. 2010). Erb (1999) reported on the post-release behaviour of translocated black rhinos within and out of the ENP in Namibia. He found that black rhinos translocated within ENP did not wander back to their original home ranges.

This chapter contains information that were originally published by Göttert et al. (2010) as the first systematic investigation of the home range establishment and habitat use patterns of black rhinos after hard-release translocation. The primary goal was to examine the cognitive and behavioural acclimatisation of reintroduced black rhinos. Moreover, data on settlement patterns related to the site of release, habitat and conspecifics are presented. The study provides valuable base-line data for future black rhino translocation programmes and is of specific interest for the management of the Etosha subpopulation, a stronghold for the entire *in-situ* population of the species (Stanley-Price and Dublin 2000, Martin 2009; 2010).

Material and methods

Data collection

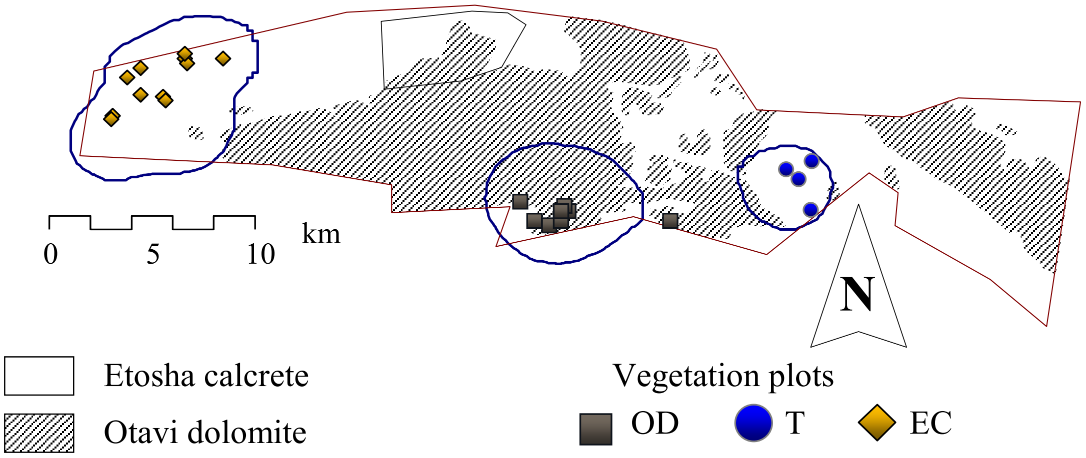
Rhino behaviour

Between March 2005 and February 2007, black rhinos were located on a regular basis (at least once a week) at irregular intervals between dawn and dusk via VHF radio telemetry, using a T4 tracking device (Telonics, Inc., Mesa, AZ, USA). In total 1,329 fixes were collected on six rhinos, with 147 to 306 fixes per animal. Observation period for individual rhinos varied between 494 and 674 days.

Signals were initially caught from high elevation and then verified by final stalking upwind by foot. On average, 19 % (11 - 26 %) of fixes reveal locations were rhinos were directly observed (sightings) and 81 % (74 - 89 %) of fixes are triangulation estimates. Therefore, bearings from two locations comprising an angle of > 60° were taken. The direction was examined by compass to an accuracy of one degree. The intersection of the two lines indicates the probable location of the respective rhino. Positions of sighting and triangulation points were determined by Global Positioning System (GPS). When two or more rhinos were observed in close distance to each other (< 50 m), only one position was taken.

Habitat use

To interpret rhino habitat use, a *post-hoc* vegetation survey was conducted by analysing the habitat types at the centres of rhino activity. During the dry season in 2006 (September-November), 23 vegetation plots of 200 m² (10 x 20 m) were established at locations where rhinos had been observed browsing and vegetation indicated frequent browsing at that time. The author established 11 plots on EC, 8 plots on OD and 4 plots on a transitory area (T [Map 2]).



Map 2. The uncorrected 95 % Kernel polygon that was calculated from 198 locations, where one or more rhinos were observed, is given. Rhinos used distinct areas on geological formation. Based on these data, plots for vegetation survey were set up on OD, EC and transition area (T).

Within each plot, cover (proportion of area covered with the respective vegetation type) of all layers was estimated. Layers are (1) trees (< 2.5 m height), (2) shrubs, (3) dwarf shrubs (> 0.6 m height) and (4) ground (grass and bare soil). Cover of bare soil and grass was estimated according to the Londo scale (Londo 1976). Cover of remaining layers (trees, shrubs and dwarf shrubs) was calculated from direct measurements. The following variables were measured (in case of trees estimated): minimum diameter, maximum diameter and height of all individual woody plants within each plot to calculate the size of an ellipsoid from the plant diameter to determine plant cover. Since the cover of the entire vegetation inventory of woody plants per plot was measured, cover can exceed the 100 % limit. Altogether, 1,750 individual plants were measured on the 23 vegetation plots. For identification of plants the following literature was used: Van Wyk and Van Wyk (1997) and Berry (2005).

Data analysis

Home ranges

Home ranges were calculated using two methods: minimum convex polygon (MCP [Mohr 1947, Kenward 1987] and Kernel method (Worton 1987, Worton 1989). The computer programs GPS Track Maker (GPSTM, Freeware, Belo Horizonte, Brazil) and ArcView 3.3 (ESRI, Redlands, CA, USA) were used, and polygons were corrected along study area borders. As most literature references on black rhino home ranges are based on MCP method, the 100% MCP of the total home ranges (home range over the study period) was calculated for comparison with these references. Home range establishment patterns were detected according to observation-area curve method (Odum and Kuenzler 1955). Accordingly, total and seasonal home ranges (dry season: April, 15 - October, 14; wet season: October, 15 – April, 14) were calculated via Kernel method with the animal movement extension for ArcView 3.3 (Hooge and Eichenlaub 1997). Fixed Kernel polygons at the 50 % and 95 % probability level were estimated, and the 50 % polygon was used to visualise black rhino core areas (Lent and Fike 2003). Seasonal home ranges were only calculated when sample size exceeded 40 fixes per individual and season (Lent and Fike 2003). Also, the migratory activity (successive linear distance between fixes) was measured.

Associations between individuals were determined by conducting a single-linkage cluster analysis (SLCA) and calculating home range and core area overlap. The SLCA was based on relative similarities, calculated from the ratio of sightings with two or more rhinos observed together (not more then 50 m away from each other) in relation to the total number of individual sightings (Morgan et al. 1976). Relative associations were fitted into a dendrogram to visualize the extent of associations (Lehner 1996). To calculate an index of total home ranges (100 % MCP) and seasonal home ranges and core an area, the following formula was used (Lazo 1994):

$$\text{Home range overlap (V)} = \frac{2P_I}{(P_A + P_B)}$$

Where: P_I = Overlap area of individuals A and B

P_A = area of individual A

P_B = area of individual B

This index may range from 0 (no overlap) to 1 (identical home ranges).

Habitat use

To analyse vegetation data median and interquartile range (IQR, distance between the 25- and the 75-quartile) of variables (cover [%] of woody plants per plot, species richness [number of species per plot], Shannon-Diversity [H`], Simpson-Diversity [S`], number of individual plants, height of *Colophospermum mopane*) were calculated. To compare samples (plots) from the two main geological formations, a Mann-Whitney U test was carried out using Sigma Plot Statistical Program for Windows, Version 11.0 (SPSS Inc. Chicago, IL, USA). Also, habitat structure and plant species composition of EC and OD plots were compared.

Plots were compared according to species richness by using the Sørensen similarity index (Sørensen 1948):

$$\text{Similarity index } (\beta) = \frac{2c}{(S_1 + S_2)}$$

Where: S_1 = the total number of species recorded on OD

S_2 = the total number of species recorded on EC

c = the number of species common to both geological formations

This index may range from 0 (no species overlap) to 1 (the same species found at both seasons).

Furthermore, the plots were analysed according to a multivariate approach (indirect gradient analysis) via detrended correspondence analysis (DCA [Hill and Gauch 1980, Leyer and Wesche 2007]). The DCA was conducted to visualize degree of associations among the 23 samples (standard settings, downweighing of rare species and detrending by segments), using the computer program CANOCO, Version 4.5 (ter Braak and Smilauer 2002). DCA were calculated based on species cover data and species height data, as these variables were expected to be more important for black rhinos then the number of species.

Results

Rhino behaviour

Establishment of total home ranges (100 % MCP)

Subadult male 1

The area-observation curve of subadult male 1 shows a fairly asymptotic development (Figure 5). The cumulative 100 % MCP steadily increases during a first period, after which the rhino already covered 70 % of the total home range. Afterwards there are two plateau phases (no or very little increase of area size with consecutive number of observations), which can be separated by a migration event between two consecutive observation days (after 130 observations [Feb 2006]). After 130 observations the curve reaches the final plateau. At the end of the investigation, there is again a slow increase of the cumulative 100% MCP size. The total home range size (100 % MCP) for subadult male 1 is 15.0 km^2.

Subadult male 2

The area-observation curve for this rhino shows similar patterns to subadult male 1 (Figure 6). There is a steady increase during a first period. In contrast to subadult male 1, the decrease period can be subdivided into an initial steep increase period and a following period of moderate increase. Similar to subadult male 1, there are two plateau phases, which can be separated by a migration event between two consecutive observation days (after 109 observations [Feb 2006]). After 109 observations the curve reaches the final plateau. The total home range size (100 % MCP) for subadult male 2 is 10.8 km^2 and thus, is of equivalent size, when compared to subadult male 1.

Adult male

The successive increase of the home range of the male adult can be divided into three main periods (Figure 7). In line with subadult males, there is an initial period of successive increase of the MCP. This increase pattern differs from subadult males, as steep and slow increase patterns alternate, resulting in a cascaded increase pattern. The area observation curve shows a rather sigmoid pattern of home range establishment during this period. The period of increase is followed by a long period, when very little or no increase in the cumulative home range size is detectable. During the final stage of the study, the male adult slightly increased the total home range size. After 84 observations the curve reaches the final plateau. The total home range size (100 % MCP) of the male adult is 243.6 km^2. This rhino held the largest home range in the group, which is > 16 times larger than home ranges of subadult males and encompasses 70.1 % of the entire study area. Figure 8 shows this quantitative difference by comparing observation area curve of the male adult and subadult male 1.

Subadult female 1

The area-observation curve for subadult female 1 reveals home range establishment patterns that clearly differ from previously described rhinos, as this curve does not follow an asymptotic progression. Directly after release, this rhino remained in a relatively small area for a short while (Figure 9, period 1) and afterwards increased the totally visited area before the curve reveals a second plateau phase (Figure 9, period 3). This plateau is followed by another increase period after which the home range was more than doubled. The curve indicates a third clear plateau period until observation number 102 (Dec 2005) that is followed by a drastic increase in the home range size. In fact, 65.5 % of the female's total home range was visited after this point of the curve. The observation area curve indicates a forth plateau after this increase period. After 124 observations the curve reaches this final plateau. The total home range size (100 % MCP) of subadult female 1 is 180.4 km^2. This rhino established the second largest home range within the group.

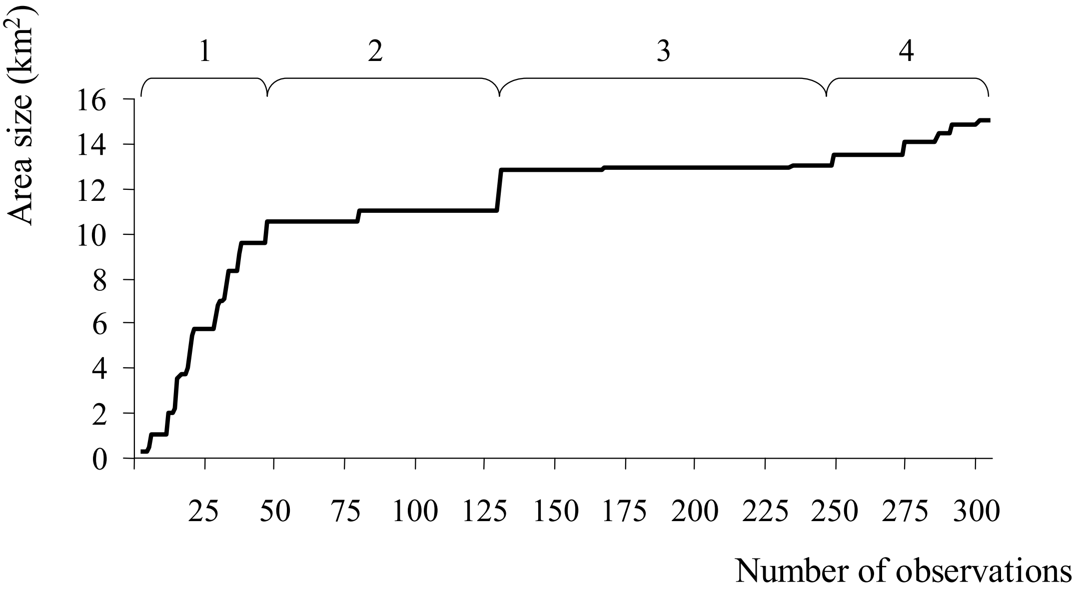


Figure 5. Area-observation curve of subadult male 1. Area size refers to the 100% MCP of the total home range (observation period: Mar 8, 2005 – Sep 12, 2006 [553 days], n = 306 fixes). 1: Mar 8 – Aug 3, 2005 (n = 48 fixes), 2: Aug 6, 2005 - Feb 7, 2006 (n = 82 fixes), 3: Feb 9 – Jul 5, 2006 (n = 119 fixes), 4: Jul 6 – Sep 12, 2006 (n = 57 fixes).

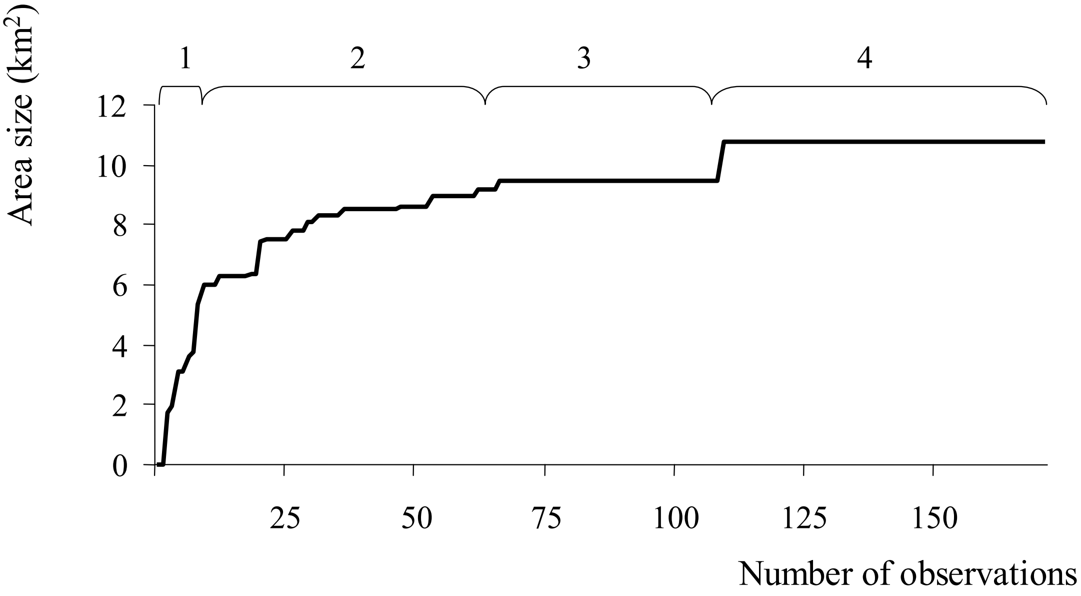


Figure 6. Area-observation curve of subadult male 2. Area size refers to the 100% MCP of the total home range (observation period: Mar 8, 2005 – Aug 20, 2006 [530 days], n = 172 fixes). 1: Mar 8 – Apr 28, 2005 (n = 10 fixes), 2: May 12 – Oct 18, 2005 (n = 57 fixes), 3: Oct 22, 2005 – Feb 7, 2006 (n = 42 fixes), 4: Feb 9 – Aug 20, 2006 (n = 63 fixes).

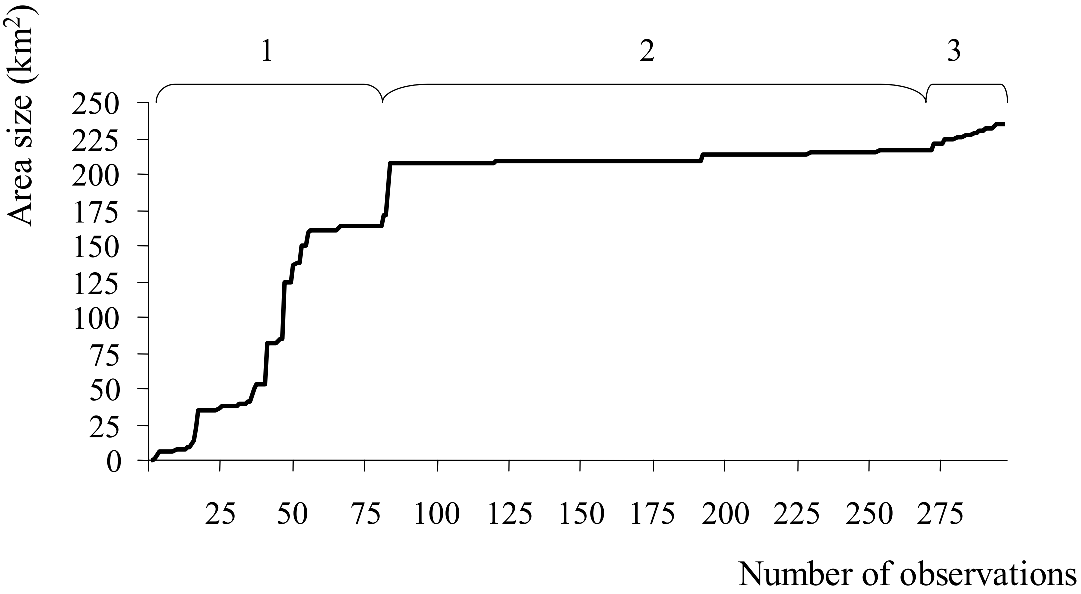


Figure 7. Area-observation curve of the adult male. Area size refers to the 100% MCP of the total home range (observation period: Apr 7, 2005 –Feb 10, 2007 [674 days], n = 298 fixes). 1: Apr 7 - Sep 29, 2005 (n = 84 fixes), 2: Oct 1, 2005 – Nov 25, 2006 (n = 188 fixes), 3: Nov 26, 2006 – Feb 10, 2007 (n = 26 fixes).

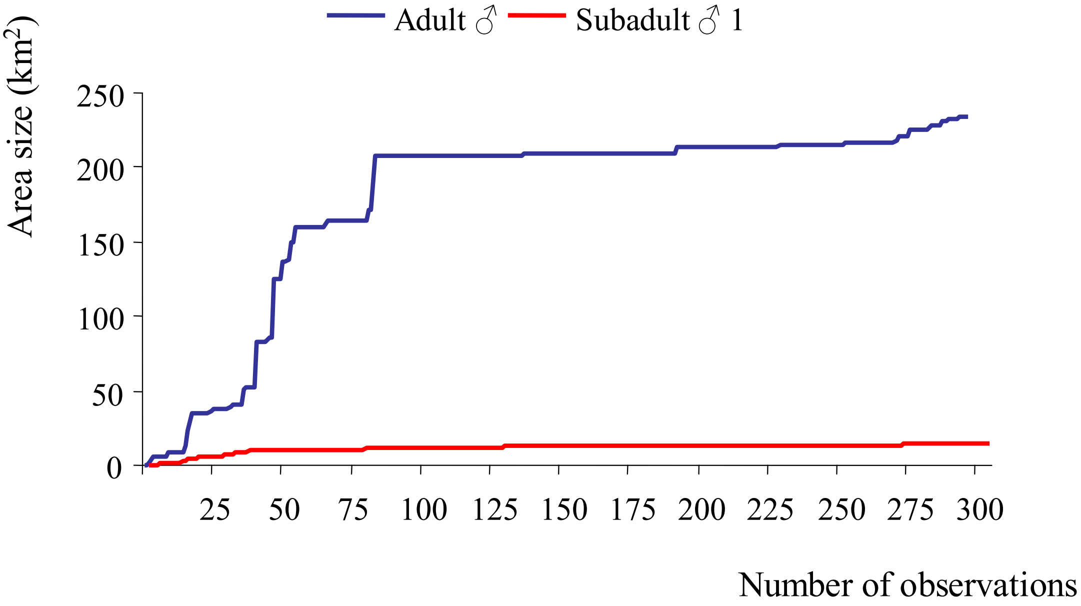


Figure 8. Area-observation curve of the adult male and subadult male 1. Note the difference in the size of the area.

Subadult female 2

Similar to subadult female 1, this rhino's observation area curve indicates a rather sigmoid home range increase pattern as the animal increases the area during a later stage of the study. Contrary to the other subadult female, here the area visited during the first 3 observations (April 2005) reveals already 21.7 % of the totally covered home range size. The following observations are characterised by a slow increase of the MCP size (period 1, Figure 10), before there is a more prominent, cascaded increase pattern. After increase period, the curve reaches a plateau that remains until the end of the investigation. After 76 observations the curve reaches the final plateau. The total home range size (100 % MCP) of subadult female 2 is 87.4 km^2.

Adult female

The observation area curve of the female adult shows the most prominent asymptotic character of all rhinos within the group. The home range establishment pattern can be divided into three periods. An initial period of steep increase is followed by a period of less prominent and cascaded increase of the total MCP size. At this stage (after 42 observations [three months after translocation]), the rhino had already visited 88.7 % of the total home range. After 42 observations the curve reaches the final plateau. The shape of this curve is similar to the curves for subadult males. However, besides this qualitative similarity in range establishment, there is a pronounced quantitative difference between subadult males and the female adult, as the total home range (100 % MCP) of the latter sizes 152.4 km^2.

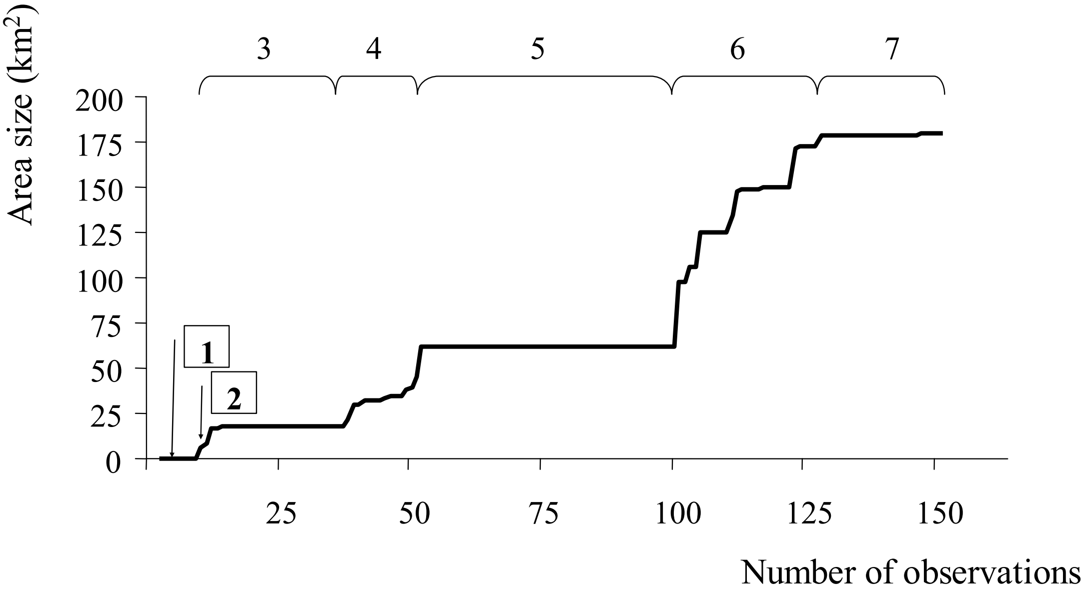


Figure 9. Area-observation curve of subadult female 1. Area size refers to the 100% MCP of the total home range (observation period: Apr 11, 2005 –Nov 25, 2006 [593 days], n = 152 fixes). 1: Apr 11 – 22, 2005 (n = 10 fixes), 2: Apr 23 – 26, 2005 (n = 3 fixes), 3: Apr 28 – Jun 18, 2005 (n = 25 fixes), 4 : Jun 19 – Aug 3, 2005 (n = 15 fixes), 5: Aug 6 – Nov 30, 2005 (n = 48 fixes), 6: Dec 2, 2005 – Feb 19, 2006 (n = 23 fixes), 7: Feb 20 – Nov 25, 2006 (n = 28 fixes).

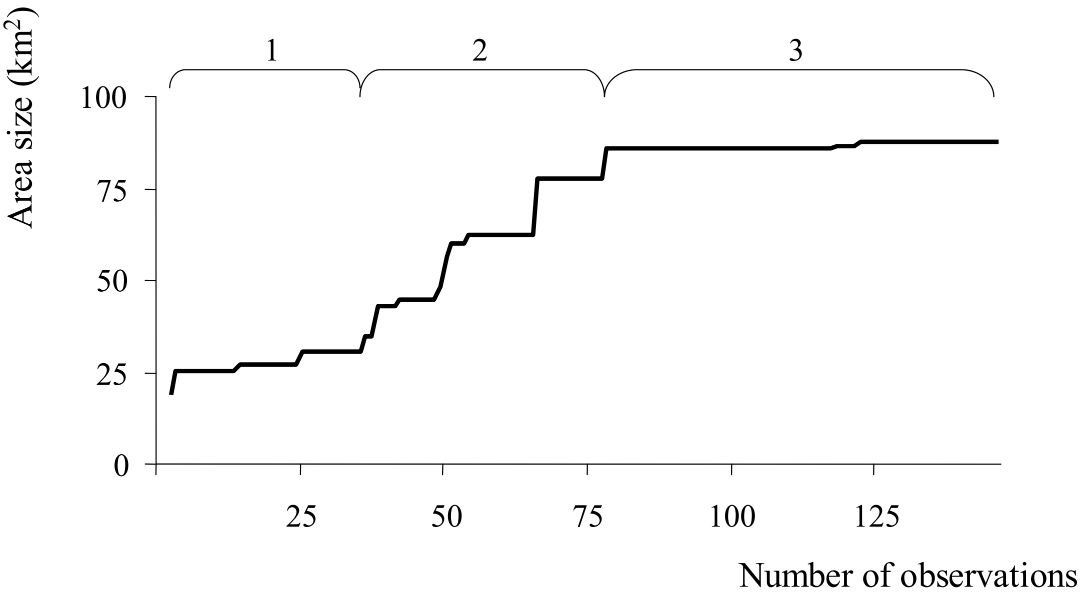


Figure 10. Area-observation curve of subadult female 2. Area size refers to the 100% MCP of the total home range (observation period: Apr 12, 2005 –Aug 19, 2006 [494 days], n = 147 fixes). 1: Apr 15 – Jun 14, 2005 (n = 33 fixes), 2: Jun 17 – Sep 27, 2005 (n = 43 fixes), 3: Sep 29, 2005 – Aug 19, 2006 (n = 68 fixes).

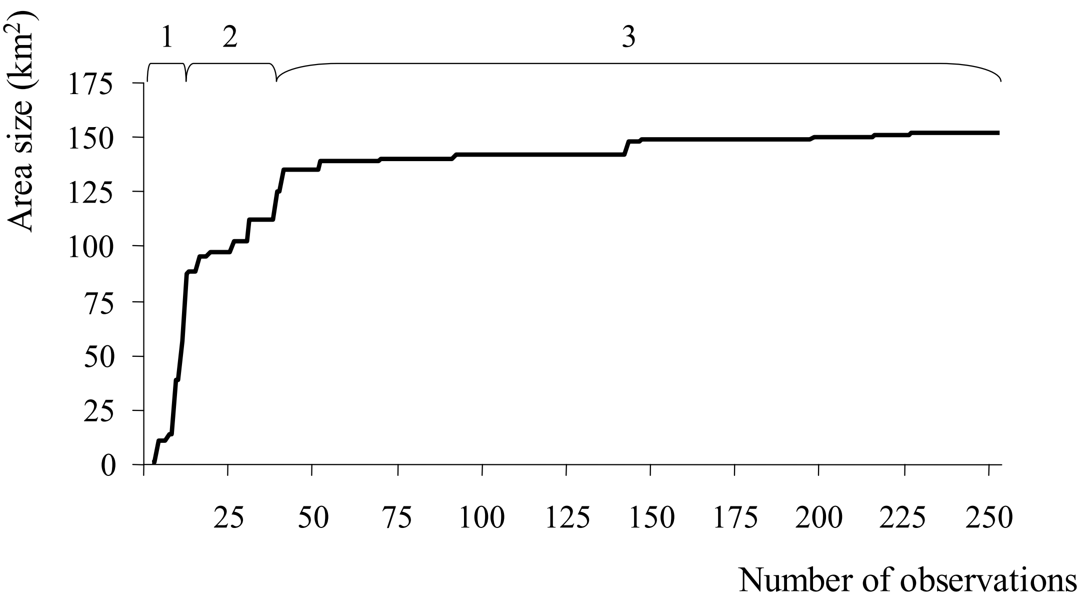


Figure 11. Area-observation curve of the adult female. Area size refers to the 100% MCP of the total home range (observation period: Apr 12, 2005 –Dec 15, 2006 [612 days], n = 254 fixes). 1: Apr 12 – May 3, 2005 (n = 16 fixes), 2: May 4 – Jul 19, 2005 (n = 26 fixes), 3: Jul 20, 2005 – Dec 15, 2006 (n = 212 fixes).

Interim conclusion

The results demonstrate apparent quantitative and qualitative differences in home range establishment of rhino individuals. The size of the total home ranges (100 % MCP) varies from 10.8 km^2 (subadult male 2) to 234.6 km^2 (adult male). The number of observations, necessary to reach the final plateau of the observation area curve ranges between 42 observations (female adult) and 130 observations (subadult male 1). The variable character of observation area curves (varying from asymptotic to sigmoid) indicates apparent differences in individual home range establishment patterns. Subadult males and rhino adults visited most of their total home range during an early part of the investigation. By contrast, subadult females clearly increased ranging activity during later stages. By the end of the investigation, all observation area curves plateau out, but two rhinos (subadult male 1, male adult) showed a slight increase pattern after a long plateau at the latest stage of the study period.

Total home ranges and core areas (Kernel method)

As expected, the Kernel approach revealed that rhinos were not uniformly distributed within their MCP, but were rather concentrated at certain core areas (Map 3). Rhinos established up to three distinct core areas, between which they either regularly switched, or which they established at different times of the survey. The size of core areas (50 % Kernel polygons) of total home ranges varies from 0.6 km^2 (subadult male 1) to 73.5 km^2 (subadult female 1). The maximum successive distance between fixes ranges from 4.0 km (subadult male 2) to 31.6 km (subadult female 1). Continually, rhino migrations of approximately 20 km linear distance between core areas were observed during one night.

Similar to the home range size of 100 % MCP method, the size of total home ranges according to Kernel method is highly variable among individual rhinos (Map 3). The 95 % Kernel polygons of total home ranges vary from 7.1 km^2 (subadult male 1) to 220.2 km^2 (adult male).

Seasonal home ranges and core areas

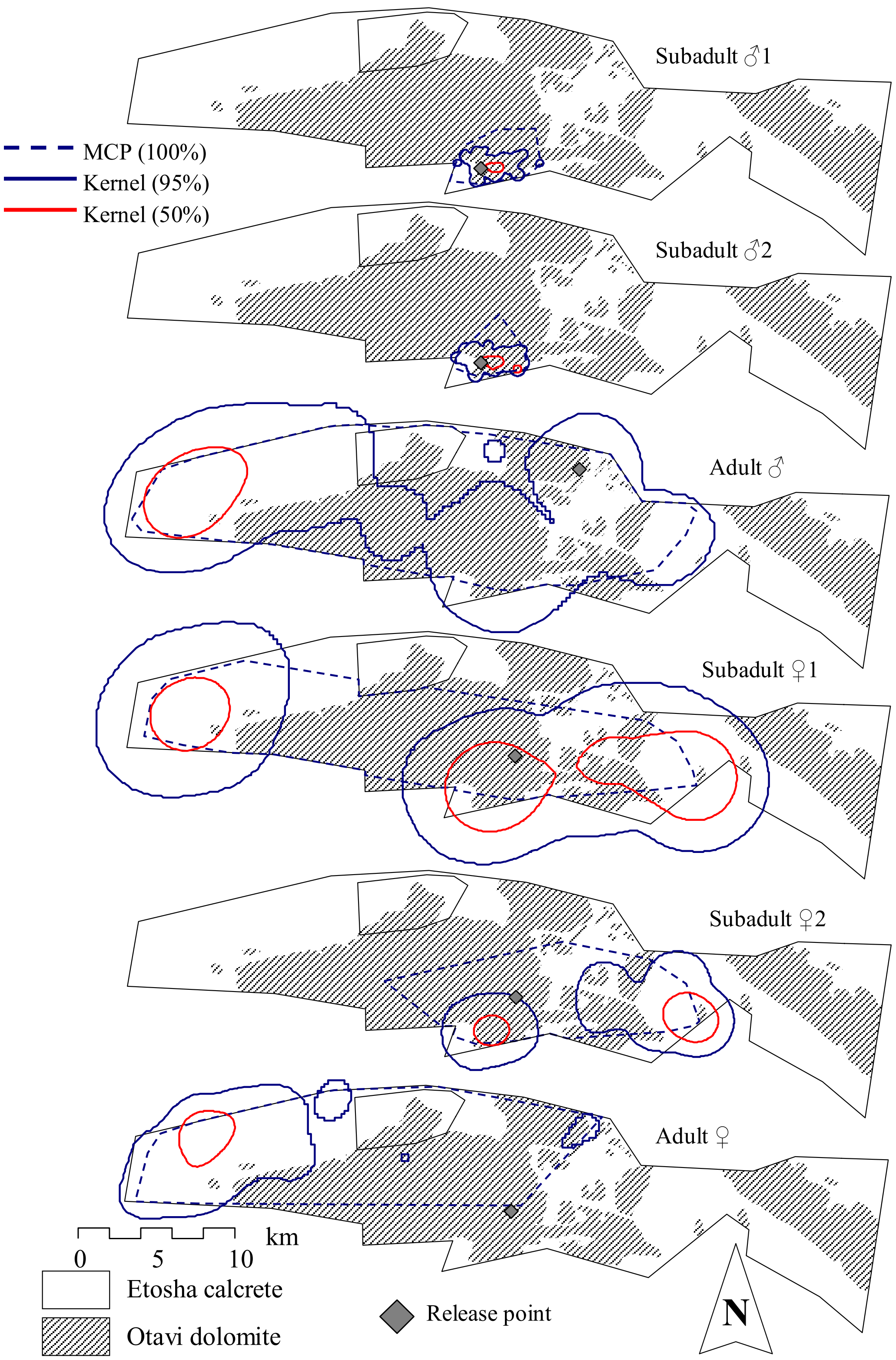
The size of seasonal home ranges (95 % Kernel polygons) varies from 5.7 km^2 (subadult male 1) to 218.6 km^2 (adult male). Core areas (50 % Kernel polygons) of seasonal home ranges are between 0.6 km^2 (subadult male 1) and 49.2 km^2 (adult male).

Rhinos roamed most of the study area using both geological areas: Otavi dolomite (OD) and Etosha calcrete (EC) (Maps 3-9). Age class specific patterns of home range establishment were found, and all rhinos showed clear seasonal movements or changes in home range and core area size.

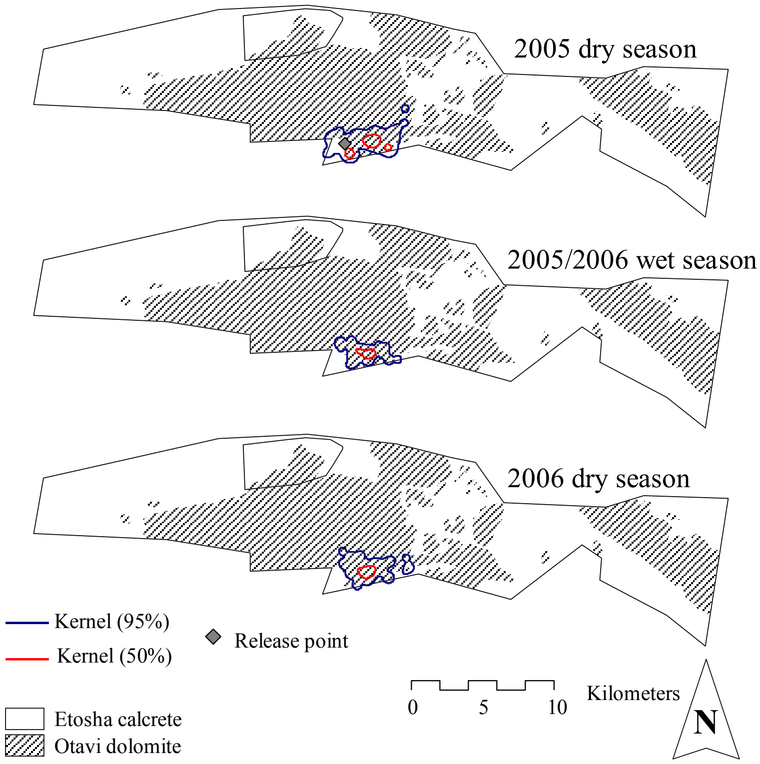
The subadult males established relatively small home ranges in the area of release (OD) and reduced home range and core area size, as well as numbers of core areas, during the wet season.

The adults initially dispersed into a westerly direction and had a pronounced exploration phase during the first season after release (2005 dry season), when they regularly returned to the release area. The phase of exploration was characterised by a stronger staying and returning behavior of the male (second distinct core area at the release area), when compared with the female adult. The inner-fenced area was routed around via a road next to the northern fence of the study area that borders ENP. Principally, both rhino adults used lowlands eastwards and westwards of the inner-fenced area during that time. During the following wet season, rhino adults significantly reduced home range and core area size and settled into much smaller areas on EC. The female established four distinct core areas, whereas the male’s core area is restricted to one center only. During the following season (2006 dry season), the female again reduced home range and core area size, as well as numbers of core areas, whereas the male adult increased ranging activity, establishing two distinct core areas on both substrate types. In late October 2006 the adult female was found with a calf.

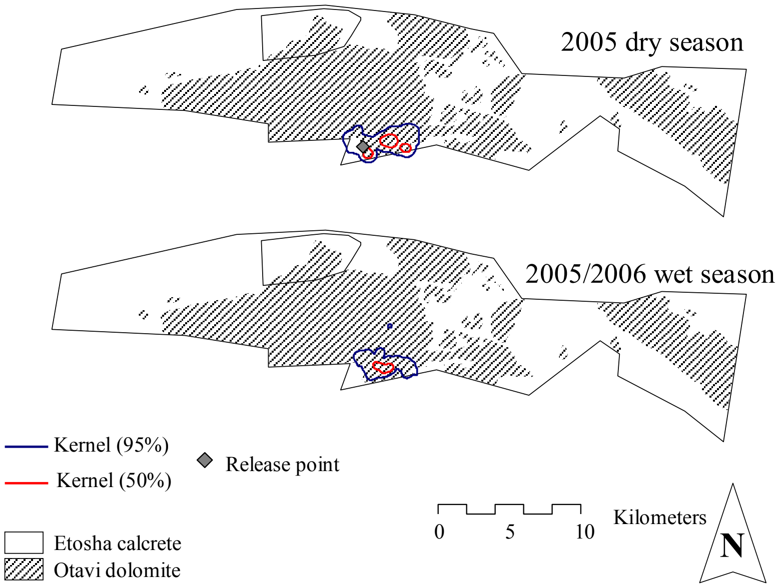
In contrast to the rhino adults, subadult females initially settled in an approximately 10 km radius distance to the release area. In the course of the 2005 dry season, subadult female 1 built three distinct core areas of comparable size, of which one was incorporating the home ranges of the subadult males, whereas subadult female 2 build one core area only. Both females regularly switched between OD and EC areas, which is indicated by regular migrations (linear distance 10 - 20 km), whereas the average linear distance between fixes on consecutive observation days was 3.5 km. During the following season however, subadult females increased exploration activity. Subadult female 2 established a second core area within its previously used home range. Female 1 gave up its initial core areas and migrated into the western area to built one new core area on EC, where the adults established their core areas at this stage of the study. A linear distance of 32 km indicates this one-way migration of subadult female 1 on consecutive observation days. Afterwards this female only sporadically visited one previously occupied area (OD).



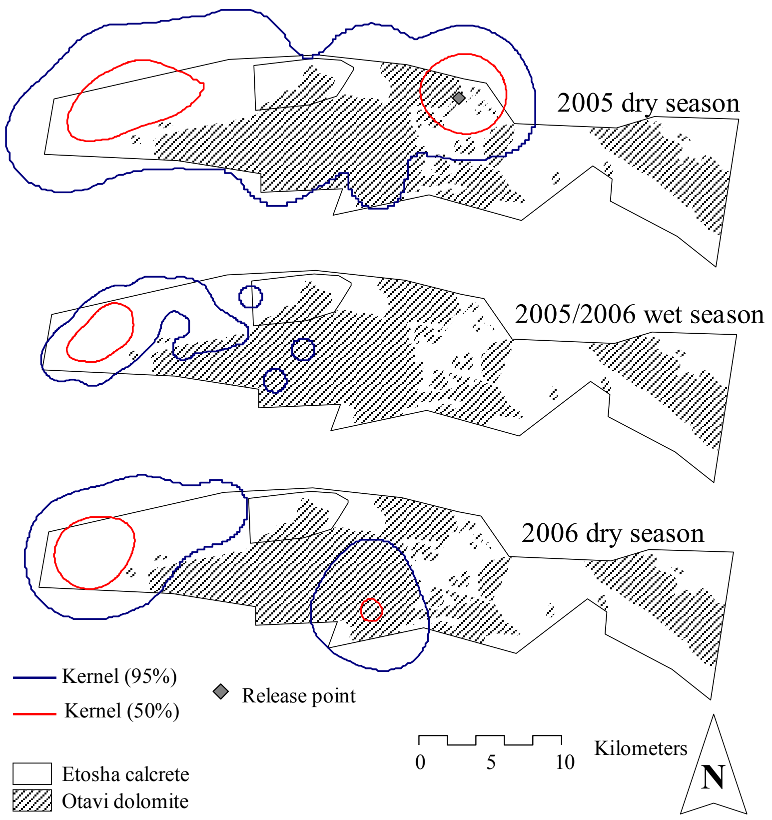
Map 3. Total home ranges (corrected 100 % MCP, uncorrected 95 % Kernel) and core areas (50 % Kernel) of individual black rhinos.



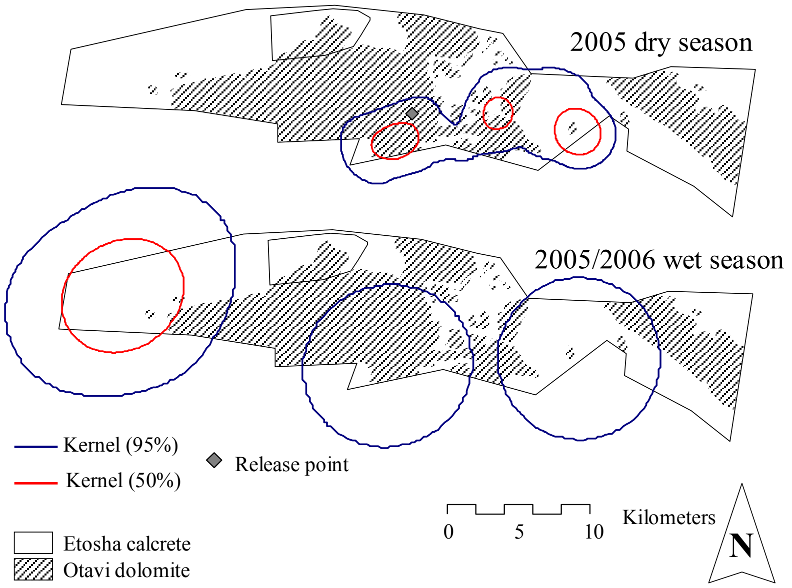
Map 4. Uncorrected seasonal home ranges and core areas of subadult male 1.



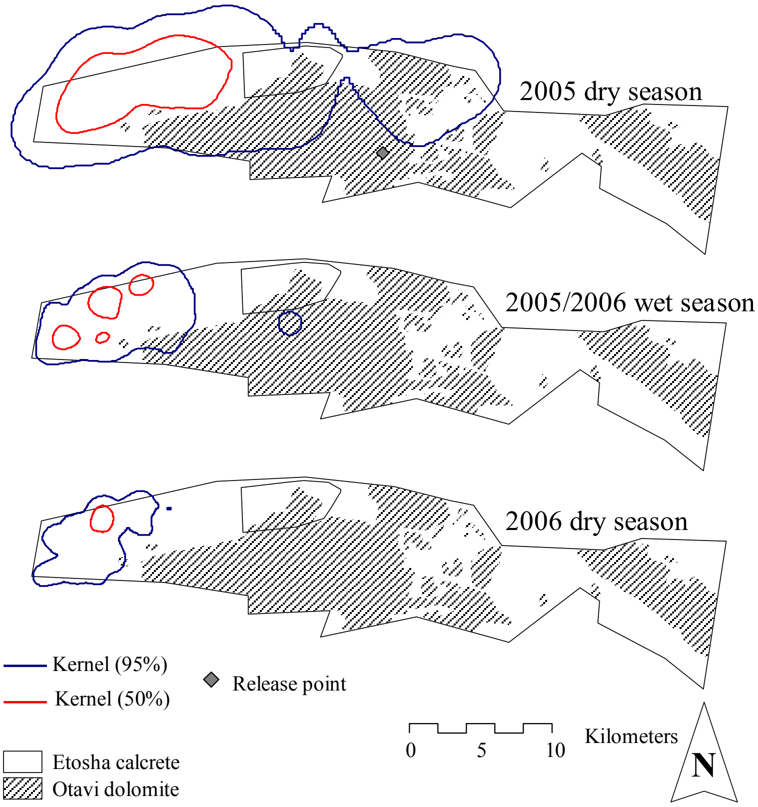
Map 5. Uncorrected seasonal home ranges and core areas of subadult male 2.



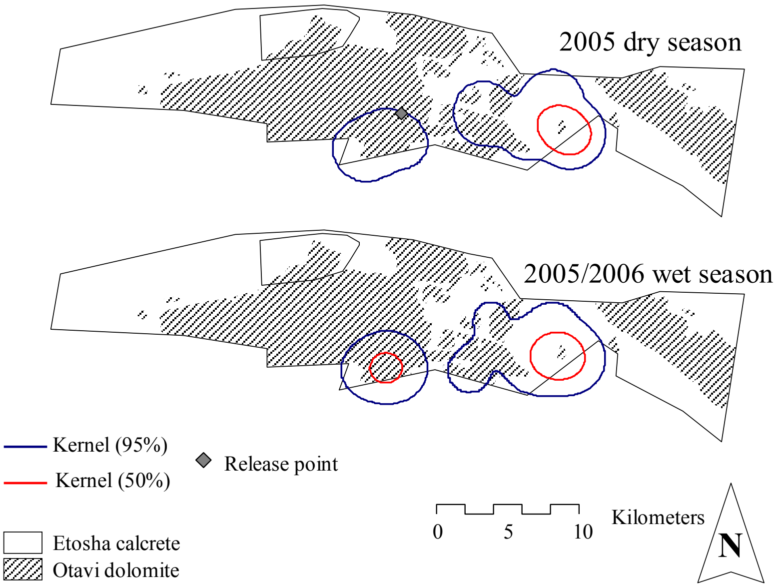
Map 6. Uncorrected seasonal home ranges and core areas of the male adult.



Map 7. Uncorrected seasonal home ranges and core areas of subadult female 1.



Map 8. Uncorrected seasonal home ranges and core areas of the female adult.



Map 9. Uncorrected seasonal home ranges and core areas of subadult female 2.

Interim conclusion

The size of total and seasonal home ranges, as well as home range establishment patterns and habitat use, are highly variable among individual rhinos (Table 7).

Table 7. Home range and core area establishment patterns for total and seasonal home ranges of individual black rhinos.

Total home range	Subadult ♂1	Subadult ♂2	Adult ♂	Subadult ♀1	Subadult ♀2	Adult ♀
Number of fixes	306	172	298	152	147	254
100 % MCP (km^2)	15.0	10.8	234.6	180.4	87.4	152.4
95% Kernel (km^2)	7.1	8.2	220.2	181.3	58.3	64.5
50% Kernel (km^2)	0.6	1.0	26.2	73.5	10.0	8.9
Number of core areas	1	2	1	3	2	1
Core area habitat	OD	OD	EC	EC, OD	EC, OD	EC
Migratory activity[1] (km)	1.1	1.3	4.4	3.5	3.5	3.7
2005 dry season						
Number of fixes	67	57	84	81	82	68
95% Kernel	9.8	9.1	218.6	77.4	61.1	164.6
50% Kernel	1.4	1.6	49.2	16.5	7.3	43.6
Number of core areas	3	3	2	3	1	1
Core area habitat	OD	OD	EC, OD	EC, OD	EC	EC
Migratory activity	1.4	1.5	4.3	2.5	3.4	5.9
2005/2006 wet season						
Number of fixes	96	85	62	47	47	61
95% Kernel	5.7	6.5	60.5	186.2	61.8	55.6
50% Kernel	0.6	0.8	13.3	40.8	12.1	8.7
Number of core areas	1	1	1	1	2	4
Core area habitat	OD	OD	EC	EC	EC, OD	EC
Migratory activity	0.9	1.1	4.0	5.0	3.6	3.9
2006 dry season						
Number of fixes	130	-	112	-	-	95
95% Kernel	7.7	-	112.0	-	-	31.4
50% Kernel	0.8	-	24.4	-	-	2.4
Number of core areas	1	-	2	-	-	1
Core area habitat	OD	-	EC, OD	-	-	EC
Migratory activity	1.1		5.0			2.5
General Settlement Pattern	Decrease	Decrease	Decrease Increase	Shift	Increase	Decrease

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[1] Mean succsessive distance between fixes

Associations between individuals

Total home range overlap (based on 100 % MCP) indicates great similarities between subadult males, rhino adults and male adult / subadult female 1. There also is considerable overlap between home ranges of the subadult females and female adult / subadult female 1 (Table 8).

Table 8. Sociometric matrix showing the index of overlap (V) of total home ranges (100 % MCP) for all possible dyads. For better reading, important dyads are denoted in bold font.

	Subadult ♂1	Subadult ♂2	Adult ♂	Subadult ♀1	Subadult ♀2
Subadult ♂2	**0.8**				
Adult ♂	0.1	0.1			
Subadult ♀1	0.1	0.1	**0.8**		
Subadult ♀2	0.3	0.2	0.5	0.6	
Adult ♀	0.0	0.0	**0.8**	0.6	0.1

Results on Kernel home range and core area overlap reveal seasonal changes of the social structure of the starter group (Table 9). During the first season after release (dry season 2005), rhinos clearly dispersed forming three dyads: subadult males, subadult females and adults. Each dyad showed a high degree of home range and core area overlap. There was little or no home range and core area overlap between these three dyads. In the 2005/2006 wet season, subadult males retained high levels of home range and core area overlap. Subadult female 1 shifted home range into a new area, forming a social unit with the adult rhinos.

Table 9. Sociometric matrix showing the index of overlap (V) of seasonal home ranges and core areas for all possible dyads. Data arrangement: V of 95 % Kernel polygons/V of 50 % Kernel polygons. For better reading, important dyads are denoted in bold font.

Dry season 2005	Subadult ♂1	Subadult ♂2	Adult ♂	Subadult ♀1	Subadult ♀2
Subadult ♂2	**0.9 / 0.9**				
Adult ♂	0.1 / 0.0	0.1 / 0.0			
Subadult ♀1	0.2 / 0.1	0.2 / 0.2	0.2 / 0.0		
Subadult ♀2	0.3 / 0.0	0.3 / 0.0	0.1 / 0.0	**0.9 / 0.5**	
Adult ♀	0.0 / 0.0	0.0 / 0.0	**0.9 / 0.6**	0.0 / 0.0	0.0 / 0.0
Wet season 2005/2006					
Subadult ♂2	**0.9 / 0.9**				
Adult ♂	0.0 / 0.0	0.0 / 0.0			
Subadult ♀1	0.1 / 0.0	0.1 / 0.0	**0.4 / 0.5**		
Subadult ♀2	0.2 / 0.1	0.2 / 0.1	0.0 / 0.0	0.4 / 0.0	
Adult ♀	0.0 / 0.0	0.0 / 0.0	**0.8 / 0.5**	**0.4 / 0.3**	0.0 / 0.0

At 198 locations, one or more rhinos were directly sighted. At most locations rhinos were observed solitary (78.3 % of locations) but they occasional formed groups of two (19.2 %), three (2 %) and four animals (0.5 %).

The largest similarity was found between the two subadult males. The next important association is the male adult and subadult female 1. At the next level, the subadult males are associated with subadult female 2. The female adult showed the lowest social tendency in the founder group (Figure 12).

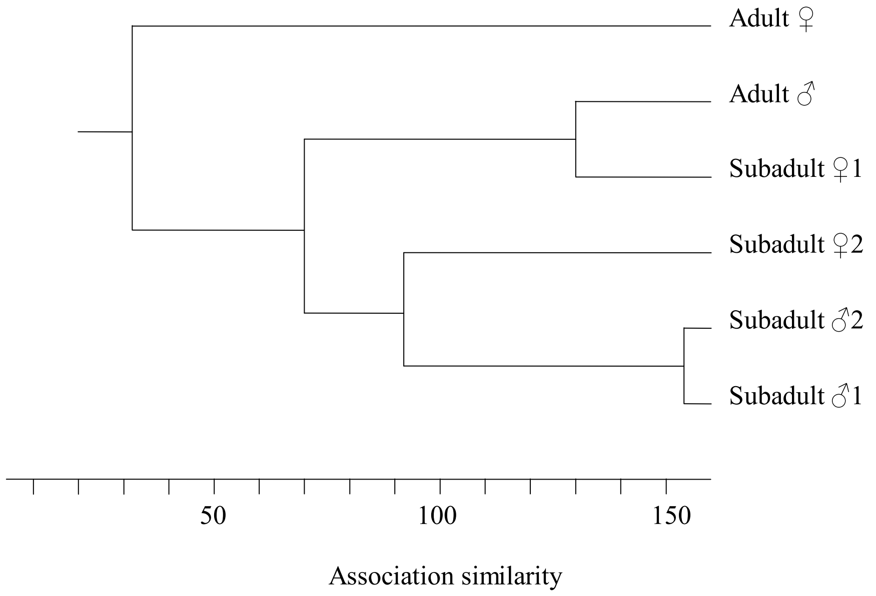

Figure 12. Relative association similarities between individual rhinos according to SLCA.

Picture 5. a) subadult male 1 and subadult female 2 in a woodland habitat on OD, b) adult male and subadult female 1 formed an important dyad, rhinos browsing on dwarf scrubs in a relatively open habitat on EC, c) in October 2006 the adult female conceived a calf, d) adult female in relatively open acacia savannah on EC, subadult male 1 in dense woodland habitat on OD, f) adult male resting flat on the side, g) scrape marks of the male adult, h) *Acacia* plant destroyed by black rhinos in order to reach appropriate shots and twigs.

Description of used habitats

Woody plant species

In total, 24 woody plant species were found, of which rhinos used 13 species as fodder plants (Table 10). The number of plant species per area is 19 (OD), 16 (T) and 17 (EC). The similarity index between the two geological formations is 0.7.

Table 10. Information on identified woody plant species.

Scientific name	OD	T	EC	Rhino browse
Acacia luederitzii	+	-	+	+
Acacia mellifera	-	+	+	+
Acacia nebrownii	-	+	+	+
Acacia nilotica	-	+	-	+
Acacia reficiens	+	+	+	+
Acacia senegal var. *rostrata*	+	+	+	+
Boscia microphylla	+	+	+	-
Catophractes alexandri	+	+	+	+
Colophospermum mopane	+	+	+	-
Combretum apiculatum	+	+	-	+
Commiphora glandulosa	+	+	+	-
Commiphora glaucescens	+	-	-	-
Dichrostachys cinerea	+	+	-	-
Grewia bicolor	+	-	+	+
Grewia flava	+	+	+	-
Grewia flavescens	+	-	-	+
Grewia villosa	-	-	+	-
Leucosphaera bainesii	+	-	+	-
Monechma genistifolium	+	+	+	+
Mundulea sericea	+	-	-	-
Petalidium engleranum	+	+	+	+
Spirostachys africana	+	-	-	-
Rhus marlothii	-	+	+	-
Terminalia prunioides	+	+	+	+

Bivariate comparison of vegetation plots

For bivariate comparison of units (plots), only OD and EC samples were used, as sample size for transitory plots is low. Cover (%) of woody plants per unit was high on both geological substrates: OD: 105.6 (IQR: 56.2), EC: 94.6 (IQR: 39.9), (U = 38.0, p = 0.65). The species richness (number of species) per plot also did not vary between substrate types: OD: 8.0 (IQR: 0), EC: 6.0 (IQR: 3.5), (U = 30.0, p = 0.25). When comparing the plots in terms of biodiversity indices, no difference was found: Shannon-Diversity (H`): OD: 1.46 (IQR: 0.33), EC: 1.15 (IQR: 0.71), (U = 27.5, p = 0.186), Simpson-Diversity (S`): OD: 0.69 (IQR: 0.13), EC: 0.59 (IQR: 0.29), (U = 24.0, p = 0.11). However, there were fewer individual plants on OD: 45.5 (IQR: 14.8) than on EC: 81.0 (IQR: 52) (U = 71.0, p = 0.03). Mopane *Colophospermum mopane* was present at most plots, with larger individuals on OD (height in m): 2.08 (IQR: 0.64; n = 8) and smaller individuals associated with EC: 1.13 (IQR: 0.77; n = 9), (U = 12.0, p = 0.02).

Habitat structure and plant species composition differed markedly between substrates (Figure 13). Most of OD ground layer was characterized by grasses (60 %), the proportion of trees (52.5 %) and shrubs (47.3 %) was almost balanced, and dwarf shrubs (0.2 %) were nearly absent. At EC there was more bare soil (75.5 %) than grass cover (24.5 %), and shrubs (73.6 %) were more important than trees (18.2 %). Dwarf shrubs (8.1 %) achieved almost half the cover of the tree layer.

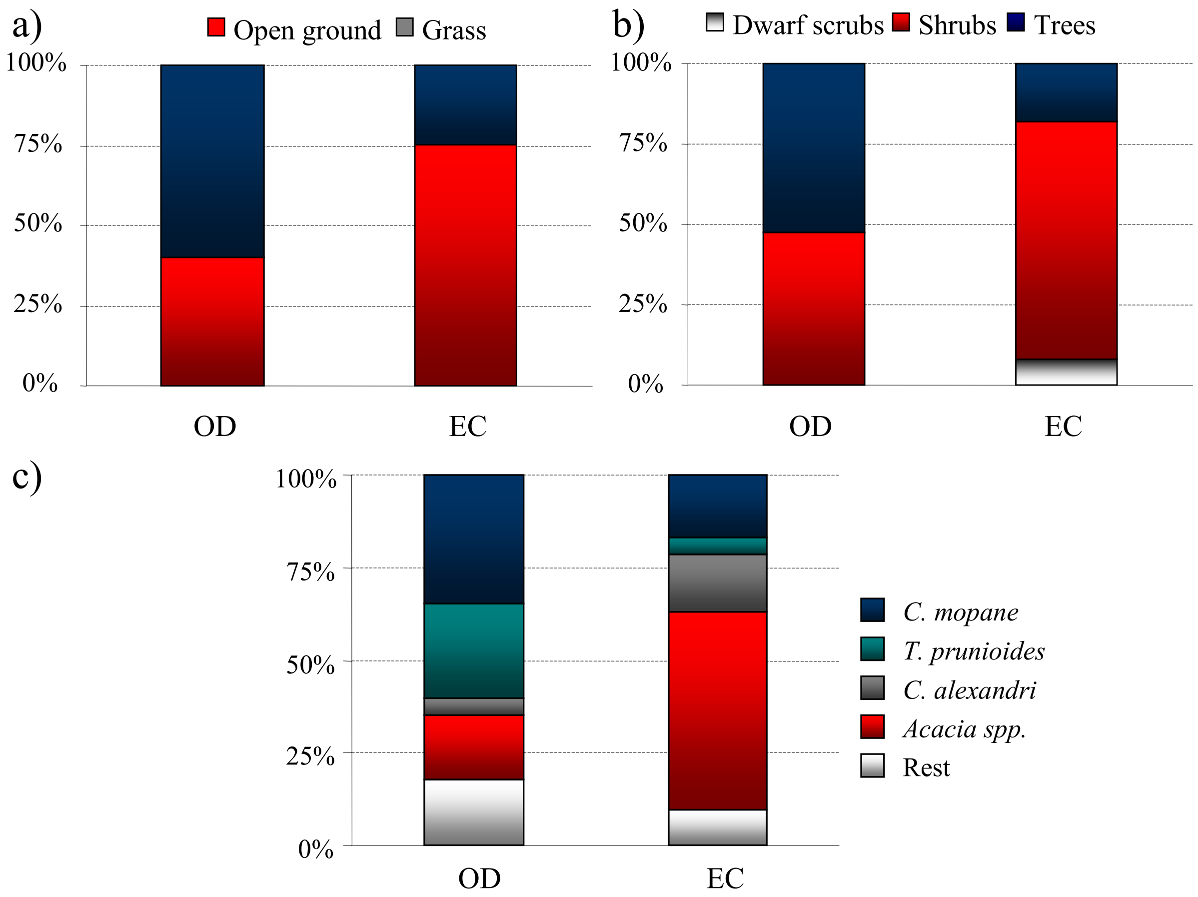

Figure 13. Comparison between OD and EC plots based on the cover of the respective layer (a, b) and species composition (c).

OD was dominated by the trees *Colophospermum mopane* (34.8 % of total cover) and purple-pod terminalia *Terminalia prunioides* (25.4 % of total cover). In contrast, the most prominent feature on EC was the dominance of *Acacia* spp., which accounted for 53.4 % of the total cover. The most common *Acacia* spp. were *A. reficiens* and *A. luederitzii*, which together accounted for 80 % (OD) and 85 % (EC) of *Acacia* spp. per area. The shrub *Catophractes alexandri* represented 4.7 % (OD) and 15.4 % (EC) of vegetation cover. *Colophospermum mopane* cover was less than half as high on EC compared to OD. *Terminalia prunioides* composed 25.4 % (OD) and 4.5 % (EC) of vegetation cover. There was no influence from distribution of water areas on the vegetation.

Multivariate comparison of vegetation plots

Data on plant community compositions were summarised in an ordination (Figures 14 and 15). The DCA of species cover data shows that OD samples are quite distinct from those on EC with only slight overlap. EC vegetation is more widely scattered in the ordination plot indicating larger differences in floristic composition. The greater variation in species composition compared to OD indicates the heterogeneity of the habitat mosaic. The species ordination indicates that *T. prunioides*, the bushy three-hook thorn *Acacia senegal* and the red bushwillow *Combretum apiculatum* are associated with OD, whereas dwarf shrubs (*Monechma genistifolium*, *Petalidium engleranum*) as well as *Catophractes alexandri*, *A. reficiens* and *A. luederitzii* were associated with EC. The plots that were initially classified as transitional substrate clustered evenly among dolomite and calcrete samples.

The DCA of species height data reveals similar patterns: 1) distinct OD and EC samples with only slight overlap, 2) greater heterogeneity of EC samples and 3) intermediately scattered transitory plots. A further similarity is that important black rhino fodder plant species on OD are *T. prunioides*, *Acacia senegal* and *Combretum apiculatum*, whereas *Petalidium engleranum*, *A. reficiens* and *A. luederitzii* are associated with the calcrete substrate. Species height DCA arranges *Colophospermum mopane* and *Catophractes alexandri* into the centre of the plot. The length of gradients (distance between most distinct samples) reveals similar results to species height DCA. Both approaches (species cover and species height DCA) reveal comparable degrees of heterogeneity of the entire set of samples.

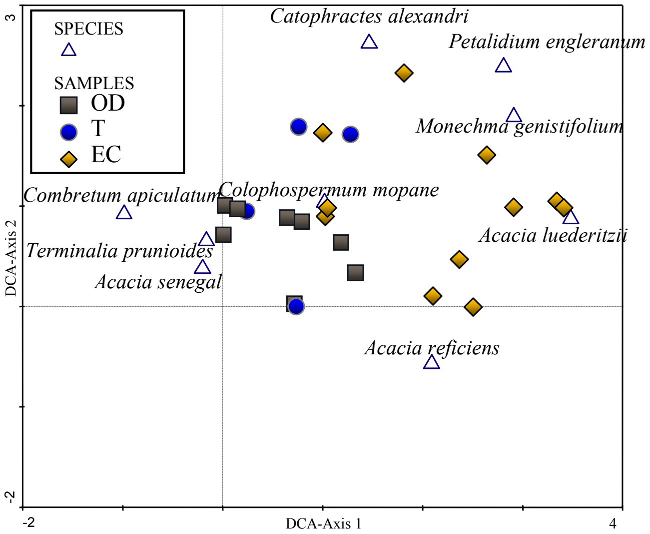

Figure 14. Detrended Correspondence Analysis (DCA) calculated from species cover data. From the best fitting 12 species that were most reliably, only species are shown, which have been black rhino fodder plants (except *C. mopane*); (detrending by segments, no downweighting of rare species, Eigenvalue / length of gradient Axis 1: 0.71 / 3.40; Axis 2: 0.24 / 2.33; Axis 3: 0.18 / 1.51).

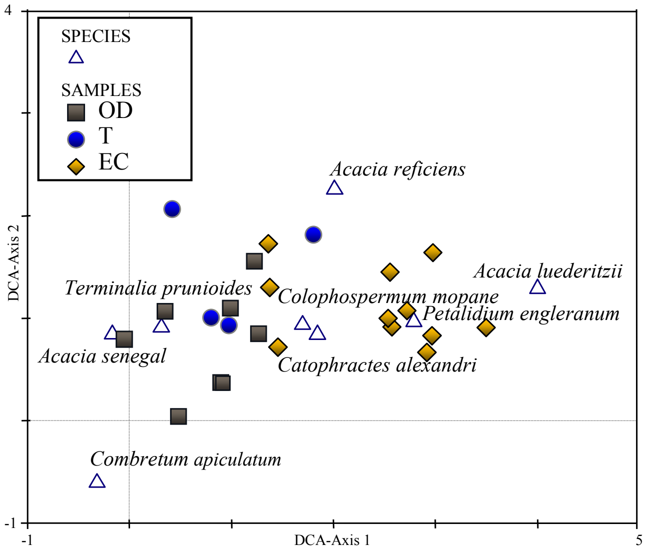

Figure 15. Detrended Correspondence Analysis (DCA) calculated from species height data. From the best fitting 12 species that were most reliably, only species are shown, which have been black rhino fodder plants (except *C. mopane*); (detrending by segments, no downweighting of rare species, Eigenvalue / length of gradient Axis 1: 0.52 / 3.53; Axis 2: 0.23 / 2.03; Axis 3: 0.13 / 1.99).

Interim conclusion

In summary, the results on the vegetation analysis reveal that rhinos used two distinct habitat types on both geological formations. Both habitat types show a comparable number of woody plant species (of which rhinos used most species as fodder plants) and a high degree of cover. OD features a woodland habitat type, which is dominated by the trees *Colophospermum mopane* and *Terminalia prunioides* and a well developed shrub layer. EC features a scrubland habitat type and a higher degree of heterogeneity among samples. The scrubland is dominated by *Acacia* spp., predominantly *A. reficiens* and *A. luederitzii*. Another important scrub on EC is *Catophractes alexandi*.

Discussion

Methodological approach

A home range is an area with a defined probability of occurrence of an animal during a specified time period (Harris et al. 1990, Robertson et al. 1998). In this study, home ranges were analysed using two methods: minimum convex polygon (MCP [Mohr 1947, Kenward 1987] and Kernel method (Worton 1987, Worton 1989).

The MCP gives the range enclosed by the outermost locations of the animal, assuming uniform use of space within this range (Kenward 2001, Kernohan et al. 2001). The Kernel method is based on the assumption that aggregation of locations provides information about differential use of space within the home range (Worton 1989). Thus, it provides the probability of an animal occurring at each location within its home range (Worton 1987, Worton 1989) and, for example, allows detecting centres of activity. For this reason, if the location sample sizes permitted, Kernel method reveals a more accurate picture of the actual ranging behaviour of an animal.

There are two reasons why not only the Kernel method but also the MCP method was used in this study. Firstly, most literature references on black rhino home ranges are based on MCP method. Therefore, the 100% MCP of the total home ranges (home range over the study period) was calculated for comparison with these references. Secondly, the MCP method can be applied to the observation-area curve method that was developed by Odum and Kuenzler (1955) to determine the number of observations necessary to define territory size of several bird species. It is based on the principle of the number of observation increasing, while the rate of increase in the area visited by an animal decreasing, so that an asymptotic curve results. Odum and Kuenzler (1955) selected the 1% level on the curve (the point of each additional observation producing <1% increase) as the point at which the territory size was determined. The ideally asymptotic shape of the observation-area curve presumes that the animal already occupies an established home range or territory when the investigation starts. In the case of this study however, the method was applied to describe the pattern of home range establishment of relocated rhinos after release. Interestingly, various patterns of the cumulative increase of the total home range (100 % MCP) of rhino individuals were found, ranging from asymptotic to sigmoid character. Curves for all individuals plateau out by the end of the investigation, assuming that the number of observations / study period was sufficient for estimating home ranges of individuals. Lent and Fike (2003) reported 35 or more observations necessary to estimate black rhino home range size for comparison with literature data. Tatman et al. (2000) found that reliable home range estimates were obtained with between 20 and 30 fixes. By contrast, this study shows that between 42 and 130 observations were necessary to reach the final plateau of the observation area curve. Contrary to the before mentioned studies, here the method was applied to a post-release study, with animals establishing home ranges simultaneously with data collection. It comes out that the observation area curves from this study, especially curves with a sigmoid character, can be divided into periods, as the curve reaches an asymptote for each period. Observation area curve indicates sufficient number of observations per period, although the actual spatial utilisation (total home range) clearly differs. This study shows that the time scale for such investigations is crucial, as sudden shifts of ranging behaviour do occur, which would not be apparent over shorter durations.

The study further shows that the observation-area curve is a useful method to describe certain aspects of ranging behaviour and detect qualitative individual differences. Sudden changes (e. g. altering steep increase and plateau periods) may indicate shifts of activity centres (Gabelmann 2008). However, to get a more detailed picture of the space utilisation of rhinos, the Kernel method was used to estimate total and seasonal home ranges and activity centres (core areas). As expected, the Kernel method made clear that rhinos were not uniformly distributed within their home range, but rather concentrated at certain core areas. Rhinos established distinct core areas, between which they either regularly switched or which they established at different times of the survey.

By estimating Kernel polygons per seasons, it could be shown that home ranges and core areas size varies between seasons and rhinos partly shifted home ranges into new areas. The great increase of the observation area curve of subadult female 1 during a later part of the study, for example, is linked with a shift of home range and core areas of this rhino. Another good example to demonstrate the validity of the Kernel method is the ranging behaviour of the female adult. Analysis of seasonal home ranges and core areas reveals a cumulative decrease of the home ranges and settlement behavior to a certain area. This pattern is not obvious when using observation area curve method only. Here, the relative difference between the total home range size according to 100 % MCP (152.4 km^2) and 95 % Kernel (64.5 km^2) polygon is an obvious indicator. The Kernel polygon is clearly reduced, as most fixes were found in a relatively small area. In summary it has been shown that a combination of both methods for home range estimation, MCP as well as Kernel method, forms a valuable approach to describe the post-release ranging behavior of rhinos in this study.

General acclimatisation cues

Acclimatisation refers to potentially beneficial adjustments made by individual organisms with respect to the environment. To assess these benefits, Mazess (1975) considered different adaptive domains: e. g. reproduction, health, nutrition, physical performance and intellectual ability. During this survey, no abnormal behaviour, mortality or signs of diseases were observed.

In October 2006 the adult female was found with a calf. The birth must have taken place between 553 and 558 days after release. Given a gestation period of 438 to 480 days (Ramsay et al 1987), successful copulation between adults must have already occurred between 73 and 120 days after their initial translocation. This is also supported by the home range overlap of this dyad during the first season after release (dry season 2005). Since both adult males were released together, the copulation could have occurred with ovulation that may have been prolonged due to translocation stress.

The age of first conception in wild black rhinos ranges from 3.5 years to > 9 years (Hillman-Smith and Groves 1994). Hence, the movement of subadult female 1 towards the home range of the adult male during the wet season 2005/2006 may be another indicator for acclimatisation in regards to reproduction.

Home range size and establishment patterns

The results show that home range size and establishment patterns were greatly variable among individuals. Accordingly, Tatman et al. (2000) reported on high individual variability of black rhino home range size. Because of varying habitat quality the literature reports of black rhino home range size (based on MCP method) vary considerably (Table 11).

Table 11. Comparison of black rhino home range sizes from different studies and areas.

Area	Reference	Method	Home range size
Hluhluwe (South Africa)	Hitchins (1969)	MCP[1]	0.5 – 0.75 km^2
Ndumu (South Africa)	Conway and Goodman (1989)	MCP	4.3 – 14.3 km^2
Masai Mara (Kenya)	Mukinya (1973)	MCP	5.6 – 22.7 km^2
Laikipa (Kenya)	Tatman et al. (2000)	MCP	2.3 – 14.4 km^2
Ngorongoro crater (Tanzania)	Goddard (1967)	MCP	2.6 – 58 km^2
	Kiwia (1989)	MCP	12.5 – 69 km^2
Serengeti National Park (Tanzania)	Frame (1980)	MCP	43 – 133 km^2
Damaraland (Namibia)	Loutit (1984)	MCP	~ 500 km^2
Great Fish River Reserve (South Africa)	Lent and Fike (2003)	95% MCP	1.7 - 18.3 km^2
		50% Kernel	1.8 – 9.9 km^2
This study	Göttert et al. (2010)	MCP	10.8 – 234.6 km^2
		95% Kernel	7.1 – 220.2 km^2
		50% Kernel	0.6 – 73.5 km^2

Lent and Fike (2003) studied ranging behaviour of an expanding black rhino population in Great Fish River Reserve in South Africa. According to the present study, these authors found great variances in individual home range size (affected by social factors) and rhinos shifting home ranges over time. The authors report core areas (50 % Kernel polygons) between 1.8 km^2 and 9.9 km^2. It has been noted that largest black rhino home ranges are found in Namibia (Loutit 1984, Berger and Cunningham 1995). Accordingly, home ranges of most individuals from the study at hand are among the largest recorded for the species. Moreover, seasonal effects on home range and core area size or seasonal movements were observed for all rhinos. Several studies have shown seasonal changes of home ranges of reintroduced large herbivores, such as roe deer *Capreolus capreolus* Linnaeus 1758

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[1] Minimum convex polygone (100%)

(Carvalho et al. 2008) and Persian fallow deer *Dama mesopotamica* Brooke 1875 (Perelberg et al. 2003). As acclimatisation includes seasonal and climatic changes (Hart 1957), the seasonal movements observed in the present study are further indicators for the cognitive and behavioural acclimatisation of the founder group. Several authors assumed that black rhino subadults generally have larger ranges than adults, probably as a means of dispersal (Goddard 1967, Mukinya 1973, Frame 1980, Loutit et al. 1987). The present study rather supports social aspects influencing exploration behaviour.

Linklater et al. (2006) were the first to give a detailed description on the daily movements of black rhinos following translocation. Linklater and Swaisgood (2008) used daily movements to described settlement patterns of 34 black rhinos released into 12 different sites across South Africa, stating that time frame for acclimatisation is 15 – 25 days post-release. Patton et al (2010) found a time frame of 1- 93 days until settlement of animals. Both studies showed that in at least 44 % of cases settlement was not complete after 100 days.

However, investigating home range establishment and related social patterns, the present study suggests that even much longer time frames may be necessary until settlement of individual rhinos, and that seasonal effects may overlap with possible settlement patterns. Based on the shape of some home ranges and core areas, it is likely that rhinos would have crossed the border of the study area, if not fenced. Erb (1999) described the post-release behaviour of translocated black rhinos within and out of the ENP in Namibia. He reported that black rhinos translocated within ENP normally settled within a 30 km radius of the release area and did not wander back to their original home ranges. Although the movement of black rhinos in the present study suggests trespassing of home range borders and enlargement or shifts of home ranges with time, rhinos clearly settled in a specific area.

Habitat use

Black rhinos select for medium to dense cover (Owen-Smith 1988, Hillman-Smith and Groves 1994). In this present study, rhinos were found using both geological substrates of the study area, each with a characteristic composition of plant communities. Generally, the utilised habitat types provided a low degree of available plant species (habitat quality) but a high proportion of thicket, which may be important for shelter. The small home ranges size of the subadult males, which exclusively roamed the OD area, may have been a result of intra-specific competition. However, considering the fact that five out of six rhinos used OD at least for certain periods, relatively small home ranges of subadult males suggest the suitability of this seemingly marginal habitat type. EC substrate features a variety of habitat types, which are also present at large areas of ENP (Mendelsohn et al. 2002). Rhinos may have been habituated to familiar habitats. However, the dominance of *Acacia reficiens* and *A. luederitzii* suggests that utilised habitats on EC were markedly influenced by bush encroachment, probably the result of former intensive livestock farming. This chapter demonstrates the ability of black rhinos to rapidly acclimise and succeed in former intensively grazed farmland. Hence, it should encourage further relocation activities on degraded farmland in this region.

An early description about the vegetation at the study area was given by Giess (1971), who classified the area as 'mopane savannah'. The present chapter shows that the tree mopane *Colophospermum mopane* is a typical habitat feature, occurring at 22 out of 23 vegetation plots. However, the growth form varied from shrub (EC) to tree (OD) depending on the geological formation. *Colophospermum mopane* has not been reported to be of importance regarding black rhino habitat selection, neither was a browsing event on this plant species observed in this study.

Social structure

The results on home range establishment and habitat use provide information regarding several adaptive domains. Adult rhinos, which should establish the highest social status within the group, had a pronounced exploration period (moving of great distances in search of appropriate habitat) during the first season after release. In contrast, subadult rhinos either showed no distinctly variation in ranging behaviour throughout the study (subadult males), or they increased exploration behaviour at later stages (subadult females). Pronounced exploration was comparable to studies on various mammalian species (Jnawali and Wegge 1993, Miller et al. 1998, Schröpfer 2003).

Although black rhinos are known to be solitary, temporary associations do occur between individuals (Klingel and Klingel 1966, Goddard 1967, Schenkel and Schenkel-Hulliger 1969). Tatman et al. (2000) used home range overlap to gain insight into black rhino social organisation. The authors found groups of rhinos (one adult male, one or more adult females with their calves and sometimes immature animals) sharing a common home range. Spatial overlap of home ranges suggests similar patterns of social organisation. McLoughlin et al. (2000) developed a model of spatial organisation in vertebrates with regards to habitat quality. The authors modelled large home range size and high home range overlap in areas of low habitat quality, a good fit to the movements of the black rhino study group using relatively low quality habitat.

Linklater and Swaisgood (2008) and Patton et al. (2010) state that rhinos appear to actively avoid other rhino after release. Contrary to this, the present study reveals the development of social units, which may also be linked with the availability of resources. When considering observations only, (76 % of observations rhinos found solitary), one would see the theory of solitary structure of the species supported. However, by also analysing home ranges and habitat use, a more detailed picture of the social system of the starter group emerges. These results rather support the semi-social tendency of black rhinos.

Management implications

The results showed the suitability of VHF-telemetry and manual sightings to successfully monitor six south-western black rhinos after release into a 350 km^2 study area. Due to potential increased exploration activity during the first months after release, management should consider the particular vulnerability of black rhinos against potential dangers, such as remaining fence, gravel pits, loose rocky terrain and roads and most importantly (resident) conspecifics. Wildlife managers of black rhinos should consider the dimensions of space utilization and the fact that dramatic shifts in migration activity may occur over time.

The habitat mosaic and large size of the study area, coupled with the study period allowed for detection of cognitive and behavioural acclimatisation processes, which would not be apparent in smaller areas, or over shorter durations. Age class specific patterns of home range establishment, typical mating and social behaviour, and clear shifts in spatial behaviour, possibly owing to seasonal availability of resources, were found. The amount and spatial distribution of water areas at the study area (0.07 water areas per km^2) may be a good reference value for future reintroduction procedures in this region. These findings showed the suitability of the black rhino to deal with former cattle grazing habitats and thus, reintroduction of black rhinos may help farmers and land owners to reduce bush encroachment.

Summary

In this chapter, post-translocation exploration behaviour, home range establishment, social organisation and habitat use of a black rhino *Diceros bicornis* Linnaeus 1758 founder group were systematically examined over a study period of two years (Mar 2005 – Feb 2007). Rhinos were radio tracked and movement data were complemented by detailed habitat descriptions at the centres of rhino activity with vegetation plot sampling. Rhinos used both geological formations of the study area: Otavi dolomite (OD) and Etosha calcrete (EC) substrate. The latter was dominated by *Acacia* spp. due to former land use for livestock farming. The size of total and seasonal home ranges and core areas, as well as home range establishment patterns and habitat use, are highly variable among individual rhinos. Home ranges of most individuals from this study are among the largest recorded for the species. Age class specific patterns of home range establishment, typical mating and social behaviour, seasonal changes of home range and core area size, and clear shifts in spatial behaviour over time were found. The results provide a reasonable uptodate accurancy of estimate for the natural cognitive and behavioural acclimatisation of black rhinos in a semi-arid savannah ecosystem.

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CHAPTER IV: DIURNAL ACTIVITY AND DISTURBANCE BEHAVIOUR OF TRANSLOCATED BLACK RHINOS

Introduction

Translocation exposes rhinos to a multi-stress environment, and systematic post-release monitoring of translocated rhinos is recommended (Hutchins and Kreger 2006, Emslie et al. 2009). With an increasing level of human recreation in natural areas and shrinking habitat for wildlife, there is a growing literature on wildlife activity patterns and response behaviour to humans (e. g. Batcheler 1968, Kufeld et al. 1988, Kilgo et al. 1998, Stankowich and Blumstein 2005). Interestingly, diurnal activity patterns and the response behaviour of black rhinos towards human observers have not been studied with regards to translocation.

Goddard (1967) was the first studying black rhino *Diceros bicornis* Linnaeus 1758 diurnal activity rhythm. He investigated two populations in northern Tanzania (Ngorongoro Crater and Olduvai Gorge) and found a bimodal activity pattern with rhinos active during the morning and afternoon hours and a phase of inactivity during midday. In a follow up study, Kiwia (1986) investigated the same populations in greater detail. In addition to a similar bimodal diurnal activity pattern, he also found seasonal changes in rhino activity.

Rhinos are ungulates that show typical patterns of disturbance behaviour towards environmentally stimuli. Disturbance behaviour has become an important tool to gain a better understanding of ungulates' behaviour and welfare. The responses of wild ungulates to human disturbance are greatly variable (Caro et al. 2004, Apollonio et al. 2005), and a range of studies deal with the behavioural responses of ungulates from various taxa to human disturbance, e.g. Sardinian mouflon *Ovis ammon musimon* Pallas 1811 (Ciuti et al. 2008), sika deer *Cervus nippon* Temminck 1838 (Koganezawa and Li 2002), Columbian black-tailed deer *Odocoileus hemionus columbianus* Richardson 1829 (Stankowich and Coss 2007), fallow deer *Dama dama* Linnaeus 1758 (Recarte et al. 1998, Apollonio et al. 2005), guanaco *Lama guanicoe* Müller 1756 and vicuña *Vicugna vicugna* Molina 1782 (Donadio and Buskirk 2006), or American bison *Bison bison* Linnaeus 1758 (Fortin and Andruskiw 2003). To enlighten adaptive significance of anti-predator behaviour in ungulates, Caro et al. (2004) compared data on 17 anti-predator behaviour patterns in 200 artiodactyl species, and

Stankowich (2008) carried out a meta-analysis of artiodactyl flight responses to human disturbance. In addition to species-specific behavioural responses towards predators (and humans), anti-predator strategies may also change with size and morphology of the prey species (Jarman 1974, Christensen and Persson 1993, Dewitt et al. 1999, Lingle and Pellis 2002). By comparing the disturbance behaviour of 19 mammal species (excluding rhinos) in strictly protected areas and in less protected areas in western Tanzania, Caro (1999) showed intra-specific changes according to the area (animals more flighty outside protected areas). Recarte et al. (1998) found high inter-individual variability in flight responses of park fallow deer, emphasising the need for individual-based behavioural studies.

The previous chapter (chapter III) has proven that exploration behaviour, home range establishment and habitat use are useful indicators to shed light on the process of post-translocation cognitive and behavioural acclimatisation of the studied black rhino starter group. In this chapter, the focus is led on diurnal activity and disturbance behaviour towards human observers. Providing information on these important behavioural correlates will help to obtain additional info on the behavioural acclimatisation of black rhinos.

Material and Methods

Data collection

Data collection of activity patterns and disturbance behaviour has been carried out during the black rhino investigation period described earlier in this thesis (chapter III).

Diurnal activity

Activity readings were collected from direct observations or via radio telemetry. Diurnal active radio-transmitters at 148.4 to 150.9 MHz frequency had an activity switch activated by rhino movements. When locating rhinos, researchers would classify rhinos as active if pulses were alternated between soft and loud, or inactive when pulses were continuously loud. When rhinos were directly observed, the initial (undisturbed) activity pattern was used instead of telemetry pulse information. To assure independence of data, usually one activity reading was recorded per observation day and animal. A total of 1,070 activity readings on six rhinos, with 136 to 288 activity readings per animal, were collected.

Disturbance behaviour

During March 2005 and February 2007, data were collected on 380 observation days (frequency of data collection: 53.7 %). A total of 1,329 fixes were estimated, of which 198 fixes reveal locations, where one or more black rhinos were directly sighted (chapter III). At these 198 locations, a total of 246 individual observations were made, of which 56.1 % were proven by photographs. These 246 observations form the sampling units for the analysis of the disturbance behaviour. The number of observations per individuals ranges between 81 (subadult male 1) and 27 (subadult female 1, adult female) ($\overline{x}$ = 41, SD = 20.6). Observation length ranges from 0.1 min to 114 min ($\overline{x}$ = 18.5 min, SD = 18.9), a total of 75.8 hours were observed. The closest distance to which observers approached rhinos was estimated according to 5 m intervals, when the distance between observer and rhino was < 20 m and 10 m intervals, when this distance was > 20 m. Each observation on disturbance behaviour was either an event (the rhino directly flees), or a behavioural sequence (no direct flight). The beginning of a sequence was defined when the rhino adopted an alert posture (facing the observers with both ears actively flipping), which has been described by Hutchins and Kreger (2006). The immediate response of rhinos (direct flight, attention, move and reorient), the outcome of the sequence (move away, calm down / appeasing [any observation sequences where the rhino starts resting or browsing after a period of giving attention to the observer], observer left alert rhino) and the duration of the longest alert posture phase of a sequence were recorded. Also, the following antipredator behaviour patterns were recorded (Caro et al. 2004): inspection (walking towards the observer once or several times after an attentive period), auditory signals (snorting, squealing, cow-calf communication) and attack (mock charge against the observer).

Data analysis

Diurnal activity

The general diurnal activity pattern (percentage of active readings) was obtained from the total number of activity readings during each one-hour period between 06:00 and 19:00 hours. Seasonal activity patterns (dry season: April, 15 - October, 14, wet season: October, 15 – April, 14) were pooled for each season into two-hour intervals between 06:00 and 18:00 hours.

Comparison of proportions was carried out by Chi square goodness-of-fit test for two and three or more variables using Sigma Plot Statistical Program for Windows, Version 11.0 (SPSS Inc. Chicago, IL, USA). When one or more expected values were less than 5, the Fisher's exact test was used (Lehner 1996).

Disturbance behaviour

The following individual response patterns were calculated: 1) frequency of disturbance, 2) immediate response of rhinos, and 3) outcome of behavioural sequences. The frequency of disturbance that was based on all observations was calculated from the proportion of disturbed and undisturbed observations. The immediate response was calculated from the proportion of disturbed observations, where rhinos 1) adopted alert posture, 2) moved and reoriented or 3) directly fled. The outcome of all behavioural sequences (disturbed observations, no direct flight) was calculated from the proportion of observations, where rhinos 1) moved away, 2) calmed down or 3) the observer left the attentive rhino. Differences among individuals were tested via Chi square goodness-of-fit test for three or more variables.

Furthermore, median and inter-quartile range of the closest observer approach distance (m) was calculated per individual. Differences among individuals were tested via Kruskal-Wallis one-way analysis of variance (ANOVA) on ranks using Sigma Plot Statistical Program. Bivariate comparison of medians was conducted via Mann-Whitney U test. Closest approach distances were compared between disturbed and undisturbed observations (based on all observations), and between direct flight and other behavioural responses (based on disturbed observations). Also, data were analysed according to the first and second year after release, and the closest approach distances were compared for all observations. Disturbed observations were analysed separately as to analyse the disturbance response.

Finally, median and inter-quartile range of the duration of the longest alert phase per observation was calculated. Differences among individuals were tested via Kruskal-Wallis one-way analysis of variance (ANOVA) on ranks, and medians were compared via Mann-Whitney U test for the first and second year after release.

Results

Diurnal activity

General activity patterns

Comparison of individual activity patterns for morning, midday and afternoon period reveals no difference between animals (Table 12). Rhinos showed high activity levels during the morning period (80 % - 93.7 %) and levels between 46.3 % and 60 % activity during midday period. In the afternoon hours, activity level was between 52.8 % and 64.8 %.

Table 12. Proportion of active readings of rhino individuals for 3 periods (morning, midday, afternoon). The result of the statistical test is also given (NS = not significant): morning: $\chi^2 = 7.517$, df = 5, p = 0.185; midday: $\chi^2 = 3.684$, df = 5, p = 0.596; afternoon: $\chi^2 = 2.543$, df = 5, p = 0.770.

	Morning		Midday		Afternoon	
	Number of readings	Activity (%)	Number of readings	Activity (%)	Number of readings	Activity (%)
Subadult ♂1	63	93.7	137	48.9	88	64.8
Subadult ♂2	49	91.8	67	46.3	40	60
Adult ♂	63	88.9	82	54.9	85	55.3
Subadult ♀1	25	80	68	51.5	36	52.8
Subadult ♀2	56	80.4	54	50	23	56.5
Adult ♀	49	80.5	75	60	112	56.2
χ^2 test	NS		NS		NS	

Due to a relatively low number of individual activity readings and a similar pattern of individual data (Table 12), all activity readings were pooled to obtain a general diurnal pattern according to one-hour intervals. Black rhinos were active during 698 of 1070 activity readings (65.2 %). There is a clear bimodal pattern of diurnal activity (Figure 16). General activity is characterised by a peak during the morning hours (between 06:00 and 09:00 hours, $\bar{x}$ = 94.6 %). Afterwards there is a steady decrease of activity at which a plateau is reached that extends between 12:00 and 16:00 ($\bar{x}$ = 45.0 %). Between 16:00 and 19:00 hours there is a steep increase in activity towards the second activity peak.

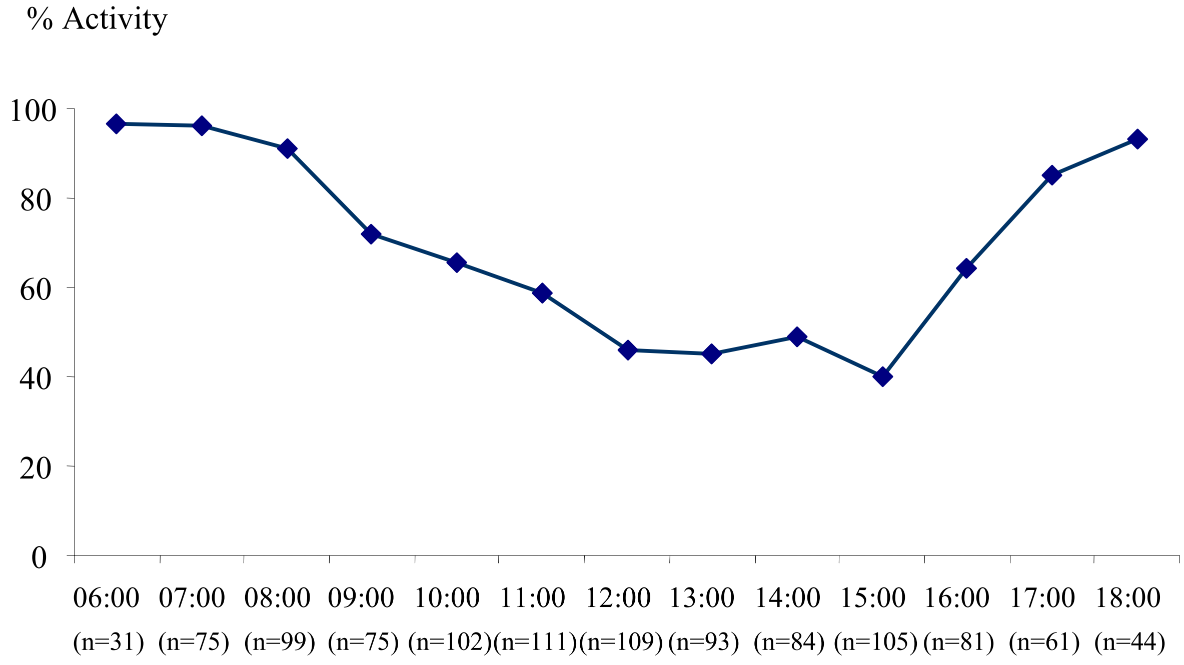

Figure 16. Diurnal activity calculated from the total number of activity readings of all six black rhinos (pooled data) during the entire study period. The number of observations per hour is also given.

Seasonal activity patterns

When comparing activity patterns per season (pooled data from all individuals according to two hours intervals), seasonal differences come into view (Figure 17). Generally, rhinos were more active during the dry season. Between 06:00 and 08:00 hours there is an activity level of almost 100 % during both seasons. At the following intervals (08:00-10:00 hours, 10:00 – 12:00 hours), the wet season activity level is significantly lower than dry season. At the 10:00 – 12:00 hour's interval, the wet season activity pattern reaches the lowest level. At the 12:00 – 14:00 hour's interval, dry season activity pattern reaches the lowest point, whereas the level for the wet season clearly increases. As sample size for following intervals is low, and no statistical difference in seasonal proportions of observations was found (14:00-16:00: dry season: 26.7 % activity, n = 15; wet season: 54.8 % activity, n = 62; Fisher's exact test: p = 0.083, 16:00-18:00: dry season: 100.0 % activity, n = 5; wet season: 65.3 % activity, n = 49; Fisher's exact test: p = 0.168), data for these intervals are not shown in Figure 17.

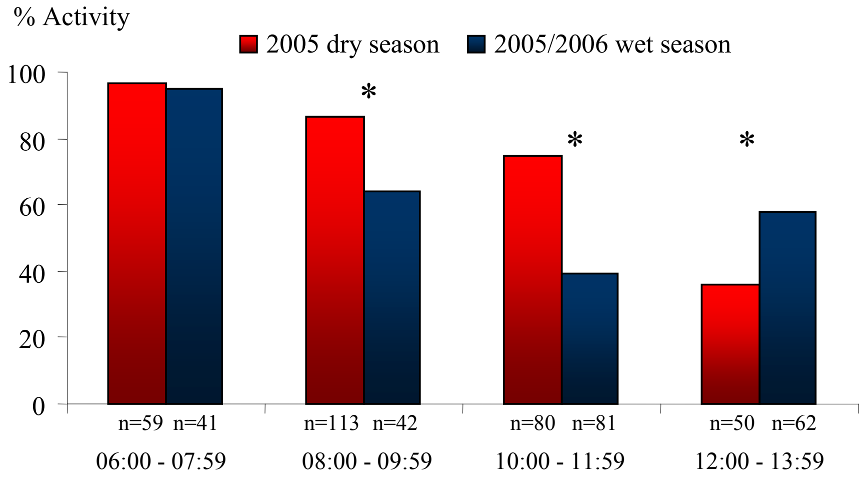

Figure 17. Seasonal activity patterns of all six black rhino individuals (pooled data). The number of observations is given below bars. * Marks statistically different proportions of observations: 06:00-07:59: Fisher's exact test: p = 1; 08:00-09:59: $\chi^2 = 0.021$, df = 1, p = 0.885; 10:00-11:59: $\chi^2 = 19.281$, df = 1, p <0.001; 12:00-13:59: $\chi^2 = 4.549$, df = 1, p = 0.033.

Disturbance behaviour

General behavioural responses

During most of the observations, the rhinos took notice of the observers (disturbed observations = 59.7 %). The individual proportion of disturbed observations varies from 44.7 % (male adult) to 69.1 % (subadult male 1, [$\bar{x}$ = 58.1 %, n = 6, Figure 18a]). There is no statistically significant difference in the degree of observer caused disturbance among the six rhino individuals ($\chi^2 = 7.043$, df = 5, p = 0.217). The dominant immediate response of most rhinos was giving attention to the observer ($\bar{x}$ = 59.4 %, n = 4, Figure 18b). Two rhinos, by contrast, showed direct flight as the dominant immediate response (subadult male 2: 50 % and subadult female 1: 52.4 %). However, there is also no statistically significant difference regarding immediate response among the six individuals: $\chi^2 = 17.319$, df = 10, p = 0.068.

A certain level of variability emerges when looking at the outcome of individual observations (disturbed observations, no direct flight, n = 98 observations). Three rhinos moved away after most of the observations (subadult male 1: 63.4 %, subadult female 1: 62.5 %, adult female: 66.6 %), whereas observations of two rhinos mostly resulted in appeasing behaviour (subadult male 2: 58.3 %, adult male: 54.5 % [Figure 18c]). The outcome of observations of subadult female 2 was balanced between moving away and appeasing. When comparing the outcome of observational sequences among the six individuals, again, no significant difference can be found: $\chi^2 = 8.382$, df = 10, p = 0.592.

Picture 6. Behavioural responses of black rhinos towards observers. a) adult male running off in zigzag patterns (tacking) with curled tail, b) subadult male 1 actively approaching observers (investigative behaviour), c) subadult male 2 trotting off with curled tail, d) subadult male 2 dust-bathing while subadult female 2 adopting the alert posture, e) subadult male 1 walking in a circle around observers, presenting itself sideways to observers, f) subadult female 2 and subadult male 1 adopting alert posture.

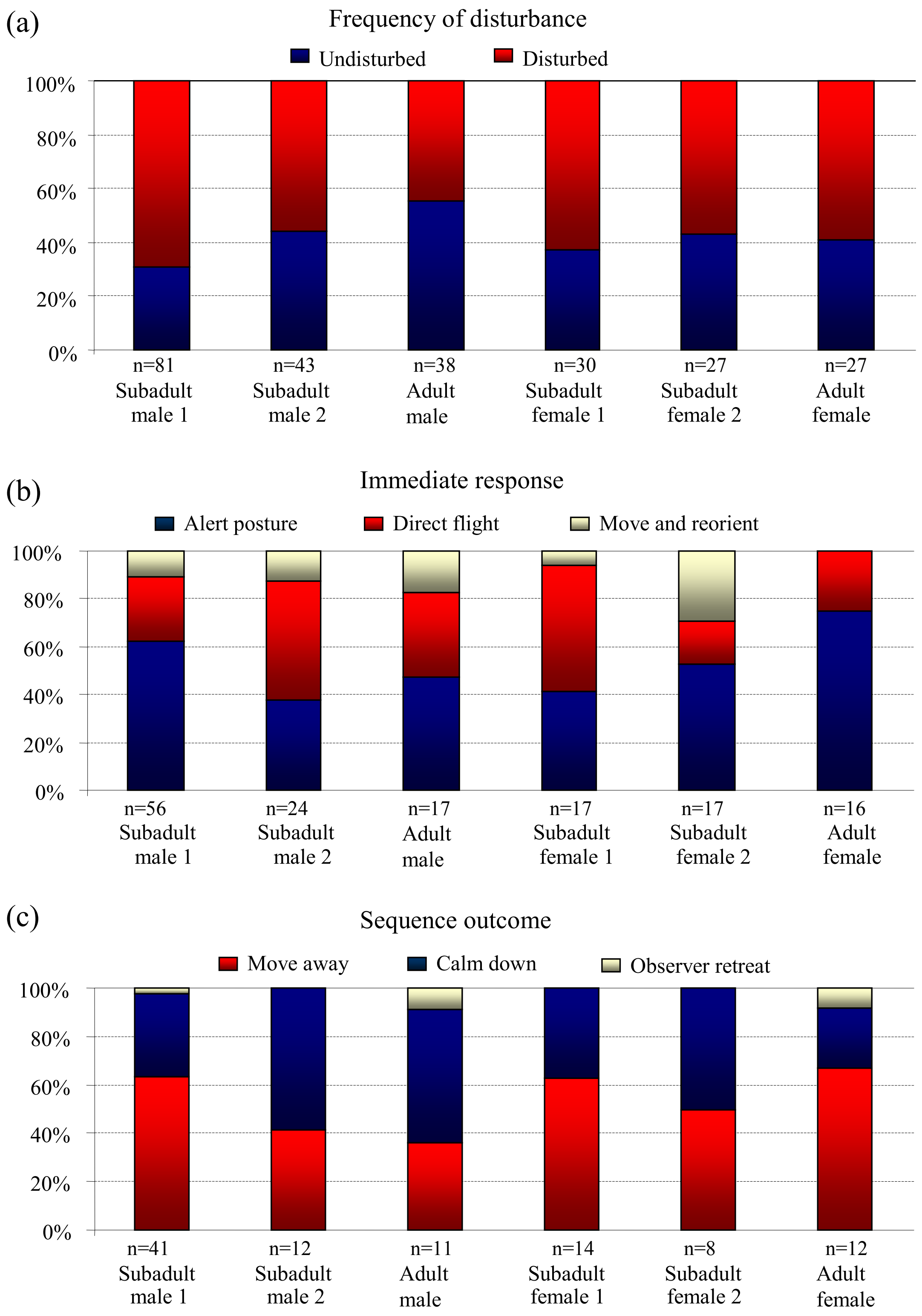

Figure 18. Percentage of observations, during which rhinos were either disturbed, or left undisturbed (a), were rhinos adopted alert posture, directly fled or moved and reoriented as an immediate response (b) and where rhinos finally moved away, calmed down or the observer left the alert rhino as a sequence outcome (c).

Antipredator behaviour patterns

The behavioural responses of individual black rhinos were variable (Table 13).

Table 13. Percentage of different anti-predator behavioural patterns per individual as based on behavioural sequences.

	Subadult ♂1	Subadult ♂2	Adult ♂	Subadult ♀1	Subadult ♀2	Adult ♀
Observations (n)	41	12	11	14	8	12
Behaviour (%)						
Inspection	31.7	25	36.4	14.3	0	8.3
Snorting	17.1	41.7	9.1	28.6	75	41.6
Attack	0	0	0	0	12.5	25

Inspection

Most rhino individuals showed investigative behaviour (actively approaching the observers one or several times throughout an observation).

Auditory signals

All rhinos were observed emitting sounds, most common acoustic signal was snorting. Subadult male 1 was furthermore observed emitting squealing sounds towards the observer, which was associated with investigative behaviour. Another form of sound emission was observed with the adult female. After this female adult gave birth to a calf, mother-offspring communication was observed during one observation in November 2006. The female adult was fleeing from the observer and the calf was not able to keep the pace. It stood and emitted a distress call that made the adult to retreat before both were fleeing into the opposite direction.

Freezing

Freezing was a typical initial behavioural response and thus, the time spent in being in an alert posture was measured and investigated in greater detail. Owing to low numbers of individual observations and no statistical difference in the median values of the longest attentive period per observation among individuals (Table 14), data were pooled for further analysis.

Table 14. Median and inter-quartile range of the duration (min) of the longest attentive period, performed per observation and rhino. ANOVA on Ranks: H = 3.452, df = 5, p = 0.631.

	Number of observations	Median	25 quartile	75 quartile
Subadult ♂1	41	5.0	2.5	11.5
Subadult ♂2	12	5.5	2.0	10.0
Adult ♂	11	4.0	2.0	10.0
Subadult ♀1	14	5.0	2.0	10.0
Subadult ♀2	8	10.0	2.0	12.75
Adult ♀	12	3.0	1.0	8.75

The comparison of the median and inter-quartile range of the longest alert phase per observation (min) during the first year after release (5.0, IQR: 8.5, n = 25) and the second year after release (6.0, IQR: 9.0, n = 73) reveal no statistically significant difference between the two periods: U = 768.5, p = 0.239.

Attack (Mock charge)

Attacks (mock charges against the observers) were only observed on four out of 98 observations: once by subadult female 2 and during three observations of the female adult.

Observer approach distance

When comparing the closest distance to which observers approached rhinos among individuals, no statistically difference can be found regarding all observations (n = 246) and disturbed observations (n = 147 [Table 15]), and data were pooled for further analysis.

Table 15. Median and inter-quartile range of the closest distance (m) to which observers approached rhino individuals. Data arrangement: values for all observations / values for disturbed observations. ANOVA on Ranks for all observations: H = 9.688, df = 5, p = 0.085; ANOVA on Ranks for disturbed observations: H = 9.540, df = 5, p = 0.089.

	Number of observations	Median	25 quartile	75 quartile
Subadult ♂1	81 / 56	30.0 / 30.0	20.0 / 15.0	40.0 / 30.0
Subadult ♂2	43 / 24	30.0 / 30.0	20.0 / 16.25	50.0 / 40.0
Adult ♂	38 / 17	35.0 / 30.0	20.0 / 17.5	50.0 / 40.0
Subadult ♀1	30 / 17	40.0 / 40.0	30.0 / 30.0	50.0 / 50.0
Subadult ♀2	27 / 17	30.0 / 30.0	20.0 / 15.0	50.0 / 45.0
Adult ♀	27 / 16	40.0 / 30.0	30.0 / 22.5	50.0 / 50.0

The closest distance (m), to which observers approached rhinos, varies significantly for disturbed and undisturbed observations, with longer distances (median: 40.0, IQR: 20.0, n =

99) associated with undisturbed observations and shorter distances (median: 30.0, IQR: 20.0, n = 147) associated with disturbed ones (Figure 19a). When looking at the disturbed observations, interestingly, direct flight behaviour was associated with longer distances (median: 40.0, IQR: 20.0, n = 49), and observations, were rhinos stayed in the area, were associated with shorter distances (median: 30.0, IQR: 17.5, n = 98 [Figure 19b]).

There is no time-related effect regarding the closest approach distance of rhinos when analysing all observations (Figure 20a). However, when analysing only the disturbed observations, there were longer distances associated with the first year after release (median: 40.0 m, IQR: 30.0, n = 59) when compared with the second year (median: 30.0 m, IQR: 15.0, n = 88 [Figure 20b]).

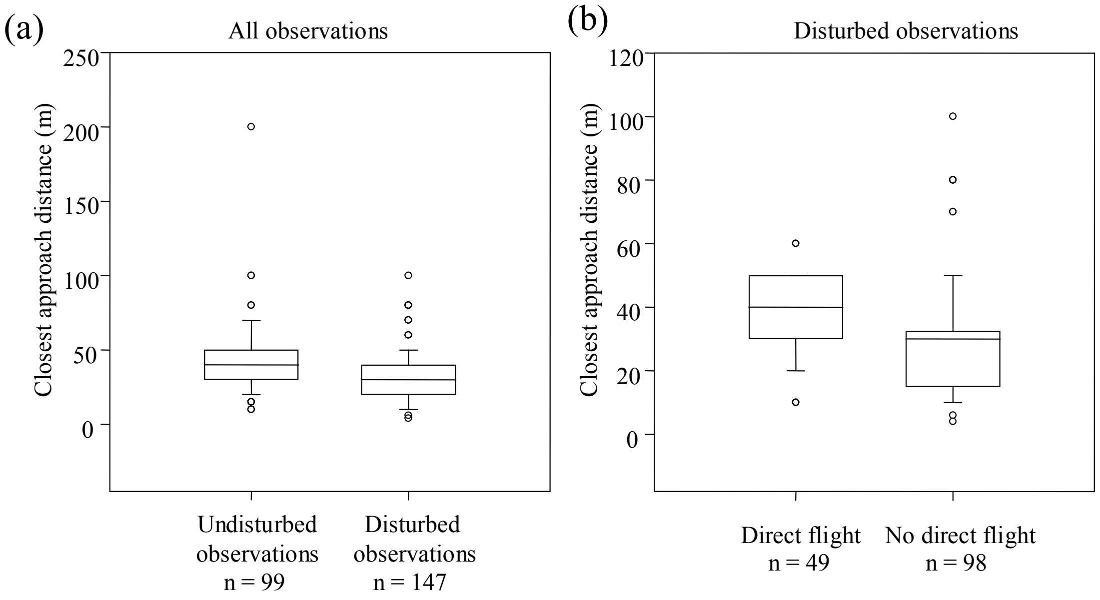

Figure 19. The median and inter-quartile range of the closest approach distance (m) for disturbed and undisturbed observations (based on all observations, Figure 19a), and observations, where rhinos directly fled or stayed in the area (based on disturbed observations, Figure 19b) is given. The approach distance of undisturbed observations (40.0, IQR: 20.0) is significantly larger than the distance for disturbed observations (30.0, IQR: 20.0): U = 5253.0, $p < 0.001$. The approach distance for observations, where rhinos directly fled (40.0, IQR: 20.0) is significantly larger than the distance for observations, where rhinos stayed in the area (30.0, IQR: 17.5): U = 1505.0, $p < 0.001$.

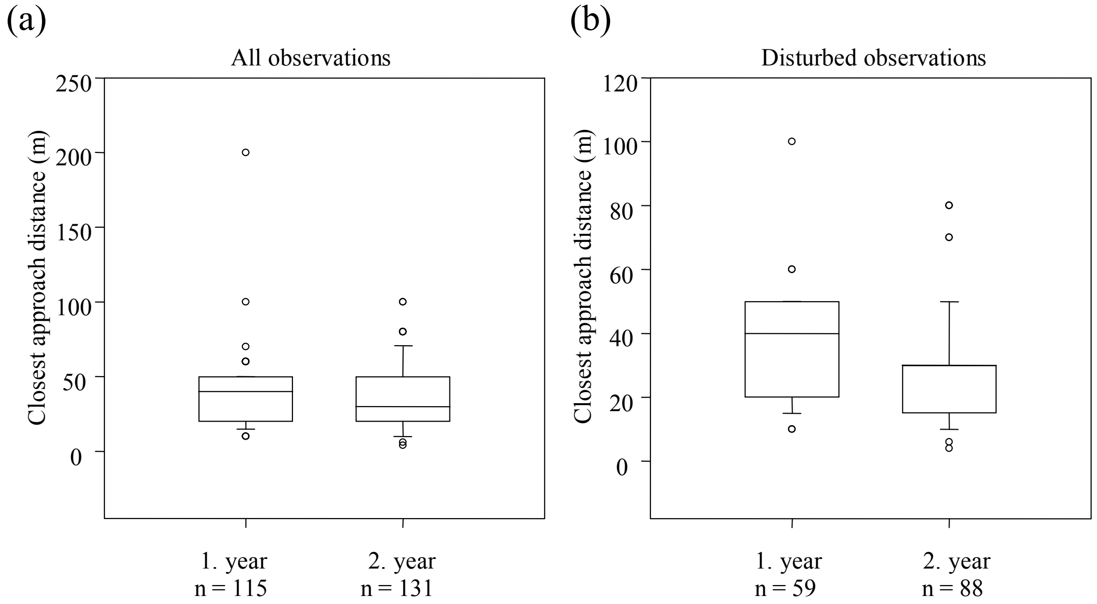

Figure 20. The median and inter-quartile range of the closest approach distance (m) for two periods (first and second year after release) is given. Comparison was made for all observations (a) and disturbed observations (b). There is not a statistically significant difference in the approach distance between the two periods when using all observations: 1. year: 40.0, IQR: 30.0; 2. year: 30.0, IQR: 30.0; $U = 6551.0$, $p = 0.072$. Closest approach distances of disturbed observations were significantly larger during the first year after release (40.0, IQR: 30.0), when compared with the second year (30.0, IQR: 15.0): $U = 1754.0$, $p < 0.001$.

Discussion

Diurnal activity

Goddard (1967) was the first systematically studying diurnal activity rhythms of black rhinos. He investigated two populations in northern Tanzania (Ngorongoro Crater and Olduvai Gorge) over a three year period, presenting a bimodal activity pattern with rhinos active during the morning and afternoon hours and a phase of inactivity during midday. The method used by Goddard (1967) is comparable to the study at hand, as in both cases the sampling unit is the observation event. In a follow up study, Kiwia (1986) investigated the same populations in greater detail. He used instantaneous scan sampling method (Altman 1974), which reveals the advantage of obtaining a larger data set over shorter periods when compared to Goddard (1967) and this study. Besides a similar bimodal diurnal activity pattern, Kiwia (1986) moreover found seasonal changes in activity of black rhinos. He showed that rhinos spent more time walking and lying/wallowing and less time feeding during the dry season.

The present study is in line with the literature information about the typical bimodal diurnal activity pattern of black rhinos. The results from Goddard (1967) and Kiwia (1986) revealed a slightly more prominent inactivity phase (between 20 % and 30 % of activity) during the hot hours of the day, whereas the present study revealed a minimum of 40 % of activity readings (Figure 21). One reason could be the difference in the study design. In the present study, stalking via VHF radio-telemetry in dense vegetation may have alarmed rhinos, leading to increased levels of observed activity. Another reason for a higher activity during the hot hours could be that the relatively low habitat quality in the semi-arid area generally forced rhinos to switch between resting and browsing periods. In addition to the normal activity rhythm, the results furthermore reveal seasonal variation in diurnal activity (during the dry season, rhinos were more active between 08:00 and 12:00 hours and less active during the hottest hours of the day [12:00 and 14:00]).

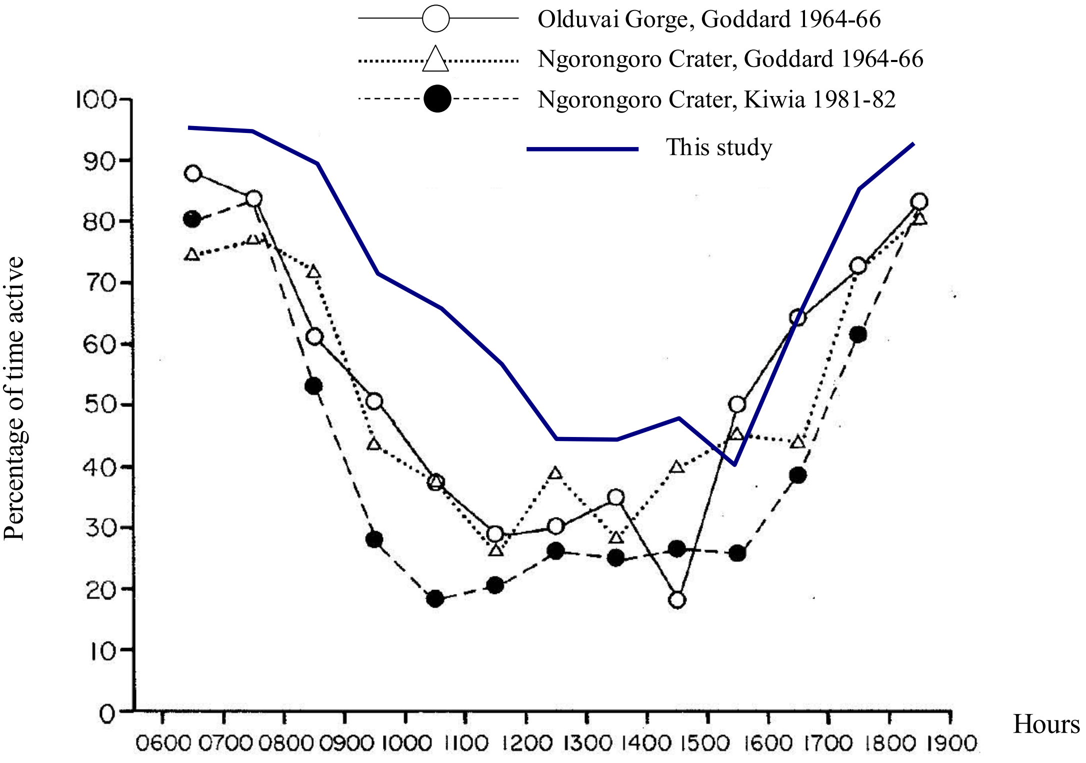

Figure 21. Comparison of the diurnal activity pattern of black rhinos from Tanzania: Goddard (1967) and Kiwia (1986) and this study. The figure was adopted from Kiwia (1986).

Altering activity rhythms due to seasonal variability occur with several ungulate species, for example red deer *Cervus elaphus* Linnaeus 1758 (Georgii 1981, Georgii and Schröder 1983, Catt and Staines 1987) and elk *Alces alces* (Craighead et al. 1973, Green and Bear 1990). Contrary to the present study, black rhino seasonal activity patterns in Kiwia's study were linked with larger home ranges in the wet season. Accordingly, Mehrdadfar (1999) showed that black rhinos became less active during cooler seasons. However, since the present study was carried out in a semi-arid savannah ecosystem in Namibia, rhinos had much larger home ranges during the dry season (chapter III), a good fit with the increased activity during the 08:00 – 12:00 hours period. An increase in diurnal activity levels during the morning and midday hours of the dry season was linked with rhinos travelling much longer distances and roaming much larger areas. The shift towards greater activity during the hottest hours of the day during the wet season may be linked with seasonal changes for different behavioural categories, as shown by Kiwia (1986). It may be possible that lower temperatures and better availability of resources during the wet season allowed rhinos to feed during the hottest hours of the day, whereas during the dry season, rhinos were forced to use the 12:00 to 14:00 hours period for resting mainly. The typical bimodal activity pattern and the seasonal effect on the diurnal activity of black rhinos are further important indicators for the behavioural acclimatisation.

Disturbance behaviour

Possibly owing to reports of early European hunters, black rhinos have a reputation for being bad-tempered and irascible (Skinner and Smithers 1990). A good description of black rhinos' natural behaviour, including the disturbance behaviour, has already been given in the early 20th century (Sclater 1900, Stigand 1913; 1919, Kenya Game Department 1937). However, these reports oppose a general aggressive behaviour. The Kenya Game Department (1937), for example, wrote: 'from my own experience of rhino, I am satisfied that the majority, under normal conditions, are blusterers and bluffers.' This was several decades before the population suffered from the tremendous population decline due to poaching, which may have caused a particular effect on the disturbance behaviour of black rhinos. It can be expected that when exposed to hunting or poaching, the species-specific disturbance behavioural patterns may change. Schenkel and Schenkel-Hullinger (1969) suggested for example that young rhinoceros learn how to react to humans while observing reactions of their mothers. Thus, early reports provide useful information to study the normal, species-specific disturbance behaviour of black rhinos in general. This information is in-line with more recent publications on the disturbance behaviour of black rhinos (Hillman-Smith and Groves 1994, Hutchins and Kreger 2006). For example, Hillman-Smith and Groves (1994) stated that when alarmed, a black rhino will usually run off with its tail curled, sometimes emitting a series of snorts; when mildly disturbed, it may approach either cautiously or in a rush. Berger and Cunningham (1998) presented a study on gender-based and inter-specific competitive interactions between African elephants and black rhinos, emphasising the need for a better understanding of the behaviour and ecology of pachyderms in order to manage today's fragmented reserves and to link such studies with the field of conservation biology. Authors found that elephants and rhinos deny immediate access over resources towards mammals ranging in size from cheetah to giraffe, and female elephants dominate both sexes of black rhinos, whereas rhino males but not females displace elephant bulls. In the study at hand, no elephants were present and thus, rhinos should not have had any dominating species to deal with. Although there are reports of lions or hyenas attacking even adult black rhinos (Ritchie 1963, Thompson 1971, Hitchins and Anderson 1983), such events are very seldom (Hillman-Smith and Groves 1994). As lions and hyenas were sighted very seldom throughout the study period (chapter II), anti-predator strategy of the investigated black rhino starter group may have been characterised by the absence of predation or inter-specific conflict regarding the released animals. Berger and Cunningham (1998) used three explanations to clarify the evolution of gender-specific asymmetries in black rhinos, which may also help to understand the results from the present study: 1) male rhinos experience little predation by non human predators and thus the incentive to drive away carnivores appears to be minimal, 2) although female black rhinos are not prey, their young are subject to predation by lions and hyenas (Hillman-Smith and Groves 1994), which causes a certain type of maternal defence behaviour, and 3) pachyderms may simply protect access to limited resources. These explanations would help to understand the overall investigative response behaviour of rhinos towards humans and the fact that aggressive behaviour towards observers (mock charges) was very seldom and only performed by females (mainly the adult female).

Reliable measures of the fearfulness of animals are the flight initiation distance (distance between the predator [or human] and the prey, at which the prey takes flight) and the alert distance (distance at which the prey becomes alert to the predator [or human]) (Dwyer 2004, Stankowich and Coss 2006, Stankowich and Coss 2007). The study at hand does not inform about either the flight initiation distance, or the alert distance. It turned out that the methodological approach and especially the study area greatly influenced data collection. Owing to the size and geology of the study area (chapter I) and the habitat use of black rhinos (chapter III), physical sightings of rhinos were relatively sparse (380 observation days with 1,329 locations [telemetry and sightings] and 198 locations, where one or more rhinos were observed). Tracking rhinos was a challenging procedure and it usually took observers more than one hour of walking in densely structured core area habitat, before an observation could be achieved. During the final phase of the tracking procedure, VHF telemetry does not allow a precise locating of the animal. Although special emphasis was given to remote data collection (slow approach against the wind, listening to rhinos induced sounds and signs, e.g. spoor, signs of browsing), at most observations rhinos took notice of observers. Owing to the limited sight, observers usually realised rhinos when less than 50 m away. Although the approach distances of observations, where rhinos were not disturbed, were significantly longer, the distance for undisturbed observations may be closer than the species-specific alert distance. Very interestingly, rhinos decided to flee at longer distances and stayed in the area at shorter ones (p. 91). At a first glance, this result is contrary to the concept of flight and alert distances, where after the animal becomes more flighty the closer the distances gets. The decision to flee may be influenced by other important factors, especially olfactory and acoustic influences (turning wind, observer induced sounds). However, it appears that in the present study, rhinos decided to flee at a medium distance but rather investigated the source of disturbance at very close distances. These findings are in-line with Schenkel and Schenkel-Hullinger (1969), stating that black rhinos had the most intense alarm response when exposed only to scent of humans. Accordingly, Hutchins and Kreger (2006) found that the degree of alarm appears to be lessened when the animals are able to locate the source of the stimulus. At distances of 30 - 40 m between human and animal, the acoustic stimuli alone do not elicit a fear response, whereas black rhinos may be able to detect moving persons from as far as 60 m away (Hutchins and Kreger 2006). A time-related effect was found in regards to the approach distance of observers (shorter distances during the second year of the study) but not regarding the duration of attentiveness. The effect of shorter observer approach distances during the second year may be linked with the acclimatisation of rhinos.

Management implications

The chapter in hand is a model for remote monitoring of behaviour of black rhinos after relocation to a new environment. The used method of VHF radio telemetry, the study area features (size, geology and vegetation) and the habitat use of black rhinos, resulted in systematic monitoring combined with a relatively low frequency of direct sightings (individual frequency of direct sightings: 7.1 % - 21.3 % of observation days). Based on the behavioural data from this chapter and the findings about the black rhinos exploration behaviour and habitat use (chapter III), it can be assumed that observers had no negative influence on the behaviour of the animals. The chapter further highlights individual behavioural differences with regard to the disturbance behaviour. It should therefore encourage individual-based research in combination with translocation procedures. Managers should consider that there may be a great variability regarding the individual responses of black rhinos toward humans. This chapter provides a useful approach to remotely monitor relocated black rhinos. It is a first systematic description of the species-specific anti-predator behaviour of translocated black rhinos. Firstly, this information may be useful to assess black rhinos' responses towards humans in combination with monitoring in future translocation programmes. Secondly, it suggests interlinking rhino monitoring with tourism (e.g. guided tours) in the area of research. Finally, it may provide reference data to judge on behavioural responses of black rhinos and to detect stress.

Summary

The primary goal of this chapter was to examine post-translocation diurnal activity patterns and disturbance behaviour of a founder group of six black rhino *Diceros bicornis* Linnaeus 1758 individuals. The study period was two years (Mar 2005 – Feb 2007). Data analysis was based on VHF radio telemetry and direct observations. A general bimodal diurnal activity pattern was found that is in line with the species-specific activity rhythm of black rhinos as

described in the literature. The results reveal seasonal variation in diurnal activity with rhinos being more active during the dry season, which is a useful indicator for the acclimatisation of the investigated rhino group. During most direct observations, black rhinos detected observers, while the dominant response was adopting an alert posture but not direct flight. Overall, rhinos displayed a rather inquisitive behaviour, and mock charges were very seldom. The closest distances to which observers approached rhinos appear to be generally shorter than the species-specific alarm distance, owing to habitat features and the study design. Interestingly, observations where rhinos directly fled were associated with longer distances than observations where the rhinos stayed in the area. This supports the hypothesis that the degree of alarm appears to be lessened when the animals are able to locate the source of the stimulus. Again, the typical, species-specific behaviour was observed. A time-related effect was found with regards to the approach distance of observers (shorter distances during the second year of the study) but not regarding the duration of attentive periods. The present results are in accordance with the limited literature available on species-specific activity patterns and response-behaviour of black rhinos towards humans. The results provide a reasonable estimation of the natural acclimatisation of black rhinos in a semi-arid savannah ecosystem. The results of this chapter are further indicators for a normal, species-specific behaviour of the investigated black rhino starter group.

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CHAPTER V: EXPLORATION BEHAVIOUR AND HOME RANGE ESTABLISHMENT OF A SUBADULT WHITE RHINO MALE AFTER RELEASE INTO A BLACK RHINO AREA

Introduction

Despite the importance of translocation for the increasing population trends of the southern white rhino *Ceratotherium simum simum* Burchell 1817, studies on the post-release behaviour of white rhinos are rare. Although several reports and studies are available on white rhino translocation procedures in the Moremi Game Reserve in the Okavango Delta in Botswana (Woodrow 2001, Woodrow 2003, Støen et al. 2009) and the Kruger National Park in South Africa (Pienaar 1970; 1993, Kruger et al. 1999, Pedersen 2009), very little info is available on white rhino translocations in Namibia. By reporting on the successful reintroduction, soft-release procedure and behavioural and physiological acclimatisation of an adult zooborn white rhino male at Etosha National Park (ENP) in Namibia, Böer (1997; 1998; 1999) demonstrated the adaptability of a white rhino to acclimate in this new environment.

Of all extant rhino species, the white rhino exhibits the highest degree of sociality (Owen-Smith 1988, Shrader and Owen-Smith 2002). Adult males hold mutually exclusive territories that are generally smaller than overlapping home ranges of females (Condy 1973, Owen-Smith 1973, Conway and Goodman 1989, Pienaar et al. 1993, Roche 2000, White et al. 2007). Rachlow et al. (1999) stated that in areas of relatively high white rhino density, not all adult males hold mutually exclusive territories. The size of territories and home ranges of white rhinos from literature varies greatly. The size of male territories ranges between 0.75 km^2 (Owen-Smith 1973) and 116 km^2 (Kretzschmar 2003), female home ranges vary from 3.6 km^2 to 69 km^2 (Rachlow et al. 1999).

Recently, two studies were focusing on the post-release ranging behaviour of white rhinos (Petersen 2009 and Støen et al. 2009). Støen et al. (2009) presented a study on the movements and the establishment of annual activity areas of 27 white rhino individuals released in the Moremi Game Reserve in Botswana. Authors found that white rhinos perform long-term dispersal when released to areas, where formerly re-introduced white rhinos already had established a territory. Based on a mean number of 37 locations per year and individual, authors calculated the MCP (95 % and 50 %) of ranges, which authors termed ‘annual activity area’.

Previous chapters of the present thesis have shown that the methodological approach based on VHF radio-telemetry and direct observations, was useful to obtain information on several aspects of the cognitive and behavioural acclimatisation of a black rhino starter group post-release. These results have shown that the methodological approach has led to a model for further black rhino translocations in Namibia and semi-arid areas in general. In this chapter, this methodological approach has been applied to one white rhino male that has been translocated to the study area at a later stage of the two years study period. When the white rhino was released at the study area, black rhinos had already established their home ranges. The present chapter reveals information on exploration behaviour and home ranges of the white rhino under these circumstances. Thus, it gives information on the inter-specific strategies of both rhino species at the specific study area.

Material and Methods

Data collection

Between Jun 2006 and Feb 2007, a subadult white rhino male (subadult male 2) was located on a regular basis (81 observation days, data collection frequency: 0.33 %) at irregular intervals between dawn and dusk via VHF radio telemetry and spoor. Since the spoor of the white rhino cannot be confused with black rhino spoor (Stuart and Stuart 2000), and since it was the only white rhino roaming the outer fenced region of the study area during this time, spoor was also useful to obtain systematic data on the animal’s locations. In total, 81 locations were collected, of which 42 % were triangulation estimates, 37 % were direct observations and 21 % were based on spoor. The VHF radio telemetry data collection procedure was similar to the black rhino investigation (chapter III).

Data analysis

Similar to the investigation on black rhino exploration behaviour and home range establishment (chapter III), home ranges were calculated using minimum convex polygon (MCP [Mohr 1947, Kenward 1987] and Kernel method (Worton 1987, Worton 1989). The computer programs GPS Track Maker (GPSTM, Freeware, Belo Horizonte, Brazil) and ArcView 3.3 (ESRI, Redlands, CA, USA) were used, and polygons were corrected along study area borders. Kernel polygons (95% and 50%) were estimated with the animal movement extension for ArcView 3.3 (Hooge and Eichenlaub 1997), the 50% Kernel polygon was used to visualise activity centres of the white rhino's distribution.

The total home range and activity centres of the white rhino male were compared with the range pattern of the black rhino group during this time of the study (Jun 2006 - Feb 2007). For estimating Kernel polygons of the black rhino group's range pattern, all individual fixes were pooled. A total of 299 individual fixes was taken at 268 locations, the mean number of fixes per individual is 49.8 (SD = 39.7).

The overlap of the Kernel polygons (95% and 50%) of the white rhino and the black rhino group was measured by applying the formula presented by Lazo (1994):

$$\text{Home range overlap (V)} = \frac{2P_I}{(P_A + P_B)}$$

Where: P_I = Overlap area of the black rhino group A and the white rhino individual B
P_A = area of the black rhino group (pooled individual data)
P_B = area of the white rhino individual

This index may range from 0 (no overlap) to 1 (identical home ranges).

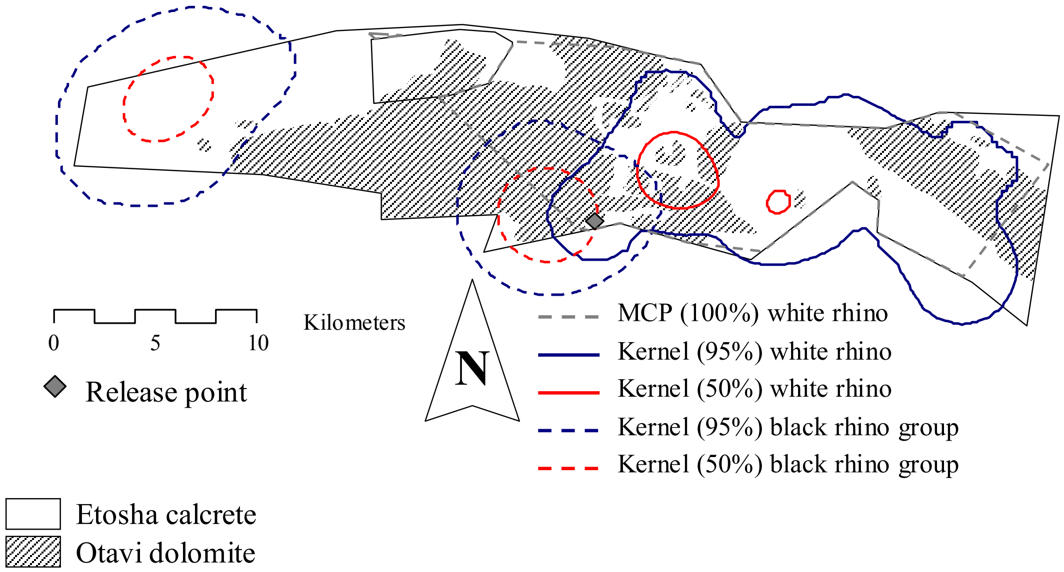
To look at temporary changes in the white rhino's spacing behaviour and other time-related effects, and in view of the short study period (seasonal effects not measurable), the observation-area curve method (Odum and Kuenzler 1955) was used to detect shifts of core areas (Gabelmann 2008) and different periods of space use. Data from different periods were analysed via Kernel method to illustrate the range pattern and compare periods (temporary home ranges).

Also, the migratory activity (successive linear distance between locations) was measured.

Results

Establishment of the total home range (100 % MCP)

The area-observation curve for the white rhino reveals a home range establishment pattern that differs from the curves of black rhino individuals (chapter III), as this curve does neither follow an asymptotic progression, nor a clearly sigmoid character (Figure 22). Owing to a change in increase patterns and plateau phases, the curve can be divided into three main periods, of which each periods is characterised by an initial increase phase followed by a plateau phase. The total home range size (100 % MCP) of the white rhino is 196.3 km^2 and thus, it is larger than the total home range of five out of six black rhinos that were investigated over a much longer period.



Map 10. Uncorrected Kernel polygons (95% and 50%) and corrected 100% MCP of the white rhino male over the study period (Jun 2006- Feb 2007, n = 81 fixes). Additionally, the uncorrected Kernel polygons (95% and 50%) for the black rhino starter group during the same time period is also given (n = 268 fixes).

Total home range and centres of activity (Kernel method)

The Kernel approach reveals that the total home range of the white rhino is characterised by one main centre of activity on an area with transitory geology between Otavi dolomite (OD) and Etosha calcrete (EC). Besides that, a second centre of activity has been established on EC. The white rhino used most of the eastern part of the study area; a section that has never been used by any of the black rhino individuals. There is only little overlap between the range pattern of the white rhino and the black rhino group at that time of the survey (Map 10). There is no overlap between the activity centres (50 % Kernel polygons) of the white rhino and the black rhino starter group. The overlap index regarding the 95 % polygons of the white rhino and the black rhino group is 0.15, indicating only slight association between the ranges of the species.

Temporary home ranges

The temporary home ranges, as calculated from time periods detected via area-observation curve method, clearly indicate a high level of variability in ranging patterns over time. The results show that numbers between 21 fixes and 38 fixes were sufficient for calculating temporary home ranges. Clear shifts in exploration behaviour and home range establishment were found with each period.

During a first period after release, the white rhino settled app. 5 km east of the release site. The Kernel polygons during this period are round with one clear centre of activity at the transitory geological area.

The next period is characterised by increased exploration behaviour of the white rhino. When compared to the first period, the size of the 95 % Kernel polygon has increased about 100 %, the size of the 50 % Kernel polygon has even increased about 500 %. The white rhino established two comparable centres of activity, one including the former activity centre and a second distinct centre on a new area in the east of the study area on EC. During this time, the white rhino made an excursion to the western side of the inner-fenced section, where several white rhinos had been released into the inner-fenced section.

During the third detected period, the white rhino decreased migratory activity and shifted the centre of activity towards a new area in the east of the study period, including both geological formations.

The results of the exploration behaviour and home range establishment of the white rhino indicate three main periods with different land and habitat use strategies and different sizes of home ranges and activity centres but no difference in regards to migratory activity. After a period of settlement near the release area, the white rhino increased exploration activity during a second period that started app. one month post-release. This period of exploration was followed by a clear decrease in home range and activity centre size (Map 11).

The Kernel method shows that temporary home ranges, obtained from the area-observation curve method, indicate a successive shift of the home range and activity centre of the white rhino from the area of release towards the easternmost area of the study site; an area that has not before been roamed by any of the black rhino individuals at this stage of the study.

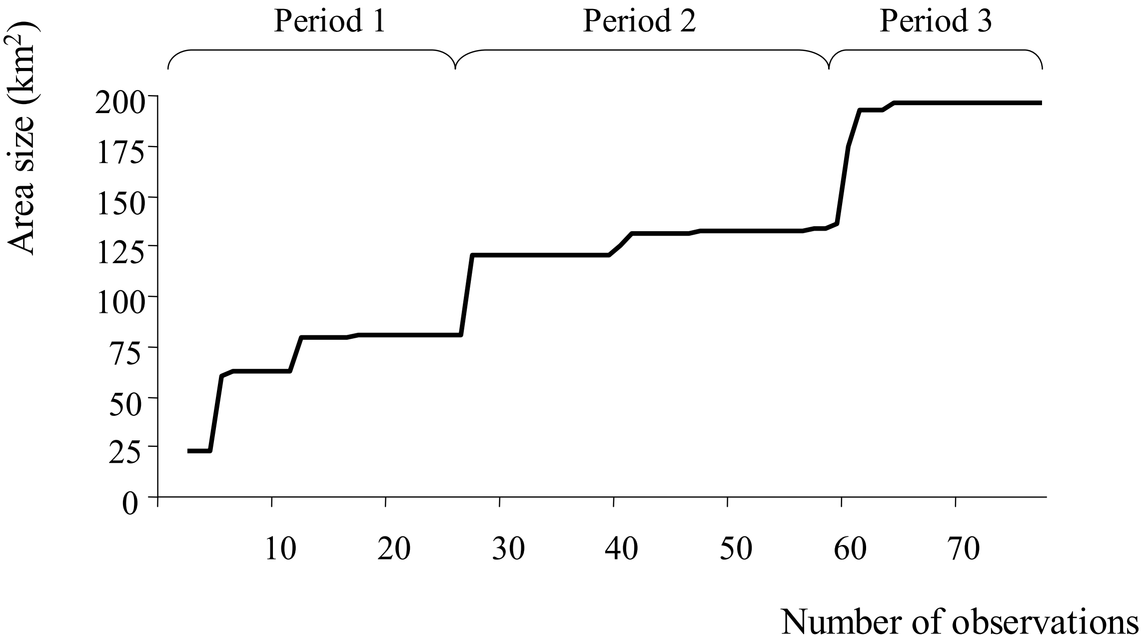
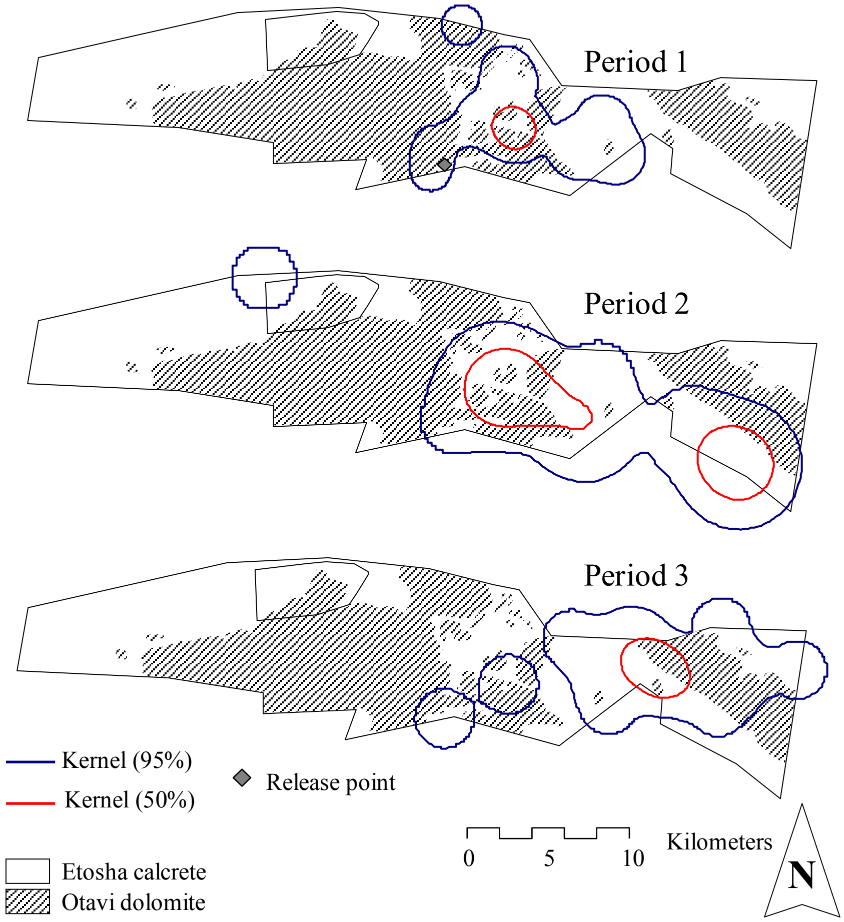


Figure 22. Area-observation curve of the white rhino male. Area size refers to the 100% MCP of the total home range (observation period: Jun 11, 2006 – Feb 02, 2007, 243 days, n = 81 fixes). Period 1: Jun 11 – Jul 12, 2006 (n = 27 fixes), Period 2: Jul 13 – Sep 06, 2006 (n = 33 fixes), Period 3: Sep 19, 2006 – Feb 08, 2007 (n = 21 fixes).



Map 11. The uncorrected temporary home ranges and core areas of the white rhino male is given. Periods were based on the observation area curve.

Table 16. Home range and core area establishment patterns for total and temporal home ranges of the white rhino.

	Total home range	**Period 1**	**Period 2**	**Period 3**
Number of fixes	81	27	33	21
Time period	11.6.`06-8.2.`07	11.6.–12.7.`06	13.7.-6.9.`06	19.9.`06-8.2.`07
100 % MCP (km^2)	196.3	-	-	-
95% Kernel (km^2)	135.1	64.1	123.9	88.8
50% Kernel (km^2)	13.2	5.6	38.5	11.8
Number of activity centres	2	1	2	1
Activity centre habitat	Transitory, EC	Transitory	Transitory, EC	Transitory
Migratory activity[1] (km)	1.7	1.4	1.7	1.7

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[1] Mean successive linear distance between fixes

Discussion

Methodological approach

Conway and Goodman (1989) considered a minimum of 10 fixes per resident white rhino group adequate to estimate the range size based on the MCP method, and Samuel et al. (1985) considered 30 independent observations adequate for estimation of core areas within home ranges of animals in general. Støen et al. (2009) argue that they would not expect white rhinos to establish home ranges soon after release. Based on a mean number of 37 samples per year and individual (27 individuals over three years), authors calculated the MCP (95 % and 50 %) of annual activity areas. Accordingly, Pienaar et al. (1993) and Pedersen (2009) assume the term ‘annual range’ is a more accurate term than ‘home range’, as one year may be not sufficient to determine an animal’s true home range. However, given the definition of a home range as an area with a defined probability of occurrence of an animal during a specified time period (Harris et al. 1990, Robertson et al. 1998), the term home range can be used for any specific time period. Thus, it can surely be applied to the post-release studies from literature and the present study as well. The focus is on the home range establishment of a white rhino individual during an eight months post-release phase. Owing to systematic measuring of daily movements and distribution of the white rhino, sufficient numbers of fixes for Kernel analysis were gathered and the home range establishment could be described according to temporary home ranges. Although data collection period of eight months was relatively short, numbers of fixes required for estimating temporary home ranges (period: 1 - 5 months) are comparable with the mean number of fixes for annual activity areas used in another post-released study by Støen et al. (2009) (n = 37). Rachlow et al. (1999) stated that Kernel method produced larger range estimates when compared to the MCP. Contrary, the present study shows a clearly larger 100 % MCP in relation to the 95 % Kernel polygon of the total home range. Larger Kernel polygons than MCPs cannot be expected in this study, as the polygons were corrected along the study areas border, which greatly reduces the size of Kernel polygons that tend to exceed study area borders. This was also shown for the black rhino starter group in chapter III. The reason for the relatively larger MCP of the white rhino was one exceptional migratory event towards the western boundary of the inner-fenced section during period 2. This migration event clearly increases the MCP whereas it has not such a great influence on the Kernel polygon, which is based on the relative probability of the rhino's occurrence calculated from a total of 81 fixes. It is likely that the borders of the study area had an influence on the ranging patterns of the white rhino that may have trespassed the area's borders, if not fenced. This is especially true for the temporary home range during period 2, when the rhino showed increased ranging behaviour.

Home range establishment and ranging behaviour

For several reasons the present study on the post-release behaviour of a subadult white rhino male into an area, where black rhino recently established spatial and social organisation, can be regarded as a field experiment in acclimatisation: On the one hand, the white rhino was released at a stage, when previously re-introduced black rhinos already had established their home ranges, core areas and social organisation. Støen et al. (2009) showed that white rhinos may perform long-term dispersal when released to areas, where formerly re-introduced (or resident) white rhinos had established a territory. The white rhino (grazer) and the black rhino (browser) can be considered to represent the largest extant herbivores truly specialised for a forage type (Owen-Smith 1988, Shrader et al. 2006, Steuer et al. 2010). Owing to these different ecological adaptations, both species can coexist in the same habitat and should not compete for the same food resources. However, the present thesis suggests that the white rhino's spacing strategy was influenced by the occurrence of black rhinos. The results from this chapter revealed little overlap between the range pattern of the white rhino and the black rhino group and no overlap between the respective activity centres. Although comparable habitat types were present over the entire study area, the white rhino exclusively used the eastern areas, which have not been used by black rhinos at this stage. It appears that the ranging behaviour of the white rhino was driven by spatial avoidance. The study on black rhinos' spacing behaviour (chapter III) revealed inter-specific associations influencing exploration behaviour. The same is known for white rhinos (Støen et al. 2009). The present chapter suggests that also inter-specific communication plays an important role in the spatial strategy of the studied white rhino. On the other hand, the white rhino was released single, and no other conspecifics were present in the outer-fenced region of the study area throughout the data collection period. In view of the natural social organisation of white rhinos, being the most social of all rhino species (Owen-Smith 1988, Shrader and Owen-Smith 2002) and the positive effect of social contacts for the welfare of the species (Osofsky et al. 1995), the unnatural situation of one individual roaming the area in the present study may also have influenced it’s spacing strategy. Accordingly, it is known that subadult white rhinos perform extensive ranging behaviour (Owen-Smith 1973; 1988). Furthermore, the strong seasonal climatic effects on habitat quality that were presented in chapters II and III, may as well have had an influence on the spacing strategy of the white rhino in the longer term. Owing to a relatively short data collection period in this chapter (eight months), such seasonal effects could not been measured here. It may be possible that seasonal effects overlap with the natural exploration pattern of this species, as it was observed with the black rhino starter group (chapter III).

Table 17. White rhino home ranges (females) and territories (males) from general and post-release studies and the results of the present study.

Area	**Reference**	**Method**	**Territory (♂♂) and home range (♀♀) size**
General studies			
Hluhluwe (South Africa)	Owen-Smith (1973)	MCP[1]	♂♂: 0.75 – 2.6 km^2 ♀♀: 8.9 – 20.5 km^2
Ndumu (South Africa)	Conway and Goodman (1989)	MCP	♂♂: 2.5 – 13.9 km^2 ♀♀: 4.7 – 22.9 km^2
Kyle National Park (Zimbabwe)	Condy (1973)	MCP	♂♂: 5 – 11 km^2 ♀♀: 8.9 – 20.5 km^2
Kruger National Park (South Africa)	Pienaar et al. (1993)	MCP	♂♂: 6.2 – 13.8 km^2 ♀♀: 7.2 – 45.2 km^2
Timbavati (South Africa)	Roche (2000)	-	♂♂: 23.4 – 52.9 km^2 ♀♀: 61.8 – 68.3 km^2
Limpopo (South Africa)	Kretzschmar (2003)	MCP	♂♂: 60.6 – 116 km^2
Matobo National Park (Zimbabwe)	Rachlow et al. (1999)	MCP	♂♂[2]: 14.6 – 50.4 km^2 ♂♂[3]: 12.2 – 33.6 km^2 ♀♀: 3.6 – 39.8 km^2
		95% Kernel	♂♂: 15.5 – 34 km^2 ♀♀: 5.9 – 69 km^2
Post-release studies			**Home range**
Kruger National Park (South Africa)	Pedersen (2009)	100% Kernel[4]	17 – 84.1 km^2
		50 % Kernel	1.8 – 12.7 km^2
Moremi, Botswana	Støen et al. (2009)	95% MCP	17 - 6,706 km^2
		50% MCP	5 – 40 km^2
This study		MCP	196.3 km²
		95% Kernel	135.1 km²
		50% Kernel	13.2 km²

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[1] Minumum convex polygon (100%)

[2] Territorial adult males

[3] Non-territorial adult males

[4] Local convex hull (LoCoH)

Böer (1997; 1998; 1999) reported on the successful reintroduction, soft-release procedure and behavioural and physiological acclimatisation of a zooborn white rhino at ENP in Namibia. Within 12 days, the adult male white rhino established a territory after dispersing more than 120 km from the release site. Formerly tame, it did not allow humans to approach any more. The size of territories and home ranges of white rhinos from the literature varies greatly and ranges between 0.75 km^2 (Owen-Smith 1973) and 116 km^2 (Kretzschmar 2003) for territories and 3.6 km^2 and 69 km^2 (Rachlow et al. 1999) for home ranges (Table 17). Recently, two studies were focussing on the establishment of ranging patterns of white rhinos in Kruger National Park, South Africa (Perdersen 2009) and Moremi Game Reserve, Botswana (Støen et al. 2009). Both studies revealed great variability in ranging patterns and relatively large areas covered by released white rhinos. Obviously, translocation seems to have a strong effect on the size of home ranges and activity centres. Støen et al. (2009) measured a mean annual activity area (95 % MCP) of 260 km^2 (57 annual activity areas of 24 rhinos, mean number of fixes per area: 37) and decreasing ranges over the following years after release. Pedersen (2009) studied the ranging patterns of one adult white rhino male, two adult females and one male/female dyad. Here, annual ranges were more in-line with the findings from general studies (Table 17). The sizes of home ranges of the re-introduced white rhino from other post-release studies are a good fit with the info from the studied animal in this chapter. However, it cannot be expected that the behavioural acclimatisation in terms of home range establishment and settlement had taken place by the end of this investigation.

Management implications

Post-release monitoring of spatial patterns of translocated rhinos provides important information regarding management decisions in the future. This chapter characterises the main features of cognitive and behavioural acclimatisation of a white rhino male after introduction to a new environment, where black rhinos had recently established home ranges and social organisation. This chapter serves as a model to describe acclimatisation processes and inter-specific associations between both African rhino species. The chapter provides data essential for assessing the black rhino – white rhino spatial strategy. The results are of value in helping to formulate recommendations on the most suitable methods for translocation in other areas in the future.

Summary

This chapter deals with the post-translocation exploration behaviour and home range establishment of a single subadult white rhino *Ceratotherium simum* Burchell 1817 male that was released into an area, in which black rhinos *Diceros bicornis* Linnaeus 1758 had recently established home ranges and social organisation. The white rhino was radio tracked over a period of eight months (Jun 2006 – Feb 2007). Owing to systematic data collection, sufficient numbers of fixes for minimum convex polygon and Kernel analysis were gathered, allowing for a detailed description of exploration behaviour. Although the data collection period was too short to investigate seasonal effects, temporary changes in exploration behaviour and home range establishment were found. The total and temporary home ranges of the white rhino are larger then most literature references for this species, possible owing to the semi-arid savannah ecosystem. Since the white rhino was found to be using entirely different areas than the black rhino group, inter-specific communication seems to play a role in the spacing strategy of the studied white rhino. In view of the sociality of white rhinos, the unnatural situation of one individual roaming the area may also have influenced the spacing strategy of the studied animal. This study serves as a model to describe inter-specific associations between both African rhino species.

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CHAPTER VI: REMOTE STRESS ASSESSMENT IN TRANSLOCATED AFRICAN RHINOS

Introduction

Translocation is likely to be a distressing event (Franceschini et al. 2008). The analysis of hormonal indicators of stress, particularly glucocorticoids, from faeces has become a reliable and valid non-invasive method that has been applied to a variety of mammalian species (Queyras and Carosi 2004). Whereas the analysis of blood plasma reveals punctual information about the hormone status at the moment of data collection, faecal glucocorticoid metabolites (FGM) represent a certain time-frame (Hunt et al. 2004). As the production of glucocorticoids occurs intermitted, this time-frame positively influences the validity of the results (Buchanan and Goldsmith 2004). Another major advantage of non-invasive methods such as FGM analysis is that data can be collected in the absence of the animal (Franceschini et al. 2008). In view of free-ranging wildlife, in particular large and very large mammals that cannot easily be handled or even observed, non-invasive measuring of FGM has become an increasingly powerful tool for the assessment of physiological cues and the development of implications for wildlife management. Besides others, FGM assays were validated for small mammals: domestic mouse *Mus musculus*, Linnaeus 1758 (Touma et al. 2004), Oldfield mouse *Peromyscus polionotus* Wagner 1843 (Good et al. 2005), Mongolian gerbil *Meriones unguiculatus* Milne-Edwards 1867 (Scheibler et al. 2004) and stoat *Mustela erminea* Linnaeus 1758 (Göttert et al. 2005); primates: grey mouse-lemur *Microcebus murinus* J.F. Miller 1777 (Labes 2003), rhesus macaque *Macaca mulatta* Zimmermann 1780 (Stavisky et al. 1994) and chimpanzee *Pan troglodytes* Blumenbach 1799 (Whitten et al. 1998); large carnivores: Steller sea lion *Eumetopias jubatus* Schreber 1776 (Hunt et al. 2004), cheetah *Acinonyx jubatus* (Jurke et al. 1997), spotted hyena *Crocuta crocuta* (Goymann et al. 1994) and African wild dog *Lycaon pictus* Temminck 1820 (Monfort et al. 1998), and African ungulates: kudu *Tragelaphus strepsiceros*, mountain nyala *Tragelaphus buxtoni* Lydekker 1910, impala *Aepyceros melampus* Lichtenstein 1812, blue wildebeest *Connochaetes taurinus*, common zebra *Equus quagga* and giraffe *Giraffa camelopardalis* (Chinnadurai et al. 2009), Grevy's zebra *Equus grevyi* Oustalet 1882 (Franceschini et al. 2008), and African elephant *Loxodonta* *africana* (Millspaugh et al. 2007). Studies on both African rhino species have shown that faecal corticoid concentrations reflect adrenal activity (Brown et al. 2001, Carlstead and Brown 2005). In recent years, a small number of studies focused on analysing FGM for assessment of stress and acclimatisation in endangered wildlife species after translocation (Turner et al. 2002, Franceschini et al. 2008, Aguilar-Cucurachi et al. 2010, Linklater et al. 2010). The major goal of this chapter was to evaluate FGM analyses for the assessment of the physiological status of both African rhino species in order to obtain empirical data on the process of physiological acclimatisation.

Material and methods

Data collection

Black rhinos

During 380 days of data collection (study period: March 2005 and February 2007), a total of 164 faecal samples were collected on 110 days. Samples were collected on an irregular basis whenever fresh material was found. To assure independence of data, only one sample per observation day and individual was collected. Samples were either gathered during following an animals tracks (38.4 %), finding them by chance while radio tracking one or more animals (58.5 %), or observing an animal defecating (3.1 %). The number of samples per individual ranges from n = 3 (subadult male 2) to n = 46 (adult male) ($\bar{x}$ = 16.6, SD = 17.1). A total of 64 samples could not be allocated to an individual rhino. The reason is that often more than one rhino was found at a time in a specific area (chapter III), which made it often impossible to identify a dung sample to the individual level. The number of dung samples from males was n = 60, the number of dung samples from females was n = 51. Immediately after collection, approximately 10 g of moist faecal material was collected from the centre of the dung heap. This amount was placed into a plastic tube, the tube was filled with ethanol (90 %), and it was sealed with a screw lid and parafilm and stored at app. +8 °C. During the transport to Germany samples were kept in a cold box.

White rhinos

A total of 55 faecal samples on white rhinos were collected between May 27, 2006 and Feb 10, 2007. Between Jun 06, 2006 and Aug 19, 2006, 11 faecal samples were collected for subadult male 2, which was the only white rhino roaming the outer-fenced section of the study area at that time. Since there is a considerable difference in the texture of black and white rhino dung piles (Unwin 2003), it was possible to identify the white rhino faecal samples at the outer-fenced section of the study area. Between May 27, 2006 and Feb 10, 2007, 44 samples were collected from remaining six white rhino individuals at the inner-fenced section. These samples could not be identified to the individual level and were pooled for further analysis (white rhino starter group). The processing of the faecal samples in the field and in the laboratory was identical with black rhino sample treatment.

Data analysis

Enzymeimmunoassays were conducted at the Department of Reproductive Biology of the German Primate Center. To test for a storage effect of black rhino faecal samples, the mean and standard deviation of FGM concentration for samples that were stored for the longest and the shortest period was calculated and compared using a t-test. Since white rhino samples were not normally distributed, the storage effect was tested using a Mann-Whitney U test on the basis of the median and interquartile range (IQR, distance between the 25- and the 75-quartile). Since the largest proportion of black rhino samples was not identified to the individual level and the number of samples per individual was generally low, all samples were pooled for further analysis. To test for an influence of the dry weight on the FGM concentration, a linear regression model was used ($y = a + b*x$). Black rhino samples were compared between adults and subadults, males and females, and samples collected during the first and the second year after release using a t-test. Consecutive white rhino FGM profiles were described using a linear regression model ($y = a + b*x$). Median and IQR of FGM concentrations of the single white rhino and the white rhino starter group were compared using a Mann-Whitney U test. All statistical tests were conducted using the computer program Sigma Plot Statistical Program.

Results

Validation

Storage effect

The storage time for black rhino samples lasted from five months up to 16 months depending on the time of sample collection. Faecal glucocorticoid concentration of samples with a storage time between 5 and 8.5 months ($\bar{x}$ = 51.7 ng/g faeces, SD: 19.9, n = 10) did not differ significantly from samples with a storage time between 11.5 and 16 months ($\bar{x}$ = 48.3 ng/g faeces, SD: 12.1, n = 10), (t = 0.461, df = 18, p = 0.65). The storage time for white rhino samples lasted from three months up to 11 months, FGM concentration of samples with a storage time between 3 and 4 months (median = 63.7 ng/g faeces, IQR: 29.4, n = 10) did not differ significantly from samples with a storage time between 9 and 11 months (median = 47.7 ng/g faeces, IQR: 44.1, n = 10) (U = 36.0, p = 0.307). Thus, prolonged storage time did not lead to a time dependent increase of FGM concentration in rhino faecal samples.

Influence of sample dry weight on FGM concentration

When plotting the concentration of FGM of the black rhino sample fraction against the dry weight of faecal samples, it turned out that FGM levels tend to increase with lower levels of the sample weight. It was determined that 1.5 g of dry weight is the critical weight below which the effect becomes significant (Figure 23). Thus, only samples with a dry weight of ≥ 1.5 g were selected and used for further analysis. A similar relationship between sample weight and FGM concentration was not found regarding white rhino faecal samples (n = 55, linear regression model: y = 1.816 - (0.00492 * x), R = 0.251, F [ANOVA] = 3.6, p = 0.065).

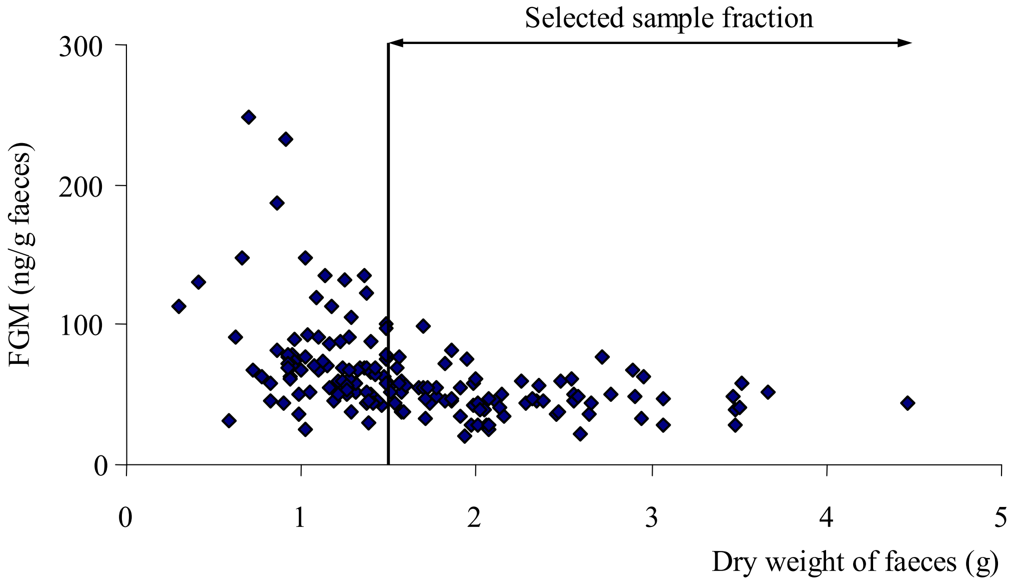

Figure 23. Relationship between sample weight and FGM concentration for all black rhino faecal samples over the study period ($n = 164$). The linear regression model for the entire data set reveals a significant relation: $y = 2.251 - (0.00941 * x)$, $R = 0.43$, F (ANOVA) = 36.9, $p < 0.001$. When using only samples ≥ 1.5 g dry weight of faeces (selected sample fraction, $n = 76$), no significant relationship exists: $y = 2.592 - (0.00717 * x)$, $R = 0.17$, F (ANOVA) = 2.1, $p = 0.15$.

Black rhinos

Black rhino FGM concentrations did neither statistically differ between age classes (adults: $\bar{x} = 50.9$ ng/g faeces, SD = 15.7, n = 28; subadults: $\bar{x} = 48.0$ ng/g faeces, SD = 15.4, n = 22; t = 0.659, df = 48, p = 0.513) nor between sexes (males: $\bar{x} = 48.5$, SD = 14.1, n = 32; females: $\bar{x} = 56.6$ ng/g faeces, SD = 13.7, n = 17; t = -1.925, df = 47, p = 0.06). Samples collected during the first year after release ($\bar{x} = 55.4$ ng/g faeces, SD = 15.5, n = 23) revealed higher FGM concentrations than samples collected during the second year after release ($\bar{x} = 45.2$ ng/g faeces, SD = 12.9, n = 53), (t = 2.97, df = 74, p = 0.004 [Figure 24]).

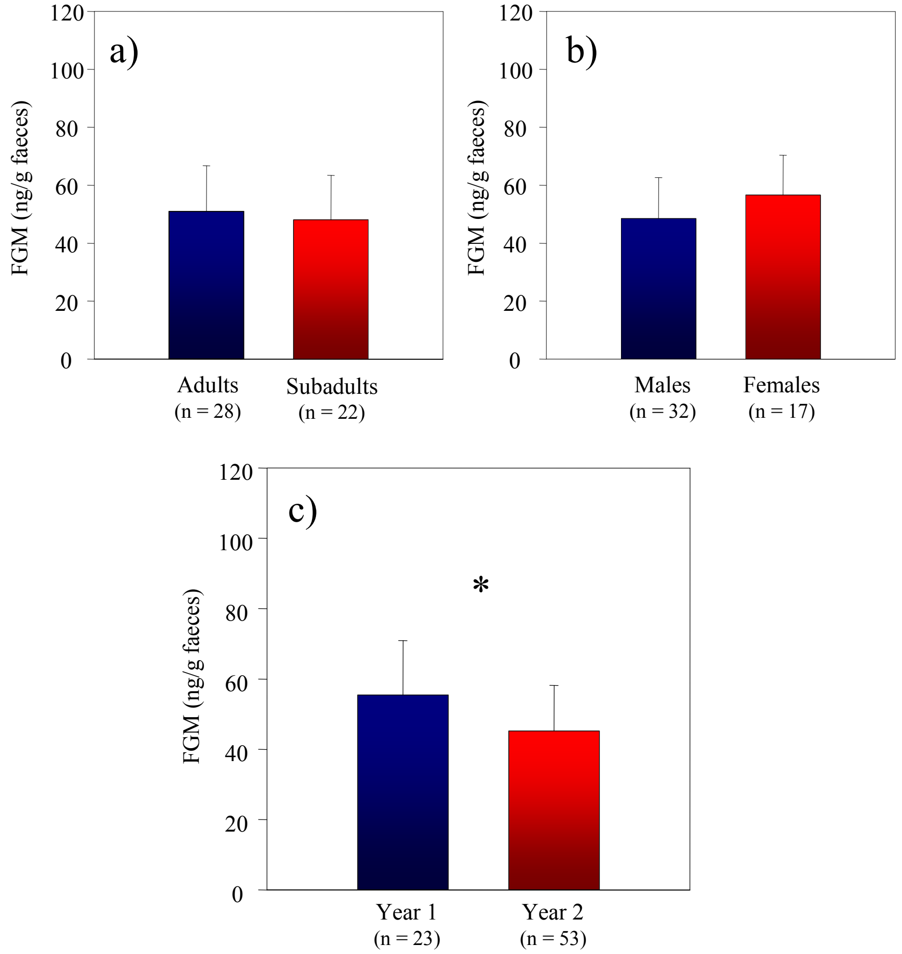

Figure 24. The mean and standard deviation of black rhino FGM concentrations is given. a) Comparison of age classes, b) comparison of sexes and c) comparison of samples collected during the first and the second year after release. * Marks statistically different values.

White rhinos

The FGM concentration of the pooled sample fraction (white rhino starter group) is statistically greater (median: 53.8 ng/g faeces, IQR: 41.9, n = 44) than the level for subadult male 2 (median: 39.2 ng/g faeces, IQR: 11.1, n = 11), (U = 133.0, p = 0.022). Temporal patterns in FGM concentrations were different between the two experiments. While the cumulative FGM pattern of the single white rhino shows a slightly positive development, the analysis of the pooled sample fraction of remaining white rhinos reveals a slightly negative progression. Both patterns indicate no statistically significant time-related effect (Figure 25). When comparing the FGM concentrations from the two species (pooled data per species), no difference was found (median black rhinos: 47.3 ng/g faeces, IQR: 17.4, n = 76; median white rhinos: 45.9 ng/g faeces, IQR: 38.1, n = 55; U = 1907.0, p = 0.395).

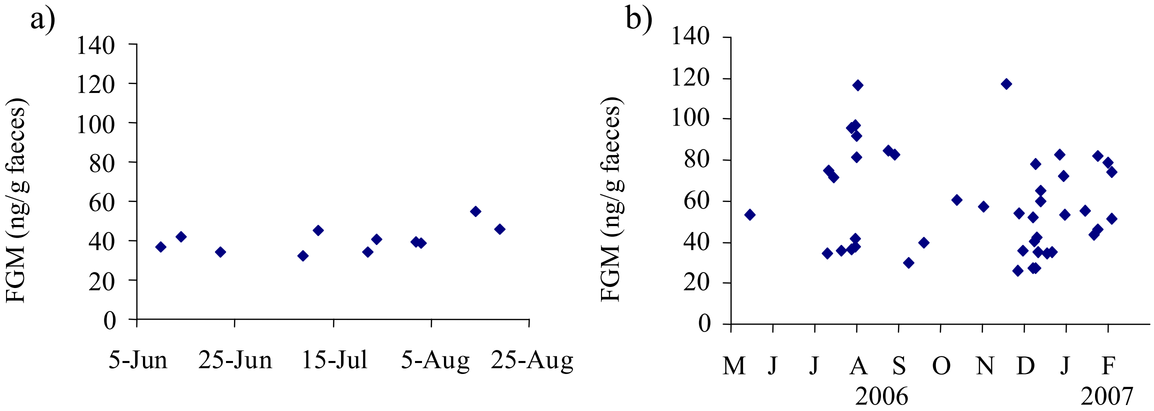

Figure 25. The concentration of white rhino faecal glucocorticoid metabolites is given over time. a) Values for subadult male 2, n = 11, linear regression model: y = 2453861.6 + (1.81 * x), R = 0.51, F (ANOVA) = 3.19, p = 0.107. b) Pooled sample fraction of the white rhino group, n = 44, linear regression model: y = 2454072.702 – (0.501 * x), R = 0.16, F (ANOVA) = 1.17, p = 0.286.

Discussion

Non-invasive measuring of physiological correlates using faecal hormone metabolites has become a useful tool for the assessment of animal health and welfare. The design of this study is characterised by a relatively large area and low numbers of animals. As shown in prior chapters (chapters III-V), VHF radio-telemetry tracking procedure in fact allowed for a systematic and regular investigation of several behavioural correlates of the black rhino group and a white rhino individual. In view of faecal sample collection, practical limitations were low sample size and relatively large proportion of samples that could not be identified to the individual level. In addition, the FGM concentration of black rhino samples was associated with the sample weight, which forced the author to exclude a large proportion of the collected samples from the analysis.

Typically, translocated mammals show an increased faecal glucocorticoid level after capture, which afterwards decreases to pre-capture levels. The time until which the faecal glucocorticoid concentration decreases to the baseline level is referred as the acclimatisation period, usually comprising several weeks (Franceschini et al. 2008, Aguilar-Cucurachi et al. 2010). This pattern has also been shown regarding translocated African rhinos in captivity (Carlstead and Brown 2005), semi-captivity and under free-ranging conditions (Turner et al. 2002), and during boma management (Linklater et al. 2010). Owing to the above mentioned limitations, the sample size was insufficient for systematically investigating the FGM profile after release.

However, when analysing the pooled black rhino sample fraction, a biological, time-related effect emerged: higher FGM concentrations during the first year and lower concentrations during the second year post-release. This result should be carefully discussed, and it should be interpreted in light of the results on the cognitive and behavioural acclimatisation of black rhinos (chapter III and IV). These results reveal the typical, species-specific behaviour as expected in a semi-arid environment. No signs of distress or disease were found. In contrast to the results on spacing strategy and habitat use, no age or sex-related differences between black rhinos were found regarding the FGM analysis. Although the author notes the limited faecal sample size, similar FGM levels for different age and sex classes of black rhinos are in line with the observation of normal behaviour and the general absence of distress cues. Spacing strategy, habitat use and reproduction furthermore indicated that behavioural and physiological acclimatisation occurred to certain degrees already after three months post-translocation (p. 69). In light of these data, the result of measurable but not dramatically lower FGM concentrations of black rhinos during the second study year is another useful indicator for a longer-term acclimatisation of black rhinos.

The white rhino is a social species and thus, welfare should be optimised when allowing rhinos to establish a social structure in combination with physiological acclimatisation after translocation. The FGM concentrations of the single white rhino (overall lower levels, slight increasing profile) and the white rhino starter group (overall higher levels, slight decreasing profile) can be explained by the specific environmental conditions. These conditions determine two different field experiments: The single rhino was released into a relatively large area, no intra-specific concurrence occurred but inter-specific responses towards black rhinos have been noticed (chapter V). The single white rhino roamed a large proportion of the study area. In view of the typical social behaviour of white rhinos, the solitude of the single rhino was an unnatural situation. Contrary, a total of six individual white rhinos were released as a starter group within a short time frame inside the inner-fenced section of the study area. On the one hand, the environmental conditions (group composition in terms of age and sex, schedule of translocation procedures) may have been a factor that positively influenced the acclimatisation of white rhinos. On the other hand, the establishment of the social structure may have also induced a certain level of distress, especially regarding subdominant group members. Moreover, the size of the inner-fenced section containing the white rhino group was relatively small and a considerable proportion of this area was situated on Otavi dolomite substrate (chapters I - III), favouring low quality habitat for grazers such as white rhinos. It is possible that this small size of the area may have led to overall higher FGM concentrations when compared with the single animal outside the fence.

However, the slightly decreasing progression of the white rhino starter group's FGM profile may be an indicator for physiological acclimatisation. In contrast, the slightly increasing FGM profile of the single white rhino male may have been linked with the unnatural situation of isolation.

Management implications

The study in hand has shown that the used methodological approach of measuring FGM has successfully been applied in this specific field study. However, it turned out that the study conditions (large size of the study area, low number of individuals, and often no individual assignment of samples possible) limited the sample size and consequently the significance of the results. The analysis of black rhino FGM concentrations has furthermore shown the existence of an artdefact: the influence of the sample weight on FGM concentrations. This shows the need for a standardised processing of samples when collecting them in the field. Ideally, a specific amount should be weighted for avoiding this effect (e.g. Kretzschmar 2003). Rhino managers may face similar limitations when applying FGM measurements in combination with future translocations. Thus, the present study stresses the importance to interlink results on FGM concentrations with additional data on the behaviour and physiology of translocated rhinos in order to successfully assess the process of physiological acclimatisation and develop implications for rhino management.

Summary

Translocated individuals face multiple stressors, and glucocorticoids have been shown to be accurate physiological measures of the stress response of individuals. This chapter deals with the analysis of faecal glucocorticoid metabolites (FGM) of translocated black rhinos *Diceros bicornis* Linnaeus 1758 and white rhinos *Ceratotherium simum* Burchell 1817 to assess the physiological status and physiological acclimatisation. The study period for black rhinos was two years (Mar 2005 - Feb 2007), and white rhinos were studied over an eight months period (Jun 2006 - Feb 2007). The methodological approach was successful for measuring FGM concentrations for both species that had comparable levels of FGM concentrations. The analysis of black rhino faecal samples revealed an artificial error, which was caused by the sample weight. Black rhino samples had significant but not dramatically higher FGM concentrations during the first year and lower concentrations during the second year, suggesting longer-term acclimatisation. The FGM concentration regarding the single white rhino (overall lower levels, slight increasing profile) and the white rhino starter group (overall higher levels, slight decreasing pattern) are in line with the respective environmentally conditions.

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CHAPTER VII: GENERAL DISCUSSION

Scientific outcome: A valuable description of the acclimatisation of translocated African rhinos

Wildlife conservation programmes in recent years involve the capture, translocation and release of free-living surplus animals from areas of relatively high abundance to suitable locations as part of restocking efforts (Fischer and Lindenmayer 2000, Franceschini et al. 2008). Translocation has been an important, commonly used and successful management tool that has been instrumental for the recovery of African rhino populations (Rookmaaker 2000, IUCN 2010). Translocation exposes animals to multiple stressors (Teixeira et al. 2007). Acclimatisation refers to adaptive adjustments made by individual organisms to a multi-stress environment (Mazess 1975). The major goal of this thesis was to systematically describe and characterise the process of acclimatisation of translocated African rhinoceros for the first time in detail. The thesis takes advantage of the translocation of six black *Diceros bicornis* Linnaeus 1758 and seven white rhinos *Ceratotherium simum* Burchell 1817 to one specific area in Namibia. This situation provides a unique and valuable case for a field-experiment in acclimatisation.

The first specific objective was to characterise the environment in terms of habitat structure and suitability for rhino translocation (climate, size, geological formations, vegetation types, distribution of water). This information is essential to be able to assess the spatial and temporal behaviour of rhinos. The study area is situated in the semi-arid savannah biome of north-central Namibia, where both rhino species explore the limits of their natural distribution (Kingdon 2003). Climate data from the first chapter of this thesis demonstrates the strong seasonality and great annual variability of precipitation of the area, a typical feature for arid and semi-arid lands (Maranga et al. 1983, Walker et al. 1981, Burke 2003). This seasonal pattern was proven to influence vertebrate species composition (chapter II) and the spacing behaviour and habitat use of black rhinos (chapter III). According to the geology of the study area (chapter I), the results of the bird species composition (chapter II), and the vegetation study (chapter III), the dominating habitat type was savannah – woodland mixed habitat; the area was characterised by a considerable level of structural complexity.

Overgrazing as a result of intensive cattle farming, coupled with episodic droughts, has caused widespread degradation and loss of floristic and faunal diversity, which is unlikely to recover to climax conditions (Du Toit and Cumming 1999, Tews et al. 2004). Although the study area has been used for commercial livestock farming between the 1960s and the beginning of this century, the vertebrate monitoring (chapter II) and the vegetation study (chapter III) assume a relatively high level of structural complexity owing to different geological formations (chapter I, III). The precipitation data indicate atypically high amounts of rain during the study period and a general increase of annual precipitation during the 20 years before the present investigation was conducted. Fortunately, the chosen time for translocating the rhinos monitored in this thesis was optimal. The 'habitat heterogeneity hypothesis' assumes that structurally complex habitats may provide more niches and increase species diversity (Simpson 1949, MacArthur and Wilson 1967, Bazzaz 1975, Tews et al. 2004). It is also known that commercial farmlands support a larger and more diverse assemblage of birds and mammals when compared to communal areas (Joubert and Ryan 1999). Thus, the former influence of commercial livestock farming may have been less intense when compared with communal rangelands in Namibia. Another important reason for the relatively high numbers of faunal diversity may be the direct adjacency to the Etosha National Park (ENP). Owing to contrasts in land use there are considerable fringe effects at the fence to ENP (p. 137). Wildlife is overcoming the fence and frequently uses wildlife crossings. The high numbers of indigenous large mammals at the study area were a consequence of translocations of several large ungulate species, including the studied rhinos. The description of the study area sets the basis for the analysis of rhinos' spatial and temporal behaviour and habitat use, and it shows the study area's suitability for re-introduction of grazers and browsers as well, including the rhinos from this thesis.

The second specific objective was to characterise the cognitive and behavioural acclimatisation of translocated rhinos. Exploration behaviour and consequently the home range establishment and habitat use include learning processes and shifts in behavioural patterns. Thus, information on exploration behaviour, home range establishment and habitat use are good examples to study both types of acclimatisation. A typical feature of mammals is their exploration behavior, which leads to latent learning in space (Tolman and Honzik 1930). When released into a new environment, mammals establish a cognitive map of the environment, which allows for repeated returns to certain locations even after long periods (Tolman 1948, Collett et al. 1986, Jacobs 2003, Schröpfer 2003). Despite the importance of translocation for conservation of many mammalian flagship species, such as the Sumatran rhino *Dicerorhinus sumatrensis* Fischer 1814 (Maguire et al. 1987), Asiatic lion *Panthera leo persica* Meyer 1826 (Johnsingh et al. 2007), Eurasian lynx *Lynx lynx* Linnaeus 1758 (Böer et al. 1995), grizzly bear *Ursus arctos* Linnaeus 1758, grey wolf *Canis lupus* Linnaeus 1758 (Soulè 1987), and black-footed ferret *Mustela nigripes* Audubon and Bachman 1851 (Harris et al. 1989), surprisingly little is known about the post-translocation exploration behaviour of such species (Kleiman 1989).

The exploration behaviour of the six black rhinos (chapter III) and a white rhino subadult male (chapter V) was characterised by obvious quantitative and qualitative differences, as well as high inter-individual variation among black rhinos, and inter-specific variability among species. The size of the home ranges and core areas, was among largest recorded for the respective species, which may be linked with a relatively low resource availability in the studied area. In addition to the exploration behaviour, the time frame until black rhinos established home ranges was highly variable. The study period of the white rhino (eight months) did in fact not allow the settlement period to be detected but temporal changes over time were still observed. It can be expected that the time period that is necessary for settlement differs among species and even among individuals of the same species in different environments. Rouco et al. (2009) showed for example that the post-translocation survival of European wild rabbits *Oryctolagus cuniculus* Linnaeus 1758 was significantly higher when rabbits had a pre-release acclimatisation period of six days (soft-release) when compared with an acclimatisation period of three days only. By studying daily movements of translocated swift foxes *Vulpes velox* Say 1823, Möhrenschlager and Macdonald (2003) found an initial acclimatisation phase when the foxes remained in the area of release (hours to days), a following establishment phase (app. two weeks) and a final settlement phase (after two weeks). This is comparable with the ranging patterns of translocated racoons *Procyon lotor* Linnaeus 1758 as reported by Mosillo et al. (1999). The only available literature on black rhinos' settlement period after translocation is 15 – 25 days (Linklater and Swaisgood 2008) and 1- 93 days (Patton et al 2010). However, both studies showed that in at least 44 % of cases black rhino settlement was not complete after 100 days. This thesis revealed that the number of observations necessary to reach the final plateau of the observation area curve, which is an indicator for settlement, ranged between 42 and 130 observations. The settlement pattern of all studied black rhinos changed with seasons, meaning there was ongoing variability in the ranging behaviour over time. This stresses the importance of longer-term studies to assess acclimatisation processes. While referring acclimatisation periods for large mammals in terms of translocation, typically only a few weeks are considered (Franceschini et al. 2008, Turner et al. 2002, Linklater et al. 2010). Emslie et al. (2009) stated that intensive post-release monitoring of African rhinos, at least for one month and preferably longer, should be implemented. Black rhino behaviour seen in this study suggests that environmental conditions in general should be included when considering acclimatisation. The fact that black rhinos responded to changing seasonal conditions by altering their spacing strategy (larger home ranges and core areas during the dry season), habitat use (use of *Acacia* dominated shrub land during the dry season) and social behaviour (formation of new social units with changing of seasons) indicates ongoing acclimatisation of the studied black rhinos. The study period of two years allowed for an in-depth and valuable description of this acclimatisation process. The results of this thesis suggest much longer settlement periods than those found in other areas. The social organisation of black rhinos, as studied via home range and core area overlap and direct observations, revealed that a certain level of acclimatisation had occurred already after three months but at the latest after six months post-translocation (formation of new social units).

Behavioural acclimatisation refers to shifts in set of behavioural correlates and activity patterns (Mazess 1975, Göttert et al. 2010). To get a more detailed picture of the behavioural acclimatisation of translocated black rhinos, diurnal activity patterns and disturbance behaviour were examined (chapter IV). A bimodal diurnal activity pattern once more suggests normal, species-specific behaviour. Seasonal variation in diurnal activity (rhinos more active during the dry season) is another useful indicator for the behavioural acclimatisation of the investigated rhino group. As typical for ungulate species in general, rhinos show characteristic patterns of response behaviour towards environmentally stimuli (e. g. snoring, zigzaggig, tacking, tail flicking). Disturbance behaviour has become an important tool to gain a better understanding of ungulate behaviour and welfare in order to develop conservation strategies. The results of the disturbance behaviour reveal that although special focus was led on the remote data collection and tracking procedures, in most cases, black rhinos took notice of the observers. The dominant response was giving attention but not direct flight. Overall, rhinos showed a rather interested and investigative behaviour, mock charges were very seldom. Reliable measures of the fearfulness of animals are the flight initiation distance (here, the distance between human and rhino, at which the rhino takes flight) and the alert distance (distance at which the rhino becomes alert). Very interestingly, observations where rhinos directly fled were associated with longer observers approach distances than observations, where the rhinos stayed in the area. This supports the hypothesis that the degree of alarm appears to be lessened when the animals are able to locate the source of the stimulus. Again, the typical, species-specific behaviour was observed. Also in view of the disturbance behaviour a time-related effect was seen, as rhinos allowed shorter observers approach distances during the second year of the study. This time-related effect once more suggests longer-term behavioural acclimatisation of black rhinos.

The final specific objective was to characterise the physiological acclimatisation of translocated rhinos. Findings regarding the cognitive and behavioural acclimatisation of rhinos additionally allow for behavioural analyses of the physiological status. The species-specific behaviour that was found using different approaches is a good indicator for the health and welfare of the studied rhinos. The fact that the adult black rhino female gave birth to a calf after 18 months post-release suggests that copulation between the adult rhinos occurred already after three months after translocation. Accordingly, the spatial behaviour of the adult rhinos and possibly later the adult male and subadult female 1 may have been linked with physiological cues, namely reproduction. Since the activity rhythm reflects the metabolism of an animal, diurnal activity (chapter IV) is also an indicator for the physiological status in terms of health and well-being. Translocated individuals face multiple stressors, and stress is a probable factor for the failure of translocations (Teixeira et al. 2007). To get a deeper knowledge on the physiological status of studied translocated African rhinos, faecal glucocorticoid metabolites (FGM) as indicators for stress were measured (chapter VI). Glucocorticoids have been shown to be accurate physiological measures of the stress response of individuals (Wasser et al. 2000). Increases in stress levels based on faecal glucocorticoid concentration after translocation were reported for several mammalian species, such as Grevi’s zebra *Equus grevy* (Franceschini et al. 2008), mantled howlers *Alouatta palliata* Gray

1849 (Aguilar-Cucurachi et al. 2010) and African rhinoceros (Turner et al. 2002, Linklater et al. 2010). Above studies refer acclimatisation periods as the time until which the FGM concentration decreases to pre-capture levels. Pronounced decrease in corticoid concentrations occurred after 11-18 weeks for Grevy's zebra, 1 – 4 weeks for mantled howlers, and 4 – 6 weeks (Turner et al. 2002) and 17 days (Linklater 2010) for African rhinos. Linklater (2010) moreover found the typical glucocorticoid profile of translocated rhinos in captivity associated with abnormally suppressed behaviour and suppressed gonad activity, suggesting that a decrease in corticoid levels may not be automatically evidence of low stress. However, owing to several factors (large size of the study area, low number of individuals, and often no individual assignment of samples possible), FGM analysis was not useable to detect the typical short-term FGM pattern of high values directly after release and decreasing levels after several weeks. However, black rhino samples had higher FGM concentrations during the first year and lower concentrations during the second year after release. The FGM patterns of white rhino reflect the specific conditions in terms of the area size and the presence or absence of conspecifics. The analysis of FGM concentrations was a useful approach to reveal empiric data on the physiological acclimatisation of translocated rhinos. The results revealed additional information supporting the longer-term acclimatisation of rhinos in this study.

In summary, this thesis introduces a comprehensive approach to describe the complex process of acclimatisation. It demonstrates the applicability of a range of non-invasive, field-based methods for providing important data on the cognitive, behavioural, and physiological acclimatisation of free-ranging African rhinos (Figure 26). Combining the different methods resulted in a more detailed understanding of the post-release acclimatisation of African rhinos. It has been shown that the two years time frame of the study was a suitable period to collect reliable data on acclimatisation responses of the black rhino group.

Although the eight months study period of white rhinos was apparently shorter, several aspects of acclimatisation were also observed and compared with findings for black rhinos. In addition to the methodological repertoire and the relatively long study period, the thesis demonstrates the importance of the features of the study area, particularly its size.

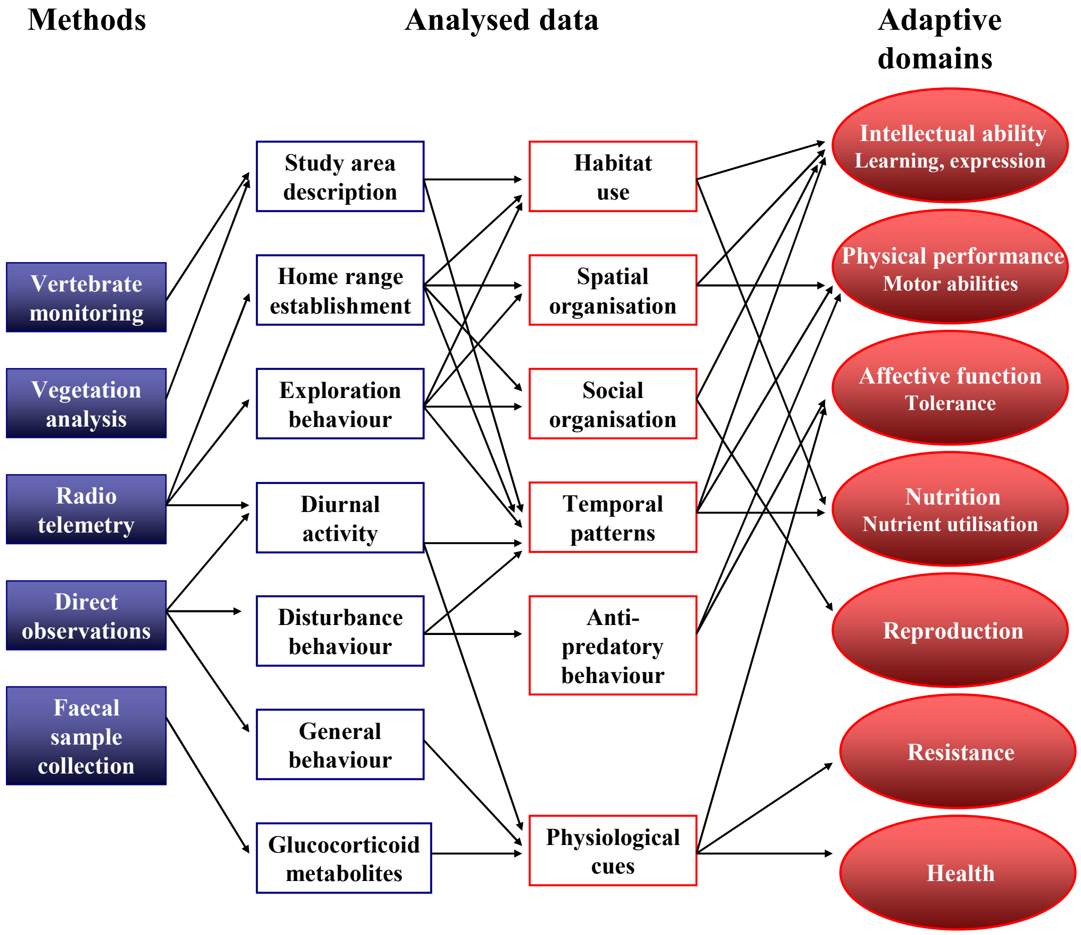


Figure 26. The multi-factorial approach of this thesis enables a concept for assessing the process of acclimatisation in translocated African rhinos.

The features and size of the study area, coupled with the study period allowed for detection of cognitive, behavioural and physiological acclimatisation processes, which would not be apparent in smaller areas, or over shorter durations. This description of acclimatisation may serve as a model for the assessment of translocations of other mammalian species in the future and is of special importance for future rhino translocations in Namibia.

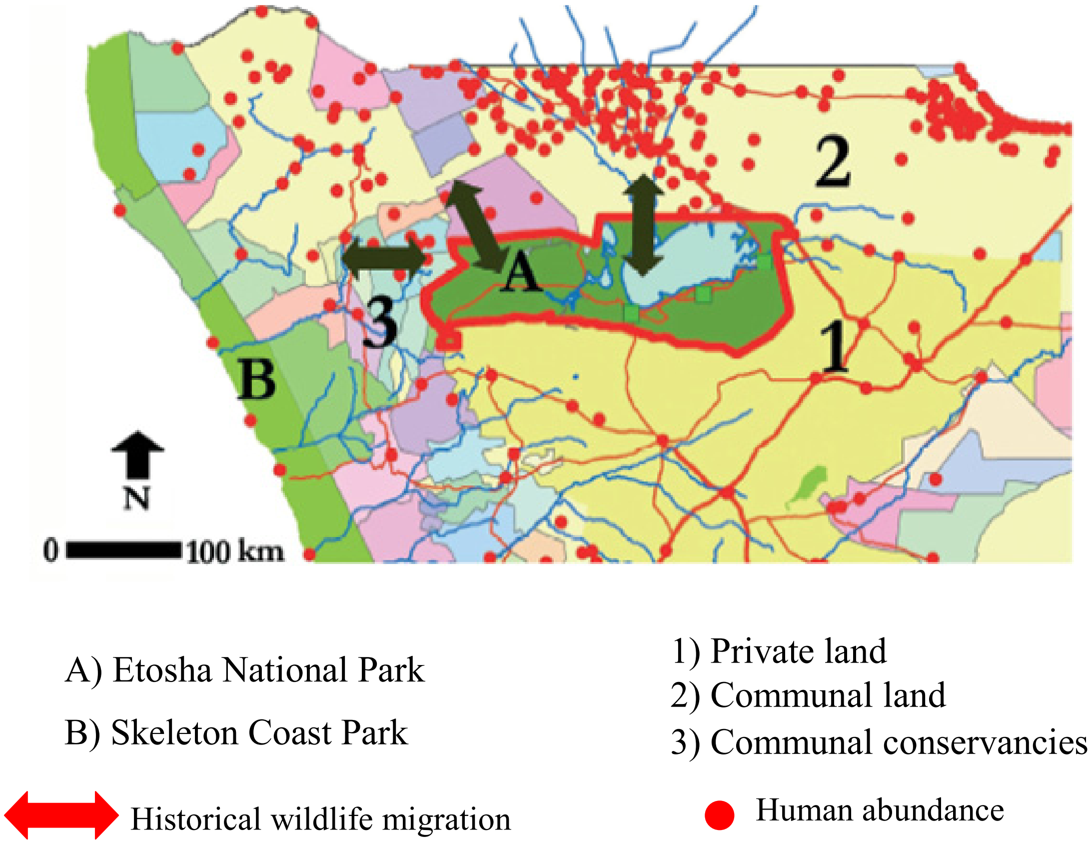
Practical outcome: Supporting the development of conservation areas at the border of the Etosha National Park

The thesis in hand has proven the feasibility of relocating both species of African rhino to former commercial livestock farmland south of Etosha National Park (ENP) in Namibia. By encouraging the use of former livestock farmland in this way, this thesis provides a model for other farms in direct neighbourhood of the ENP. This is of considerable value for the management of the ENP, which is the ‘engine’ driving the production of rhino for the entire country (Martin 2010). The importance of the specific area studied in this thesis is linked with the historical development of the ENP.

When Charles Anderson and Francis Galton discovered the Etosha salt pan in 1851 as first Europeans, there were unimaginable large numbers of wildlife. However, with the expanding of Europeans and an assignment of firearms, coupled with rinderpest epidemic, once highly abundant and widespread wildlife species went almost extinct in 1884 (Hennig 1987). Consequently, Game Reserve No. 2 – today ENP - was proclaimed in 1907 by the governor of ‘*Deutsch-Südwestafrika*’, Dr. Friedrich von Lindequist. Game Reserve No. 2 covered fairly 80.000 km^2 and incorporated the natural migration patterns of the wildlife (Barnard 1998). Between 1947 and the early 1970s, the borders of the park were changed several times and finally, the protected area was dramatically reduced to its present size of 22,912 km^2. Furthermore, the entire park was surrounded by 850 km of game fence. Today, there are many examples for contrasting land use strategies between the National Park and its surrounding areas. Main factors and the resulting problems are:

- Complete fencing forms isolation and cuts off traditional wildlife migration routes
- Livestock farming in direct neighbourhood to the park threatens mega-carnivores
- Tourism level causes negative ecological impacts
- Indigenous communities are inadequately involved

Cutting off interactions between the ENP and its surrounding areas has reduced nature’s ability to adapt to the lack of resources. The United Nations Development Program (UNDP) and the Namibian Ministry of Environment and Tourism (MET) developed the project ‘Strengthening the Protected Area Network’ (SPAN) to expand the existing system of state protected areas in Namibia. One major objective of the SPAN project is the establishment of the ‘Etosha Skeleton Coast Link’, a wildlife corridor between the ENP and the Skeleton Coast National Park. In this context, the Etosha buffer zone project aims at supporting current efforts to connect the ENP to the trans-boundary network of protected areas in the southern African sub-region (Göttert and Zeller 2008; 2009).



Map 12. Land use in north-central Namibia. The fenced Etosha National Park is surrounded by areas of different land use. There is an indefinite pressure of the ENP on surrounding areas. In the North, there are serious conflicts caused by elephants *Loxodonta africana* that overcome the fence and vanish infrastructure on communal land. In the South, large carnivores, especially lions *Panthera leo* are threatened by landowners when entering livestock farmland. This map was adapted from Göttert and Zeller 2008.

The overall goal of the Etosha buffer zone project is the establishment of effective buffer zones and wildlife corridors according to IUCN-criteria on land that is adjacent to ENP and under different forms of utilisation (Map 12). Consequently, traditional land use strategies on communal and private land need to be considered respectively.

The concrete objectives of the Etosha buffer zone project are:

- to capture the ecological pressure of the park on surrounding areas
- to assess existing gradients of land use
- to evaluate the socioeconomic development potentialities
- to define specific priorities of the buffer zone after land use strategies
- to open the fence at selected points in combination with ongoing monitoring

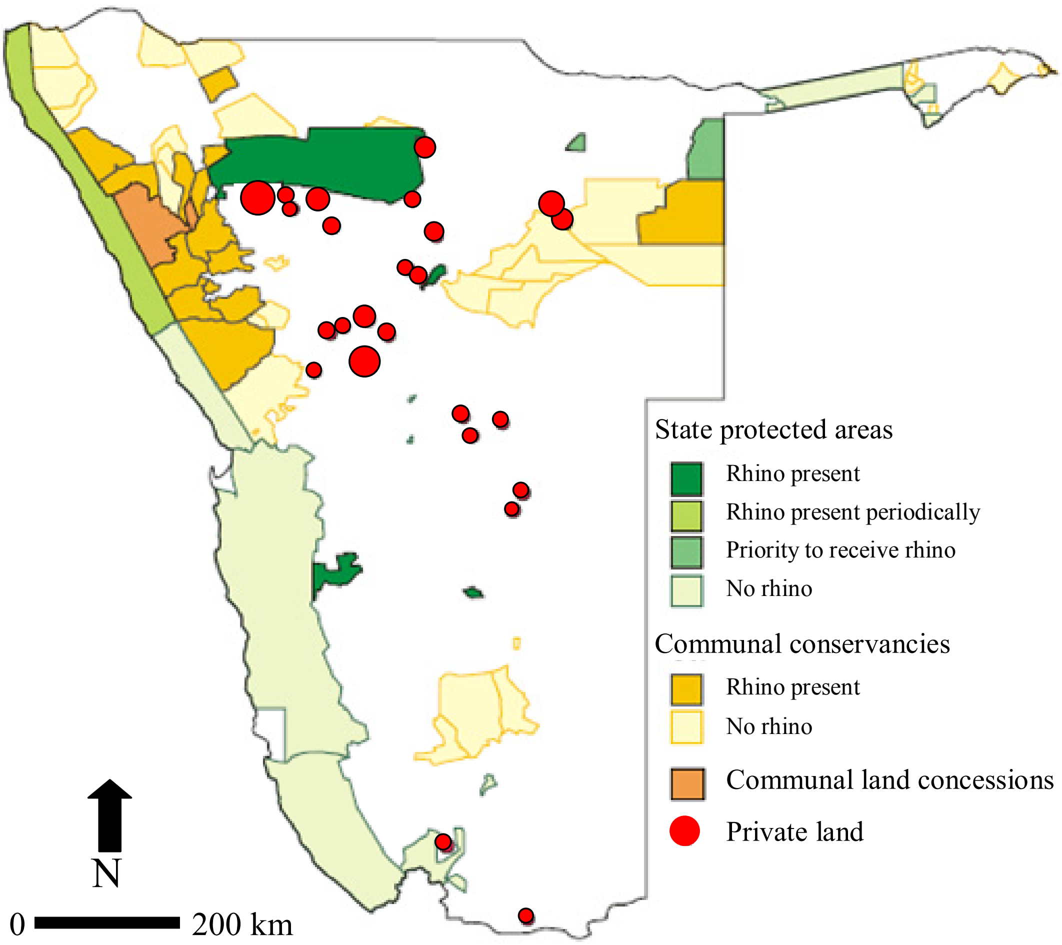
The methodological approach can be structured as follows:

- Selection of suitable areas
- Assessment of biodiversity levels
- Selection of bio-indicators (indicator species)
- Development of specific management strategies for conservation of flagship species

The black rhino has been proven to be an important species for the development of conservation activities on communal land in Namibia. Owing to locally-based conservation actions on communal land in the North of ENP (Kunene region), the Kunene subpopulation of the black rhino recovered after the heavy poaching period in the 1970s and 1980s (Loutit 1996). Hearn et al. (2000) discussed results on range patterns and habitat use of three black rhino populations in north-western Namibia in view of the development of conservancies in the communal areas of Kunene and Erongo as part of the implementation of the Community Based Natural Resource Management (CBNRM) by the MET. Hearn et al. (2000), for example, considered management options to secure the conservation of black rhinos alongside with the economic development and self-empowerment of farmers in this region.

Besides the scientific outcome of a concept of acclimatisation, the present thesis is also a case study illustrating the above mentioned methodological outline for the development of additional protected areas at the southern border of ENP on private land. The results have highlighted the importance of the studied area in terms of its geographical position, size and habitat features. Moreover, the area has once been part of the former Game Reserve No. 2, which is today the ENP. Historically, the Otavi dolomite formation was a natural barrier for migrating wildlife. After the data collection period for this thesis was finished in 2007, the size of the area increased in 2008, when the two additional farms ‘Vlakwater’ and ‘Safarihoek’ were incorporated into the area. Since then, the entire area sizes a total of 481.4

km^2. Vertebrate species monitoring (chapter II) is a good tool to obtain a state-description of the area for the planning of conservation strategies. Bird species assemblage turned out to be valuable for the selection of bio-indicators for an indirect assessment of the habitat quality. Owing to the direct adjacency to the ENP and the change of land use from former livestock farming towards wildlife consumption on private land in Namibia (Hennig 1997, Krug 1999, Göttert and Zeller 2008), the studied area forms an important additional conservation area for the ENP. In the present thesis, the scientific interest in rhino behaviour and physiology (chapters III-VI) goes along with conservation efforts and the development of specific management strategies for rhinos as important conservation flagship species. Thus, the scientific information from this thesis forms the basis for the establishment of practical management implications. Rhino management strategies make a good case for the development of conservation areas, since large-scale windfall gains come into play. Rhinos serve as important species for several kinds of tourism industry. Moreover, they have a key-function in the ecosystem. Particularly the black rhino is known as an umbrella species (Berger 1997). The umbrella species concept is based on the assumption that the requirements of demanding species should encompass those of many other species (Lambeck 1997, Roberge and Angelstam 2004). Berger (1997), for example, evaluated the umbrella value of a black rhino subpopulation for six large herbivore species in the Namib Desert (Namibia). He concludes that particularly desert-adapted black rhinos possess huge home ranges, and the area needed to sustain a viable population would contain sufficiently large populations of other herbivores of a similar trophic level. The relatively large size of home ranges and core areas of rhinos from this thesis are useful data when it comes to setting out the dimensions of a specific buffer zone in the area of research. A recent description of the development of black rhino sub populations within the Namibian Rhino Custodianship Scheme has been given by Martin (2009, 2010). Until 2009, there were 25 custodian areas on private land (Map 13). The number of black rhino individuals per area varied from 2 to 35 ($\bar{x}$ = 10.3, SD: 7.9). The estimated maximal number of black rhino individuals per area (abundance reaching the ecological carrying capacity of the area) ranges from 4 to 61 ($\bar{x}$ = 17.1, SD: 15.5). Martin (2009) estimated that the ecological carrying capacity of the studied area will be reached with a total of 61 black rhinos.



Map 13. The black rhino metapopulation in Namibia in 2009 is given. The map was adopted from Martin (2009, 2010). The size of the red dots referring to private areas indicates the estimated number of individuals that the respective area can maintain (ecological carrying capacity).

Hence, the area studied in this thesis has become the most important custodian area on private land in Namibia! However, further research needs to be conducted to accurately assess the ecological carrying capacity of the study area in terms of both rhino species, especially in view of the seasonal availability of resources. The long-term goal of re-introducing black rhinos on former communal and private farmland in Namibia is the creation of viable subpopulations in these areas. This can only be achieved by an interlinking of existing conservancies, which could allow migration and gene flow between isolated subpopulations. Within the Rhino Custodianship Scheme, selected areas are partly in direct adjacency to the ENP and also in close proximity to other custodian areas (Map. 13). Considering the size of this potentially possible area, the creation of a self-sufficient and sustainable metapopulation of both African rhino species at the south western border of the ENP seems feasible. Results on the habitat use of black rhinos allow for making another important management implication. Rhinos established core areas on both existing geological formations featuring different habitat types. This shows that the entire area is valuable for black rhino conservation. However, the dominance of *Acacia* species on the Etosha calcrete formation suggests that utilised habitats were here markedly influenced by bush encroachment, probably the result of former intensive livestock farming. Hence, the present thesis suggests that black rhinos may help farmers and land owners to reduce bush encroachment. This thesis should encourage further black rhino relocation activities on degraded farmland in the studied region and elsewhere in southern Africa. In practical terms, the findings on black rhino disturbance behaviour (chapter IV) suggest to interlink rhino monitoring with tourism in the area of research. In the Damaraland for example, vastly experienced community game scouts were seconded to Palmwag Lodge and Desert Rhino Camp as trackers and guides, offering walking excursions to observe black rhinos in the wild. Since the habitat at the studied area greatly differs from the semi-desert and desert habitat in the Damaraland, guided rhino tours in the studied area could become a unique experience for tourists visiting this area. In contrast to the strictly protected ENP, such tourism activities could be implemented in a buffer zone that would allow for such activities (Dyer and Holland 1991).

In summary, the results of this thesis are valuable for the development of additional conservation areas on private land at the southern border of the ENP, covering another important form of land use in the surroundings of the ENP. In order to evaluate the socioeconomic development potentialities of the studied area, Jokisch (2009) investigated the attitudes of landowners and land users towards a buffer zone. He found that consistent land use strategies in the form of some sort of wildlife farming and management are needed for the implementation of a buffer zone. Also in this respect, African rhinos are important flagship species for the development of this specific area. In view of the negative economic development of livestock farming and the increasing development of the tourism sector in the Namibian economy, the realisation of an effective buffer zone in the studied area seems to be possible. Only such a complex approach, taking into account the variegated influencing factors, allows for sustainable species conservation – also in view of African rhinos.

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SUMMARY

Thomas Göttert

ON THE ACCLIMATISATION OF AFRICAN RHINOCEROS AFTER RE-INTRODUCTION TO FORMER LIVESTOCK FARMLAND IN NAMIBIA

Translocation has become an important management tool for the conservation of both African rhino species, the black rhino *Diceros bicornis* Linnaeus 1758 and the white rhino *Ceratotherium simum* Burchell 1817. Translocations are invasive procedures that expose rhinos to multiple stressors. Acclimatisation is the adaptive response of individuals towards a multi-stress environment. This thesis is a first, systematic investigation of the post-translocation acclimatisation responses of one starter group of each African rhino species to a specific area in Namibia.

The study was carried out in a fenced area of 368 km^2, directly adjacent to the Etosha National Park (ENP) in Namibia, and it has been formerly used for commercial livestock farming. Black rhinos (n = 6) were investigated over a two years period (March 2005 – February 2007). The study period of white rhinos (n = 7) was eight months (June 2006 – February 2007).

Although the study area has been intensively used for commercial livestock farming in the past, an initial study on the suitability of the habitat (on the basis of a monitoring of the vertebrate fauna, particularly birds and medium sized and large mammals) revealed a high level of structural complexity of the area. This suggests the suitability of the area for the relocation of both rhino species.

In order to describe the acclimatisation responses of rhinos, the following parameters were investigated: i) exploration behaviour, ii) establishment of home ranges, activity centres and social organisation, iii) habitat use, iv) diurnal activity, v) disturbance behaviour towards observers, and vi) faecal glucocorticoid metabolite concentrations.

The black rhinos were radio tracked and movement data were complemented by detailed habitat descriptions at the centres of rhino activity with vegetation plot sampling. Rhinos used both existing geological formations of the study area: Otavi dolomite featuring a woodland habitat type (dominating plant species: *Colophospermum mopane* and *Terminalia prunioides*) and Etosha calcrete featuring shrub savannah (dominating plant species: *Acacia reficiens* and *A. luederitzii*). Home ranges of most individuals are among the largest recorded for the species. The size of home ranges and core areas, as well as patterns of home range establishment and habitat use was highly variable among individual rhinos. The results show i) age- and sex-specific exploration patterns, ii) seasonal changes of home range and core area size (larger ranges during the dry seasons), iii) clear shifts in spatial behaviour over time, and iv) seasonal changes of the social organisation. It is the first post-release telemetry study determining the home ranges of black rhinos.

The investigation of the diurnal activity of black rhinos confirms a bimodal pattern, and seasonal changes of the diurnal activity were detected (rhinos more active during the dry season).

The dominant response of black rhinos towards observers was giving attention but not direct flight. Overall, rhinos showed a rather inquisitive behaviour, and mock charges were very seldom. During the second year of the study, rhinos allowed shorter distances between themselves and the observers, which may be an indicator for longer-term acclimatisation processes. Observations where rhinos directly fled were associated with longer distances than observations where the rhinos stayed in the area.

The exploration behaviour and home range establishment of a subadult white rhino male was investigated via radio telemetry. When the white rhino was released into the study area, the black rhinos had already established home ranges and social organisation. Interestingly, the white rhino used entirely different areas than the black rhinos. Seasonal changes in ranging behaviour could not be detected, owing to a shorter study period. However, temporary changes in spacing strategy were still observed.

The analysis of faecal glucocorticoid metabolites (FGM) was conducted to generate data on the physiological acclimatisation of the studied rhinos. Black rhinos had significantly lower FGM concentrations during the second year of the study, indicating longer-term acclimatisation responses. The FGM concentration of white rhinos was in line with the respective environmentally conditions (size of the area, presence/absence of conspecifics) but no temporal effect was measured.

The results of this thesis provide reliable data on the acclimatisation responses of a starter group of both African rhino species after release into a specific area in Namibia that was formerly used for commercial livestock farming. Collectively, these data provide a framework applicable to further studies on post-release acclimatisation responses of rhinos in Namibia and other countries within the distribution range. These data may help for the planning of additional protected areas (buffer zones, wildlife corridors) at the border of the ENP in Namibia.

ZUSAMMENFASSUNG

Thomas Göttert

ÜBER DIE AKKLIMATISIERUNG AFRIKANISCHER NASHÖRNER NACH WIEDERANSIEDLUNG AUF EHEMALIGEM VIEHFARMLAND IN NAMIBIA

Umsiedlungsmaßnahmen spielen für den Erhalt beider afrikanischer Nashornarten, des Spitzmaul- *Diceros bicornis* Linnaeus 1758 und des Breitmaulnashorns *Ceratotherium simum* Burchell 1817, eine entscheidende Rolle. Umsiedlungen zwingen die Nashörner zur Auseinandersetzung mit zahlreichen, potenziell Stress induzierenden Faktoren. Individuelle Anpassungsprozesse gegenüber komplexen Umweltfaktoren werden als Akklimatisierung bezeichnet. Die vorliegende Dissertation ist eine erste, systematische Untersuchung der Akklimatisierung einer Gründerpopulation beider afrikanischer Nashornarten nach Wiederansiedlung in einem bestimmten Gebiet in Namibia.

Die Untersuchung fand in einem 368 km^2 großen, vollständig umzäunten Gebiet statt, das sich in direkter Nachbarschaft zum Etosha Nationalpark (ENP) in Namibia befindet und in der Vergangenheit als kommerzielles Viehweideland genutzt wurde. Die Spitzmaulnashörner (n = 6) wurden über einen Zeitraum von zwei Jahren (März 2005–Februar 2007) untersucht. Der Untersuchungszeitraum der Breitmaulnashörner (n = 7) betrug acht Monate (Juni 2006-Februar 2007).

Obwohl das Untersuchungsgebiet in der Vergangenheit intensiv als kommerzielles Viehweideland genutzt wurde, belegt eine erste Habitateignungsstudie (auf der Basis eines Monitorings der Wirbeltierfauna, v. a. der Avifauna und mittelgroßer und großer Säugetiere) ein hohes Maß struktureller Komplexität des Gebietes, sowie dessen Eignung zur Wiederransiedlung beider Nashornarten.

Zur Beurteilung der Akklimatisierung der Nashörner wurden folgenden Parameter untersucht: i) Explorationsverhalten, ii) Entwicklung von Belaufsgebieten, Aktivitätszentren und sozialer Organisation, iii) Habitatnutzung, iv) Tagesaktivitätsmuster, v) Störungsverhalten gegenüber Beobachtern und vi) Konzentration von Glukokortikoidmetaboliten aus Kotproben.

Die Spitzmaulsnashörner wurden radiotelemetriert, und die Beschreibung der genutzten Habitate erfolgte auf der Basis einer vegetationskundlichen Transektstudie. Die Tiere nutzten die beiden vorhandenen geologischen Formationen des Untersuchungsgebietes: Dolomitfelsen mit waldartigem Habitattyp (dominierende Pflanzenarten: *Colophospermum mopane* und *Terminalia prunioides*) und verwitterte Dolomitbrekzie mit Strauchsavanne (dominierende Pflanzenarten: *Acacia reficiens* und *A. luederitzii*). Die Belaufsgebiete der meisten Individuen sind größer, als dies in der Literatur beschrieben ist. Die Explorations- und Habitatnutzungsmuster sowie die Größe der Belaufsgebiete und Aktivitätszentren sind durch eine hohe inter-individuelle Variabilität gekennzeichnet. Die Ergebnisse zeigen: i) alters- und geschlechtsabhängige Explorationsmuster, ii) saisonale Änderungen der Größe der Belaufsgebiete und Aktivitätszentren (größere Areale während der Trockenzeiten), iii) deutliche Veränderungen des Raumnutzungsverhaltens über den gesamten Beobachtungszeitraum und iv) saisonale Änderungen der sozialen Organisation. Die Untersuchung ist die erste Telemetriestudie zur Ermittlung von Belaufsgebieten umgesiedelter Spitzmaulnashörner.

Die Untersuchung der Tagesaktivität der Spitzmaulnashörner bestätigt ein bimodales Verlaufsmuster. Außerdem wurden saisonale Änderungen der Aktivitätsrhythmik festgestellt (höhere Aktivität während der Trockenzeit).

Die häufigste Reaktion der Spitzmaulnashörner gegenüber den Beobachtern war Aufmerksamkeit jedoch nicht sofortige Flucht. Insgesamt zeigten die Tiere ein eher interessiertes Störungsverhalten, Scheinangriffe waren äußerst selten. Während des zweiten Untersuchungsjahres erlaubten die Tiere kürzere Distanzen zwischen sich und den Beobachtern, was auf längerfristige Akklimatisierungsprozesse hindeutet. Sofortige Flucht wurde bei längeren Distanzen zwischen Beobachter und Nashorn ausgelöst als Bleibeverhalten.

Das Explorationsverhalten und die Belaufsgebietsentwicklung eines subadulten Breitmaulnashorns wurden mittels Radiotelemetrie untersucht. Zum Zeitpunkt der Ansiedlung des Tieres hatten die Spitzmaulnashörner bereits ihre Aktionsräume und soziale Organisation etabliert. Auffällig war, dass das Breitmaulnashorn andere Areale als die Spitzmaulnashörner nutzte. Aufgrund des kürzeren Untersuchungszeitraumes konnten keine saisonalen Änderungen des Raumnutzungsverhaltens aufgedeckt werden. Jedoch wurden auch hier temporäre Veränderungen der Raumnutzung festgestellt.

Die Messung von Glukokortikoidmetaboliten aus Kotproben erfolgte, um Erkenntnisse zur physiologischen Akklimatisierung zu gewinnen. Die Spitzmaulnashörner hatten im zweiten Untersuchungsjahr signifikant niedrigere Metabolitkonzentrationen, was auf längerfristige Akklimatisierungsprozesse hinweist. Die Metabolitkonzentrationen der Breitmaulnashörner zeigt keinen zeitlichen Trend, deckt sich aber mit den jeweiligen Umweltbedingungen (Größe des Areals, Vorhandensein von Artgenossen).

Die Ergebnisse vorliegender Dissertation liefern zuverlässige Daten zur Akklimatisierung einer Gründerpopulation beider afrikanischer Nashornarten nach Wiederansiedlung in einem Gebiet am Rande des ENP in Namibia, das in der Vergangenheit als Viehfarmland genutzt wurde. Insgesamt liefern diese Daten ein Model, das für zukünftige Studien zur Akklimatisierung wiedereangesiedelter Nashörner in Namibia und andernorts anwendbar ist. Die Ergebnisse vorliegender Dissertation können bei der Planung zukünftiger Schutzgebiete (Pufferzonen, Wildtierkorridore) am Rand des ENP in Namibia hilfreich sein.

ACKNOWLEDGEMENTS

The present work would have never been possible without the kind assistance of many competent persons. I am thoroughly grateful to all people and institutions that have supported me during the last years. Especially, I want to thank:

Niedersächsische Bingostiftung für Umwelt- und Entwicklungszusammenarbeit - for funding my stay in Namibia, which only became possible through an official research permit (for the monitoring of translocated black rhinos in the frame of the black-rhino custodianship) to Prof. Böer via the **Namibian Ministry of Environment and Tourism**.
Gesellschaft der Freunde der Tierärztlichen Hochschule Hannover, Mrs **Antje Rendigs -** for administration and settlement of finances.

Prof. Dr. Michael Böer – who has imparted on to me the invaluable topic of this thesis for his supervision, scientific advice, and sharing his valuable experience with me.
Prof. Dr. J. Keith Hodges – for his supervision, scientific advice, and providing the possibility to present and discuss the progress of my work within the seminars of his workgroup.

Dr. Joachim Schöne – for the establishment of rhino monitoring procedures, his valuable assistance with the field work, and providing info and training in the field.
Dr. Michael Heistermann – for helpful suggestions and discussions, and providing access and training to the enzymeimmunoassays used.
Dr. Dietmar Zinner – for his intellectual support, feedback, and providing access and training to the GIS software used.
Dr. Jens Birger and **Annegret Schönbrodt** – for providing access and training to the GIS software used.
PD Dr. habil. Karsten Wesche – for his kind assistance with revision of the statistical analysis of the vegetation data.
Pierre du Preez, **Birgit Kötting**, **Dr. Mark Jago** and **Dr. Reinhard Göltenboth** – for valuable information on rhino translocation, behaviour and management.
Birgit Möhring, **Jeanette Busch**, **Karl H. Busch** and **Andreas Wienecke –** for their friendly support and establishing the vital requirements during the field study period.
Leen de Koster, **Andrè Nel** and **Kiepie** and **Janni Burger** – for infrastructure, transport, and various other aspects of practical help throughout the field study period. I further thank the latter two for their valuable rain measurements.
Issaskar Haraeb - for continuous support in the field work.
Andrea Heistermann – for her valuable assistance with the laboratory work.
Dr. **Niels Mensing**, **Henning Petersen** and **Dimitri Widmer** – for their valuable assistance with bird and reptile species identification in the field.
Dr. Jay F. Bolin – for useful advice regarding English wording.
Dr. Stephan Buch and **Jose H. Grau** – for friendship and fruitful discussions during the writing phase.

Prof. Dr. Ulrich Zeller – for his helpful suggestions and advice, and providing the general conditions that enabled me to write up this thesis.

Finally, I thank the entire staff of the **Reproductive Biology Unit** at the **German Primate Centre** in Göttingen and the **Chair of Systematic Zoology** at the **Museum für Naturkunde** in Berlin for the nice atmosphere and their support.

My special thanks go to my family, especially **Ria** and **Theodor Uhlemann** for their loving care.