ASSESSMENT OF DIET COMPOSITION, BROWSE PREFERENCE AND HABITAT SUITABILITY PRIOR TO NEW BLACK RHINOCEROS (*Diceros bicornis minor*) TRANSLOCATIONS AT MAJETE WILDLIFE RESERVE

A dissertation submitted to the School of Biological Sciences of the University of East Anglia, in partial fulfilment of the requirements for the degree of Master of Science

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I dedicate this work to

Péter Kárpáti,

a great intellect, Friend and mentor whose endless encouragement and continuous advice provided guidance and direction at the various stages of my university years.

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ABSTRACT

Forming organic part of regional efforts to better conserve the taxon, this project studied the feeding preference of recently reintroduced black rhino (*Diceros bicornis minor*) in Majete Wildlife Reserve and assessed the browse availability and overall habitat suitability of its vegetation strata. Field work was conducted in the late hot-wet and early cool-dry season, a period that presented a broad and varied botanical backdrop to collecting forage data. In the first phase of the study, basic dietary information was collected along 26 feeding tracks in the reserve's Sanctuary, during which 59 diet species were classified and 1743 standard bite volumes were recorded. The study pointed out a significant overlap between 'important' (staple or principal) diet items and those that are 'preferred' (highly palatable) by black rhino. Both rankings disclosed a strong representation of species from the Mimosaceae and Fabaceae families. Stratified random sampling was adopted to establish survey plot-, vegetation type-, and sub-area specific browse availability indices over the larger study area. The eastern half of the reserve possessed over 2/3rd of the total rhino browse available and produced an above average overall mean availability score (i.e. if compared with other rhino areas in the Zambezian region). The *miombo* woodland dominated western realm showed poor diversity and density of selected forage. Knowing the absolute proportional availability of highly suitable forage items (i.e. species both important and preferred) within each realm, vegetation type-based results yielded sub-area specific habitat suitability deductions. Out of the six main vegetation types, the Riverine and Alluvial matrix turned out to possess both the largest amount of mean overall standing browse biomass and the greatest absolute proportion of highly suitable forage to black rhino. A widely distributed type, the Low Altitude Mixed Woodland showed the greatest area-weighted browse availability in two key areas: of all species selected and those highly suitable. Reserve management thus informed by the fundamentals of rhino habitat ecology can formulate cognizant plans for the new reintroduction campaign in 2013–2015. This study fills the gap in understanding the key properties of diet utilisation and habitat capacity for the rapid expansion of this small reintroduced stock and thus furthers the long-term restoration of an ecologically sound and functioning national black rhino population in Malawi.

Key phrases: Majete Wildlife Reserve, black rhinoceros, reintroduction, feeding track, browse availability, diet preference, habitat suitability, ecological carrying capacity, IUCN/SSC AfRSG.

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1. INTRODUCTION

1.1. Background to the project

1.1.1. An Overview of and motivation for the study

This study set its focus on assessing the diet selection of and habitat suitability for a reintroduced population of the south-central ecotype of the endangered black rhinoceros (*Diceros bicornis minor*) at Majete Wildlife Reserve (MWR) in Malawi. Yet, this paper *per se* might be read in a wider context as its approaches may be applicable to studies conducted on other large-bodied species with threatened status.

Black rhinos (BR) are browsers preferring mainly woody vegetation (small trees and shrubs), but also forbs, herbs and succulents are known to be eaten by them (Hall-Martin *et al.*, 1982; Oloo *et al.*, 1994). To manage a newly established BR population efficiently, its ecological requirements must be addressed (Emslie & Brooks, 1999; Muya & Oguge, 2000). In this work, key emphasis was given to the resource use dynamics of a recently restored and growing founder population of BR living in the Sanctuary (143km^2) within the larger reserve area (689km^2). The Sanctuary is a strictly protected and perimeter-fenced refuge where the rhinos (as of 3 June 2011: seven adults and four calves) together with other re-introduced wildlife (i.e. antelopes, buffalo and elephant) are managed and closely monitored on a regular basis (Dorian Tilbury, operational manager, MWR, *pers. comm.*, 2011). This research study was induced by the growing interest of the managing body (the joint board of APN[1] and the DNPW[2]) first in finding out about dominant patterns of browse utilisation of this young BR population, second in ranking diet species in terms of preference by rhinos and lastly defining the most suitable habitat mosaic with particular emphasis on the historically sound Eastern Block[3] of the reserve (*Figure 1*). In order for *in situ* BR conservation to become more cost effective, results emerging from continuous applied ecology research must produce an essential toolbox that can help provide answers to grey areas not yet understood by managers. Only by grasping the gist of habitat use and browse selection of BRs, as well as possessing the know-hows when needing to react rapidly on possible future challenges posed by their altering living conditions (i.e. due to climate change or environmental degradation), will the survival of this species be secured (Brooks, 1993; Adcock, 2001; Saffery, 2009).

1.1.2. Shifting trend in black rhino management: the increasing role of applied ecology

Initially, most BR rehabilitation initiatives have focused mainly on enhanced security through the deployment of paramilitary squads and fencing off small sanctuaries to protect rhino from poachers (Tatham & Taylor, 1989; Du Toit, 1994; Walker, 1994). Although important factors, the role (or potential lack) of effective, internationally enforceable legal frameworks as well as initiatives aiming at describing the preferred

[1] African Parks Network: an NGO based in Johannesburg characterised by a unique business model of entering into long term public-private partnership agreements with African governments to rehabilitate centrally run parks and reserves and commit to working together with the state conservation body (i.e. DNPW of Malawi).

[2] Department of National Parks and Wildlife: body responsible for managing Malawi's state-protected areas.

[3] Two sub-areas, the Sanctuary (northeast) and the Pende section (southeast) constitute the Eastern Block.

ecological and habitat requirements of BR have received less attention among financial donors and resource managers (Emslie & Brooks, 1999; Ganqa & Scogings, 2007). Recently, feeding- and population ecology have started to be recognised as key pillars in understanding the wider implications of black rhino conservation such as estimating optimal stocking rates for wild populations and enhancing productivity for captive animals through improved nutrition (Emslie & Brooks, 1999; Buk & Knight, 2010; Shaw, 2011). The complexity of browse selection affected among others by particular ecological and chemical factors is vital for management to grasp because its role gets enhanced importance during trans- and relocations, calving periods, large scale population augmentation measures and (re)establishment of new populations (Muya & Oguge, 2000). To date, a good numb er of studies have attempted to describe the diet preference and habitat requirements of BR in various range states (Goddard, 1968; Mukinya, 1977; Hall-Martin *et al.*, 1982; Emslie & Adcock, 1990; Oloo *et al.,* 1994; Bhima & Dudley, 1996; Muya & Oguge, 2000; Tatman *et al.*, 2000; Brown *et al.*, 2003; Buk, 2004; Van der Heiden, 2005). However, only recent research projects (Brown, 2008; Buk & Knight, 2010; Shaw, 2011) have applied Adcock's (2006) *"Visual assessment of black rhino browse availability, Version 3.0"* model[4]. Steps ascertaining the adoption of applied approaches in ecological science and creating a cohesive working environment where the findings of research are reflected in long-term management decisions are central to breeding and augmenting Majete's BR cost-effectively and to the successful restoration of the species' overall national population in Malawi.

[4] Designed by Keryn Adcock [IUCN/SSC African Rhino Specialist Group (AfRSG)]. This manual describes a visual method of how to conduct comprehensive browse availability (BA) surveys and assess %BA indices for BR.

1.2. Justifications for the project

1.2.1. International interests

As target of heavy and recurrent poaching throughout its natural range, the BR is one of the greatest losers of modern human impact unleashed on wild habitats in Africa (Hall-Martin, 1988; Brooks & Adcock, 1997). According to the IUCN[5] Species Survival Commission (SSC) African Rhino Specialist Group (AfRSG) (2008), few other African mammal taxa have been hit by such a dramatic population collapse (96% loss between 1970 and 1995). Emslie & Brooks (1999) asserts that if the Asian demand for rhino horn as a medicinal (i.e. traditional remedy in the Far East) and ornamental (i.e. handle of *jambiya* daggers in Yemen) product continues, rhinos can soon be doomed as a consequence. Demonstrating its heightened protection status, the *D. bicornis* have been listed in CITES's Appendix I since 1977 and classified as "Critically Endangered" on the IUCN Red List since 1996. Hence, *in situ* management and accretion of remaining BR populations, the assessing of their major ecological needs and capacity of their habitats are key for their survival. As a new development, reflecting on their notable restoration success with rhinos, CITES during its 13th CoP in Bangkok (2004), endorsed annual quota applications for South Africa's five *D. b. minor* and Namibia's five *D. b. bicornis* (south-western subspecies, also called "desert rhino") to be trophy hunted for premium fees (Leader-Williams *et al.*, 2005). There are only about 4880 *D. bicornis* surviving in 121 wild populations today –, managed mainly in small stocks of less than 100 individuals (Emslie & Knight, 2011; Emslie *et al.*, 2012) *(Table 1).*

[5] IUCN: International Union for the Conservation of Nature and Natural Resources (World Conservation Union).

Table 1. IUCN-SSC AfRSG population estimates of black rhinoceros in the range states as of 31 December 2010 (Emslie *et al.*, 2012).[6]

Ecotypes →	**South-Western**	**Western**	**Eastern**	**South Central**	**Total**	**Trend**
Range states ↓	*Diceros Bicornis bicornis*	*Diceros bicornis longipes*	*Diceros bicornis michaeli*	*Diceros bicornis minor*		
Angola	1				1	?
Botswana				7	7	Up
Cameroon		0?			0?	Extinct?
Ethiopia			0?		0?	Extinct?
Kenya			594		594	Up
Malawi				24	24	Up
Mozambique				1	1	?
Namibia	1,750				1,750	Up
South Africa	171		60 (*ex situ*)	1,684	1,915	Up
Swaziland				17	17	Stable
Tanzania			88	25	113	Up/Down?
Zambia				27	27	Up+Intro
Zimbabwe				431	431	Down
Total	**1,920**	**Extinct**	**740**	**2,220**	**~ 4,880**	**Up**

[6] Overall subspecies totals have been rounded to nearest five rhino.

Despite recent trends emphasising the need of ecosystem-based conservation as the only way forward, still existing commitments to species conservation can not be regarded anachronistic. This is so because for an increasing number of endangered taxa only a strict species-focused approach can bring remedy and possible long-term recovery through the prevention of genetic impoverishment and providing direct protection (Emslie *et al.*, 2009; Morgan *et al.*, 2009; Göttert *et al.*, 2010). Being a charismatic flagship- and crisis species due to its staggering population collapse (driven by commercial poaching and with its population growth smothered by low reproductive rates and wide calving intervals), the *in situ* restoration and accretion of remaining BR populations are of supreme importance to conservation (Emslie & Brooks, 1999). Understanding the vegetation component and estimating the Ecological Carrying Capacity (ECC) of an area in sustaining a threatened species like BR is fundamental to their survival (Adcock, 2001). Responding to the 'rhino crisis', most range states have adopted translocations to restore decimated or extirpated stocks on secure and suitable habitats within the specie's historical range (Adcock *et al.,* 1998; Emslie *et al.,* 2009).

1.2.2. Regional interests

The IUCN/SSC AfRSG and the SADC Regional Programme for Rhino Conservation (SADC RPRC)[7] defines country-specific continental frameworks and provides task-specific, tailored directions for effective African rhino (black and white) conservation (Emslie & Brooks, 1999; Emslie, 2005). Every single range state with remaining or reintroduced

[7] Fostering strong links with the IUCN/SSC AfRSG, this conservation initiative coordinates black and white rhino management across 15 African states that belong to the Southern African Development Community (SADC).

population(s) of BR has to have a National Rhino Conservation Plan with clear-cut steps how to implement the objectives of minimising death rates and maximising breeding performance (Adcock, 2001). The prescribed strategies and policies set forth measures that make *D. b. minor* stocks (regardless of the designation level of the protected area) as organic part of larger national and regional meta-populations[8] (Emslie & Brooks, 1999; Emslie, 2005; Du Toit *et al.,* 2006). Where adequate security and protection are coupled with sound biological management, backed with robust, long-term financial commitments and complemented with skilled capacity, efforts can turn out to be capable of registering success stories with BR (Brooks & Adcock, 1997; Brett, 1998).

Since the late 1960s, the *D. b. minor* has been being managed in number of widely distributed meta-populations throughout its natural range (increasingly on private lands in South Africa) with goals of increasing overall rhino numbers as swiftly as possible (Emslie & Brooks, 1999; Hutchins & Kreger, 2006). Maintaining BR populations in productive densities via careful meta-population management (i.e. moving around productive males) and adopting translocations to keep source populations at Maximum Productivity Carrying Capacity (i.e. MPCC is ~75% of ECC for rhinos) are central to the biological management of BRs (Emslie & Brooks, 1999). Provided tight security has been installed and its permanence is assured, such hands-on measures will enhance genetic selectivity, lessen density-dependent feedback (i.e. lengthened calving intervals, older age at first calving, increased calf mortalities and social conflicts) and ensure predictable growth rates (Emslie & Brooks, 1999; Adcock, 2001; Buk, 2004; Emslie, 2005).

[8] Meta-population: geographically distinct sub-populations that are managed as one genetic stock.

To outpace the impacts of poaching and maximise genetic diversity, a min. 5% annual population growth rate has become a widely accepted goal to achieve (Brooks & Adcock, 1997; Hall-Martin & Castley, 2003; Buk & Knight, 2010). The Southern African Rhino Management Group (RMG) Black Rhino Carrying Capacity Model Vs 1.0 (Adcock, 2001) and Vs 2.1 (Adcock, 2006*b*) show highly significant correlations between rhino carrying capacity of an area and visually-assessed browse availability. Hence, assessing the overall availability and suitability of eaten browse for new populations of BR is vital to have meaningful projections of ECC. Building on former studies conducted elsewhere, this research on Malawi's youngest BR stock hopes to become a useful addition to the science already applied by the SADC RPRC.

1.2.3. Local interests

Due to human pressures (particularly poaching and the tripled human population of Malawi between 1970 and 1995), the vast majority of mammalian fauna in MWR was severely extirpated by the early 1990s (Martin, 2005). Malawi's once strong *D. b. minor* population, having registered a steady decline since the early 1970s (about 40 rhinos remaining in 1980 and only five in 1991), became extinct by 1992 (Emslie & Brooks, 1999). Since the first reintroduction of the species into Liwonde National Park from South Africa's Kruger N.P. in 1993, Malawi's national BR population has grown (totalling 25 individuals as of June 2011) and now boasts a second population: the one in MWR (Bhima & Dudley, 1996; Bentley Palmer of ESOM[9], *pers. comm.*, May 2011).

[9] Endangered Species of Malawi (ESOM): a national initiative with interest in rehabilitating endangered species.

When APN's mandate in Majete commenced in 2003, the reserve was almost completely devoid of mammalian wildlife (Staub, 2011). APN by signing a 25 years agreement with the state authority (DNPW) committed itself to managing and developing the reserve as well as providing funding for its various projects. APN's objectives at Majete are ecological restoration, creation of ecotourism capacity through developing infrastructure and skilled workforce as well as encouraging research potential and income generating opportunities for local residents (Fearnhead, 2010). APN's ultimate aim is to rehabilitate Majete's depleted wildlife and build a self-sufficient protected area which is not only capable of attracting holiday goers but can in fact serve as a living scientific laboratory for visiting researchers (Patricio Ndadzela, APN Project coordinator, MWR, *pers. comm.*, 2011). It is hoped that if operated as a park run by informed decisions, MWR may become a role model for other initiatives on how to develop a neglected and ravaged African reserve in the 21st century (Fearnhead, 2010).

In the course of this study, the Sanctuary has got a growing, productive, *in situ* and wild-managed[10] BR population counting 11 individuals (seven adults, one sub-adult and three juveniles), six of which were introduced from South Africa in 2007 and one donated from Liwonde National Park in 2003 (Dudley, 2001; Patton, 2011). Majete's founder population has experienced 6 births in the last three years (two perished during their first months). According to recent negotiations between APN and a donor, two transports of BR are to be dispatched from South Africa and released in MWR in 2013-2014 (Hall-Martin, Director of Conservation and Development, APN, *pers. comm.*, 2011).

[10] Definitions on the various black rhino population categories, as well as modes and systems of management are set by the IUICN-SSC AfRSG (Leader-Williams *et al.* 1997; Emslie & Brooks, 1999).

The main catalyst of this research was that, though Majete is now a functioning protected area, knowledge on the patterns of habitat and browse utilisation of its young and expanding BR population (managed in the secure, perimeter-fenced Sanctuary of the larger reserve) has not been gathered before. Constantly patrolled, being on the species' historical range and possessing similar vegetation structure and landscape characteristics to those of the Sanctuary (Bell, 1984), the Pende sub-area had been presumed by APN's rhino expert to be a similarly ideal place for future population augmentation (Hall-Martin, *pers. comm.,* 2011). Still, whether the Eastern Block is capable of supporting an expanding BR population (and if it is, then at what capacity) is expected to be answered by this study. Hence, the other motivator was to acquire scientifically tested information on BR habitat suitability of the Eastern Block (to be based on the availability and proportion of highly palatable browse species occurring in its vegetation zones) before future reintroduction measures could proceed there. For comparative purposes similar attributes of the third sub-area, the Western Majete realm (dominated primarily by miombo) was also attempted to be assessed. The findings of this study are to become organic part of the reserve's BR management strategy, for (due mainly to the lack of targeted funds and expertise) neither thorough scientific investigation into BR habitat requirements nor detailed assessment on the conduciveness and capacity of the various vegetation types in supporting suitable rhino browse species has yet been undertaken in MWR. Results are expected to help encourage research on discovering possible diet overlaps with other herbivorous taxa (i.e. greater kudu), define key plant species as early warning indicators of possible food limitations, estimate ecologically sound stocking rates that can support natural levels of BR densities in Majete, and lastly, direct management focus towards blocks with the greatest potential to sustain this species (De Boer & Ijdema, 2007; Buk & Knight, 2010).

1.3. Aims and objectives

Apprising management on BR browse utilisation and assessing overall habitat suitability constituted the paramount motive for this study, whose results will inform decisions aiming at ecologically sound population augmentation measures at MWR in the future.

1.3.1. Research aims

- To study the basic patterns of feeding ecology and forage use of BR in the Sanctuary (i.e. diet composition, browse importance and preference).
- To appraise the overall proportional availability of standing browse biomass in the reserve's three sub-areas and its six distinct vegetation types.
- To define the most suitable habitat mosaic for BR in MWR.

1.3.2. Specific research objectives

Phase 1 (tracking):

- To collect diet composition data by taxonomically identifying consumed browse plants to species level (to compile a 'Browse Species List').
- To rank browse plants in terms of their 'Importance' to BR (based on feeding intensity on consumed browse).

Phase 2 (sampling):

- To obtain the absolute Proportional (%) Browse Availability (BA) score[11] for the three sub-areas, the six vegetation strata and the entire MWR through a set of quantitative assessments following guidelines of the IUCN/SSC AfRSG.

Further objectives:

- To establish the 'Preference' indices of browse plants (reflecting palatability).
- To classify diet species in distinct classes according to their 'Suitability' for BR.
- To rate each vegetation type for its 'Habitat Suitability' and thus have a lucid picture of the most valuable BR habitat mosaic in MWR.

[11] The %BA score (proportional or % fill) is an index which is *correlated* with the actual browse biomass available to BR in the range of ≤ 2m canopy height in a given area (Adcock, 2006*a*). A %BA score reflects the percentage to which a feeding space (i.e. that of a plot, sub-area, vegetation type or reserve) is filled with selected diet species (or a single species), namely: absolute quantity (m^3) of browse relative to total feeding space (m^3).

2. METHODS

2.1. Study area

2.1.1. Geography and recent history

Majete Wildlife Reserve, located at south-western corner of Malawi was gazetted as a game reserve in 1955 and further extended in 1969 (Sherry, 1989). Its major part (about 90%) lies within Chikwawa District and the extreme northern section belongs to Mwanza District (Martin, 2005). This 689km² protected area, sustaining catchments of the Mkurumadzi, Mwanza and the Shire rivers, is nested in the Zambezian Miombo Woodland Ecoregion along the southern reaches of Africa's Great Rift Valley *(Figure 1).*

Majete's mega-fauna was almost completely wiped out by the mid-1990s due to local and cross-border poaching during the incursions of militias of the Mozambican civil war (Martin, 2005). Illegal logging though formerly a severe problem has by now been brought under control, while illegal charcoal production is still rife in areas buffering the reserve (Tilbury, *pers. comm.,* 2011). Since the start of its mandate in 2003, the APN working together with the DNPW, has strengthened security, created skilled capacity, built a perimeter fence, developed the road network and reintroduced over 2550 mammals (11 species). The likewise fenced Sanctuary (140km²) provided a secure refuge and supportive environment for high priority species (e.g. black rhino and sable antelope) to reproduce and thrive. As a recent development, after years of service, the inner fence of the Sanctuary began to be pulled down in May 2011 in order to allow its closely managed populations of endangered fauna to range out into the outer reserve.

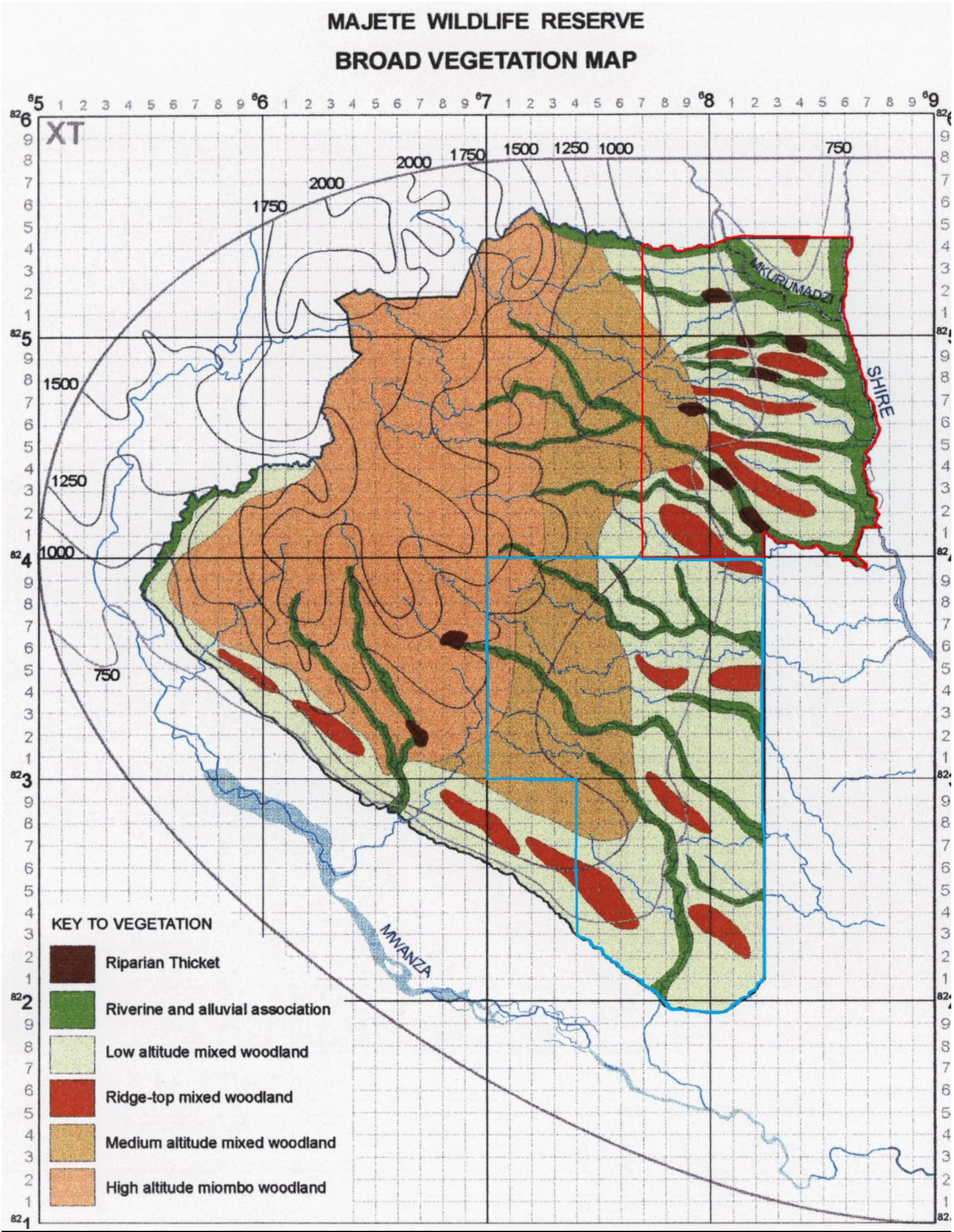

Figure 1. Vegetation map (1:250,000) of MWR [adopted from Sherry's (1989) map]. Coordinates are in UTM units, altitude contours in feet above mean sea level. Brown line: Reserve boundary; Red line: Sanctuary boundary; Blue line: Pende area boundary.

2.1.2. Climate and hydrology

Given that MWR is situated in the tropical belt of southern East Africa, altitude and proximity to water sources are the principal factors affecting climate and therefore life histories of organisms (Sherry, 1989; Hall-Martin, *pers. comm.,* 2011). Semi-arid conditions are characteristic to the Lower Shire Valley with annual precipitation ranging between 680-800mm in the East/South-eastern corner, up to 700-1000mm in the western uplands (Staub, 2011). Rainfall throughout the year is seasonal and concentrated principally between November and early April (Martin, 2005; Tilbury, *pers. comm.,* 2011). The annual average temperature is ~23°C (Staub, 2011). Three main seasons recognised in Majete based on rainfall and temperature characteristics (Sherry, 1989; Hall-Martin, *pers. comm*., 2011):

- Hot wet season: November–April (high relative humidity and temperature)
- Cool dry season: May–August (high relative humidity/no significant rain)
- Hot dry season: September–November (generally low relative humidity without significant rain and high temperatures)

Along with the two main perennial rivers of the park (the Shire on the eastern and Mkurumadzi on the northern border), there are a number of small seasonal rivers (i.e. Nsepete, Nakamba, Mwambezi, Milassi, Masakale, Mthumba and Kakoma) that flow in a NW to SE direction towards the fast flowing Shire (Sherry, 1989).

There are five artificially operated waterholes in the reserve (completed between 2003 and 2009), accounted for by the severe scarcity of permanent water bodies within its perimeter and further boreholes are planned to be established by APN in the near future (Staub, 2011). A large hydroelectric dam above the rapids of Kapichira Falls (completed in 1996) generates power to the entire region (Martin, 2005).

2.1.3. Topography, soils and vegetation types

The main landscape characteristics of MWR are defined by its position in an angle of the Shire section of the Great Rift Valley (Bell, 1984). The topography is dominated by the NW-SE fault structure of the escarpment stretching parallel to the Mwanza River, which created a steeply undulating landscape dissected by river valleys and gullies (Bell, 1984)

Majete's soil composition can best be described as primarily lithosols, shallow and stony, ferruginous type of low fertility with narrow stretches of fertile alluvial soils occurring along some of the small rivers (Sherry, 1989; Martin, 2005). The majority of the area is not suitable for cultivation due to the poor soil structure and the frequency of slopes over 12% gradient (Sherry, 1989).

MWR possesses a diverse tapestry of different vegetation types *(Figure 1)* from moist miombo woodland in the western hills, rich riverine and alluvial matrix as well as significant patches of riparian thickets along and near rivers, to dry mixed savannah woodland of low and medium altitudes in the eastern and central areas (Sherry, 1989; Fairnhead, 2007). A short overview of the dominant vegetation types of MWR [quantitative data are derived from Brian Sherry's (1989) work]:

- Riverine and Alluvial Associations (12% of the reserve)

These comprise alluvial, riverbed and riverbank communities, confined to narrow valleys below 230m throughout the study area. It is dominated by (trees): *Acacia tortilis, Kigelia africana and Lonchocarpus capassa;* (shrubs): *Allophylus spp.*, *Cardiogyne africana* and *Grewia spp.;* as well as (grasses): *Cynodon, Digitaria* and *Phragmites*. The high overall biomass of this type is due to the deep, well-drained, sandy, alluvial and black clay soils of high nutrient status (i.e. Mthumba alluvium) that sustain quality woody growth.

- Riparian Thicket (1%)

This vegetation type is found along rivers and at river junctions particularly in level areas (below 240m) and where tributaries meet (i.e. along the the eastern periphery of the reserve). It appears to be associated with deeper, sandy, well-drained alluvial soils of high nutrient content. The tributaries form effective fire breaks and the occurrence of thickets in the confluence areas suggests that thicket is the climatic climax vegetation of the alluvial soils (Bell, 1984). The tree layer is dominated by *Adansonia digitata, Albizia anthelmintica, Diospyros quiloensis and Euphorbia ingens*. The shrub layer's key representatives are *Bauhinia tomentosa, Diospyros senensis, Ehretia spp.* and *Grewia bicolor.* The *Brachiara* and *Leptochloa* species are the main constituents of grasses. The Riparian Thicket is reputed for its relatively high tree density although with low average canopy heights (~5.2m). Its biomass is analogous to that of the Low

Altitude Mixed Deciduous Woodland (high). The shrub layer is very dense and relatively tall (mean height of 1.64m).

- Low Altitude Mixed Deciduous Woodland (30.7%)

It is the second largest vegetation community occurring in Majete, lying at the 205-280m altitudinal rage. In contrast to the Riverine and Alluvial Associations, in this community the overall shrub component is sparser but the tree layer is dense with higher average canopy heights. It still offers a relatively open woodland of high biomass dominated by *Acacia*, *Combretum*, *Sclerocarya, Sterculia and Grewia spp.* favoured by elephants, rhinos, baboons and most antelopes. This type also supports perennial grasses (e.g. *Heteropogon*) that can produce relatively hot flames when bush fires sweep across them. Grey sandy clay loams with sand and stone cover are its main soil types (Martin, 2005). Dry season water is seldom available only by digging (i.e. elephants) in sand rivers.

- Ridge-top Mixed Woodland (7.2%)

It is confined to flatter ridge-tops and upper slopes of higher ground between the tributaries of the Shire River in the eastern part of the reserve (220-300m). This type supports a short (mean height of 5.4m), medium density woodland with low tree biomass. In the tree layer, *Terminalia sericea* is rife and *Diospyros kirkii* is characteristic. *Diplorhynchus condylocarpon* is dominant in the high density but low shrub layer (mean height of 0.92m). This community supports the lowest overall biomass of all the vegetation types. It is caused by poor, shallow soils sustaining only stunted tree growth and fire-resistant trees.

- Medium Altitude Mixed Deciduous Woodland (16.8%)

This intermediary eco-tonal association (230-410m) covers a belt in the centre of the reserve in the escarpment zone that divides the lower slopes of the eastern fringes from the more rugged higher western area. Consequently, this type incorporates a large selection of the most characteristic flora found in both the low altitude matrix in the east and the high altitude one in the west. This category possesses the highest biomass of trees (dominated by *Brachystegia boehmii*) in the study area. The shrub layer is dense (1.23 per hectare) and relatively short (mean height 0.91m) with fairly low biomass, characterised by the dominance of *Pterocarpus rotundifolius,* a species which occurs sparse in the tree layer suggesting it being fire-resistant in younger stages.

- High Altitude Miombo Woodland (32.3%)

Found in the higher (410-770m), western part of the study area, dominated by *Brachystegia boehmii* and *Julbernardia globiflora*. Being relatively well-fed by perennial surface water, the soils of the miombo are in low to medium soil nutrient status and characterised by red-brown clay loams with some stony and gravel upper layers found mainly on the ridge tops (Martin, 2005). Predominantly, the tree layer supports high biomass of low browse quality, covered in large by *Brachystegia spp.*, *Burkea africana, Crossopteryx febrifuga, Diplorhynchus condylocarpon, Pterocarpus angolensis, Terminalia stenostachya* and a range of *Julbernardia spp*. Shrubs are mainly represented by *Acacia torrei, Acacia erubescens, Bridelia cathartica, Bauhinia petersiana and Ormocarpum kirkii.* The grass component is constituted by *Andropogon, Diheteropogon, Heteropogon* and *Hyparrhenia.*

2.1.4. Sub-areas of the larger study area (MWR) *(Figure 1)*[12]

A). THE EASTERN BLOCK (EB) (365.4km², 53% of MWR)

- SANCTUARY sub-area (143.8km² → 20.9% of MWR and 39.4% of EB)

  Plot codes representing this sub-area was: **"ST"**

  Overall proportions of vegetation types in the Sanctuary:

  - Riverine & Alluvial Association **(26.9%)**
  - Riparian Thicket **(3.6%)**
  - Low Altitude Mixed Deciduous Woodland **(47%)**
  - Ridge-top Mixed Woodland **(13.7%)**
  - Medium Altitude Mixed Deciduous Woodland **(8.8%)**
  - High Altitude Miombo Woodland **(0%)**

[12] Data on the proportional area cover of various vegetation strata in the sub-areas and that of the sub-areas in MWR (needed for weighted calculations in data analysis) were provided by Tizola Moyo (DNPW-APN, MWR).

- PENDE sub-area (221.6km² → 32.1% of MWR and 60.6% of EB)

  Plot codes in Pende were based on its three dominant river domains:

  1. Masakale domain (northern Pende) → plot codes: "**MK**"
  2. Mthumba Alluvium domain (central Pende) → plot codes: "**MB**"
  3. Kakoma domain (southern Pende) → plot codes: "**KK**"

  Overall proportions of vegetation types in Pende:

  - Riverine & Alluvial Association **(12.5%)**
  - Riparian Thicket **(0%)**
  - Low Altitude Mixed Deciduous Woodland **(49.4%)**
  - Ridge-top Mixed Woodland **(9%)**
  - Medium Altitude Mixed Deciduous Woodland **(25%)**
  - High Altitude Miombo Woodland **(4.1%)**

B). THE WESTERN MAJETE BLOCK (323.6km², 47% of MWR)

Plot codes representing this sub-area was: **"MJ"**

Overall proportions of vegetation types in the Western Majete Block:

- Riverine & Alluvial Association **(5.1%)**
- Riparian Thicket **(0.5%)**
- Low Altitude Mixed Deciduous Woodland **(10.6%)**
- Ridge-top Mixed Woodland **(3%)**
- Medium Altitude Mixed Deciduous Woodland **(14.7%)**
- High Altitude Miombo Woodland **(66%)**

2.2. Study animals

Numbering 2,220 surviving individuals, the *D. b. minor* is the most numerous of the three surviving ecotypes (Emslie *et al.*, 2012) *(Table 1)*. Despite the wave of recurrent rhino poaching in the Southern African region in recent years, most populations have managed to maintain a stable state while some shown marked increase under strict protection (Knight *et al.*, 2011) *(Table 1).* Majete's recently reintroduced BR (numbering 11 individuals at the time of field work) provided feeding data for this research. During data collection six of the founding adults (one ♂: Lundu; and five ♀: Shamwari, Cassia, Callista, Kumi, Regan) and their four offspring (three ♂ and one ♀) were ranging freely in the Sanctuary. One solitary male (Chimpanje) was being held separated within a $2km^2$ *boma* (fenced enclosure) within the Sanctuary to avert conflicts with the other male. Each female had got offspring sired by Chimpanje between 2008 and 2010 (before his isolation), but Shamwari and Regan had lost their calves due most probably to predation in 2008 and 2010 respectively. Overall, the presence of the four healthy calves and the pregnant state of Regan (impregnated by Lundu) betokened a remarkable population growth rate at the time of the study. The majority of research efforts were expended assessing the habitat use of the 10 rhinos and only three visits were paid to the solitary bull's enclosure so as to obtain additional feeding data during Phase 1.

2.3. Data collection

2.3.1. The Rhino Monitoring Unit

During field work the assistance and guidance of five experienced rhino monitoring professionals (employed by the DNPW) were used. For each outing two armed scouts were deployed by their superior, Mr Fyson Suwedi (Head of Law Enforcement), namely:

- Mr Tizola Moyo (Leader of Rhino Monitoring)
- Mr Nelio Stuart
- Mr Francis Chambo
- Mr John Jiya
- Mr James Kamtsokota

The objectives of Majete's Rhino Monitoring Unit, though closely tuned with the aims of this project, are to collect as much behavioural, population, condition-related and other descriptive ecological data as possible. They have to spot and identify each rhino at least once a month for the ecological monitoring database as well as security purposes. The following physical characteristics help identify rhino: distinctive ear-notches, general look, horn shape, scars, the size and shape of footprints (spoors) or the presence of an accompanying calf (Oloo *et al.,* 1994). Research work with the monitoring team covered the entire area of the Sanctuary and was not biased towards sections associated with intensive habitat use by rhinos, which provided opportunities for the scouts to record the presence and activities of other threatened species like Lichtenstein hartebeest, sable antelope, giant kudu, African elephant, Livingstone's eland or Sharpe's grysbok.

2.3.2. Materials used (Phase 1 and Phase 2)

- *Monitoring equipment:* a pair of binoculars; a high zoom compact camera
- *Orientation:* compass, MWR Road and Vegetation Map, 'e-trex Garmin field GPS'
- *Communication with HQ:* hand held radio and mobile phones
- *Transport:* 4WD Honda quad bike (500cm^3)
- *Data recording and -input:* pen, pencil, datasheet, writing pad, laptop computer
- *Surveying equipment:* 1 surveying tape (20m) for setting plots; 1 tape measure (5m) for measuring canopy diameter; and a 2m surveying rod for getting data on vertical canopy depth of plant specimens

2.3.3. The timing and limitations of field work

This work – due to time constraints – could not have the scope of examining BR diet availability throughout all seasons of the year. Keryn Adcock (2006) from AfRSG suggests that if only one annual survey is possible, the best time to conduct it should fall between the end of the wet and the beginning of the dry seasons (April-May-June in the Southern African region), which can provide a picture on both seasons' browse conditions or at least a reasonable average of those. Complying with this recommendation field work was being conducted between the 22nd of March and the 2nd of June in 2011. The 10 weeks this research study spent in MWR was sufficient to gather adequate field data on BR diet composition, relative consumption rates (diet importance) and proportional browse availability –, aspects that allowed meaningful deductions on browse preference and major habitat suitability patterns during the subsequent data analyses.

2.3.4. Data collection in Phase 1 (Week 1 – Week 6) – Browse utilisation

2.3.4.1. Daily schedule and destinations visited

According to early studies the best time to monitor BR is typically early dawn when it usually goes drinking, then its early morning and late afternoon feeding peaks when its activities are most intense (Goddard, 1968; Mukinya 1977). Therefore the schedule of setting off just before sunrise for 5-7 hour long outings six days a week was adopted. Quad- and motorbikes were used. In trying to avoid observer bias in such aspects as diurnal browsing, some twilight/late afternoon sessions (3.20pm-6.30pm) were carried out. Equipped with nigh vision binoculars, two full moon night trials set from a tree hide overlooking Nsepete waterhole were also conducted (5.00pm-11.30pm) to witness possible rhino activities after nightfall. As BRs are reliant on regular water intake, research focused on looking for rhino signs (other than along the network of gravel roads while driving) by visiting natural ponds, fresh water springs, larger rain puddles, artificial waterholes, muddy pools, river banks and the often semi-wet soils of dried out river beds *(Figure 2),* which attract BR regularly and retain fresh spoor (footprint) longer than any other substrate (Emslie & Adcock, 1994*b*; Hall-Martin *et al.*, 1982).

2.3.4.2. Examining diet composition - looking for BR browse marks

Methods used to assess the diet of black rhino (e.g. feeding tracks, feeding stations, faecal analysis, direct observation and indirect quantitative methods) vary and depend on conditions such as the type of vegetation, season, or the specific objectives pursued (Brown, 2008). The 'feeding track' observation technique, applied successfully by

Mukinya (1977) and Hall-Martin *et al.* (1982), was adopted in this study. Feeding data were collected by tracking rhinos on foot in the Sanctuary. Trackers defined fresh spoor as one being not older than 3-4 hours (Tizola Moyo, *pers. comm.,* 2011). The complex network of well-beaten elephant paths, used intensively by most large-bodied game in the Sanctuary, aided registering rhino movements. On a feeding trail (leading often to/from a drinking place), fresh bites left by rhinos or their characteristic three-toed footprints were often well preserved and fairly conspicuous in the loose, sandy but sometimes soggy soil *(Figure 2)* (Mukinya, 1977). Tracking BR is a challenging and time-consuming exercise. Whereas its success depends primarily on the experience of the tracker, the wind direction, the animal's alertness and actual behaviour, it can go awry often due to a set of miscellaneous conditions (Adcock & Emslie, 2003), such as:

- Old, parched or extensively long grass layer.
- Dry soil or increased disturbance of ground surface by strong wind, heavy rain or passing wildlife (i.e. a buffalo herd can deface fresh rhino footprints rapidly).
- Thick and impenetrable vegetation structures fresh rhino trails may lead into or across (i.e. bush clumps or intermingled thicket patches of low visibility).
- Sudden attack by aggressive, large mammals (i.e. elephant, buffalo, rhino).
- Extremely hot days that make browse marks turn dry faster than normal, whereby making the judging of their freshness difficult.

Wet grainy riverbed substrate

Dry sandy soil

Figure 2. The characteristic three-toed black rhino footprints in two soil types (photos taken by the author).

After fresh spoors have been detected the rhino trail was followed and all fresh signs of browsing activity was recorded (Mukinya, 1977). Walking along a feeding track and locating feeding rhinos live was an added bonus in providing first-hand browse usage data. BR browse marks differ from those of other browsers (i.e. elephant, kudu) in that they prune the vegetation resulting in a distinctive clear-cut bite that leaves no pulp or other leftover hanging off at the sore area (Joubert & Eloff, 1971; *pers. observ.*). Stem tips, twigs and branches eaten by BR (often ~0.5–1.8cm thick in Ø) are severed by their proximal molars clipping an almost perfect 45° diagonal cut *(Figure 3)* – as if done by a garden shearer (Du Toit *et al.*, 1990; Oloo *et al.*, 1994). Fresh browse signs (can be called *cuts*) were distinguished from old ones by the colour and wetness of the wood at the bite wound (Emslie & Adcock, 1994*a*).

When following a feeding trail, the vernacular- and (if known) the botanical names of browsed vegetation were noted and photo samples taken for subsequent botanical identification. The exact GPS (Global Positioning System) locations of feeding rhino(s), fresh browse marks, scattered dung, frequented dung middens and resting places along with the date and time were also recorded. Following recommendations of Goddard (1968) and Joubert & Eloff (1971), for browse species that could not be identified on the feeding site botanical samples (supplementing photo samples) were also collected in order to assist the often tedious classification process at HQ. By recording the taxonomic names of eaten plants day after day, a 'Browse Species List' was being compiled.

Acacia karoo

Ziziphus mucronata

Croton macrostachyus

Figure 3. The typical 45° black rhino bite, called *cut* (sample photos taken by the author).

2.3.4.3. Assessing consumption rate of browse ('Diet Importance')

The importance of diet species was extrapolated from the overall number of Standard Bite Volumes (SBV) recorded on their browsed specimens in the so called 'BR feeding space' (≤ 2m above the ground) along the tracks (Buk, 2004; Adcock, 2005). The concept of SBV is to represent the average amount of browse removed from a plant by BR in one bite (Hall-Martin *et al.*, 1982; Kotze & Zacharias 1993; Oloo *et al.,* 1994; Buk, 2004).

In this technique:

- Following Hall-Martin *et al.* (1982), a **single bite** (SBV) was scored for:
  - Any isolated severed shoot or branch (found in the ≤ 2m browsing range).
  - Where contiguous shoots or branches were bitten off at the same height and were less than 5mm in thickness each and grew within a hypothetical circle of 5cm in diameter (i.e. in case of adjacent browse marks on the freely branching, multi-stemmed dwarf shrub *Ormocarpum kirkii*).
- On every specimen with browse marks the SBVs were counted (first the number of bites on a specimen in a feeding site, then total bites on all specimens of that species per day, then total bites on that species during Phase 1).
- Important (intensively browsed) diet plants were those with high feeding rates, which were expressed by the large proportion their overall SBVs had out of the total sum of SBVs recorded on all browse species (Hall-Martin *et al.,* 1982).

2.3.4.4. Safety rules during black rhino tracking and encounters

1. On an feeding trail of low visibility, the tracker must focus on pursuing footprints and locating potential browse marks, while the other two observers (other than helping the tracker) are advised to scan the flanks to avert a possible charge.
2. When noticing BR signs, efforts must be maximised to identify the individual for making precise deductions concerning BR behaviour and maximise data influx.
3. When noticing feeding rhinos the observer is advised to (Adcock & Emslie, 2003):
    - Approach site from the leeside by walking upwind for their especially acute sense of smell will warn rhinos instantly of human presence (when alarmed, BR may flee or attack the observer).
    - Get close to the animal(s) by moving slowly without being detected.
    - Do not progress across the rhino's field of vision while it is looking your direction. If it catches sight of you – freeze!
    - Hide among the branches of nearby tree canopies (min. 3m in height), which can allow a good view of the animal(s) and offer a secure hideout.
    - Prevent negative impacts to BR behaviour (i.e. direct disturbance, noise).
    - Exercise extra caution when observing mother with calf.
    - Examine it critically and weigh correctly what 'tolerable distance' may mean in a situation (i.e. by judging the level of aggression or alertness of the observed rhino and testing the intensity and direction of wind).

2.3.5. Data collection in Phase 2 (Week 5 – Week 10) – Browse availability[13]

2.3.5.1. Sampling design

According to Bell (1984) and Sherry (1989), MWR is characterized by great variations in terms of the density and distribution of its six dominating vegetation types. The study area was decided to be divided into three sub-areas representing disparate management entities (Hall-Martin, *pers. comm.,* 2011). The principal goal in Phase 2 was to assess the relative availability of rhino browse in the various vegetation strata of the sub-areas – manifested by browse availability (BA) scores at different levels. Reported to be historically sound BR habitats, sampling efforts focused on the Sanctuary and Pende sub-areas with limited time spent assessing BA of the poor Western Majete Block dominated by *Brachystegia* and *Julbernardia* woodland (Hall-Martin, *pers. comm.,* 2011). During sampling the sub-areas were stratified by their vegetation communities (it was possible due to their known % area coverage within) – a method that assured separate estimates of the means and variances to be calculated for each stratum resulting in higher precision in overall mean estimations of %BA (Sutherland, 2006; Adcock, *pers. comm.*, 2011). Though distributed patchily in a largely discontinuous matrix, each of the six vegetation types occurring in MWR appeared homogenous in composition according to Bell's (1984) definitions and could be differentiated based on thorough ground-truthing and their individual visual classification by consulting Sherry's (1989) map (*Figure 1*).

[13] That Phase 2 overlaps with Phase 1 during Week 5 and Week 6 is accounted for by the ongoing work on SBV recordings and not by trying to add new taxa to the Browse Species List (it was closed at the end of Week 5).

The research team consisting of the author and two armed members of the Rhino Monitoring Team used quad- and motorbikes for transport (similarly to Phase 1). As the study was conducted at the end of the wet-hot and the beginning of the cool-dry season, the biomass of foliage on plants were sufficient (vital for identification), yet some species (i.e. *Sterculia* and *Holarrhena* spp.) started shedding leaves in late May. Sampling plots were set randomly within each vegetation community in the sub-areas. Their localities were geo-referenced on a GPS, photographed from two angles with main features noted. The number of plots set in a vegetation type was determined by the size of the unit, its historical conduciveness to BR and statistical considerations (Buk, 2004). The yellow flags of all coded plots were displayed on Sherry's (1989) vegetation map of MWR by using the Ozi Explorer GIS software *(Figure 7).*

2.3.5.2. Measuring absolute browse volumes (m^3)

1. Each plot was set as a 20m (length) x 20m (width) x 2m (height) cuboid space.
2. Specimens of browse plants (those identified in Phase 1) were sought out within.
3. In this study, species were not grouped into various layers (i.e. small trees, shrubs, dwarf shrubs, succulents, herbs, forbs) to ease the estimation of canopy dimensions through the application of categorised mid-class values, but individual (absolute) plant measurements were recorded (highest accuracy).

4. For each diet specimen two measurements were recorded *(Figure 4 & Figure 5)*:

    - **Canopy cover (m^2):** area which is covered by a plant's edible matter.
    - **Canopy depth (m):** vertical distance between the lowest and highest point of edible material on a plant (canopy outside the 0-2m range was precluded).[14]

5. Multiplying these two values (m^2 x m) yielded an approximate estimate of the canopy volume that an individual plant specimen occupied (like an imaginary cylinder) in a plot. It is called **absolute browse volume** (m^3).

6. The sum total of the individual absolute browse volumes measured for all its specimens within yielded the absolute browse volume for a species in a plot (m^3).

7. The sum total of the individual absolute browse volumes recorded for all diet species found within yielded the absolute browse volume for a plot (m^3).

8. Relating the absolute browse volume of a species to the total browse volume of all diet species found in a plot yielded its % browse contribution in that sample.

9. Possible difficulties faced during measurements of canopy dimensions:[15]

    - Measuring canopy diameter: detailed list of advice given on *pp. 13-14*.
    - Measuring canopy depth: detailed list of advice given on *pp. 17.*

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[14] Keryn Adcock (2006) [IUCN/SSC AfRSG] suggests that though BRs feed in the 0.5-1.2m height range, studies should take into account all preferred biomass found below 2m because the 0-2m space layer over a certain area (i.e. quadrat, vegetation stratum or the whole reserve) represents the actual browse space or "pie" for BR.

[15] For a list of advice on precautionary considerations on measuring canopy dimensions of BR browse species Adcock's (2006) manual on *Visual Assessment of Black Rhino Browse Availability, Version 3.0.* was consulted.

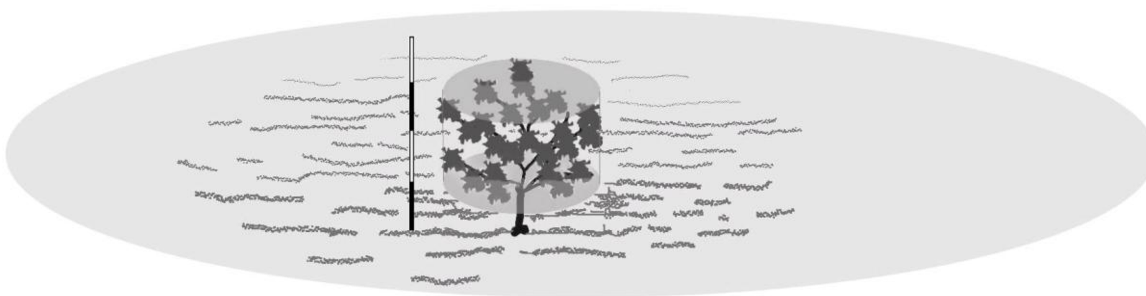


Figure 4. Measuring canopy depth in the 0-2m range (Adcock, 2006*a*).

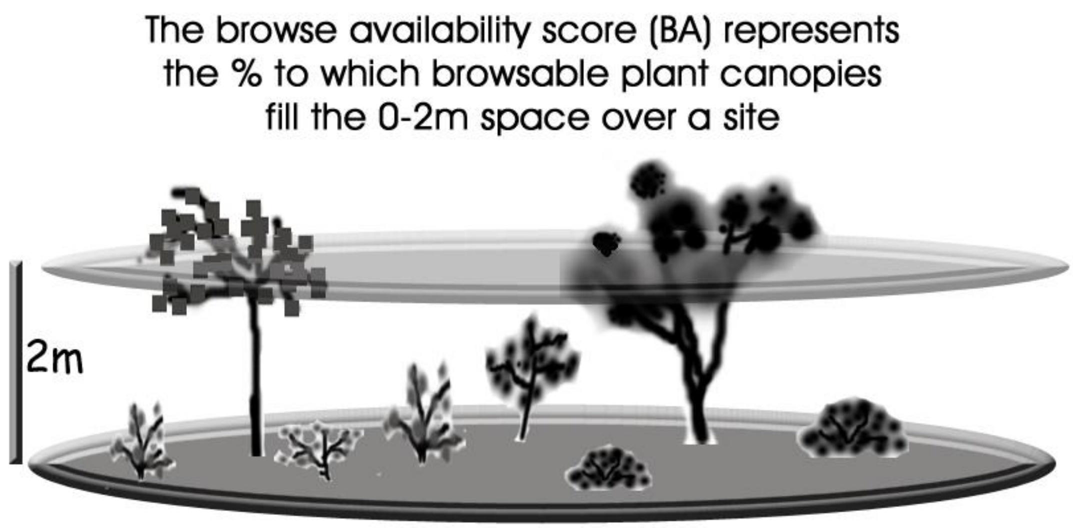


Figure 5. Visual demonstration of available browse to black rhino in an imaginary circle-based plot (Adcock, 2006*a*). [Comment: this study used square plots!]

2.4. Data analyses

2.4.1. Data analysis - Phase 1

1. In order to establish the taxonomic identity of each browse plants and thus compile a 'Browse Species List' for this study (using both biological and photo samples) the following sources were utilised:
    - Relevant plant identification books on woody flora of the region (Van Wyk & Van Wyk, 1997; Smith & Allen, 2004).
    - The vast botanical expertise of Mr Hassam Patel from the National Herbarium of Malawi, who joined field work and the identification sessions for a week's time (inspected each specimen carefully several times).
    - As complimentary resource, local botanical knowledge was also used in order to differentiate some particularly challenging taxa prior to their eventually successful scientifically classification.
2. To assess the relative (%) importance of a forage species to BR, the number of SBVs recorded on its specimens was divided by the total SBVs counted on all browse taxa during Phase 1 (and x 100). The resultant proportional (%) bite scores reflect a species' individual position in the importance ranking order. Thereby, species contributing most to overall browse consumed (i.e. highest feeding rates) are regarded as the most important or principal diet plants (Oloo *et al.,* 1994; Hall-Martin *et al.,* 1982; Brown & Van der Westhuizen, 2005).

2.4.2. Data analysis - Phase 2[16]

1. A plot was considered as an 800m³ rectangular cuboid with square basal area of 400m² and pre-defined canopy height of 2m.

2. To get the absolute proportional (%) BA score for a species in a plot, its absolute browse volume (m³) was divided by the total volume of the plot (800m³).

3. To get the %BA score for a plot, the individual %BA scores of the species forming its entire browse material were added up (or else: the absolute total browse volume of the plot was divided by its total volume).

4. To get the %BA score for a vegetation type within a sub-area, the average of the %BA scores given to plots established in that type was calculated.

5. To get the overall %BA score for a sub-area, the total sum of the area-weighted %BA scores given to its vegetation types was calculated [considering their proportional (%) area cover within the sub-area].

6. To get the overall %BA score for a vegetation stratum in the entire MWR, its overall sub-area specific weighted %BA scores (first weighted by the % area cover it forms in the particular sub-area, then the resultant score weighted again by the % area cover of the sub-area in MWR) were summed.

7. To get the overall %BA score for MWR, the total sum of the area-weighted average %BA scores of its six vegetation types (or those of the three sub-areas) was calculated.

[16] Adopting steps suggested by Adcock's (2006) *Visual Assessment of Black Rhino Browse Availability V3.0.*

2.4.3. Further analyses

1. Establishing preference indices for each forage plant was done by using data collected in the Sanctuary only (study area for assessing rhino diet). Preferred or intensely sought after plants are those that occur in larger proportion in the diet than in the habitat (Adcock 2006*b*). The preference index of a species is gained by dividing its *importance score* (i.e. reflecting % feeding rate on its specimens) by its *relative availability score* (Petrides, 1975). Phrasing it otherwise:

   Preference = % contribution to diet / % contribution to available browse

   - Nominator of the 'preference division' was calculated as of *2.4.1.* on page 36.
   - Denominator of 'the preference division' was calculated as follows:
     - Within each plot the absolute %BA score for each plant species was calculated (i.e. the proportional vertical fill of the species in the ≤ 2m canopy height of the plot – namely: the % that its absolute browse volume forms in the total volume of the plot) (*Appendix 1a*).
     - Within each vegetation stratum, species-specific %BA scores were averaged considering all the plots surveyed in the stratum and not only those ones with positive species occurrences (this gave correct vegetation type averages for each species taking into account that some plots may not have some taxa) (*Appendix 2a*).
     - Within the Sanctuary the overall weighted average %BA score was calculated for each plant by adding up its area-weighted absolute average %BA scores from the vegetation types (i.e. considering the % area cover of the type in the Sanctuary) (*Appendix 2a*).
     - Relating the overall weighted average %BA score of a diet plant to the average %BA score of the Sanctuary (and x100) yielded the relative contribution of that species to the total edible browse (*Appendix 2a*).

- The resulted indices (between 0 and infinity) reflected the position of species in the preference ranking. It is a gradient, so plants with values well below 1 are rejected, near 1 are neutral and well above 1 are preferred (i.e. higher index represents higher preference).

- However, if a species' sizeable or moderate SBV happened to couple with extremely low representation in the sample (i.e. <1%), it often resulted in disproportionally (and unjustifiably) high preference indices. As one can not tell how preferred very rare species are, when ranking browse items in terms of preference such resultant distorting statistical aberrations were eliminated by considering species only with >1% contribution to the available browse.

2. Suitability ratings of browse were made by combining results of this research with those of other studies conducted in miombo/sourveld areas in the Southern African region (*see under 3.5.2. on pages 51-52*) – e.g. aggregated feeding intensity and palatability information (Adcock, 2006*b*). This furthered the understanding – through the resultant increment of precision and thus representativeness of the estimates – of how BR rates browse plants across a range of different species abundances (i.e. overall value of selected forage plants to rhino in the eco-region). Hence, relying on a larger pool of relevant data also helped define the suitability ratings of species characterised by only meagre abundance in this study. The established suitability classes (Adcock, 2006*b*) are:

Suit 1 = important (often eaten) and preferred (palatable) in all studies.

Suit2 = quite important in diet (maybe seasonally) but not preferred in all studies; or those readily selected but data deficient in terms of %BA (i.e. 'suit unknown').

Suit3 = not highly important in diet and rejected (unpalatable) in most studies.

3. Defining the most suitable habitat mosaic in MWR was done by rating vegetation types based on the summed absolute %BA of Suit1, Suit2 and Suit3 species. Top suitability areas had higher overall density of Suit1 + Suit2 (valuable) plants.

3. RESULTS

3.1. Field efforts

50 days were spent with actual field work (Phase 1 and Phase 2). The overall distance covered on foot was 276.6km. 165km was expended on tracking rhinos (Phase 1), 116.6km on assessing browse availability (sampling - Phase 2). The approximate distance driven by the quad bike was 1300km. 242.4 hours were spent on the field in total.

3.2. Live rhino sightings (Phase 1)

Tracking brought about 18 occasions of live rhino sighting with 37 animals observed at close range in total. Individuals were identified at all times. Overall, 34 fresh BR tracks were pursued, 26 of which were feeding trails with substantive dietary information.

3.3. Diet composition and importance (Phase 1)

Along the feeding trails, fresh foraging marks bore evidence of basic dietary information and thus facilitated the compilation of the Browse Species List, totalling 59 taxonomically identified rhino diet plants *(Table 2).* In total, 1743 Standard Bite Volumes (SBVs) were counted on browsed vegetation along the live tracks in the Sanctuary. Based on the relative proportion of bites out of the total; relative importance scores were calculated for all species *(Appendix 2b)*. 62.42% of all recorded bites were found on specimens belonging to the 10 most important (principal) diet plants *(Figure 6, Appendix 4)* with substantial representation of species belonging to the Mimosaceae and Fabaceae families (i.e. five out of the ten most intensively utilised browse taxa).

Table 2. The Browse Species List (59 taxa recorded to be eaten by black rhino).

Scientific Names	Family Names	Local vernacular (Chichewa name)
Acacia burkei	Mimosaceae	?
Acacia nigrescens	Mimosaceae	(Nkunkhu)
Acacia nilotica	Mimosaceae	(Chisio or Ngagaga)
Acacia karoo	Mimosaceae	?
Acacia tortilis	Mimosaceae	(Fungo or Nchongwe)
Acacia xanthophloea	Mimosaceae	(Mchezime)
Albizia harveyi	Mimosaceae	(Njenjete)
Albizia anthelmintica	Mimosaceae	(Chitale)
Allophylus africanus	Sapindaceae	?
Becium grandiflorum	Lamiaceae	?
Burkea africana	Caesalpiniaceae	?
Cardiogyne africana	Moraceae	(Mphabulu)
Catunaregam spinosa	Rubiaceae	(Chipembere)
Combretum adenogonium [former name: *C. fragrans*]	Combretaceae	?
Combretum apiculatum	Combretaceae	(Kagolo)
Combretum collinum	Combretaceae	?
Combretum mossambicense	Combretaceae	(Nkotamu or Manga)
Combretum zeyheri	Combretaceae	?
Commiphora africana	Burseraceae	(Kobo)
Croton macrostachyus	Euphorbiaceae	(Mfumpu)
Dalbergia melanoxylon	Fabaceae	(Mphingo)
Deinbollia nyikensis	Sapindaceae	(Ntalala)
Dichrostachys cinerea	Mimosaceae	(Kapangale)
Diospyros senensis	Ebenaceae	(Mfupa or Nyongolo)
Diospyros squarrosa	Ebenaceae	(Msindira)
Diospyros quiloensis	Ebenaceae	(Kasinja)
Diospyros zombensis	Ebenaceae	(Mdima)
Diplorhynchus condylocarpon	Apocynaceae	(Tombozi)
Dyschoriste verticillaris	Acanthaceae	?
Ehretia amoena	Boraginaceae	(Chisikisira anamwali)
Ekebergia capensis	Meliaceae	(Lesser mbaritza)

Euphorbia ingens	Euphorbiaceae	(Goleka)
Gardenia ternifolia	Rubiaceae	?
Grewia bicolor	Tiliaceae	(*Grewias* are called Tenza)
Grewia flavescens	Tiliaceae	"
Grewia forbesii	Tiliaceae	"
Grewia villosa	Tiliaceae	"
Gymnosporia buxifolia [former name: *Maytenus heterophylla*]	Celastraceae	(Mkolasato/Mtambasato)
Gymnosporia senegalensis	Celastraceae	(Nkolaminga)
Holarrhena pubescens	Apocynaceae	(Tombozi chipete)
Hymenocardia acida	Euphorbiaceae	
Karomia tettensis	Verbenaceae	(Mkhaladundu)
Kigelia africana	Bignoniaceae	(Mvunguti)
Lannea discolor	Anacardiaceae	(Ntonongoli)
Lannea schweinfurthii [former name: *L. stuhlmannii*]	Anacardiaceae	(Chirusa)
Ormocarpum kirkii	Fabaceae	(Nsungamwana)
Pouzolzia mixta	Urticaceae	?
Pterocarpus rotundifolius	Fabaceae	(Big Mbaritza)
Rhus tenuinervis	Anacardiaceae	?
Schrebera trichoclada	Oleaceae	?
Sclerocarya birrea	Anacardiaceae	(Marula)
Sterculia appendiculata	Sterculiaceae	(Njale)
Stereospermum kunthianum	Bignoniaceae	?
Terminalia sambesiaca	Combretaceae	?
Urena lobata	Malvaceae	?
Vangueria randii	Rubiaceae	?
Vitex buchananii	Lamiaceae	?
Xeroderris stuhlmannii	Fabaceae	(Nonde or Mlonde)
Ziziphus mucronata	Rhamnaceae	Kankhande

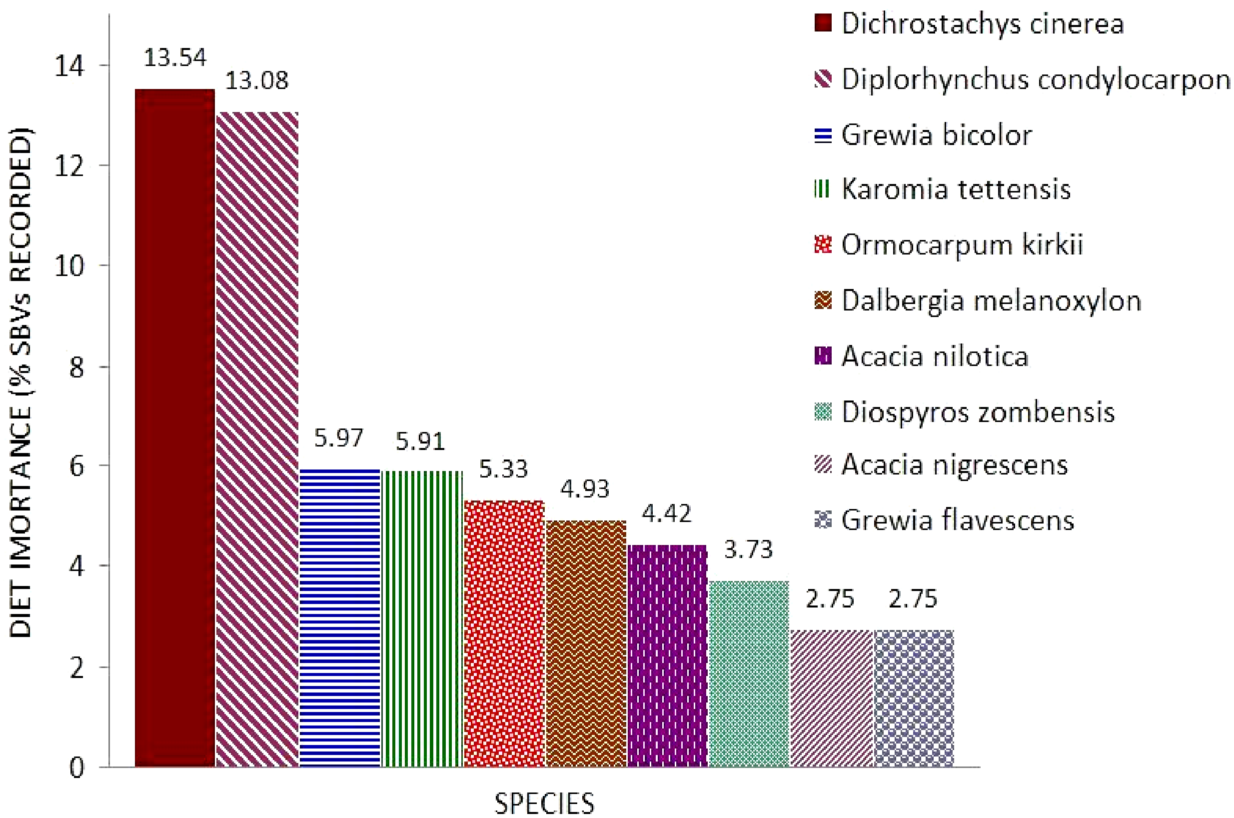


Figure 6. Ranking of the 10 most important (principal) diet species expressed by the intensity (rate) of their having been selected by feeding rhinos in the Sanctuary. The % values represent the proportion of overall bites counted on a single species out of the total number of bites (1743) recorded on all browse species during Phase 1.

3.4. Browse availability assessment (Phase 2)

During this phase dedicated to sampling, 111.6km was covered on foot spanning the last six weeks of field work. In total, 36 plots were set in the six vegetation communities of the sub-areas *(Figure 7)*.

3.4.1. Species richness

A. SUB-AREAS

- Pende (17 plots): 43 diet species (out of the total 59).
- Sanctuary (15 plots): 38 diet species (out of the total 59).
- Western Majete (4 plots): 14 diet species (out of the total 59).

B. VEGETATION TYPES

- Riverine & Alluvial Association (10 plots): 44 diet species (out of the total 59).
- Low Altitude Mixed Woodland (11 plots): 34 diet species (out of the total 59).
- Medium Altitude Mixed Woodland (4 plots): 19 diet species (out of the total 59).
- Ridge-top Mixed Woodland (6 plots): 18 diet species (out of the total 59).
- Riparian Thicket (2 plots): 15 diet species (out of the total 59).
- High Altitude Miombo Woodland (3 plots): 10 diet species (out of the total 59).

3.4.2. %BA scores (proportional or % fill) computed at different levels

- For each browse species within a particular plot (*Appendix 1a/b/c*)
- For each plot within a particular vegetation type of a given sub-area *(Table 3/4/6)*
- For each vegetation type within a particular sub-area *(Table 3/4/6)*
- For each sub-area of the MWR *(Table 3/4/5/6)*
- For each vegetation type of MWR *(Table 7/8)*
- For the entire MWR *(Table 7/8)*

Among the sub-areas, the Sanctuary possessed the greatest absolute browse availability on average (%BA: 16.91%), whilst the Western Majete Block (dominated by *miombo* woodland) had the lowest (7.39%). In terms of vegetation strata, the highest average browse representation was found in the Riverine and Alluvial Association (23.8%), followed by the Ridge-top Mixed Woodland (16.92%) and Low Altitude Mixed Woodland (15.06%). Plot 'MB1' of the riverine stratum produced a record 39.5% vertical fill with 20(!) diet species recorded. The High Altitude Miombo Woodland (poorest in species richness) had the lowest average browse availability score (3.7%). When considering area-weighted scores, the Low Altitude Mixed Woodland (due to its large, 30.7% summed area coverage in MWR) produced the largest overall browse availability by far (4.6% of MWR's total volume in the ≤2m canopy height range). The Riparian Thicket, though identified with significant average %BA score, fared lowest in area-weighted BA (0.14%) due primarily to its very small overall area representation in MWR (*Table 7/8*).

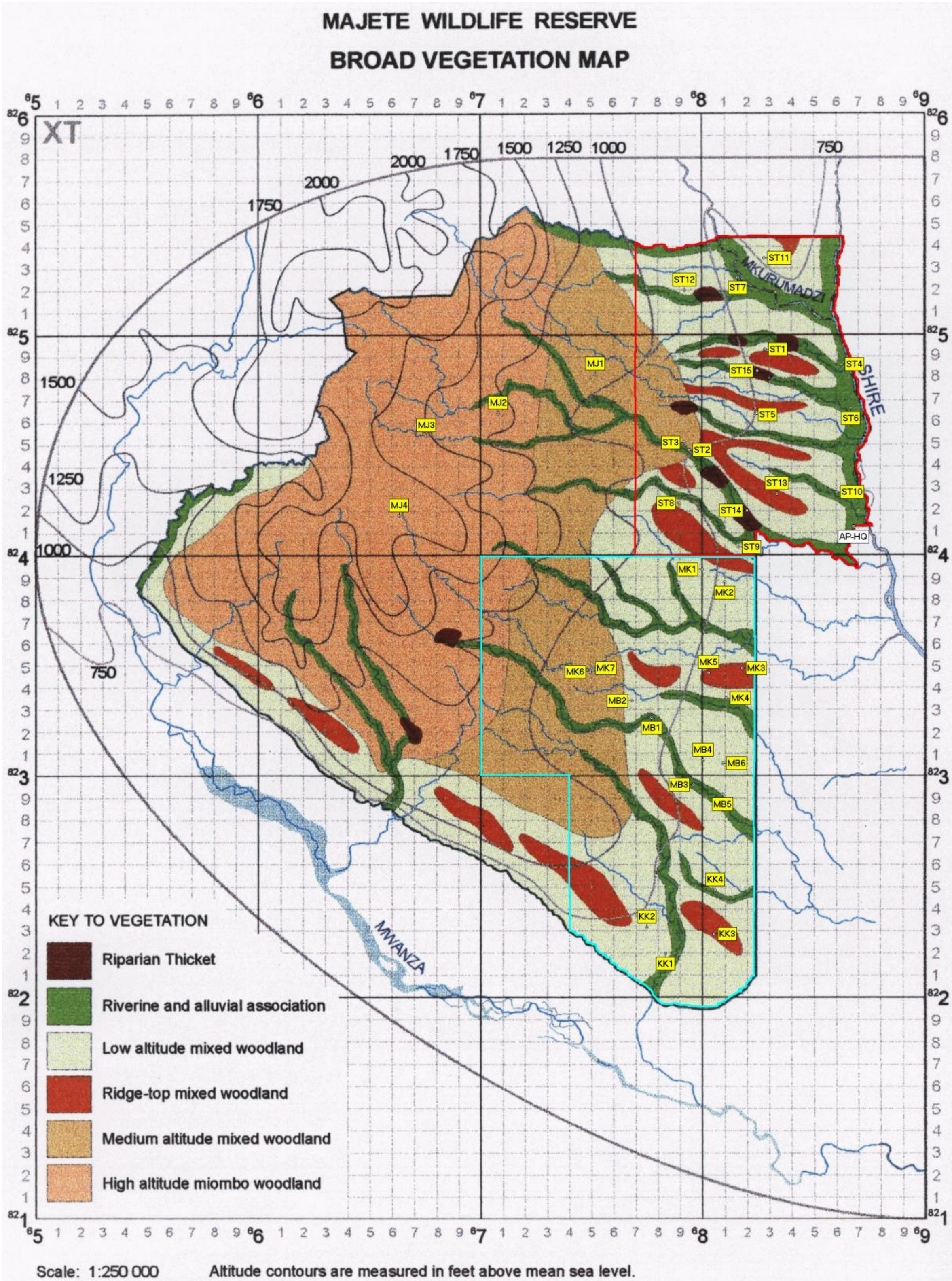


Figure 7. Sample plots (yellow flags) displayed by Ozi Explorer GIS on the vegetation map of Majete W.R. [Sherry's (1989) map]. Coordinates are in UTM units. Brown line: Reserve boundary; Red line: Sanctuary boundary; Blue line: Pende sub-area boundary.

Table 3. Proportional browse availability (%BA) scores in the SANCTUARY sub-area.

SUB-AREA	Vegetation types of the SANCTUARY and their % area cover within → / Plot codes ↓	Riparian Thicket (3.6%)	Riverine & Alluvial Association (26.9%)	Ridge-top Mixed Woodland (13.7%)	Low Altitude Mixed Woodland (47%)	Medium Altitude Mixed Woodland (8.8 %)	High Altitude Miombo Woodland (0%)
SANCTUARY	ST 1			• (17.2%)			
	ST 2		• (11%)				
	ST 3					• (5.2%)	
	ST 4		• (25.1%)				
	ST 5				• (23.1%)		
	ST 6		• (17.9%)				
	ST 7		• (16.2%)				
	ST 8			• (18.8%)			
	ST 9				• (14.3%)		
	ST 10		• (29%)				
	ST 11				• (11.7%)		
	ST 12				• (23.8%)		
	ST 13			• (8.6%)			
	ST 14	• (18.7%)					
	ST 15	• (9.8%)					
	Average %BA scores of the vegetation types found in the SANCTUARY [the mean of all BA scores given to plots within a type]	**14.25%**	**19.84%**	**14.87%**	**18.23%**	**5.2%**	***Not represented in the Sanctuary***
	Area-weighted %BA scores of the vegetation types in the SANCTUARY [taking the % area cover of the vegetation types in this sub-area into account]	14.25% x 0.036 = **0.513%**	19.84% x 0.269 = **5.337%**	14.87% x 0.137 = **2.037%**	18.23% x 0.47 = **8.568%**	5.2% x 0.088 = **0.458%**	---

Overall average %BA score of the SANCTUARY [sum of the weighted %BA scores of its vegetation types]

0.513% + 5.337% + 2.037% + 8.568% + 0.458% =

<u>16.91%</u>

Table 4. Proportional browse availability (%BA) scores in the PENDE sub-area.

SUB-AREA		Vegetation types of PENDE and their % area cover within → / Plot codes	Riparian Thicket (0%)	Riverine & Alluvial Association (12.5%)	Ridge-top Mixed Woodland (9%)	Low Altitude Mixed Woodland (49.4%)	Medium Altitude Mixed Woodland (25%)	High Altitude Miombo Woodland (4.1%)
PENDE	MASAKALE	MK 1				• (4.9%)		
		MK 2				• (5.7%)		
		MK 3			• (30.5%)			
		MK 4		• (23%)				
		MK 5			• (16.4%)			
		MK 6					• (5.2%)	
		MK 7					• (3.2 %)	
PENDE	MTHUMBA	MB 1		• (39.7%)				
		MB 2				• (22.3%)		
		MB 3		• (24.4%)				
		MB 4				• (18.2%)		
		MB 5		• (24.5%)				
		MB 6				• (17.2%)		
PENDE	KAKOMA	KK 1				• (13.3%)		
		KK 2				• (11.2%)		
		KK 3			• (10%)			
		KK 4		• (27.2%)				
Average %BA scores of the vegetation types found in PENDE [the mean of all BA scores given to plots within a type]			***Not represented in Pende***	**27.76%**	**18.97%**	**13.26%**	**4.2%**	**3.73%** *(Extrapolated %BA based on average %BA of this veg. type in an another sub-area)* **Veg. type was represented but no plots were possible**
Area-weighted %BA scores of the vegetation types in PENDE [taking the % area cover of the vegetation types in this sub-area into account]			---	27.76% x 0.125 = **3.47%**	18.97%x 0.09 = **1.71%**	13.26% x 0.494 = **6.55%**	4.2% x 0.25 = **1.05%**	3.73% x 0.041 = **0.15%**

Overall average %BA score of PENDE
[sum of the weighted %BA scores of its vegetation types]

3.47% + 1.71% + 6.55% + 1.05% + 0.15% =

<u>12.93%</u>

Table 5. Proportional browse availability (%BA) scores of the EASTERN BLOCK (EB).

SUB-AREAS →	**SANCTUARY** (39.4% of the EB)	**PENDE** (60.6% of the EB)
Overall average %BA scores of the sub-areas in the EB [sum of the weighted %BA scores of the vegetation types within a sub-area]	**16.91%**	**12.93%**
Area-weighted %BA scores of the two key sub-areas making up the EB [taking the % area cover of the sub-areas in the EB into account]	16.91 x 0.394 = **6.66%**	12.93 x 0.606 = **7.84%**
Overall average %BA score of the EB [sum of the weighted %BA scores of the two key sub-areas]	**6.66% + 7.84% = 14.5%**	
Area-weighted %BA score of EB in MWR [EB is 53% of total area in MWR]	**14.5% x 0.53 = 7.69%**	
% Contribution of browse availability of the EB to total browse availability of MWR	**7.69% / 11.17% = 68.8%**	

Table 6. Proportional browse availability (%BA) scores in the WESTERN MAJETE BLOCK[17]. For the two vegetation types that were represented in this sub-area but no plots were possible to be established, extrapolated scores were given, e.g. the overall average of %BA scores of plots that had been set in the same vegetation component found in other sub-areas. This made it possible to get area-weighted sums of %BA indices for this least studied realm. The same reasoning applies for the extrapolated value in *Table 4*.

SUB-AREA	Vegetation types of the WESTERN MAJETE and their % area cover within → / Plot codes ↓	Riparian Thicket (0.5%)	Riverine & Alluvial Association (5.1%)	Ridge-top Mixed Woodland (3%)	Low Altitude Mixed Woodland (10.6%)	Medium Altitude Mixed Woodland (14.7%)	High Altitude Miombo Woodland (66%)
WESTERN MAJETE	MJ 1					• (10.5%)	
	MJ 2						• (2.8%)
	MJ 3						• (4.7%)
	MJ 4						• (3.7%)
Average %BA scores of the vegetation types found in WESTERN MAJETE [the mean of all BA scores given to plots within a type]		***Veg. type was represented but no plots were possible*** ***<u>Extrapolated %BA::</u>*** **14.25%**	***Veg. type was represented but no plots were possible*** ***<u>Extrapolated %BA::</u>*** **23.8%**	***Veg. type was represented but no plots were possible*** ***<u>Extrapolated %BA::</u>*** **16.92%**	***Veg. type was represented but no plots were possible*** ***<u>Extrapolated %BA::</u>*** **15.06%**	**10.5%**	**3.73%**
Area-weighted %BA scores of the vegetation types in WESTERN MAJETE [taking the % area cover of the vegetation types in this sub-area into account]		14.25 x 0.005 = **0.07%**	23.8 x 0.051 = **1.21%**	16.92 x 0.03 = **0.51%**	15.06 x 0.106 = **1.60%**	10.5% x 0.147 = **1.54%**	3.73% x 0.66 = **2.46%**

Overall average %BA score of WESTERN MAJETE
[sum of the weighted %BA scores of its vegetation types]

0.07% + 1.21% + 0.51% + 1.60% + 1.54% + 2.46% =

<u>7.39%</u> [Area weighted score (47% of MWR): 7.39% x 0.47 = <u>3.47%</u>]

These average (and weighted) %BA scores are only approximate values for no adequate research effort was possible to assess the %BA of all the six vegetation communities of this otherwise *miombo* dominated sub-area.

[17] No thorough examination of this *miombo* dominated sub-area was attempted due to the limited time available and also because it has got a very high overall density of reportedly unpalatable *Brachystegia* species (Shaw 2011; Hall-Martin, *pers. comm.,* 2011). Objectives of this study were not set to expend much research effort in this realm. The four plots set there provided some rough %BA data for two of its vegetation types.

Table 7. Average proportional as well as area- weighted %BA scores of the vegetation types in the sub-areas and in the entire MWR. Values in *Italic* show the average of all %BA scores of plots set in a particular type within a sub-area (or extrapolated scores in some cases). Values in parentheses show the % area cover of the types in the sub-areas.

Vegetation types → **Sub areas ↓**	**Riparian Thicket**	**Riverine & Alluvial Association**	**Ridge-top Mixed Woodland**	**Low Altitude Mixed Woodland**	**Medium Altitude Mixed Woodland**	**High Altitude Miombo Woodland**
SANCTUARY	*14.25% [average %BA score]*	*19.84% [average %BA score]*	*14.87% [average %BA score]*	*18.23% [average %BA score]*	*5.2% [average %BA score]*	*Not represented in the Sanctuary*
BA scores of vegetation types weighted by their % area cover in the Sanctuary	(3.6%) 14.25 x 0.036 = 0.513%	(26.9%) 19.84 x 0.269 = 5.337%	(13.7%) 14.87 x 0.137 = 2.037%	(47%) 18.23 x 0.47 = 8.568%	(8.8%) 5.2 x 0.08 = 0.458%	–
BA scores of vegetation types weighted by the % area cover of the Sanctuary in MWR [20.9%]	0.513 x 0.209 = **0.11%**	5.337x 0.209 = **1.12%**	2.037x 0.209 = **0.43%**	8.568x 0.209 = **1.79%**	0.458x 0.209 = **0.1%**	–
PENDE	*Not represented in Pende*	*27.76% (Average %BA score)*	*18.97% (Average %BA score)*	*13.26% (Average %BA score)*	*4.2% (Average %BA score)*	***Veg. type was represented but no plots were possible*** ***<u>Extrapolated %BA:</u>*** *3.73%*
BA scores of vegetation types weighted by their % area cover in Pende	–	(12.5%) 27.76 x 0.125 = 3.47%	(9%) 18.97 x 0.09 = 1.71%	(49.4%) 13.26 x 0.49 = 6.55%	(25%) 4.2 x 0.25 = 1.05%	(4.1%) 3.73 x 0.041 = 0.15%
BA scores of vegetation types weighted by the % area cover of Pende in MWR [32.1%]	–	3.47 x 0.321 = **1.11%**	1.71 x 0.321 = **0.55%**	6.55 x 0.321 = **2.1%**	1.05 x 0.321 = **0.34%**	0.15 x 0.321 = **0.05%**
WESTERN MAJETE	***Veg. type was represented but no plots were possible*** ***<u>Extrapolated %BA:</u>*** *14.25%*	***Veg. type was represented but no plots were possible*** ***<u>Extrapolated %BA:</u>*** *23.8%*	***Veg. type was represented but no plots were possible*** ***<u>Extrapolated %BA:</u>*** *16.92%*	***Veg. type was represented but no plots were possible*** ***<u>Extrapolated %BA:</u>*** *15.06%*	*10.5%*	*3.73%*
BA scores of vegetation types weighted by their % area cover in Western Majete	(0.5%) 14.25 x 0.005 = 0.07%	(5.1%) 23.8 x 0.051 = 1.21%	(3%) 16.92 x 0.03 = 0.51%	(10.6%) 15.06 x 0.106 = 1.60%	(14.7%) 10.5 x 0.147 = 1.54%	(66%) 3.73 x 0.66 = 2.46%
BA scores of vegetation types weighted by the % area cover of Western Majete in MWR [47%]	0.07 x 0.47 = **0.03%**	1.21 x 0.47 = **0.57%**	0.51 x 0.47 = **0.24%**	1.60 x 0.47 = **0.75%**	1.54 x 0.47 = **0.72%**	2.46 x 0.47 = **1.16%**
Total area-weighted %BA scores of veg types in MWR	**<u>0.14%</u>**	**<u>2.80%</u>**	**<u>1.22%</u>**	**<u>4.64%</u>**	**<u>1.16%</u>**	**<u>1.21%</u>**
Overall %BA score of MWR	0.14 + 2.8 + 1.22 + 4.64 + 1.16 + 1.21 = **<u>11.17%</u>** (%BA for MWR)					

3.5. Further analyses

3.5.1. Browse preference

Eight of the 10 most important (staple) forage species *(Figure 6)* qualified to be among the 10 most highly preferred diet plants *(Figure 8)* in this study.[18] *Dichrostachys cinerea* topping both importance and preference rankings thus turned out to be the most valuable nutritional plant to BR in MWR. *Diplorhynchus condylocarpon,* the second most frequently selected, did not qualify to be among the 10 most preferred forage items.

N.B. It is important to underpin that this preference is only local (i.e. significantly dependent on the absolute abundance of the given species). Hence, deciding the value of particular forage plants to rhino, diet data of the same taxa collected by this and 22 other studies in similar rhino habitats (with emphasis on miombo/sourveld areas in the Southern African region) were collated so as to see on average how BR is rating forage items across a range of relative species abundances (Adcock, *pers. comm*., 2011). This gives a more accurate picture because a certain number of browse plants are rare in MWR and therefore provide little data to show how preferred or suitable they are.

3.5.2. Suitability classification of browse plants

Classifying rhino browse species in three categories in terms of suitability (e.g. Suit1, Suit2 and Suit3) was based on combined diet information of this as well as the following regional studies: Adcock & Shaw (2009), Brown (2008), Brown, *et al.* (2003), Brown & Van der Westhuizen (2005), Buk (2004), Buk, K. (2008), Buk, K. (2009), Buk & Knight

[18] Importance scores and preference indices can be consulted in *Appendix 2b;* sample photos in *Appendix 4-5*.

(2010), Emslie & Adcock (1994), Erb (1995), Kotze (1990), Kotze & Zacharias (1992), Kotze & Zacharias (1993), Matipano (2003), Morgan (2010), Ndlovu & Mundy (2009), Shaw (2011), Shaw *et al.* (2009), Smidt (2002), Rossouw (1998), Van der Westhuizen (2011), Winkel (2004). Of the 59 diet plants found browsed by BR in this study, 16 (27.1%) were classed as highly suitable (Suit1); 28 (47.5%) classed as average suitability (Suit2); and 15 plants (25.4%) as poor (Suit3). Species-specific suitability ratings are displayed in *Table 8.*

3.5.3. Habitat suitability

The Riverine and Alluvial Association was identified with the largest absolute average availability of the (summed) pool of highly valuable 'Suit1 + Suit2' species (21.28%), representing 89.44% of its overall %BA in MWR; with the Ridge-top Mixed Woodland coming second with 15.61% *(Table 8)*. The Low Altitude Mixed Woodland (with a 13.77% absolute score for Suit1 + Suit2 species) produced the greatest overall, area-weighted browse availability for these highly suitable forage plants (4.23%) in Majete; followed by the riverine (2.55%), miombo (1.18%) and ridge-top (1.12%) communities *(Table 8)*. In terms of producing the largest relative contribution of 'Suit1 + Suit2' species to the total edible browse mass within a type, the poor browse capacity High Altitude Miombo Woodland stratum turned out to produce the highest figure (97.94%). The Riparian Thicket showed the largest representation of 'Suit1' species in any one type (63.74%). The lowest contribution of both 'Suit1' species (15.54%) and 'Suit1 + Suit2' species (81.89%) to total rhino browse within any one community was found in the Medium Altitude Mixed Woodland – a stratum identified with fair-average species richness.

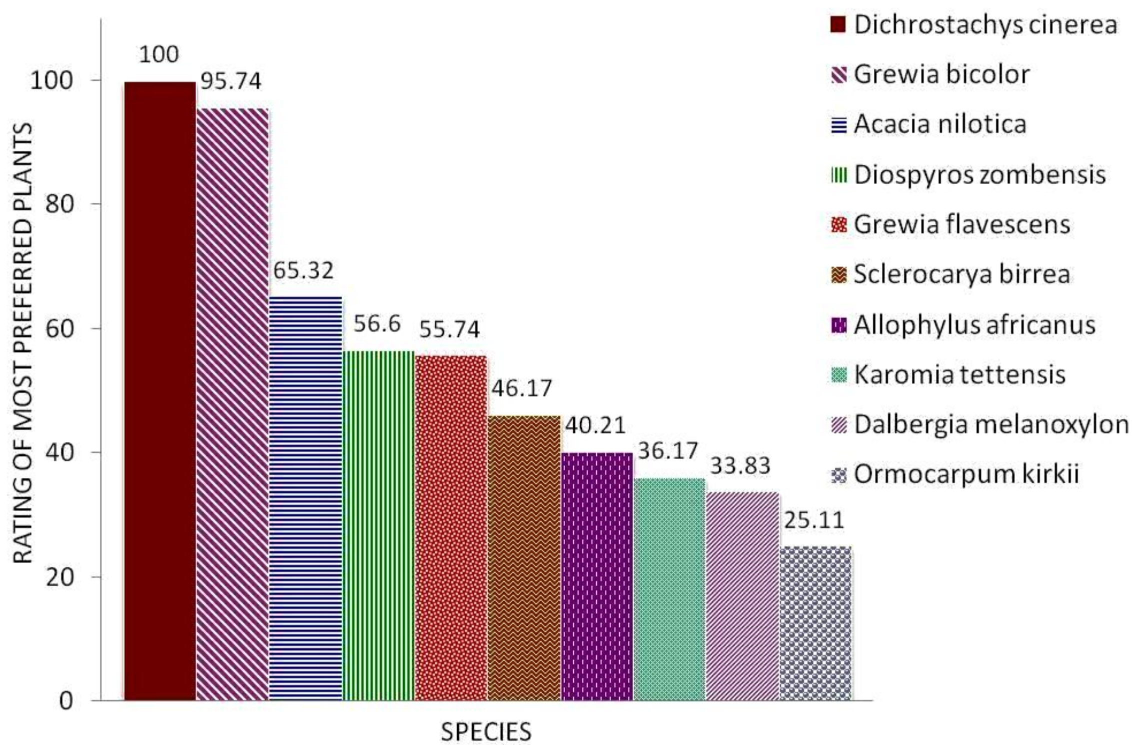


Figure 8. Ranking of the 10 most preferred BR browse plants in MWR. Scores shown are computed from proportionally rescaled preference indices [e.g. preference index of *D. cinerea* (4.7) equals 100]. Browse species with <1% contribution to available browse (only in Sanctuary) are disregarded due to statistical aberrations caused by their low-high feeding rates (during Phase 1) coupling with their extremely low representation in the plots (during Phase 2) – the result of which is unrealistically high preference indices.

Table 8. Availability of diet species (expressed by their absolute average %BA scores) shown in the six vegetation strata of MWR. These values are based on the average of their plot-specific BA scores considering all the plots in the type and not only those with positive species occurrences (Adcock, 2006*a*). Browse plants are also classed in terms of their overall suitability to BR (basing it on wider regional results). Only Class 1 and Class 2 species are considered for habitat suitability calculations in the BR carrying model V2.1 (Adcock, 2006*b*). *'Not seen'* taxa: not encountered during sampling (Phase 2).

VEGETATION TYPES OF MWR → **PLOT CODES →** **SPECIES LIST ↓**	**SUITABILITY CLASS**	**Riparian Thicket**	**Riverine & Alluvial Association**	**Ridge-top Mixed Woodland**	**Low Altit. Mixed Woodland**	**Medium Altit. Mixed Woodland**	**High Altit. Miombo Woodland**
		Plots of this type with %BA scores: ST14 (18.7%) ST15 (9.8%)	*Plots of this type with %BA scores:* ST2 (11%) ST4 (25.1%) ST6 (17.9%) ST7 (16.2%) ST10 (29%) MK4 (23%) MB1 (39.7%) MB3 (24.4%) MB5 (24.5%) KK4 (27.2%)	*Plots of this type with %BA scores:* ST1 (17.2%) ST8 (18.8%) ST13 (8.6%) MK3 (30.5%) MK5 (16.4%) KK3 (10%)	*Plots of this type with %BA scores:* ST5 (23.1%) ST9 (14.3%) ST11 (11.7%) ST12 (23.8%) MK1 (4.9%) MK2 (5.7%) MB2 (22.3%) MB4 (18.2%) MB6 (17.2%) KK1 (13.3%) KK2 (11.2%)	*Plots of this type with %BA scores:* ST3 (5.2%) MK6 (5.2%) MK7 (3.2%) MJ1 (10.5%)	*Plots of this type with %BA scores:* MJ2 (2.8%) MJ3 (4.7%) MJ4 (3.7%)
Acacia burkei	1		0.079%	0.015%	0.437%	0.015%	
Acacia nigrescens	1	6.285%	1.638%	3.058%	0.013%	0.05%	
Acacia nilotica	1				0.197%		0.987%
Acacia tortilis	1		0.026%				
Acacia xanthophloea	1		0.025%				
Catunaregam spinosa	1		0.01%	0.002%	0.261%	0.335%	0.177%
Dalbergia melanoxylon	1		2.368%	0.476%	1.135%	0.345%	0.21%
Dichrostachys cinerea	1	0.07%	0.468%	0.273%	0.433%	0.163%	0.157%
Diospyros quiloensis	1	0.44%	0.03%				
Diospyros zombensis	1		0.37%	0.285%	0.43%	0.018%	
Euphorbia ingens	1	*Not seen*					
Grewia bicolor	1	1.17%	0.294%	0.23%	0.191%		
Grewia flavescens	1	1.115%	1.633%		0.298%		
Karomia tettensis	1		1.408%		0.572%		
Ormocarpum kirkii	1		0.45%	1.778%	0.035%	0.01%	0.021%
Vangueria randii	1		0.077%				
SUM OF SUIT 1 (GOOD):		**9.08%**	**8.876%**	**6.117%**	**4.002%**	**0.936%**	**1.552%**
Acacia karoo	2	2.525%	0.315%	0.117%	0.025%		
Albizia harveyi	2	*Not seen*					
Cardiogyne africana	2	*Not seen*					
Combretum adenogonium	2		0.179%		0.052%	0.203%	
Combretum apiculatum	2	0.25%	1.511%	0.275%	1.544%		
Combretum mossambicense	2	0.015%	1.143%		0.007%		

Combretum zeyheri	2		0.117%	0.093%	0.037%			
Commiphora africana	2	0.08%	0.16%		0.034%			
Croton macrostachyus	2		0.004%					
Diospyros senensis	2	0.01%				0.018%		
Diospyros squarrosa	2				0.031 %			
Diplorhynchus condylocarpon	2		7.025%	4.498%	6.857%	2.995%	2.093%	
Dyschoriste verticillaris	2	0.37%	0.351%			0.0001%	0.003%	
Ehretia amoena	2		0.124%		0.064%	0.125%		
Grewia forbesii	2		0.024%		0.056%			
Grewia villosa	2	*Not seen*						
Gymnosporia buxifolia	2				0.013%		0.008%	
Kigelia africana	2		0.004%					
Lannea discolor	2		0.022%		0.013%			
Lannea schweinfurthii	2		0.019%		0.021%			
Pterocarpus rotundifolius	2		1.101%	4.173%	0.825%	0.505%		
Rhus tenuinervis	2	*Not seen*						
Schrebera trichoclada	2				0.055 %			
Sclerocarya birrea	2		0.008%	0.332%	0.085%	0.038%		
Stereospermum kunthianum	2	0.09%	0.14%	0.002%	0.015%	0.113%		
Vitex buchananii	2	*Not seen*						
Xeroderris stuhlmannii	2		0.16%		0.037%			
Ziziphus mucronata	2	*Not seen*						
SUM OF SUIT 2 (MEDIUM):		**3.34%**	**12.407%**	**9.49%**	**9.771%**	**3.997%**	**2.104%**	
Albizia anthelmintica	3		0.017%					
Allophylus africanus	3	0.105%	0.59%		0.012 %	0.243%		
Becium grandiflorum	3		0.154%	0.028%				
Burkea africana	3		0.01%				0.02%	
Combretum collinum	3		0.101%		0.022%			
Deinbollia nyikensis	3	1.5%	0.211%		0.025%	0.275%		
Ekebergia capensis	3		1.252%	1.195%	1.135%	0.393%	0.057%	
Gardenia ternifolia	3		0.015%					
Gymnosporia senegalensis	3		0.022%					
Holarrhena pubescens	3		0.011%		0.092%			
Hymenocardia acida	3	0.22%	0.071%	0.085%		0.18%		
Pouzolzia mixta	3	*Not seen*						
Sterculia appendiculata	3	*Not seen*						
Terminalia sambesiaca	3		0.06%					
Urena lobata	3	*Not seen*						
SUM OF SUIT 3 (POOR):		**1.825%**	**2.514%**	**1.308%**	**1.286%**	**1.091%**	**0.077%**	
Average BA of veg. types (MWR)		**14.245%**	**23.797%**	**16.915%**	**15.059%**	**6.024%**	**3.733%**	
% area cover of veg. types (MWR)		**1%**	**12%**	**7.2%**	**30.7%**	**16.8%**	**32.3%**	
Area-weighted BA of veg. types (all taxa)		0.142%	2.856%	1.218%	4.623%	1.012%	1.206	MWR→ **11.06%**
Area-weighted BA of veg. types (A: Suit1 + Suit2 only ; B: Suit1 only)		A: 0.124% B: 0.091%	A: 2.554% B: 1.065%	A: 1.124% B: 0.440%	A: 4.228% B: 1.229%	A: 0.829% B: 0.157%	A: 1.181% B: 0.501%	**→ A: 10.04% → B: 3.48%**
% contribution of species to the total browse available in a vegetation type (A: Suit1 + Suit2 only ; B: Suit1 only)		A: 87.19% B: 63.74%	A: 89.44% B: 37.30%	A: 92.27% B: 36.16%	A: 91.46% B: 26.58%	A: 81.89% B: 15.54%	A: 97.94% B: 41.58%	

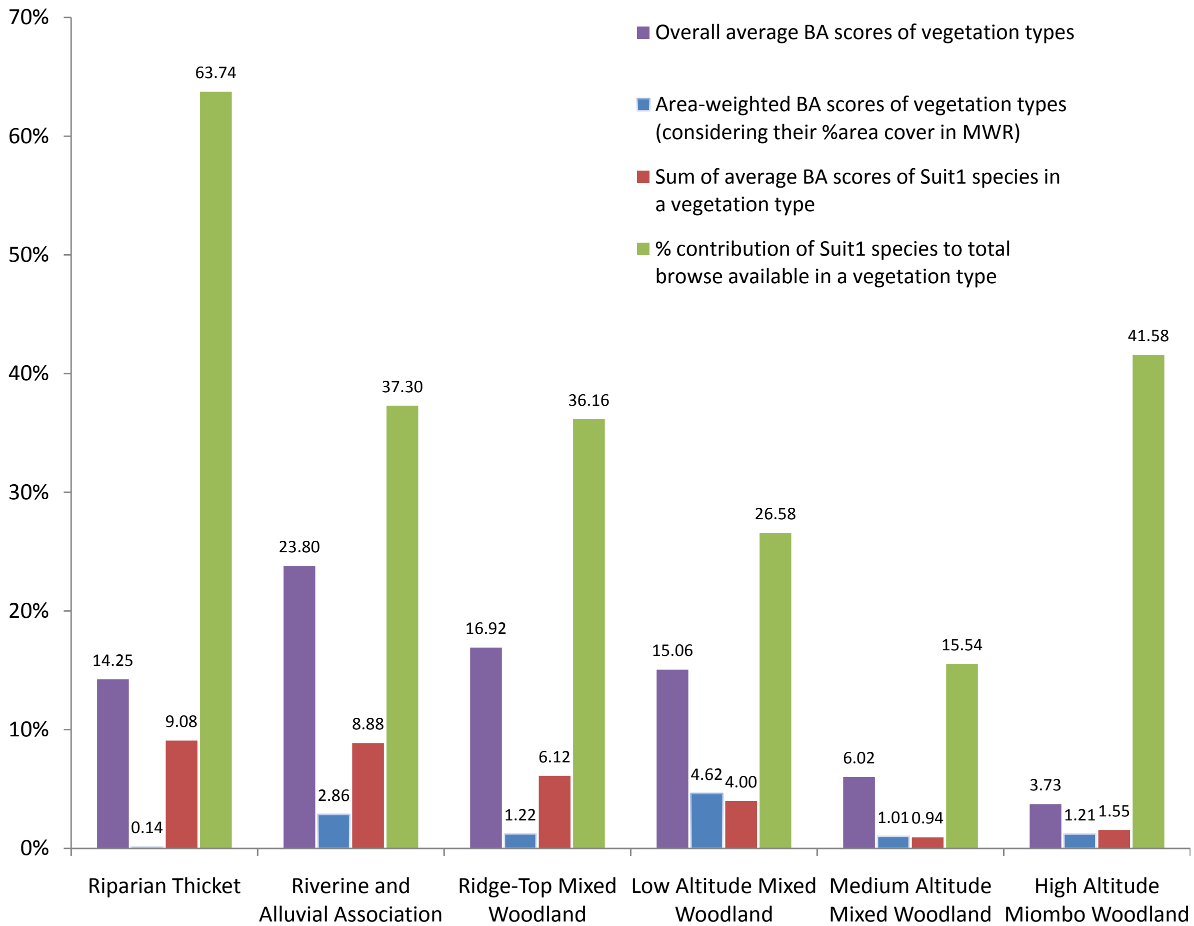


Figure 9. Comparison of vegetation types in terms of their possessing black rhino browse plants and their capacity of sustaining 'Suit 1' browse species (consult *Table 8* for detailed calculations).

4. DISCUSSION

Dynamic ecological processes (e.g. resource fluctuations) influencing the composition and distribution of vegetation communities determine overall habitat quality for large bodied herbivores (Bell, 1984). It is fundamental that management be aware of two key determinants of the average long term holding capacity of the actual rhino habitat: the availability of palatable browse biomass and the proportion of highly suitable diet species found in its vegetation communities (Emslie & Adcock, 1994*a*).

Diet composition

Black rhino is a selective browser choosing a great number of often regenerating food plants from various families, e.g. Capparidaceae, Combretaceae, Euphorbiaceae, Fabaceae, Mimosaceae or Tiliaceae (Mukinya, 1977; Oloo *et al.* 1994). This work positively assembled a list of 59 classified diet species, containing mainly small trees and woody shrubs *(Table 2)*. Some long term studies looking at cross-seasonal variation produced greater figures (Goddard, 1968; Mukinya, 1977), e.g. John Goddard's pioneering research on the black rhino in Ngorongoro Crater and Olduvai Gorge (completed in 1968) counted 191 browse species, whilst his findings in Tsavo National Park (completed in 1970) reported on 102 diet plants.

Principal (staple) food items are diet species that are consumed in the largest quantities unaffected by proportional availability or abundance (Petrides, 1975; Kotze & Zacharias, 1993). This study reports the overall dominance of Mimosaceae, Apocynaceae, and Fabaceae in black rhino diet: 13 species of the total 59 selected and six of the 10 most frequently browsed food items belong to either of these families *(Figure 6)*. Two deciduous woody species, *D. cinerea* (Mimosaceae) and *D. condylocarpon* (Apocynaceae) contributed nearly 27% to rhino diet, indicating their supreme importance to rhino in Majete. The very high representation of *D. condylocarpon* in diet was accounted for – other than its good/moderate palatability – by its even distribution and greatest overall availability in the study area (i.e. with its area-weighted absolute BA score of 4.45% it formed 40.23%(!) of the total available browse in MWR). Other important contributors to diet were species of the Anacardiaceae, Ebenaceae, Sapindaceae, Tiliaceae and Verbenaceae families. The representation of herbs, succulents, forbs and annuals with differing seasonal stages of development was negligible in the foraging data. Brown *et al.* (2003) suggest that it be due to their inconspicuous presence (e.g. small size); their often being tipped over, uprooted and entirely consumed by animals; or the lack of full certainty in identifying characteristic rhino browse marks on their thin stalks. This study confirmed the observation of Oloo *et al.* (1994) that tracks often lead to solitary candelabra trees *(Euphorbia ingens),* localities that seem to influence rhino ranging in broad areas. Earlier works reported that *E. ingens*, though not scoring high in importance or suitability rankings of this study, appears as a definite attraction to BR (Goddard, 1968; Joubert & Eloff, 1971; Bhima & Dudley, 1996; Dudley, 1997; Brown *et al.*, 2003)[19]. Faecal analyses could have complemented feeding data and confirmed possible herb and/or grass intake by rhinos (Buk & Knight, 2010).

[19] *Euphorbia* species and other succulents are known food items to BR as they provide liquid material (although poisonous to other animals) during dry times or in the absence of surface water (Emslie & Adcock, 1994*a*).

Browse availability

Browse availability (BA) is a strong influential factor on black rhino holding capacity (Adcock, 2001; Adcock, 2006*a*). When considered together with browse palatability, BA assessments of rhino habitats can hone our understanding of how best to manage threatened stocks and their vital food resources in the long term (Emslie & Adcock, 1994*a*; Emslie & Adcock, 1994*b*; Adcock, 2006*b*). Food scarcity and resource limitations (e.g. availability of good quality browse and sufficient surface water) are primary players on large mammal survival and reproduction (Hall-Martin *et al.*, 1982; Shaw, 2011). *D. condylocarpon* was found to be the most abundant food item in MWR.

Stratified survey of an area is usually the only practical means of sampling all the vegetation available to rhino (Adcock, 2005). The results outlined in this paper corroborate the importance of browse information to be based on vegetation types (Brown *et al.,* 2003). This study affirms Emslie & Adcock's (1994*a*) findings that the Riverine and Alluvial Association holds not only the largest diversity of diet items [i.e. 44 species (74.6% of all selected)] but also the highest absolute average density of rhino browse (23.8%) *(Figure 9, Table 8)*. The Low Altitude Mixed Woodland produced the greatest area-weighted BA score, while the Riparian Thicket the lowest. The Eastern Block had good proportional browse availability on average with its Sanctuary sub-area possessing a slightly higher %BA score (16.91%) than its Pende sub-area (12.93%). If considering Pende's larger area contribution in the Eastern Block, it scored higher in terms of overall weighted browse biomass (7.84%) than the Sanctuary (6.66%) *(Table 5)*. Due to its having notable stretches of rich riverine/alluvial matrix (i.e. Mthumba

Alluvium, associated with the highest species richness and density figures), the Pende sub-area's %BA could even be higher had sampling design precluded western Pende –, an area dominated by large swathes of the Medium Altitude Mixed Woodland type of low overall browse availability (1.15%) *(Table 7).* The poor *miombo* scrub-dominated Western Majete Block showed the lowest species richness as well as contributed less significantly (31.2%) to total edible browse biomass than the Eastern Block (68.8%). The overall average browse availability of the Eastern Block (14.5%) is identical to that of Pilanesberg National Park of South Africa (range of 10-15%), about 4 times larger than that of the Kunene region of Namibia, but only half of one of the best rhino habitats in Southern Africa, the Hluhluwe Game Reserve (range of 25-30%) (Adcock, 2005). If considering the entire reserve's overall average proportional BA of 11.17% (2/3rd of which was found in the vegetation communities of the Eastern Block), it fares only average in the Southern African region due to poor conduciveness of the vast *miombo* realm dominating the western half of the reserve.

Browse preference and suitability classification

In case of non-ruminant herbivores, forage availability is an important factor in utilization so rhinos are expected to seek widely available browse of high quality (Muya & Oguge, 2000). Knowing about principle diet species (e.g. frequently browsed, staple forage) is important, yet having a clear picture of the highly sought after, preferred forage plants (e.g. those of high palatability) can grant a better understanding of potential browsing pressure because species with high and low preference indices are the ones with good indication on habitat suitability (Petrides, 1975; Brown, 2008).

Preference equals importance relative to availability, with preferred species being those that are proportionally more frequent in the diet than available in the habitat (Petrides, 1975). Therefore a plant species is defined as a potentially 'preferred browse' when it has been eaten in great quantities relative to its occurrence in a given area (Oloo *et al.,* 1994; Muya & Oguge, 2000, Ganqa *et al.,* 2005). Browse preference is a difficult concept to assess and interpret and because it is only local and inversely correlated with relative abundance, it can not show how good very rare plants are. (Ganqa *et al.,* 2005; Shaw *et al.*, 2009). Hence, very low %BA scores of a species (i.e. result of rarity or small sample size), when coupled with moderate-high consumption values, can yield high (skewed) preference indices due to this apparent statistical aberration (Ganqa *et al.,* 2005).

D. cinerea, *G. bicolor* and *A. nilotica* (also representatives of the 10 principal browse items in diet) were found to be the most preferred forage species by BR in MWR *(Figure 8, Appendix 5)*. Interestingly, *D. condylocarpon,* a key staple forage species with the second highest browsing intensity did not qualify to be among the 10 most preferred forage species due to its extremely high relative contribution (40.1%) to overall availability of selected browse. High palatability forage species are good 'impact indicators' because browsers tend to maintain intensive feeding pressure on them (Brown, 2008). Hence if such highly preferred plants take up a significant proportion of the diet (particularly if providing critical browse during the resource poor dry season) then it is essential to monitor their utilisation to avert pernicious effects of overharvesting which could lead to browse density drop and even local extinction in the long term (Buk 2004; Brown, 2008; Buk & Knight, 2010). Therefore, given the wide representational overlap between principal and preferred diet species in this study, it is imperative that cross-seasonal browse availability assessments with emphasis on these key forage items are regularly conducted in MWR. This study did not have the time and scope to try to find existing correlations between browse preference and the effect of chemical compositions of plants on rhino diet.

Shaw *et al.* (2009) asserted that occasional restricted browsing on favoured plants could have a negative impact on habitat suitability through the removal of high palatability diet from the habitat. This study contributed meaningfully to refining and rectifying regional suitability classes for a greater set of already known browse items selected by BR in the Zambezian Miombo Woodland Ecoregion and other low nutrient sourveld areas. Scores were also developed for a set a new diet species, with their accuracy awaiting (re-)confirmation by prospective studies in this realm. This study confirmed findings of Emslie & Adcock (1994*a*) and Shaw *et al.* (2009) that Mimosaceae, Fabaceae, Tiliaceae and Ebenaceae species rank high in terms of suitability to BR (i.e. both frequently selected and highly palatable).

Habitat suitability

Woody plant phenology and chemistry largely determine seasonal fluctuations in both quantity and quality of selected diet plants for browsing herbivores (Shaw, 2011). Hence, habitat quality is dependent on the presence of diet components that provide vital forage for rhinos during resource minima, e.g. peak of the critical dry months (Owen-Smith, 2002; Shaw, 2011). The degree of highly suitable browse (relative to the total available) in a vegetation type is useful indicator for of an area's BR holding capacity (Adcock, 2006*b*).In this study, the most conducive environment defined for rhinos were areas with the greatest proportion of vegetation associations found to hold the largest concentrations of highly suitable ('Suit1 + Suit2') diet plants. When assessing the overall availability of 'Suit1 + Suit2' rhino browse in the vegetation types, the same ranking emerged (both for absolute and area-weighted scores) as for overall browse availability. The Riverine & Alluvial Association and the Ridge-top Mixed Woodland were found to have the largest relative abundance of such high suitability forage plants *(Table 8)*, followed by the Low Altitude Mixed Woodland (i.e. in terms of area-weighted scores the latter scored highest due to its much larger area coverage). The Riparian Thicket's highest 'Suit1' species holding capacity was due to a single dominating 'Suit1' plant, *Acacia nigrescens,* contributing 44% to its total BA. The reason for the *miombo* realm, associated with the poorest overall browse availability (absolute BA: 3.73%), producing the largest relative proportion of high suitability forage items (97.9% of its total browse) was accounted for by its overall mean browse biomass being dominated by a single 'Suit2' species, *D. condylocarpon* (56.1%).

Conducting BR browse availability and suitability studies are central to the understanding of potential rhino stocking rates and actual introduction numbers for new areas (Adcock, 2001; Adcock, 2006*b*). Such attempts can also gather information on a diverse set of habitat attributes of existing rhino areas. This study confirmed that not only does the Eastern Block possesses significant amount of browse material if compared with results of other regional studies, but by having 29% of its area covered by the most valuable habitat types (Riverine and Alluvial Association: 18.18%; Ridge-top

Mixed Woodland: 10.85%) and 48.5% by the likewise suitable Low Altitude Mixed Woodland type (highest in overall weighted availability of most suitable forage), its capacity for sustaining an expanding black rhino population looks propitious.

Conclusions, conservation and research implications

Understanding a browser's diet selection sets the fundamental basis for determining the suitability and ultimately the capacity of various habitat and vegetation types because they define vital conditions and life processes that trigger population changes for endangered species (Owen-Smith, 2002; Shaw, 2011). In times of browse density declines driven by pernicious effects of draught, disease, unpalatable plant infestation (e.g. *Lantana camara*), browser competition intensification (e.g. by African elephant, giant kudu) or grass encroachment, rhino resources get strained so management must take immediate steps to curb or limit such effects (Amin *et al.*, 2006). Availability of the principal and highly suitable forage biomass largely determines the holding capacity of a rhino habitat, so standardised habitat assessments accounting often for long-term vegetation changes must exert strong influence on the planning of restocking schemes and overall management of black rhino stocks (Adcock, 2005; Okita-Ouma *et al.*, 2007).

Rhino browsing is affected by a great deal of factors, of which plant physiology (i.e. responses like changing leaf area, increased spinescence or internode distance) and chemical composition require further investigations (Shaw, 2011). This study produced basic BR diet information and provided resource management with a clearer picture on habitat and forage suitability in MWR. With field work conducted in the transitional period during the late hot-wet and early cool-dry seasons, a good average picture of prevailing resource use patterns and browse conditions were obtained. This study had capacity of establishing 36 plots in the six vegetation types only. It is recommended that future attempts consider setting a minimum of 20-25 randomly or well-distributed units per vegetation community in order to better capture the range of variability in browse species composition and abundance within each stratum and thus lead to increased precision and representativeness of the estimates (Sutherland, 2006; Adcock, *pers. comm*., 2011). To complement these findings, prospective studies are invited to assess a broader cross-seasonal BR browse utilisation and focus on the temporal and spatial availability of critical late dry season browse resource availability, palatability and habitat quality oscillations so as to shed light on the maximum average productive habitat capacity of the Eastern Block. Forthcoming reintroduction attempts in this important eastern realm (e.g. Sanctuary and Pende sub-areas) are recommended to set release sites near S 15° 57.73’, S 15° 58.92’ and E 034° 38.07’, E 034° 39.64’ – localities with great absolute density of highly valuable rhino browse biomass and sufficient perennial watering points. Future research may try assessing in more detail the supposedly conducive (though isolated) riverine habitats of the Western Majete block and intensify overall stratification levels with greater number of plots in each sub-area so as to make browse availability calculations more accurate. Given that the availability of preferred browse biomass and the size of top suitability habitat patches reflect the nutritional status of resident herbivores, there remains tremendous scope for a detailed vegetation study in MWR (Sherry, 1989).

Food scarcity and resource limitations (e.g. lack of good quality browse or sufficient surface water) are primary players on large mammal survival and reproduction (Fowler, 1987). Reported demographic responses of black rhino to nutritional restrictions are delayed age of first calving and broadened birth intervals in adult females (Shaw, 2011). Therefore, to achieve maximum population growth rates in the Majete population, rhino cows should be managed at a density where no nutritional restrictions affect their reproductive success (Fowler, 1987; Shaw, 2011). The need of regularly appraising the health and capacity of the vegetation will need to be underpinned in BR conservation strategies and national action plans with regional goals of rehabilitating impoverished stocks (Emslie *et al.*, 2009). In the long term successful biological management of the species, this condition is fundamental to assure a stably sustainable population augmentation. Among range states with viable meta-populations there is need to further improve standardised methodologies, pool species-specific diet information and further refine suitability classification (Adcock, *pers. comm.*, 2011). Strengthening the SADC RPRC regional framework and underscoring the importance of research results sharing among vegetation scientists, rhino ecologists and managers, will increase understanding of rhino habitat specifics, forage use and related BR population performance in the range states and thus enhance the long-term restoration of the wider continental stock.

REFERENCES

Adcock, K. (2001). RMG Black rhino carrying capacity model version 1.0. User's guide (Evaluation Draft). *Harare, SADC Regional Programme for Rhino Conservation*, pp. 1-64.

Adcock, K. (2005). Visual assessment of black rhino browse availability V2.1. Harare. *SADC Regional Programme for Rhino Conservation*, pp. 1-113 (Part 1: pp. 1-54; Part 2: pp. 55-113).

Adcock, K. (2006*a*). Visual assessment of black rhino browse availability. V3.0. Harare. *Darwin Initiative and SADC Regional Programme for Rhino Conservation*, p. 31.

Adcock, K. (2006*b*). Rhino Management Group Black Rhino Carrying Capacity Model V2.1. Darwin Initiative and SADC Regional Programme for Rhino Conservation.

Adcock, K.; Hansen, H.B.; Lindemann, H. (1998). Lessons from the introduced black rhino population in Pilanesberg National Park. *Pachyderm*, No. 26, pp. 40-51.

Adcock, K.; Emslie, R. H. (2003). Monitoring African rhino: a trainee's guide. *Part of IUCN/SSC AfRSG's Sandwith's Training Course for Field Rangers.* 5th edition. p. 12.

Adcock, K.; Shaw, J. (2009). An EAZA Survey of black rhino browse availability and dry season diet survey in Waterberg Plateau Park (January).

Amin, R.; Okita-Ouma, B.; Adcock, K.; Emslie, R.H.; Mulama, M. & Pearce-Kelly, P. (2006). An integrated management strategy for the conservation of Eastern black rhinoceros *Diceros bicornis michaeli* in Kenya. *International Zoo Yearbook*, Vol. 40(1), pp. 118-129.

Bell, R.H.V. (1984). Majete Game Reserve: report of an ulendo and suggestions for management and utilisation. *Malawi Government Report WRU/1//50/5/3//1 dated 16th Jan. 1984*, p. 65.

Bhima, R.; Dudley, C.O. (1996). Observations on two introduced black rhinos in Liwonde National Park, Malawi. *Pachyderm*, No. 21, pp. 46-54, figs. 1-3, tables 1-2.

Brett, R.A. (1998). Mortality factors and breeding performance of translocated black rhinos in Kenya: 1984-1995. *Pachyderm*, No. 26, pp. 69-82, figs. 1-8, tables 1-2.

Brooks, M. (1993). Chairman's report, African Rhino Specialist Group. Ed. Martin, E. B. WWF Regional Office, *Pachyderm*, No. 16, pp. 3-10.

Brooks, M.; Adcock, K. (1997). Conservation plan for the black rhinoceros (*Diceros bicornis)* in South Africa. *Compiled by the Rhino Management Group*, (February), p. 66.

Brown, D.H. (2008). The feeding ecology of the black rhinoceros (*Diceros bicornis minor*) in the Great Fish River Reserve, Eastern Cape Province, South Africa. *A Master of Science Thesis submitted to the Faculty of Science and Agriculture, University of Fort Hare,* p. 163.

Brown, D.H.; Lent, P.C.; Trollope, W.S.W.; Palmer, R.A. (2003). Browse selection of black rhinoceros (*Diceros bicornis*) in two vegetation types of the Eastern Cape Province, South Africa, with particular reference to *Euphorbiaceae*. *Proceedings of the VIIth International Rangelands Congress*, 7: pp. 509-512, figs. 1-5.

Brown, D.H.; Van der Westhuizen, E. (2005). The woody diet of the black rhino (Diceros bicornis minor) in a sanctuary in the North Luangwa National Park, Zambia. *Unpublished report for the Frankfurt Zoological Society and the Zambian Wildlife Authority.*, p. 17.

Buk, K.G. (2004). Diet selection and habitat suitability for black rhino in Augrabies Falls National Park, South Africa. *A Masters Thesis.* (September), p. 129.

Buk, K. (2008). Diet of black rhino in Tembe Elephant Park. An EAZA / NRF report.

Buk, K. (2009). Diet of the black rhino in Isimangaliso Wetland Park. An EAZA / NRF report.

Buk, K.G.; Knight, M.H. (2010). Seasonal diet preferences of black rhinoceros in three arid South African National Parks. *African Journal of Ecology*, Vol. 48(4), pp. 1064-1075.

De Boer, F.; Ijdema, H. (2007). Competition between black rhinoceros (*Diceros bicornis*) and greater kudu (*Tragelpahus strepsiceros*) in the Great Fish River Reserve, South Africa. *An M.Sc. Thesis*. Submitted to the University of Wageningen in February 2007, p. 57.

Du Toit, R. (1994). Management of black rhino in Zimbabwean conservancies: pp. 95-99. *In: Penzhorn, B.L. et al. Proceedings of a symposium on rhinos as game ranch animals. Onderstepoort, Republic of South Africa, 9-10 September 1994: pp. i-iv, 1-242*.

Du Toit, J.T.; Bryant, J.P.; Frisby, K. (1990). Regrowth and Palatability of Acacia Shoots Following Pruning by African Savanna Browsers. Published by: Ecological Society of America. *Ecology*, 71(1), pp. 149-154.

Du Toit, R.; Brooks, M.; Emslie, R. H. (2006). Summary of guidelines for strategic planning for rhino conservation. pp. 3-16. *In: Du Toit, R. Guidelines for implementing SADC rhino conservation strategies. Harare, SADC Regional Programme for Rhino Conservation: pp. i-vii, 1-95*, p. 13.

Dudley, C.O. (1997). The candelabra tree (*Euphorbia ingens*), a source of water for black rhino in Liwonde National Park, Malawi. *Koedoe*, Vol. 40, pp. 57-62.

Dudley, C.O. (2001). Ecological evaluation for Liwonde NP, Malawi, with respect to the development and management of a viable population of black rhino (*Diceros bicornis minor*). *SADC Regional Programme for Rhino Conservation*, pp. 1-25.

Dunham, K.M. (2001). Reintroduction of Black Rhino in the Luangwa Valley, Zambia. Evaluation of areas for the reintroduction. *An analysis. Semester 4, Task 1.2-4.1. SADC Regional Programme for Rhino Conservation*, p.40.

Emslie, R.H. (1994). Property assessment for introduction of black rhinos: pp. 93-94. *In: Penzhorn, B.L. et al. Proceedings of a symposium on rhinos as game ranch animals. Onderstepoort, Republic of South Africa, 9-10 Sept. 1994. pp. i-iv, 1-242*.

Emslie, R.H. (2005). Managing a rhino programme. IUCN/SSC, African Rhino Specialist Group. p. 3. *In: Fulconis, R. Save the rhinos: EAZA Rhino Campaign 2005/6 Info Pack. London*, pp. 1-164.

Emslie, R.H.; Adcock, K. (1990). Black rhino 2000 update: preliminary findings on black rhino habitat use in Hluhluwe/Umfolozi Game Reserve. *Endangered Wildlife*, Vol. 4, pp. 13-23, photos A-H, fig. 1.

Emslie, R.H.; Adcock, K. (1994*a*). Feeding ecology of black rhinos. pp. 65-81. *In: Penzhorn, B.L. et al. Proceedings of a symposium on rhinos as game ranch animals. Onderstepoort, Republic of South Africa, 9-10 September 1994: pp. i-iv, 1-242*.

Emslie, R.H.; Adcock, K. (1994*b*). Managing black rhinos: pp. 100-107. *In: Penzhorn, B.L. et al. Proceedings of a symposium on rhinos as game ranch animals. Onderstepoort, Republic of South Africa, 9-10 September 1994: pp. i-iv, 1-242*.

Emslie, R.H.; Brooks, M. (1999). African rhino. Status survey and conservation action plan. *IUCN Species Survival Commission African Rhino Specialist Group, IUCN. Gland, Switzerland*, p. 102.

Emslie, R.H., Amin, R.; Kock, R. (2009). Guidelines for the *in situ* re-introduction and translocation of African and Asian rhinoceros. *Occasional paper of the IUCN Species Survival Commission* No. 39, pp. 125.

Emslie, R.H.; Knight, M.H. (2011). Update on African rhino status and trends from IUCN/SSC African Rhino Specialist Group (AfRSG). *Report to CITES*, pp. 1-4.

Emslie, R.H.; Milliken,T.; Talukdar,B. (2012). African and Asian Rhinoceroses – Status, Conservation and Trade. *A Report from the IUCN/SSC AfRSG & AsRSG and TRAFFIC to the CITES Secretariat, CoP16 Doc.*, p. 18.

Erb, P. (1995). Diet of black rhino as assessed along feeding trails in the rocky areas of Waterberg Plateau Park. *An unpublished Namibian Ministry of Environment and Tourism report.*

Fearnhead, P. (2010). African Parks Network. *Annual report 2010*, (Source: http://african-parks.org/apffoundation/index.php?option=com_docman&task=doc_details&gid=549&Itemid=31), p. 68.

Fowler, C.W. (1987). A review of density dependence in populations of large mammals. *Current Mammalogy,* Vol. 1, pp. 401–441.

Ganqa, N.M.; Scogings, P.F.; Raats, J.G. (2005). Diet selection and forage quality factors affecting woody plant selection by black rhinoceros in the Great Fish River Reserve, South Africa. *South African Journal of Wildlife Research*, Vol. 35 (April), pp. 77-83.

Ganqa, N.M.; Scogings, P.F. (2007). Forage quality, twig diameter, and growth habit of woody plants browsed by black rhinoceros in semi-arid subtropical thicket, South Africa. *Journal of Arid Environments*, Vol. 70(3), pp. 514-526.

Goddard, J. (1968). Food preference of two black rhinoceros populations. *East African Wildlife Journal*, Vol. 6, pp. 1-18; pl. 1; tables 1-7.

Göttert, T.; Schöne, J.; Zinner, D.; Hodges, J.K.; Böer, M. (2010). Habitat use and spatial organisation of relocated black rhinos in Namibia. *Mammalia*, Vol. 74(1), pp. 35-42.

Hall-Martin, A.J. (1988). Conservation of the black rhino: the strategy of the National Parks Board of South Africa. *REF Journal*, Vol. 1, pp. 12-17, figs. 1-4.

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*, Vol. 25, pp. 63-82, figs. 1-5, tables 1-7.

Hall-Martin, A.J.; Castley, J.G. (2003). The status of the black rhinoceros (*Diceros bicornis*) on private land in South Africa in 2001. *Pachyderm*, No. 34, pp. 24-32.

Hutchins, M.; Kreger, M.D. (2006). Rhinoceros behaviour: Implications for captive management and conservation. *International Zoo Yearbook*, Vol. 40 (1), pp. 150-173.

Joubert, E.; Eloff, F.C. (1971). Notes on the ecology and behaviour of the black rhinoceros *Diceros bicornis* Linn. 1758 in South West Africa. *Madoqua*. Vol. 3, pp. 5–53.

Knight, M.H.; Balfour, D.; Emslie, R.H. (2011). Biodiversity management plan for the black rhinoceros (Diceros bicornis) in South Africa 2010-2020. *Government Gazette*, No. 34304 (24 May 2011), p. 67.

Kotze D.C. (1990). Woody vegetation types of western Itala Game Reserve and their utilisation by black rhinoceros. *BSc in Agriculture Hon. Thesis.* University of Natal, Pietermaritzburg. p. 85.

Kotze, D.C.; Zacharias, P.J.K. (1992). Browsing of woody plants by black rhino in the western Itala Game Reserve. *First Natal Bushveld Symposium*. pp. 9-11.

Kotze, D.C.; Zacharias, P.J.K. (1993). Utilization of woody browse and habitat by the black rhino (*Diceros bicornis*) in western Itala Game Reserve. *Afr. J. Range For Sci.,* Vol. 10(1). pp. 36-40.

Labuschagne, R.S. (2001). Options for the future management of the black rhinos (*Diceros bicornis minor*) in Liwonde National Park, Malawi. Ecological evaluation and development of guidelines for future management of black rhinos at Liwonde NP, Malawi. Semester 4 task 1.2-4.1. *Harare, SADC Regional Programme for Rhino Conservation*, pp. 1-24.

Leader-Williams, N.; Milledge, S.; Adcock, K.; Brooks, M.; Conway, A.; Knight, M. *et al.* (2005). Trophy hunting of black rhino *Diceros bicornis*: proposals to ensure its future sustainability. *Journal of International Wildlife Law & Policy*, Vol. 8(1), pp. 1-11.

Linklater, W.L.; Adcock, K.; du Preez, P.; Swaisgood, R.R.; Law, P.R.; Knight, M.H. *et al*. (2011). Guidelines for large herbivore translocation simplified: black rhinoceros case study. *Journal of Applied Ecology*, Vol. 48(2), pp. 493-502.

Martin, R.B. (2005). Majete Wildlife Reserve: a park plan. November 2000. *First Draft,* (15 June 2005), p. 156.

Matipano, G. (2003). A comparison of woody browse selection by hand-raised, boma-adapted and wild black rhinoceros *Diceros bicornis* in Matusadona National National Park, Zimbabwe. *Koedoe*, Vol. 46(2), pp. 83–96.

Mills, A.; Morkel, P.; Runyoro, V.; Amiyo, A.; Binamungu, T.; Borner, M.; Thirgood, S. *et al.* (2003). Management of black rhino in the Ngorongoro Crater. *Ngorongoro black rhino workshop*, (September), p. 26.

Morgan, S. (2010). Black rhinoceros (*Diceros bicornis*) habitat selection and movement analysis. *PhD Thesis*. School of Biological and Conservation Sciences, University of KwaZulu-Natal. Westville (Dec).

Morgan, S.; Mackey, R.; Slotow, R. (2009). A priori valuation of land use for the conservation of black rhinoceros (*D. bicornis*). *Biological Conservation*, Vol. 142(2), pp. 384-393. Elsevier Ltd.

Mukinya, J.G. (1977). Feeding and drinking habits of the black rhinoceros in Masai Mara Game Reserve. *East African Wildlife Journal*, Vol. 15, pp. 125-138; figs. 1-3, tables 1-6.

Muya, S.M.; Oguge, N.O. (2000). Effects of browse availability and quality on black rhino (*Diceros bicornis michaeli,* Groves 1967) diet in Nairobi National Park, Kenya. East African Wildlife Society. *African Journal of Ecology*, Vol. 38(1), pp. 62-71.

Ndlovu, M.; Mundy, P.J. (2009). Browse preference of captive black rhinos at Chipangali Wildlife Orphanage, Zimbabwe. *Pachyderm*, *No. 45*, pp. 41-46.

Okita-Ouma, B.; Amin, R.; Kock, R. (2007). Conservation and management strategy for the black rhino and management guidelines for the white rhino in Kenya (2007-2011). Formulated at the Rhino Stakeholders' Workshop, Naivasha (29 Jan - 2 Feb 2007), p. 73.

Oloo T.W.; Brett R.; Young, T.P. (1994). Seasonal variation in the feeding ecology of black rhinoceros (*Diceros bicornis*) in Laikipia, Kenya. *African Journal of Ecology*, Vol. 32, pp. 142-157.

Owen-Smith, N. (2002). Adaptive herbivore ecology. From resources to populations in variable environments. *Cambridge University Press,* Cambridge, p. 374.

Patton, F. (2011). Black rhino spearheads Malawi wildlife makeover. East African Wildlife Society, *Swara,* Nairobi, Vol. 1, pp. 48-53.

Patton, F.; Jones, M. (2007). Determining minimum population size and demographics of black rhinos in the Salient of Aberdare National Park, Kenya. *Pachyderm*, No. 43, pp. 63-72.

Patton, F.; Jones, M. (2008). The demographics and use of space of the black rhino population of the Sweetwaters Game Reserve, an enclosed reserve in Kenya. *Endangered Species UPDATE*, Vol. 25(2), pp. 45-56.

Petrides, G.A. (1975). Principal foods versus preferred foods and their relations to stocking rate and range condition. *Biological Conservation*, Vol. 7, pp. 161–169.

Rossouw, D.J. (1998). Baseline survey of dietary preferences of black rhino on the Eastern Shores of Lake St. Lucia. *B. Tech. Nature Conserv. Degree Thesis*. Technikon Pretoria University.

Saffery, J. (2009). Assessing the potential effects of climate change on two species of rhinoceros, *Diceros bicornis* and *Rhinoceros unicornis*, using species distribution modelling. *A Masters thesis.* Submitted to the Imperial College of London in September 2009, p. 64.

Shaw, J.A. (2011). Adaptive resource use in a re-introduced black rhinoceros population. *Thesis of the Degree of Doctor of Philosophy.* Submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, p. 221.

Shaw, J.A.; Kachali, R.; Chiweshe, E. (2009). Browse assessment and carrying capacity of the Black Rhino Sanctuary in North Luangwa National Park, Zambia. *A report by the Centre for African Ecology, University of the Witwatersrand, South Africa*, (November), pp. 1-15.

Sherry, B.Y. (1989). Aspects of the ecology of the African elephant (*Loxodonta africana*, Blumenbach 1797) in the Middle Shire Valley. *An MSc Thesis.* Submitted to the University of Malawi in March 1989, p. 144.

Sileshi, G.; Mafongoya, P.L. (2006). The short-term Impact of forest fire on soil invertebrates in the miombo. *Biodiversity and Conservation*, Vol. 15(10), pp. 3153-3160.

Smidt, E.F. (2002). First approximation of principle and preferred foods of black rhino in Marakele National Park. *A thesis.* Technikon Pretoria University.

Smith, P.; Allen, Q. (2004). Field guide to the trees and shrubs of the miombo woodlands. *Kew Field Guides, Royal Botanic Gardens, Kew,* p. 176.

Staub, C.G. (2011). Elephant browsing in Majete Wildlife Reserve, south-western Malawi. *An MSc thesis.* Presented to the Graduate School of the University of Florida, p. 46.

Sutherland, W.J. ed. (2006). Ecological census techniques: a handbook. 2nd edition. *Cambridge University Press*, p. 448.

Tatham, G.H.; Taylor, R. D. (1989). The conservation and protection of black rhinoceros (*Diceros bicornis*) in Zimbabwe. *Koedoe*, Vol. 32(2), pp. 31-42, figs. 1-5, tables 1-2.

Tatman, S.C.; Stevens-Wood, B.; Smith, V.B.T. (2000). Ranging behaviour and habitat usage in black rhinoceros, *Diceros bicornis*, in a Kenyan sanctuary. *African Journal of Ecology. East African Wildlife Society*, Vol. 38(2), pp. 163-172.

Van der Heiden, C. (2005). Utilization distribution as a predictor in modelling black rhino (*Diceros bicornis*) habitat in Africa's southern Rift Valley. *An M.Sc. Thesis.* Submitted to the Charles E. Schmidt College of Sciences, Florida Atlantic University, p. 69.

Van der Westhuizen, H. (2006). Re-establishment of black rhino in Zambia – North Luangwa National Park. *Report of the Zambia Wildlife Authority & Frankfurt Zoological Society*, p. 7.

Van der Westhuizen, R. (2011). Biology and management affecting the decline of a black rhinoceros population in Ndumo Game Reserve. *Thesis for Magister Scientiae in Wildlife Management.* Faculty of Natural and Agricultural Sciences. University of Pretoria, p. 75.

Van Wyk, B.; Van Wyk, P. (1997). Field guide to the trees of Southern Africa. C. Struik, Cape Town, p. 537.

Walker, C.H. (1994). Rhinos in Africa–the present situation. pp. 1-3. *In: Penzhorn, B.L. et al. Proceedings of a symposium on rhinos as game ranch animals*. Onderstepoort, Republic of South Africa, 9-10 September 1994: pp. i-iv, 1-242.

Walpole, M. (2000). GIS as a tool for rhino conservation. *Pachyderm*, No. 28, pp. 65-72.

Winkel, F. (2004). Diet choice of the black rhinoceros in the Double Drift Game Reserve, South Africa. *MSc Thesis.* Resource Ecology Group, Wageningen University, p. 36.

Young, T.P.; Augustine, D.J. (2007). Inter-specific variation in the reproductive response of *Acacia* species to protection from large mammalian herbivores. *Biotropica*, Vol. 39(4), pp. 559-561.

APPENDIX 1a: Relative (%) species contributions to total browse available in the Sanctuary plots (bold *Italic* values show absolute %BA scores – % vertical fill – of species in the plots).

PLOTS → (SANCTUARY)	**ST 1**	**ST 2**	**ST 3**	**ST 4**	**ST 5**	**ST 6**	**ST 7**	**ST 8**	**ST 9**	**ST 10**	**ST 11**	**ST 12**	**ST 13**	**ST 14**	**ST 15**
SPECIES LIST	**%BA: 17.2%**	**%BA: 11%**	**%BA: 5.2%**	**%BA: 25.1%**	**%BA: 23.1%**	**%BA: 17.9%**	**%BA: 16.2%**	**%BA: 18.8%**	**%BA: 14.3%**	**%BA: 29%**	**%BA: 11.7%**	**%BA: 23.8%**	**%BA: 8.6%**	**%BA: 18.7%**	**%BA: 9.8%**
Acacia burkei									2.97 ***[0.42]***		11.1 ***[1.3]***		1.02 ***[0.09]***		
Acacia nigrescens	45.6 ***[7.84]***	19.1 ***[2.1]***		8.6 ***[2.16]***	0.6 ***[0.14]***	40.53 ***[7.25]***	26.9 ***[4.36]***		0.02 ***[0.003]***				0.17 ***[0.01]***	67 ***[12.53]***	0.4 ***[0.04]***
Acacia nilotica					8.73 ***[2.02]***				0.33 ***[0.05]***						
Acacia karoo					1.21 ***[0.28]***	17.57 ***[3.15]***								27 ***[5.05]***	
Acacia tortilis															
Acacia xanthophloea							1.52 ***[0.25]***								
Albizia harveyi															
Albizia anthelmintica															
Allophylus africanus		21.9 ***[2.41]***													2.13 ***[0.21]***
Becium grandiflorum	1 ***[0.17]***	3.14 ***[0.35]***				2.76 ***[0.49]***									
Burkea africana															
Cardiogyne africana															
Catunaregam spinosa						0.54 ***[0.1]***		0.04 ***[0.01]***				10.7 ***[2.55]***			
Combretum adenogonium															
Combretum apiculatum				24.9 ***[6.25]***	31.6 ***[7.3]***	24.68 ***[4.42]***	8.05 ***1.3]***		8.9 ***[1.27]***			16.1 ***[3.83]***	3.85 ***[0.33]***	2.7 ***[0.5]***	
Combretum collinum					1.02 ***[0.24]***		6.21 ***[1.01]***								
Combretum mossambicense				3 ***[0.75]***											0.33 ***[0.03]***
Combretum zeyheri										1.68 ***[0.49]***			6.47 ***[0.56]***		
Commiphora africana				3.2 ***[0.8]***		1.54 ***[0.28]***	3.01 ***[0.49]***					0.09 ***[0.02]***			1.6 ***[0.16]***
Croton macrostachyus		0.36 ***[0.04]***													
Dalbergia melanoxylon	4.67 ***[0.8]***		1.99 ***[0.1]***	0.1 ***[0.03]***	8.3 ***[1.92]***	0.25 ***[0.04]***	9.66 ***[1.56]***	0.33 ***[0.06]***	3.41 ***[0.49]***			3.48 ***[0.83]***	1.86 ***[0.16]***		
Deinbollia nyikensis						3.2 ***[0.57]***									30.6 ***[3]***
Dichrostachys cinerea	7.17 ***[1.23]***		4.81 ***[0.25]***		8.8 ***[2.03]***	5.38 ***[0.96]***	10.1 ***[1.64]***		0.03 ***[0.004]***	0.06 ***[0.02]***	1.31 ***[0.15]***		2.35 ***[0.2]***		1.46 ***[0.14]***
Diospyros senensis															0.23 ***[0.02]***
Diospyros squarrosa															
Diospyros quiloensis						1.67 ***[0.3]***									8.93 ***[0.88]***
Diospyros zombensis	8.68 ***[1.49]***			2.57 ***[0.65]***			13.9 ***[2.25]***		0.5 ***[0.07]***				1.31 ***[0.11]***		
Diplorhynchus condylocarpon	10.9 ***[1.87]***		76.5 ***[3.98]***		37.9 ***[8.75]***		13.5 ***[2.19]***	50.6 ***[9.51]***	78.3 ***[11.2]***	47.2 ***[13.69]***	28.6 ***[3.35]***	55.9 ***[13.3]***	38.1 ***[3.28]***		
Dyschoriste verticillaris		31.9 ***[3.51]***													7.6 ***[0.74]***

PLOTS → (SANCTUARY) **SPECIES LIST**	**ST 1** **%BA: 17.2%**	**ST 2** **%BA: 11%**	**ST 3** **%BA: 5.2%**	**ST 4** **%BA: 25.1%**	**ST 5** **%BA: 23.1%**	**ST 6** **%BA: 17.9%**	**ST 7** **%BA: 16.2%**	**ST 8** **%BA: 18.8%**	**ST 9** **%BA: 14.3%**	**ST 10** **%BA: 29%**	**ST 11** **%BA: 11.7%**	**ST 12** **%BA: 23.8%**	**ST 13** **%BA: 8.6%**	**ST 14** **%BA: 18.7%**	**ST 15** **%BA: 9.8%**
Ehretia amoena				4.8 ***[1.2]***											
Ekebergia capensis			13.5 ***[0.7]***					10.3 ***[1.94]***	1.64 ***[0.23]***	31.1 ***[9.02]***	53.7 ***[6.28]***	6.6 ***[1.57]***	5.35 ***[0.46]***		
Euphorbia ingens															
Gardenia ternifolia															
Grewia bicolor	8.05 ***[1.38]***			7.6 ***[1.91]***		1.72 ***[0.31]***									23.9 ***[2.34]***
Grewia flavescens		23.2 ***[2.55]***													22.8 ***[2.23]***
Grewia forbesii				0.01 ***[0.003]***											
Grewia villosa															
Gymnosporia buxifolia					0.6 ***[0.14]***										
Gymnosporia senegalensis															
Holarrhena pubescens															
Hymenocardia acida	2.95 ***[0.51]***						4.37 ***[0.71]***							2.34 ***[0.44]***	
Karomia tettensis				43.5 ***[10.92]***											
Kigelia africana		0.36 ***[0.04]***													
Lannea discolor							0.87 ***[0.14]***			0.06 ***[0.02]***		0.58 ***[0.14]***			
Lannea schweinfurthii															
Ormocarpum kirkii			0.38 ***[0.02]***					38.7 ***[7.28]***	2.02 ***[0.29]***	15.5 ***[4.5]***			39.4 ***[3.39]***		
Pouzolzia mixta															
Pterocarpus rotundifolius												6.7 ***[1.59]***			
Rhus tenuinervis															
Schrebera trichoclada															
Sclerocarya birrea	11 ***[1.89]***		2.9 ***[0.15]***						0.86 ***[0.12***		5.39 ***[0.63]***				
Sterculia appendiculata															
Stereospermum kunthianum									1.05 ***[0.15]***	4.41 ***[1.28]***			0.15 ***[0.01]***	0.96 ***[0.18]***	
Terminalia sambesiaca				1.68 ***[0.42]***		0.15 ***[0.03]***									
Urena lobata															
Vangueria randii															
Vitex buchananii															
Xeroderris stuhlmannii					1.14 ***[0.26]***		1.67 ***[0.27]***								
Ziziphus mucronata															
Total % :	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

APPENDIX 1b. Relative (%) species contributions to total browse available in the Pende plots (bold *Italic* values show absolute %BA scores – % vertical fill – of species in the plots).

PLOTS → (PENDE)	MK 1	MK 2	MK 3	MK 4	MK 5	MK 6	MK 7	MB 1	MB 2	MB 3	MB 4	MB 5	MB 6	KK 1	KK 2	KK 3	KK 4
SPECIES LIST	**%BA: 4.9%**	**%BA: 5.7%**	**%BA: 30.5%**	**%BA: 23%**	**%BA: 16.4%**	**%BA: 5.2%**	**%BA: 3.2%**	**%BA: 39.7%**	**%BA: 22.3%**	**%BA: 24.4%**	**%BA: 18.2%**	**%BA: 24.5%**	**%BA: 17.2%**	**%BA: 13.3%**	**%BA: 11.2%**	**%BA: 10%**	**%BA: 27.2%**
Acacia burkei	10.7 ***[0.52]***	29.4 ***[1.68]***												4.33 ***[0.58]***	2.81 ***[0.31]***		2.9 ***[0.79]***
Acacia nigrescens					64 ***[10.5]***		2.36 ***[0.08]***	0.14 ***[0.06]***		1.84 ***[0.45]***							
Acacia nilotica	2.04 ***[0.1]***																
Acacia karoo					4.25 ***[0.7]***												
Acacia tortilis				1.13 ***[0.26]***													
Acacia xanthophloea																	
Albizia harveyi																	
Albizia anthelmintica								0.44 ***[0.17]***									
Allophylus africanus						18.7 ***[0.97]***		8.78 ***[3.49]***	0.59 ***[0.13]***								
Becium grandiflorum								1.76 ***[0.7]***									
Burkea africana				0.45 ***[0.1]***													
Cardiogyne africana																	
Catunaregam spinosa														2.42 ***[0.32]***			
Combretum adenogonium		10 ***[0.57]***								7.35 ***[1.79]***							
Combretum apiculatum			1.15 ***[0.35]***					6.77 ***[2.69]***	10.2 ***[2.27]***	1.84 ***[0.45]***			12.4 ***[2.13]***	0.23 ***[0.03]***	1.35 ***[0.15]***	9.7 ***[0.97]***	
Combretum collinum																	
Combretum mossambicense								26.9 ***[10.68]***	0.36 ***[0.08]***								
Combretum zeyheri		7.27 ***[0.41]***								2.8 ***[0.68]***							
Commiphora africana										0.14 ***[0.03]***			2.03 ***[0.35]***				
Croton macrostachyus																	
Dalbergia melanoxylon		1.97 ***[0.11]***	0.01 ***[0.003]***	91.4 ***[21.02]***	9.8 ***[1.61]***		11.3 ***[0.36]***			4.19 ***[1.02]***	0.33 ***[0.06]***	0.06 ***[0.01]***	48.6 ***[8.36]***		6.35 ***[0.71]***	2.2 ***[0.22]***	
Deinbollia nyikensis						21.1 ***[1.1]***		3.89 ***[1.54]***	1.25 ***[0.28]***								
Dichrostachys cinerea		12.9 ***[0.74]***		1.18 ***[0.27]***	1.27 ***[0.21]***		2.16 ***[0.07]***	1.42 ***[0.56]***		4.9 ***[1.2]***		0.02 ***[0.005]***		12.5 ***[1.66]***	1.6 ***[0.18]***		0.07 ***[0.02]***
Diospyros senensis						1.37 ***[0.07]***											
Diospyros squarrosa									0.17 ***[0.04]***		1.64 ***[0.3]***						
Diospyros quiloensis																	
Diospyros zombensis				2.29 ***[0.53]***	0.68 ***[0.11]***	1.39 ***[0.07]***		0.67 ***[0.27]***	20.9 ***[4.66]***								
Diplorhynchus condylocarpon	86.2 ***[4.22]***	38.2 ***[2.18]***	31.1 ***[9.49]***		0.32 ***[0.05]***	39.1 ***[2.03]***	44.1 ***[1.4]***			61.9 ***[15.1]***	80.3 ***[14.6]***	52.8 ***[12.94]***	0.56 ***[0.1]***	69.3 ***[9.22]***	76 ***[8.51]***	27.9 ***[2.79]***	96.8 ***[26.33]***
Dyschoriste verticillaris																	

PLOTS → (PENDE)	MK 1	MK 2	MK 3	MK 4	MK 5	MK 6	MK 7	MB 1	MB 2	MB 3	MB 4	MB 5	MB 6	KK 1	KK 2	KK 3	KK 4
SPECIES LIST	**%BA: 4.9%**	**%BA: 5.7%**	**%BA: 30.5%**	**%BA: 23%**	**%BA: 16.4%**	**%BA: 5.2%**	**%BA: 3.2%**	**%BA: 39.7%**	**%BA: 22.3%**	**%BA: 24.4%**	**%BA: 18.2%**	**%BA: 24.5%**	**%BA: 17.2%**	**%BA: 13.3%**	**%BA: 11.2%**	**%BA: 10%**	**%BA: 27.2%**
Ehretia amoena				0.16 ***[0.04]***		9.7 ***[0.5]***			3.14 ***[0.7]***								
Ekebergia capensis			5 ***[1.53]***		3.41 ***[0.56]***		17.4 ***[0.56]***		0.16 ***[0.04]***	9.2 ***[2.24]***	3.8 ***[0.69]***	5.15 ***[1.26]***	11.8 ***[2.03]***	9.6 ***[1.28]***	3.3 ***[0.37]***	26.8 ***[2.68]***	
Euphorbia ingens																	
Gardenia ternifolia								0.38 ***[0.15]***									
Grewia bicolor								1.82 ***[0.72]***	9.41 ***[2.1]***								
Grewia flavescens								34.7 ***[13.78]***	14.7 ***[3.28]***								
Grewia forbesii								0.61 ***[0.24]***	2.78 ***[0.62]***								
Grewia villosa																	
Gymnosporia buxifolia																	
Gymnosporia senegalensis								0.55 ***[0.22]***									
Holarrhena pubescens								0.28 ***[0.11]***	4.52 ***[1.01]***								
Hymenocardia acida							22.6 ***[0.72]***										
Karomia tettensis								7.95 ***[3.16]***	28.2 ***[6.29]***								
Kigelia africana																	
Lannea discolor								0.16 ***[0.06]***									
Lannea schweinfurthii								0.48 ***[0.19]***	1.01 ***[0.23]***								
Ormocarpum kirkii											0.55 ***[0.1]***						
Pouzolzia mixta																	
Pterocarpus rotundifolius			62.7 ***[19.12]***	3.04 ***[0.7]***	16.3 ***[2.67]***					0.1 ***[0.02]***	13.2 ***[2.4]***	42 ***[10.29]***	24.5 ***[4.21]***	0.33 ***[0.04]***	7.5 ***[0.84]***	32.5 ***[3.25]***	
Rhus tenuinervis																	
Schrebera trichoclada									2.69 ***[0.6]***								
Sclerocarya birrea		0.26 ***[0.01]***	0.06 ***[0.02]***							0.06 ***[0.01]***	0.05 ***[0.01]***	0.02 ***[0.005]***	0.04 ***[0.007]***	1.24 ***[0.16]***	0.03 ***[0.003]***	0.8 ***[0.08]***	0.23 ***[0.06]***
Sterculia appendiculata																	
Stereospermum kunthianum	0.12 ***[0.01]***					8.59 ***[0.45]***				0.5 ***[0.12]***					0.1 ***[0.01]***		
Terminalia sambesiaca								0.37 ***[0.15]***									
Urena lobata																	
Vangueria randii								1.95 ***[0.77]***									
Vitex buchananii																	
Xeroderris stuhlmannii	0.89 ***[0.04]***			0.33 ***[0.08]***						5.13 ***[1.25]***	0.04 ***[0.01]***				0.86 ***[0.1]***		
Ziziphus mucronata																	
Total % :	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

APPENDIX 1c. Relative (%) species contributions to total browse available in Western Majete plots (bold *Italic* values show absolute %BA scores – % vertical fill – of species in the plots).

PLOTS (WESTERN MAJETE BLOCK) → SPECIES LIST ↓	MJ 1 %BA: 10.5%	MJ 2 %BA: 2.8%	MJ 3 %BA: 4.7%	MJ 4 %BA: 3.7%
Acacia burkei	0.6 ***[0.06]***			
Acacia nigrescens	1.1 ***[0.12]***			
Acacia nilotica		1.2 ***[0.03]***	62.4 ***[2.93]***	
Acacia karoo				
Acacia tortilis				
Acacia xanthophloea				
Albizia harveyi				
Albizia anthelmintica				
Allophylus africanus				
Becium grandiflorum				
Burkea africana		0.6 ***[0.02]***	0.48 ***[0.02]***	0.4 ***[0.02]***
Cardiogyne africana				
Catunaregam spinosa	12.78 ***[1.34]***	3 ***[0.08]***	8.2 ***[0.39]***	1.5 ***[0.06]***
Combretum adenogonium	7.71 ***[0.81]***			
Combretum apiculatum				
Combretum collinum				
Combretum mossambicense				
Combretum zeyheri				
Commiphora africana				
Croton macrostachyus				
Dalbergia melanoxylon	8.76 ***[0.92]***		6.2 ***[0.29]***	9.18 ***[0.34]***
Deinbollia nyikensis				
Dichrostachys cinerea	3.14 ***[0.33]***	0.5 ***[0.01]***	2.14 ***[0.1]***	9.8 ***[0.36]***
Diospyros senensis				
Diospyros squarrosa				
Diospyros quiloensis				
Diospyros zombensis				
Diplorhynchus condylocarpon	43.52 ***[4.57]***	91.4 ***[2.56]***	20.4 ***[0.96]***	74.5 ***[2.76]***
Dyschoriste verticillaris	0.002 ***[0.0003]***		0.22 ***[0.01]***	
Ehretia amoena				
Ekebergia capensis	2.94 ***[0.31]***	0.7 ***[0.02]***		4.13 ***[0.15]***
Euphorbia ingens				
Gardenia ternifolia				
Grewia bicolor				
Grewia flavescens				
Grewia forbesii				
Grewia villosa				
Gymnosporia buxifolia			0.08 ***[0.004]***	0.5 ***[0.02]***
Gymnosporia senegalensis				
Holarrhena pubescens				
Hymenocardia acida				
Karomia tettensis				
Kigelia africana				
Lannea discolor				
Lannea schweinfurthii				
Ormocarpum kirkii	0.14 ***[0.02]***	2.3 ***[0.06]***	0.01 ***[0.0005]***	0.05 ***[0.002]***
Pouzolzia mixta				
Pterocarpus rotundifolius	19.21 ***[2.02]***			
Rhus tenuinervis				
Schrebera trichoclada				
Sclerocarya birrea				
Sterculia appendiculata				
Stereospermum kunthianum				
Terminalia sambesiaca				
Urena lobata				
Vangueria randii				
Vitex buchananii				
Xeroderris stuhlmannii				
Ziziphus mucronata				
Total % :	**100**	**100**	**100**	**100**

APPENDIX 2a. Availability of diet species in the five vegetation communities found in the Sanctuary (study area for collecting rhino feeding data). Each taxon is shown with its absolute average %BA score in each type and its overall weighted average %BA score for the Sanctuary. Relative contribution of each species to the total browse available (key determinant of preference indices) is shown in the extreme right column.

Vegetation Types of the Sanctuary →	Riparian Thicket	Riverine & Alluvial Association	Ridge-top Mixed Woodland	Low Altit. Mixed Woodland	Medium Altit. Mixed Woodland	The SANCTUARY (%BA score: 16.91%)	
	Its plots: ST14, ST15	*Its plots:* ST2, ST4, ST6, ST7, ST10	*Its plots:* ST1, ST8, ST13	*Its plots:* ST5, ST9, ST11, ST12	*Its plots:* ST3	*Its sample:* 15 plots	
% Area cover of vegetation types in the Sanctuary →	**3.6%**	**26.9%**	**13.7%**	**47%**	**8.8%**		
Browse species list ↓	**Absolute average %BA scores of browse species in this veg. type of the Sanctuary ↓**	**Absolute average %BA scores of browse species in this veg. type of the Sanctuary ↓**	**Absolute average %BA scores of browse species in this veg. type of the Sanctuary ↓**	**Absolute average %BA scores of browse species in this veg. type of the Sanctuary ↓**	**Absolute average %BA scores of browse species in this veg. type of the Sanctuary ↓**	**Overall weighted average %BA scores of browse species in the Sanctuary ↓**	**Relative contribution of species to the total browse available [Sanctuary]** ***(Denominator of pref. indices)***
Acacia burkei			0.03%	0.43%		Calc. example: *[(0.03x13.7/100) + (0.43x47/100] = 0.2062%*	Calc. example: 0.2062% */ 16.91% x 100 = 1.219%*
Acacia nigrescens	6.285%	3.174%	2.617%	0.036%		1.4555%	8.607%
Acacia nilotica				0.518%		0.2435%	1.44%
Acacia karoo	2.525%	0.63%		0.07%		0.2933%	1.734%
Acacia tortilis	*- Species was not seen in the SANCTUARY sub-area during Phase 2 (sampling) -*						
Acacia xanthophloea		0.05%				0.0135%	0.08%
Albizia harveyi	*- Species was not seen in any sub-area during Phase 2 (sampling) -*						
Albizia anthelmintica	*- Species was not seen in the SANCTUARY sub-area during Phase 2 (sampling) -*						
Allophylus africanus	0.105%	0.482%				0.1334%	0.789%
Becium grandiflorum		0.168%	0.057%			0.053%	0.313%
Burkea africana	*- Species was not seen in the SANCTUARY sub-area during Phase 2 (sampling) -*						
Cardiogyne africana	*- Species was not seen in any sub-area during Phase 2 (sampling) -*						
Catunaregam spinosa		0.02%	0.003%	0.638%		0.3057%	1.808%
Combretum adenogonium	*- Species was not seen in the SANCTUARY sub-area during Phase 2 (sampling) -*						
Combretum apiculatum	0.25%	2.394%	0.11%	3.1%		2.1251	12.567%
Combretum collinum		0.202%		0.06%		0.0825%	0.488%
Combretum mossambicense	0.015%	0.15%				0.0409%	0.242%
Combretum zeyheri		0.098%	0.187%			0.052%	0.307%
Commiphora africana	0.08%	0.314%		0.005%		0.0897%	0.53%

Croton macrostachyus		0.008%				0.0022%	0.013%
Dalbergia melanoxylon		0.326%	0.34%	0.81%	0.1%	0.5238%	3.097%
Deinbollia nyikensis	1.5%	0.114%				0.0847%	0.501%
Dichrostachys cinerea	0.07%	0.524%	0.477%	0.546%	0.25%	0.4874%	2.883%
Diospyros senensis	0.01%					0.0004%	0.002%
Diospyros squarrosa	*- Species was not seen in the SANCTUARY sub-area during Phase 2 (sampling) -*						
Diospyros quiloensis	0.44%	0.06%				0.032%	0.189%
Diospyros zombensis		0.58%	0.533%	0.018%		0.2375%	1.404%
Diplorhynchus condylocarpon		3.176%	4.887%	9.15%	3.98%	6.1746%	36.515%
Dyschoriste verticillaris	0.37%	0.702%				0.2022%	1.195%
Ehretia amoena		0.24%				0.0646%	0.382%
Ekebergia capensis		1.804%	0.8%	2.02%	0.7 %	1.6059%	9.497%
Euphorbia ingens	*- Species was not seen in any sub-area during Phase 2 (sampling) -*						
Gardenia ternifolia	*- Species was not seen in the SANCTUARY sub-area during Phase 2 (sampling) -*						
Grewia bicolor	1.17%	0.444%	0.46%			0.2246%	1.328%
Grewia flavescens	1.115%	0.51%				0.1773%	1.049%
Grewia forbesii		0.001%				0.0003%	0.002%
Grewia villosa	*- Species was not seen in any sub-area during Phase 2 (sampling) -*						
Gymnosporia buxifolia				0.035%		0.0165%	0.097%
Gymnosporia senegalensis	*- Species was not seen in the SANCTUARY sub-area during Phase 2 (sampling) -*						
Holarrhena pubescens	*- Species was not seen in the SANCTUARY sub-area during Phase 2 (sampling) -*						
Hymenocardia acida	0.22%	0.142%	0.17%			0.0694%	0.41%
Karomia tettensis		2.184%				0.5875%	3.474%
Kigelia africana		0.008%				0.0022%	0.013%
Lannea discolor		0.032%		0.035%		0.0251%	0.148%
Lannea schweinfurthii	*- Species was not seen in the SANCTUARY sub-area during Phase 2 (sampling) -*						
Ormocarpum kirkii		0.9%	3.557%	0.073%	0.02%	0.7655%	4.527%
Pouzolzia mixta	*- Species was not seen in any sub-area during Phase 2 (sampling) -*						
Pterocarpus rotundifolius				0.398%		0.1871%	1.106%
Rhus tenuinervis	*- Species was not seen in any sub-area during Phase 2 (sampling) -*						
Schrebera trichoclada	*- Species was not seen in the SANCTUARY sub-area during Phase 2 (sampling) -*						
Sclerocarya birrea			0.63%	0.188%	0.15%	0.1879%	1.111%
Sterculia appendiculata	*- Species was not seen in any sub-area during Phase 2 (sampling) -*						
Stereospermum kunthianum	0.09%	0.256%	0.003%	0.038%		0.0904%	0.534%
Terminalia sambesiaca		0.09%				0.0242%	0.143%
Urena lobata	*- Species was not seen in any sub-area during Phase 2 (sampling) -*						
Vangueria randii	*- Species was not seen in the SANCTUARY sub-area during Phase 2 (sampling) -*						
Vitex buchananii	*- Species was not seen in any sub-area during Phase 2 (sampling) -*						
Xeroderris stuhlmannii		0.054%		0.065%		0.0451%	0.267%
Ziziphus mucronata	*- Species was not seen in any sub-area during Phase 2 (sampling) -*						
TOTAL:	**14.25%** Average %BA of type (sum of average %BA scores of species)	**19.84%** Average %BA of type (sum of average %BA scores of species)	**14.87%** Average %BA of type (sum of average %BA scores of species)	**18.23%** Average %BA of type (sum of average %BA scores of species)	**5.2%** Average %BA of type (sum of average %BA scores of species)	**16.91%** Sanctuary %BA (sum of weighted average %BA scores of spp.)	**100%** Sum of species contributions to total browse
Area-weighted %BA scores of the vegetation types in the Sanctuary	14.25 x 3.6 /100 = **0.513%**	19.84x 26.9 /100 = **5.337%**	14.87 x 13.7 /100 = **2.037%**	18.23% x 47 /100 = **8.568%**	5.2% x 8.8 /100 = **0.458%**	Sum of weighted %BA scores of types →→ **16.91%**	-

APPENDIX 2b. Forage utilization of black rhino in the Sanctuary. The preference index is defined as the relation of a species' % in diet (feeding intensity) and its % out of the total browse available in the habitat (the Sanctuary sub-area in this study) (Petrides, 1975).

BROWSE SPECIES	NUMBER OF DAYS SPECIES WERE SEEN BEING EATEN	SBVs RECORDED ON BROWSE SPECIES [Equation: number of bites recorded on browse species per day and summed as of all occasions]	%CONTRIBUTION TO TOTAL BITES (SBVs) Relative Importance (Feeding rates)	%CONTRIBUTION TO TOTAL BROWSE AVAILABLE Relative Availability	DIET PREFERENCE Preference Indices
Acacia burkei	2	3+2 = **5**	**0.29%**	**1.219%**	0.29 / 1.219 = **0.24**
Acacia nigrescens	7	10+12+5+5+3+7+6 = **48**	**2.75%**	**8.607%**	2.75/ 8.607 = **0.32**
Acacia nilotica	10	4+12+9+14+8+7+3+6+11+3= **77**	**4.42%**	**1.44%**	4.42 / 1.44 = **3.07**
Acacia karoo	2	4+5 = **9**	**0.52%**	**1.734%**	0.52 / 1.734 = **0.3**
Acacia tortilis	1	6 = **6**	**0.34%**	**0%**	-
Acacia xanthophloea	1	4 = **4**	**0.23%**	**0.08%**	0.23 / 0.08 = **2.88**
Albizia harveyi	2	3+4 = **7**	**0.4%**	**0 %**	-
Albizia anthelmintica	1	3 = **3**	**0.17%**	**0%**	-
Allophylus africanus	4	6+4+11+5 = **26**	**1.49%**	**0.789%**	1.49 / 0.789 = **1.89**
Becium grandiflorum	3	1+4+12 = **17**	**0.98%**	**0.313%**	0.98 / 0.313 = **3.13**
Burkea africana	1	4 = **4**	**0.23%**	**0%**	-
Cardiogyne africana	2	6+6 = **12**	**0.69%**	**0%**	-
Catunaregam spinosa	3	2+11+3 = **16**	**0.92%**	**1.808%**	0.92 / 1.808 = **0.51**
Combretum adenogonium	2	8+7 = **15**	**0.86%**	**0%**	-
Combretum apiculatum	3	4+6+4 = **14**	**0.8%**	**12.567%**	0.8 / 12.567 = **0.06**
Combretum collinum	2	3+2 = **5**	**0.29%**	**0.488%**	0.29 /0.488 = **0.59**
Combretum mossambicense	2	6+10 = **16**	**0.92%**	**0.242%**	0.92 / 0.242 = **3.8**
Combretum zeyheri	3	5+7+2 = **14**	**0.8%**	**0.307%**	0.8 / 0.307 = **2.61**
Commiphora africana	3	8+3+8 = **19**	**1.09%**	**0.53%**	1.09 / 0.53 = **2.06**
Croton macrostachyus	4	6+11+7+10 = **34**	**1.95%**	**0.013%**	1.95 / 0.013 = **150**
Dalbergia melanoxylon	6	22+8+14+8+21+13 = **86**	**4.93%**	**3.097%**	4.93 / 3.097 = **1.59**
Deinbollia nyikensis	2	4+6 = **10**	**0.57%**	**0.501%**	0.57 / 0.501 = **1.14**
Dichrostachys cinerea	13	26+21+11+22+5+4+4+15+35+13+14+35+31 = **236**	**13.54%**	**2.883%**	13.54 /2.883 = **4.7**
Diospyros senensis	2	3+4 = **7**	**0.4%**	**0.002%**	0.4 / 0.002 = **200**
Diospyros squarrosa	2	4+7 = **11**	**0.63%**	**0%**	-
Diospyros quiloensis	2	14+17 = **31**	**1.78%**	**0.189%**	1.78 / 0.189 = **9.42**

Diospyros zombensis	4	16+6+10+33 = **65**	**3.73%**	**1.404%**	3.73 /1.404 = **2.66**
Diplorhynchus condylocarpon	15	8+17+14+23+13+3+11+5+16+5+17+48+22+9+17 = **228**	**13.08%**	**36.515%**	13.08 /36.515 = **0.36**
Dyschoriste verticillaris	1	13 = **13**	**0.75%**	**1.195%**	0.75 / 1.195 = **0.63**
Ehretia amoena	3	17+11+8 = **36**	**2.07%**	**0.382%**	2.07 / 0.382 = **5.42**
Ekebergia capensis	3	5+7+8 = **20**	**1.15%**	**9.497%**	1.15 / 9.497 = **0.12**
Euphorbia ingens	3	4+2+1 = **7**	**0.4%**	**0%**	-
Gardenia ternifolia	2	2+1 = **3**	**0.17%**	**0%**	-
Grewia bicolor	8	21+6+9+5+7+31+6+19 = **104**	**5.97%**	**1.328%**	5.97 / 1.328 = **4.5**
Grewia flavescens	5	13+12+4+5+14 = **48**	**2.75%**	**1.049%**	2.75 / 1.049 = **2.62**
Grewia forbesii	1	3 = **3**	**0.17%**	**0.002%**	0.17 / 0.002 = **85**
Grewia villosa	1	8 = **8**	**0.46%**	**0%**	-
Gymnosporia buxifolia	4	7+6+3+13 = **29**	**1.66%**	**0.097%**	1.66 / 0.097 = **17.11**
Gymnosporia senegalensis	4	3+3+10+17 = **33**	**1.89%**	**0%**	-
Holarrhena pubescens	1	11 = **11**	**0.63%**	**0%**	-
Hymenocardia acida	2	6+9 = **15**	**0.86%**	**0.41%**	0.86 / 0.41 = **2.1**
Karomia tettensis	5	17+15+14+45+12 = **103**	**5.91%**	**3.474%**	5.91 / 3.474 = **1.7**
Kigelia africana	2	1+1 = 2	**0.11%**	**0.013%**	0.11 / 0.013 = **8.46**
Lannea discolor	2	4+3 = **7**	**0.4%**	**0.148%**	0.4 / 0.148 = **2.7**
Lannea schweinfurthii	2	5+1 = **6**	**0.34%**	**0%**	-
Ormocarpum kirkii	6	15+21+12+26+14+5 = **93**	**5.34%**	**4.527%**	5.34 / 4.527 = **1.18**
Pouzolzia mixta	2	2+3 = **5**	**0.29%**	**0%**	-
Pterocarpus rotundifolius	4	5+7+11+2 = **25**	**1.43%**	**1.106%**	1.43 / 1.106 = **1.29**
Rhus tenuinervis	2	11+7 = **18**	**1.03%**	**0%**	-
Schrebera trichoclada	1	2 = **2**	**0.11%**	**0%**	-
Sclerocarya birrea	5	12+4+16+3+7 = **42**	**2.41%**	**1.111%**	2.41 / 1.111 = **2.17**
Sterculia appendiculata	1	5 = **5**	**0.29%**	**0%**	-
Stereospermum kunthianum	2	11+16 = **27**	**1.55%**	**0.534%**	1.55 / 0.534 = **2.9**
Terminalia sambesiaca	1	3= **3**	**0.17%**	**0.143%**	0.17 / 0.143= **1.19**
Urena lobata	2	2+4 = **6**	**0.34%**	**0%**	-
Vangueria randii	2	4+12 = **16**	**0.92%**	**0%**	-
Vitex buchananii	1	2 = **2**	**0.11%**	**0%**	-
Xeroderris stuhlmannii	2	4+3 = **7**	**0.4%**	**0.267%**	0.4 / 0.267 = **1.5**
Ziziphus mucronata	3	4+7+8 = **19**	**1.09%**	**0%**	-
Total:	**187**	**1743** (total number of SBVs counted on all species)	**100%**	**100%**	-

APPENDIX 3. Plot codes with geographical coordinates in degrees and minutes and their elevation data (for five plots elevation data could not be recorded).

PLOTS (code names)	COORDINATES (degrees & decimal minutes)	ELEVATION (metres)
ST 1	S 15° 49.927′ E 034° 42.412′	-
ST 2	S 15° 52.329′ E 034° 40.531′	-
ST 3	S 15° 52.147′ E 034° 40.403′	-
ST 4	S 15° 50.199′ E 034° 44.353′	176m
ST 5	S 15° 51.447′ E 034° 42.176′	235m
ST 6	S 15° 51.276′ E 034° 44.591′	180m
ST 7	S 15° 48.085′ E 034° 41.712′	226m
ST 8	S 15° 53.649′ E 034° 40.311′	260m
ST 9	S 15° 54.705′ E 034° 41.792′	202m
ST 10	S 15° 53.348′ E 034° 44.264′	165m
ST 11	S 15° 47.597′ E 034° 42.380′	257m
ST 12	S 15° 48.424′ E 034° 40.372′	279m
ST 13	S 15° 53.390′ E 034° 42.750′	264m
ST 14	S 15° 53.811′ E 034° 42.008′	210m
ST 15	S 15° 50.370′ E 034° 42.235′	232m
MK 1	S 15° 55.263′ E 034° 40.874′	216m
MK 2	S 15° 55.584′ E 034° 41.448′	239m
MK 3	S 15° 57.683′ E 034° 41.908′	225m
MK 4	S 15° 58.423′ E 034° 41.518′	218m
MK 5	S 15° 57.816′ E 034° 41.053′	228m

MK 6	S 15° 57.727’ E 034° 38.070’	-
MK 7	S 15° 57.634’ E 034° 38.098’	-
MB 1	S 15° 58.918’ E 034° 39.636’	249m
MB 2	S 15° 58.512’ E 034° 39.141’	271m
MB 3	S 16° 00.559’ E 034° 40.709’	207m
MB 4	S 15° 59.960’ E 034° 40.924’	224m
MB 5	S 16° 00.773’ E 034° 41.439’	193m
MB 6	S 16° 00.034’ E 034° 41.430’	217m
KK 1	S 16° 04.704’ E 034° 40.025’	165m
KK 2	S 16° 04.067’ E 034° 39.554’	231m
KK 3	S 16° 04.224’ E 034° 41.254’	210m
KK 4	S 16° 03.148’ E 034° 41.277’	206m
MJ 1	S 15° 50.480’ E 034° 38.159’	349m
MJ 2	S 15° 51.471’ E 034° 35.709’	413m
MJ 3	S 15° 52.021’ E 034° 33.912’	446m
MJ 4	S 15° 54.002’ E 034° 33.219’	544m

APPENDIX 4. The 10 most important diet species to black rhino in Majete Wildlife Reserve (sample photos of *Appendix 4* and *Appendix 5* were taken by the author).

A. nigrescens

D. condylocarpon

D. cinerea

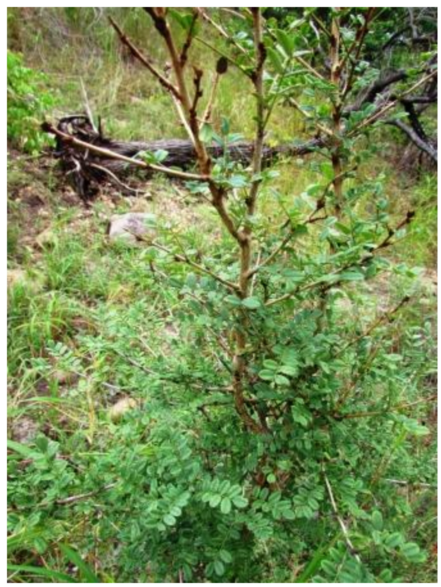
A. nilotica

D. zombensis

G. flavescens

D. melanoxylon

K. tettensis



O. kirkii

G. bicolor

APPENDIX 5. The 10 most preferred diet species by black rhino in Majete Wildlife Reserve.

A. nilotica

S. birrea

D. zombensis

D. cinerea

A. africanus

G. bicolor

G. flavescens

D. melanoxylon

K. tettensis

O. kirkii