## RESEARCH

# Forage choice of the reintroduced black rhino and the availability of selected browse species at Majete Wildlife Reserve, Malawi

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***Krisztián Gyöngyi** was tragically killed by a black rhino on 7 June 2017 while assisting with the reintroduction of the species in Rwanda. Krisz was extremely dedicated to rhino conservation and thrived in the field doing applied research. Krisz started his wildlife conservation work with assignments in eastern and southern Africa and trained as a wildlife manager. After university studies in the UK, he was drawn back to Africa to study black rhinos in Majete Wildlife Reserve, Malawi. I had the pleasure to meet Krisz in Liwonde National Park and help him to write up this work as a paper. Sadly, he will never see the final result. Morten Elmeros*

## Abstract

We investigated the forage choice of recently reintroduced black rhino and the availability of standing browse biomass in Majete Wildlife Reserve (MWR) in Malawi. Field work was conducted in the late hot–wet to early cool–dry season, a period that presented a broad botanical backdrop to collect forage data. Two management sub-areas of the eastern half of MWR constituted the larger study area. We recorded 59 diet species and 1,743 standard bite volumes along black rhino feeding trails with Mimosaceae and Fabaceae species dominating the diet. Out of the six main vegetation types, the Riverine and Alluvial matrix possessed the largest proportional standing browse biomass, with the widely distributed Low Altitude Mixed Woodland showing the greatest area-weighted scores. The High Altitude Miombo Woodland produced both the lowest average proportional and weighted browse availability for black rhino. By providing information on the selected diet species of black rhino and the availability of black rhino browse species in the reserve's different vegetation types, this study provides the foundations for a better understanding of black rhino holding capacity of MWR. Results should help to identify potential release sites for future black rhino reintroduction schemes. A better understanding of the dietary attributes and feeding ecology of the Majete rhinos and the capacity of habitat to sustain their growing population will lead to better stock management (i.e. avoiding translocation stress when nearing holding capacity margins) and thus serve the long-term goals of augmenting the meta-population.

## Résumé

Nous avons étudié le choix du fourrage des rhinocéros noirs récemment réintroduits et la disponibilité de la biomasse de brousse sur laquelle ils peuvent brouter dans la Réserve de la faune de Majete (MWR) au Malawi. Le travail sur le terrain a été mené de la fin de la saison chaude et humide jusqu'au début de la saison fraiche et sèche, une période qui présente un large cadre botanique pour la collecte des données fourragères.

Deux sous-zones de gestion dans la moitié orientale de la MWR servaient de zone d'étude. Nous avons enregistré 59 espèces consommées et 1 743 volumes de morsure standard le long des pistes d'alimentation du rhinocéros noir où des espèces de Mimosaceae et Fabaceae dominaient le régime alimentaire. Sur les six principaux types de végétation, la matrice riveraine et alluvionnaire possédait la plus grande biomasse de brousse proportionnelle alors que la forêt mixte de basse altitude très répandue présentait les plus grands scores pondérés en surface. La forêt boisée de haute altitude de Miombo produisait le taux moyen de disponibilité de brout pour le rhinocéros noir proportionnel et pondéré le plus bas. En fournissant des informations sur les espèces sélectionnées par les rhinocéros noirs et la disponibilité des espèces de brout consommées par ces animaux parmi les différents types de végétation de la réserve, cette étude fournit les bases d'une meilleure compréhension de la capacité de charge du rhinocéros noir de la MWR. Ces résultats devraient faciliter l'identification des sites potentiels de réintroduction future du rhinocéros noir. Une meilleure compréhension des attributs alimentaires et de l'écologie alimentaire des rhinocéros de Majete et la capacité de l'habitat à soutenir leur population croissante produira une meilleure gestion des stocks (c.-à-d. éviter le stress de la translocation lorsqu'on s'approche des limites de la capacité de charge) et servir ainsi les objectifs à long terme d'augmenter la méta-population.

## Introduction

As the target of heavy persecution throughout its natural range, the critically endangered black rhino (*Diceros bicornis*) is one of the greatest losers as a result of modern human impact unleashed on wild habitats in Africa (Brooks and Adcock 1997). To outpace the impacts of poaching and maximise genetic diversity, a minimum 5% annual population growth rate has become a widely accepted goal among managers of black rhino populations (Brooks and Adcock 1997; Buk and Knight 2010) Keeping source populations at maximum productivity (~75% of ecological holding capacity) is a central objective when managing black rhino sub-species as organic parts of larger meta-populations, i.e. national and regional stocks (Du Toit et al. 2006). Long-term continent-wide recovery of this elusive mega-herbivore can only be achieved through a strict species-focused approach, considering core ecological requirements, thwarting genetic impoverishment, enhancing productivity and providing direct protection (Du Toit et al. 2006) The black rhino is a browser, preferring mainly woody vegetation (small trees and shrubs), but forbs, herbs and succulents are also selected (Goddard 1968; Hall-Martin et al 1982; Kotze and Zacharias 1993; Oloo et al. 1994). Dynamic ecological processes like resource fluctuations that affect the composition and distribution of vegetation communities determine overall habitat quality and thus are primary influences on large herbivore reproduction and survival (Bell 1984; Fowler 1987). When the density of food plants declines as a result of drought, disease, infestation by unpalatable plants (e.g. *Lantana camara*), browser competition (e.g. by African elephant, giant kudu) or grass encroachment, management is required to mitigate effects on rhino populations (Fowler 1987; De Boer and Ijdema 2007). Assessing the availability of principal forage biomass for new populations of black rhino is important to enable informed projections of the holding capacity of the habitat (Emslie and Adcock 1994; Adcock 2006). Knowledge of the complex ecological and chemical factors that influence browse selection is essential, particularly when planning translocations and relocations, large-scale population augmentation measures and (re)establishment of new populations (Muya and Oguge). According to Buk and Knight (2010), understanding the diet component and estimating the approximate capacity of an area to sustain threatened species like black rhinos is vital because this information is required to estimate optimal stocking rates. There is also a need for research to study possible diet overlaps with other browsers (De Boer and Ijdema 2007) and to improve understanding of nutritional requirements of wild as well as captive populations. When key diet items have been identified, these can also serve as indicators of food limitation (Buk 2004; Shaw 2011).

This study examines the diet composition of and browse availability for a reintroduced population of black rhino in Majete Wildlife Reserve (MWR) in Malawi. The catalyst for this research was the need for baseline data to inform ongoing management of the fenced Rhino Sanctuary in the Reserve. This required ranking of browse taxa in terms of their importance to black rhino (tracking/diet assessment phase) and rigorous quantitative appraisal of palatable standing vegetation biomass in and outside the sanctuary (sampling phase). The results provide inputs for MWR's rhino management plan, and specifically for decisions on ecologically sound (re-)stocking rates and identification of blocks with the greatest potential to sustain the species, as well as for Malawi's National Black Rhino Management Strategy.

## Materials and methods

### *Study area*

The study was conducted in MWR located in south-western Malawi (S 15.8°, E 34.7°). The Reserve, lying within the historical range of the southern-central black rhino subspecies (*Diceros bicornis minor*), is considered as one of the few remaining protected areas in Malawi with existing ecological and management potential to rehabilitate this taxon (Martin 2005; Hall-Martin pers. comm. 2011). MWR, covering 689 km² and 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. Within the MWR, the fenced Rhino Sanctuary, established in 2003, occupies an area of 143 $km^2$ in the Eastern Block (EB) of the Reserve. The topography is dominated by the NW–SE fault structure of the escarpment stretching parallel to the Mwanza River, which creates a steeply undulating landscape dissected by river valleys and gullies (Bell 1984). Soils are primarily lithosols; shallow and stony low fertility ferruginous soils are interspersed with narrow stretches of fertile alluvial deposits along some small rivers (Sherry 1989; Martin 2005). MWR is characterized by a diverse tapestry of six different vegetation types (Fig. 1), ranging from high altitude miombo (*Brachystegia spp.*) (32.3%) and medium altitude mixed deciduous woodlands (16.8%) that dominate the western half of the reserve to the rich riverine and alluvial associations (12%), riparian thickets (1%), ridge-top mixed woodlands (7.2%) and low altitude mixed savannah woodlands (30.7%) that are found in the eastern and central areas (Bell 1984; Sherry 1989). The miombo-dominated western realm (with abundant presence of *Brachystegia* and *Julbernardia* species) has historically been deemed to constitute poor and/or below average habitat for black rhino (Sherry 1989; Hall-Martin pers. comm.). For this reason, the EB of the reserve (53% of MWR) was selected as the study area for this research, comprising two key focal areas: the Rhino Sanctuary (39.4% of EB) and the Pende sub-area (60.6% of EB).

By the mid-1990s, the mega-fauna of the Reserve had almost completely been wiped out by poaching (Martin 2005). The MWR Rhino Sanctuary received two bull black rhino from Liwonde National Park in 2003, and five females and a bull from South Africa in 2007 (Hall-Martin pers. comm.). One of the Liwonde bulls was taken to South Africa in 2007. During the period that this study was carried out (2011), there were 10 rhinos in MWR, all within the Rhino Sanctuary. (During phase one–the diet study–the sanctuary was fenced). The inner fence has since been pulled down to allow the rhinos to roam in the entire reserve.

## Data collection

The tracking phase to collect a browse list was carried out from 22 March to 06 May 2011, and the sampling phase to assess browse availability from 26 April to 02 June 2011.

### *Tracking phase*

Information on black rhino diet was collected using the 'feeding track' observation technique (Mukinya 1977, Hall-Martin et al. 1982). Tracking was undertaken on foot at dawn and in late afternoon during peak feeding times (Mukinya 1977). The entire area of the Sanctuary was searched systematically for fresh rhino tracks to avoid biases towards sections most intensively used by black rhino. Trackers defined as 'fresh' those tracks that were estimated to have been imprinted less than seven hours beforehand (Tizola Moyo pers. comm.). Upon locating fresh activity, tracking ensued. Botanical and photo samples of black rhino browse plants were collected and identified according to Van Wyk and Van Wyk (1997) and Smith and Allen (2004) to compile a 'browse species list'. If known, the vernacular names of browsed plants were also noted. The importance of each diet species was extrapolated from the overall number of standard bite volumes (SBV) recorded on the browsed specimens in black rhino 'browsing range (≤2m above the ground) along the tracks (Buk 2004; Adcock 2006). The SBV represents the average amount of browse removed from a plant by black rhino in one bite (Hall-Martin et al. 1982; Kotze and Zacharias 1993; Oloo et al. 1994; Buk 2004).

Following Hall-Martin et al. (1982), an SBV was scored for (1) any isolated severed shoot or branch (found in the ≤2m browsing range) and (2) where contiguous shoots or branches were bitten off at the same height and were less than 5 mm in thickness each and grew within a hypothetical circle of 5 cm in diameter.

### *Sampling phase*

For the sampling phase, which followed after diet assessment in the tracking phase, browse availability was assessed for each vegetation type within the Sanctuary and Pende sub-areas, and total browse availability was calculated based on the area coverage of each vegetation type in two sub-areas. This method provided separate estimates of the means and variances of browse availability each stratum and resulted in higher precision in overall mean estimations of proportional browse availability (%BA) (Sutherland 2006; Adcock pers. comm.). Though distributed patchily in a largely discontinuous matrix, each of the six vegetation types appeared homogenous in composition according to Bell's (1984) definitions and could be differentiated based on thorough ground-truthing and visual classification, with reference to Sherry's (1989) map (Figure 1; see colour plates: i). As the study was conducted between the end of the hot–wet season through to the beginning of the cool–dry season, the biomass of foliage on plants was sufficient for identification. Sampling plots were set randomly within each vegetation type. 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 proportion of the stratum in the study area, its historical conduciveness to black rhino, and logistical considerations (Buk 2004). The yellow, coded flags of the sampling plots were displayed on Sherry's (1989) vegetation map of MWR using Ozi Explorer GIS software (Figure 1; see colour plates: page i). As noted above, the poor quality, miombo-dominated western block of MWR (Shaw 1989) was excluded from the study area due to accessibility and time issues. However four test plots (MJ1, MJ2, MJ3, MJ4) were surveyed in the western block, two in each of the two major vegetation types (i.e. high altitude miombo and the medium altitude mixed deciduous woodland) during one field trip. Data collected on these plots were incorporated into data on the same strata from plots in the adjacent study area in order to increase sample size and because approaching the miombo stratum was logistically challenging in the EB. Absolute browse volumes ($m^3$) were estimated following the method by Adcock (2006):

1. Each plot was set up as a 20 m (length) × 20 m (width) × 2 m (height) cuboid space.
2. Specimens of diet species, which were recorded to have been selected by rhino during the tracking phase in the sanctuary, were sought out in the plot.
3. Measurements were made of all specimens found in order to attain the most accurate estimate of total browse volume for each diet species in a plot.
4. For each diet specimen two measurements were recorded using tape measure and measuring rod: canopy cover ($m^2$), which is the area covered by a plant's edible matter, and canopy depth (m), which is the vertical distance between the lowest and highest point of edible material on a plant (canopy above 2 m was excluded).
5. The browse volume ($m^3$) of a specimen was calculated by multiplying these two values. In case of concave or overlapping canopies, Adcock's (2006) advice was followed.
6. The sum total of the individual absolute browse volumes measured for all its specimens yielded the absolute browse volume for a diet species in a plot ($m^3$).
7. The sum total of the individual absolute browse volumes recorded for each diet species within a plot 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 (i.e. availability) in that sample.

## Data analysis

### Diet composition

On every plant with browse marks the SBVs were counted: first the number of bites on a specimen in a feeding site, then the total bites on all specimens of that species per day, and finally total bites on that taxon in the entire study. Important diet species 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. To assess the relative importance of a diet species to black rhino, the number of SBVs recorded on its specimens was divided by the total SBVs counted on all browse taxa; values were multiplied by 100 convert to percentages. The resultant proportional (%) bite scores reflected a species' individual position in the importance ranking order. Based on the relative proportion of bites out of the total, relative importance scores were calculated for all species. Species contributing greatest to overall consumed browse volume (i.e. with the highest feeding rates) were rated as the principal diet species (Oloo et al. 1994; Hall-Martin et al. 1982; Brown and Van der Westhuizen 2005).

### Browse availability

A plot was considered as an 800 $m^3$ rectangular cuboid with square basal area of 400 $m^2$ and pre-defined canopy height of 2 m. To calculate the absolute proportional %BA score for a plant species in a plot, its absolute browse volume ($m^3$) was divided by the total volume of the plot (800 $m^3$). To get the %BA score for a plot, the individual %BA scores of the species forming its entire browse material were added up (or in other words, the absolute total browse volume of the plot was divided by its total volume). To get the %BA score for a vegetation type within a sub-area, the average of the %BA scores of plots established in that type of vegetation was calculated. To get the overall %BA score for a sub-area, the sum of the area-weighted %BA scores for its vegetation types was calculated. To get the overall %BA score for a vegetation type in the entire study area (EB), area-weighted %BA scores for the two sub-areas were summed. To get the overall %BA score for the EB, the total sum of the area-weighted average %BA scores of its six vegetation types (or those of its two sub-areas) was calculated.

## Results

### Diet composition

Overall, 34 individual black rhino trails were pursued along feeding routes during the study. Based on knowledge of an individual's spoor sizes, cohort compositions and observed characteristics of habitat use (e.g. medium-sized adult cow with new-born calf; single large prints leading to a male midden), it was nearly always clear to the team which individual rhino was tracked. When an individual was sighted it could be identified from the ear notches. A total of 1,743 SBVs were recorded comprising 59 diet species (Table 1). Assessed as SBV, the 10 principal diet species represented 62.42% of the plants browsed by black rhino. *Mimosaceae* and *Fabaceae* families represented 5 of the 10 most frequently selected species by rhino. *Dichrostachys cinerea*, *Diplorhynchus condylocarpon* and *Grewia* bicolor dominated the diet (Table 2).

### Browse availability

A total of 43 plant taxa were found in the 17 plots established in the Pende sub-area, while 38 diet species were found in the 15 plots in the Rhino Sanctuary. Among vegetation types, in terms of browse species richness, the riverine and alluvial association scored highest (44 diet species), while the other five types showed less diversity (Table 3). Amongst the vegetation types of the whole study area, the highest average browse availability was found in the riverine and alluvial association, followed by the ridge-top mixed woodland and the low-altitude mixed woodland (Table 4). When considering area-weighted results, the low-altitude mixed woodland had the highest %BA due to its largest area coverage in the EB, followed by the riverine and alluvial association (Table 3). The Rhino Sanctuary sub-area had higher absolute browse availability while, due to its larger size, the Pende sub-area had a higher weighted BA value (Table 4).

Table 1. The browse species list of the 59 taxa eaten by black rhino in Majete Wildlife Reserve. Local vernacular names are given in Chichewa language

| Scientific names | Family | Local vernacular name |
|---|---|---|
| *Acacia burkei* | Mimosaceae | |
| *Acacia karoo* | Mimosaceae | |
| *Acacia nigrescens* | Mimosaceae | Nkunkhu |
| *Acacia nilotica* | Mimosaceae | Chisio or Ngagaga |
| *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 [formerly 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 | Tenza |
| *Grewia flavescens* | Tiliaceae | Tenza |
| *Grewia forbesii* | Tiliaceae | Tenza |
| *Grewia villosa* | Tiliaceae | Tenza |
| *Gymnosporia buxifolia [formerly Maytenus heterophylla]* | Celastraceae | Mkolasato or 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 [formerly 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 lobate* | Malvaceae | |
| *Vangueria randii* | Rubiaceae | |
| *Vitex buchananii* | Lamiaceae | |
| *Xeroderris stuhlmannii* | Fabaceae | Nonde or Mlonde |
| *Ziziphus mucronata* | Rhamnaceae | Kankhande |

Table 2. The 10 principal diet species of black rhino in Majete Wildlife Reserve, Malawi. Contribution to diet was calculated as the proportion (%) of standard bite volumes (SBVs) recorded on browse species relative to total SBVs in the sample plots. Contribution to total available browse biomass was calculated as the proportion (%) of browse volume (m3) of the species relative to total browse volume in the sample plots.

| Plant species | Contribution to diet (%) | Contribution to total browse biomass (%) |
|---|---|---|
| *Dichrostachys cinerea* | 13.54 | 2.88 |
| *Diplorhynchus condylocarpon* | 13.08 | 36.52 |
| *Grewia bicolor* | 5.97 | 1.33 |
| *Karomia tettensis* | 5.91 | 3.47 |
| *Ormocarpum kirkii* | 5.33 | 4.53 |
| *Dalbergia melanoxylon* | 4.93 | 3.10 |
| *Acacia nilotica* | 4.42 | 1.44 |
| *Diospyros zombensis* | 3.73 | 1.40 |
| *Acacia nigrescens* | 2.75 | 8.61 |
| *Grewia flavescens* | 2.75 | 1.05 |

Table 3. Area coverage, black rhino browse species richness and area-weighted %BA scores of the vegetation types in the Eastern Block (EB) of Majete Wildlife Reserve (see Table 4 for details of calculation of %BA scores)

| | Area cover of vegetation type in EB (%) | Black rhino browse species richness (no.) | Area-weighted %BA scores |
|---|---|---|---|
| Riparian thicket | 1.42 | 15 | 0.20 |
| Riverine and alluvial association | 18.18 | 44 | 4.21 |
| Ridge-top mixed woodland | 10.85 | 18 | 1.84 |
| Low-altitude mixed woodland | 48.46 | 34 | 7.35 |
| Medium-altitude mixed woodland | 18.62 | 19 | 0.82 |
| High-altitude miombo woodland | 2.48 | 10 | 0.09 |
| **Total** | **100** | — | **14.5** |

Table 4. Browse availability for black rhino in different vegetation types in the Rhino Sanctuary and Pende sub-areas in the Eastern Block (EB) of the Majete Wildlife Reserve, Malawi. Proportional browse availability (%BA) was calculated as % volume of all browse species as a proportion of total volume of each plot. Area-weighted values were calculated based on % cover of each vegetation type within the sub-areas; total %BA for each sub-area was calculated as the sum of weighted values for each vegetation type. Values for each sub-area in relation to the EB as a whole were calculated based on the % of the EB occupied by each sub-area, and these values were summed to calculated total %BA values for each vegetation type in the EB.

| **RHINO SANCTUARY sub-area** | **Riparian Thicket** | **Riverine and Alluvial Association** | **Ridge-top Mixed Woodland** | **Low Alt. Mixed Woodland** | **Medium Alt. Mixed Woodland** | **High Alt. Miombo Woodland** | **Total** |
|---|---|---|---|---|---|---|---|
| Average %BA scores in the sample plots (±SD) | 14.25 (±6.3) | 19.84 (±7.2) | 14.87 (±5.5) | 18.23 (±6.1) | 5.20 (±0.0) | 0.0 | |
| % area cover in the Sanctuary | 3.6 | 26.9 | 13.7 | 47 | 8.8 | 0 | |
| Weighted %BA based on % area cover in the Sanctuary | 0.513 | 5.337 | 2.037 | 8.568 | 0.458 | 0.00 | 16.91 |
| Weighted %BA based on % area of the Sanctuary in EB (39.4%) | 0.20 | 2.10 | 0.80 | 3.38 | 0.18 | 0.00 | 6.66 |
| **PENDE sub-area** | **Riparian Thicket** | **Riverine and Alluvial Association** | **Ridge-top Mixed Woodland** | **Low Alt. Mixed Woodland** | **Medium Alt. Mixed Woodland** | **High Alt. Miombo Woodland** | **Total** |
| Average %BA scores in sample plots (±SD) | 0.00 | 27.76 (±6.8) | 18.97 (±10.5) | 13.26 (±6.5) | 4.20 (±1.4) | 3.73 (±0.9)[a] | |
| % area cover in Pende | 0 | 12.5 | 9 | 49.4 | 25 | 4.1 | |
| Weighted BA scores based on % area cover in Pende | | 3.47 | 1.71 | 6.55 | 1.05 | 0.15 | 12.93 |
| Weighted BA scores based on % area cover of Pende in EB (60.6%) | 0.00 | 2.10 | 1.04 | 3.97 | 0.64 | 0.09 | 7.84 |
| Total area-weighted %BA scores in the EB | 0.20 | 4.21 | 1.84 | 7.35 | 0.82 | 0.09 | 14.5 |

[a] Extrapolated figure from the test plots in the Western Block of the Reserve

## Discussion

### Diet composition

A total of 59 plant species comprising mainly small trees and woody shrubs were recorded as black rhino diet species in MWR. Results substantiated findings of previous studies describing black rhino as a selective browser choosing a great number of often regenerating food plants from various families including *Capparidaceae, Combretaceae, Euphorbiaceae, Fabaceae, Mimosaceae* or *Tiliaceae* (Mukinya 1977; Oloo et al. 1994).

Principal food items are diet species that are consumed in the largest quantities (Petrides 1975; Kotze and Zacharias 1993). *Mimosaceae, Apocynaceae* and *Fabaceae* species dominated black rhino diet in MWR: 13 species of the total 59 selected and six of the 10 most frequently browsed food items belong to one of these three families. Similarly to Brown and Van der Westhuizen's (2005) findings in North Luangwa National Park, the supreme importance of two deciduous woody species, *Dichrostachys cinerea* (Mimosaceae) and *Diplorhynchus condylocarpon* (Apocynaceae) in black rhino diet was evident (these taxa contributed nearly 27% to rhino diet in this study). The very high representation of *D. condylocarpon* in black rhino diet was accounted for—in addition to its good/moderate palatability—by its wide distribution and greatest overall availability in the study area (its dense matrix covered 5.3% of the entire study area and contributed 36.5% of the total available browse volume; see Table 1). 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 this is due to their small size: they are often tipped over, uprooted and entirely consumed by animals, and it is often difficult to identify characteristic rhino browse marks with certainty 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, appeared as a definite attraction to black rhino (Bhima and Dudley 1996). *Euphorbia* species and other succulents are eaten by black rhino (although *Euphorbia* is poisonous to some other animals) as they provide water during dry months when surface water is unavailable (Goddard 1968; Emslie and Adcock 1994; Bhima and Dudley 1996). Faecal analyses (not carried out in this study) could have complemented the data on consumption of woody plants and revealed possible herb and grass intake by black rhino in MWR (Buk and Knight 2010).

### Browse availability

Browse availability is one primary factor determining black rhino carrying capacity of a habitat (Adcock 2006). When considered together with browse palatability, browse availability 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 and Adcock 1994). Food scarcity and resource limitations (e.g. of surface water) are primary constraints for large mammal survival and reproduction (Hall-Martin et al. 1982; Shaw 2011).

A stratified survey of an area is usually the only practical means of sampling all the vegetation available to rhino (Adcock 2006). The results outlined in this paper corroborate the importance of browse information based on vegetation types (Brown et al. 2003). This study affirms Emslie and Adcock's (1994) findings that the riverine and alluvial association holds not only the largest diversity of diet species (i.e. 44 taxa, 74.6% of all browse taxa identified selected) in the MWR but also the highest average browse availability (calculated as %BA) in the study area. Low-altitude mixed woodland and high-altitutude miombo woodland had the highest and lowest area-weighted %BA scores, respectively (Table 4). The EB had higher proportional browse availability than the Western Block with the Sanctuary sub-area possessing a slightly higher %BA score than its Pende sub-area. However, taking account of its larger contribution to the total area of the EB, the Pende sub-area scored higher in terms of overall weighted browse biomass than the Sanctuary. Due to its having notable stretches of rich riverine/alluvial matrix (i.e. alluvium associated with the highest species richness and density figures), the Pende sub-area's %BA score could have been even 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 (1.05%). The poor miombo scrub showed the lowest species richness and contributed least to browse availability. The overall average browse availability

(%BA = 14.5%) of the EB of MWR is similar to that of Pilanesberg National Park of South Africa (range 10–15%), about five 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 25–30%) (Adcock 2006). If the entire MWR is taken into consideration, proportional browse availability would be close to the average for the Southern African region, due to the preponderance of low quality miombo woodland in the western half of the reserve.

## Conclusions

Understanding a browser's diet selection is fundamental for determining the suitability of different habitat and vegetation types and their capacity to support the population of an endangered species because diet is vital for survival and influences physiological processes that trigger population changes (Shaw 2011). Black rhino browse availability studies are therefore central in order to calculate potential rhino stocking rates and actual introduction numbers for new areas (Adcock 2006). Pragmatic, evidence-based research can elucidate a diverse set of habitat attributes that determine the capacity of potentially suitable rhino areas.

This study produced baseline information on black rhino diet, habitats, and forage capacity that will provide inputs for resource management in MWR. With field work conducted in the transitional period between the late hot–wet and early cool–dry seasons, a good average picture of prevailing resource use patterns and browse conditions was obtained. The results show that the EB of MWR possesses above average black rhino browse availability if compared with other rhino reserves due to the fact that 77.5% of its area covered by highly conducive habitat types, e.g. riverine and alluvial association (18.18%), ridge-top mixed woodland (10.85%) and low-altitude mixed woodland (48.5%). These results confirm that the Reserve's eastern half provides habitat capable of sustaining an expanding black rhino population in Malawi.

It is recommended that future research consider establishing a minimum of 20–25 study sites per vegetation type in order to better capture the range of variability in browse species composition and abundance within each stratum and thus enable increased precision and representativeness in the estimates of browse availability (Sutherland 2006; Adcock, pers. comm.). Future studies should assess broader cross-seasonal black rhino browse utilisation and focus on the temporal and spatial availability of critical late dry season browse resource availability, and on variations in palatability and habitat, in order to shed light on the carrying capacity of the reserve. Study of the apparently suitable, though isolated riverine habitats of the Western block of the Reserve is also recommended. Black rhino browsing is affected by many factors; of these, plant physiology (e.g. changing leaf area, increased spinescence or internode distance) and chemical composition in particular require further investigation (Shaw 2011). Given that the availability of preferred browse biomass and the size of suitable habitat patches have a profound influence on the nutritional status of resident herbivores, there is clearly tremendous scope for detailed vegetation studies to contribute to rhino conservation strategies in MWR (Sherry 1989; Hall-Martin pers. comm. 2011).

Our results suggest that forthcoming reintroductions in the EB of MWR should release animals at sites near the riverine and alluvium areas in the Pende, an area possessing both great absolute density of black rhino browse biomass and sufficient permanent watering points. As demographic responses of black rhino to nutritional restrictions include delayed age of first calving and longer interbirth intervals in adult females, black rhino cows in Majete should be maintained at a density which does not impose limitations affecting their reproductive success, thereby providing conditions for maximum population growth rates in the long term (Shaw 2011).

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