Biology and management affecting the decline of a black rhinoceros, *Diceros bicornis minor* (Linnaeus, 1758), population in Ndumo Game Reserve, KwaZulu-Natal, South Africa

By

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Submitted in partial fulfilment of the requirements for the degree Magister Scientiae in Wildlife Management

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Co supervisors: Prof. B.J. van Rensburg & Dr. W.S. Matthews

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I, Rickert van der Westhuizen, declare that the dissertation, which I hereby submit for the degree Magister Scientiae (Wildlife Management) at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

2011-07-23

Signature Date

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Summary

Black rhinoceros (*Diceros bicornis*) are classified as critically endangered on the IUCN red data list (IUCN 2010). In Ndumo Game Reserve in northern KwaZulu-Natal, South Africa, a black rhino population has seen a decline in numbers from nearly 50 rhino in 1988 to only eight in 2006. This study aimed to determine the factors or events responsible for the decline in black rhino numbers in Ndumo.

The first part of this study focuses on the historical data and literature on Ndumo's black rhino population. Specifically, I examined historical data regarding Ndumo's black rhino population estimates, recruitment patterns, mortality rates, number of removals, introductions, densities and other large herbivore population estimates. Results suggest that a combination of high removals due to inaccurate estimates and competition from other herbivore populations, specifically nyala (*Nyala angasi*) and impala (*Aepyceros melampus*), played a role in this population's decline. Also, a change in the Usuthu River course negatively affected the population's social structure, movement patterns and recruitment success. The introduction of five black rhino from Hluhluwe-iMfolozi Park in 2008 seems to have been a success, and should increase reproductive success.

Secondly, we determined the amount of browse currently (2008) available to black rhino in Ndumo, the proportional species composition of this browse and its suitability for black rhino. The results show that browse availability is fairly high (average of 17.8%) in Ndumo but the suitability is low. *Croton menyhartii* is the single biggest contributor to browse availability in Ndumo, contributing 25% of all available browse. This plant species is unfortunately rejected by black rhino and most other browsers. Furthermore, two invasive alien plant species (*Chromolaena odorata* and *Lantana camara*) are amongst the four most abundant plant species in Ndumo and are also rejected by black rhino. An effective alien plant clearing programme is needed to eradicate invasive alien species in Ndumo, which will help alleviate the poor browse conditions.

A population viability analysis (PVA) was done during the last part of the study to predict the possibility of extinction or survival of this black rhino population in future. The VORTEX model was used in this study. Data and trends as actually observed in Ndumo since 1988 was used as the first simulation's input parameters, to test whether the model will predict a similar decline in black rhino numbers as observed in Ndumo. Furthermore, sensitivity analyses with different input parameters were done to test the probability of extinction or survival under all possible circumstances. The model predicted a high probability of survival, even with most of the sensitivity analyses**,** suggesting that small populations of less than 50 individuals are viable if managed correctly. Parameters that impacted negatively on the growth rate of this population were density dependant breeding, a low recruitment rate and a decline in carrying capacity.

Keywords: Black rhino, population estimates, decline, browse availability and suitability, VORTEX model.

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Acknowledgements

I would firstly like to thank Ezemvelo KZN (EKZNW) Wildlife for granting me the opportunity to work on this project. Wayne Matthews needs a special mention as he was the person who asked me if I was interested in doing this project, thereby starting my professional career in conservation.

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CHAPTER 1: General introduction

Introduction

Black rhinoceros (*Diceros bicornis*) are classified as critically endangered on the IUCN red data list (IUCN 2010). Yet, only 50 years ago, in the 1960's, it was estimated that there were over 100 000 black rhino roaming Africa (Emslie & Brooks 1999). From 1970 to 1987, poaching caused black rhino numbers to plummet by 95% (Muya & Oguge 2000). In 2001 there were *c.* 1100 individuals in South Africa (IUCN 2006). Most rhino are now in fenced off sanctuaries where they can be better protected and monitored (Tatman *et al.* 2000). Therefore a metapopulation conservation plan (Brooks *et al.* 2002) was drawn up for black rhino, which prescribes that 5 - 8% of a population at or around carrying capacity should be removed annually, or every second or third year in the case of smaller populations. This is done to prevent adverse genetic and demographic effects (Foose *et al.* 1993), to establish new populations elsewhere, thus creating genetic links (Brett 1993, Emslie & Brooks 1999) and to keep the source population under carrying capacity, thereby preventing any density dependent mortalities and keeping the population growth rate from stagnating.

Even though black rhino are currently well protected in sanctuaries, some populations have shown declines caused by factors and events other than poaching. In the Hluhluwe-iMfolozi Park, South Africa, the black rhino population has declined due to negative habitat changes and the resulting reduction in carrying capacity (Emslie 1999; Reid *et al.* 2007). In the Masai Mara National Reserve, Kenya, a decline was attributed to three possible causes: Natural deaths, dispersal or an increased reclusiveness in some individuals (Walpole *et al.* 2001). In order to effectively conserve black rhino as one metapopulation, the cause of declines in small and isolated populations need to be thoroughly investigated and mitigation measures applied. Several key and important reserves are recognized by the rhino conservation action plan (Emslie & Brooks 1999), with Ndumo Game Reserve in KwaZulu-Natal listed as an important population. This population has however seen a drastic decline in black rhino numbers.

NATURE OF THE DECLINE IN NDUMO AND OBJECTIVES OF THIS STUDY

Sixteen black rhino from Mkuzi, Hluhluwe and Umfolozi Game Reserves were introduced into Ndumo between 1962 and 1970 (Hitchins 1984). By 1988, the population had reached a maximum of 47 individuals, but thereafter population numbers gradually declined until only eight individuals were left in 2006. Considerable concern existed over this decline, especially as the population seemed to be flourishing in the late 1980's. As this decline was not poaching related, as one would normally first suspect, the cause of this decline was highly debated. Since April 2003 numerous meetings and workshops took place which attempted to identify circumstances which may have led to the decline. It has even been suggested that the rhino be removed from Ndumo and re-established elsewhere, but the KZN Rhino Group resolved at a meeting in November 2005 that "the black rhino population in Ndumo Game Reserve remain *in situ*, as they have the proven potential of contributing to the National and Provincial strategies, to maximize metapopulation growth". The main objectives of Ezemvelo KZN Wildlife's (EKZNW) strategy for the management of black rhino are to establish and maintain a viable metapopulation of black rhino in KwaZulu-Natal and to allow populations to achieve densities that allow ecological processes (such as a healthy recruitment rate) to prevail (Brooks *et al*. 2002). Understanding the factors that lead to the decline in Ndumo is of cardinal importance to prevent further declines elsewhere in the metapopulation.

Several hypotheses explaining the decline in black rhino numbers in Ndumo exist, and are summarized in Adcock (2004). These include: Increased competition for food from high nyala (*Nyala angasi*) numbers, a decline in suitable browse, a decline in areas available to black rhino due to flooding and changes in the Usuthu River course, a possible increase in ticks and tick-borne diseases, loss of rhino through the open Mozambique border, fencing off of important areas of browse for several years and social disruptions caused by removals. Except for a previous survey on the browse conditions in Ndumo (Adcock 2004), none of the above mentioned hypotheses have been tested up to date. This study was started to identify possible factors and events responsible for the decline.

STUDY AREA

Ndumo Game Reserve (Fig. 1.1) is a small (10 117 ha) reserve established in 1924 as a hippopotamus (*Hippopotamus amphibihius*) sanctuary (EKZNW 2007). The reserve is made up of tropical bush and Lowveld savanna which includes 10 main vegetation formations (Pooley 1978), namely: Riverine forest, Floodplain, Fever tree (*Acacia xanthoploea*) forest, "Pan-edge" communities, Sand forest, *Acacia tortilis* woodland, Mahemane thicket, Deciduous broad-leaf woodland, *Acacia nigrescens* woodland and Open woodland. It is situated at the confluence between the Usuthu and Pongola Rivers on the Mozambique coastal plain (26º 52'S and 32º 15'E). In summer the climate is hot and humid, and warm and dry in winter, with a mean annual rainfall of 630 mm.

Approximately 4% of the reserve is open water, pans and rivers (Conway & Goodman 1989). Ndumo was proclaimed as a RAMSAR wetlands site in 1997. The reserve is fenced in the west, south and east, but the Usuthu River forms the northern boundary between South Africa and Mozambique and is not fenced.

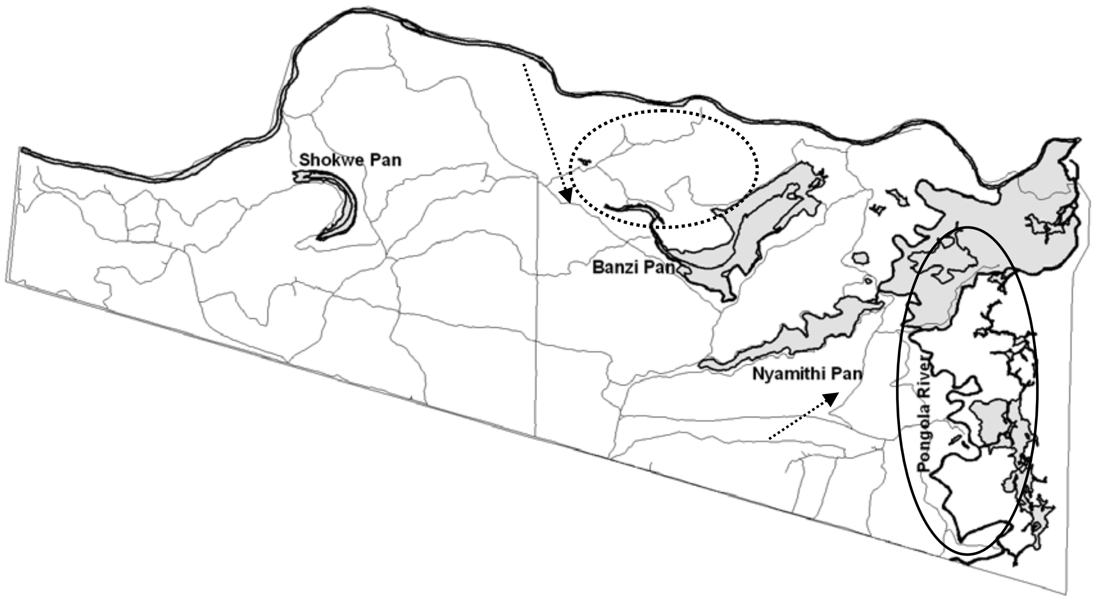

Figure 1.1 Map of Ndumo Game Reserve. Dashed arrows indicate the new Usuthu River course, the dashed circle illustrates the 'island' where a large portion of the black rhino

population lives and the solid circle indicate the area east of the Pongola River where 10 black rhino were removed in 1989.

CHAPTER CONTENTS

This thesis contains three data chapters, chapters 2 – 4, which have been prepared for submission to, or publication in, a range of scientific journals. As a result styles may vary between chapters in the thesis and overlap may occur to secure publication entities. Chapter 2 has been submitted for publication in the journal *Koedoe*.

Chapter 2: Factors responsible for the decline in a managed black rhinoceros (*Diceros bicornis minor*) population

The first data chapter examines the history of this black rhino population, more specifically, information on black rhino population estimates, recruitment patterns, mortality rates, number of removals, introductions, densities and other large herbivore population estimates. Results suggest that a combination of factors including competition with nyala and impala (*Aepyceros melampus*), a change in the Usuthu River course and too many removals at the wrong time impacted negatively on the black rhino population.

Chapter 3: Browse availability and the impact of invasive plants on browse quality in Ndumo Game Reserve as related to black rhino (*Diceros bicornis minor*)

The amount of browse currently (2008) available to black rhino in Ndumo, the proportional species composition of this browse and its suitability for black rhino was determined following the method described in Adcock (2006). Results show that browse availability is high in Ndumo, but the abundance of invasive alien plants and other low quality species in the reserve resulted in low browse suitability.

Chapter 4: Using a population viability analysis to predict the future of Ndumo's black rhino (*Diceros bicornis minor*) population

A population viability analysis (PVA), using the VORTEX model, was done during the last part of the study to predict the possibility of extinction or survival of this black rhino population in future. The model predicted a high probability of survival, even with most of the sensitivity analyses.

References

Adcock, K. (2004). Report on the findings of a survey of browse conditions for black rhino at Ndumu Game Reserve, Kwazulu-Natal, 27–31 April 2004, Unpublished.

Brett, R. (1993). Conservation strategies and management plan for black rhinoceros (*Diceros bicornis*) in Kenya. Kenya Wildlife Service, Unpublished Report, Kenya.

Brooks, M., Conway, A., Goodman, P., Balfour, D., Rushworth, I., Potter, D., Cooke, M. & Hartley, P. (2002). Ezemvelo KZN Wildlife Strategy for the Management of Black Rhino in KwaZulu-Natal, Ezemvelo KZN Wildlife, Pietermaritzburg.

Emslie, R.H. (1999). The feeding ecology of the black rhinoceros (*Diceros bicornis minor*) in Hluhluwe-Umfolozi Park, with special reference to the probable causes of the Hluhluwe population crash. Unpublished Ph.D. Thesis, University of Stellenbosch.

Emslie, R. & Brooks, M. (1999). African Rhino. Status and Conservation Action Plan. IUCN/SSC African Rhino Specialist Group, Gland, Switzerland.

EKZNW (2007). Integrated Management Plan: Ndumo Game Reserve, South Africa. Ezemvelo KZN Wildlife, Pietermaritzburg.

Foose, T.J., Lacy, R.C., Brett, R. & Seal, U.S. (1993). Kenya Black Rhino Metapopulation Workshop. Apple Valley, MN: IUCN/SSC Captive Breeding Specialist Group (CBSG).

IUCN, (2010). IUCN Red List of Threatened Species. Version 2010.1. <www.iucnredlist.org>. Downloaded on 18 March 2010.

Muya, S.M. & Oguge, N.O. (2000). Effects of browse availability and quality on black rhino (*Dicernos bicornis michaeli* Groves 1967) diet in Nairobi National Park, Kenya. *African Journal of Ecology*. **38**: 62-71.

Reid, C., Slotow, R., Howison, O. & Balfour, D. (2007). Habitat changes reduce the carrying capacity of the Hluhluwe-Umfolozi Park, South Africa, for Critically Endangered black rhinoceros *Diceros bicornis*. *Oryx*. **41**: 247 – 254.

Tatman, S.C., Stevens-Wood, B. & Smith, V.B.T. (2000). Ranging behavior and habitat usage in black rhinoceros, *Diceros bicornis*, in a Kenyan sanctuary. *African Journal of Ecology*. **38**: 163-172.

CHAPTER 2: Factors responsible for the decline in a managed black rhinoceros (*Diceros bicornis minor*) population

ABSTRACT

The black rhinoceros (*Diceros bicornis minor*) population in Ndumo Game Reserve has declined by 80% the past 14 years from 1994 to 2008, but the reason for this decline is unknown. The history of the population was examined in detail to determine factors or events that could have contributed to the decline. Data regarding population estimates, recruitment patterns, mortality rates, removal rates, introductions, rhino densities and other large herbivore numbers were collected from Ndumo's archives. The historical data suggest that a combination of high removals due to inaccurate estimates and competition from other herbivore populations played a role in this population's decline. A change in the Usuthu River course also had detrimental effects on the population's social structures, movement patterns and recruitment success. The recent introduction of five black rhino from Hluhluwe-iMfolozi Park seems to have been a success, and is likely to increase reproductive rate. I show how continued intensive monitoring of small populations of black rhino is necessary to effectively manage them; to not only prevent the population from going extinct but to maintain a healthy population growth rate and contributing towards the metapopulation through translocations.

Keywords: Accurate population estimates; black rhino; competition; intensive monitoring; population decline; removals

INTRODUCTION

Black rhinoceros (*Diceros bicornis*) are classified as critically endangered on the IUCN red data list (IUCN 2010). Four ecotypes of African black rhinos are currently recognized (Brooks & Adcock 1997), namely *Diceros bicornis minor* (southern central Africa), *Diceros bicornis bicornis* (south-western Africa), *Diceros bcornis michaeli* (eastern Africa) and *Diceros bicornis longipes* (central western Africa). *Diceros bicornis bicornis* is listed as vulnerable whereas the other three ecotypes are listed as critically endangered

(IUCN 2010). From 1970 to 1980, black rhino numbers in Africa declined by 95% due to poaching (Emslie & Brooks 1999; Muya & Oguge 2000). In 2001 there were less than 3000 black rhino individuals left across its range, and these animals were distributed in small and isolated populations across a few countries (Emslie & Brooks 1999; Harley *et al*. 2005) with *c*. 1100 individuals in South Africa (IUCN 2006). Consequently, a managed metapopulation approach was recommended for black rhinos, whereby translocations of individuals would take place to prevent adverse genetic and demographic effects (Foose *et al*. 1993). A metapopulation is a number of discrete sub populations of the same species, viewed as one big population, with animals being moved between them (Emslie & Brooks 1999). Metapopulation management decreases the effect of density-related declines, as game reserves have finite borders that limit the dispersal of rhino into new areas, thereby limiting population growth.

The principle of metapopulation management was further supported by the notion that smaller populations are more susceptible to extinction than larger ones as a result of stochastic events (Gilpin & Soule 1986), and the loss of genetic variation (Newman & Pilson 1997). Berger (1990) found that in 122 populations of bighorn sheep (*Ovis canadensis*) 100% of all populations with fewer than 50 animals went extinct within 50 years. The process of extinction and adaptation both scale with the generation time of a population (Fisher 1930; Leigh 1981), therefore, 50 years might not be a meaningful biological time frame for organisms with long generation times (Armbruster *et al.* 1999), such as black rhino in this particular study. In addition, random genetic drift will result in small populations losing genetic variation. This loss in genetic variation can furthermore result in a decrease in adaptive fitness (Charlesworth & Charlesworth 1987; Westemeier *et al.* 1998).

In spite of recent successful relocations and an increase in numbers within the metapopulation, a decline in a black rhino population in Ndumo Game Reserve in northern KwaZulu-Natal (KZN), South Africa, has been noted. Sixteen black rhinos were reintroduced into Ndumo between 1962 and 1970 (Hitchins 1984). This population appeared to flourish, as records indicated that black rhino numbers grew close to 50 animals in 1988 (Thornhill 1989). However, since 1994 the population gradually declined to a low of eight individuals in 2006, before five more rhinos were re-introduced into

Ndumo in 2008 to increase the population total to 13 individuals. Several hypotheses were proposed by Adcock (2004) to explain this rapid decline and can be summarised as (1) management induced through social disruptions brought about by removal of rhino over time, (2) competition with extremely high nyala (*Nyala angasi*) numbers and (3) natural habitat change and the disruptions brought about by the change in the Usuthu River course. However, none of these hypotheses have been tested and a long-term intervention strategy is therefore needed. These data will also serve to meet the objectives of a recovery plan drawn up by the KZN Rhino Group in 2005 (A.J. Conway pers. comm.). The objectives of the recovery plan include: determining the exact black rhino population size, investigating the biomass of other herbivore species and their possible implications on the black rhino population, reviewing current and historical monitoring techniques and defining possible management interventions. The main aim of the present study was to examine the history of Ndumo's black rhino population in order to identify factors or events that could have led to the decline. These events will then be categorised under the three main hypotheses to determine which is possibly responsible for the decline in rhino numbers.

METHODS

Study area

Ndumo Game Reserve is a small (10 117 ha) reserve established in 1924 as a hippopotamus (*Hippopotamus amphibihius*) sanctuary (EKZNW 2007). The reserve is made up of tropical bush and Lowveld savanna which includes 10 main vegetation formations (Pooley 1978), namely: Riverine forest, Floodplain, Fever tree (*Acacia xanthoploea*) forest, "Pan-edge" communities, Sand forest, *Acacia tortilis* woodland, Mahemane thicket, Deciduous broad-leaf woodland, *Acacia nigrescens* woodland and Open woodland. It is situated at the confluence between the Usuthu and Pongola Rivers on the Mozambique coastal plain (26º 52'S and 32º 15'E). In summer the climate is hot and humid, and warm and dry in winter, with a mean annual rainfall of 630 mm. Approximately 4% of the reserve is open water, pans and rivers (Conway & Goodman 1989). Ndumo was proclaimed as a RAMSAR wetlands site in 1997. The reserve is fenced in the west, south and east, but the Usuthu River forms the northern boundary between South Africa and Mozambique and is not fenced.

Historical information review

A review of all historical information was carried out in order to address the hypotheses related to management induced actions and competition as potential explanations for the declining black rhino population in Ndumo. Specifically, I analyzed data concerning Ndumo's black rhino population estimates, recruitment patterns, mortality rates, number of removals, introductions, densities and other large herbivore population estimates. Even though any source of information available was examined, the literature mostly consisted of interim rhino monitoring reports compiled by previous rhino monitors and reserve managers, archived at Ndumo. Black rhino monitoring was conducted by reserve management. In addition, several black rhino monitors were employed on a regular basis since 1990, who collected detailed information on the population status and compiled black rhino monitoring reports. These reports were used to derive the historical black rhino population estimates, their recruitment patterns, mortality rates, number of removals and introductions. Information captured and stored electronically by Ezemvelo KZN Wildlife's scientific staff, as well as literature on Ndumo's black rhino population (e.g. Conway & Goodman 1989; Adcock 2004) were also incorporated into the analysis. Some discrepancies between estimates were however noted, which led to the belief that some previous population estimates were inaccurate. For example, an anonymous report estimated the black rhino population to be 30 individuals in 1995, whereas a rhino monitoring report and a KZN Rhino Group meeting memo estimate was 26 individuals. Such discrepancies were thoroughly investigated to ensure that the most accurate data was used during analyses.

Data on other herbivore population estimates, more specifically nyala and impala (*Aepyceros melampus*) were collected from Ndumo's archives, and these estimates are based on line transects using the Distance Sampling technique (Buckland *et al.* 2003). There are eight permanently marked transects in Ndumo, ranging from 5 to 8 km long, running through all the major vegetation types in the reserve. Sampling usually takes place in the dry season during June or July when visibility in thick bush is at its highest.

Transects are walked by a field ranger and two observers, who record species, radial distance, transect bearing and species bearing once an animal is sighted. A range finder and compass is used to determine distances and bearing. Nyala and impala take a minimum of 40% and 13% of their diet as browse respectively (Hancock 1978) and browse in a similar height category (0 – 2 m) to black rhino (Tello & Van Gelder 1975; Adcock *et al*. 2008). Furthermore, several studies (East 1984; Fritz & Duncan 1994; Fritz *et al.* 2002; Adcock *et al.* 2008) imply that while resources are partitioned among species within a feeding type (e.g. browsers); competition must play some role in determining the relative metabolic biomass densities. Thus, these two species are expected to compete with black rhino for browse. Nyala and impala are also the two most abundant species in Ndumo with relatively high population densities (0.159 and 0.110 per ha respectively), therefore only these two species' population estimates were examined.

In order to further quantify the potential impact of these two competing browser species (nyala and impala) on the black rhino's food sources, the metabolic biomass of competing browsers was converted to "rhino equivalent" biomass as a function of the annual population estimate of each species (see more details on the method in Adcock *et al*. 2008). This metabolic biomass conversion was therefore calculated for nyala, impala and black rhino for each year from 1985 to 2008 (see Appendix 1). First, species body mass values were taken from Adcock *et al.* (2008). According to Owen-Smith (1993), in general 66% of the average between adult male and female mass is used as the average species mass. Second, the metabolic mass for each species was calculated as the mean body mass$^{0.75}$. Third, the proportion of a species' diet that is made up of browse occurring in the rhino feeding layer (0 – 2 m) was estimated from Adcock *et al*. (2008). Fourth, the competing browser metabolic mass was expressed as a function of black rhino metabolic mass and then multiplied by the proportion of browse occurring in the rhino feeding layer to convert to black rhino equivalent biomass. Fifth, the black rhino equivalent biomass (black rhino scores a 1.00 whilst impala and nyala score 0.028 and 0.082 respectively following the calculations made by Adcock *et al*. (2008)) was then multiplied by the population estimate of each species in a given year to determine the total rhino equivalent biomass of each species for the year in question.

To address the hypothesis dealing with natural habitat change, the potential impact related to the Usuthu River course diversion on Ndumo's black rhino population was examined. During extensive flooding in 2000, the Usuthu River, which forms the northern boundary between South Africa and Mozambique, changed course (illustrated with dashed arrows in Fig. 1.1) and flowed south from its original course along a narrow channel into Banzi Pan. The river exits Banzi Pan in the east where it flows north-east towards the original course. Before the 2008 introductions six of the eight remaining black rhinos resided in the area north of the river (dashed circle in Fig. 1.1), which is in effect an 'island' cut off from the rest of the reserve, as animals cannot cross the river during the rainy season. During the dry season when river levels are low enough animals are able to cross into the main part of the reserve (pers. obs.). Animals are however able to cross freely into Mozambique at any time of the year, as the northern boundary is not fenced and the old river course is mostly dry. This 'island' is approximately 1000 ha in size and is made up primarily of Floodplains, a small thicket of Mahemane bush and Riverine forest. During October 2007, the Department of Forestry and Water Affairs blocked the channel where the river diverted in order to try and restore some water flow back onto the original Usuthu River course. This effort however was not successful with the blockage being swept away within a few months causing the water flow to once again divert.

In addition, past and present (1989 to 2008) black rhino densities (population estimate divided by reserve size) were examined. The only formal black rhino carrying capacity (*K*) for Ndumo was estimated in 2003 (Adcock 2004) following the method of Adcock (2000). Environmental factors and habitat features such as browse availability and suitability across different vegetation types and their proportional areas, total annual rainfall, average monthly distribution of rainfall, underlying substrate (soil/rock) fertility, and the average minimum July temperature were taken into account when calculating carrying capacity.

RESULTS

Population estimates and removals

After reaching a maximum of 47 individuals in 1988, the black rhino population declined gradually over *c.* 14 years from 1994 (Fig. 2.1). Although it was recommended to remove only two animals per annum (Conway & Goodman 1989), five males and five females were relocated to Kruger National Park in 1989 (Table 2.1), which led to a significant decrease in numbers (Fig. 2.1). All 10 rhinos were captured east of the Pongola River (solid circle in Fig. 1.1). From 1990 to 1993 the population recovered from this loss and increased to 43 individuals (Fig. 2.1). A second group of 10 black rhinos was relocated from Ndumo to Tembe Elephant Park in 1994. Again, five males and five females were relocated. Six animals were removed from the Manganeni area (now north of the Usuthu River) and four animals from the main part of the reserve. The population estimate for 1994 before the removals was 36 animals, but the sex ratio and age structure of the population at that time were unknown. After this second set of removals in 1994 the population gradually declined to eight individuals in 2006 (Fig. 2.1; two males and six females).

The recommended removals for 2002 and 2003 were four and two animals respectively. Only two males in 2002 and one female in 2003 were successfully captured and removed. Only after the female was removed in 2003, was it discovered that she was *c.* 14 months pregnant. The increase in recorded numbers from 2005 to 2006 was not due to any calves being added to the population but rather the discovery of three previously unknown individuals.

One calf was born in 2007 and an additional five rhino from Hluhluwe-iMfolozi Park were released into Ndumo in December 2008, increasing the population estimate from nine to 14 individuals.

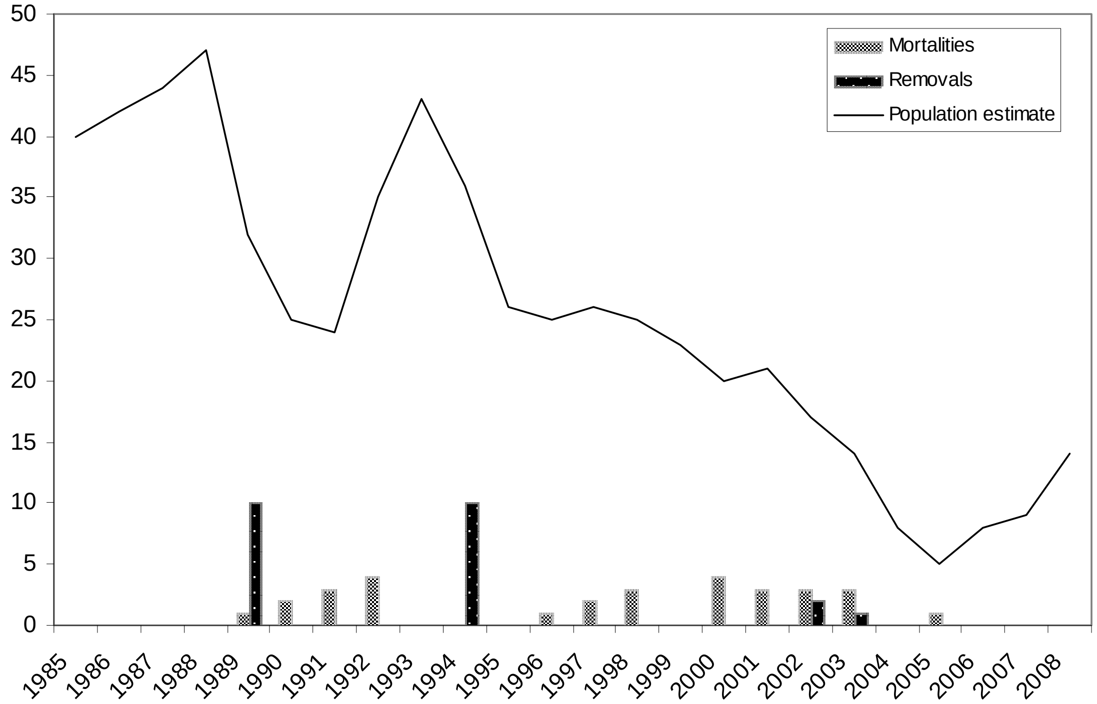

Figure 2.1 Black rhino population estimates, mortalities and removals for Ndumo Game Reserve from 1983 to 2008.

Fifteen of the 23 (12 male and 11 female) rhinos removed from Ndumo were adults (F-class) (Table 2.1). The youngest rhinos removed were two C-class calves in 1989. Only one D-class calf was removed in 1994, thereafter only E and F-class animals were removed. Juveniles (A or B-class) were not removed due to the high mortality rates and low success rate of releasing them into new conservation areas (D. Cooper pers. comm.; Hearne & Swart 1991; Linklater *et al.* 2011). In addition, very old rhinos are not as frequently relocated, as there is a reluctance to take them due to the high risk of death during transit and the possibility of them being non-productive (W. Matthews pers. comm.).

Table 2.1 Sex and age classes of black rhino relocated from Ndumo Game Reserve between 1989 and 2003.

Sex	A-class (0-3 months)	B-class (4-12 months)	C-class (1-2 years)	D-class (2-3.5 years)	E-class (3.5-6.9 years)	F-class (7 years and older)
Males 1989			1	1		3
Females 1989			1	1		3
Males 1994				1		4
Females 1994					2	3
Males 2002					1	1
Females 2003						1

Mortalities and losses

There were 30 black rhino mortalities between 1989 and 2006 (Figs. 2.1 & 2.2). The cause of death could be determined for six animals only; five due to fighting wounds and one poaching incident. The cause of death of the other 24 rhinos could not be determined, and about a third (37%) of all carcasses found were so decomposed that the animals could not be identified or sexed. Seven adult males and five adult female mortalities were recorded (Fig. 2.2). There was an increase in juvenile mortalities from 2000 to 2006, with six (42.9%) of the 14 reported deaths being juveniles. As only one confirmed poaching incident was reported during the study, poaching was not considered to have had any significant influence on the population decline. Approximately seven rhinos are known to have crossed into Mozambique during the mid 1990’s and were unlikely to have crossed back because of the high probability of them being poached across the border (F. Myburgh pers. comm.). There were however no signs that rhino have crossed this boundary into Mozambique during the study period (pers. obs.).

Recruitment patterns

Conway & Goodman (1989) recorded recruitment to be in the region of 10% per annum in Ndumo. Based on sightings that were made in Ndumo, the mean percentage of black rhino females calving between 1995 and 2001 was 13% (Adcock 2004). Blood tests analysed in September 2006 (Onderstepoort 2006) revealed that two F- class female rhinos were pregnant. One of those females had a deformed udder and the calf was not sighted again after birth. The other calf was born between July and September 2007 and seems to be doing relatively well (pers. obs.).

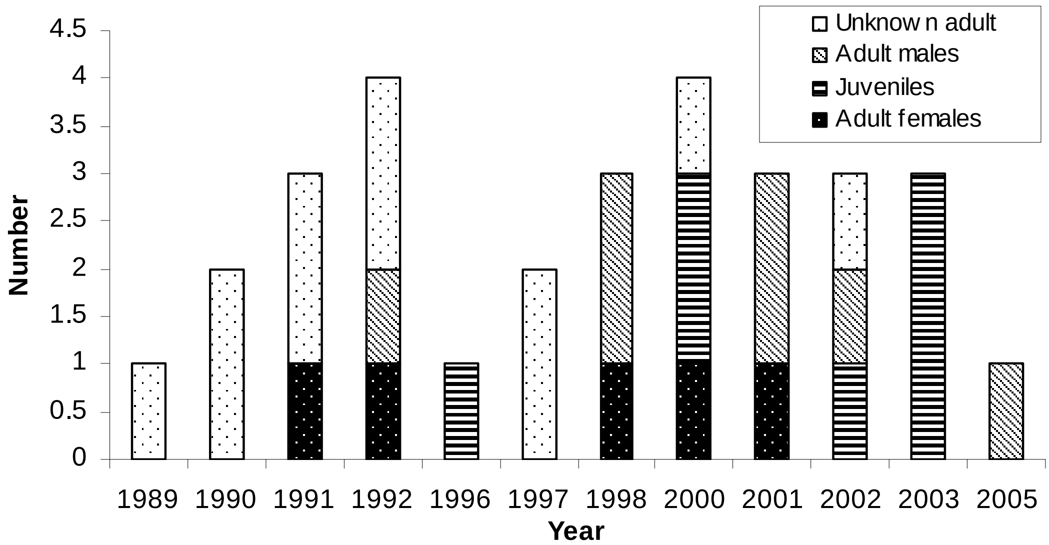

Figure 2.2 Sex and age ratio of recorded black rhino mortalities in Ndumo Game Reserve from 1988 to 2005.

Introductions

Before the commencement of this study, only one sub-adult male black rhino was introduced into Ndumo in September 1998 from Ithala Game Reserve. This animal broke through the park's fences shortly after introduction (P. Ruinard pers. comm.) and was removed from Ndumo. At the end of 2008, after the preliminary results of this study were presented to Ezemvelo KZN Wildlife, an additional five rhinos were re-introduced into Ndumo in an attempt to increase population numbers and reproductive success. Three adult females and two adult males from Hluhluwe-iMfolozi Park were released during December 2008.

Natural habitat change and densities

The population was at its maximum density of 0.38 individuals per km^2 in 1988 (Conway & Goodman 1989). Certain areas within the reserve, namely the area east of the Pongola River (Fig. 1.1), had a higher density (1.64 rhino per km^2) than that of the reserve average. The 10 rhinos relocated in 1989 all came from this area east of the Pongola River and it has since then mostly been devoid of any black rhino (F. Myburgh pers. comm.). In 2007 the mean density for Ndumo was 0.08 rhino per km^2, which was lower than the mean density in 1988. The density for two sections, south and north of the Usuthu River was also calculated. South of the river on the main part of the reserve the density was 0.02 rhino per km^2 before the introductions in 2008, and 0.07 rhino per km^2 after. The section north of the river's density is 0.6 rhino km^2.

No formal carrying capacity (*K*) estimate of Ndumo's black rhino population before 2003 was found in the records. However, Conway & Goodman (1989) found that with the population at 42 individuals, densities and home range sizes indicated a habitat close to optimum. From this I derive that *K* was between 40 and 50 rhino (maximum of 0.4 per km^2) at that time. *K* was estimated to be 11 rhino (0.13 per km^2) for Ndumo in 2003, two rhino (0.2 per km^2) in the area north of the Usuthu River and 9 rhino (0.12 per km^2) in the remainder of the reserve (Adcock 2004). The actual number of rhino in the area north of the Usuthu River is however much higher than the estimated *K*-value with a minimum of six animals (0.6 per km^2) living there for a number of years.

Nyala and impala population trends

Ndumo has had a history of high nyala numbers (Fig. 2.3), with estimates reaching close to 7000 in 1992. From 2005 to 2008 the nyala population numbers have declined from approximately 2500 to *c.* 1800 animals (Fig. 2.3). Impala numbers are lower than nyala numbers, but show a steady increase starting in the early 1990's, reaching approximately 3000 in 2000. After 2002 the impala population drastically declined, but showed an increase again in 2004, and has been stable at approximately 1400 animals since then (Fig. 2.3).

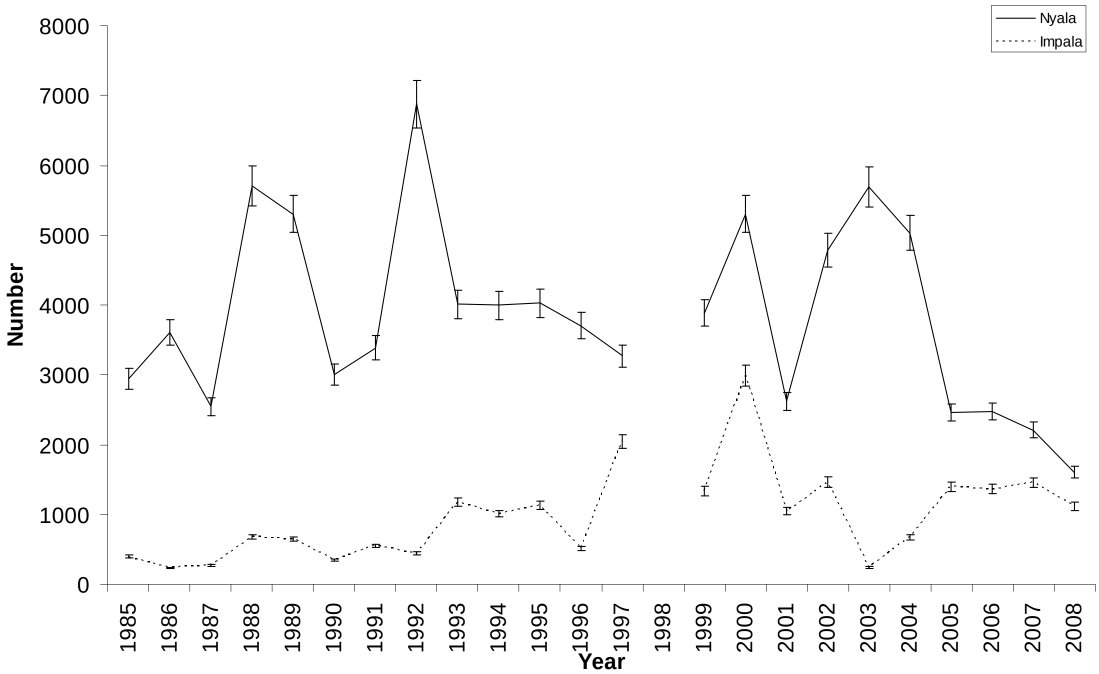

Figure 2.3 Population estimates showing 95% confidence intervals of nyala & impala in Ndumo Game Reserve from 1985 to 2008. There are no estimates for 1998.

Black rhino equivalent biomass

The total black rhino equivalent biomass of nyala, impala and black rhino from 1985 to 2008, as calculated according to the method by Adcock *et al*. (2008), is illustrated in Fig. 2.4. It is clear that in earlier years, before 1995, black rhino contributed a much larger proportion of browser biomass compared to more recent years (after 2000). For example, in 1987 black rhino contributed 17% of the total biomass of nyala, impala and black rhino compared to only 3% in 2007 (Fig. 2.4). The introduction of five black rhino in 2008 increased the proportion of biomass contributed by black rhino from 3% in 2007 to 8% in 2008. Parallel to the black rhino decline from 1985 to 2007, the impala population's biomass increased from 4% in 1988 to 15% in 2007. The total biomass of all three species combined is currently the lowest it has ever been since 1985.

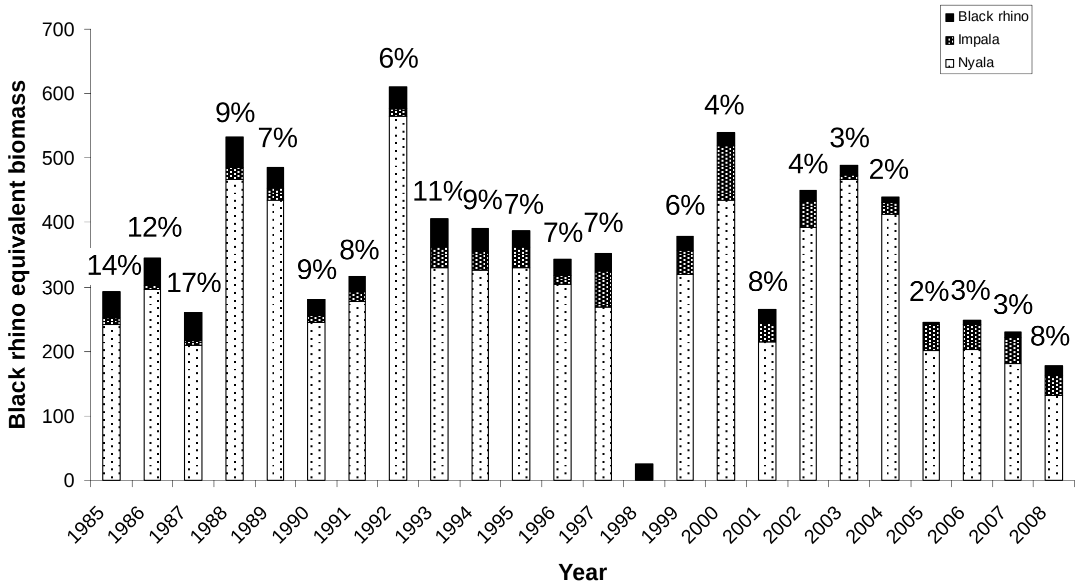

Figure 2.4 Black rhino equivalent biomass contribution by nyala, impala and black rhino in Ndumo Game Reserve between 1985 and 2008. No nyala or impala estimates are available for 1998. The percentage values given at the top of each bar represents the percentage or proportion of biomass contributed by black rhino in relation to the total biomass of black rhino, nyala and impala for that year.

DISCUSSION

Too many removals at the wrong time, competition from nyalas and impalas, the change in the Usuthu River course, a low recruitment rate and high mortality rate come to the fore as being instrumental in this black rhino population's decline. Metapopulation management requires that animals be continually removed to keep the population in a reproductive state, and that introductions from other populations be made to improve or maintain genetic diversity (Brooks & Adcock 1997). Brooks & Adcock (1997) proposed that "each population of black rhino should be managed at its maximum productive carrying capacity (MPCC), in other words at 75% of the estimated ecological carrying capacity." The social behaviour of black rhino should however be kept in mind when removing animals from a population (Adcock *et al*. 2001; Reid *et al*. 2007). Small populations in small conservation areas such as Ndumo will however be more sensitive to removals and introductions compared to larger reserves such as Kruger National Park.

The amount of space available to establish new home ranges is limited in smaller reserves, which can lead to fighting and a higher mortality rate. The mating success in smaller reserves will be lower as there are fewer females to mate with in smaller populations, and the availability of suitable browse will be less in smaller reserves than in larger ones where rhino can travel greater distances in search of food.

Conway & Goodman (1989) proposed that an average of two animals per annum should be removed from Ndumo, as their calculations of population increase could support these removals. However, large numbers of rhino were removed twice from the population (10 in 1989 and 10 in 1994). Also, the removal made in 1994 was done without detailed knowledge of the population's size and structure. The recommended removals for 2002 and 2003 (four and two respectively) were in accordance with Ezemvelo KZN Wildlife's strategy for the management of black rhino which came into effect in 2002 (Brooks *et al*. 2002). This strategy prescribes that 5% − 8% of a population has to be removed annually, or every second or third year in the case of smaller populations. Ndumo's black rhino population estimate for 2002 in this document was 25 animals. However, the recommended number of four animals for offtake amounts to 16% of the population. In addition, the recommended removal of two animals in 2003 amounts to 14% of the population at that time. When the historical records on Ndumo's black rhino population estimates were examined during this study, it was found to be inconsistent, as several reports gave differing estimates for the same years. There is thus a high likelihood that some of the estimates on which removal decisions were based were not only inaccurate, but also overestimating the actual black rhino population for Ndumo. Such inaccuracies would have resulted in a larger proportion of the population being removed than intended.

Several examples from other parts of Africa serve as evidence that the removal strategy, when conducted correctly, is viable, even for smaller populations. For example, in the Nairobi National Park 56 black rhino were removed between 1992 and 2005 from a population of 52 to 80 animals, at an average removal rate of 5.68% over the period. In 2005 the population still numbered *c*. 73 rhino with an average growth rate of 6% − 10% (K. Adcock pers. comm.). Also, in the Kaross (Namibia – Etosha) 25 animals were removed from a small population of 15−30 rhino since 1989. This population's size is still between 27 and 30 rhino with a good calving rate (K. Adcock pers. comm.).

The total number of black rhino that Ndumo has lost since 1989 through mortalities, removals and movement across the Mozambique border is c. 60. For this population to still show a healthy growth rate after so many losses, a high recruitment rate is needed. Ndumo's population however had a low recruitment rate (only 13% of females breeding each year) which could not support these losses.

Not knowing the cause of most deaths makes it difficult to determine the reason for the high mortality rate. Although fighting between black rhino individuals accounted for 37% of the known deaths, population densities were never uncommonly high, which one would not expect to cause an increase in fighting between males. The removal of large numbers of rhino in 1989 and 1994, the availability of new territories and the resulting imbalance in social structures (removal of all the breeding adults) could however have caused increased fighting.

Although the reason for the increase in juvenile mortalities since 2000 is unknown, it may be a result of density-dependent stress (see Eberhardt 1977) or nutritional stress (Hearne & Swart 1991). A study by Hitchins & Anderson (1983) in Hluhluwe-iMfolozi Park, and by Goddard (1970) found that black rhino calves less than three months old are vulnerable to predation by spotted hyena (*Crocuta crocuta*). Previous work has shown that 97% of maimed animals, such as earless or tailless animals, are results from unsuccessful predation attempts (Hitchins 1986, 1990). Unfortunately very little is known of the hyena population in Ndumo, except that there are a minimum of six individuals. Whether the two mutilated black rhino were attacked by hyena can only be speculated. The effect hyena can have on black rhino must however not be underestimated, as it has been shown that it is quite possible for hyena to affect recruitment of young (Berger 1994). It is also quite possible for predators, especially hyena, to almost completely consume a black rhino calf carcass resulting in not all mortalities being reported.

Habitat change has been identified as an important threat to the conservation of the African rhino (Emslie & Brooks 1999). Previous studies have however concentrated on the effect changes in vegetation (Emslie 1999) and fire (Marchant & Pullen 1995) have had on black rhino. Sudden habitat changes such as river course diversions are a rare occurrence, but when they do happen they can impact profoundly on animal populations. In Ndumo, the Usuthu River course diversion created a geographical barrier and divided the population into two. This certainly impacts on their movement and hence, recruitment. In 2006, the only black rhinos on the main part of the reserve were an adult male and adult female. This female had a deformed udder and would not have been able to successfully raise a calf, meaning that the only recruitment would take place north of the Usuthu River. Even though animals are able to cross the river during dry winter months, for some unknown reason the black rhino population north of the river does not make use of the opportunity to cross back into the main part of the reserve.

Black rhino occur in densities from 0.01 to 1 individual per km^2, depending on various factors such as rainfall, browse availability, browse quality and soil nutrient status (Adcock *et al*. 2008). Density dependence is an important factor in regulating population size (Hanski 1990; Saether 1997; Lundberg *et al*. 2000). For instance, in a predator free environment, the population dynamics of ungulates are strongly influenced by a combination of stochastic variation in the environment and population density (Owen-Smith 1990). This means that at higher population densities resource availability per individual is reduced, negatively affecting fecundity, age at maturity and mortality (Saether & Heim 1993; Saether 1997). White rhinos (*Ceratotherium simum*) not only lose body condition, but the rates of population growth and recruitment of calves also decrease with increasing density (Rachlow & Berger 1998). For small black rhino populations such as Ndumo's, such density dependent effects can have a huge impact on the performance and ultimately the survival of the population. The 0.38 individuals per km^2, which was recorded in 1988, is high but well within the range for this species from other estimates elsewhere (Goddard 1970; Hall-Martin *et al*. 1982; Western 1982; Hitchins & Anderson 1983; Metzger *et al*. 2007), and suggest that this population would not have been under density dependent stress. However, when taking into account the exceptionally high nyala and impala (species browsing in a similar height category as black rhino) densities in earlier years, this population could well have suffered from density dependent stress.

The reproductive cycle of female black rhino is well documented (Hitchins & Anderson 1983; Smithers & Skinner 1990; Owen-Smith 1992; Bertschinger 1994; Adcock 1996). The age of first calving ranges between 6–9 years, while the oestrus cycle lasts for *c*. 35 days and occurs all year round. A single calf is born after a gestation period of 15 months. The minimum inter-calving interval (ICI) ranges between 21 and 23 months under natural conditions. Various factors have been found to have an impact on ICI resulting in ICI varying widely under different conditions. Factors such as density-dependence (Hitchins & Anderson 1983; Hrabar & du Toit 2005), nutrition (Owen-Smith 1992) and possible female age (Adcock *et al*. 1998) have been proposed to result in varying ICI.

The calving rate recorded in 1989 (Conway & Goodman 1989) and between 1995 and 2001 is significantly lower than the 35% or more often reported for healthy growing populations spanning a variety of habitats (Adcock 2004). The reason for the low recruitment rate in Ndumo is not known, but various factors could possibly have played a role. A social disruption brought about by the removal of animals is one factor that can negatively influence an animal's productivity. 65% of the rhino removed between 1988 and 2003 were adults which mean that young animals, and possibly very old animals, which might be non-productive, are left behind. An imbalanced social structure can lead to changes in home ranges, which lead to a decline in productivity as the animal now spends more energy in creating a new home range rather than in reproduction (Reid *et al*. 2007). The social structure was most probably affected even more by the change in Usuthu River course, which restricted animals' movements and dispersal opportunities. The presence of large predators can also influence the recruitment of black rhino calves (Berger 1994). Whether the hyena population has affected black rhino recruitment in Ndumo is however unknown. However, the low recruitment figures for Ndumo could be an under representation due to the low sighting success of black rhinos in Ndumo since re-introduction.

Mortality rates after the first months of release are often high (Adcock *et al*. 1998). This is true especially for small reserves where there is not always abundant space to establish new home ranges, and space to escape when fights arise is limited. Previous introductions elsewhere have highlighted the vulnerability of young introduced rhino, indicating that they are not able to defend themselves and are not adept at finding the right browse, water and cover (Adcock *et al.* 1998). Conway & Goodman (1989) proposed that one new introduction every 12 years (as the mean generation time for black rhino is 12 years) should be efficient to enhance the effective population size in Ndumo. The introduction in 2008 of three females and two males was an attempt to increase the population size and reproductive success. A year after the introduction no mortalities have been recorded and the introduction seems to have been a success.

Black rhinos browse to a height of up to 2 m (Adcock 2000), very similar to other browsers such as nyala and impala, which take a minimum of 30% and 13% respectively of their diet as browse (Hancock 1978). It has been found that black rhinos form on average 13% of total browsing biomass, but even up to 35% where competing browser densities are low (Adcock *et al.* 2008). Ndumo's black rhino population never contributed more than 11% since 1989, and even went as low as 2% in 2004 and 2005. It has much been debated (Adcock 2004; F. Myburgh pers. comm.) about the effect other browsers, especially nyala, has had on the browse conditions in Ndumo and consequently the black rhino population. High and uncontrolled herbivore populations can damage vegetation and possibly lead to irrevocable changes in habitat condition, threatening the survival of less competitive species sharing similar niches (Hanks *et al.* 1981; Walker & Goodman 1983). It is possible that removing large numbers of rhino at once allowed other browsers to fill the opened niche, consequently out-competing the remaining black rhino population. This is true especially for young black rhino that need the space and resources to survive and claim their own territories. When one examines the population numbers and black rhino equivalent biomass, the data appear to support the idea that impala filled the niche left open by black rhino as their numbers increased substantially parallel to the black rhino decline.

CONCLUSION

These results suggest that a combination of (1) miss directed management decisions due to inaccurate estimates, and (2) competition from other herbivores, mainly nyala and impala contributed to the decline in black rhino numbers in Ndumo. A change in the natural habitat, in this case the change in Usuthu River course, also played a role in disrupting the population's social structure and recruitment. Wrong management decisions, i.e. too many removals at the wrong time, cannot be held responsible for the decline alone, as other populations in similar situations reacted differently and showed healthy growth rates even after large numbers of removals (K. Adcock pers. comm.). Rather, a combination of the above-mentioned factors together over time most likely pushed this population to the brink of extinction.

However, all the animals are at present (2008, pers. obs.) in good condition, and the birth of a calf in 2007 indicates that the few remaining rhino are still breeding. The 2008 introductions seem to be a success and may increase the reproductive success of the population even further. An option for range expansion into a neighbouring community conservation area, Usuthu Gorge, seems promising, which will add another 4000 ha onto Ndumo's 10 117 ha.

The present population is small and each individual is known, making monitoring and management fairly easy. But if the population is to increase in numbers, continued effective monitoring is needed in order to make sound decisions on the management of this population. Data collection need to be meticulous and precise in order to prevent gaps and inaccuracies such as discovered in the historical records. In order for such a small population well below 50 individuals to be viable, it has to be managed as part of a larger metapopulation. However, the population's sex and age structure, reproductive rates and carrying capacity need to be examined in detail before considering any future removals or introductions. It is also recommended that other potentially competing browsers, especially nyala and impala, are not left to reach high and uncontrolled numbers as in the past, whereby they start out competing black rhino for food sources.

REFERENCES

Adcock, K. (1996). Status and management of black rhino in South Africa and Namibia, Report for the Rhino Management Group of South Africa and Namibia, Unpublished.

Adcock, K. (2000). Rhino Management Group black rhino carrying capacity model version 1.0, SADC Regional Programme for Rhino Conservation Report.

Adcock, K. (2004). Report on the findings of a survey of browse conditions for black rhino at Ndumu Game Reserve, Kwazulu-Natal, 27–31 April 2004, Unpublished.

Adcock, K., Amin, R. & Khalaye, C. (2008). Modelling black rhinoceros (*Diceros bicornis*) carrying capacity relationships in Africa, In prep.

Adcock, K., Balfour, D., Buk, K., Linklater, W. & Owen-Smith, N. (2001). Results and recommendations from working groups, Working group 2: Monitoring resources. in R. Emslie (ed.), Proceedings of a SADC Rhino Management Group (RMG) Workshop on Biological Management to Meet Continental and National Black Rhino Conservation Goals, pp. 102–107, SADC Rhino Management Group, Harare, Zimbabwe.

Adcock, K., Hansen, H.B. & Lindemann, H. (1998). Lessons from the introduced black rhino population in Pilanesburg National Park. *Pachyderm.* **26**: 40−51.

Armbruster, P., Fernando, P. & Lande, R. (1999). Time frames for population viability analysis of species with long generations: an example with Asian elephants. *Animal Conservation.* **2:** 69-73.

Berger, J. (1990). Persistence of different-sized populations: an empirical assessment of rapid extinctions in bighorn sheep. *Conservation Biology.* **4:** 91−98.

Berger, J. (1994). Science, conservation, and black rhinos. *Journal of Mammalogy.* **75**: 298−308.

Bertschinger, H. J. (1994). Reproduction in black and white rhino: a review. Proceedings of a Symposium on Rhinos as game ranch animals, Onderstepoort, 910.

Brooks, M. & Adcock, K. (1997). Conservation plan for the black rhinoceros *Diceros bicornis* in South Africa, Compiled for the Rhino Management Group.

Brooks, M., Conway, A., Goodman, P., Balfour, D., Rushworth, I., Potter, D., Cooke, M. & Hartley, P. (2002). Ezemvelo KZN Wildlife Strategy for the Managment of Black Rhino in KwaZulu-Natal. Ezemvelo KZN Wildlife, Pietermaritzburg.

Buckland, S.T., Anderson, D.R., Burnham, K.P. & Laake, J.L. (2003). Distance Sampling. Estimating abundance of biological populations, Chapman & Hall.

Charlesworth, D. & Charlesworth, B. (1987). Inbreeding depression and its evolutionary consequences. *Annual Review of Ecology and Systematics*. **18**: 237–268.

Conway, A.J. & Goodman, P.S. (1989). Population Characteristics and management of Black Rhinoceros *Diceros bicornis minor* and White Rhinoceros *Ceratotherium simum simum* in Ndumu Game Reserve, South Africa. *Biological Conservation.* **47**: 109−122.

East, R. (1984). Rainfall, soil nutrient status and biomass of large African savanna mammals. *African Journal of Ecology*. **22:** 245-279.

Eberhardt, L.L. (1977). Optimal policies for conservation of large mammals, with special reference to marine ecosystems. *Environmental Conservation.* **4**: 205−212.

Emslie, R.H. (1999). The feeding ecology of the black rhinoceros (*Diceros bicornis minor*) in Hluhluwe-Umfolozi Park, with special reference to the probable causes of the Hluhluwe population crash. Unpublished Ph.D. Thesis, University of Stellenbosch.

Emslie, R. & Brooks, M. (1999). African Rhino. Status Survey and Conservation Action Plan. IUCN/SSC African Rhino Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK.

EKZNW (2007). Integrated Management Plan: Ndumo Game Reserve, South Africa. Ezemvelo KZN Wildlife, Pietermaritzburg, 70 pp and 24 maps.

Fisher, R.A. (1930). The genetical theory of natural selection, Oxford: Clarendon Press.

Foose, T.J., Lacy, R.C., Brett, R. & Seal, U.S. (1993). Kenya Black Rhino Metapopulation Workshop, Apple Valley, MN: IUCN/SSC Captive Breeding Specialist Group (CBSG).

Fritz, H. & Duncan, P. (1994). On the carrying capacity for large ungulates of African savanna ecosystems. *Proceedings of the Royal Society of London, Biological Sciences.* **1345**: 77-82.

Fritz, H., Duncan, P., Gordon, J. & Illius, I.W. (2002). Megaherbivores influence trophic guild structure in African ungulate communities. *Oecologia.* **131**: 620-625.

Goddard, J. (1970). Age criteria and vital statistics of a black rhinoceros population. *East African Wildlife Journal.* **6:** 133−150.

Gilpin, M.E. & Diamond, J.M. (1980). Subdivision of nature reserves and the maintenance of species diversity. *Nature.* **285**: 567−568.

Gilpin, M.E. & Soule, M.E. (1986). Minimum viable populations: processes of extinction, in M.E. Soule (ed.), Conservation biology: the science of scarcity and diversity, pp. 19−34, Sinnauer Associates, Sunderland, MA.

Hall-Martin, A.J., Erasmus, T. & Botha, B.P. (1982). Seasonal variation of diet and faeces composition of black rhinoceros Diceros bicornis in the Addo Elephant National Park. *Koedoe.* **25**: 63−82.

Hancock, P.G. (1978). Dynamics of an over utilized area in the Ndumu Game Reserve. Tongaland, MSc thesis, University of Natal.

Hanks, J., Denshaw, W.D., Smuts, G.L., Jooste, J.F., Joubert, S.C., Le Roux, P. & Milstein, P.S. (1981). Management of locally abundant mammals – the South African experience, in P.A. Jewell, S. Hott & D. Hart (eds.), Problems in Management of locally abundant wild animals, pp. 21−57, Academic Press, New York.

Hanski, I. (1990). Density dependence, regulation and variability in animal populations. *Philosophical Transactions of the Royal Society of London.* **330**: 141−150.

Harley, E.H., Baumgarten, I., Cunningham, J. & O'Ryan, C. (2005). Genetic variation and population structure in remnant populations of black rhinoceros. *Diceros bicornis,* in Africa, *Molecular Ecology.* **14**: 2981−2990.

Hearne, J.W. & Swart, J. (1991). Optimal translocation strategies for saving the Black Rhino. *Ecological Modelling.* **59**: 279−292.

Hitchins, P.M. (1984). Translocation of black rhinoceros *Diceros bicornis minor* from the Natal game reserves 1962 – 1983. *Lammergeyer.* **33**: 45−48.

Hitchins, P.A. (1986). Earlessness in the black rhinoceros – a warning. *Pachyderm.* **7**: 8−10.

Hitchins, P.A. (1990). Census and marking systems for black rhinoceros *Diceros bicornis* with special reference to the Zululand Game Reserves. *The Game Ranger*. **1**: 1−12.

Hitchins, P.M. & Anderson, J.L. (1983). Reproduction, population characteristics and management of the black rhinoceros *Diceros bicornis minor* in the Hluhluwe/Corridor/Umfolozi Game Reserve Complex. *South African Journal of Wildlife Research*. **13:** 78–85.

Hrabar, H. & Du Toit, J.T. (2005). Dynamics of a protected black rhino (*Diceros bicornis*) population: Pilanesberg National Park, South Africa. *Animal Conservation*. **8**: 259−267.

IUCN, (2010). IUCN Red List of Threatened Species. Version 2010.1. <www.iucnredlist.org>, Downloaded on 18 March 2010.

Leigh, E.G. (1981). The average lifetime of a population in a varying environment. *Journal of Theoretical Biology*. **90**: 213-239.

Linklater, W.L., Adcock, K., Du Prees, P., Swaisgood, R.R., Law, P.R., Knight, M.H., Gedir, J.V., & Kerley, G.I.H. (2011). Guidelines for large herbivore translocationsimplified: black rhinoceros case study. *Journal of Applied Ecology*. 48: 493-502.

Lundberg, P., Ranta, E., Ripa, E. & Kaitala, V. (2000). Population variability in space and time. *Trends in Ecology & Evolution*. **15:** 460−464.

Marchant, A., & Pullen, C. (1995). Burning for black rhino (*Diceros bicornis*). Unpublished Natal Parks Board Poster Paper, Pietermaritzburg.

Metzger, K.L., Sinclair, A.R.E., Campbell, K.L.I., Hilborn, R., Hopcraft, J.G.C., Mduma, S.A.R. & Reich, R.M. (2007). Using historical data to establish baselines for conservation: The black rhinoceros (*Diceros bicornis*) of the Serengeti as a case study. *Biological Conservation*. **139**: 358−374.

Muya, S.M. & Oguge, N.O. (2000). Effects of browse availability and quality on black rhino (*Dicernos bicornis michaeli* Groves 1967) diet in Nairobi National Park, Kenya. *African Journal of Ecology*. **38**: 62−71.

Newman, D. & Pilson, D. (1997). Increased probability of extinction due to decreased genetic effective population size: Experimental populations of *Clarkia pulchella*. *Evolution.* **51**: 354−362.

Onderstepoort, Faculty of Veterinary Science, Department of Reproduction, Onderstepoort, Pretoria, South Africa

Owen-Smith, N. (1990). Demography of a large herbivore, the greater kudu, *Tragelaphus strepsiceros* , in relation to rainfall. *Journal of Animal Ecology.* **59**: 893−913.

Owen-Smith, N. (1992). Megaherbivores, Cambridge University Press, Cambridge.

Owen-Smith, N. (1993). Comparative mortality rates of male and female kudus: the cost of sexual size dimorphism. *Journal of Animal Ecology.* **62**: 428–440.

Pimm, S.L., Diamond, J., Reed, T.M., Russell, G.J. & Verner, J. (1993). Times to extinction for small populations of large birds. *Proceedings of the National Academy of Sciences of the United States of America.* **90**: 10871−10875.

Pooley, E.S. (1978). A checklist of the plants of Ndumu Game Reserve Nort-Eastern Zululand. *Journal of South African Botany.* **44**: 1−54.

Rachlow, J.L. & Berger. J. (1998). Reproduction and population density: trade-offs for the conservation of rhinos *in situ*. *Animal Conservation.* **1**: 101−106.

Reid, C., Slotow, R., Howison, O. & Balfour, D. (2007). Habitat changes reduce the carrying capacity of the Hluhluwe-Umfolozi Park, South Africa, for Critically Endangered black rhinoceros' *Diceros bicornis*. *Oryx.* **41**: 247–254.

Saether, B.E. (1997). Environmental stochasticity and population dynamics of large herbivores: a search for mechanisms. *Trends in Ecology & Evolution.* **12:** 143−149.

Saether, B.E. & Heim, M. (1993). Ecological correlates of individual variation in age at maturity in female moose (*Alces alces*): the effects of environmental variability. *Journal of Animal Ecology.* **62**: 482–489.

Smithers, R.H.N. & Skinner, J.D. (1990). The mammals of the Southern African sub-region, University of Pretoria, Republic of South Africa.

Tello, J.L.PL & Van Gelder R.G. (1975). The natural history of nyala, *Tragelaphus angasi* (Mammalia, Bovidae), in Mozambique. *Bulletin of the American Museum of Natural History.* **155**: 323−385.

Thornhill, H. (1989). Ndumo Black Rhino Monitoring. Unpublished Natal Parks Board report. Ndumo Game Reserve, KwaZulu-Natal.

Walker, B. & Goodman, P. (1983). Some implications of ecosystem properties for wildlife management, in R.N. Owen-Smith (ed.), Management of large mammal in African conservation areas, pp 79−91, Haum Educational Publishers, Pretoria.

Westemeier, R.L., Brawn, J.D., Simpson, S.A. *et al.* (1998). Tracking the long-term decline and recovery of an isolated population. *Science.* **282**: 1695–1698.

Western, D. (1982). Patterns of depletion in a Kenya rhino population and the conservation implications. *Biological Conservation.* **34**: 147−156.

Wilcox, B.A. & Murphy, D.D. (1985). Conservation strategy: the effects of fragmentation on extinction. *American Naturalist.* **125**: 879−887.

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Appendix 1: Converting nyala and impala metabolic biomass to black rhino equivalent biomass as a function of the annual population estimate of each species based on 1985 population estimates values (adapted from Adcock 2008)

Species	**Mean body mass (kg)**	**Metabolic mass (body mass ^ 0.75)**	**Proportion of browse in diet in 0 - 2m height class**	**Black rhino equivalent biomass (A)**	**Population estimate x A = rhino equivalent biomass**
Nyala	56	20.5	0.60	0.082	2940 x 0.082 = 241
Black rhino	**792**	**149.3**	**1.00**	**1.000**	**40**
Impala	33	13.9	0.30	0.028	400 x 0.028 = 11

Note: body mass reflects 66% of mean male and female mass

CHAPTER 3: Browse availability and the impact of invasive plants on browse quality in Ndumo Game Reserve as related to black rhino (*Diceros bicornis minor*)

Abstract

Black rhinoceros (*Diceros bicornis*) are classified as critically endangered on the IUCN red data list (IUCN 2010). From 1994 to 2007, the black rhino (*Diceros bicornis minor*) population in Ndumo Game Reserve gradually declined from 43 to eight individuals. Determining the current browse availability and quality inside the reserve is of cardinal importance in order for reserve managers to effectively manage this population, especially in light of the decline in numbers over the last 15 years. I therefore determined the amount of browse currently (2008) available to black rhino in Ndumo, the proportional species composition of this browse and its suitability for black rhino. The results show that browse availability is fairly high (average of 17.8%) in Ndumo compared to conditions elsewhere and should not be a limiting factor. Browse suitability is however low, with two of the four most abundant plants being invasive alien species scoring a suitability rating of 3, and should be rejected by black rhino and most herbivore species. If effective, an alien plant clearing programme currently undergoing in the reserve could alleviate the poor browse conditions by controlling and eradicating invasive alien species.

Keywords: Invasive alien species, black rhino, browse availability, browse suitability, population decline

Introduction

Compared to most other browsers, black rhino (*Diceros bicornis*) can feed on a wider variety of plants, and being hind-gut fermenters, they have a higher tolerance to low quality browse as both hind-gut and rumen fermenters require less energy and protein per unit weight with an increase in body size (Bell 1970, 1971; Janis 1976). Moreover, black rhino often feed on moderately toxic plants such as *Euphorbia ingens, Euphorbia virosa,* *Lopholeana corrifolia, Phytolacca dodecandra* and *Datura stramonium* that are toxic to other herbivore species (Goddard 1968; Loutit *et al.* 1987; Emslie & Adcock 1994). Irrespective of black rhino's ability to feed on lower quality and moderately toxic plants, they are selective in their use of habitat (Tatman *et al.* 2000), and selectively forage for specific plants and plant parts (Oloo *et al.* 1994; Muya & Ogugue 2000; Ganqa *et al.* 2005, Buk & Knight 2010). Consequently, as with other herbivores (Slansky 1993; Lill & Marquis 2001), habitat quality may impact profoundly on a population's performance (Brooks 2001; Du Toit 2001). For example, in Hluhluwe-iMfolozi Park (HIP), the black rhino (*Diceros bicornis minor*) population declined from 279 to 87 individuals in the Hluhluwe section (26 921 ha) between 1961 and 1985 due to changes in the natural vegetation (a decline in habitat quality) and a resulting reduction in carrying capacity (Emslie 1999; Emslie & Brooks 1999). In addition to food availability, ecological and chemical factors that influence diet selection by herbivores are important to keep in mind, and have resulted in an increase in attention to factors affecting foraging behaviour (Gartlan *et al.* 1980; Holecheck *et al.* 1982).

One of the oldest protected areas in the KwaZulu-Natal province (KZN), proclaimed as a RAMSAR wetlands site in 1997 (EKZNW 2007), and well-known for its significant biological importance spanning a wide range of taxa (EKZNW 2007), namely Ndumo Game Reserve, is another example of where black rhino conservation is facing severe challenges. That is, in just over 10 years (from 1994 to 2007), Ndumo's black rhino population was reduced by 81% with a decline from 43 to eight individuals. During 2007, one calf was born and a further five individuals were re-introduced into Ndumo in 2008 in order to try and stimulate the growth rate bringing the population total to 14 animals in 2009. Several hypotheses have been proposed to explain this rapid decline (Adcock 2004). These include a change in habitat quality, a decrease in the availability of suitable browse species and an increase in the availability of less suitable browse species. Except for the survey done in 2004 (Adcock 2004), there are no historical data on the browse conditions relating to black rhino in Ndumo. The previous survey concluded that "while absolute browse availability is not limited at Ndumo, browse suitability is", and that "an estimated 72% of the basic Ndumo land area (without the Usuthu river fence) contains vegetation with an overall low suitability rating for black rhino." This was a quick survey done in only four days with plots on line transects or near easily accessible roads, therefore a more intensive and detailed survey was needed to test the above-mentioned hypotheses.

Biological invasions have been identified as a major threat to the reservation of modern biodiversity, ecosystem functioning and ecosystem service provision (Higgins *et al.* 2000; Chown *et al.* 2009). According to a survey by the South African Plant Invaders Atlas, approximately 10 million hectares of South Africa's land surface has been invaded by invasive alien plant species (Van Wilgen *et al.* 2001). In KZN, Ezemvelo KZN Wildlife spent more than R31 million to clear nearly 100 000 hectares of alien invasive plants during 2009-2010 (EKZNW 2010). In the case of Ndumo, it is well documented that several invasive alien plant species have infested large areas of this reserve in recent years. To date, more than 20 known invasive alien plant species have been recorded in Ndumo and these include aggressive invaders known for their conservation concern such as *Lantana camara* (Ghisalberti 2000) and *Chromolaena odorata* (Macdonald & Jarman 1985; Apori *et al.* 2000). The impact of these invasive alien species on the quality of herbivore browse, specifically for black rhino, in the reserve is however unknown. Determining the current browse availability and quality is of cardinal importance in order for reserve managers to effectively manage Ndumo's black rhino population, especially in light of the decline in numbers over the last 15 years. The aim of this survey was to determine the amount of browse currently (2008) available to black rhino in Ndumo, the proportional species composition of this browse and its suitability for black rhino.

Methods and materials

STUDY AREA

Ndumo Game Reserve is a small (10 117 ha) reserve established in 1924 as a hippopotamus (*Hippopotamus amphibihius*) sanctuary (EKZNW 2007). The reserve is made up of tropical bush and Lowveld savanna which includes 10 main vegetation formations (Pooley 1978), namely: Riverine forest, Floodplain, Fever tree (*Acacia xanthoploea*) forest, "Pan-edge" communities, Sand forest, *Acacia tortilis* woodland, Mahemane thicket, Deciduous broad-leaf woodland, *Acacia nigrescens* woodland and Open woodland. It is situated at the confluence between the Usuthu and Pongola Rivers on the Mozambique coastal plain (26º 52'S and 32º 15'E). In summer the climate is hot and humid, and warm and dry in winter, with a mean annual rainfall of 630 mm. Approximately 4% of the reserve is open water, pans and rivers (Conway & Goodman 1989). Ndumo was proclaimed as a RAMSAR wetlands site in 1997. The reserve is fenced in the west, south and east, but the Usuthu River forms the northern boundary between South Africa and Mozambique and is not fenced.

SURVEY STRUCTURE

Two surveys were conducted, the first from August to October 2006 (winter survey) and the second from February to April 2007 (summer survey). One hundred and thirteen plots were randomly set throughout five vegetation types within Ndumo, with a minimum of four plots per vegetation type (Fig. 3.1). The exact coordinates of each plot were recorded during the first survey with a Global Positioning System (GPS) in order to survey the same sites during the second survey. The area east of the Pongola River (see Fig. 3.1) was not assessed as this area is geographically cut off from the main part of the reserve and no rhinos occur there. Only four plots were done in Floodplains, as this is not ideal black rhino habitat and consists mainly of reeds (*Phragmites australis*). The Sand forest was not assessed as this vegetation type only makes up about 1% of Ndumo's land area and is not utilised by black rhino. In contrast to the previous survey conducted by Adcock (2004), no plots were assessed outside the reserve due to time constraints.

Each square plots' length and width was 10m and within each plot, all plant species including herbs, seedlings, shrubs, trees and overhanging branches within the height range of 0 - 2 m were measured. Canopies higher than 2 m were thus not included in this study as it is unavailable to black rhinos. Dead plants are not eaten by black rhino and were excluded in the data collection, but dormant plants that have only lost their leaves were included.

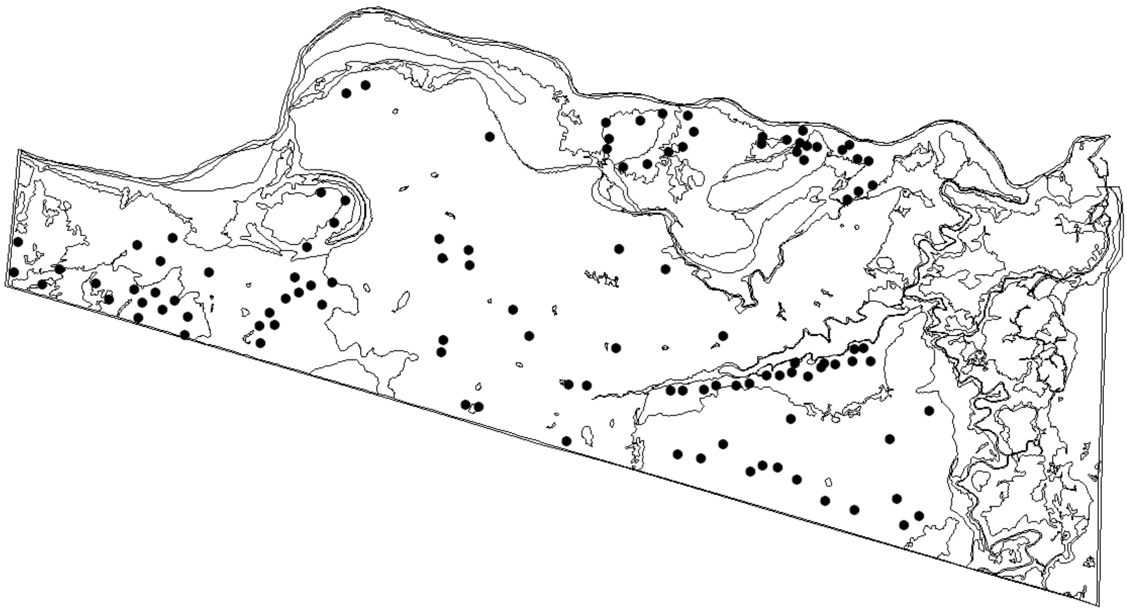


Figure 3.1 Location (indicated by the round dots) of browse survey plots in Ndumo Game Reserve.

Following Adcock (2006) the survey method consisted of two steps. First, to identify all the plant species within the 10 m^2 plot and record the number of plants of each species within the plot. Second, the average canopy depth for each species within the plot was estimated with the help of a meter-stick (see Fig. 3.2). Average canopy diameter for each species is then estimated in the same manner.

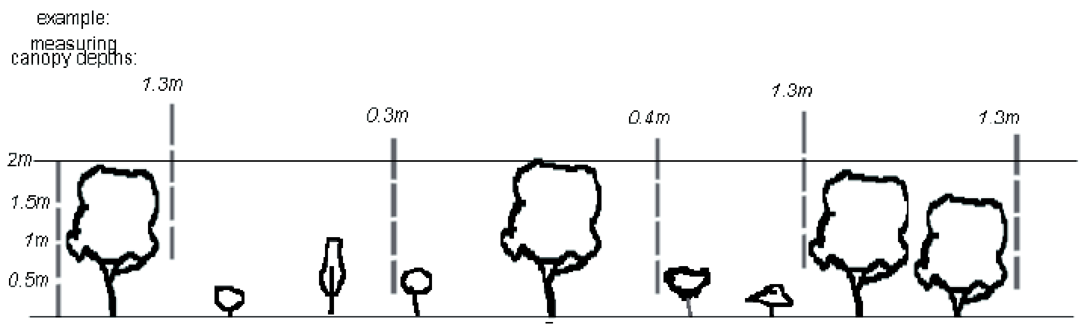


Figure 3.2 Estimating canopy depth (taken from Adcock 2006).

BROWSE AVAILABILITY

Browse availability refers to the actual browse that is available to a black rhino within the 0 - 2 m height range. Browse only within this height range was surveyed, as black rhinos are browsers and generally browse from 0 - 2 m height, although they prefer browse between 0.5 – 1.2 m (Adcock 2006). If plant canopies were to completely fill a plot within the 0 - 2 m layer, then the browse availability for that plot would be 100%. This is mostly not the case; therefore all the individual plant canopies within a plot had to be summed to give total browse availability for that plot.

Calculating browse availability:

- For a plot with a 10 m diameter, the plot area will be 78.54 m^2 (Pi x $radius^2$).
- The plot volume is 78.54 m^2 x 2 m (depth) = 157.1 m^3.
- The plant dimensions of a specific species are, for this example, 1.5 m average canopy diameter and 1 m average canopy depth.
- Plant volume is: canopy area of plant = Pi x $radius^2$ = 3.1415927 x 0.75^2 = 3 m^2
- Canopy area x canopy depth = 1 x 3 = 3 m^3.
- Browse availability is thus the plant volume as a proportion of the plot volume: BA = plant volume / plot volume = 3 / 157.1 = 0.019096
- The percentage browse availability for that species in the plot is thus 0.019 x 100 = 1.910%.

- Browse availability is calculated in this manner for each plant species within the plot. As this is only the average browse availability for that species (as the average canopy depth and average canopy diameter was used in the calculations) and we want the total browse availability, the average browse availability for that species is then multiplied by the number of plants of that species within the plot.
- The browse availability of all the species in the plot is then summed to give total browse availability for each plot.

All plant species were furthermore divided into different groups namely woodies (trees), non-woodies (forbs and shrubs), succulents and invasive alien plants. The total browse availability for each group was then calculated by adding all the species' browse availability in each group together. The average browse availability across each vegetation type was also calculated.

BROWSE SUITABILITY RANKING

Following Adcock (2006), browse suitability was determined by giving each plant species, based on its proportion being represented in the diet of black rhino, a ranking score of between 1 and 3; 1 being highly preferred plant species, 2 being plant species that were regarded as neutral or with a slight preference, and 3 being species that are highly rejected in the diet of black rhinos. Species of unknown diet preference also scored a 2. Preferred plant species are those that occur in greater proportion in the diet than in the habitat (Adcock 2006). In other words, less abundant plants that black rhino actively forage for. Suitability ratings are based on aggregated preference and information from a number of studies (listed in Adcock 2006). Suitable browse was finally defined as species scoring a 1 or 2.

Results

BROWSE AVAILABILITY

Ndumo scored an average browse availability of 17.8% during this study. Although data on browse availability estimates from elsewhere are limited, Ndumo's browse availability estimate is slightly higher than the average (17.3%) from other reserves surveyed (K. Adcock pers. comm.; Fig. 3.3).

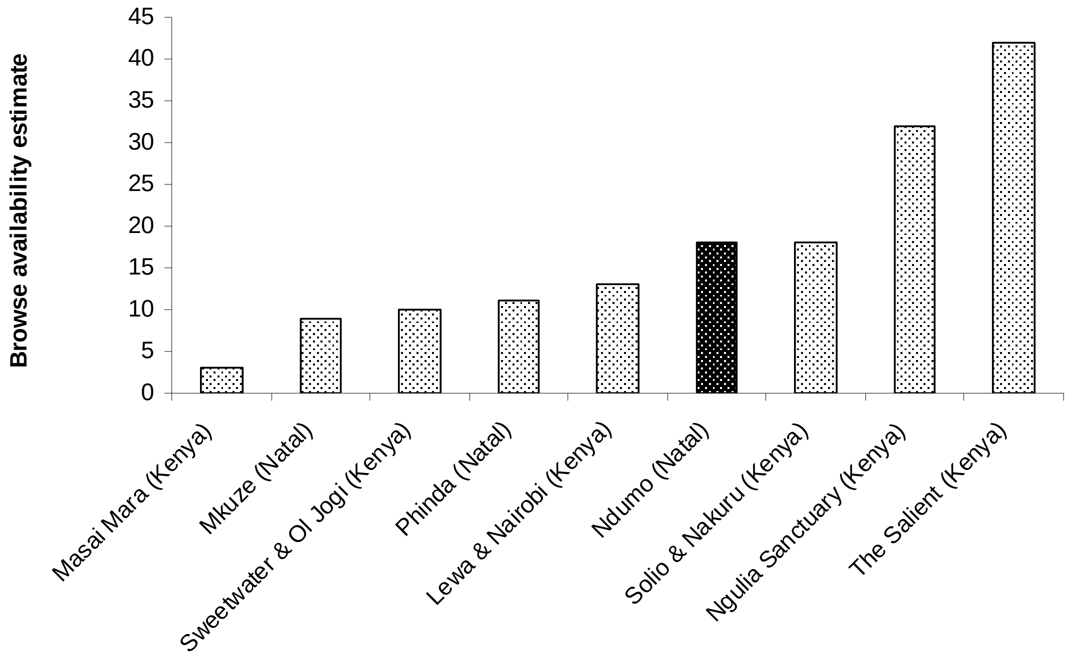


Figure 3.3 Browse availability estimates of Ndumo Game Reserve compared to estimates of other reserves.

Of the different vegetation types sampled, the Mahemane thicket has the highest browse availability (29%) followed by Pan-edge (17%) and Riverine forest (16%, Table 3.1).

Table 3.1 Browse availability estimates for the different vegetation types in Ndumo Game Reserve.

	Riverine forest	**Floodplain**	**Mahemane**	**Deciduous broad-leaf woodland**	***Acacia nigrescens* woodland**	***Acacia tortillis* woodland**	**Pan-edge**
Winter avg. BA	8.197%	11.441%	35.838%	6.438%	6.536%	8.118%	19.683%
Summer avg. BA	23.009%	9.808%	21.361%	4.197%	10.112%	18.159%	14.455%
Avg.	15.603%	10.625%	28.600%	5.318%	8.324%	13.138%	17.069%

Two vegetation types had relatively low browse availability scores, namely the Deciduous broad-leaf woodland with only 5% and *Acacia nigrescens* woodland with 8%. The average browse availability across all vegetation types was slightly higher in summer than in winter (14.44% and 13.75% respectively).

Fig. 3.4 illustrates the proportion of each vegetation type which is filled with available browse. The Mahemane is by far the largest vegetation type and also has the highest proportion of available browse. Even though Floodplains have lower browse availability than other vegetation types such as Riverine forest and Pan-edge communities, the size of this vegetation type ensures that a large proportion of the available browse in Ndumo is found in Floodplains.

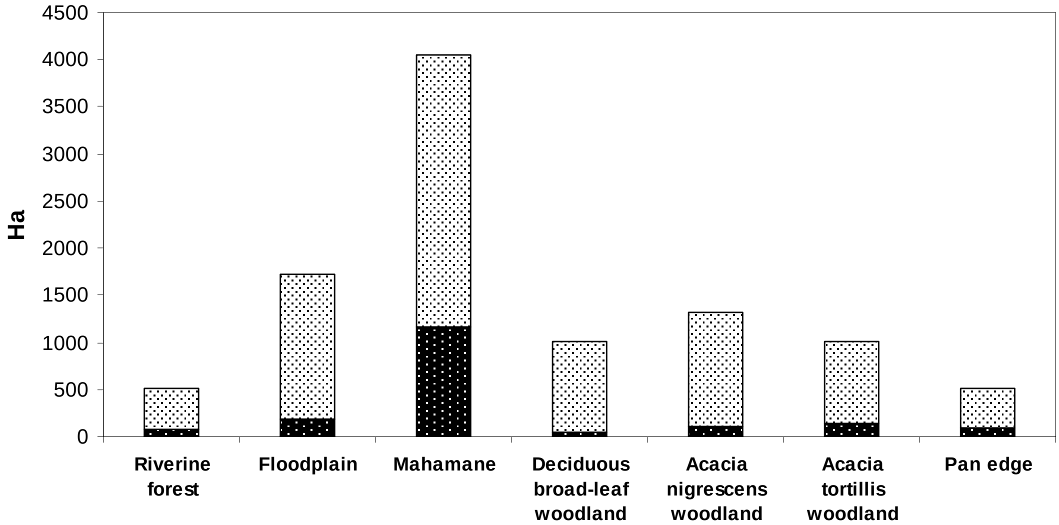


Figure 3.4 Proportion of the different vegetation types in Ndumo Game Reserve that is filled with available browse (represented by the black in each bar).

Comparing Ndumo's overall browse availability between the present survey and that of Adcock (2004), the estimated availability of our study (17.8%) is lower than the 2004 study (21.3%; Fig. 3.5). Current browse availability estimates for Pan-edge and Riverine forest communities are less than 50% of 2004's estimate. All the different vegetation types, except for Floodplains, scored lower browse availability estimates during our survey (Fig. 3.5).

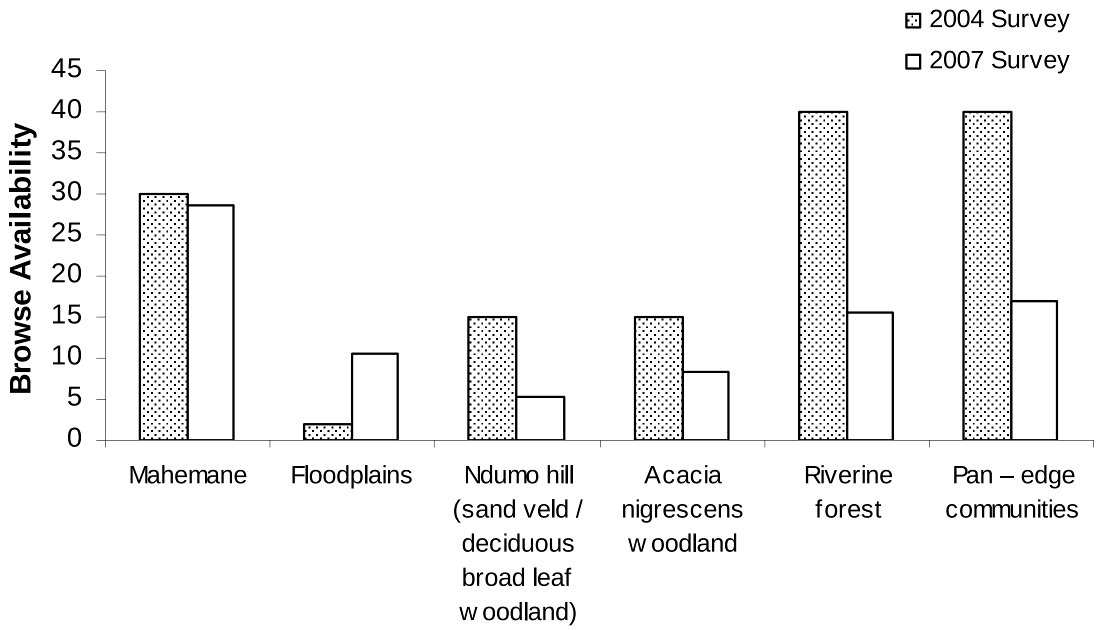


Figure 3.5 Comparison between browse availability estimates from this survey and the 2004 survey.

Fig. 3.6 illustrates the different vegetation groups' contribution to the overall browse availability. Woody plants contribute 75% of all available browse, invasive alien vegetation 18%, non-woodies 2% and succulents 5%. This lack of herbs and forbs (non-woodies) in the understory of closed woodlands was also noted during the previous survey (Adcock 2004). In contrast to the condition inside the reserve, plots assessed outside the reserve near the boundary had an abundance of herbs and forbs (Adcock 2004).

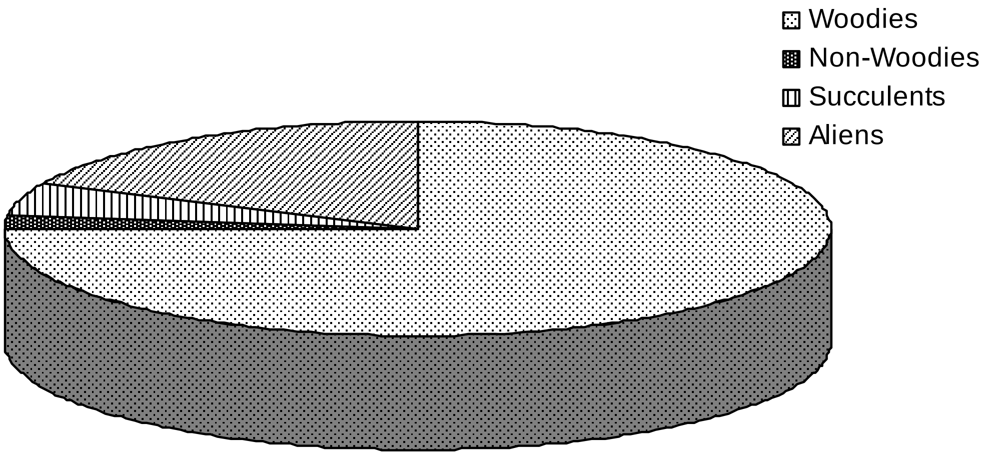


Figure 3.6 Different vegetation groups' contributions to Ndumo Game Reserve browse availability.

BROWSE SUITABILITY

Considering the nine most abundant plant species within the 0- 2 m height range, three of the four most abundant species have a suitability rating of 3 and should therefore be rejected by black rhino and most other herbivore species (Table 3.2). These unsuitable species include two alien invaders, and *Croton menyhartii;* the single biggest contributor to browse availability in Ndumo, contributing 25% of all available browse. Only two of the nine species are ranked as highly preferred by black rhino, namely *Dichrostachys cenerea* and *Euphorbia grandicornis*. Four species are ranked as neutral or slightly preferred.

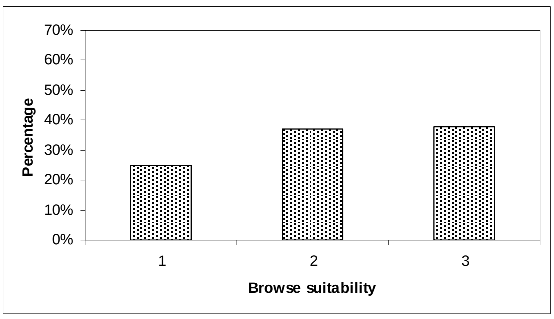
Table 3.2 Individual species' contribution to browse availability and its suitability rating in Ndumo Game Reserve.

Species	**Percentage contribution to Ndumo browse availability**	**Suitability rating**
Croton menyhartii	25%	3

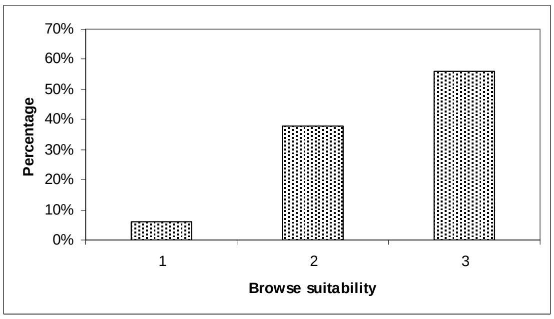
**Chromolaena odorata*	11%	3
Azima tetracantha	9%	2
**Lantana camara*	7%	3
Gardenia cornuta	6%	2
Euphorbia grandicornis	4%	1
Dichrostachys cenerea	4%	1
Grewia monticola	3%	2
Gymnosporia senegalensis	3%	2

* Invasive alien species

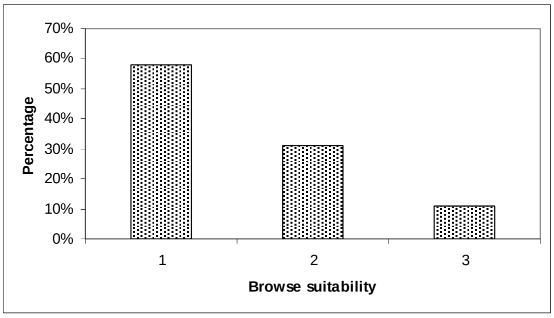
Browse suitability across the different vegetation types is illustrated in Fig. 3.7. The low suitability ranking in the Mahemane is due to the abundance of *Croton menyhartii*, and in the Riverine forest species such as *Chomolaena odorata* and *Lantana camara* account for the low browse suitability. The *Acacia nigrescens* woodland (Fig. 3.7) is the only vegetation type with a high suitability ranking, with 58% of the available browse ranked as preferred and a further 31% ranked as neutral or slightly preferred browse.

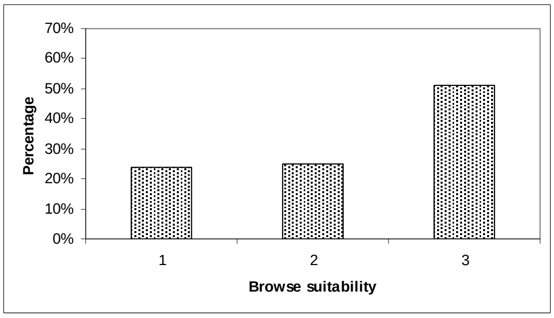


Deciduous broad-leaf woodland

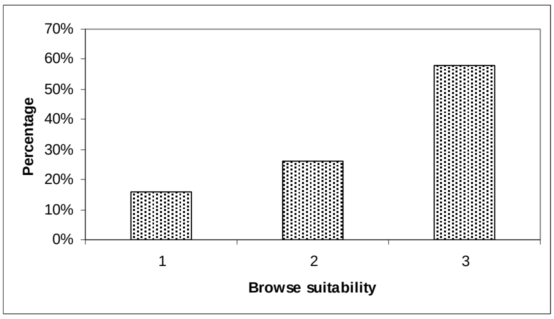


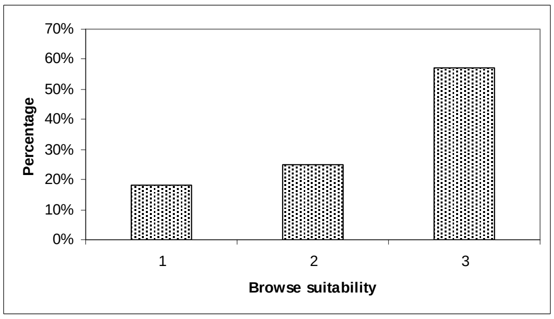
Mahemane



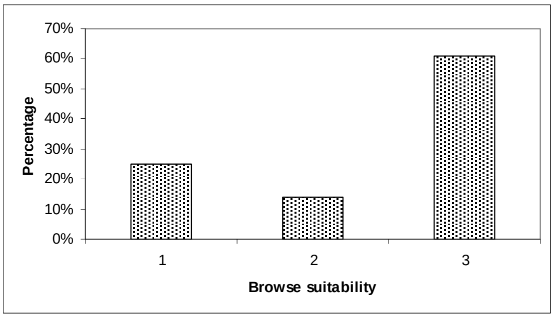


***A. nigrescens* woodland** **Pan-edge communities**





Riverine forest ***A. tortillis* woodland**



Floodplains

Figure 3.7 Browse suitability rankings of the different vegetation types in Ndumo Game Reserve.

Discussion

BROWSE AVAILABILITY

Browse availability is high in Ndumo compared to conditions elsewhere (Fig. 3.3) and should therefore not be a limiting factor to the black rhino population. Even though plant communities do change over time, it was not expected to find any significant differences between this survey and the survey completed three years previously (Fig. 3.5). The difference in browse availability estimates for Ndumo between the 2004 (21.3%) and 2007 (17.8%) survey could be accounted for by the difference in survey structure, more plots were surveyed over a longer time in 2007 than in 2004. In addition, the area north of the Usuthu River was not assessed previously as it is difficult to access, but as a large proportion of Ndumo's black rhino population (6 out of 14) live in this area, it was assessed during this survey. There is also some degree of subjectivity in estimating the browse availability conditions.

Floodplains were furthermore not expected to score a high browse availability estimate (10.6%) as this vegetation community is dominated by reeds (*Phraghmites australis*), and does not support a high abundance of woody vegetation. An increase in invasive aliens (such as *Lantana camara* and *Chromolaena odorata*), which are not favoured by black rhino, contributed significantly to the relatively high browse availability estimate. The relatively high abundance value, even though most of this is made up of alien vegetation, might explain the ability of this vegetation type to support the high density of black rhino presently found in the area north of the Usuthu River. Even though this community type is able to support large numbers of rhino, it is not sufficient enough to support a high recruitment rate, as is evident by the low recruitment rate observed between 2006 and 2010 (only 1 calf was recorded, personal observation).

The high number of woody plants as opposed to the lack of herbs and forbs (non-woodies) inside the reserve is most probably a result of the severe browse pressure from high nyala (*Nyala angasi*) and impala (*Aepyceros melampus*) densities, resulting in bush encroachment and thickening. This is clearly evident by the dominance of the bush *Croton menyhartii*. This also accounted for the high browse availability, but low suitability estimates recorded in most of the vegetation types. Herbs and forbs have been found to be important food sources for black rhino (Buk & Knight 2010), and the lack thereof in Ndumo could impact negatively on black rhino calve (with limited reach) nutrition.

BROWSE SUITABILITY

The vegetation type with the highest browse suitability estimate, the *Acacia nigrescens* woodland (Fig. 3.7), is relatively small with a small proportion of the available browse occurring in it (Fig. 3.4). Conversely, the largest vegetation type with the highest proportion of browse occurring in it, the Mahemane (Fig. 3.4) has a low browse suitability estimate (Fig. 3.7). This means that although large parts of the reserve if filled with available browse, good quality browse is scarce.

Two of the four most abundant plants in Ndumo are invasive alien species with a suitability rating of 3 (Table 3.2), which, together with *Croton menyhartii*, make up 43% of the available browse in the 0 - 2 m height category. This means that nearly half of the vegetation in Ndumo within the 0 - 2m height category consists of plants with a low suitability rating, not only for black rhino but for most other browsers too. The second most dominant invasive alien species identified here, *Lantana camara* (4th most abundant species, Table 2), is known for its significant habitat transformation effects (Ghisalberti 2000) and negative implications in as far as maintaining viable native animal and plant communities. This is true not only for South Africa but globally where this species invades environments where it is non-native (Ghisalberti 2000). For example, it has been estimated that four million hectares in Australia has been infested (Ross 1999). It is listed as one of the world's 100 worst invaders (Global Invasive Species Database 2007). It impacts heavily on other plant species and crowds out more desirable species to become the dominant species. It has been recorded in some cases where *Lantana camara* infestations have become so prominent that they have completely stalled the regeneration of rainforests for three decades (Lamb, 1991 in Day *et al*. 2003). This species is also one of the most common causes of livestock and game poisoning in South Africa, including cattle (*Bos taurus*), buffalo (*Syncerus caffer*), sheep (*Ovis aries*) and goats (*Capra hircus*) (Steyn 1934; Vahrmeijer 1981; Kellerman *et al*. 1988; Day *et al.* 2003). The active toxin is triterpenoids, found in leaves and seeds. It has also been shown that poisoning mainly occurs in newly introduced young animals without access to other fodder (Day *et al*. 2003).

Chromolaena odorata (second most abundant species, Table 3.2) is a fast-growing perennial shrub native to South and Central America. *Chromolaena* is an invasive weed which forms dense stands preventing establishment of other species, and has also been nominated as among the world's 100 worst invaders (Global Invasive Species Database 2007).

Parthenium hysterophorus, although not prominent during this survey, has also started to invade large areas of Ndumo (personal observation). This species is an herbaceous annual or ephemeral member of the Asteraceae, reaching a height of 2 m. As with *Lantana* and *Chromolaena*, this weed has been nominated as one of the 10 worst weeds in the world (International Parthenium Research Group).

However, during 2008/9 more than R1.5 million was spent in KwaZulu-Natal by Ezemvelo KZN Wildlife's Alien Invasive Species Programme to clear invasive alien vegetation in protected areas. In Ndumo alone, almost R2 million was spent from 2006 to 2009 to clear 9100 ha of invasive alien vegetation (H. Pretorius pers. comm.). Nineteen invasive alien species have been identified in Ndumo by the Alien Invasive Species Programme, which are being targeted during clearing. If these efforts are effective, browse suitability and quality should increase as these low quality and rejected species are eradicated.

Conclusion

Browse availability and suitability estimates cannot be interpreted independently. Ndumo scored a higher than average browse availability estimate, but the quality of this abundant browse is low, and will be limiting to the black rhino population. Even though black rhino have a high dietary diversity and have a higher tolerance to low quality food, high quality food, and enough of it, is imperative to ensure a healthy population recruitment rate (Buk & Knight 2010).

Conversely to what Muya & Oguge (200) found, Ganqa *et al.* (2005) found that the most abundant plant species are not necessarily highly utilized and that the most utilized plants are often less available. In addition, Buk & Knight (2010) confirmed that black rhino are selective browsers, with only three plant species contributing more than 65% of their diet. This study showed that nearly half (43%) of the available browse in Ndumo is of low quality and should be rejected by black rhino and most other browsers. This means that they have to actively forage more for preferred browse, expending more energy and time on browsing and less on recruitment. Diet overlap with other species, for example nyala, could further reduce the carrying capacity of the vegetation in Ndumo as they are all competing for the less available high quality browse, especially during the winter.

If effective, the alien plant clearing programme should help alleviate the poor browse conditions by controlling and eradicating the low quality invasive alien species. Follow up treatments, removing regrowth in areas originally cleared, are essential to ensure that invasive alien plants do not re-sprout from soil-stored seed banks (Marais *et al.* 2004).

References

Adcock, K. (2004). Report on the findings of a survey of browse conditions for black rhino at Ndumu Game Reserve, KwaZulu-Natal, 27–31 April 2004.

Adcock, K. (2006). Visual assessment of black rhino browse availability, version 3.

Apori, S.O., Long, R.J., Castro, F.B. & Orskov, E.R. (2000). Chemical composition and nutritive value of leaves and stems of tropical weed *Chromolaena odorata*. *Grass and Forage Science.* **55**: 77-81.

Bell, R.V.H. (1970). The use of herb layer by grazing ungulates in Serengeti. *Symposium of the British Ecological Society.* **10**: 11–124.

Bell, R.V.H. (1971). A grazing ecosystem in the Serengeti. *Scientific American.* **225**: 86–93.

Brooks, P.M. (2001). Black rhino in the Midlands, Zimbabwe. in Emslie, R. (Ed.) Proceedings of a SADC Rhino Management Group (RMG) workshop on biological management to meet continental and national black rhino conservation goals.

Buk, K.G. & Knight, M.H. (2010). Seasonal diet preferences of black rhinoceros in three arid South African National Parks. *African Journal of Ecology.* **48**: 1064-1075.

Chown, S.L., Spear, D., Lee, J.E. & Shaw, J.D. (2009). Animal introductions to southern systems: lessons for ecology and for policy. *African Zoology.* **44**: 248 – 262.

Day, M.D., Wiley, C.J., Playford, J. & Zalucki, M.P. (2003). Lantana: Current Management Status and Future Prospects. Australian Centre for International Agricultural Research: Canberra 2003.

Du Toit, R.F. (2001). Black rhino in the Midlands, Zimbabwe. in Emslie, R. (Ed.) Proceedings of a SADC Rhino Management Group (RMG) workshop on biological management to meet continental and national black rhino conservation goals.

Emslie, R.H. (1999). The feeding ecology of the black rhinoceros (*Diceros bicornis minor*) in Hluhluwe-Umfolozi Park, with special reference to the probable causes of the Hluhluwe population crash. PhD thesis, University of Stellenbosch, Stellenbosch, South Africa.

Emslie, R.H. & Adcock, K. (1994). Feeding ecology of black rhinoceros. In B.L. Penzhorn, N.P.J. Kriek (eds.). Proceedings of the symposium "Rhinos as game range animals". SAVA Wildlife Group, Onderstepoort, pp. 65-81.

Emslie, R. and Brooks, M. (1999). African Rhino. Status Survey and Conservation Action Plan. IUCN/SSC African Rhino Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK, 92 pp.

EKZNW (2007). Integrated Management Plan: Ndumo Game Reserve, South Africa. Ezemvelo KZN Wildlife, Pietermaritzburg, 70 pp.

EKZNW (2010). EKZNW Invasive Alien Species Programme. Unpublished Report, Ezemvelo KZN Wildlife, Pietermaritzburg.

Ganqa, N.M., Scogins, P.F., Raats, J.G. (2005). Plant factors affecting diet selection by black rhino in the Great Fish River Reserve, South Africa. *South African Journal of Wildlife Research*. **35**: 77-83.

Gartlan, J.S., McKey, D.B.,Waterman, P.G. & Struhsaker, T.T. (1980). A comparative study of the phytochemistry of two African rain-forests. *Biochemical Systematics and Ecology*. **8**: 401–422.

Ghisalberti, E.L. (2000). *Lantana camara* L. (Verbenaceae). *Fitoterapia*. **71**: 467-586.

Global Invasive Species Database (2007). http://www.issg.org/database/species/. Downloaded 28 November 2007.

Goddard, J. (1968). Food preferences of two black rhinoceros populations. *East African Wildlife Journal*. **6**: 1-18.

Higgins, S.I., Richardson, D.M. & Cowling, R.M. (2000). Using a dynamic landscape model for planning the management of alien plant invasions. *Ecological Applications*. **10**: 1833-1848.

Holechek, L.H., Martin, V. & Pieper, R.D. (1982). Botanical composition determination of range herbivore diets: a review. *Journal of Range Management.* **35**: 600–608.

IUCN (2010). IUCN Red List of Threatened Species. Version 2010.1. <www.iucnredlist.org>. Downloaded on 18 March 2010.

Janis, C. (1976). The evolutionary strategy of equidae and the origins of rumen and caecal digestion. *Evolution*. **30**: 757–774.

Kellerman, T.S., Coetzer, J.A.W. & Naude, T.W. (1988). Plant Poisonings and Mycotoxicoses of Livestock in Southern Africa. Oxford University Press, Cape Town.

Lill, J.T. & Marquis, R.J. (2001). The effects of leaf quality on herbivore performance and attack from natural enemies. *Oecologia.* **126**: 418-428.

Loutit, B.D., Louw, G.N. & Seely, M.K. (1987). First approximation of food preferences and the chemical composition of the diet of desert-dwelling black rhinoceros (*Diceros bicornis*). *Madoqua*. **15**: 35-54.

Macdonald, I.A.W. & Jarman, M.L., (1985). Invasive alien plants in the terrestrial ecosystems of Natal, South Africa. Council for Scientific and Industrial Research, South African National Scientific Programmes, Rep. No. 118, 88 pp.

Marais, C., Van Wilgen, B.W. & Stevens, D. (2004). The clearing of invasive alien plants in South Africa: a preliminary assessment of costs and progress. *South African Journal of Science*. **100**: 97-103.

Muya, S.M. & Oguge, N.O. (2000). Effects of browse availability and quality on black rhino (*Dicernos bicornis michaeli* Groves 1967) diet in Nairobi National Park, Kenya. *African Journal of Ecology.* **38**: 62-71.

Oloo, T.W., Brett, R.A. & Young, T.P. (1994). Seasonal variation in feeding ecology of black rhinoceros (*Diceros bicornis* L) in Laikipia, Kenya. *African Journal of Ecology*. **32**: 142–156.

Ross, I.A. (1999). Medicinal plants of the world. Chemical constituents, traditional and modern medical uses. Humana Press, New Jersey.

Slansky, F.J. (1993). Nutritional ecology: the fundamental quest for nutrients. In: Stamp NE, Casey TM (eds) Caterpillars. Ecological and evolutionary constraints on foraging. Chapman and Hall, New York, pp 29–91

Steyn, D.G. (1934). The toxicology of Plants in South Africa. Central News Agency, South Africa.

Tatman, S.C., Stevens-Wood, B. & Smith V.B.T. (2000). Ranging behavior and habitat usage in black rhinoceros, *Diceros bicornis*, in a Kenyan sanctuary. *East African Wildlife Journal*. **38**: 163-172.

Vahrmeijer, J. (1981). Poisonous Plants of Southern Africa That Cause Stock Losses. Tafelberg Publishers, Cape Town.

Van Wilgen, B.W., Richardson, D.M., Le Maitre, D.C., Marais, C. & Magadlela, D. (2001). The economic consequences of alien plant invasions: Examples of impacts and approaches to sustainable management in South Africa. *Environment Development and Sustainability*. **3**:145-168.

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<u>CHAPTER 4</u>: Using a population viability analysis to predict the future of Ndumo's black rhino (*Diceros bicornis minor*) population

Abstract

Population viability analyses (PVA) are useful in predicting future population numbers as well as the probability of extinction or survival. The VORTEX model is highly suitable for modelling black rhino populations and was therefore used in this study. In 2006 the black rhino population in Ndumo Game Reserve was on the brink of extinction, and the decline in rhino numbers since 1994 raised considerable concern. Monitoring of this population has been ineffective due to dense vegetation and the inaccessibility of certain areas. Historical data were collected from Ndumo's archives to compare simulated trends with the observed trends. A sensitivity analysis with different input parameters was done to test the probability of extinction or survival under all possible circumstances. Parameters that impacted negatively on the growth rate of this population were density dependant breeding, a low recruitment rate and a decline in carrying capacity (*K*). The model predicted a 100% chance of survival over 100 years which indicates that even small populations are viable if managed correctly.

Keywords: Black rhino, small populations, population decline, population viability analyses, probability of extinction, VORTEX model.

Introduction

Population viability analysis (PVA) is a methodology for predicting the future fate of wildlife populations based on demographic, environmental and genetic parameters (Shaffer 1981; Gilpin & Soule 1986; Norton 1995), usually with the use of computer simulation. PVA's are widely used in conservation biology to compare management strategies and predict probabilities of extinction for endangered species (Brook *et al.* 1999). Organizations such as the US Fish and Wildlife Service, the World Conservation Union (IUCN) and the Endangered Wildlife Trust (EWT) have used PVA's for a wide variety of species (Boyce 1992; Lacy 1993, Coverdale *et al.* 2006). PVA models are useful to predict the number of individuals in the following year to overcome monitoring problems and to rule out expensive procedures such as aerial counts.

Black rhinoceros (*Diceros bicornis*) are classified as critically endangered on the IUCN red data list (IUCN 2010). One black rhino population in Ndumo Game Reserve, KwaZulu-Natal has gradually declined over the past 15 years from nearly 50 animals in 1988 to only eight in 2006. Monitoring of Ndumo's black rhino since re-introduction has been largely ineffective due to dense vegetation and the inaccessibility of certain areas, resulting in inaccurate population estimates. Models such as the VORTEX model are useful in estimating future population numbers and the probability of extinction or survival of such populations. The VORTEX model was originally designed for vertebrate populations of low fecundity and long life span, so it is highly suitable for modelling black rhino populations, eliminating many of the criticisms around its use (Coulson *et al.* 2001; Lindenmayer *et al.* 2003). The programme incorporates age structure, demographic and environmental stochasticity, density dependence, inbreeding depression, systemic pressures such as habitat decline, catastrophic events and metapopulation structure (Brook *et al.* 1999).

Considerable concern exists over the future of Ndumo's black rhino population and I hypothesized that there is a high probability that it will go extinct in the near future, as it has previously been found that small populations are more susceptible to extinction than larger populations (Gilpin & Soule 1986). I therefore ran several simulations with different input parameters to test the probability of this population going extinct under different conditions and to predict future population estimates.

Methods

STUDY AREA

Ndumo Game Reserve is a small (10 117 ha) reserve established in 1924 as a hippopotamus (*Hippopotamus amphibihius*) sanctuary (EKZNW 2007). The reserve is made up of tropical bush and Lowveld savanna which includes 10 main vegetation formations (Pooley 1978), namely: Riverine forest, Floodplain, Fever tree (*Acacia xanthoploea*) forest, "Pan-edge" communities, Sand forest, *Acacia tortilis* woodland, Mahemane thicket, Deciduous broad-leaf woodland, *Acacia nigrescens* woodland and

Open woodland. It is situated at the confluence between the Usuthu and Pongola Rivers on the Mozambique coastal plain (26º 52'S and 32º 15'E). In summer the climate is hot and humid, and warm and dry in winter, with a mean annual rainfall of 630 mm. Approximately 4% of the reserve is open water, pans and rivers (Conway & Goodman 1989). Ndumo was proclaimed as a RAMSAR wetlands site in 1997. The reserve is fenced in the west, south and east, but the Usuthu River forms the northern boundary between South Africa and Mozambique and is not fenced.

SIMULATION INPUT

To test the extinction hypothesis I used the VORTEX model (version 9.99b) which takes a stochastic approach to modelling population extinction, while the causes of stochasticity can be divided into demographic and environmental (May 1974; Lande 1993). Deterministic projections assume no stochastic fluctuations, no inbreeding depression, no limitation of mates, no harvest, and no supplementation. Therefore only stochastic projections were examined in this study. Several simulations with different input parameters were run. The first simulation was run as far as possible with data and trends as actually observed in Ndumo since 1988. Where necessary default options were taken or data from populations elsewhere were examined to aid where there was a lack of data for Ndumo.

This first simulation was labelled "true dynamics". The input parameters were as follows: 20 iterations were run over a temporal scale of 100 years, with extinction defined as less than two animals surviving. The simulation's population started with 47 individuals (population estimate in 1988, Thornhill 1989), just under the carrying capacity (*k*) which was set at 50 individuals for simulation purposes. The exact carrying capacity at that time is unknown, but as 47 rhino was the highest number this population ever reached it is safe to say the population had to be close to carrying capacity. The reproductive rate was set at 35%, as noted previously in other healthy growing populations (Adcock 2004). Although the reproductive rate will decrease as a population reaches carrying capacity, a large removal was made in 1989 which should have stimulated population growth again. Mortality rates were set at 3% for each age class and simulations were run without density dependence having any effect on reproduction. The age of first offspring for both males and females was set at 7 years, with the maximum age of reproduction at 40 years. From 1988 to 2003, 23 animals were removed from Ndumo and relocated elsewhere. To simulate these removals three harvests were added with eight animals taken off each time. No re-introductions were made from 1988 to 2007, but in December 2008 five black rhino were re-introduced into the population. However, to test whether the population would have survived without this introduction the supplementation parameter was kept at zero, and a new simulation was run during the sensitivity analysis to examine the probability of extinction after the population was supplemented.

I performed sensitivity analyses with the same input parameters as the "true dynamics" simulation, but changing a different parameter each time (Table 4.1) in order to determine which parameters best fit the current situation. In the density dependent simulation 40% of the population's females will successfully reproduce at low population densities, but at carrying capacity only 20% will reproduce. Flooding was added in another simulation as a catastrophe to simulate the flood that took place in Ndumo in 2001. Although it is difficult to accurately predict the reproductive rate during years of catastrophes, the reproductive rate for females during catastrophes was set at 15%, less than half of the 35% in normal years for healthy growing populations.

Simulations were also run to predict the probability of extinction after 2009, therefore the population size was set at 14 animals. No harvesting took place during this simulation and no future change in carrying capacity was set. The temporal scale was set at 100 years. The rest of the parameters were the same as the true dynamics simulation. A second simulation was run without the introduction of five animals in 2008, hence a starting population of nine. The last simulation was run to test the outcome of applying the current KZN Black Rhino Management Strategy (Brooks *et al.* 2002), whereby 5 - 8% of the population is removed annually.

Results

The results from the VORTEX simulations are displayed in Table 4.2. The simulations showed mean growth rate was highest for the simulation run with 70% of adult females breeding ($r = 0.092$) and 50% of adult females breeding ($r = 0.070$). A negative change in carrying capacity had the lowest (26) mean final population, whilst density dependence (r = 0.018) and 20% of adult females breeding (r = 0.016) had the lowest growth rates.

Table 4.1 Different input parameters simulated with the VORTEX model to test the probability of extinction or survival of Ndumo's black rhinoceros population.

Parameter	**Initial value (True dynamics simulation)**	**New value**	**Simulation name**
Initial population size	47	30	SSP
		80	LSP
		9	2009 NI
		14	2009 Intro
No. of iterations	20	500	MI
No. of catastrophes	0	1	Flood
% Adult females breeding	35	20	20% B
		50	50% B
		70	70% B
Density dependence	No	Yes	DDB
Carrying capacity (*K*)	50	80	LSP
Future change in *K*	None	-5% annually over 7 years	CIK
Harvesting	3 times 8	0	NH
		3 every 3 years	H 5%
		1 every 3 years	2009 H5
Introductions	0	2 every 5 years	2 Intro
	0	5	RI
	0	5	2009 Intro

SSP = Smaller starting population, LSP = Larger starting population, MI = More iterations, Flood = Flooding added as catastrophe, 100yrs = True dynamics run over 100 years, CIK = Change in K, 20% B = 20% of adult females breeding, 50% B = 50% of adult females breeding, 70% B = 70% of adult females breeding, DDB = Density dependent breeding, H 5% = Harvest 5% every 3 years, 2 Intro = 2 Introductions every 5 years, NH = No harvests, 2009NI = predictions after 2009 without recent introductions, 2009 Intro = Predictions after 2009 with recent introductions, RI = True dynamics with recent introductions, 2009 H5 = Harvesting 5% every 3 years after 2009.

Table 4.2 Results from the VORTEX model on the probability of extinction or survival of Ndumo's black rhinoceros population.

Simulation name	Mean growth rate (r)	Probability of extinction	Mean time to first extinction	Mean final population
True dynamics	0.048	0%	NA	47
RI	0.052	0%	NA	45
MI	0.049	0%	NA	46
LSP	0.050	0%	NA	47
SSP	0.043	0%	NA	47
2 Intro	0.055	0%	NA	46
DDB	0.018	0%	NA	44
NH	0.054	0%	NA	45
H 5%	0.048	0%	NA	44
20% B	0.016	0%	NA	42
50% B	0.070	0%	NA	46
70% B	0.092	0%	NA	47
CIK	0.044	0%	NA	26
Flood	0.042	0%	NA	43
2009NI	0.054	0%	NA	47
2009 Intro	0.058	0%	NA	47
2009 H5	0.035	5%	82	43

SSP = Smaller starting population, LSP = Larger starting population, MI = More iterations, Flood = 1 type of catastrophe, 100yrs = True dynamics run over 100 years, CIK = Change in K, 20% B = 20% of *adult females breeding, 50% B = 50% of adult females breeding, 70% B = 70% of adult females breeding, DDB = Density dependent breeding, H 5% = Harvest 5% every 3 years, 2 Intro = 2 Introductions every 5 years, NH = No harvests, 2009NI = predictions after 2009 without recent introductions, 2009 Intro = Predictions after 2009 with recent introductions, RI = True dynamics with recent introductions, 2009 H5 = Harvesting 5% every 3 years after 2009.*

The "true dynamics" simulation predicted that this population, as it was in 1988, will survive in the short term and even has a 100% chance of survival after 100 years. The VORTEX model's predicted trends are however not in accordance with the observed trends in Ndumo (Fig. 4.1). The model predicted that the population will fluctuate between 40 and 50 individuals, just under carrying capacity (50), whereas the real population gradually declined until only nine individuals were left in 2007.

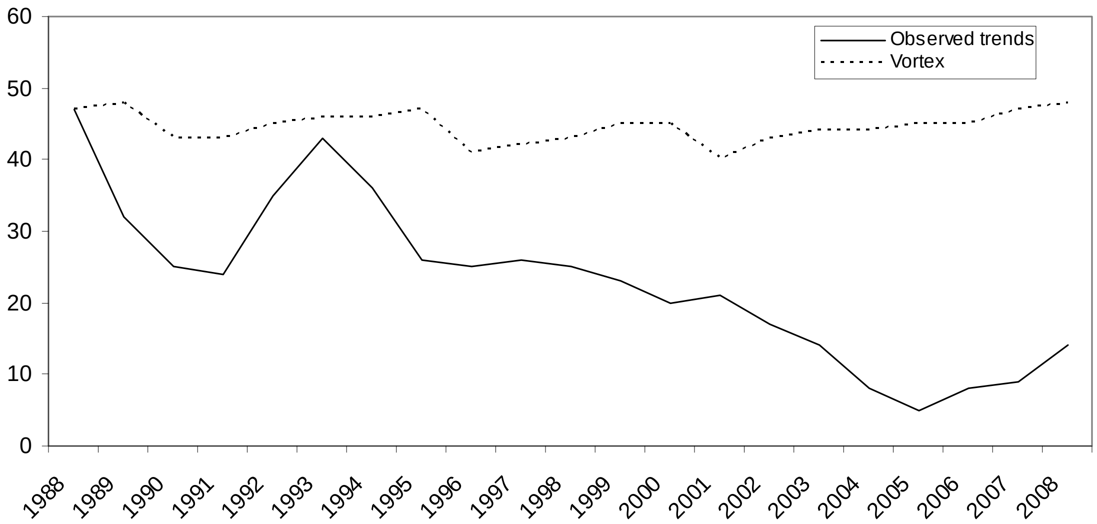

Figure 4.1 Predicted trends by the VORTEX model compared to actual observed trends in Ndumo Game Reserve.

The stable population, fluctuating just below carrying capacity (50), is also predicted by most other simulations (Fig. 4.2). Although a negative change in carrying capacity brought about a drop in numbers, the population did not keep declining as seen in Ndumo (Fig. 4.1) and still had a positive growth rate (r = 0.044).

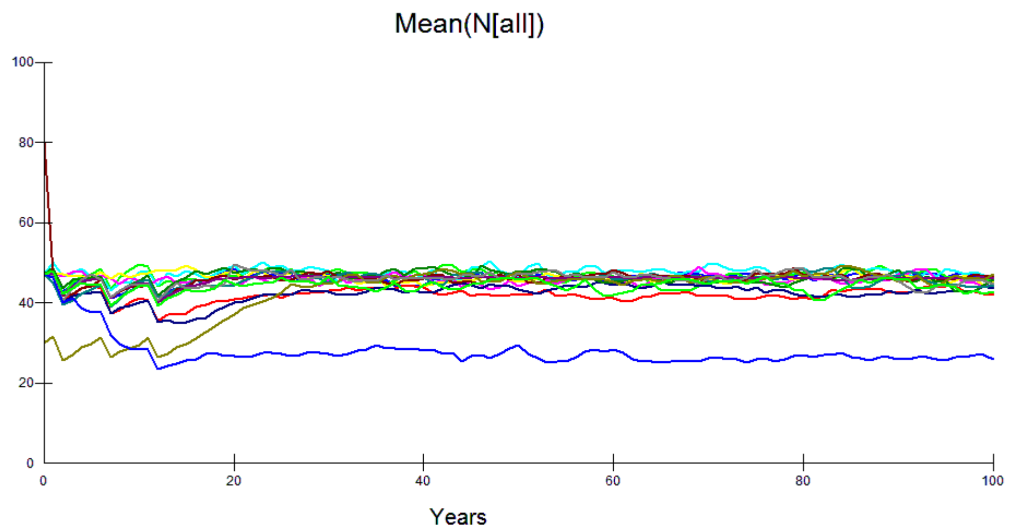

Figure 4.2 Most simulations predict a stable population fluctuating just under carrying capacity.

Simulations after 2009 predict that this population will increase in numbers until it reaches carrying capacity, which was set at 50 individuals (Fig. 4.3). As expected, the simulation with the introduction of five rhino had a slightly higher growth rate (r = 0.058) than the simulation without the introduction (r = 0.054). Both simulations had a mean final population of 47 however. Although applying the removal strategy of 5% every three years predicted a 5% chance of extinction, it still had a positive growth rate (r = 0.035), with a mean final population of 43 individuals.

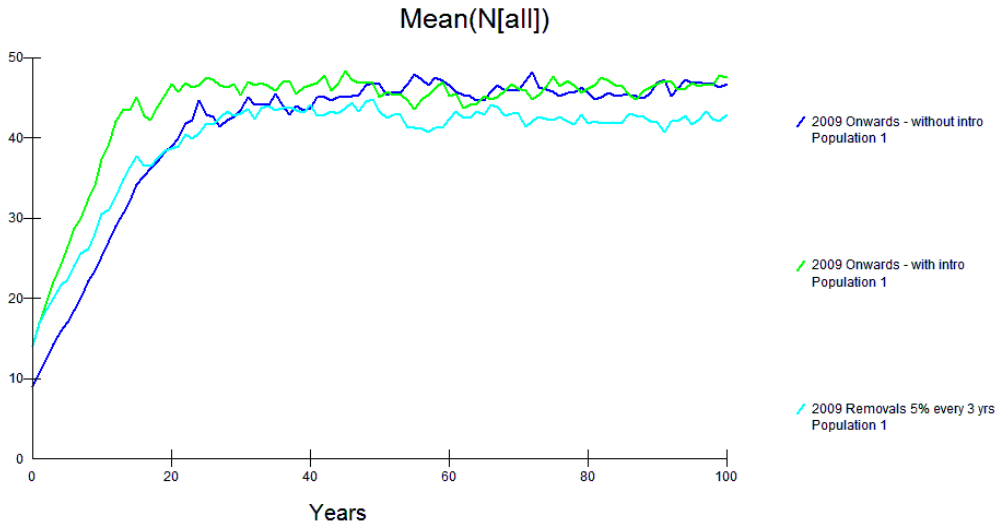

Figure 4.3 Predicted trends by the VORTEX model after 2009.

Discussion

The successful use of the VORTEX model in predicting future population numbers has undoubtedly been demonstrated previously (Clark *et al.* 1991; Brook *et al.* 1999). However, the true dynamics simulation run during this study did not correctly fit the observed trends in Ndumo and simulation results are contrary to what was expected, as the model predicted a high probability of survival, even with most of the sensitivity analyses. This suggests that there might be other issues not identified in this study, and that not one parameter alone could have accounted for the decline. It is highly likely that a combination of several parameters or events, over time, is accountable.

One might argue that 100 years is relatively short when examining the possibility of a species or population going extinct, especially animals with a long life-span such as black rhino (Armbruster *et al*. 1999). However, the population has declined by more than 80% in 15 years, and a large proportion of the remaining animals (6 of the 14) are very old (F-class) (Table 2.1), some possibly near post reproductive age. Several hypotheses trying to explain this drastic decline exists (see Chapter 2). The population was therefore already on the brink of extinction before the recent introductions in 2008 and the possibility of it going extinct within the next 100 years had to be investigated.

Density dependence (r = 0.018) and only 20% of adult females breeding (r = 0.016) accounted for the lowest growth rates, although they still predicted a relatively large (44 and 42 respectively) mean final population after 100 years. However, if another event had to impact negatively on this population in combination with these two parameters, the low growth rate would not be able to sustain this population and it will start declining.

Although a negative change in carrying capacity had a relatively high growth rate (r = 0.044), it would seem that this parameter is the most limiting, as population numbers cannot exceed carrying capacity in the VORTEX model. Even though this simulation had a zero per cent chance of extinction, its mean final population was significantly lower than other parameter simulations (26) and best fits the observed population trends in Ndumo. The carrying capacity in Ndumo has recently (2004) been estimated at 11 rhino (Adcock 2004), whereas the current (2010) population total is 14. Even though the accuracy of this carrying capacity estimate can be debated, it clearly illustrates that there has been a significant reduction in carrying capacity since 1988 when the reserve was home to nearly 50 rhino. The population estimate in 2008 before the introduction of five animals is only 20% of what the population used to be in 1988. Or, in other words, there has been an 80% decline in population numbers. If this is a reflection of carrying capacity alone, it means that there has been an 80% decline in carrying capacity since 1988. It is however unlikely that carrying capacity has declined by 80% within 20 years and alone accounted for the decline in black rhino numbers.

Ezemvelo KZN Wildlife's strategy for the management of black rhino (Brooks *et al*. 2002) prescribes that 5 - 8% of a population at or around carrying capacity should be removed annually, or every second or third year in the case of smaller populations. This is done to keep the source population in a reproductive state, and to establish new populations in new conservation areas. In theory, removing animals from a population close to carrying capacity will obviously result in an immediate drop in numbers, but this will stimulate growth as the population is now below carrying capacity. The VORTEX model predicted that applying the 5% harvesting strategy to this population after 1988 would have no significant impact, as the growth rate (r = 0.048) and mean final population (44) were not significantly lower than the simulation run with no harvests (r =

0.054, mean final population of 45). But applying the same harvesting strategy to the population after 2009 resulted in a lower growth rate (r = 0.035) with a 5% chance of this population going extinct within the next 82 years. These results suggest that there is a small risk in applying the 5% harvesting rate to a smaller starting population.

The VORTEX model predicts that this presently small population will show a positive growth rate and increase in numbers until it nearly reaches carrying capacity (Fig. 4.3), which was set at 50 for this simulation. This is however assuming that there has not been a reduction in carrying capacity, or any other negative impacts such as harvesting, natural catastrophes, density dependence etc.

Conclusion

The predicted trends by the VORTEX model compared to actual observed trends in Ndumo (Fig. 4.1) suggests that there are other unknown factors that have been overlooked in this study. The results from the VORTEX model indicate that relatively small populations are viable if managed correctly. The VORTEX model was useful in this particular study to identify factors which could possibly have played a role in the population decline, and to predict future population estimates. The 100% chance of survival predicted by the model for most simulations greatly assists conservation managers in the management decision processes. We recommend that no harvesting be applied to this population until numbers exceed a minimum of 20 individuals. A formal carrying capacity estimation needs to be obtained. I also strongly recommend the use of PVA models such as VORTEX before expensive management procedures are carried out.

References

Adcock, K. (2004). Report on the findings of a survey of browse conditions for black rhino at Ndumu Game Reserve, KwaZulu-Natal, 27–31 April 2004.

Armbruster, P., Fernando, P. & Lande, R. (1999). Time frames for population viability analysis of species with long generations: an example with Asian elephants. *Animal Conservation*. **2**: 69-73.

Boyce, M.S. 1992. Population viability analysis. *Annual Review of Ecology and Systematics*. **23**: 481-506.

Brook, B.W., Cannon, J.R., Lacy, R.C., Mirande, C. & Frankham, R. (1999). Comparison of the population viability packages GAPPS, INMAT, RAMAS and VORTEX for the whooping crane (*Grus Americana*). *Animal Conservation*. **2**: 23-32.

Brooks, M., Conway, A.J., Balfour, D., Goodman, P., Rushworth, I., Potter, D., Cooke, M., & Hartley, P. (2002). Ezemvelo KZN Wildlife Strategy for Biological Management of Black Rhino (*Diceros bicornis minor*) in Kwazulu-Natal. Unpublished. Ezemvelo KZN Wildlife, Pietermaritzburg.

Clark, T.W., Bachouse, G.N., & Lacy, R.C. (1991). Report of a workshop on population viability assessment as a tool for threatened species management and conservation. *Australian Journal of Zoology*. **27**: 28-35.

Coulson, T., Mace, G.M., Hudson, E. & Possingham, H. (2001). The use and abuse of population viability analysis. *Trends in Ecology and Evolution*. **16**: 219-221.

Coverdale, B., Daly, B., Friedman, Y., Lemmer, F., Marchant, A., McCann, K., Rushworth, I. & Wakelin, J. (Eds.) (2006). Oribi antelope (*Ourebia ourebi*) Population and Habitat Viability Assessment Workshop Report. Conservation Breeding Specialist Group (SSC / IUCN) / CBSG Southern Africa. Endangered Wildlife Trust, Johannesburg.

Gilpin, M.E. & Soule, M.E. (1986). Minimum viable populations: processes of extinction. In Conservation biology: the science of scarcity and diversity. 19-34. Soule, M.E. (Ed.). Sunderland , MA: Sinnauer Associates, Massachusetts.

IUCN (2010). IUCN Red List of Threatened Species. Version 2010.1. <www.iucnredlist.org>. Downloaded on 18 March 2010.

Lacy, R.C. (1993). VORTEX – a model for use in population viability analysis. *Wildlife Research.* **20**: 45-65.

Lande, R. (1993). Risks of population extinction from demographic and environmental stochasticity and random catastrophes. *American Naturalist.* **142**: 911-927.

Lindemayer, D.B., Possingham, H.P., Lacy, R.C., McCarthy, M.A. & Pope, M.I. (2003). How accurate are population models? Lessons from landscape-scale tests in a fragmented system. *Ecology Letters*. **6**: 41-47.

May, R.M. (1974). Stability and complexity in model ecosystems, 2nd edition. Princeton University Press, Princeton.

Norton, T.W. (ED.) (1995). Special issue: applications of population viability analysis to biodiversity conservation. *Biological conservation.* **73**: 91-176.

Shaffer, M.L. (1981). Minimum viable population sizes for species conservation. *Bioscience.* **31**: 131-134.

Thornhill, H. (1989). Ndumo Black Rhino Monitoring, Unpublished Natal Parks Board report. Pietermaritzburg.

CHAPTER 5: Summary and conclusion

The results from this study consisting of a historical review, a browse assessment and a population viability assessment were used to determine factors or events which may have contributed to the decline in black rhino (*Diceros bicornis minor*) numbers in Ndumo. Several factors and events were identified during this study, but it is highly unlikely that any of these on their own can be held accountable for the decline. Rather, it would seem that a combination of several factors, over time, accounted for the population decline.

Firstly, it was hypothesized that a change in the natural habitat and a resulting reduction in carrying capacity contributed towards the decline (Adcock 2004). Results obtained during this study seem to support this theory. Historical records indicate that Ndumo had a high carrying capacity and was able to sustain more than 40 black rhino for a number of years (1980's to 1994). The most recent formal carrying capacity estimate for Ndumo is 11 rhino (Adcock 2004), which on its own clearly illustrates that there has been a massive reduction in carrying capacity. In addition, the recent browse survey results showed that although there is presently (2008) enough browse, the quality of this browse is very low and would not be able to sustain high numbers of browsers. Simulating a negative change in carrying capacity during the PVA analysis obtained a similar decline in black rhino numbers, although not as drastic as seen in Ndumo, but a steady decline in numbers nonetheless (Fig. 4.2, Chapter 4). The decreasing carrying capacity and change in natural habitat might have been brought about by very high nyala (*Nyala angasi*) and impala (*Aepyceros melampus*), densities in earlier years, resulting in increased bush thickening. The high abundance of invasive alien plant species also impact negatively on browse quality and hence carrying capacity. The change in the Usuthu River course since the flooding in 2000 affected the social structure and recruitment of black rhino in Ndumo, as it limits the movement of rhino between the main part of the reserve and the "island" north of the Usuthu River.

Competition with other herbivores, namely nyala and impala, has also been hypothesized as a potential contributor to the black rhino population decline (Adcock 2004). The historical records show that nyala numbers have been excessively high in previous years (7000 in 1992), and that impala biomass has increased substantially parallel to the black rhino biomass decline (Fig. 2.4, Chapter 2). Buk & Knight (2010) confirmed that black rhino are selective browsers, with only three plant species contributing more than 65% of their diet. In addition, Ganqa *et al.* (2005) found that the most abundant plant species are not necessarily highly utilized and that the most utilized plants were less available. Diet overlap with other species, in this instance up to 7000 nyala in some years, would have been a limiting factor to population growth. On top of this competition with other browsers is the low browse quality, partly due to the most abundant plant species in Ndumo being of low quality and not preferred by black rhino (Table 3.2, Chapter 3), with two invasive alien species in the top four most abundant. This means that the black rhino population will have to compete with other browser species for the less abundant high quality browse, actively forage more and spend more energy and time on foraging rather than on reproduction.

Results from the literature review also show that too many removals at the wrong time have further decreased the population growth rate. Although the population recovered well after the first removal of 10 rhino in 1989 and showed a positive growth rate afterwards, the gradual decline in numbers seemed to have started after the second removal of 10 rhino in 1994 (Fig. 2.1, Chapter 2). Furthermore, the removals made in 2002 and 2003 were made at a time when this population was already in trouble and low in numbers, and only pushed the population closer to the brink of extinction. It would seem that the decision to remove so many rhino at that time was made with inaccurate population estimates.

Although poaching of rhino in Ndumo has not been of any concern historically, the recent (2010-2011) increase in rhino poaching in southern Africa is of major concern. With the northern boundary of Ndumo not fenced, the losing of rhino either through poaching by Mozambique poachers or through natural dispersion across this boundary remains a concern. Furthermore, the dispute over a land claim with a local community on the eastern boundary of Ndumo also poses a serious threat as poaching and setting of snares throughout the park, but more so in the eastern parts of the reserve, have increased dramatically since then (F. Myburgh pers. comm.). It is imperative that reserve management address these risks by any means possible.

This study assisted not only the managers of Ndumo Game Reserve, but also managers with black rhino populations elsewhere in identifying similar threats, and addressing them before they adversely affect their black rhino populations. The PVA analysis predicted that if managed effectively, this population is viable in the long term and can still contribute to metapopulation growth. I would therefore like to make several recommendations to the management of Ndumo to better manage this small but important black rhino population:

1. Undertake a formal black rhino carrying capacity estimation which takes into account the results from this study.
2. Increase rhino patrol and monitoring effort in the reserve. It is essential to have accurate information on the status of this population at all times.
3. Implement an effective invasive alien plant clearing programme to help alleviate the poor browse conditions.
4. Keep competition with other browsers low by preventing the nyala and impala populations to reach uncontrollably high numbers.
5. Examine range expansion possibilities into Usuthu Gorge.
6. Determine whether predation by hyena has any effect on the black rhino population.
7. Refrain from harvesting any black rhino until the population reaches 20 individuals or more.
8. Repeat the browse assessment every 5 years to detect any possible changes in browse conditions.
9. Undertake a study to determine the exact diet selection of the current population.

References

Adcock, K. (2004). Report on the findings of a survey of browse conditions for black rhino at Ndumu Game Reserve, KwaZulu-Natal, 27–31 April 2004.

Buk, K.G. & Knight, M.H. (2010). Seasonal diet preferences of black rhinoceros in three arid South African National Parks. *African Journal of Ecology*. 48: 1064-1075.

Ganqa, N.M., Scogins, P.F. & Raats, J.G. (2005). Plant factors affecting diet selection by black rhino in the Great Fish River Reserve, South Africa. *South African Journal of Wildlife Research*. **35**: 77-83.

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