Post-release monitoring of diet profile and diet quality of reintroduced African Buffalo (Syncerus caffer) in Umfurudzi Park, Zimbabwe

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Research Article

Post-release monitoring of diet profile and diet quality of reintroduced African buffalo (*Syncerus caffer*) in Umfurudzi Park, Zimbabwe

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Abstract

Post-release monitoring of wildlife is essential to the success of ecological restoration initiatives. Translocation of wildlife to new ecosystems is associated with changes in diet profiles of individuals and ultimately animal performance, since productivity of rangelands varies in time and space. The population decline and local extinction of buffalo and other species in Umfurudzi Park, Zimbabwe, in the late 1980s led to temporary suspension of hunting activities. Recently, efforts have been made to resuscitate Umfurudzi Park through wildlife reintroductions and active ecosystem management. We assessed the diet profile and diet quality of the African buffalo *(Syncerus caffer)* between 2011 and 2012. A total of 42 grass species constituted the diet spectrum of buffalo. *Heteropogon contortus, Eragrostis racemosa, Steroechlaena tenuifolia* and*Themeda triandra* contributed significantly to the buffalo diet during the four seasons of the study period. Although a wide spectrum of grass species was selected in the wet season, the diversity of grass species selected was not significantly different among the seasons. Grass species crude protein deteriorated from 4.5% in the wet season to 3.5% in the dry season. Crude protein and phosphorus levels in buffalo faecal samples were within the recommended nutrient scale for southern Africa large herbivores. We conclude that feed availability and quality may not be limiting the persistence of the reintroduced buffalo. There is a need to closely monitor grass availability, dietary shifts, and forage quality over time, as well as resource partitioning with other feeding guilds.

Key words: Habitat, herbivores, crude protein, phosphorus, biodiversity

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Introduction

Wildlife reintroductions and translocations to part of their former habitat are widely acknowledged as a wildlife management tool with conservation and economic incentives [1, 2]. Wildlife reintroductions are used to restore populations and save species from extinction in many instances [3]. However, several factors can affect the success of these programs, notably ecological factors (e.g., habitat quality, competition and post-release predation [2, 3]) and non-ecological factors (e.g., long-term commitment to re-introduction program by management; public relations; and education [4-6]). Post-release monitoring of reintroduced individuals is important to the success of reintroduction programs [7, 8]. Habitat quality of the release site has an impact on survival of species and their ability to adapt to the new environment [3, 9]. Newly released individuals often avoid utilisation of habitats close to the release sites, preferring to forage in familiar habitats and rejecting novel areas different from their habitat of origin [10].

Resource availability and utilization among feeding guilds should be considered in every reintroduction program through monitoring the foraging patterns of introduced individuals. Reintroduction sites which are fenced may influence habitat preference, since individuals are restricted with few chances of adaptive habitat selection through experiential learning [10]. However, large herbivores are known to concentrate in nutrient-rich sites and select feed items of high nutritive value [11, 12]. We expected that reintroduced buffalo would select foraging patches with grasses of high quality to obtain sufficient quantities of the most limiting forage nutrients such as nitrogen and phosphorus [13-15] and avoid patches with high structural carbohydrates and low nutritive value [13, 16, 17]. Forage quality measures such as the levels of nitrogen and phosphorus are mainly crucial in the dry season when their concentrations decline, while the structural carbohydrate components increase [13]. Similarly, the digestible quality of range forage is inversely related to rainfall, to the extent that the energy and nutrients per unit biomass extractable by herbivores tend to decline in wetter areas [18]. We argue that the translocation of wildlife to new ecosystems is often associated with change in diet profiles of individuals and ultimately animal performance, given that rangeland productivity varies both seasonally and geographically [19].

The population decline and local extinction of buffalo and several other species in Umfurudzi Park, Zimbabwe in the late 1980s led to the continuing temporary suspension of hunting activities. Through a public/private partnership initiative, in 2010 an agreement was reached between the Zimbabwe Parks and Wildlife Management Authority and a private partner to reintroduce locally extinct species into Umfurudzi Park. This initiative resulted in several species being reintroduced into Umfurudzi Park in 2011. However, the success of this program depends upon the ability of the reintroduced individuals to adapt to the new environment, a key aspect that requires proper monitoring programs. In several cases, research questions on reintroduction programs were largely driven by the monitoring data available (such as population dynamics and habitat usage data) rather than the monitoring being driven by questions identified apriori [10]. Accordingly, we designed monitoring programs to address certain questions relating to the diet of the introduced buffalo, an important animal species in the reintroduction program.

In this study, we assessed the diet profile and quality of buffalo translocated from the south-east lowveld of Zimbabwe, a sweetveld with range forage of high nutritive value compared to Umfurudzi Park, which may greatly challenge the adaptation and viability of these individuals. Umfurudzi Park is in the highveld of Zimbabwe, where herbage crude protein usually drops to less than 30 g kg^{-1} in the dry season, while the lowveld has highly palatable grass species with herbage crude protein content of more than 60 g kg^{-1} in the dry season [20]. The diet profile of buffalo is affected by the acceptability of forage within the range at any time, as well as the availability of high nutritive value forage species within the range [21]. The diet profile of buffalo is expected to shift as with changing seasons (i.e. from wet season to dry season) as the availability of palatable species with high nutritive value declines. Seasonal changes in phenology and nutritive value of grass species influence how these grasses are ultimately utilised by herbivores.

Both the quantity of forage and the availability of a diet with optimum nutritional value are critical to the success of reintroduction programs. Several other factors such as competition, predation, and diseases may contribute to the success of the reintroduction, but herein we focus mainly on the availability, acceptability, and nutritional content of the diet selected by the buffalo with changing seasons. Understanding the seasonal changes in selection of particular plant species and the consequent changes in reintroduced buffaloes' diet composition is important for Park managers in monitoring the success of the reintroduction program and taking appropriate actions to ensure that changing seasons do not limit feed quality and quantity. The objectives of this study were twofold: (1) to assess the availability, acceptance, and dietary contribution of grass species selected by the reintroduced buffalo and, (2) to establish if there were any seasonal variations of crude protein and phosphorus levels in the selected grass species and in the faecal samples of reintroduced buffalo in Umfurudzi Park.

Methods

Study area

Umfurudzi Park is located in Mashonaland Central province of Zimbabwe. It has a surface area of 760 km^2 and lies between 17^o 15´ and 16^o 50´ south and 31^o 40´ and 32^o 0´ north, with altitude from 740 to 1,020 metres (Fig. 1). Umfurudzi Park is in a rehabilitation phase with several wildlife species being reintroduced, buffalo being one of the important species. The area is dominated by grass species such as *Eragrostis racemosa*, *Loudetia simplex,* and *Panicum maximum*. The woody species common in the area include *Brachystegia boehmii, Julbernadia globiflora, Diplorhynchus condylocarpon, Combretum spp., and Colophospermum mopane*. Characteristic of the tropics, there are two distinct seasons, wet and dry, which can be split into four seasons. Umfurudzi Park receives an average rainfall of 650mm, and the temperatures range from 8^oC in winter to 41^oC in summer.

Data collection

All the observations were done in a 30 km^2 double-fenced buffalo release enclosure in the south-west of Umfurudzi Park, established as part of the restoration programme in compliance with a veterinary requirement to avoid mixing of reintroduced buffalo with cattle (Fig. 1). Data were collected from September 2011 to June 2012, a period which covered the natural seasons in Zimbabwe. Data collection was grouped into four seasons: the early wet season (November 2011 to January 2012), late wet season (February to April 2012), cool dry season (May and June 2012), and hot dry season (September and October 2012) [22]. All observations were made during daylight, three days per week between 0600-0900 hours and 1500-1700 hours, for a total of five hours per day. We used a single herd of 25 buffalo, translocated from the south-east lowveld of Zimbabwe, Mwenezi, approximately 650 km from Umfurudzi Park. Umfurudzi Park and Mwenezi have different vegetation types, the former being a typical miombo ecosystem and the latter dominated by *Colophospermum mopane* and *Combretum* spp. Based on general observations, non-provisioned and free-ranging buffalo in Mwenezi graze on grass species such as *Heteropogon contortus*, *Digitatiria* spp., *Phragmitis australis*, and *Stenochlaena cameronii* (J. Stander, *pers. comm.*). Possible levels of competition for forage resources from other feeding guilds in the two areas are almost similar due to the presence of zebra and wildebeest in Mwenezi and Umfurudzi Park.

Our single herd of 25 buffalo were habituated to human presence during a period of acclimatization in bomas before they were released. Bomas are fortified enclosure facilities where captured or translocated animals are kept for a while before they are released to be closely monitored for signs of capture stress, injuries, or other ailments. As a precautionary measure, the Umfurudzi Park management ensured that these buffalo were provisioned during the dry season to increase their chances of survival. Provisioning involved occasionally placing some urea-molasses blocks consisting of 5% urea, 20% molasses, 2% dicalcium phosphate, 30% protein meal, and 4% salt along some common trails in the release area.

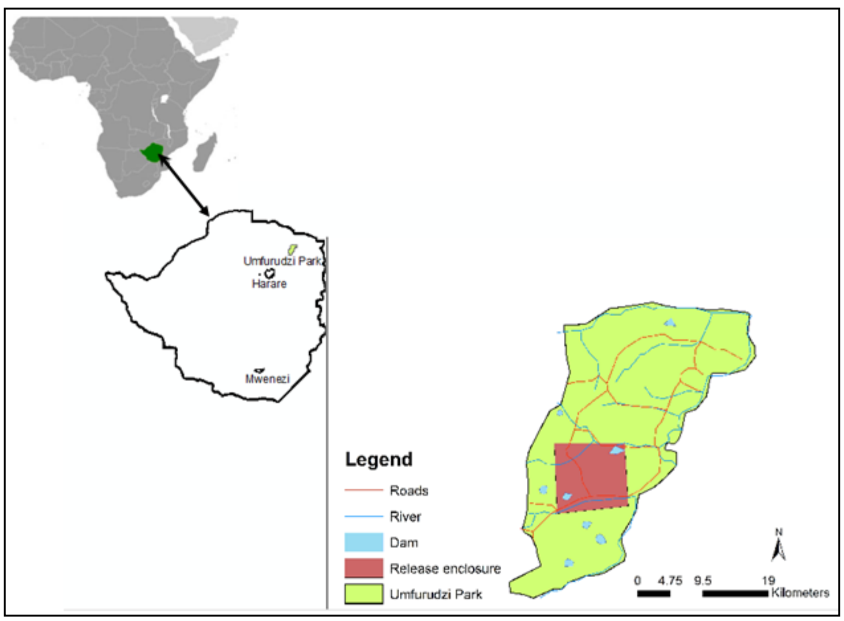

Fig 1: Map of study area showing the reintroduced buffalo release enclosure in Umfurudzi Park, Zimbabwe.

Grass selection

To locate the buffalo herd, spoors were tracked in areas where they are commonly known to occur. The first animal sighted was used as a focal animal to locate the herd's feeding site [23]. The entire area where the herd was observed grazing was considered as the feeding site. Feeding animals were observed from a distance of 50-300 m to avoid disturbing them, with the aid of 10 x 40 Nikon binoculars. To establish a 'micro path', four 1 m^2 quadrats were systematically placed in the feeding site soon after the buffalo left [22]. All grass species within each quadrat were identified (i.e., the species names) and the number of freshly grazed and ungrazed tufts for each species were recorded [23]. In the nearby area where no grazing had occurred, an additional four 1 m^2 quadrats were placed 10 to 15 m apart and the grass species therein were recorded. The selected grass species were used to establish the diet profile of the buffalo. Within the grazed area, grass samples were clipped at 5 cm above the ground to determine the crude protein and phosphorus levels in the selected grasses [19].

Faecal crude protein and phosphorus levels

Fresh dung samples of buffalo were collected twice per week within each feeding site. Where dung was not present within the feeding site, it was collected from nearby areas, an average 10-15 m from the feeding sites. Sand and detritus were carefully brushed off and then the dung samples were put in khaki paper bags. Dung samples were air dried, later crushed and pooled for each site for laboratory analysis to determine faecal crude protein and phosphorus levels [19, 22]. We used nitrogen and phosphorous levels in the grasses and faecal samples as indicators of the nutritive value of reintroduced buffalo diet [24]. The levels of nitrogen and phosphorus in the selected grasses and faecal samples were determined using a Technicon Auto-analyser II [25].

Data analysis

The diversity of grass species selected by buffalo was calculated by the Shannon-Weiner Index [26], using the formula, $H' = -\sum (p_i \times \ln(p_i))$, where p_i is the fraction of the entire population made up of species i, and ln is the natural logarithm. Selected grass species evenness was calculated using the formula E= H'logS, where S is the number of species and H' is the diversity index [26].

Based on the grass species selected by the buffalo, acceptability, availability and dietary contribution were determined using the following: (1) acceptability as the number of quadrats in which the species eaten divided by the number of plots in which the species was present, (2) availability as number of quadrats in which the species was present divided by the total number of quadrats, (3) dietary contribution as number of grass tufts of each species eaten divided by the total number of grass tufts of all species [22, 27]. Statistical analyses were conducted using Statistical Package for Social Sciences version 16.0 for Windows (SPSS Inc, Chicago, USA). Data were tested for normality and homogeneity of variance using Kolmogorov-Smirnov test and Levene's test for homogeneity of variance respectively. Data were found to conform to the normality assumptions.

To test for variation among seasons in the diversity of grass species selected, and levels of crude protein (e.g. % nitrogen × 6.25, [28]) and phosphorus, a one-way ANOVA test was computed. Bonferroni *Post-hoc* tests were performed on variables noted to be significantly different ($p < 0.05$). We further used two ordination approaches, (1) an indirect ordination approach, principal component analysis (PCA), to explore the main components of variation in the selected grasses species diversity and seasons, and (2) a direct gradient analysis, Canonical Correspondence Analysis (CCA) to assess the relationship between the selected grass species and the levels of crude protein and phosphorus using CANOCO Version 4.5 software for Windows and CanoDraw for Windows [29].

Results

A total of 42 grass species were recorded from the buffalo feeding sites in the release area. The reintroduced buffalo selected for 34; 27; 19 and 17 grass species for the early wet, late wet, cool dry and hot dry season respectively. The diversity of grass species selected by buffalo were significantly different ($F_{(3, 44)} = 17.33$; $p < 0.05$) among seasons. However, the evenness of selected grass species was not significantly different among all four seasons. Post-hoc Bonferroni tests for the grass species diversity and evenness across the seasons are shown in Table 1.

Table 1: Diversity attributes of grass species (Mean ± SD) selected by buffalo across seasons in the release area in Umfurudzi Park, Zimbabwe.

Indices	SEASONS			
	Early Wet	Late Wet	Cool Dry	Hot Dry
Shannon-Weiner Index	1.67 ± 0.08^{a}	1.69 ± 0.09^{b}	$0.56 \pm 0.11^{a,b}$	$1.09 \pm 0.10^{a,b}$
Evenness	0.88 ± 0.03	0.83 ± 0.03	0.78 ± 0.04	0.88 ± 0.04

Similar superscripts (a, b) in the same row indicate significant differences (*Bonferroni tests,* $p < 0.05$).

Diet profile

Heteropogon contortus was readily available in all seasons, with a relatively high acceptance level as well as dietary contribution. Similarly, *Lodetia simplex* constituted the bulk of buffalo diet during the cool and hot dry season with the highest acceptance value of 1 compared to other species. The seasonal availability, acceptability and dietary contribution of the various grass species is shown in Table 2. Other than grass species, we noted that buffalo sometimes shifted their diet and spent almost 20% of their time browsing shrubs of woody species such as *Dichrostachys cinerea*, *Brachystegia boehmii* and *Julbernadia globiflora* especially during the dry season.

Table 2. Seasonal availability, acceptance and dietary contribution of grass species selected by reintroduced buffalo in Umfurudzi Park, Zimbabwe. [a]Number of quadrats in which the species was present divided by the total number of quadrats *(n).* [b]Number of quadrats in which the species eaten divided by the number of plots in which the species was present. [c]Number of grass tufts of each species eaten divided by the total number of grass tufts of all species.

Season and Species	[a]Availability	[b]Acceptance	[c]Dietary contribution
Early Wet (n = 48)			
Heteropogon contortus	0.31	1.00	0.25
Eragrostis racemosa	0.27	0.92	0.05
Stenochlaena tenuifolia	0.27	0.75	0.03
Pogonathria squarossa	0.25	0.67	0.01
Themeda triandra	0.23	0.67	0.01
Diheteropogon amplectens	0.17	0.50	0.02
Digitaria diagonalis	0.13	0.42	0.01
Late Wet (n = 40)			
Heteropogon contortus	0.28	0.90	0.14
Hyparrhenia nyassae	0.28	0.71	0.10
Themeda triandra	0.25	0.70	0.11
Eragrostis racemosa	0.23	0.70	0.10
Stenochlaena tenuifolia	0.23	0.81	0.12
Diheteropogon amplectens	0.20	0.50	0.10
Cynodon dactylon	0.18	0.80	0.05
Cool Dry (n = 28)			
Lodetia simplex	0.25	1.00	0.09
Heteropogon contortus	0.21	0.86	0.11
Phragmitis australis	0.21	0.86	0.44
Eragrostis racemosa	0.18	0.71	0.04
Andropogon gayanus	0.14	0.57	0.02
Cyperus rotundas	0.14	0.57	0.02
Cenchrus ciliaris	0.14	0.57	0.03
Hot Dry (n = 24)			
Heteropogon contortus	0.25	1.00	0.09
Lodetia simplex	0.21	0.83	0.01
Phragmitis australis	0.21	0.83	0.09
Eragrostis racemosa	0.17	0.67	0.14
Hyparrhenia hirta	0.17	0.67	0.05
Andropogon gayanus	0.13	0.50	0.05
River hedge grass	0.13	0.50	0.01
Stenochlaena tenuifolia	0.13	0.50	0.01

The seasonal PCA output of the grass species selected by the reintroduced buffalo shows Axis 1 accounting for 38.7% and Axis 2 accounting for 18.5% of the variance (Table 3). There was a distinct separation of grass species in the PCA ordination diagram for the two axes in relation to the four seasons in the release area (Fig. 2).

Table 3. Eigenvalues and variance explained by the Principal Component Analysis.

Axes	1	2	3	4
Eigenvalues	0.39	0.19	0.14	0.08
Cumulative percentage variance of species data	38.70	57.20	71.00	79.10

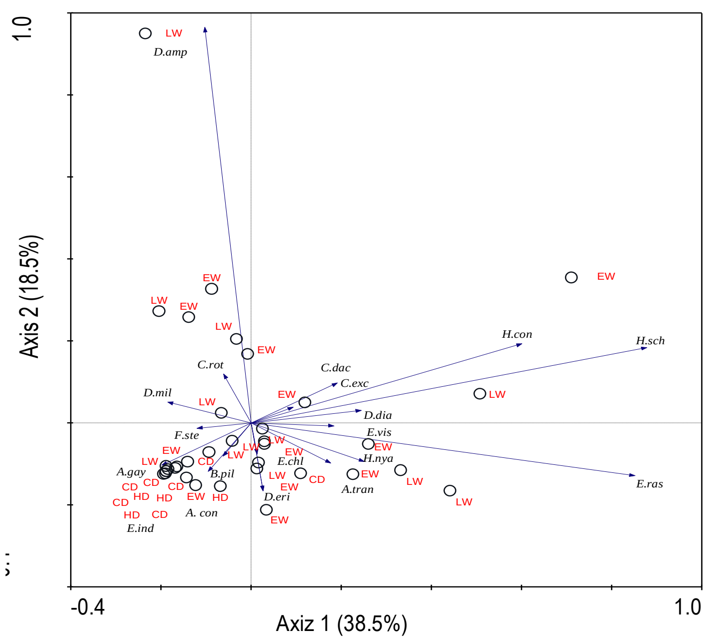

Fig 2. PCA biplot for the selected grass species and seasons in Umfurudzi Park, Zimbabwe. Notes: Grass species selection and seasons: *EW- Early wet season, LW- Late wet season, CD - Cool dry season, HD- Hot dry season*. *D.mil* (*Digitaria milanjiana*), *C.rot* (*Cyperrus rotundus*), *F.ste* (*Fibre stem*), *A.gay* (*Andropogon gayanus*), *E.ind* (*Elusine indica*), *A.con* (*Aristida congesta*), *D.eri* (*Digitaria eriantha*), *A.tra* (*Aristida transvalensis*), *H.nya* (*Hyparrhenia nyassae*), *E.chl* (*Eragrostis chloromelas*), *B.pil* (*Bidens pilosa*), *E.ras* (*Eragrostis rasmosa*), *E.vis* (*Eragrostis viscosa*), *C. exc* (*C. excavata*), *C.dac* (*Cynodon dactylon*), *H.con* (*Heteropogon contortus*), *H.sch* (*Heteropogon schinzii*), *C.rot* (*Cyprrus rotundus*).

Grass and Faecal Crude Protein and Phosphorus Levels

The level of crude protein in grass species selected by reintroduced buffalo were significantly different among seasons ($F_{(3, 44)} = 7.46$; $p < 0.05$). However, Bonferroni post-hoc test showed no significant differences ($p > 0.05$) in the crude protein levels in grass species selected during the early wet, late wet and cool dry seasons. Crude protein levels in the buffalo faecal samples collected between the early wet and hot dry season were not significantly different ($p > 0.05$). However, significant differences ($p < 0.05$) were noted in the crude protein levels in faecal samples, specifically in the early wet, late wet and cool dry seasons (Fig. 3). We noted significant differences ($F_{(3, 44)}$ =13.99; p = 0.014) in the faecal phosphorus levels among seasons. The phosphorus levels in the grass species selected by the buffalo were significantly different ($F_{(3, 44)}$ = 12.23; p < 0.05). Post-hoc test comparisons for the phosphorus levels in faecal and grass samples among the four seasons are shown Table 4.

Table 4. Phosphorous level in grass and faecal samples (Mean ± SD) collected in buffalo feeding sites

	Season			
	Early Wet	**Late Wet**	**Cool Dry**	**Hot Dry**
Faecal	0.51 ± 0.03^{a}	$0.32 \pm 0.04^{a,b}$	$0.29 \pm 0.01^{a,c}$	$0.31 \pm 0.02^{b,c}$
Grasses	0.24 ± 0.11^{d}	0.51 ± 0.12^{d}	0.24 ± 0.04^{e}	$0.14 \pm 0.02^{d,e}$

*Similar superscripts (a, b, c, d, e) in the same row indicate significant difference (*Bonferroni tests, p < 0.05*).

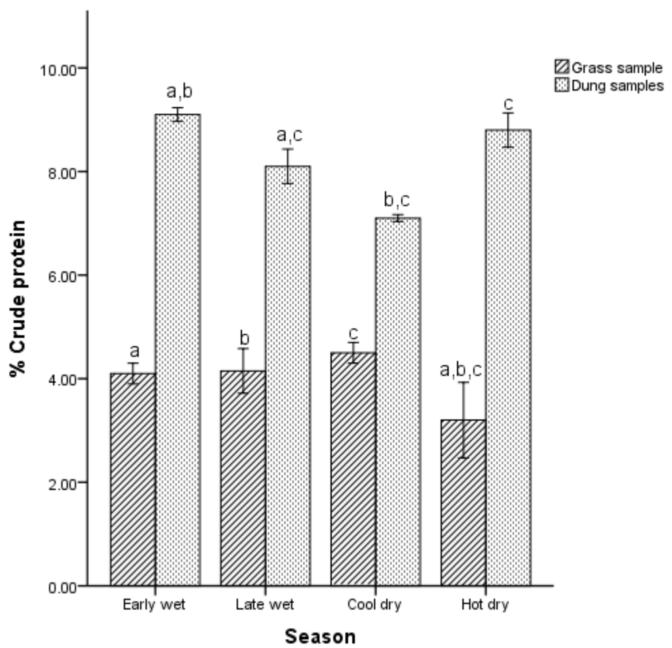

Fig 3: Crude protein levels in the grass and faecal samples (Mean ± SD) collected in feeding sites. Notes: ****Similar superscripts (a, b, c) in the same category represent significant difference (Bonferroni tests, p < 0.05).***

The CCA output for the selected grass species and the associated crude protein and phosphorus levels are shown in Figure 4. The cumulative percentage variance of species-environmental data explained by Axis 1 and 2 of the ordination was 100%. The species-environment correlations of 0.80 and 0.72 for Axis 1 and Axis 2 respectively were high. There was a clear separation of the grass species found in association with the nutrient as well as the season (Fig. 4).

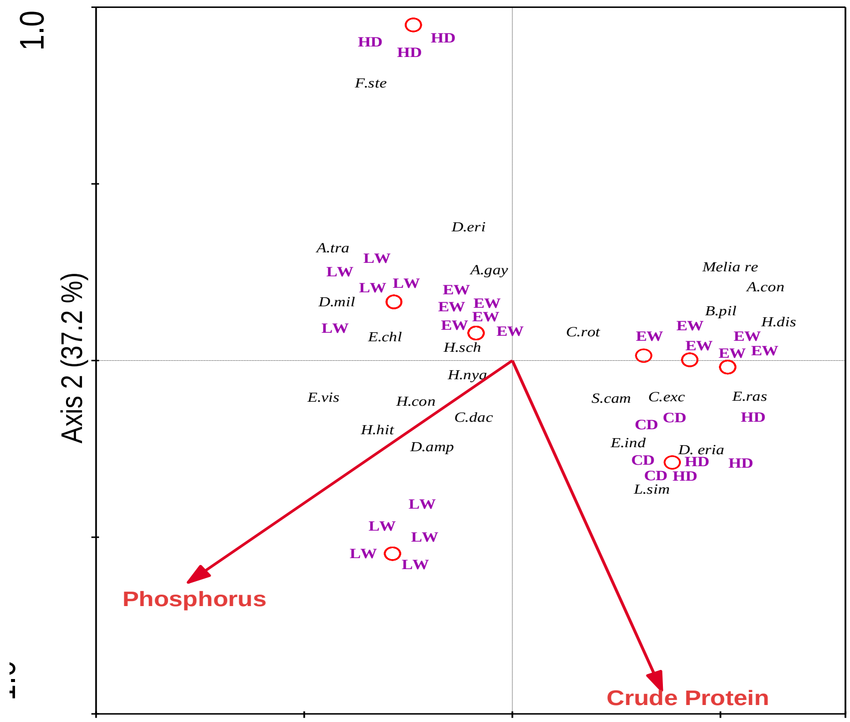

Fig 4. Canonical Correspondence Analysis (CCA) biplot for grass species selected by seasons and the corresponding crude protein and phosphorus levels. Notes: EW-Early Wet season; LW-Late wet Season; CD-Cool Dry Season and HD- Hot Dry Season; *D.mil* (*Digitaria milanjiana*), *C.rot* (*Cyperrus rotundus*), *F.ste* (*Fibre stem*), *A.gay* (*Andropogon gayanus*), *E.ind* (*Elusine indica*), *A.con* (*Aristida congesta*), *D.eri* (*Digitaria eriantha*), *A.tra* (*Aristida transvalensis*), *H.nya* (*Hyparrhenia nyassae*), *E.chl* (*Eragrostis chloromelas*), *B.pil* (*Bidens pilosa*), *E.ras* (*Eragrostis racemosa*), *E.vis* (*Eragrostis viscosa*) *C.exc* (*C. excavate*), *C.dac* (*Cynodon dactylon*), *H.con* (*Heteropogon contortus*), *H.sch* (*Heteropogon schinzii*), *C.rot* (*Cyprrus rotundus*), *H.hit* (*Hyparrhenia hirta*), *S.cam* (*Stenochlaena tenuifolia*).

Discussion

The grass species selected by the reintroduced buffalo in Umfurudzi Park were different from the main species they had foraged in Mwenezi. This difference is attributed to the differences in the eco-regions between these two sites. The seasonal variation in diversity of species selected by the reintroduced buffalo in Umfurudzi Park has been also observed elsewhere [21, 30]. During the wet season, reintroduced buffalos were less selective and utilized a wider spectrum of grass species than in the dry season likely because the nutritive value of grasses generally changes with their morphological development, declining with advancing phenological stage [31]. As the growing stage progresses, i.e. from early wet through the hot dry season, there is a systematic decline in the nutritive value of most grass species [32]. Animals are known to select grass species on the basis of their nutritive value as well as the greenness and the leaf-stem ratio. We argue that most grass species satisfy this criteria during the wet season and are therefore consumed with minimum selectivity compared to the dry season, when most have lost their nutritive value and their acceptability is reduced [21, 32]. Our observations, however, were limited to a smaller, fenced section (i.e., 30 km^2) of Umfurudzi Park, possibly reducing the selectivity of the reintroduced buffalo.

The occurrence of grass species such *Themeda triandra, Diheteropogon amplectens, Digilatira diagonalis* and *Stenochlaena tenuifolia* in the buffalo diet spectrum during the wet season and not in the dry season may not be related to nutritive value but to availability. The observations in this study are, however, contrary to those of buffalo in Doornkloof Nature Reserve (DNR) in the Nama-Karoo, South Africa, where *T. triandra* did not contribute significantly to their diet during the wet season compared to the dry season [30]. In our study, we noted that *Heteropogon contortus* contributed greatly to the diet of buffalo, as it was readily available and acceptable in all seasons, and is a fairly palatable grass species with moderate nutritional value [9, 30]. Though *Panicum* spp. is highly palatable and preferred by most grazers [23], its dietary contribution in this study was very low, likely due to its low availability in the reintroduction area. However, given that buffalo are considered bulk grazers [33], selectivity may be reduced during the dry season when both feed quality and quantity are limiting [17]. We recorded the importance of *Phragmites australis* in the diet of buffalo in Umfurudzi Park particularly during the dry season. Although *P. australis* is not extensively documented in literature, we attributed its occurrence in the buffalo diet to its greenness, as it is confined along the Umfurudzi River.Similar preferences were observed in sable antelope in the Okavango Delta region of northern Botswana, where fibrous grass species that stayed very green through the dry season were selected [27]. The utilization of relatively unpalatable species such as *L. simplex* during the dry season has also been noted in sable antelope (*Hippotragus niger)* [22, 34].

Our results show that grass crude protein levels were higher in the wet season compared to the hot dry season, confirming seasonal variation in the levels of crude protein in forage [31, 35]. However, we noted no differences in crude protein levels between the wet season and cool dry season, which we attribute to availability and acceptance of palatable nutritious grasses [36]. In our study, buffalo selected grass species like *H. contortus, S. cameronni* and *E. racemosa*, which are known to retain their nutritive value, especially crude protein levels, even after the growing season [9]. The high levels of crude protein during the cool dry season may also be related to the green regrowth from the early dry season burning program conducted by the Umfurudzi Park management, as also occurs where similar practices are applied [37]. Phosphorus levels were highest in the cool wet season compared to other seasons, due to the burning program, which increases soil phosphorus levels, unlocking nutrients to the soil and making them available to the plants [38]. This observation is consistent with that for sable antelope in Kgaswane Mountain Reserve, South Africa, where faecal crude protein and phosphorus were higher in burnt areas than in unburnt sections of the Park [37]. In this study, we observed buffalo feeding on *Phragmitis australis* and shrubs of some woody species that were greener during the cool and hot dry seasons. Our results indicate that large herbivores seek out greener than expected vegetation throughout the year by utilizing vegetation with different phonologies and selecting landscapes that are greener than their surroundings [39].

The levels of phosphorus in the grasses did not deviate from other studies where the lowest levels are observed during the hot dry season [24, 35]. Since crude protein and phosphorus levels are usually regarded as a reliable indicator of both the overall nutrient status and palatability of forage [16, 17], we argue that the buffalo can acquire a diet of relatively high nutritive value if fire is used as a management tool during critical periods of the year. More importantly, ungulates prefer burnt areas with higher quality forage [40, 41] since fire influences the quality and structure of grass sward [42]. Fire affects both primary production of ecosystems and the strength of bottom-up control of large herbivores [43]. However, Bond [44] argues that if not managed well, fire may cause nitrogen loss and affect net primary production in ecosystems. In this study, we did not assess the dietary shift in reintroduced buffalo from grazing to browsing during the dry season, when feed quality is usually limiting. We note that browse could have contributed to the crude protein levels that we observed, as was also observed in Kruger National Park, South Africa, where buffalo faecal samples confirmed the utilization of some browse species during the dry season [21]. Nevertheless, Gandiwa [45] reported that grass cover had a stronger influence on wild herbivore densities and distribution in Gonarezhou National Park, southeast Zimbabwe. We did not consider surface water availability as a factor that would affect the habitat quality [45], since there are two perennial rivers as well as several artificial water points in Umfurudzi Park. The contribution of browse species in buffalo diet therefore could be low in Umfurudzi Park but may need to be ascertained with time.

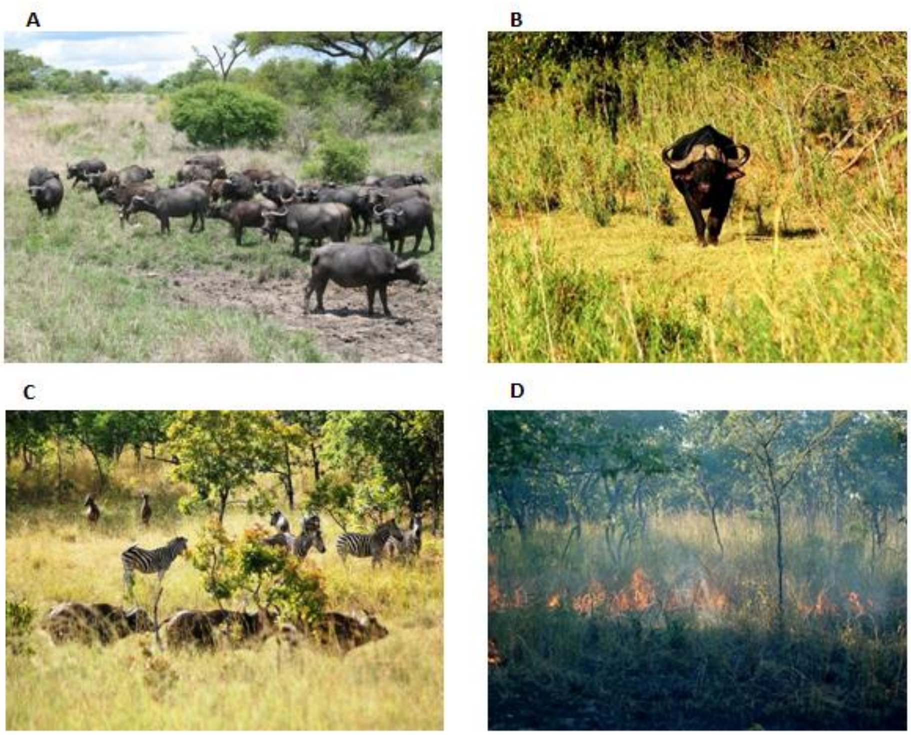

Fig 5- Occurrence of reintroduced buffalo in Umfurudzi Park; (A) Part of the reintroduced buffalo herd during the late wet season (B) Utilization of *Phragmitis australis* along the Umfurudzi river banks by reintroduced buffalo during the dry season (C) Coexistence of reintroduced buffalo with zebra, wildebeest and tsetsebe during the wet season and (D) Early burning programme as part of the active fire management by Umfurudzi Park Management. Photo credits- A, B, C: A. Chanyandura; D: V.K. Muposhi.

The high levels of faecal crude protein during the hot dry season in this study are contrary to the assertion that faecal crude protein follows seasonal variations in the quality of the vegetation [21]. This deviation from the norm may be due to supplementary feeding of reintroduced buffalo using wildlife cubes rich in crude protein during the hot dry season to reduce nutritional stress [46, 47]. However, Venter and Watson [30] recorded no differences between wet and dry season in the faecal crude protein and phosphorus levels of non-provisioned, free-ranging buffalo in the Nama-Karoo, South Africa. Venter and Watson [30] recorded higher values for faecal crude protein and phosphorus than the threshold levels of crude protein (11.5g/kg) and phosphorus (1.9-2.0) levels below which the condition of buffalo deteriorated in Kruger National Park, South Africa. We note that the faecal crude protein and phosphorus levels in the reintroduced buffalo in Umfurudzi Park were also above the recommended threshold for these nutrients [48].

In African savannas, rainfall, temperature, and primary productivity influence the movements of large herbivores and drive changes at different scales [49]. Due to the spatial and temporal heterogeneity of habitats in Umfurudzi Park, we argue that buffalo reintroductions would be viable [50, 51]. Nonetheless, since it is not possible to fence off the whole park in the short term, feed quantity rather than quality might limit the success of this initiative due to the size of the release area, which is currently fenced as a veterinary requirement. Until the release area has been expanded, active management, particularly through provisioning, is thus recommended, to supplement reduced feed quantity during the dry season.

Implications for conservation

Although the importance of reintroductions is widely acknowledged as a tool in conservation, several programs have failed [52]. Success of most translocations has been hindered by neglecting post-release monitoring programs [2, 53]. Our findings form a basis for a long-term monitoring of the buffalo in Umfurudzi Park by first investigating their diet profile and quality, as these affect the viability of most populations. Due to climate variability in the southern Africa region, Umfurudzi Park is also prone to droughts, which may reduce primary productivity and available feed resources for herbivores such as buffalo. Therefore, monitoring of the buffalo diet will be critical, especially during droughts that may affect availability of some preferred grass species and cause mortality due to starvation of wildlife species [54, 55]. We found that there is greater diversity of acceptable grass species in Umfurudzi Park and that the limiting nutrients for most herbivores, such as crude protein and phosphorus, are above the threshold for optimum animal production. Therefore, we assert that the viability of the reintroduced buffalo in Umfurudzi Park will depend on active park management initiatives such as fire management, water provision, and expansion of the release area.

The coexistence of buffalo with other mega herbivores such as zebra (*Equus quagga*) and wildebeest (*Connochaetes taurinus)* in Umfurudzi Park may lead to competition for available food resources. The management of the stocking rates of other mega herbivores and buffalo will be important to reduce density-related mortalities. However, research has shown that although some grazers may use the same patches in the wet season, they tend to occupy and utilise different feeding during the dry season [56], thus reducing the levels of competition through spatial separation [57]. The use of provisioning to supplement the buffalo diet during critical periods is commendable, but should be done with caution as that it may lead to habituation and loss of evolutionary adaptation by the reintroduced buffalo.

We conclude that: (1) there are seasonal variations in the diet profile of the reintroduced provisioned buffalo in Umfurudzi Park as shown by the food availability, acceptance and dietary contribution of selected grass species. Feed availability as a function of habitat quality in the study area may not be limiting for the persistence of the reintroduced buffalo in Umfurudzi Park. (2) Although there were noted seasonal variations in food quality, the reintroduced buffalo selected grass species with relatively higher crude protein and phosphorus levels that were above the recommended threshold levels for survival of herbivores in southern Africa.

We recommend further long-term research to assess: (1) primary productivity of Umfurudzi Park and the actual carrying capacity of the study area, (2) the food resource availability and phenological status, food plant preference, dietary shifts and nutritional quality of protein and fibre and minerals essential to buffalo and other mega herbivores, and (3) the level of competition and resource partitioning with other feeding guilds such as zebra and wildebeest in Umfurudzi Park.

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