Key resource areas and management of buffalo (*Syncerus caffer caffer*) on Molemane Eye Nature Reserve

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A research report submitted to the Faculty of Science, University of the Witwatersrand, in partial fulfillment of the requirements for the degree of Master of Science (Environmental Sciences)

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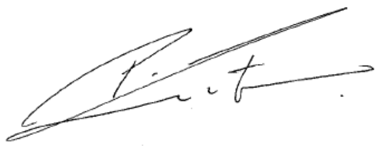
Declaration

I declare that this thesis is my own, unaided work. It is being submitted for the Degree of Master of Science in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.



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ABASTRACT

In 2004 Molemane Eye Nature Reserve was stocked with 46 disease-free buffalo with the intention of generating sustainable revenues for the Reserve. However, the buffalo's poor population growth rate and poor body condition during the dry seasons led to management reducing the buffalo population to 21 animals in 2010. The buffalo's poor performance has drawn the attention to the potential nutritional limitations of the forage available during the dry season and to the importance of key resource areas. I examined the nutritional content of the buffalo forage using faecal analyses as proxy for nitrogen (N) and phosphorus (P), expecting a nutritional stress towards the latter part of the dry season. Data from the GPS/GSM collar on one of the buffalo cows was used to determine the dry season vegetation type selection and to identify key resource areas. A comparison of veld conditions was also done on the lowland vegetation types on Molemane Eye Nature Reserve and an adjacent property (Eye Area), which was earmarked for incorporation, to determine whether veld restoration work was required prior incorporation. It was established that the extended period of poor forage quality during the 2010 dry season was an important limiting factor for the buffalo as the forage quality dropped below the buffalo minimum nutritional requirements (N_f < 1.52 %, P_f < 2 %). A faecal sampling during early 2011 indicated that the nutritional stress period may last as long as 5 months (April to August). The buffalo did not select the vegetation types in proportional to their availability and narrowed their selection as the dry season progressed, preferring those containing woody elements. Of the 8 vegetation types indentified as key resource areas for buffalo during the dry season, the Eye Area holds 4 and contributes less than 5% to the key resource area already available on Molemane Eye Nature Reserve. The overall veld condition of the two areas was similar and no veld restoration work was deemed necessary. Although the incorporation of the Eye Area will shorten the distance between water and forage areas and have some nutritional benefits for buffalo in the dry season, mineral

supplementation will be necessary for these valuable animals to become more productive and contribute to the economic objectives of Molemane Eye Nature Reserve.

AIM

The aim of this study was to investigate the importance of incorporating additional lowlands into the Molemane Eye Nature Reserve to sustain the buffalo during the critical dry season.

OBJECTIVES

1. To determine the vegetation types selected by buffalo during the dry season and early wet season with special emphasis on potential key resource areas.
2. To quantify the nutritional status of the buffalo during the dry season by using faecal indices.
3. To compare the vegetation of two adjacent lowland areas (one inside the reserve and the other outside the reserve) in relation to veld condition, species richness and preferred forage species for buffalo.

GENERAL INTRODUCTION

The need for the study

Molemane Eye Nature Reserve (MENR) is the latest addition to North West Parks & Tourism Board's protected areas. In 2004 this former cattle farm was stocked with wildlife including 47 buffalo (*Syncerus caffer*). The broad herbivore management objectives on MENR are to contribute to biodiversity conservation and to generate revenues through game sales and tourism. The buffalo contribute to the functioning of the MENR ecosystem by opening up tall grassland for the short grass feeders including Burchell's zebra (*Equis burchelii*), black wildebeest (*Connochaetes gnou*) and blesbok (*Damaliscus pygargus*). The economic value of the buffalo is derived primarily from their 'disease-free' status (free of foot-and-mouth disease, corridor disease and brucellosis) and their allure to tourists as one of the 'Big Five' animals.

During the late dry season of 2008 serious concerns were raised about the buffalo's poor body condition and the overall suitability of MENR to sustain buffalo. Areas with high population numbers and abundant water during the dry season can result in overgrazing and subsequent high game mortalities (Owen-Smith 2002; Gaylard *et al.* 2003). For fear of losing this valuable buffalo population to malnutrition, park management considered various interventions including, amongst other, (1) the total removal of the buffalo, (2) a reduced buffalo stocking rate (3) a reduced stocking rate for competing herbivores and (4) supplementary feeding. The decision was taken to reduce the buffalo population and to commission a buffalo research project. The buffalo population was steadily reduced from 59 animals in 2008 (Knoop *et al*. 2008) to 40 animals in 2009 (Knoop *et al*. 2009) and finally to 21 animals in 2010 (Seithlamo *et al*. 2010).

Even with the reduced buffalo stocking rate, the body condition of the buffalo remained a concern during the dry seasons of 2009 and 2010 (*Pers. obs.*). The body condition scores, following Prins (1996), ranged from 'Poor' to 'Very Poor'. An investigation into the buffalo population growth rate also revealed that the buffalo were not recruiting at the expected 12% level as initially forecasted by Newbery and van Heerden (2002). Instead, the buffalo population declined by 30% between the 2008 and 2009 game counts which could not be fully explained by the buffalo removals and mortalities recorded over the same period. No game counts were conducted during 2006 and 2007 but the game count of September 2005 (Seithlamo 2005) showed a zero percent growth rate over a period of a year since their introduction. The growth rate was expected to be positive as ten buffalo were confirmed pregnant at the time of the introductions. A low buffalo population growth rate impacts directly on the economic objective of MENR and provided a strong motivation for this study to be conducted.

Buffalo are well adapted to survive in a wide number of vegetation types, at high and low altitudes, in areas experiencing frost at night, areas with high humidity and at high ambient temperatures (Sinclair 1977; Skinner *et.al* 1990). Buffalo herds tend to have seasonal movements to occupy different habitats at different times of the year for optimal food and water intake (Sinclair 1977; Scoones 1995). Many conservation areas today are just fragments of the historic buffalo range eliminating the buffalo's ability to exploit the spatio-temporal distribution of forage especially during the critical dry season. The confinement of large herbivores, especially at high densities, may lead to vegetation overutilization, an altered vegetation composition and structure (Owen-Smith and Danckwerts 1997) and ultimately to high herbivore mortalities (Owen-Smith 2002). The under-nutrition of the buffalo is important as it affects the buffalo calving interval (Prins1996) and buffalo survival rates (Sinclair 1977).

MENR falls marginally outside the historical buffalo distribution range (Du Plessis, Fig. 1). The sour-mixed grassveld of MENR (Newbery and van Heerden 2002), is mostly unpalatable and contains little nutritional value for 4-6 months (Tainton 1999). The low nutrition in the sour-mixed grassland may be a reason for buffalo not having been recorded in this area (Du Plessis 1969). Buffalo confined to a sour-mixed grassveld can experience a sudden population crash during a drought year unless stocking rates are calculated conservatively (Winterbach 1999). The study by Winterbach (1999) was conducted on Willem Pretorius Game Reserve, in the Free State, where 53 buffalo died by the end of the cold dry season in September 1992 as a result of starvation.

Understanding the adaptive response of animals to the seasonal changes in the environment can help address management questions. Areas selected by herbivores during the late dry season can be regarded as key resource areas used to bridge this critical period when forage quality deteriorates elsewhere (Scoones 1995). Although forage supplementation, fire and rotation of waterholes are ways to improve animal performance while minimizing veld damage (Bothma 1989; Tainton 1999), it remains important to expand small reserves to reduce edge effect and improve overall ecosystem functioning (Didham 2010). Land acquisitions are generally expensive and prior knowledge of herbivore key resource areas will assist in park expansion planning.

The majority of studies indicate that buffalo select the lower catenas in the landscape during the dry season (Leuthold 1972, Sinclair 1977; Funston *et al.*1994). These studies were conducted mainly on much larger and more fertile systems with predators and seasonal water limitations. From the numerous studies on buffalo habitat selection in the dry season I found only one study (Winterbach 1999) to have similar conditions to those on MENR. Both reserves are predator–free, rich in water, have a sour-mixed grassveld and are located outside the historical distribution of buffalo (Du Plessis 1969). Even so, MENR is only approximately 4800 ha whereas the area where the buffalo roam on Willem Pretorius Game Reserve is approximately 8682 ha (Winterbach 1999) and located in a different Dry Highveld Grassland Bioregion unit, namely, the Carletonville Dolomite Grassland as opposed to the Winburg Grassy Shrubland (Mucina and Rutherford 2006). On a small reserve, such as MENR, it is particularly important to understand the buffalo selection of vegetation types during the dry season for planning future property expansion. The possibility exists for the incorporation of an adjacent property (henceforth called the Eye Area) which could potentially add to the key resource area for buffalo.

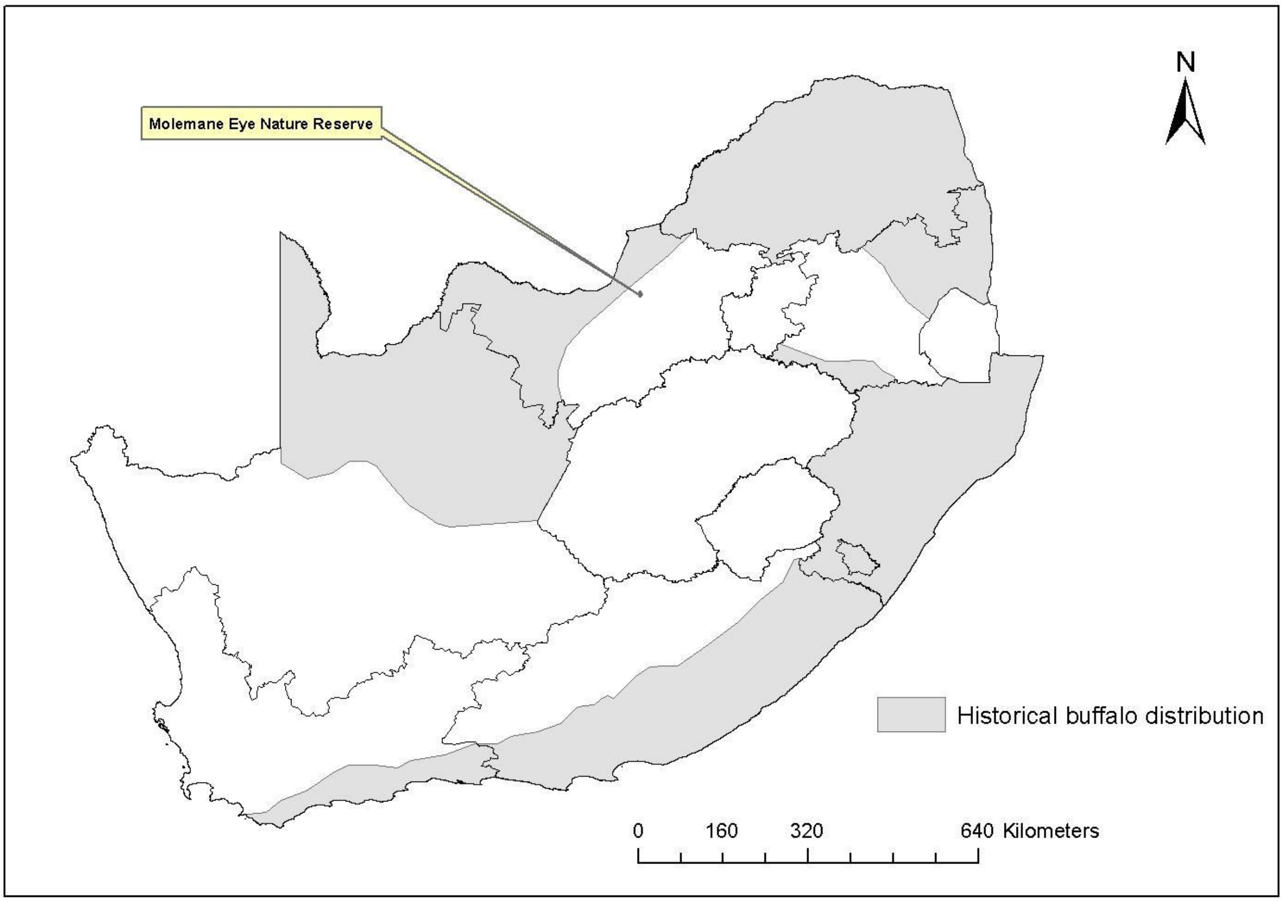

Figure 1 The location of MENR in relation to the historical distribution of buffalo in South Africa. The map was adapted from Du Plessis (1969).

Buffalo space use during the dry season

Large herbivores are influenced by spatial heterogeneity in their environments at scales ranging from feeding patch to biome (du Toit 2003). Habitat use behavior can be influenced by food distribution, proximity of water, competition, risk of predation and shelter from weather extremes (Sinclair 1977; Owen-Smith 2002). Animals have a tendency to disperse in search of more favourable environments as habitat conditions deteriorate. Cattle in the savanna of Zimbabwe for example demonstrated an adaptive response to the change in forage quality across seasons by selecting different parts of the landscape (Scoones 1995). Owen-Smith (1983) stressed the importance of dispersal in larger long lived herbivores to prevent the overutilization of vegetation, especially where predation is absent.

Buffalo are gregarious large herbivores that show a preference for midslopes and lowlands in the dry season (Prins 1996; Winterbach 1999; Bowers 2006; Macandza 2009). Funston *et al*. (1994) suggested a number of reasons for this, including lower predation risk (due to improved visibility after leaf drop), the availability of high biomass of favoured forage species and the presence of water. Buffalo are highly water dependant (Skinner and Smithers 1990) and the proximity of water helped to explain the buffalo moving to the lowlands in the Kruger National Park (Bowers 2006; Macandza 2009). In earlier studies Sinclair (1977) and Leuthold (1972) pointed to the drying out of grass, making them less palatable, as the main driver for the migration to moister areas containing denser patches of grass, whereas the availability of water seemed to be of lesser importance. Prins (1996) reported the importance of the floodplains in providing green forage during the dry season in the Manyara, Tanzania. The evergreen perennial sedge *Cyperus laevigatus* growing in these flood plains has a low protein content but provided enough bulk for the buffalo intake needs. Similarly, Scoones (1995) found that cattle selected the lower lying areas in the landscape which maintained a higher herbaceous green biomass and browse than the highlands. The attraction to the lowland may also be influenced by higher protein levels of the grasses growing in the lowland soils. In a study in Zululand (Downing 1972 cited in Owen-Smith 1982), the crude protein levels of *Themeda trianda, Panicum maximum and Panicum deustrum* were 55 to 70% higher in illuvial lowlands compared to the same species collected on eluviated hillcrest soils. Clay soils, usually found in lowlands, also have a good soil moisture retention capacity which enable grasses to retain their greenness (Macandza 2009). O’Reagain and Owen-Smith (1996) conducted research in sourveld and found grass sward greenness to be the best determinant of dietary quality. Macandza *et al*. (2004) found that the buffalo did not visit the lowlands as frequently in the granite landscapes of the KNP due to heavy grazing on the sodic soils from other animals which kept the grass too short for these bulk grazers. This highlights the influence of inter-specific competition and the adaptive response of buffalo to find alternative forage areas.

Valley bottoms have a greater accumulation of heavy clay soils and are vegetated by deeper rooted plant species (Morison *et al*. 1984). Owen–Smith (1998) suggested that the browse resource provided by the evergreen trees, often associated with lowlands and seasonal streams, may be important to buffalo during the dry season. Prins (1996) observed buffalo in Tanzania browsing on a variety of herbs and shrubs depending on the area and availability of grazing. However, Leuthold (1972) and Sinclair (1977) showed that the general contributions of dicotyledons to the buffalo diet seldom exceeded 5-6 %.

Dry season fires stimulate grass growth at a time when most grasses have dried out and are senescent. The attraction of new grass shoots influences the movement of general large herbivore across MENR (*Pers. obser.*). Sinclair (1977) found that the short grass in the 'greenflush' seldom attracted buffalo herds, instead, fires caused buffalo to move down the catena to lowland habitats more rapidly in the dry season. Skinner *et al.* (1990) allude to buffalo being attracted to fresh grass shoots on burnt areas but that they are less partial to it than most herbivores. This may be linked to the small bite size and consequent reduced food intake rate offered by the re-sprouting grasses (Owen–Smith 2002).

Diet quality

Crude protein is regarded by Sinclair (1977) as the most critical limiting food quality parameter for buffalo. Under-nutrition is directly associated to higher mortality rates (Sinclair 1977) and lower fecundity rates (Prins1996) in buffalo. The quality of the forage consumed by herbivores varies with the seasons (Owen-Smith 1982; Grant *et al.* 2000) and across large-scale landscapes (Grant *et al.* 2000). Plant crude protein levels are usually at their highest during the growing season and at their lowest in the cold dry season (Owen-Smith 1982). In summarizing various studies done across six African countries, Owen-Smith (1982) calculated the average crude protein content of unspecified grass species to peak in the early growing season at 12% of dry mass and steadily decline to 5% in the late dormant season. Forbs and woody species generally had a higher crude protein content than grasses and were able retain their crude protein levels better than grasses during the dry season. The average crude protein of forbs dropped from 17% to 12% and that of woody species from 18% to 12% over the same seasons. Green leaves are highly favoured by buffalo not only for their high crude proteins levels but also for their supply of minerals, vitamins and photosynthetic enzymes (Field 1976).

Animals lose crude protein in their feaces in the form of undigested food particles, intestine lining, micro-organisms and enzymes (Orskov 1982). Crude protein in faeces is calculated from the faecal nitrogen (N_f) content (Dőrgeloh *et al.*1998). Forage must therefore contain crude protein levels above the N_f level to provide for the herbivore metabolic requirements (Owen–Smith 1982). Faecal indices for N and P are useful proxies to determine the nutritional status of the veld (Grant *et al.* 1995; Leslie *et al.*2008) and to relate it to the minimum nutritional requirements of grazers. Grant *et al*. (1995) were able to correlate the body condition of buffalo in the Kruger National Park with N_f and found that the buffalo body condition declined quickly when the N_f level dropped below 1.15%. Prins (1996) determined the minimum crude protein requirement in a balanced diet to be 7% (N_f 1.33%). Prins and Beekmann (1987) set the forage crude protein content requirement for non-lactating cows at 9 % (N_f 1.75 %) and for lactating cows at 11.4 % (N_f 1.52 %). Crude protein levels are important as they also determine the digestibility of food and therefore the rate at which food is passed through the ruminant’s gut (Prins and Beekman 1989). As crude protein levels drop during the dry season, digestion is slowed and buffalo are not able to compensate by merely increasing forage intake.

N_f analyses is best used for studies monitoring dietary quality in grazers as grasses contain very little or no soluble digestion inhibitors (Irwin *et al*. 1993). This may however not be the case in sour-grassveld as many grasses contain carbon-based tannin-like substances that bind proteins and makes proteins less digestible (Tainton 1999). Digestion inhibitors, such as tannins and alkoloids, raise N_f levels (Howery and Pfister 1990) by varying degrees (Leslie and Starkey 1987), which adversely affect N_f and dietary crude protein correlations. Studies on juvenile impala (Wrench *et al.* 1996), cattle calves (Grant 1989) and juvenile elk (Cook *et al*.1994) have shown that faecal samples from unweaned animals should be avoided due to the high N_f concentrations that cannot be directly related to food intake. Older animals, irrespective of sex, showed no significant difference.

P is the most limiting mineral in South Africa (Du Toit *et al.* 1940) and deficiencies of P limits growth and fertility in large mammals (Wrench *et al*. 1997). Feacal phosphorus (P_f) concentration can also be used to determine dietary phosphorous (Wrench *et al.* 1997). There is however a complicated relationship between the P and N budgets which must be taken into account when assessing the nutritional status of herbivores (Ryan *et al.* 2004). Grant *et al*. (1996) found that phosphorus supplementation increased average daily weight gain of cattle only when N concentrations were above 1.2%. P absorption was also depressed at simultaneously low P and dietary crude protein intakes (Bortolussi *et al.* 1996). Cattle lost weight and had a low conception level when P_f dropped below 2,2 g P/kg OM (Grant 1989). Importantly, during drought conditions, N_f increased when P_f dropped below 2,2 g P/kg OM. This phenomena amplified when P_f dropped below 2 g P/kg OM (Grant *et al.* 1995). African ungulates generally store very little body fat and catabolize muscle tissue under periods of nutritional stress (Hungate 1975) thereby resulting in higher N_f excretions. Wrench *et al.* (1997) propose $P_f < 2$ g P/kg OM to indicates a dietary deficiency in grazers. Grant (1989) also found a significant correlation between Calcium (Ca) and P. When the faecal Ca: P ratio $\geq$ 8:1, both minerals were excreted at higher levels and an adjustment to the critical dietary P levels was proposed to provide for the higher P losses.

Veld condition

Veld management is the management of vegetation for specific objectives related to different forms of land use (Bothma 1989; Trollope 1990). Veld condition assessment must therefore consider the functional characteristics of the veld type being managed to achieve the objectives for a particular land use (Trollope and Trollope 1990). Normally, the veld type characteristics relate to maximum forage production and resistance to soil erosion (Tainton 1999). Vegetation is a sensitive indicator for ecosystem change and is commonly used for veld condition assessment as opposed to soil. Grass species are sensitive to specific abiotic (e.g. rainfall and soil) or biotic (e.g. grazing and fire) conditions and can therefore be used as indicators (Tainton 1999). Veld condition assessments are useful in comparing plant communities and provide a means to quantify spatial and temporal changes within particular plant communities or vegetation types (Tainton 1999).

Veld condition assessment methodologies have been criticized for not separating the effects of spatial and temporal environmental variability from the effects of management (Friedel 1991). Friedel (1991) argues that veld condition deterioration or improvement are not necessarily linear with the level of grazing taking place. Restoration efforts may therefore require more than just adjustments of stocking rates and involve interventions such as ploughing, fertilization and erosion control. The agricultural influence of the stable state concept revolving around matters such as carrying capacity and species composition has strongly influenced conservation thinking in the past (Rogers 2003). Veld condition from a conservationists perspective would need to take into account the concept of heterogeneity in ecological systems brought about by the interaction of biotic and abiotic components functioning at different space and time scales (Picket *et al.* 2001). The use of thresholds of potential concern (TPC) and adaptive management (Rogers 2003) allows flux between upper and lower limits of change and presents a practical means of monitoring veld condition.

Buffalo forage

Buffalo are predominantly unselective bulk grazers but are also known to occasionally browse from trees, shrubs, herbs, and sedges (Sinclair 1977; Prins 1996). During the late dry season, forage becomes depleted and herbivores may die of starvation (Prins and Beekman 1989). On small reserves buffalo are unable to migrate to more favourable forage areas and must therefore adopt a foraging strategy to include more grass and browse species (Prins and Beekman 1989). None of the woody species known to be eaten by buffalo in the KNP (Pienaar 1969; Bowers 2006) and in East Africa (Sinclair 1977; Prins 1996) are listed in the MENR species list (Seitlhamo *et al*. 2010) and therefore makes it difficult to compare the areas. However, a number of grasses and monocotyledonous species identified as food items for the buffalo in KNP (Pienaar 1969) also occur on the grass species list for the MENR (Seitlhamo *et.al* 2010). These are: *Brachiaria nigropedata, Eragrostis superba, Heteropogon contortus, P.maximum, T.triandra, Phragmitis spp., Cyperaceae spp.* and *Typha capensis.* Other grass species, known to occur on MENR and recorded as forage species for buffalo in the Kruger National Park (Macandza *et al*. 2004) included *Digitaria eriantha, Bothriochloa insculpta, Cenchrus ciliaris* and *Panicum coloratum.* There is a possibility that *C.ciliaris* and *P.coloratum,* which were also recorded as buffalo forage species in the Kruger National Park (Macandza *et al*. 2004), may also occur on MENR (Oudtshoorn 2009). Bowes (2006) noted that the buffalo in KNP had a preference for grazing patches dominated by *P.maximum, Urochloa mosambicensis, D. eriantha, T. triandra, H. contortus* and *P.coloratum.* Prins (1996) noted that the buffalo in the Manyara National Park, Tanzania, also consumed *Tragus berteronianus, Cynodon dactylon, Eragrostis superba and Enneapogon cenchroides,* all of which also occur on MENR. Sinclair (1977) makes reference to unspecified *Eragrostis spp*. as forage species for buffalo in Tarangire and Tsavo in East Africa. Six *Eragrostis spp*. have been logged for the MENR (Seitlhamo *et al.* 2010). An earlier study by Leuthold (1972) recorded an unspecified *Dactyloctenium sp*. as one of the top 10 grass species taken by buffalo in the Tsavo National Park. Although not recorded for MENR (Seitlhamo *et.al* 2010), *Dactyloctenium aegyptium* and *Dactyloctenium giganteum* may occur on MENR (van Oudtshoorn 2009). Grimsdell (1973) and Sinclair (1977) recorded *Eustachys paspaloides* as a less favoured forage species for buffalo and *Imperata cylindrica* as untouched. *I. cylindrica* , common in the wetlands of this study area, was readily taken by cattle in the Eye Area (*Pers. obs*.) but this may have been influenced by winter supplementation provided by the farmer to help extend the useful grazing period in sourveld (Tainton 1999). The young shoots from *Phragmitis australis* and mixed sedges are also consumed by cattle on the wetland adjacent to the MENR (*Pers. obs*.) Buffalo are known to forage on less palatable species under special circumstances. Macandza *et al.*(2004) observed buffalo eating the less palatable *Bothriochloa spp*. during the dry season as the availability of more favoured forage species declined and in the Rwenzori National Park in Uganda buffalo ate the re-growth of *Cymbopogon spp.* and *Bothriochloa spp.* after fires (Field 1976).

HYPOTHESES

<u>Hypothesis relating to objective</u> 1:

1. The buffalo select the vegetation types in the lowland area during the dry season.

<u>Hypothesis relating to objective 2:</u>

2. The buffalo experience a critical nutrient deficiency in terms of nitrogen and phosphorus, in the latter part of the dry season, September until October.

<u>Hypothesis relating to objective 3:</u>

3.1 The veld condition is better in MENR than in the Eye Area because of overgrazing by cattle in the Eye Area.

3.2 MENR has a larger number of forage items for buffalo than the adjacent Eye Area containing the same vegetation types.

MATERIALS AND METHODS

Study area

The study took place on MENR (25 43’ S, 27 11’ E; Fig. 2) which is located along the Lichtenburg Ottoshoop road in the North West Province of South Africa. The Reserve (4979 hectares) comprises the farms Kareebosch, Naauwpoort and Oog van Malmanie, some of which cross main roads in the area. The buffalo roam on the approximately 4800 hectare portion of the Nature Reserve which is adjacent to the 57 hectare Eye Area. As mentioned before, the Eye Area is fenced out of the MENR. Cattle from the neighbouring farm grazed the Eye Area heavily particularly from 2006 onward. The fence was repaired in September 2010 to exclude the cattle from the Eye Area to assist in the identification of the grasses for the veld condition assessment. Water is freely available from two artificial watering holes and from a perennial stream passing through MENR.

Mucina and Rutherford (2006) classified the vegetation as the Carltonville Dolomite Grassland, within a subdivision of the Grassland Biome known as the Dry Highveld Grassland. On a finer scale, Nel and Seithlamo (2010) divided the MENR vegetation into 14 vegetation types (Fig. 3). The undulating landscape is predominantly open with scattered clumps of shrubs and trees and dense bushveld along the drainage lines. The veld is regarded as a sour-mixed grassveld (Newbery and van Heerden 2002).

The underlying geology consists mainly of dolomite and chert of the Malmani Subgroup (Transvaal Supergroup) with shallow Mispah and Glenrosa soil forms interspersed by occasional deeper red to yellow apedal soils of the Hutton and Clovelly forms (Mucina and Rutherford 2006).

The altitude ranges from 1474 meters above mean sea level in the low-lying north eastern part to 1540 meters in the eastern section of MENR. In the lowland area a cluster of springs give rise to a perennial stream populated with dense *P.australis* reed stands and occasional pools of open water. The terrain to the east of the stream rises gently up a stony catena. A prominent feature along the catena is a canal diverting some of the spring water to artificial lakes outside the study area. The canal is lined with large trees, dominated by *Rhus lancea*, forming a distinct green belt between the lowland flats and the higher lying grasslands.

MENR is stocked with a range of herbivores species, as recorded during the 2009 game count (Knoop *et al.* 2009), including: buffalo *Syncerus caffer* (40), zebra *Equus burchelii* (97), kudu *Tragelapus strepsiceros* (18), black wildebeest *Connnochaetes gnou* (117), red hartebeest *Alcephalus buselaphus* (100), blesbok *Damaliscus dorcas* (170), springbok *Antidorcas marsupialis* (36), warthog *Phacochoerus aethiopicus* (14), common duiker *Sylvicapra grimmia* (13) and steenbok *Raphicerus campestris* (8). During the dry season, park management apply a burning program which attracts herbivores to the 'greenflush' (*Pers. obser.*)

The climate is mild, with cool to cold winter days and cold winter nights (lowest minimum of - 5°C) and warm to hot summer days with highest maximum of 35°C (Boonzaier 2003). The mean daily maximum temperature for December is 28.5°C and the mean daily minimum temperature for July is 1.3°C (SA Weather Services 2010). The property falls within the summer rainfall area. The Lichtenburg weather station 30 km away has a 72 year mean annual rainfall of 614 mm (SA Weather Services 2010). The lowest rainfall occurs during winter (June, July, August, September and October). Most of the rain (77%) falls from November to March, thus defining a wet and a dry season. Mean Frost Days (days when screen temperature falls below 0°C) for the Dry Highveld Grassland is 37 days a year (Mucina and Rutherford 2006).

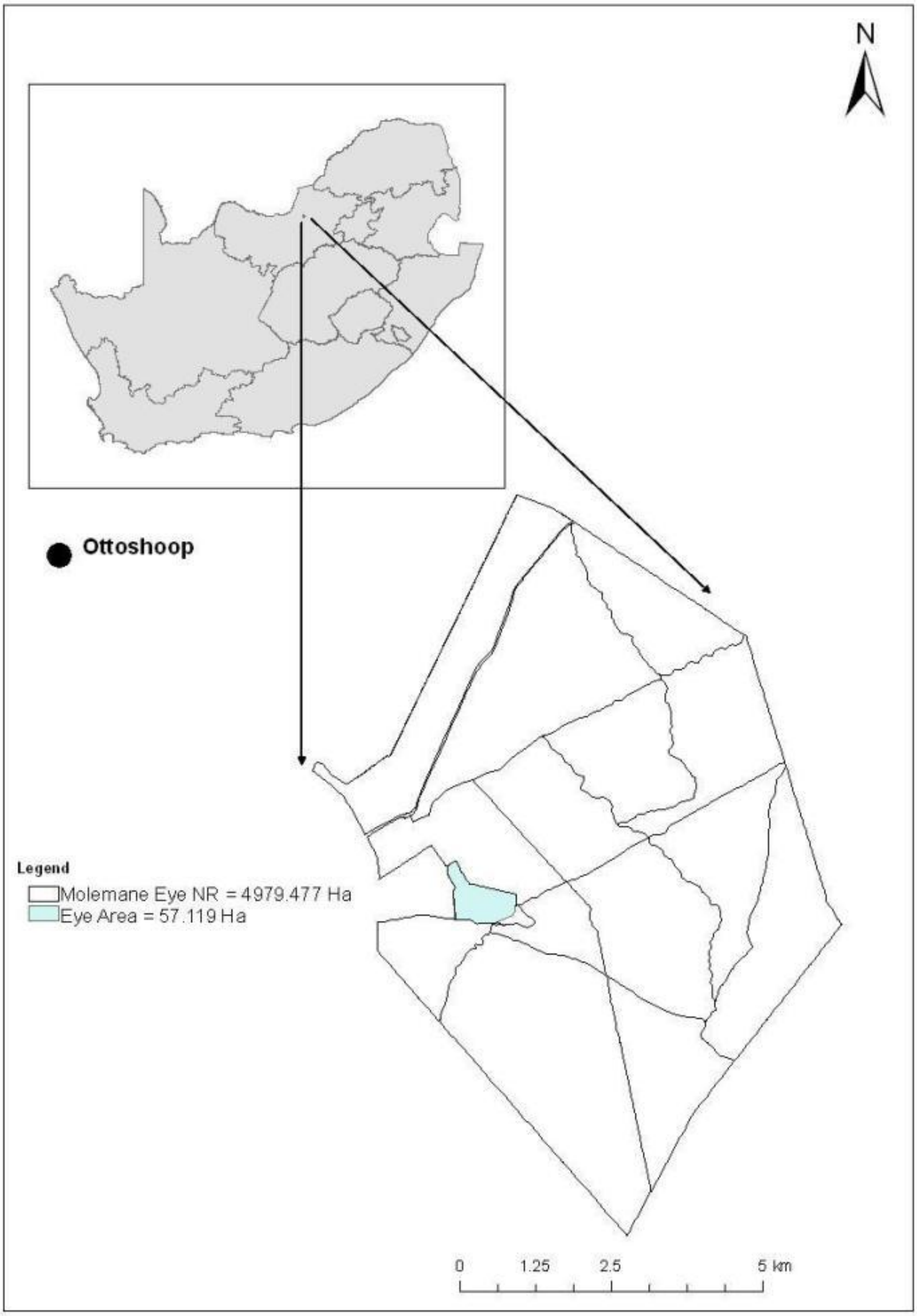

Figure 2 The study area: Molemane Eye Nature Reserve, North-West Province, South Africa.

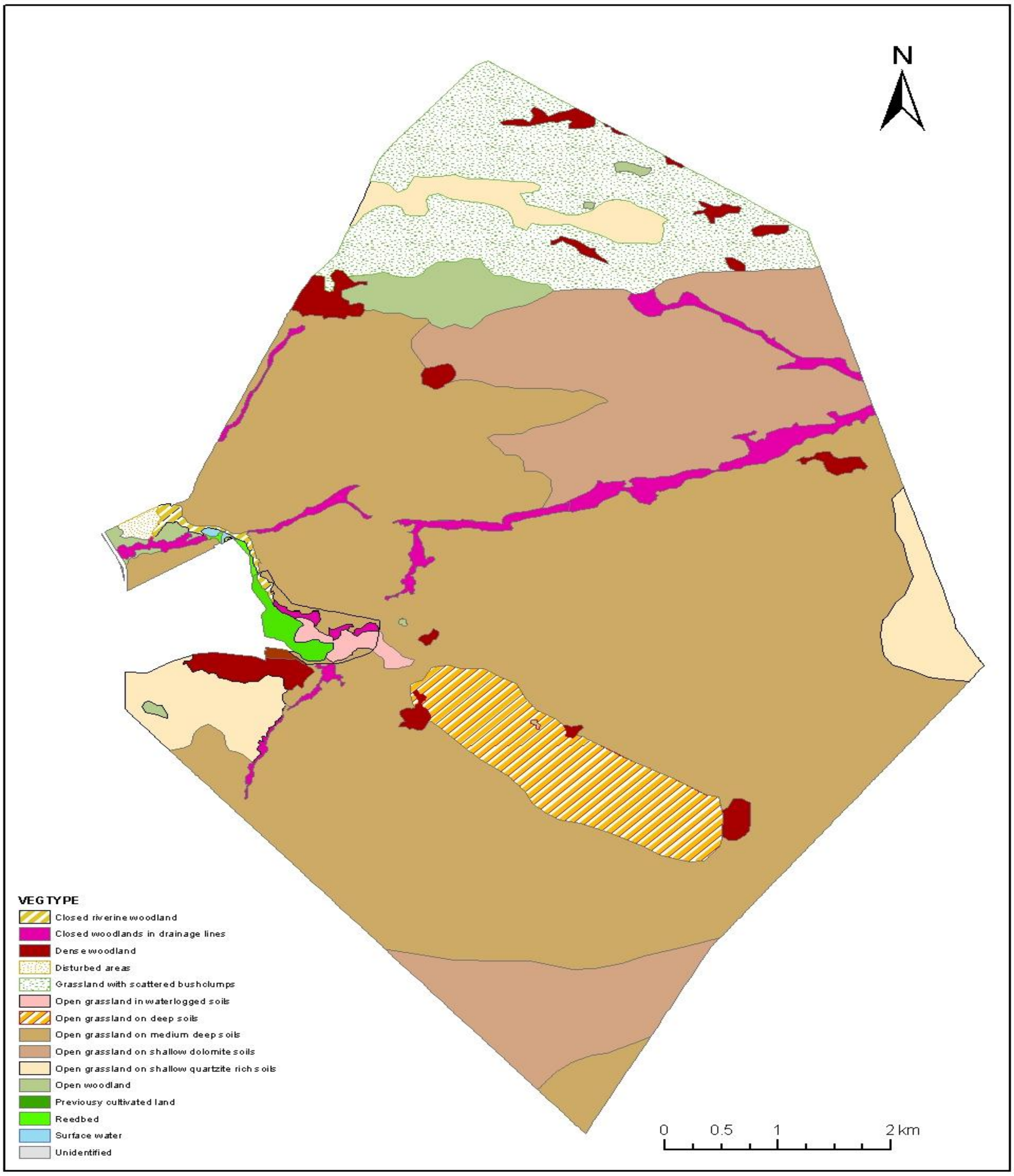

Figure 3 Vegetation map of Molemane Eye Nature Reserve. Adapted from Nel and Seitlhamo 2010.

Data collection

Buffalo locations

At the time of this study 21 buffalo remained on MENR after the planned buffalo removals. Apart from a few bulls that roamed on their own or in small groups, the buffalo cows along with their offspring and a few adult bulls formed a single herd. One of the young adult buffalo cows had been fitted with a Global System for Mobile Communications (GSM) collar (Africa Wildlife Tracking, http://www.awt.co.za) that allowed for GPS locations recording. Cows have strong social bonding with the herd (Sinclair 1977) and the tracking data of the collared animal therefore represents the movements of the breeding herd. Ground monitoring was also used to observe the cohesiveness of the herd. The frequency and schedule of data readings were set remotely by Africa Wildlife Tracking. The frequency of GPS readings was set to one - hourly intervals for the duration of the study. The data captured by the GPS were transmitted via the cellular network to a secured data base accessible via the internet. I collected data from the 01 July 2010 to the end of 30 November 2010 incorporating the last four months of the dry season and first month of the wet season. The buffalo locations were used to determine the selection of vegetation types on MENR over the course of the study period. The lowland vegetation types I refer to in this study are *Reedbeds, Open grassland in waterlogged soils, Closed riverine woodland* and *Closed woodland in drainage lines.*

The study did not interfere with the normal burning program on MENR and three blocks were burnt over three consecutive days (29 June 2010 to 01 July 2010). The impact of fire on the buffalo movement was not the main focus in this study but some basic observations were made.

Grazing pressure

To further assist in identifying key resource areas for buffalo, I measured the level of grass depletion in the four vegetation types that appeared to be most frequented by the buffalo based on personal observations, *Closed riverine woodland, Closed woodland in drainage line, Open woodland* and *Dense woodland.* In addition, I included *Open grassland in waterlogged soils* (Figure 3) for its important area contribution to the Eye Area (Figure 3) and moist soil conditions throughout winter. Moist soil conditions were expected to keep grass greener and more nutritious throughout the dry season and therefore attract herbivores. *Reedbeds* were left out of this survey as they formed impenetrable dense stands of predominantly old material which was last burnt in 2005. The waterlogged conditions also made the reedbeds inaccessible for transect work. I did however note that the reed shoots along the outside edge of the reed stands were cropped by cattle in the Eye Area and presumably by buffalo in MENR.

I placed transects in a stratified random fashion in each of the above vegetation types at the end of November 2010. Along each transect, I placed 100 x 1m^2 quadrats 10 meters apart and surveyed for grazing pressure using the eight point scale (Walker 1976). Quadrats were classed as either 0%, 1 – 10%, 11-25%, 26-50%, 51-75%, 76-90%, 91-99%, or 100% grazed. I later grouped the classes for ease of data interpretation, to represent 0-25%, 26-50%, 51-75% and 76-100% grazed. For each quadrat I first noted whether more or less than 50% of the grass biomass remained in the quadrat. Depending on the level of grazing in each quadrat, the next class up or down was considered and the process repeated until I could match a class with the level of biomass removed. I also identified and recorded the closest faecal deposit to each quadrat to indicate the presence of large herbivores including buffalo, zebra, black wildebeest and red hartebeest in that vegetation type. The faecal deposits were accumulated deposits over the dry season while dung removal by dung beetles is at its lowest (Davis 1996).

Dietary quality

I was interested in establishing the change in the nutritive value of the veld as it relates to the diet of the buffalo during the dry season. For this I used the non-invasive faecal sampling method to primarily determine N, P and Ca. The Ca : P ratio was needed to interpret the P_f levels as P absorption is negatively affected by a Ca : P ratio exceeding 8 : 1 (Grant

1989). The isotopic signatures ($\delta^{13}C$) of C^4 and C^3 vegetation contained in selected faecal samples were also determined to help interpret N_f fluctuations resulting from a change in the diet composition, that is, grass versus browse.

Faecal sampling was initially intended for the late dry season of 2010 as I had hypothesized that buffalo experience an N and P deficiency late in the dry season (September and October). However, after receiving the analysis report of the first sampling period, it became apparent that the onset of the nutritive deficit for buffalo was much earlier than anticipated. For this reason I decided to sample for a second time in the following year (2011), starting approximately two months earlier. During 2010 I analyzed 23 samples for the period 29 June to 30 November and in 2011 I analyzed four samples for the period 30 April to 31 May. To take into account the variation of N and P excreted by individuals in a herd, Wrench *et al*. (1996) proposed that faecal samples for buffalo should be pooled samples from 7 sub-samples. On all but two occasions I was able to collect 10 sub-samples. The exceptions were on the 27 May 2011 and 22 June 2011when nine and eight sub-samples were collected respectively, both of which still exceeded minimum requirements. The samples were collected randomly from the buffalo pathways with the assumption that the samples were from different individuals of the herd. The buffalo pathways from the night before were located by means of the GPS readings from the GPS/GSM collar.

The window period in which faecal samples should be collected from the field range from two days (Wrench *et al*. 1996) to 14 days (Pearce *et al*.1993). In this study, only faecal samples less than 24 hours old were collected to limit exposure to sunlight and insects which can affect the N concentrations in the samples (Wrench *et al*.1996). The faecal samples were dried in thin layers to avoid fungal growth and stored in marked brown paper bags in a cool well ventilated room. Once the faecal samples were dry, the faecal samples were combined for each collection date to form a single 100 gram pooled sample composed of equal weights from each sub-sample.

MENR and the Eye Area are part of the same farm donated to the North West Parks and Tourism Board but, for practical reasons, were separated by a game fence during the establishment of the nature reserve in 2003. Since the separation of the two areas, the grazing treatment in the two areas diverged. The Eye Area continued to be utilized by cattle from the neighbouring farm while MENR was grazed by a wide spectrum of herbivores and was periodically burned. I decided to conduct an herbaceous vegetation assessment in the two sites (MENR and the Eye Area) to inform management of any veld restoration work required before contemplating the incorporation of the Eye Area.

I used the Step-point Method (Evans and Love 1957; Mentis 1981) to collect data on forbs and grasses as it saves time, manpower and equipment while still providing useful and reliable data (Mentis 1981; Panagos and Reilly 2006). In the Step-point Method, a mark is made at the tip of each shoe and a stake is lowered at the mark after each step to determine the herbaceous plant to be recorded. If no herbaceous plant is hit, the nearest plant to the stake (in a forward direction within a180º arc) is recorded, otherwise a bare patch is recorded. Mentis (1981) suggested a cut-off radius of between 15 and 30 cm for savanna areas. I decided on a 15cm radius due to the denser grass cover in sour grassveld (Tainton 1999). According to van Oudtshoorn (2009), 100 points are sufficient for a quick vegetation condition assessment. In this study I sampled 220 points in each vegetation type in each of the two sites totaling 1760 points (880 points for the Eye Area and 880 for MENR).

The Step-point Method was applied along line transects, for each vegetation type on each site (stratified sampling). As most of the vegetation types in the lowland are stretched in narrow interrupted bands parallel to the main stream, I routed the transects parallel to the stream. Each vegetation type on each site was divided into four areas from which I selected two areas randomly for 110 m transects. The transects ran along the centerline between the narrow ends of the vegetation patches. I also took into consideration the aspect of the landscape by only sampling from the eastern side of the stream which comprises the largest portion of the Eye Area and, unlike the western side, is unimpeded by fences and narrow sections of property. I provided an arbitrary 10 m space between the transects and adjoining disturbances such as roads and fences to take the edge effect into account.

I surveyed four vegetation types in each site to allow for comparisons among vegetation types and sites. The four vegetation types included *Open grassland in waterlogged soils, Closed riverine woodland, Closed woodland in drainage lines* and *Open grassland on medium deep soils*. *Reedbeds* was excluded as they form dense stands of predominantly *P.australis* interspersed by a *Typha sp*. on each site producing the same veld condition scores. Unfortunately no benchmark or Threshold of Potential Concern is available for MENR, to represent the 'ideal' and preferred range of veld conditions respectively. Instead I made a relative comparison of veld condition between the two sites using two methods. The first method involved calculating the percentage contribution of grasses falling in five ecological groups (van Oudtshoorn 2009) to indicate whether veld was over-grazed, under-grazed or in good condition. The second method entailed calculating the overall veld condition index using the Ecological Index Method adapted for the use in grasslands (Tainton 1999). Both approaches are based on the succession theory of veld moving from a pioneer stage (poor veld condition) through to a climax stage (excellent veld condition), influenced by the intensity of defoliation by grazing or fire (Tainton 1999). Decreaser grasses decrease when the veld is under – or overgrazed and Increaser 3 grasses increase with over grazing (van Oudtshoorn 2009). The same field data were used for both methods. Grass species which could be classified under more than one ecological group (depending on area) or for which no classification was found, were subjectively assigned to groups erring on the pioneer side of the pioneer to climax continuum. *Bewsia biflora* (only six hits) was regarded as an unimportant grazing grass (van Oudtshoorn 2009) and was assigned to the Increaser 2 group. *Cymbopogon plurinodis* (only 4 hits) was regarded as an Increaser 1 or Increaser 3 (van Oudtshoorn 2009) and classified here as an Increaser 3 in the method comparing group percentage contributions and as an Increaser 2 c in the Ecological Index Method. *Paspalum dilatatum* (only 2 hits) is a persistent grass with high forage production but because it is an exotic species was assigned to the Increaser 3 category in the method using percentage contribution of ecological groups and as an Increaser 2 c for the Ecological Index method. Herbaceous plants including sedges were grouped under forbs and classed as Increaser 3 for the method using the percentage contribution of ecological groups and as Increaser 2 c for the Ecological Index Method. Due to the higher rainfall of the study area I used the Increaser 3 group as opposed to the Increaser 2 group as an indicator of over-utilized (van Oudtshoorn 2009).

Buffalo forage

The vegetation assessment survey was done in February 2011 when the grasses were mature and identifiable. The data collection for this part of the study was already done under the veld condition

assessment section. The data for the buffalo forage species were extracted from the veld condition assessment field sheets for separate analysis. As buffalo forage species selection did not form part of this study, I summarized known forage species from literature and assumed that the buffalo on MENR consumed the same. Unlike in the veld condition assessment, I kept the forbs separate from *Cyperaceae spp.* Forbs, in this case, is a collection of herbaceous plant species as it was beyond the scope of this study to identify the plants at a species level.

Data Analysis

Space use pattern

I used the ArcGIS 9 software to determine the surface area and the percentage contributions of each vegetation type for MENR and the Eye Area. I also used the same software to overlay the buffalo GPS fixes on the vegetation map and to calculate the number of buffalo observations per vegetation type. I divided the five months of this study period into three periods to determine any changes in vegetation type selection by the buffalo. The three periods included the middle and latter part of the dry season (July & August and September & October) and the first month of the wet season (November). To ensure independent data, I only used two of the 24 daily fixes on buffalo locations, namely, 06h00 and 18h00, the times of day when peak foraging in buffalo was observed during the same months by Winterbach (1999).

I used the chi-square test to test whether the buffalo used the vegetation types in proportion to their occurrence across the three periods. The hypothesis that lowland vegetation types were selected for during the dry season was tested by calculated Bonferroni confidence intervals (Neu *et al*. 1974) at a 95% significance. Vegetation types selected for by the buffalo during the most critical period of the dry season would indicate key resource areas.

Grazing pressure

To compare the grazing pressure in each vegetation type, I calculated the percentage contribution of each grazing pressure class to each of the five vegetation types measured. I used a 100% Stacked Column chart to present the percentage contribution of each vegetation type to each of the four grazing pressure classes. To compare the presence of the four large herbivores in each vegetation type, I calculated the percentage occurrence of faecal deposits for each vegetation type and also presented it in a 100% Stacked Column chart.

Dietary quality

I requested BemLab (Pty) Ltd of Cape Town to conduct a total faecal analyses (N, P, K, Ca, Mg, Na, Mn, Fe, Zn, Cu and B) to have a record for the MENR. N was measured by total combustion with a Leco Nitrogen analyzer. P was ashed at 850 °C and the ash taken up in hydrochloric acid for analysis in a ICP-AES Spectrometer (Van Deventer, *pers. comm*.). I calculated the % N_f equivalents of the minimum dietary crude protein requirements for buffalo, provided by Prins and Beekman (1989), using equations provided by Sinclair (1977): Faecal crude protein = (dietary crude protein + 6.93) / 1.667 and % N_f = faecal crude protein / 6.25. I then compared the % N_f results from the buffalo faecal analyses to the maintenance level of 1.52 % N_f (9 % dietary crude protein), for a 500kg non-lactating buffalo. The % N_f values were also compared to the diet requirements of a lactating cow (1.75 % N_f or 11.4 % dietary crude protein). Lactating cows, with their higher crude protein requirements, are particularly vulnerable to malnutrition which could help explain the poor buffalo population growth rate. The 0.2% P_f threshold for grazers (Wrench *et al.* 1997) was used to indicate a P deficiency in buffalo. I plotted the N_f data from the faecal analysis against the minimum % N_f values for lactating and non-lactating buffalo (Prins and Beekman 1987, Figure 7). The P_f data were plotted against the minimum 0.2 % P_f level required for maintenance in grazers (Wrench *et al.* 1997, Figure 8).

A further ten compound faecal samples, weighing ~5mg each, from the same faecal samples of 2010, were packed into tin caps and sent to the Dept. of Biological Sciences, Idaho State University for stable Carbon (C) isotopic analysis. Isotope analysis was used to reveal the isotopic signatures ($\delta^{13}C$) of C^4 and C^3 vegetation contained in the faecal samples. I used the $\delta^{13}C$ to detect the buffalo's selection for C^4 and C^3 vegetation. The $\delta^{13}C$ signature for C^4 and C^3 vegetation varies from area to area, so I selected the $\delta^{13}C$ signature for C^4 and C^3 vegetation of the Sandveld Nature Reserve (Swap *et al*. 2004) for being the closest location to the study area with complete data. The mean $\delta^{13}C$ signatures for C^4 and C^3 vegetation in Sandveld Nature Reserve are -14.10/00 and -26.2 0/00 respectively (Swap *et al*. 2004). As C^3 grasses are most abundant on the Drakensberg and winter rainfall areas of the Cape (Tainton 1999), the C^3 grasses are not expected to confound results of the C^3 woody component on MENR.

Veld condition assessment

To calculate the relative abundance of ecological groups, the number of strikes of grasses and forbs belonging to the same ecological groupings were summed and expressed as a percentage of total strikes per vegetation type. The same approach was used to make site comparisons. For the Ecological Index Method the number of strikes in each ecological group was multiplied by the group's relative index value. The sum of the scores for each ecological group provided the veld condition index for each vegetation type and the total area. The index is expressed as a value out of a maximum of 1000 (in the case where all strikes are Decreaser species). The minimum score is 100 (in the case where all species are Increaser 2 c species).

To provide a further indication of the state of the veld I totaled the number of grass species logged on each site and used the R version 2.10.1 (R Development Core Team 2010) for the Welch two sample t-test for two independent samples to determine whether the number of grass species logged in MENR and the Eye Area differed significantly at the 0.05 level.

Forage Species

I drew up a table to make a comparison of the forage species found on MENR and the Eye Area and the number of hits logged for each species. For statistical analyses I also used the R version 2.10.1 (R Development Core Team 2010) for the Welch two sample t-test for two independent samples to determine whether the frequency of forage grass hits in MENR and the Eye Area differ significantly at the 0.05 level. Although forbs are known to be taken by buffalo, it was beyond this study to identify forbs individually. I therefore compared the grass species hits first and then combined the forb and forage grass hits separately.

RESULTS

Vegetation types on MENR and Eye Area

The area contribution by all the vegetation types on MENR and the Eye Area were calculated to help evaluate the benefit of incorporating the vegetation types in the Eye Area (Table 1). Only five of the 11 vegetation types on MENR occur on the Eye Area, namely, *Open grassland in waterlogged soils, Closed riverine woodland, Closed woodland in drainage lines, Reedbeds* and *Open grassland on medium deep soils*. Even though the Eye Area is only 1.5% of the size of MENR, the area occupied by *Reedbeds* in the Eye Area is 140% of the size of the *Reedbeds* in MENR and *Open grasslands in waterlogged soils* are of similar size on both sites. *Closed riverine woodland* is 16.35 % of the size of the same vegetation type in MENR and *Woodland in drainage lines* only 5.38 %. The vegetation type covering the largest surface area on MENR and the Eye Area is the *Open grasslands on medium deep soils* (Table 1) but the Eye Area represents only 1.03% of what is already available on MENR.

Table 1 Area contributions of the vegetation types found on Molemane Eye Nature Reserve (in hectares and as proportions of the total area) and the Eye Area (in hectares, as proportions of the total area and as proportion of the area covered by the same vegetation type in MENR).

Vegetation Type	MENR		Eye Area		Eye Area proportion to MENR
	ha	%	ha	%	%
Closed riverine woodland	10.92	0.29	1.78	3.12	16.30
Closed woodland in drainage lines	106.36	2.78	5.72	10.02	5.38
Grassland with scattered bushclumps	485.33	12.70			
Open grassland in waterlogged soils	13.78	0.36	13.89	24.32	100.80
Open grassland on deep soils	214.71	5.62			
Open grassland on medium deep soils	1828.91	47.84	18.75	32.83	1.03
Open grassland on shallow dolomite soils	731.66	19.14			
Open grassland on shallow quartzite rich soils	232.64	6.09			
Open woodland	88.44	2.31			
Reedbed	12.19	0.32	16.98	29.72	139.28
Surface Water	1.56	0.04			
Total	3822.67	100	57.12	100	

Buffalo locations

From ground observations, the buffalo remained as a cohesive herd during the study period. The buffalo locations during the two hours a day peak grazing times from July to November are depicted on the MENR vegetation map (Figure 4). It is noteworthy that there are no buffalo locations recorded on the south-eastern portion of MENR, notwithstanding that the greatest portion of the management burns are located in this part of MENR. As a general observation, the buffalo locations within the burned areas are closely associated to the narrow band of *Closed riverine woodland* that runs through the burned areas and not to the *Open grassland in medium deep soils* which make up the largest portion (85%) of the burned areas.

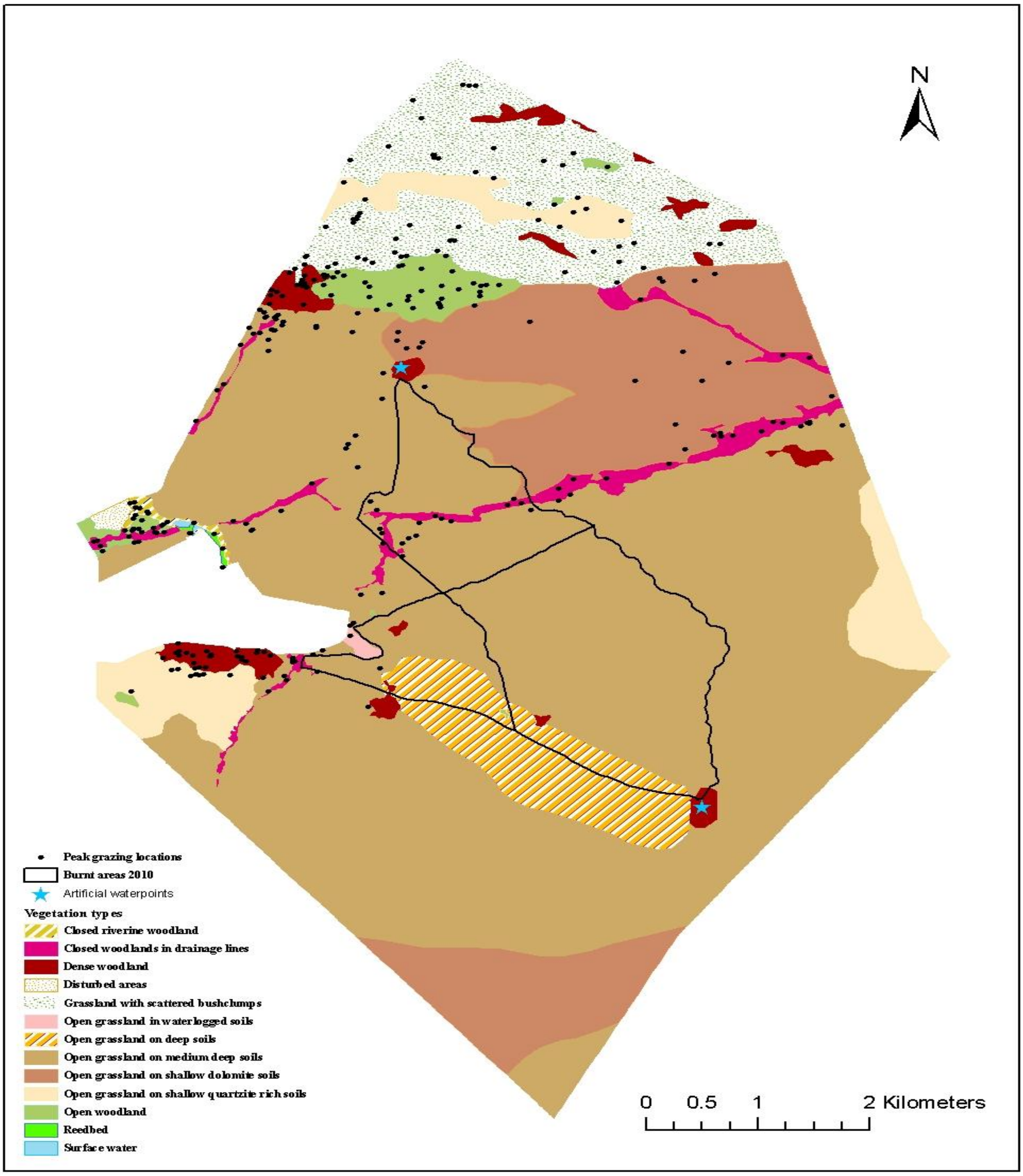

Figure 4 Buffalo locations for the period July to November 2010in Molemane Eye Nature Reserve over imposed to a vegetation and burned areas map. The buffalo locations represent the daily 06h00 and 18h00 locations logged over the study period. The fire in the three burnt areas occurred between 29 June 2010 and 01 July 2010

As expected the buffalo did not use vegetation types in proportion to their availability (Table 2) over the three periods - indicating selection. During July and August 2010, eight vegetation types were positively selected and three were avoided (Table 3). The number of positive selected vegetation types decreased to six in the second period (September and October, Table 4) and to only four in the third period (November, Table 5). *Open grasslands in deep soils, Open grassland in medium deep soils* and *Open grassland in shallow dolomitic soils* were avoided throughout the study (Tables 3-5). Additional pure grassveld vegetation types, *Open grassland on shallow quartzite rich soils* and *Open grassland in waterlogged spoils,* were avoided as the dry period progressed to the September and October period but *Grasslands with scattered bushclumps* remained a favoured vegetation type throughout the three periods (Tables 3-5). In November the only vegetation types still utilized in greater proportion to their availability were those with woody elements, namely, *Closed* w*oodlands in drainage line*s, *Dense woodland, Open woodland* and *Grasslands with scattered bushclumps,* of which only *Closed* w*oodlands in drainage line*s occurs in the lowlands of the Eye Area (Table 1). In the preceding period (September and October), *Closed riverine woodland* was selected for by buffalo, of which the lowlands in the Eye Area contains 1.78 hectares (Table 1). *Open grasslands on medium deep soils,* which do not occur in the lowlands but is the largest area contributor to MENR and the Eye Area (Table 1), was not positively selected for in all three periods. *Open grasslands in waterlogged soils,* a lowland vegetation type, was only selected for in greater proportion to its occurrence during the July and August period. Reedbeds, which make up 29 % of the lowland vegetation, were positively selected for during the first two dry season periods. The hypothesis that buffalo use the lowlands during the dry season holds as all lowland vegetation types were selected, albeit for different periods, during the 2010 dry season.

Table 2 Chi-squared statistic for the selection of vegetation types on Molemane Eye Nature Reserve over three periods in 2010.

	July and August			September and October			November		
Vegetation type	Exp.	Obs.	Chi	Exp.	Obs.	Chi	Exp.	Obs.	Chi
CRW	0.286	5.263	86.756	0.286	3.361	33.126	0.144	0.000	0.144
WDL	2.782	15.789	60.808	2.782	10.924	23.827	1.403	8.403	34.934
DW	2.516	15.789	70.019	2.516	9.244	17.987	1.269	9.244	50.133
GSB	12.696	17.544	1.851	12.696	19.328	3.464	6.401	10.924	3.196
GWS	0.360	1.754	5.390	0.360	0.000	0.360	0.182	0.000	0.182
GDS	5.617	0.000	5.617	5.617	0.000	5.617	2.832	0.000	2.832
GMS	47.844	19.298	17.031	47.844	28.571	7.763	24.123	5.042	15.093
GSD	19.140	3.509	12.766	19.140	8.403	6.023	9.650	5.042	2.201
GSQ	6.086	9.649	2.087	6.086	3.361	1.220	3.068	1.681	0.628
OW	2.313	9.649	23.260	2.313	15.126	70.959	1.166	10.084	68.174
RB	0.319	1.754	6.464	0.319	1.681	5.817	0.161	0.000	0.161
Total			292.048			176.162			177.677
Degrees of freedom			10			10			10
Significance			$p < 0.001$			$p < 0.001$			$p < 0.001$

CRW = Closed riverine woodland; WDL = Closed woodland in drainage lines; GSB = Grassland with scattered bushclumps; GWS = Open grassland in waterlogged soils; GDS = Open grassland on deep soils; GMS = Open grassland on medium deep soils; GSD = Open grassland on shallow dolomite soils; GSQ = Open grassland on shallow quartzite rich soils; OW = Open woodland, RB = Reedbed

Table 3 Proportional availability and locations logged for buffalo on the vegetation types during peak feeding times on Molemane Eye Nature Reserve during July and August 2010. Bonferroni confidence intervals were used to determine buffalo selection or avoidance of vegetation types. Confidence interval determined at 95% level.

Vegetation type	Total hectares	Proportion of total hectares	Number of buffalo locations	Expected number of buffalo locations	Proportion locations per vegetation type	Confidence interval on proportion of locations	
CRW	10.92	0.0029	6	0.33	0.0526	$0.0318 \le P_o \le 0.0735$	+
WDL	106.36	0.0278	18	3.17	0.1579	$0.1238 \le P_o \le 0.1920$	+
DW	96.19	0.0252	18	2.87	0.1579	$0.1238 \le P_o \le 0.1920$	+
GSB	485.33	0.1270	20	14.48	0.1754	$0.1399 \le P_o \le 0.2110$	+
GWS	13.78	0.0036	2	0.41	0.0175	$0.0053 \le P_o \le 0.0298$	+
GDS	214.71	0.0562	0	6.41	0.0000	$0.0000 \le P_o \le 0.0000$	-
GMS	1828.91	0.4786	22	54.56	0.1930	$0.1561 \le P_o \le 0.2299$	-
GSD	731.66	0.1915	4	21.83	0.0351	$0.0179 \le P_o \le 0.0523$	-
GSQ	232.64	0.0609	11	6.94	0.0965	$0.0689 \le P_o \le 0.1241$	+
OW	88.44	0.0231	11	2.64	0.0965	$0.0689 \le P_o \le 0.1241$	+
RB	12.19	0.0032	2	0.36	0.0175	$0.0053 \le P_o \le 0.0298$	+
Total	3821.11	1.0000	114	114	1.00		

(+) = selection for vegetation type, (-) = avoidance of vegetation type. CRW = Closed riverine woodland; WDL = Closed woodland in drainage lines; GSB = Grassland with scattered bushclumps; GWS = Open grassland in waterlogged soils; GDS = Open grassland on deep soils; GMS = Open grassland on medium deep soils; GSD = Open grassland on shallow dolomite soils; GSQ = Open grassland on shallow quartzite rich soils; OW = Open woodland, RB = Reedbed

Table 4 Proportional availability and locations logged for buffalo on the vegetation types during peak feeding times on Molemane Eye Nature Reserve during September and October 2010. Bonferroni confidence intervals were used to determine buffalo selection or avoidance of vegetation types. Confidence interval determined at 95% level.

Vegetation type	Total hectares	Proportion of total hectares	Number of buffalo locations	Expected number of buffalo locations	Proportion locations per vegetation type	Confidence interval on proportion of locations	
CRW	10.92	0.0029	4	0.34	0.0336	$0.0171 \leq P_o \leq 0.0501$	+
WDL	106.36	0.0278	13	3.31	0.1092	$0.0807 \leq P_o \leq 0.1378$	+
DW	96.19	0.0252	11	3.00	0.0924	$0.0659 \leq P_o \leq 0.1189$	+
GSB	485.33	0.1270	23	15.11	0.1933	$0.1572 \leq P_o \leq 0.2294$	+
GWS	13.78	0.0036	0	0.43	0.0000	$0.0000 \leq P_o \leq 0.0000$	-
GDS	214.71	0.0562	0	6.69	0.0000	$0.0000 \leq P_o \leq 0.0000$	-
GMS	1828.91	0.4786	34	56.96	0.2857	$0.2444 \leq P_o \leq 0.3270$	-
GSD	731.66	0.1915	10	22.79	0.0840	$0.0587 \leq P_o \leq 0.1094$	-
GSQ	232.64	0.0609	4	7.24	0.0336	$0.0171 \leq P_o \leq 0.0501$	-
OW	88.44	0.0231	18	2.75	0.1513	$0.1185 \leq P_o \leq 0.1840$	+
RB	12.19	0.0032	2	0.38	0.0168	$0.0050 \leq P_o \leq 0.0286$	+
Total	3821.11	1.0000	119	119	1.0000		

(+) = selection for vegetation type, (-) = avoidance of vegetation type. CRW = Closed riverine woodland; WDL = Closed woodland in drainage lines; GSB = Grassland with scattered bushclumps; GWS = Open grassland in waterlogged soils; GDS = Open grassland on deep soils; GMS = Open grassland on medium deep soils; GSD = Open grassland on shallow dolomite soils; GSQ = Open grassland on shallow quartzite rich soils; OW = Open woodland, RB = Reedbed

Table 5 Proportional availability and locations logged for buffalo on the vegetation types during peak feeding times on Molemane Eye Nature Reserve during November 2010. Bonferroni confidence intervals were used to determine buffalo selection or avoidance of vegetation types. Confidence interval determined at 95% level.

Vegetation type	Total hectares	Proportion of total hectares	Number of buffalo locations	Expected number of buffalo locations	Proportion locations per vegetation type	Confidence interval on proportion of locations	
CRW	10.92	0.0029	0	0.17	0.0000	$0.0000 \leq P_o \leq 0.0000$	-
WDL	106.36	0.0278	10	1.67	0.1667	$0.1187 \leq P_o \leq 0.2147$	+
DW	96.19	0.0252	11	1.51	0.1833	$0.1335 \leq P_o \leq 0.2332$	+
GSB	485.33	0.1270	13	7.62	0.2167	$0.1636 \leq P_o \leq 0.2697$	+
GWS	13.78	0.0036	0	0.22	0.0000	$0.0000 \leq P_o \leq 0.0000$	-
GDS	214.71	0.0562	0	3.37	0.0000	$0.0000 \leq P_o \leq 0.0000$	-
GMS	1828.91	0.4786	6	28.72	0.1000	$0.0614 \leq P_o \leq 0.1386$	-
GSD	731.66	0.1915	6	11.49	0.1000	$0.0614 \leq P_o \leq 0.1386$	-
GSQ	232.64	0.0609	2	3.65	0.0333	$0.0102 \leq P_o \leq 0.0565$	-
OW	88.44	0.0231	12	1.39	0.2000	$0.1485 \leq P_o \leq 0.2515$	+
RB	12.19	0.0032	0	0.19	0.0000	$0.0000 \leq P_o \leq 0.0000$	-
Total	3821.1120	1.0000	60	60	1.0000		

(+) = selection for vegetation type, (-) = avoidance of vegetation type. CRW = Closed riverine woodland; WDL = Closed woodland in drainage lines; GSB = Grassland with scattered bushclumps; GWS = Open grassland in waterlogged soils; GDS = Open grassland on deep soils; GMS = Open grassland on medium deep soils; GSD = Open grassland on shallow dolomite soils; GSQ = Open grassland on shallow quartzite rich soils; OW = Open woodland, RB = Reedbed

At the time of the faecal deposit survey (end November 2010) there was still very low insect activity and faecal deposits were easily recognizable. The data therefore represent the deposits across the whole of the dry season due to the lack of insect activity associated with dung in the dry season. *Dense woodland* and *Closed riverine woodland* were the most frequented by buffalo over the dry period (Figure 5). The same vegetation types also had the highest grazing pressure (Figure 6). 89 % of quadrats in *Dense woodland* and 52 % of quadrats in *Closed riverine woodland* were grazed between 75 % and 100 % respectively. The *Open grasslands in waterlogged soils* was the least frequented vegetation type by buffalo (Figure 5) and also reflected lowest grazing pressure with the majority of quadrats (73 %) grazed between 0 and 25 %. The buffalo and zebra remained the most dominant large herbivores in the woody vegetation types (Figure 5). The greater variation of buffalo faecal deposits compared to zebra faecal deposits found in the different vegetation types indicate that buffalo were more selective in choosing vegetation types than zebra (Figure 6).

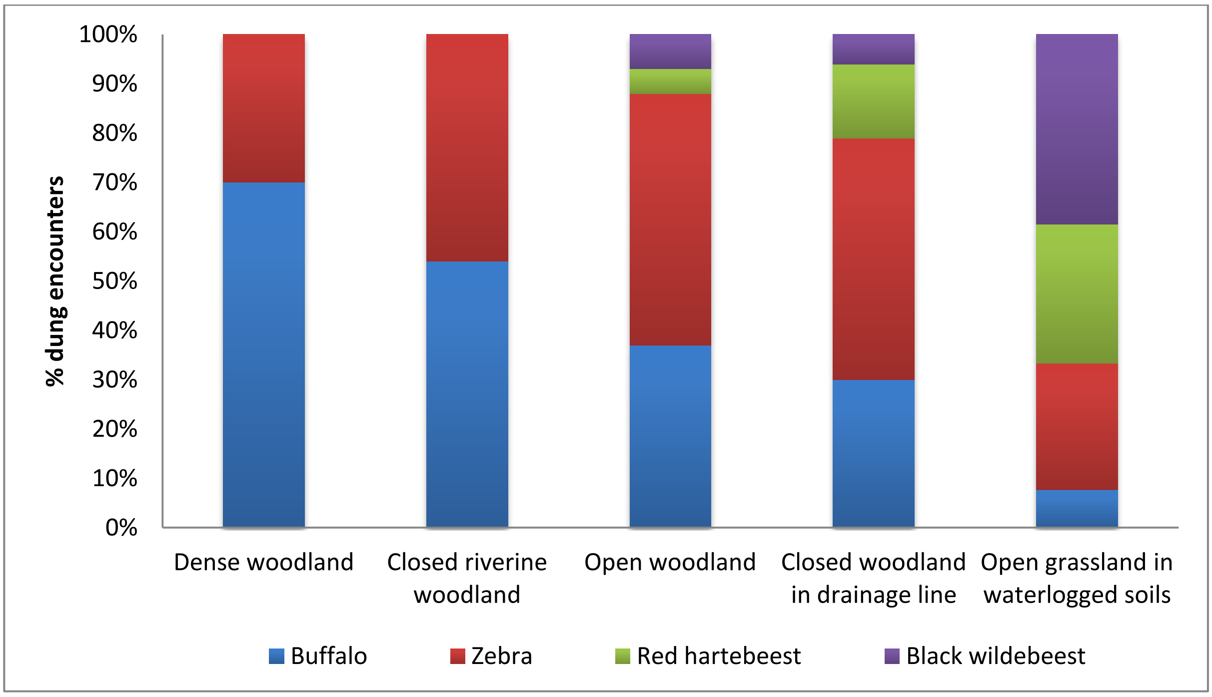

Figure 5 The percentage occurrence of faecal deposits of the larger grazing herbivores on Molemane Eye Nature Reserve indicating large herbivore presence in specific vegetation types.

Figure 6 Grazing pressure on vegetation types as measured at the end of November 2010 on Molemane Eye Nature Reserve. The colours represent the percentage grass depletion in quadrats sampled in the five vegetation types.

Diet quality and C3 versus C4 composition

Contrary to my expectations both P and N values were already very low between June and end of August 2010, and to my surprise started to increase from September onwards (Figure 7 and Figure 8). The second faecal sampling period which started in April 2011 revealed an N_f deficiency already from the earliest sample taken (30 April 2011). In contrast, P_f was marginally higher in the earlier 2011 dry season indicating a slower decline than N_f with the onset of the 2011 dry season. The N_f showed a spike (> 1.52 %) at the beginning of August 2010 but this was not mirrored in P_f or by any notable change in the $\delta^{13}C$ signature for the same sample (Figure 9). After P_f and N_f reached their lowest level between the 17 and 2 of August respectively, both nutrients rose rapidly over the following five weeks and remained well above maintenance levels for the remainder of the 2010 sampling period (Figures 7 and 8). The isotope analysis suggests a diet of increased C^4 vegetation during August and September coinciding with the observed P and N increases and thereafter an increased C^3 vegetation intake as the dry season progressed (Figure 9). The Ca:P ratio was also calculated (Figure 10) and only exceeded the 8:1 ratio on one occasion (6 July 2010). The data show the highest Ca to P ratio ratios in the earlier part of the dry season for 2010 and 2011.

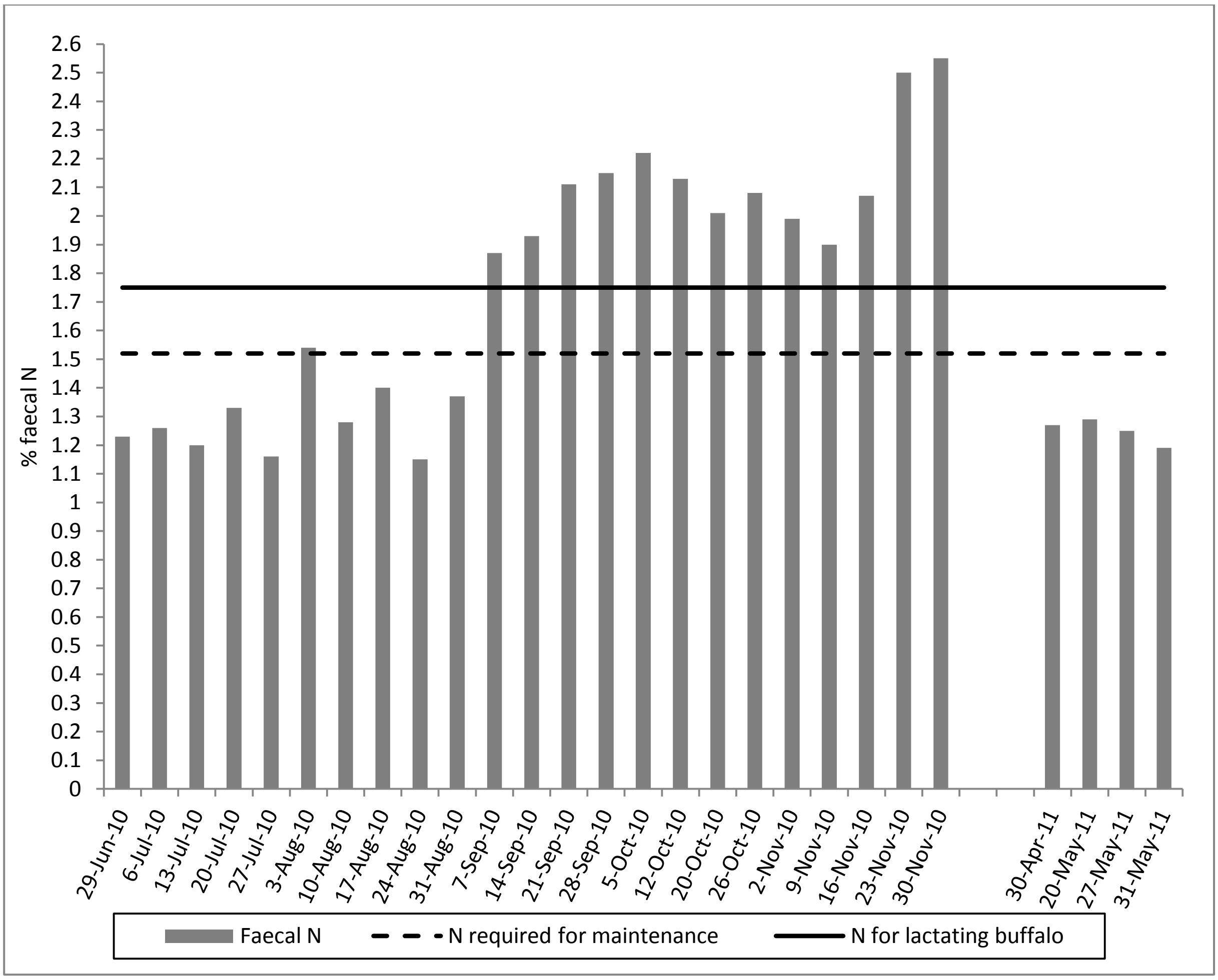

Figure 7 Percentage faecal N levels of buffalo on Molemane Eye Nature Reserve during the 2010 and 2011 dry periods in relation to N requirements for buffalo maintenance and lactating buffalo (Prins and Beekman 1987).

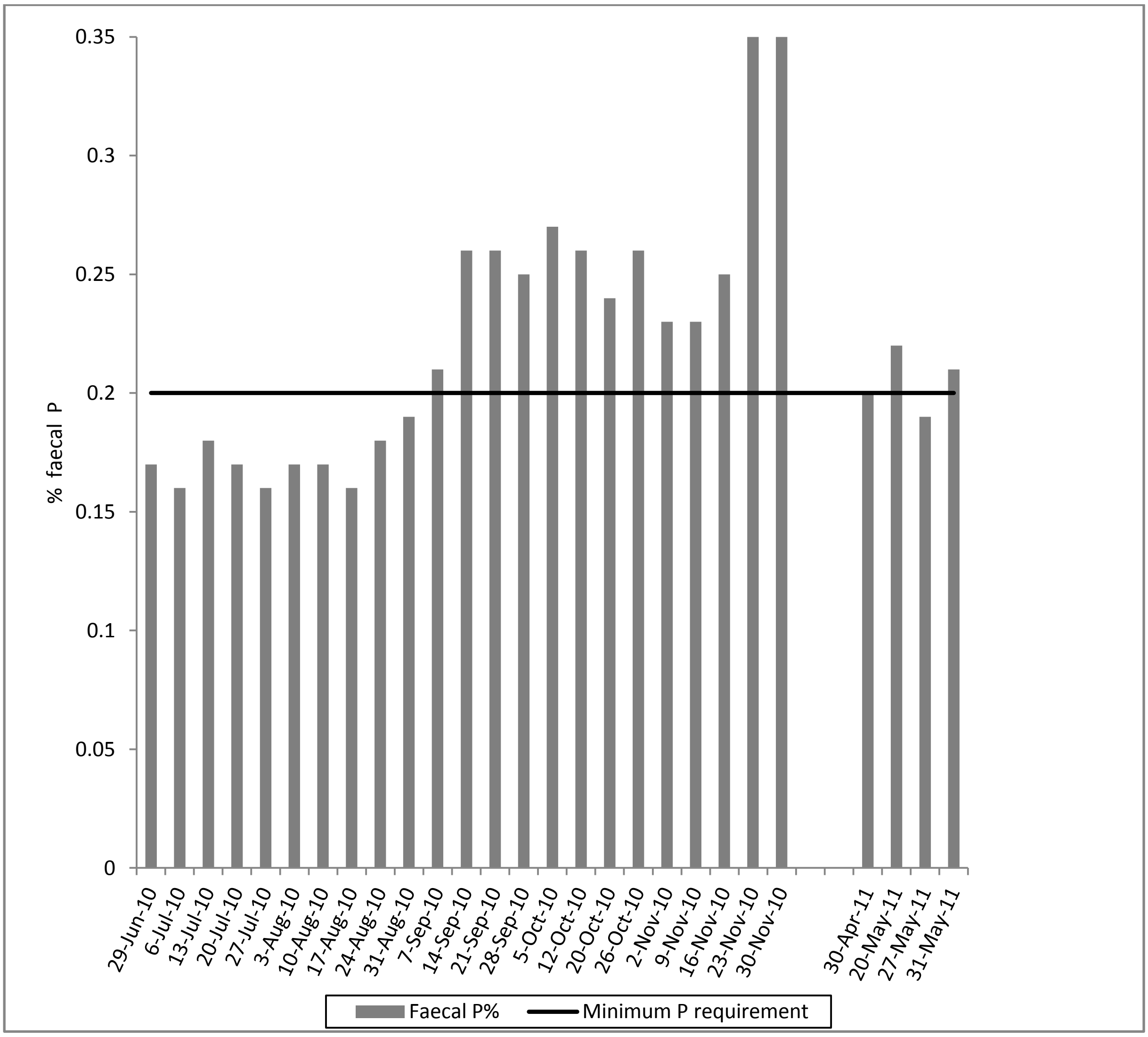

Figure 8 Percentage faecal P for buffalo on Molemane Eye Nature Reserve during the 2010 and 2011 dry periods in relation to the P deficiency threshold for grazers as determined by Wrench *et al.* (1997).

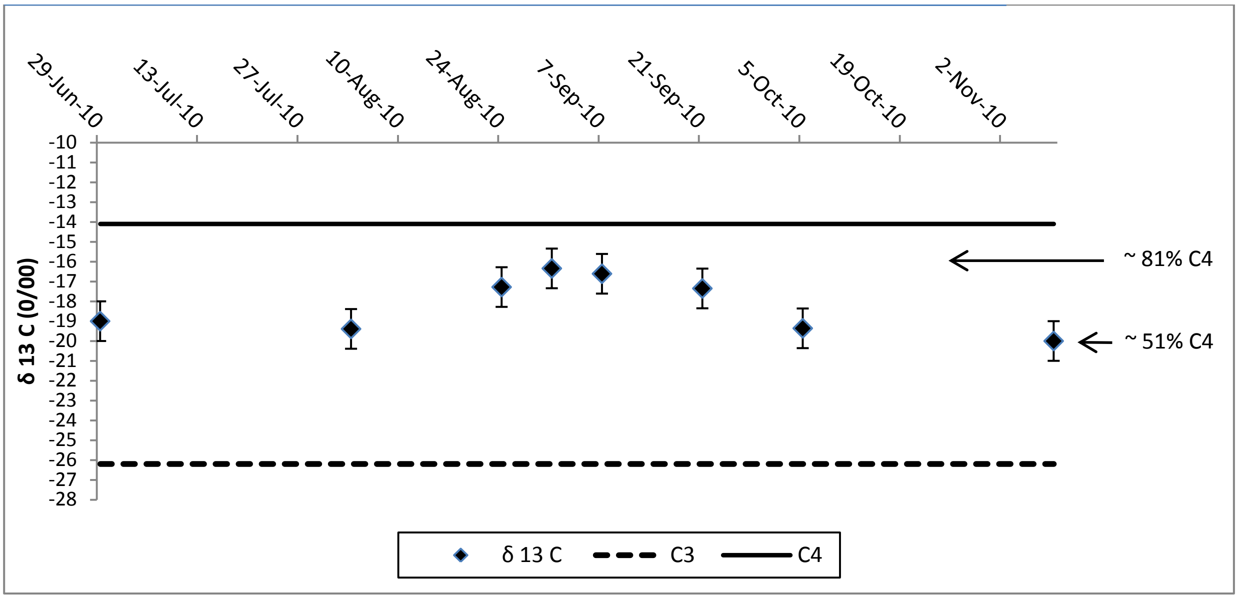

Figure 9 Carbon isotopic analyses on faecal samples revealing the δ^{13}C signatures for vegetation consumed by buffalo during the dry season and during the first week of the 2010 wet season. The mean δ^{13}C signature for C3 and C4 vegetation was listed in Swap *et al*. (2004).

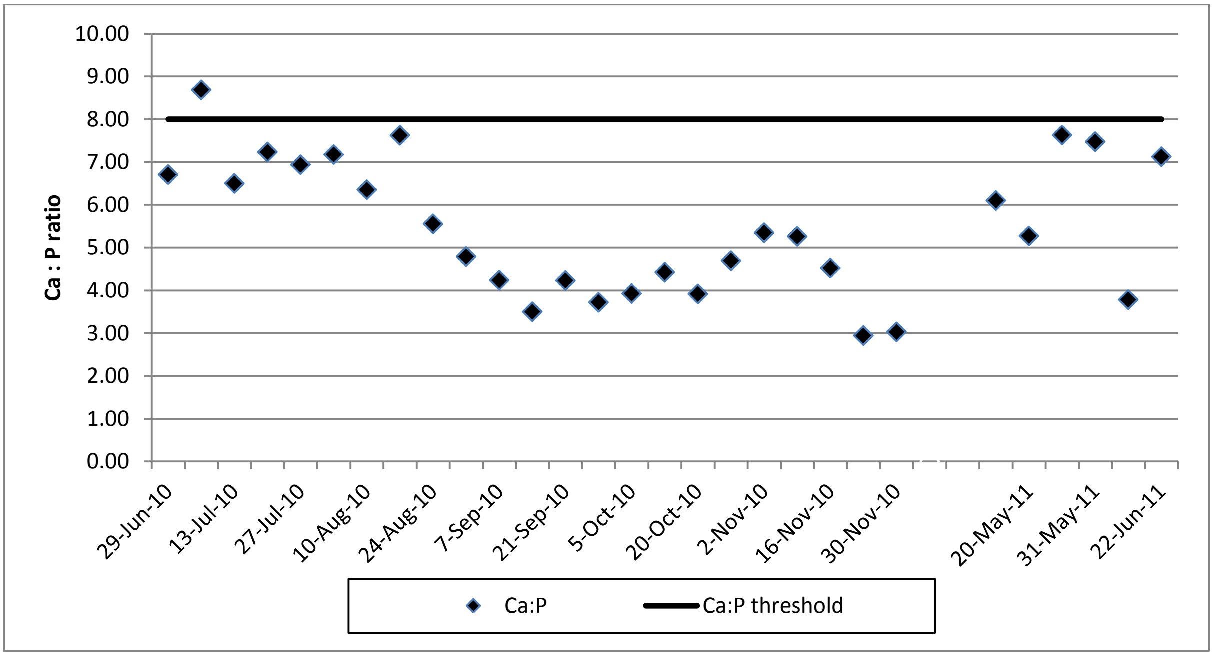

Figure 10 Calcium to phosphorus ratio in Molemane Eye Nature Reserve buffalo faecal samples indicating the 8:1 threshold over which phorporus excretion increases.

Veld condition

The Eye Area was heavily grazed by cattle from the neighbouring farm from 2006 to 2010. MENR on the other hand has been exposed to controlled burns and a wider spectrum of herbivores over the same period. The effect of the two veld management practices was visually most striking on the *Open grassland on medium deep soils* (Plate 1).

Plate 1 The sharp fence-line contrast resulting from the different veld management practices on the two sites in the study area. The Eye Area (LHS) utilized for cattle ranching compared to the Molemane Eye Nature Reserve (RHS) utilized by a wide spectrum of grazing herbivores and periodically control burnt. The photo was taken at the start of the study, 28 June 2010.

The outcome of the veld condition survey, using the method of van Oudtshoorn (2009), revealed that MENR had a marginally better veld condition than the Eye Area. This was evident from the higher number of Decreaser species in MENR and the higher number of Increaser 3 for the Eye Area (Table 6). The higher Increaser 1 value for MENR (Table 6) indicates that MENR is more under – or selectively grazed (van Oudtshoorn 2009) than the Eye Area. The main contributors to the higher Increaser 1 value on MENR are *Grassland in waterlogged soils* and *Grassland in medium deep soils* (Table 6). The vegetation survey revealed no bare patches in the four vegetation types for both sites, keeping in mind that I classified a bare patch as having no herbaceous plants within a 15 cm radius and within a180º arc in a forward direction from the step point.

On comparing the individual vegetation types, *Closed riverine woodland* stands out as having similar overgrazing pressures on both sites (Increaser 3: MENR 60%, Eye Area 68%) whereas open *Grasslands in waterlogged soils* on both sites show undergrazing (Increaser 1: MENR 80%; Eye Area 58%). In stark contradiction was the veld condition of *Closed woodland in drainage lines* on MENR which was in very good condition whereas in the Eye Area it was in a very poor condition (given the proportion of scores for Decreasers to Increaser 3).

Table 6 Percentage occurrences of ecological groups for the two sites in the study area and for each of the vegetation types surveyed in the two sites of the study area.

Ecological group	Sites		GWS		GMS		WDL		CRW	
	MENR	Eye Area	MENR	Eye Area	MENR	Eye Area	MENR	Eye Area	MENR	Eye Area
Decreaser	23	22	0	4	20	37	47	26	25	23
Increaser 1	28	16	80	58	25	0	0	3	4	1
Increaser 2	16	13	4	5	19	39	33	12	10	8
Increaser 3	34	48	16	32	36	24	20	59	60	68
Invaders	0	0	0	1	0	0	0	0	0	0
Total	100	100	100	100	100	100	100	100	100	100

GWS = Open grassland in waterlogged soils; GMS = Open grassland in medium deep soils; WDL = Closed woodland in drainage lines; CRW = Closed riverine woodland.

The results from the Ecological Index Method (Table 7) confirmed a relatively better veld condition for MENR (555) compared to the Eye Area (545). However, the difference in scores is so marginal that, from a practical perspective, there is really no difference in the veld condition.

Table 7 Veld condition indexes for four vegetation types on Molemane Eye Nature Reserve the Eye Area using the Ecological Index Method.
Table

	Sites		GWS		GMS		WDL		CRW	
Ecological group	MENR	Eye Area	MENR	Eye Area	MENR	Eye Area	MENR	Eye Area	MENR	Eye Area
Decreaser	2010	1990	0	80	410	820	1040	580	560	510
Increaser 1a	1498	833	1113	462	343	273	7	42	35	56
Increaser 1b	20	0	8	0	12	0	0	0	0	0
Increaser 2a	0	0	0	0	0	0	0	0	0	0
Increaser 2b	1196	1880	108	308	256	376	324	572	520	624
Increaser 2c	161	90	32	67	63	5	34	13	29	5
Invader	0	2	0	2	0	0	0	0	0	0
Total	4885	4795	1261	919	1084	1474	1405	1207	1144	1195
Veld condition index	555	545	573	418	493	670	639	549	520	543

GWS = Open grassland in waterlogged soils; GMS = Open grassland in medium deep soil; WDL = Closed woodland in drainage lines; CRW = Closed riverine woodland.

The grass diversity for MENR and the Eye area was statistically different (Welch Two Sample t-test, $t_{5.995,\,4} = 2.781$, $p < 0.05$) , with a greater diversity on MENR (MENR:16±0.34; Eye Area: 10.75±0.40).

Buffalo forage

A summary of forage items was compiled along with the number of strikes recorded (Table 8) for each forage item. Four new species were found not previously recorded on the MENR species list. Six grasses were exclusively found on MENR, of which the majority were in very low numbers; *B. nigropedata* (1), *E. curvula* (23) , *E. superba* (7) *, P. coloratum* (1) *and T. berteronianus* (1). No forage items were exclusive to the Eye Area. The numbers of forage item strikes in the Eye Area were much higher with 654 strikes as opposed to the MENR with 436 strikes. Even though MENR had fewer forage item strikes, the area logged five more forage species than the Eye Area (Table 8), with the difference mainly made up by the high number of forbs strikes and to a lesser extent by *P. maximum* and *Cyperaceae spp.* Statistically however, the null hypothesis that there was no significant difference in frequencies of forage species hits between MENR and the Eye Area was retained (Welch Two

Sample t-test, $t_{4.69, 4} = 0.8493$, $p < 0.05$). Similarly, for the combined forage grass and forb hits, the null hypothesis was also retained (Welch Two Sample t-test, $t_{5.794, 4} = 0.3077$, $p < 0.05$). The hypothesis that MENR had more forage items than the Eye Area was therefore not upheld.

Table 8 Buffalo forage items and the number of strikes logged for each item occurring on Molemane Eye Nature Reserve and the Eye Area. The number of strikes per forage item was out of a total of 880 points surveyed in each area during February 2011 using the Step Point Method (Mentis 1981).

Buffalo forage items	MENR species list	Strikes MENR	Eye Area
Brachiaria nigropedata [c]	√	1	0
Cyperaceae spp. [a,b,c]	√	19	48
Cynodon dactylon [b]		10	21
Digitaria eriantha [d,e]	√	62	50
*Eragrostis curvula**	√	23	0
*Eragrostis lehmanniana**	√	29	21
Eragrostis superba [b,c,d]	√	7	0
Eustachys paspaloides [a]	√	0	0
Forb spp. [a,b]	√	232	426
Heteropogon contortus [c,d,e]	√	9	14
Panicum coloratum [c,d,e]		1	0
Panicum maximum [c,d,e]	√	16	64
Phragmitis spp. [c]		√	√
Themeda triandra [c,d,e]	√	26	10
Tragus berteronianus [b]	√	1	0
Typha spp. [c]		√	√
Total number of strikes		436	654
Total number of forage items		15	10

Data from: [a]Sinclair (1977); [b]Prins (1996); [c] Pienaar (1969); [d]Macandza et al. (2004); [e] Bowers (2006);
* Sinclair (1977) made reference to the genera only. Presence of forage item indicated by (√).

DISCUSSION

Vegetation Types on MENR and Eye Area

Of the 11 vegetation types identified in the study area, five occurred in the adjacent 57 hectare Eye Area considered for incorporation. Although the Eye Area is only 1.5 % of the size of MENR, it held more land under *Reedbeds* and the total surface area for the vegetation types found in or next to water (*Open Grassland in waterlogged soils*, *Closed riverine woodland*

and *Reedbeds*) are very similar (Eye Area 33 ha; MENR 37 ha). One of the observations made during the study was that the *Open grassland in waterlogged soil* on MENR dried up at the end of August as opposed to the Eye Area which remained waterlogged throughout the study period. The buffalo utilization of this vegetation type in the MENR may therefore not fully reflect how the same vegetation type may be utilized in the Eye Area during the latter part of the dry season. *Open grassland on medium deep soil* was by far the largest contributor of land on both sites but, as discussed below, was avoided by the buffalo during the study period.

Buffalo locations

An important finding of this study was that the buffalo distribution was restricted to approximately half of the area available to them. This highlights the risk associated with stocking an area based on a standard herbivore grazing capacity, generally given as hectares per Large Animal Units (Meissner 1982). MENR was stocked with 46 buffalo (approximating 30 Large Stock Units), as recommended by Newberry and van Heerden (2002) but no adjustments were made for their specific habitat requirements. Although convenient as a general guideline, especially under organizational resource constraints, this method is outdated (Van Hoven 1990) as it does not consider the specific habitat requirements of herbivores, herbivore grazing overlap (Dekker 1997) and inter-specific facilitation. Coughenour (1991) warns that overlooking the spatial aspect of herbivory can lead to overgrazing and declines in wildlife populations. The poor population growth rate and poor body condition of the buffalo on MENR during the 2010 dry season attests to that. Indications are that MENR provides marginal habitat for buffalo which can explain that no buffalo were recorded historically in this area (Du Plessis1969).

The buffalo adjusted their forage strategy by selecting for different vegetation types as the dry season progressed. Scoones (1995) also found that cattle in the savannas of southern

Zimbabwe were able to adapt to a changing environment in the dry season and optimized their forage intake by moving to lowland areas which had the highest herbaceous biomass per unit area. In the current study, buffalo always avoided *Open grasslands in deep soil*, *Open grasslands in medium deep soil* and *Open grassland in shallow dolomitic soil* whereas *Open grassland in waterlogged soil* and *Open grassland on shallow quartzite rich soil* were avoided from September and October forward. *Open grasslands in medium deep soil,* which makes up the greatest portion of the Eye Area, will therefore not contribute to the buffalo key resource area. All woodland vegetation types were selected for by the buffalo throughout the study period with the exception of *Closed riverine woodland* which was only avoided in November, by which time the nutritional stress for the buffalo had already lifted. It appears that the woodland vegetation types had a higher percentage of Decreaser species than the grasslands, indicating an overall better veld condition (Outshoorn 2009) despite the apparent grazing pressure. The lower dominance of Decreaser species in the grasslands may be as a result of the impact of grasslands being more prone to fires and the subsequent grazing by short grass and selective feeders. Bowers (2006) found that the abundance of grass material was the most important variable in determining buffalo selection of feeding patches. This could probably not explain the buffalo avoidance of the *Closed riverine woodland* in November when this vegetation type was only moderately grazed compared to the severely grazed *Dense Woodland*, which was yet, still selected for by the buffalo. Of interest were also the very different levels of grazing pressure between *Dense woodland* and *Open woodland* and the switch of the dominant large herbivore from buffalo to zebra respectively. The difference in grazing pressures was likely as a result of forage plants occurring at different concentration, given that *Dense woodland* has a more homogeneous cover and *Open woodland* comprises patches of bush interspersed with grassland. The dominance of the zebra over the buffalo in the *Open woodland* was likely a factor of zebra being less selective than buffalo - they are partial to open woodland and grassland (Skinner and Smithers 1990;

Davidson 1993). Although zebra are generally regarded as short grass feeders, they may, as in Kruger National Park, take tall grass too (Skinner and Smithers 1990). Davidson (2003) noted that even though zebra and roan had different forage species preferences in the Kruger National Park, zebra would utilize the same forage when resources were scarce. In MENR zebra would be able to compete strongly due to their ability to forage short grass, making buffalo more vulnerable to malnutrition in the dry season. Direct competition from zebra could therefore be an important factor for buffalo, also considering that zebra and buffalo were the most abundant large mammals in five of the six vegetation types surveyed for the presence of faecal deposits.

Open grassland in waterlogged soil was dominated by dense stands of *I. cylindrica* , a hard leafed grass generally poorly utilized by grazers (van Oudtshoorn 2009) and avoided by buffalo (Grimsdell 1973; Sinclair 1977), which explains why this vegetation type was the least grazed of the five vegetation types for which grazing pressure was estimated. Even though the faecal deposits indicated that the buffalo were the least dominant large herbivore in the *Open grasslands in waterlogged soils,* the buffalo did select for this vegetation type in July and August, at a time when the nutrient status of the buffalo was still below metabolic requirements. The selection of this vegetation type may be as a result of the presence of water (Skinner and Smithers 1990; Scoones 1995) and the presence of evergreen sedges which are low in protein content but can provide enough bulk for the buffalo intake needs (Prins 1996). When the water dried up at the end of August, the buffalo avoided *Open grasslands in waterlogged soils* and narrowed their selection to only six of the 11 vegetation types. In the Eye Area *Open grassland in waterlogged soil* is permanently waterlogged which may extend the time that buffalo would select for this vegetation type. Coincidentally the nutritional status of the buffalo rose rapidly above the critical level and remained there for the remainder of the study period directly after *Open grassland in waterlogged soil* was avoided- indicating a nutrient flush in the woody vegetation types selected for during that time.

Open grasslands on medium deep soil were avoided both before and after the burns suggesting that the green flush emerging after fires had no effect in attracting buffalo away from their previously preferred vegetation types. Sinclair (1977) made a similar observation in the Tsavo National Park where fires had little benefit to buffalo herds, instead, the buffalo tended to move to the lowland areas faster. Inter-specific competition with short grass feeders, keeping grasses too short after the burns to provide buffalo with sufficient bite sizes and protein (Owen-Smith 2002), may also be a factor on MENR. Increasing the size of burns to exceed the forage requirements of short grass feeders and allow the grass to grow taller for buffalo is not advisable as 17 % of MENR was burnt over three successive days at the time of the study. Indications are therefore that *Open grasslands on medium deep soils,* even when burnt, will contribute little to buffalo habitat. Fire may however be beneficial in *Reedbeds* as buffalo selected for this vegetation type during the dry season despite their moribund state, having last burned in 2005. Reeds are reportedly grazed by buffalo in the dry season (Newberry and van Heerden 2002) and young shoots of *Phragmitis communis* is taken by buffalo in the Kruger National Park (Pienaar 1969(a)). An additional 16.9 ha *Reedbeds* from the Eye Area could prove to be an important forage resource for buffalo especially once buffalo can fully access *Reedbeds* after fire.

Diet quality

The buffalo on MENR can be expected to enter a period of nutritional stress in the dry season due to the decline in palatability and nutritional value of sour-mixed grassland (Tainton 1999). I did however not anticipate a severe nutrient deficiency over the 2010 dry season due to the high rainfall in the preceding wet season. Even though the area is predominantly sour, the growth of sweet grasses would be affected by rainfall inthat much of MENR has shallow soils which are prone to drying out. However, the study established that the quality of the buffalo diet in the dry season was already below maintenance requirements in June 2010 and April 2011. In 2011 the nutrient levels in the diet only reached the minimum maintenance levels again at the beginning of September. The overall trend in the N_f and P_f levels were very similar over the study period, a general observation also made by Grant (1989). The very low P_f levels (< 0.2%, Wrench *et al*. 1997) and low N_f values (< 1.52 %, Prins and Beekmam1987) between June 2010 and end of August 2010 indicate a forage quality which was well below metabolic requirements. The rise in N_f and P_f as from mid August coincides with the rise in the $\delta^{13}C$ signature for C_4 vegetation suggesting that the buffalo were able to benefit from more nutritious grass over that period. An early grass flush resulting from the warmer temperatures was most likely the reason for the improved diet. Rainfall recoded on MENR for the preceding wet season was 226 mm above the long term mean rainfall which would have resulted in higher ground moisture to support the grass re-growth. The buffalo were narrowing their selection of vegetation types as the dry season progressed which makes it unlikely that good quality forage, remaining from the previous season, was suddenly discovered. It is also unlikely that the reason for the sharp N_f rise was confounded by buffalo ingesting unpalatable sourveld grasses containing protein binding substances (Tainton 1999) as Owen-Smith (1982) considered such grasses to have a negligible effect on N_f. Browse material can also raise N_f levels (Howery and Pfister 1990; Wrench *et al.* 1997), but as already mentioned the isotopic results indicated a raised grass intake.

The N and P maintenance levels became positive again in the first week of September 2010 and remained high while the δ^{13} C values tapered off again towards C^3 vegetation from September to early November 2010. During the latter part of the dry season the early green grass flush may have becoming depleted before the first effective rains in November 2010 forcing the buffalo to adapt their forage selection to include more browse plants. This relates well with Grant (1989) who observed cattle in Namibia taking to bush shoots during the hot dry season.

The relationship between N and P must be taken into account when assessing the N and P values. Grant *et al*. (1995) found that higher P supplementation for cattle only contributed to weight gain in cattle when N_f levels were >1.2 %. At the start of the 2010 sampling period, P_f fell short of the minimum grazing herbivore requirement of P_f 0.2 % and most N_f values were marginally under the1.2 % required for P supplementation to be effective, assuming off course that cattle and buffalo have a similar physiology. For N, the situation was even direr when considering the amplification of N_f levels as a result of the P dropping < 0.22 % levels (Grant *et al.* 1995), as is the case for all the early faecal samples taken. At such low N_f levels the buffalo would most likely have started to catabolized muscle tissue and further raised the N_f excretions (Hungate 1975).

Therefore the most critical period would have been July /August just before the recovery of the forage quality and for that reason I regard the vegetation types selected by the buffalo during this period as key resources. Eight of the 11 vegetation types on MENR were selected during this critical period of which four, namely, *Closed riverine woodland*, *Closed woodland in drainage lines*, *Reedbeds* and *Open grassland in waterlogged soil* also occur on the Eye Area. Although only 38 ha in extent, these lowland vegetation types make up the majority of the Eye Area and would contribute to sustaining the small buffalo population on the Reserve during the dry season and even more so during dry years. Water is an important factor for buffalo in determining feeding patches (Sinclair 1977). The removal of the fence between MENR and the Eye Area could have an added benefit by opening up a direct route from forage areas to water in the south western part of MENR. A shorter walking distance would be an important energy saver for the buffalo in the dry season when their nutrient status is below maintenance levels. This hold especially true for the lactating cows with high energy and N requirements (Prins and Beekmann 1987).

The nutritional status of the buffalo was deficient especially for lactating cows for at least five months when forage N and P levels were well below maintenance requirements notwithstanding the high rainfall in the preceding wet season and a more conservative buffalo stocking rate. In dry years the situation would be exacerbated (Winterbach 1999). An extended period of the dietary deficiency in N and P is known to raise mortality rates and lower fecundity rates (Sinclair 1977; Prins 1996) and therefore likely to be the cause for a low population growth rate on MENR. Both faecal sampling periods could not capture the onset of the decline in the diet quality on MENR and therefore it is recommended that future dietary studies start in March.

Veld Condition

The herbaceous vegetation assessment was undertaken on MENR and the Eye Area to provide a relative comparison between the two sites that had different treatments since 2003 when the game fence was erected. Unfortunately no benchmark veld condition (Foran *et al.* 1978) has been determined for MENR against which the veld condition results could be compared. Nevertheless this snap shot of the two sites provided a relative comparison and a basis for decisions regarding restoration work prior the incorporation of the Eye Area. MENR would benefit from developing Thresholds of Potential Concerns as presented by Grant *et al.* (2011) to manage the herbaceous layer in a way that allows for flux in the system as opposed to strict targets for the abundance of palatable and unpalatable grass species. Cover and standing crop should also be considered as response variables for a long term monitoring program.

The results of the two veld condition assessments techniques showed that despite the different fire and grazing treatments on the two sites since 2003, there was no real difference of veld condition in the two sites. Even so, at the vegetation type level, some of the ecological group scores between the sites varied widely and often contradicted the outcome of the overall score for the site they contributed to. *Grasslands in waterlogged soils* showed signs of undergrazing on both sites probably due to the high presence of *I. cylindrica* as already discussed in the previous section. The *Closed riverine woodland* sites however had signs of overgrazing on both sides of the fence which could be as as result of the proximity of water, especially in the dry season when cattle and buffalo are known to concentrate foraging near water (Scoones 1995; Skinner and Smithers 1990). The incorporation of the Eye Area would be beneficial as the grazing pressure would be spread accross a longer stream front. Unlike commercial farms where the grazing pressure can be controlled for each vegetation type by means of camp systems, it would be impractical to try and manage for each of these variations on a conservation area such as MENR. No bare patches were recorded on either site indicating a good ground cover able to provide protection against surface runoff and soil erosion (Tainton 1999). The similar Decreaser scores for the two sites is likely the effect, on the one hand, of the over-grazing on the Eye Area (indicated by relative higher score of the Increaser 3 group) and the selective- or under grazing on MENR (indicated by the relative higher score of the Increaser 1 group). The grass sward on the Eye Area was already visually depleted by cattle at the inception of this study in June 2010. The neighbouring farmer, who's cattle grazed the Eye Area, revealed that his grazing strategy was to, "trap die veld soet" which translates to "trampling the veld sweet". This is a High Utilization Grazing philosophy for sour veld (Acocks 1966) requiring a high animal stocking level to force the animals to be non-selective and keep all the mixed-sourveld grasses at a more nutritious young and leafy growth stage. This approach on a continuous grazing basis (as was the case in the Eye Area over the past 5 years), can have a negative impact on the composition of the veld and undermine the long term stability and productivity of the veld (Tainton 1999). The lower grass species richness on the Eye Area may be early indications of this. Grant *et al.* (2011) state that overgrazing leading to the degradation of the herbacious layer is a function of time and not necessarily the number of animals. Conservation areas are single camp systems where control over the herbivore selection of forage areas is limited (van Rooyen 1999) and heavily grazed vegetation types such as *Dense woodland* selected by buffalo throughout the study period may suffer the same long term consequences. On MENR the moderate grazing pressure on *Closed woodland in drainage lines* would have resulted in the more palatable grasses being foraged first leaving the less palatable grasses ungrazed, which under fire exclusion systems, can lead to unpalatable species becoming moribund and less dominant (Tainton 1999). The exclusion of fire from vegetation types such as *Closed woodland in drainage lines* would be a function based habitat design (Coetzee *et al.* 1999) to give the palatable grass species a competitive advantage and as in MENR increase buffalo forage production. Overall, there is no indication that major restoration work is required on the Eye Area prior incorporation. For the time being however, management would be advised to maintain the vigour of all the grass sward components by allowing moderate cattle grazing and resting periods along with a fire program to remove the moribund sward from time to time (Tainton1999).

CONCLUSION

The study has illustrated that the buffalo malnutrition and consequent poor population growth rate on MENR is as a result of the inherintly poor veld. Park expansion, suppliment feeding and a revised stocking plan, especially for likely competitor species such as zebra, are proposed management interventions for an improved buffalo management strategy. This study should form the basis of a vegetation monitoring program on MENR. The collection of time- series data will assist in performing meaningful and time-series analysis of rangeland changes which in turn will inform management actions. The Eye Area does not require rehabilitation and should be considered as a useful land expansion project that will shorten the perimeter fence line and improved buffalo access to water and key resource areas. The addition of the large reedbeds is particularly important for buffalo forage during the critical dry period. I therefore propose that the Eye Area is incorporated into MENR to help achieve the conservation and economic goals of the reserve.

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