BROWSE ASSESSMENT AND CARRYING CAPACITY OF THE BLACK RHINO SANCTUARY IN NORTH LUANGWA NATIONAL PARK, ZAMBIA

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Executive summary

The aim of this report was to assess the browse availability, suitability and overall quality for black rhino within different vegetation types in the original sanctuary in North Luangwa National Park (NLNP) created in 2003 to hold five black rhino translocated to Zambia from South Africa (Figure 1). This data was compared with values previously recorded for the sanctuaries added in 2006 and 2008 for further rhino translocations and the new sanctuary designed for the planned 2010 rhino translocation to assess the impact of restricted browsing by rhino and other herbivores, particularly elephant, on black rhino habitat quality in the old sanctuary. Information on habitat quality was then combined with data on rainfall, soil type and fire frequency in this area to estimate the current carrying capacity for black rhino within the sanctuaries using the RMG Black Rhino Carrying Capacity model.

Data was collected from 128 samples sites (97 in the old sanctuary, 31 in the new sanctuary) during October 2009 using the visual browse assessment technique. Adjustments were later made to woody plant cover estimates to counteract the underestimates caused by low leaf retention at this time of year. The vegetation map produced from LandSat imagery during an earlier study was updated using ground-truthed information from this study to increase accuracy of the map within the old sanctuary area.

The trend for all vegetation types was for overall browse quality to be greater in the new sanctuary than in the top sanctuary and for these both to be greater than the old sanctuary. This suggests that restricted browsing may be having a negative impact on browse quality for black rhino. Elephant damage ratings on woody plant species were markedly greater on woody plant species within the old sanctuary than within the unfenced new sanctuary.

Miombo scrub and alluvial thicket were found to be highest quality vegetation types for black rhino in NLNP and mopane scrub the lowest, based on browse availability and suitability. Rhino were found to select for alluvial thicket and valley riverine vegetation types and to avoid mopane scrub areas. It is suggested that the lower than predicted use of miombo scrub vegetation type by rhino could be related to high elephant densities in this habitat type. The results of this study indicate that rhinos are more selective in habitat use in the dry season and this could be related to their attempts to find high quality browse to satisfy nutritional requirements during this critical time of year. Movements at this time of year could also be more severely impacted by water requirements. The lower than predicted use of the miombo scrub vegetation type by black rhino means that the actual number of rhino that can be supported may be over-estimated in these carrying capacity calculations.

The findings of this study suggest that the number of rhino within the current sanctuaries in NLNP have exceeded carrying capacity. Rhino numbers in the old and middle sanctuaries are approaching the estimated carrying capacities and have exceeded the maximum productivity carrying capacity (75% estimated carrying capacity) recommended for rhino populations by the IUCN AfRSG. It is recommended that urgent management action be taken to ensure the long-term availability of sufficient suitable habitat to allow continued growth and expansion of the NLNP black rhino population in line with the Rhino Conservation Plan for Zambia.

Objectives;

A.1 Assess the total browse availability within different vegetation types in the old sanctuary and compare with values for top and new sanctuaries.

A.2 Determine current browse quality in the old sanctuary and compare with top and new sanctuary.

A.3 Estimate current carrying capacity for black rhino within the sanctuaries.

Introduction

The aim of this report was to calculate the current estimated carrying capacity for black rhino in the old NLNP sanctuary (Figure 1). The original sanctuary (referred to in this report as the "old sanctuary" was created in 2003 to hold five black rhino translocated to Zambia from South Africa. This data was compared with values previously recorded for the sanctuaries added for 2006 and 2008 rhino translocations (referred to as "middle sanctuary" and "top sanctuary") and the planned 2010 rhino translocation (referred to as "new sanctuary").

Estimates of predicted carrying capacity for this site were made by a number of black rhino ecologists from the IUCN African Rhino Specialist Group (AfRSG) prior to the rhino re-introductions. The ecological carrying capacity (ECC) of an area is the maximum number of animals that can be supported in that area by its natural resources in the long term, whereas the maximum productivity carrying capacity (MPCC) which is approximately 75 % of ECC is the density at which the growth rate of the population is maximised. Black rhino populations are advised by the IUCN AfRSG to be maintained at MPCC to maximise population growth and therefore, species recovery.

Dunham (2001) proposed that a figure of 0.1 rhinos per km^2 be used as the stocking rate for re-introduction to NLNP, emphasising that this low figure was chosen to eliminate any danger that rhinos within a fenced area become over-stocked. Adcock (2003) used the RMG black rhino carrying capacity model to calculate an estimated carrying capacity of 0.33 rhino per km^2 or 0.25 rhino per km^2 at maximum productive density. However, her gut feel was a lower estimate of around 0.20 rhino per km^2 or 0.15 per km^2 at maximum productive density. Raoul du Toit estimated that the ecological carrying capacity for this area should be approximately 0.18 rhino per km^2, which translates to 0.13 rhino per km^2 at maximum productive density (Adcock, 2003).

Since re-introduction, research has been carried out into the diet content and browse preferences of the rhino re-introduced to this area from South Africa (Brown and van der Westhuizen, 2004; Brown, 2005) and rhino browse has been recorded by ZAWA staff during rhino monitoring exercises. This enhanced understanding of plant acceptability and rhino dietary content allows more accurate predictions to be made on the carrying capacity of habitats within NLNP for black rhino based on their actual foraging behaviour.

In February 2008 an assessment was made of browse quality and availability within the top sanctuary (Adcock, 2008). Adcock *et al*. (2008) found that the overall proportion of suitable browse was markedly low although cover was generally good. The MPCC for the 70.66 km^2 area was 0.077 rhino per km^2 for recently re-introduced animals or 0.102 rhino per km^2 for adapted

animals. Subsequently, a new sanctuary was required for the final five animals to arrive in May 2010. The area to the east of the old sanctuary was surveyed and a new sanctuary was designed with the aim of including as much of the more favourable vegetation types as possible. The MPCC of this area was initially estimated at 0.071 rhino per km^2 or 0.119 rhino per km^2 for adapted animals.

The carrying capacity of an area for black rhino is not fixed but fluctuates in response to habitat changes linked to browsing impact, changes in fire regime and seasonal oscillations in rainfall. This is a particularly pertinent issue in fenced populations where browsing pressure from rhino and other herbivores, particularly elephant, can have a negative impact on both the volume of browse available and the species composition or browse suitability for black rhino.

As the fenced sanctuaries in NLNP were created at different times (old, 2003; middle, 2006; top, 2006 (split with intermediate fence in 2007); new, unfenced to date) they provide an opportunity to assess the impact of restricted elephant and rhino feeding on browse availability and suitability for black rhino. For example in Kenya, the 62 km^2 Ngulia rhino sanctuary in Tsavo West NP became overstocked with black rhino and other competing browsers due to lack of management action relating to animal density. The degradation of resources within the sanctuary reached the point where drought conditions could have not only reduced the future productivity of the area for some decades, but also jeopardised the survival of the rhinos themselves (Brett and Adcock, 2002). Routine re-assessment of carrying capacity over time is therefore needed to optimize black rhino management as exceeding the carrying capacity of an area can cause degradation of its natural resources and might negatively affect the future survival and growth rate of rhino populations and require management action.

Methods

Study site

NLNP is situated in the Northern part of the Luangwa valley in the Mpika district of the Northern Province of Zambia. The park covers a total area of 4,636 km^2, (latitude S 11°25 to 12°20, longitude E 31°45 to 32°40) with the Luangwa River forming the eastern boundary and the western boundary running along the Muchinga escarpment. The rhino sanctuaries are located in the centre of the park within the foothills of the escarpment and are bisected by the perennial Lubanga River (Figure 1). Average annual rainfall is between 700-900mm, with the wet season extending from November to April. Soil types range from the deep, red sandy loams of the upper escarpment to the alluvial sands and clays of the Luangwa floodplain (Astle *et al*., 1969 in Smith, 1998).

A.1. Browse availability

Total browse availability was assessed at 97 sites in the old sanctuary (Figure 2a) using the visual browse assessment method (Adcock, 2006a) between 19th-28th October 2009. This technique correlates with the actual biomass of potential black rhino browse based on the relationship between the canopy dimensions of a plant and the weight of browsable material on that plant.

Sample sites were selected using random stratification between vegetation types using the vegetation map previously produced from ground-truthing LANDSAT images using browse availability data from the new sanctuary (Shaw *et al*., 2008). As initial sites showed that this map was not extrapolating correctly to the old sanctuary area, additional plots were added where necessary to record the scale of vegetation change observed on the ground. Sixteen new sites were recorded in the new sanctuary to ground-truth the accuracy of the vegetation map created in 2008 for this area (Figure 2b). The new sanctuary survey was undertaken 29-30th October 2009.

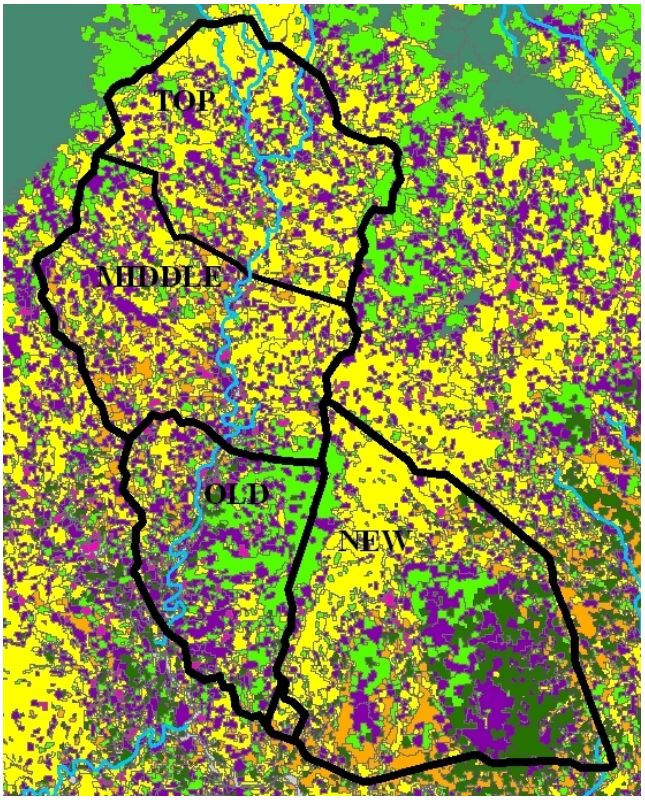
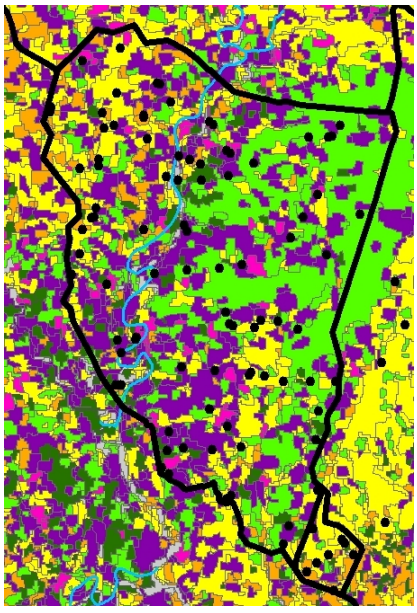


Figure 1. Location of black rhino sanctuaries in North Luangwa National Park. Intermediate fence between old and middle sanctuaries was removed in March 2009; the fence between the middle and top sanctuaries was removed in July 2009.

a) 

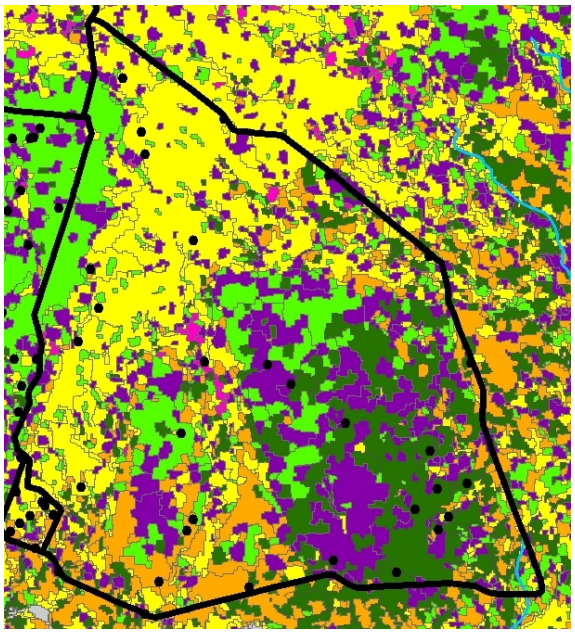
b) 

Figure 2. Sample sites for browse assessments recorded in the a) old sanctuary and b) new sanctuary areas.

It is recommended that browse assessment surveys are conducted during the late wet – early dry season to aid plant identification and allow accurate estimates of total cover and hence browse availability (Adcock, 2006b). Logistical constraints required this study to be carried out at the end of the dry season 2009, when plant leaf retention and hence cover were extremely low. Therefore, repeat sample plots were made in each vegetation type in the area which will form the new sanctuary (fifteen in total) and data from October 2009 was compared to that from April 2008 (Shaw *et al*., 2008).

Six vegetation types were identified in the sanctuaries on the ground in line with earlier studies by Brown and van der Westhuisen (2005) and Smith (1998) and those detected using TWINSPAN analysis during an earlier study (Shaw *et al*., 2008). The vegetation map for the entire area was updated using the 97 sites from the new sanctuary and 164 sites in the old sanctuary. This was from Landsat imagery using NDVI data as described in Shaw *et al*. (2008).

A.2. Browse suitability

Plant species composition in sample sites was recorded by listing all plant species and then ranking species abundance against each other. Scores for a plot were summed and rescaled to give species proportional browse compositions. Plant species were then categorised according to their suitability as rhino browse;

Rating 1 = highly palatable/preferred relative to availability;
Rating 2 = not clearly preferred/rejected, may be important seasonally;
Rating 3 = rejected relative to availability.

The total browse availability measure is for all plant species and so contains the sum of all ratings (i.e. 1, 2 and 3); however, suitable browse consists of only those with rating 1 or 2. The suitability rating of plant species followed the data in Adcock (2008) with additional information from Brown and van der Westhuizen (2005) and Elias Chiweshe (*pers. comm.*). Any signs of rhino browsing within sample sites or detected when walking between sites were also recorded using the Walker scale (0:0, 1:1-10%, 2:11-25%, 3:26-50%, 4:51-75%, 5:76-90%, 6:90-100%, 7:dead) to estimate proportional impact on each plant species add to information on black rhino diet content in this area. At each sample site, an estimate of the impact of elephant browsing on each plant species was also recorded utilising on the Walker scale to allow comparison of this factor between sanctuaries.

Data on browse availability and browse suitability for each sample site were combined to give an overall measure of browse quality. This data was then combined for all sample sites in each vegetation type to give an overall average estimate. The measures of browse availability, suitability and overall quality recorded in each vegetation type in the old sanctuary during this survey were compared with data previously recorded from the top sanctuary (Adcock *et al*., 2008) and the new sanctuary (Shaw *et al*., 2008) to assess the potential impact of different rhino and elephant densities over different periods of time.

Data on rhino sightings within the sanctuaries at NLNP were used to test whether these estimates of the value of different vegetation types to rhino were related to actual rhino preference. All sightings of individual rhino from introduction to date were intersected with the new vegetation map to give a measure of use of the different vegetation types. This was related to the proportion of different vegetation types available to each rhino in the different sanctuaries. The data for individual rhino was combined to produce an average value of rhino preference which was correlated with estimates of browse quality for each vegetation type (total sightings = 1618; no. rhinos = 19; individual sighting no's: 17-247).

A.3. Carrying capacity

The current black rhino carrying capacity for the old sanctuary was calculated using Adcock's (2006a) black rhino carrying capacity model based on browse quality data as described above and scaled to actual proportions of habitat types within the sanctuary. Additional data on rainfall, soil type and fire was as detailed in Shaw *et al*. (2008). A rough estimate of likely carrying capacity for the middle sanctuary was made using data on browse quality of vegetation types from the old sanctuary rescaled to actual proportions of vegetation types in this area. Data for the top sanctuary was taken from Adcock *et al*. (2008) and for the new sanctuary from Shaw *et al*. (2008). Maximum productivity carrying capacities were calculated as 75% carrying capacity.

Results

A1. Browse availability

Comparison of estimates of plant cover and plant depth from April 2008 with those repeated in October 2009 were consistently around 66% higher. As the volume of browse available is a key measure in browse assessments, a correction factor of 1.66 was applied to data collected in the old sanctuary during dry season 2009.

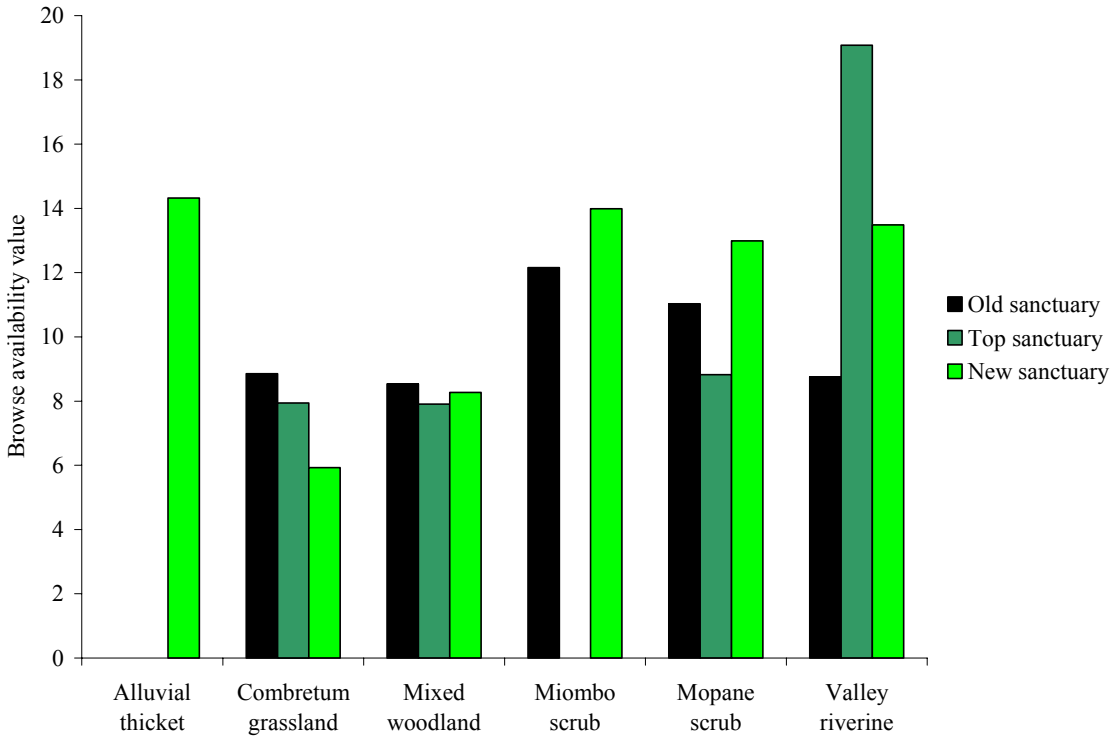


Figure 3. Comparison of mean browse availability in six different vegetation types in the old (this study), top (Adcock *et al*., 2008) and new (Shaw *et al*., 2008) sanctuaries.

Combretum grassland and mixed woodland vegetation types tended towards lower levels of browse availability than the others in all sanctuaries (Figure 3). There was no clear pattern of differences in overall browse availability in the different sanctuaries, however, browse availability was lower in valley riverine and miombo scrub in the old compared to the top and new sanctuaries.

A2. Browse suitability

Minor changes were made in plant species suitability ratings for black rhino from Adcock *et al.* (2008) based on recent observations to allow direct comparison with results from this study (see Appendix 1 for plant rating details). Mopane scrub had markedly lower browse suitability results in all sanctuaries than the other vegetation types, whereas miombo scrub showed higher suitability than other vegetation types (Figure 4). There was a general pattern of lower proportion of preferred rhino browse species in the old sanctuary compared to the top or new sanctuary.

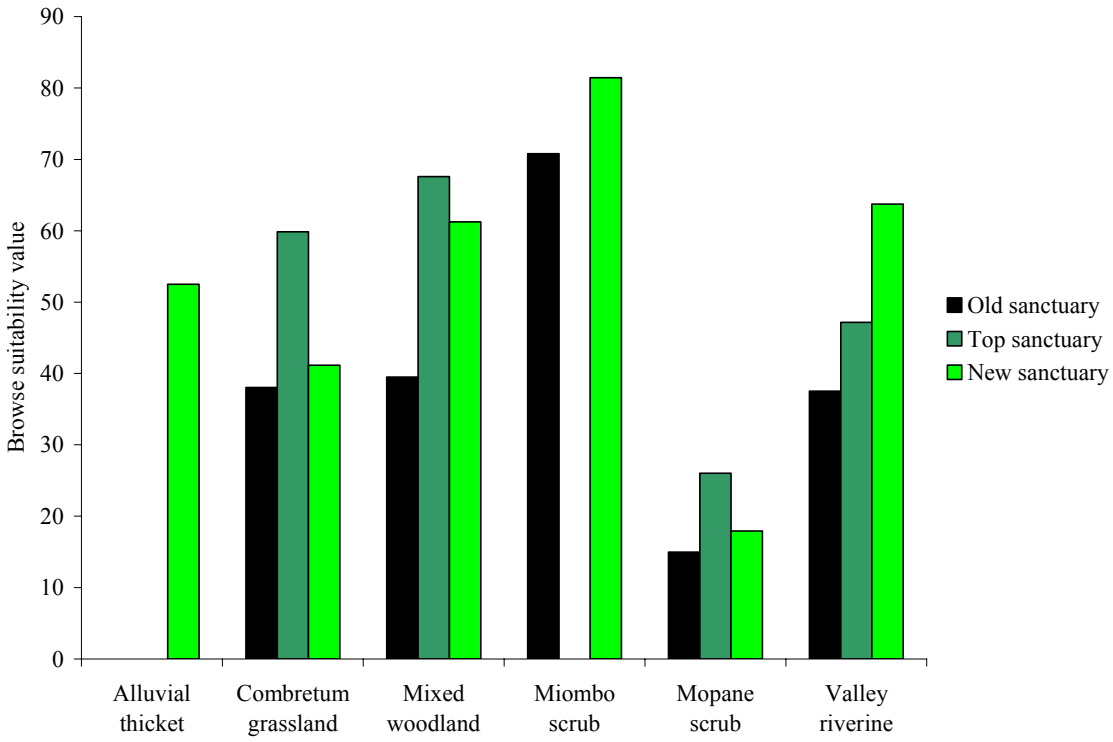


Figure 4. Comparison of mean proportion of preferred browse species (rating 1 and 2) in different habitat types in the old (this study), top (Adcock *et al*, 2008) and new (Shaw *et al*., 2008) sanctuaries.

Browse quality

The overall measure of browse quality was markedly higher in miombo scrub than the other vegetation types in all sanctuaries. Valley riverine vegetation was also relatively high in the top and new although not in the old sanctuary. The alluvial thicket vegetation type in the new sanctuary also rated as good quality rhino habitat. Mopane scrub was rated poorly as black rhino habitat. The trend of lower quality within vegetation types in the old compared to the new and top sanctuaries was similar to that for habitat suitability (Figure 5).

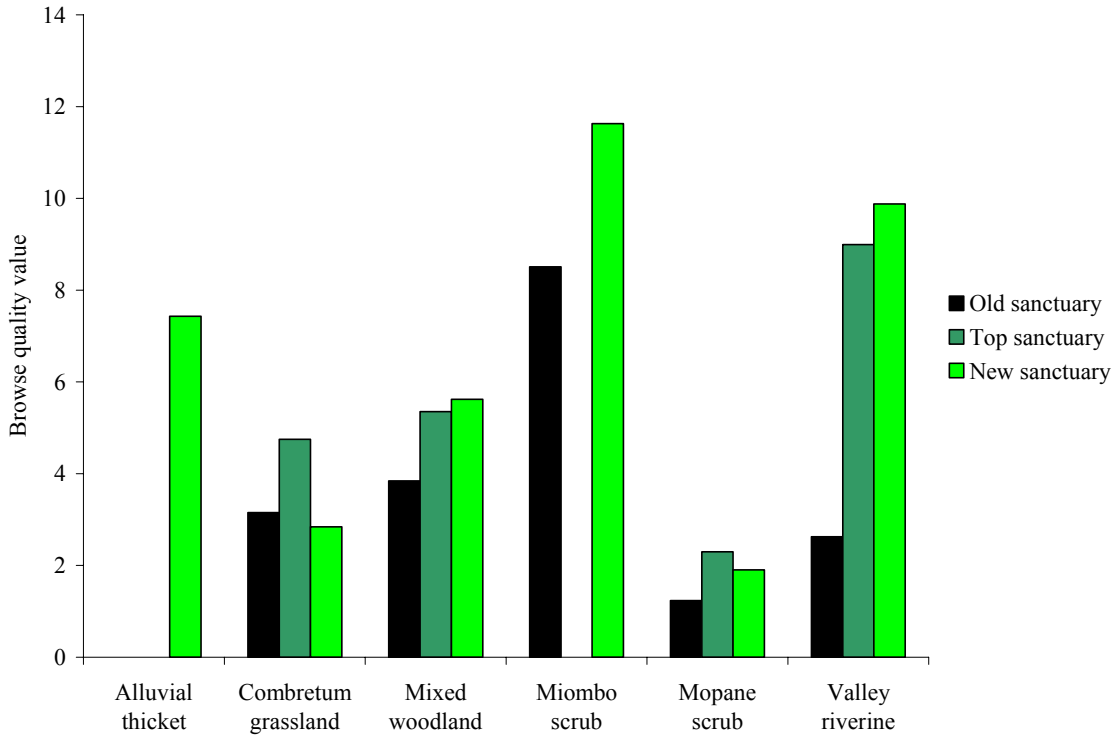


Figure 5. Comparison of mean overall browse quality (as availability and suitability combined) for six vegetation types in the old, top and new sanctuary.

Elephant impact

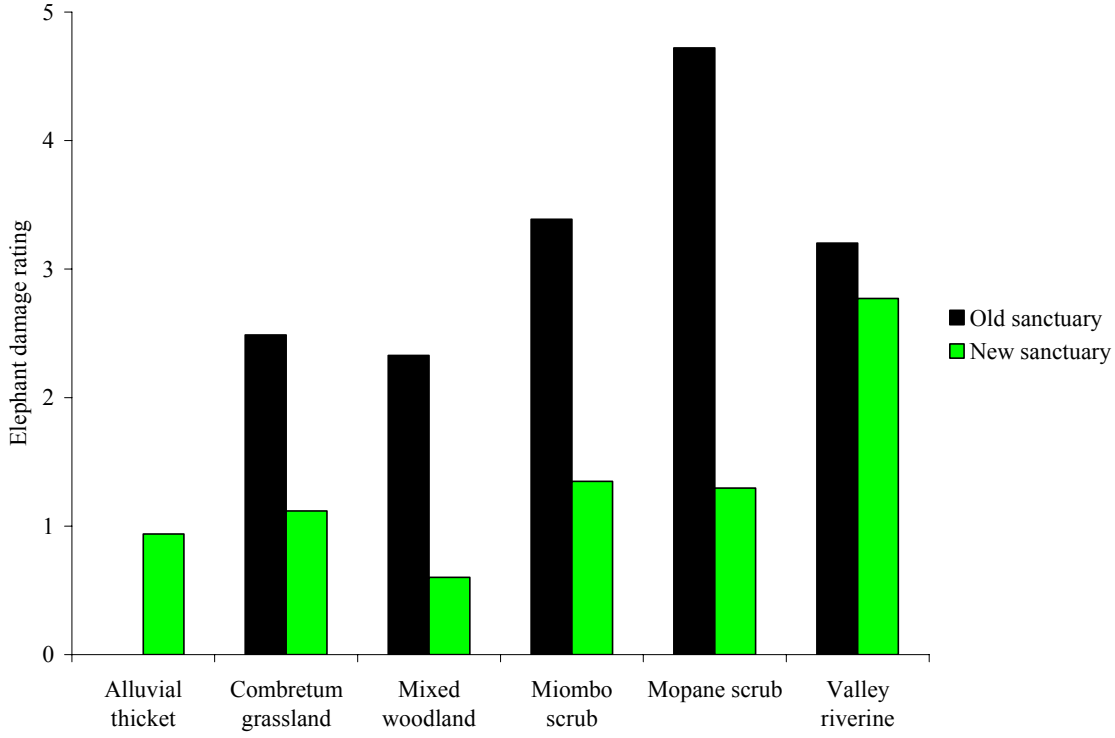


Figure 6. Elephant damage rating score compared between the old and new sanctuaries.

The impact of elephant browsing in the old sanctuary compared to the unfenced new sanctuary was clear both on the ground and in the results of the survey (Figure 6). All five habitat types showed greater elephant damage in the old compared to the new sanctuary, although this was less marked in the valley riverine vegetation type than might be anticipated.

Rhino habitat preference

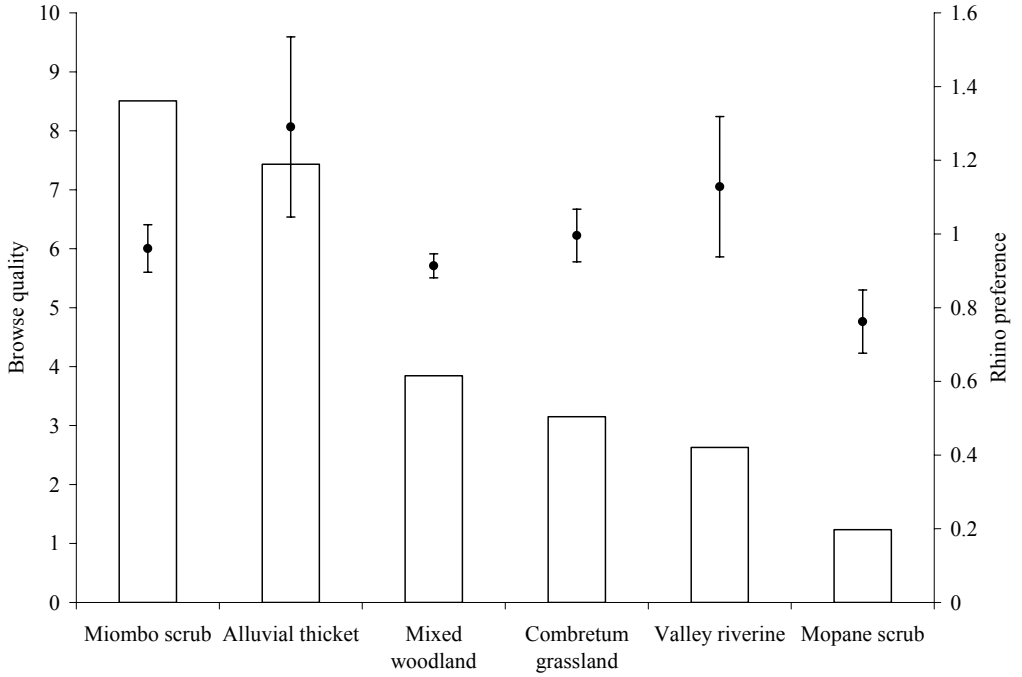


Figure 7. Estimated browse quality of vegetation types in relation to rhino preference for vegetation types in the old, top and new sanctuary.

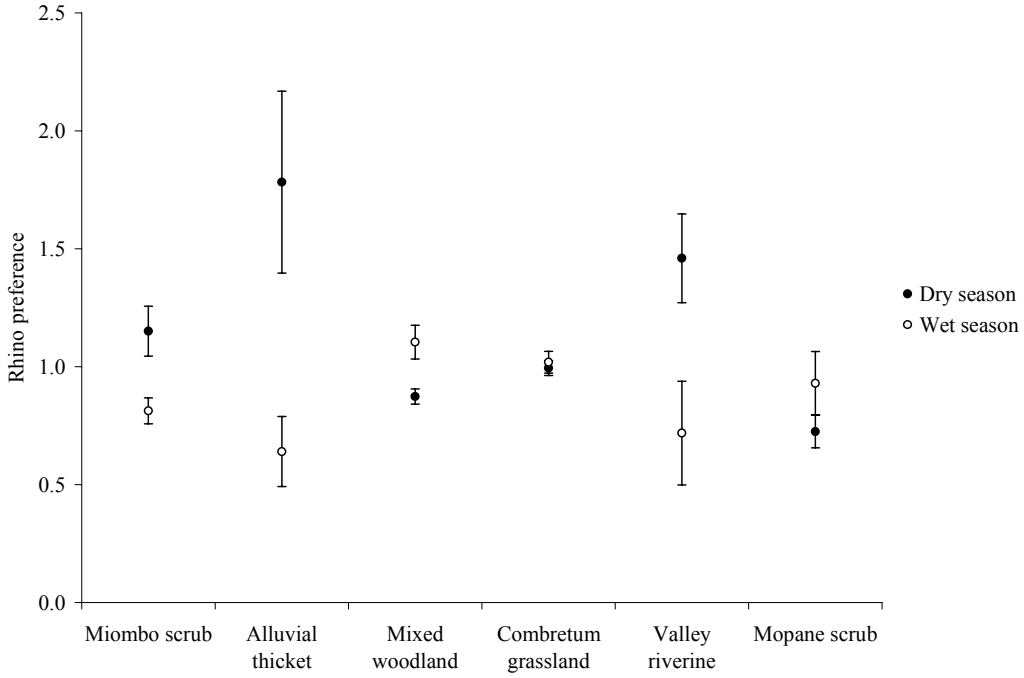


Figure 8. Comparisons of rhino preference for vegetation types in the wet and dry seasons.

Analysis of all rhino sightings data suggested a preference by rhino for the alluvial thicket and valley riverine vegetation types (Figure 7). There was no significant relationship between overall quality of all vegetation types and individual rhino preference based on sightings data. However, rhino tended to not use the low quality mopane scrub habitat and did not show a preference for the medium quality *Combretum* grassland or mixed woodland types. More surprisingly, the high quality miombo scrub vegetation type was not selected for by the rhino. Seasonal analysis of selection of vegetation types by black rhino in the sanctuaries showed a preference for alluvial thicket, valley riverine and to some extent miombo scrub vegetation types occurred more during the dry season than the wet and some increased use of mixed woodland during the wet compared to the dry season (Figure 8).

A3. Carrying capacity estimates

The current density of black rhino in the old sanctuary (see Appendix 2 for rhino population data) is exceeding the estimated MPCC for this area and is close to the ECC (Table 1). The density of rhino in the middle sanctuary has exceeded both the extrapolated MPCC and ECC. Rhino density in the top sanctuary remains below MPCC at present, however when considering the current density in all three sanctuaries combined (0.10 rhino/km^2) the overall population has exceeded the MPCC for the combined sanctuaries (0.09 rhino/km^2).

When the future area of the new sanctuary is included the average MPCC for the entire 312 km^2 area will be 0.10 allowing the population to increase by a further six animals (in addition to the five animals to be introduced in 2010) before reaching MPCC.

Table 1. [§]Estimates for middle sanctuary based on browse quality data from the old sanctuary. [Ψ]Data from Adcock *et al*. (2008). [†]Data from Shaw *et al*. (2008). *Numbers post 2010 re-introduction. Two dependent calves in the old sanctuary were counted as one animal for density purposes hence figure in brackets.

Sanctuary	Area (km^2)	Total rhinos	Current density (rhino/km^2)	ECC	ECC no. rhinos	MPCC (cc*0.75)	MPCC no. rhinos
Old	53	**7 (8)**	**0.13**	0.14	7.2	**0.10**	**5.4**
Middle	79	**10**	**0.13**	0.10[§]	8.1[§]	**0.08**[§]	**6.0**[§]
Top	67	**2**	**0.03**	0.14[Ψ]	9.1[Ψ]	**0.10**[Ψ]	**6.8**[Ψ]
Total in sanctuaries	199	**19 (20)**	**0.10**	0.12	24.5	**0.09**	**18.4**
New	113	5*	0.04	0.14[†]	16.0[†]	0.11[†]	12.0[†]
TOTAL	312	24 (25)*		0.13	40.2	0.10	30.2

Discussion and conclusions

Impacts on browse quality within sanctuaries

The results of this study suggested that browse suitability for black rhino, in terms of the proportion of woody plant species present known to be preferred by black rhino, was lower in the old sanctuary which had been subjected to restricted browsing by elephant, rhino and other herbivores for the greater period of time compared to the top or new sanctuaries. The trend for all vegetation types was for overall browse quality to be greater in the unfenced area that will form the new sanctuary than in the top sanctuary that has been fenced since 2006, and for these both to be better than the old sanctuary, fenced since 2003. This suggests that restricted browsing could be having a negative impact on browse suitability by removal of preferred browse species and hence reducing browse quality.

Elephant impact

The impact of restricted elephant browse upon woody plant species within the old sanctuary was clear. However, it is difficult to relate this to impacts upon black rhino browse availability and suitability. The somewhat lower browse availability and lower proportion of favoured rhino plant species in the old sanctuary may be related to elephant browsing impact or sustained heavy utilisation by the rhino themselves or other herbivores.

Brown (2006) suggested that the potential competition between black rhino and elephant is minimized by elephant feeding on many species that are either hardly browsed by rhino or those plant species that are sufficiently widespread to support both herbivore species. In particular, these plant species include *Colophospermum mopane*, *Brachystegia stipulata* and the various Combretaceae (*Combretum* spp. and *Terminalia* spp.). It was not possible to record elephant diet during this short study, but this would be an interesting topic for further research.

Rhino preference

We aimed to corroborate estimates of habitat quality for black rhino by comparing estimated browse value within vegetation types with actual use, to check whether rhino value areas as predicted (Morgan *et al*., 2009). Although the relationship was not significant there was a trend of greater use in better vegetations types and of lower quality vegetation types such as mopane scrub being avoided. The alluvial thicket and valley riverine vegetation types favoured by the rhino only form a relatively small proportion of the total available area in the current sanctuaries (alluvial thicket 1.6%; valley riverine 2.9%) therefore, rhino may be forced to also use less preferred habitat types to meet their nutritional demands. The miombo scrub habitat type which was estimated to be of high quality was not found to be highly selected by rhinos and was avoided in the wet season. We encountered the greatest density of elephants in this vegetation type during the data collection period and it is possible that rhino avoid this area to avoid interactions with the high number of elephants. The lower than predicted use of the miombo scrub vegetation type by black rhino means that the actual number of rhino that can be supported may be over-estimated in these carrying capacity calculations.

Selection for key vegetation types by rhino was more distinct during the dry season. It may be more important for rhino to be able to access their preferred vegetation types retaining quality browse during this critical time of year when many woody plant species have lost their leaves (Owen-Smith, 2002). As the valley riverine region is one of the important vegetation types it may be that access to water in these areas is additionally influencing rhino movement patterns. Removal of the fences would allow rhino to move more freely to access preferred habitat types in the ecosystem throughout the year.

Brown and van der Westhuizen (2005) found that mixed *Combretum* woodland showed a markedly greater proportion of rhino browse signs per kms that any other habitat type suggesting this vegetation type is of particular value to rhino Valley riverine and alluvial thicket habitat types were found to show the next highest level of browse (Brown and van der Westhuizen, 2005). Dunham (2001) also found a positive correlation between rhino sightings and thicket (alluvial thicket or *Combretum* thicket) and valley riverine vegetation distribution (based on Caughley's aerial transect data, 1973 and Smith's vegetation map, 1998) which supports the browse quality estimates of this study.

Carrying capacity

The results of this study suggest that the number of rhino within the current sanctuaries in NLNP have exceeded MPCC. Rhino numbers in the old and middle sanctuaries are approaching the estimated carrying capacities for these areas and have already exceeded the maximum

productivity carrying capacity (75% estimated carrying capacity) recommended by the IUCN AfRSG. These figures of carrying capacity are likely to be over-estimates of the actual recommended density for rhino in the sanctuaries, as rhino are not using the miombo scrub habitat type as much as would be expected, possibly due to the high density of elephants in this area. As the estimated carrying capacity for the middle sanctuary used in this report is extrapolated from habitat quality data from the old sanctuary and the vegetation map produced from the old and new sanctuaries, further analysis in this area is required to confirm these estimates.

The rhino density in the new sanctuary post-introduction in May 2010 will be under MPCC and removal of the fence between the old and new sanctuary may relieve some immediate pressure on the rhinos in the old sanctuary. However, this would be dependent upon dispersal of individual animals from their current established home ranges. This is likely to be a slow process, particularly for adult males whose movements east into the new sanctuary would be restricted by exclusive territories maintained by males along the current border. There are seven females within the sanctuary network that are expected to calve before December 2010, providing great potential for population increase (Ed Sayer *Pers. comm.*).

It is interesting to note that the outputs from this and other recent studies (Table 1; Adcock *et al*., 2008; Shaw *et al*., 2008) suggest that carrying capacities for black rhino in NLNP are lower than initial estimates made prior to their re-introduction (Table 2). This seems likely to be related to actual differences in the suitability of the habitat rather than simply the impact of restricted browsing over time as it includes estimates from the unfenced area for the new sanctuary. However, the results of this study do suggest that browse availability and suitability in the old sanctuary has been further reduced by browsing impact.

Source	ECC rhino per km^2	MPCC rhino per km^2
R. du Toit estimate (2003)	0.18	**0.13**
K. Adcock estimate (2003 cautious gut feel)	0.20	**0.15**
K. Adcock estimate (2003 model extrapolation)	0.33	**0.25**
This study	0.13	**0.10**

Table 2. Estimates for black rhino carrying capacity in an IPZ in North Luangwa National Park (taken from Adcock, 2003).

Emslie commented in 2002 that there should be no problem with introducing 5-6 animals to the original sanctuary (initially conceptualised as being 75km^2 but actually 53km^2) and allowing each cow to have one or two calves, before either expanding the sanctuary or removing the fence. As the rhino population has now reached MPCC within the sanctuaries, this point has been reached and decisions must be taken to decide the most appropriate management actions to ensure the future success of black rhino in NLNP. This will require long-term planning to ensure the availability of sufficient suitable habitat to allow continued growth and expansion of the NLNP black rhino population in line with the Rhino Conservation Plan for Zambia.

Acknowledgments

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Appendix 1: Plant species rhino browse ratings

Plant species	NEW RATING
Acacia gerrardii	1
Acacia hockii	1
Acacia nilotica	1
Acacia spp	1
Antidesma venosum	2
Baphia massaiensis	2
Bauhinia petersiana	2
Berchemia discolor	2
Boscia spp	2
Brachystegia allenii	2
Brachystegia boehmii	2
Brachystegia bussei	3
Brachystegia manga	2
Breonadia salicina	3
Bridelia carthartica	3
Burkea africana	3
Canthium crassum	3
Cassia abbreviata	2
Cassipourea mollis	3
Catunaregam spinosa	2
Cissus cornifolia	2
Colophospermum mopane	3
Combretum adenogonium	3
Combretum apiculatum	2
Combretum elaeagnoides	3
Combretum imberbe	2
Combretum molle	2
Combretum obovatum	3
Combretum spp	3
Combretum spp 2	3
Combretum zeyheri	3
Commiphora africana	2
Commiphora angolensis	2
Commiphora mollis	2
Commiphora mossambicensis	2
Commiphora pyracanthoides	2
Crossopteryx febrifugia	3
Croton gratissimus	3
Dalbergia melanoxylon	1
Dalbergia nitidula	3
Dichrostachys cinerea	1
Diospyros kirkii	3
Diospyros mespiliformis	2
Diospyros quiloensis	1
Diospyros senensis	1
Diplorhynchus condylocarpon	1
Elephantorrhiza goetzei	2
Erythrophleum africanum	3
Faidherbia albida	1
Feretia aeruginescens	1
Flacoutia Indica	1
Flueggia virosa	1

Plant species	NEW RATING
Friesodielsia obovata	2
Herb spp	1
Hippocratea spp	1
Holarrhena pubescens	2
Hymenocardia acida	3
Hymenodictyon parvifolium	2
Indigofera spp	1
Isoberlina angolensis	3
Julbernardia globiflora	2
Kigelia africanna	2
Lannea discolor	2
Lonchocarpus capassa	1
Maprounea africana	3
Markhamia zanzibarica	1
Maytenus senegalensis	3
Monotes africanus	2
Monotes spp	2
Mundulia sericea	3
Ochna pulchra	3
Ochna spp	3
Oldfieldia dactylophylla	3
Oncoba spinosa	3
Ormocarpum kirkii	1
Ozoroa paniculosa	3
Pavetta eylesii	3
Peltophorum africanum	2
Pericopsis angolensis	3
Phyllanthus reticulatus	2
Phyllocosmus lemaireanus	3
Piliostigma thonningii	2
Pseudolachnostylis maprouneifolia	3
Pterocarpus rotundifolia	2
Riverine spp.	2
Rothmannia englerana	3
Schrebera trichoclada	2
Sclerocarya birrea	2
Senna petersiana	3
Sesamum angolensis	1
Stereospermum kunthianum	2
Tamarindus indica	3
Terminalia sericea	3
Terminalia stenostachya	3
Terminalia stuhlmannii	3
Vangueria infausta	1
Vangueriopsis lanciflora	3
Vitex mombassae	2
Winthonia spp	1
Wissadula rostorata	1
Xeroderris stuhlmannii	2
Ximenia americana	2
Ximenia caffra	2
Xylopia odoratissima	3
Ziziphus abyssinica	1

Appendix 2: Rhino population data

No	Rhino	Sex	Arrival / Born	Old	Middle	Top	Outside
1	(Kanabesa)	M	2003	X			
2	Londokeni	M	2003	1			
3	Mapalo	F	2003	1			
4	Natwangwe	F	2003	1			
5	Twatemwa	F	2003	1			
6	Buyantanshi	M	b. 2005	1			
7	Twatasha	F	b. 2006	1			
8	Chawama	F	b. 2008	0.5			
9	Shangila	F	b. 2008	0.5			
11	Kango	M	2006		1		
13	Buntungwa	F	2006		1		
14	Twashuka	F	2006		1		
17	Bwacha	M	2008		1		
18	Ichuma	M	2008		1		
19	Intanda	F	2008		1		
20	Mwine mpanga	F	2008		1		
21	Nalabuka	F	2008		1		
12	Kondobole	M	2006		0.6	0.4	
10	Subilo	M	2006		0.6	0.4	
15	Chilenje	F	2006		0.4	0.6	
16	Twikatane	F	2006		0.4	0.6	
22	Julila	F	2006				1
23	Twibukishe	F	b. 2006				1
No. rhinos				8 (7)	10	2	2
Total in sanctuaries							20