African Journal of Ecology

Edge effects: impact of anthropogenic activities on vegetation structure and diversity in western Umfurudzi Park, Zimbabwe

Victor K. Muposhi*, Thelma C. Chademana, Edson Gandiwa and Never Muboko
School of Wildlife, Ecology and Conservation, Chinhoyi University of Technology, P Bag 7724, Chinhoyi, Zimbabwe

Abstract

Understanding the patterns and intensity of anthropogenic impacts on habitats is important in the conservation of tropical ecosystems. The aim of the study was to establish the associated edge effects of anthropogenic disturbances on vegetation in western Umfurudzi Park, Zimbabwe. Three study strata were established using distance from the boundary into the park. Vegetation attributes and anthropogenic disturbance levels data were collected in 2012. Significant differences ($P < 0.05$) were noted on tree and shrub density, woody plant height, woody plant diversity, grass height and grass sward width across the three strata. Land clearing, livestock grazing and firewood collection were the most frequent and pronounced disturbances occurring along the park boundary. These disturbances decreased in intensity as distance from the boundary increased. We recommend the following: (i) the need to revisit the buffer zone concept and policy measures associated with ecosystem services and goods provision for communities surrounding protected areas, (ii) engaging neighbouring communities on sustainable ways of deriving ecosystem goods and services from buffer zones and protected areas and (iii) further studies on the regeneration and recovery of cleared patches along the boundary and their use by wildlife species in the park.

Key words: buffer zone, ecosystem services, Intermediate disturbance hypothesis, protected area management, savannah

Résumé

Bien comprendre le schéma et l'intensité des impacts anthropogéniques sur les habitats est important pour la conservation des écosystèmes tropicaux. Le but de cette étude était de définir les effets de lisière associés aux perturbations d'origine humaine sur la végétation de l'ouest du Parc Umfurudzi, au Zimbabwe. Trois strates furent établies en fonction de la distance par rapport à la limite du parc. Des données ont été collectées en 2012 sur les qualités de la végétation et sur le niveau des perturbations anthropogéniques. Nous avons noté entre les trois strates des différences significatives ($P < 0.05$) dans la densité des arbres et arbustes, la hauteur des plantes ligneuses, leur diversité, la hauteur des herbes, la largeur des bandes herbeuses. Le défrichage, le pâturage du bétail et la collecte de bois de feu étaient les perturbations les plus fréquentes et les plus marquées le long de la limite du parc. Ces perturbations diminuaient d'intensité lorsqu'on s'éloignait de la limite du parc. Nous recommandons ce qui suit : (i) revoir le concept de zone-tampon et les mesures de protection liées aux services écosystémiques et à la fourniture de biens pour les communautés qui entourent les aires protégées, (ii) impliquer les communautés voisines dans des façons durables de prélever des biens et des services dans les zones-tampons et les aires protégées et (iii) faire de nouvelles études sur la régénération et le rétablissement des parties défrichées le long de la limite et sur leur fréquentation par des espèces sauvages dans le parc.

Introduction

There is an emergent realization that the existence of extractive reserves is increasingly becoming important for conserving biodiversity through ecotourism, nontimber forest products and maintenance of ecosystem services (De-Groot *et al.*, 2010; Chambers, Simmons & Wackernagel, 2014; Palomo *et al.*, 2014). Humans are generally physically inseparable from natural systems due to the heavy

*Correspondence: E-mail: muvicck@gmail.com

reliance of local people on natural resources for their subsistence living in tropical areas (Singh & Sharma, 2009). Research has indicated that these areas often coincide with dense human settlements with adverse impacts on the vegetation and ecosystem functioning (Banda, Schwartz & Caro, 2006; Muboko *et al.*, 2014). However, anthropogenic disturbances if left unchecked reduce the capacity of ecosystems to provide goods and services to the reliant human communities (Burkhard *et al.*, 2012). If self-sustaining human environmental systems and a sustainable utilization of natural capital are to be achieved, the supply of multiple goods and services by nature should match the demands of the society (Schneiders *et al.*, 2012; Jax *et al.*, 2013). Rural communities surrounding protected areas often depend on forest resources for their livelihoods. Resource utilization by local communities includes physical processes such as tree felling and biological components such as biomass extraction, species selection and new species introduction (Fischer, Marshall & Camp, 2013). However, threats emanating from utilization of ecosystems are mostly minimized through several approaches, for example policy instruments, incentives and penalties, and law enforcement (Gandiwa, 2013).

Anthropogenic disturbances profoundly alter vegetation structure and diversity (Mligo, 2011; Muboko *et al.*, 2014). Accordingly, the frequency and intensity of disturbances in an area will influence the vegetation structure and diversity of such ecosystems (Banda, Schwartz & Caro, 2006). However, anthropogenic disturbances may influence species diversity as promulgated by the intermediate disturbance hypothesis (IDH) (Connell, 1978). The IDH assumes species diversity would be higher in areas with intermediate disturbances whilst excessive and very little disturbances result in low diversity (Rawal, Gairola & Dhar, 2012). Within this context, species diversity is regulated by disturbance regime and the resultant successional tendency of the ecosystem (Zhang, Chen & Taylor, 2014). There has been a realization that anthropogenic disturbances and resultant edge effects in most protected areas are seldom quantified or assessed and is a critical challenge in conservation (Balme, Slotow & Hunter, 2010). However, proper management of such areas depends on knowledge of ecological processes and variation in species composition and diversity along anthropogenic disturbance gradients (Nesheim, Halvorsen & Nordal, 2010). Nonetheless, monitoring programs towards understanding the relationships between disturbance and vegetation patterns, species diversity and population dynamics in plant communities are least developed in most protected areas (Rawal, Gairola & Dhar, 2012).

In this study, we focus on Umfurudzi Park, a protected area in Zimbabwe under ecological restoration through a public–private partnership between Zimbabwe Parks and Wildlife Management Authority and Pioneer Corporation Africa (Muposhi *et al.*, 2014a). Umfurudzi Park has been subjected to resource exploitation by resettled communities in the western side for firewood, poles, fruits and other nontimber forest products (NTFP) such as insects, for example silkmoth (*Anaphe panda*), pallid emperor moth (*Cirina forda*), *caterpillars* (*Gonimbrasia belina*) and traditional medicine extraction among others (Mukwada, 2008). Here, we explore the influence of anthropogenic impacts on the vegetation structure and diversity in western section of Umfurudzi Park. Understanding the patterns and intensity of anthropogenic impacts is important in the development of management plans for protection or possible revival of such important systems (Shrestha *et al.*, 2013). Accordingly, the objectives of this study were to (i) determine vegetation diversity and structure in relation to distance from the park boundary into the park and (ii) establish the levels of anthropogenic disturbance from the park boundary into the park at different distance gradients in western section of Umfurudzi Park, Zimbabwe.

Materials and methods

Study area

Umfurudzi Park is located in Mashonaland Central province of Zimbabwe. It has a surface area of 760 km² and lies between 17°15′ and 16°50′ south and 31°40′ and 32°00′ north with varying altitude from 740 to 1020 m. Several wildlife species, for example buffalo (*Syncerus caffer*), African elephant (*Loxodonta africana*), wildebeest (*Connochaetes taurinus*) and zebra (*Equus quagga*) have been reintroduced into the park. Dominant grass species in the park include the following: *Eragrostis racemosa*, *Loudetia simplex* and *Panicum maximum* whereas *Brachystegia boehmii*, *Julbernardia globiflora*, *Combretum spp.* and *Colophospermum mopane* are some of the dominant woody species. The average rainfall received per annum is 650 mm whereas the temperatures range from 8°C in winter to 41°C in summer (Muposhi *et al.*, 2014a). This study was conducted in the western section of Umfurudzi Park (Fig. 1).

Study design and sampling procedure

Data collection was conducted between March and May in 2012. A stratified random sampling as modified from Zisadza-Gandiwa *et al.* (2013b) was used in this study. The study area was divided into three strata on the basis of distance from the park boundary at 1.5 km interval between strata;that is boundary strata (within 1 km of park boundary), middle strata (2.5 km from park boundary) and inner strata (4.5 km from park boundary). Five line transects were established systematically at 2.5 km interval in each stratum perpendicular to the park boundary, thus covering about 10.15 km of the western section of Umfurudzi Park boundary where most of the human settlements are located. Along each transect, five-belttransects measuring 300 × 30 m were randomly placed in each strata to assess level of anthropogenic disturbances (see Fig. 1).

Vegetation assessment

To assess woody vegetation and grasses, a series of nested quadrates were established in each belt transect as follows: (i) a plot of 30 × 20 m in size was randomly established in each belt transect for tree species, (total of 15 sampling plots), (ii) 5 × 2 m quadrat nested in the tree plot for shrubs species and (iii) 1 × 1 m quadrats nested in the 5 × 2 m quadrats, two in each for saplings and grasses species assessment as adopted and modified from Mligo *et al.* (2009). Following the approaches outline by Gandiwa & Kativu (2009), the following vegetation attributes were assessed in each plot or quadrat: woody plant height, stem circumference, canopy dimensions (short and long diameter at 90°) and grass sward width. Woody species of 3 m and above were classified as trees

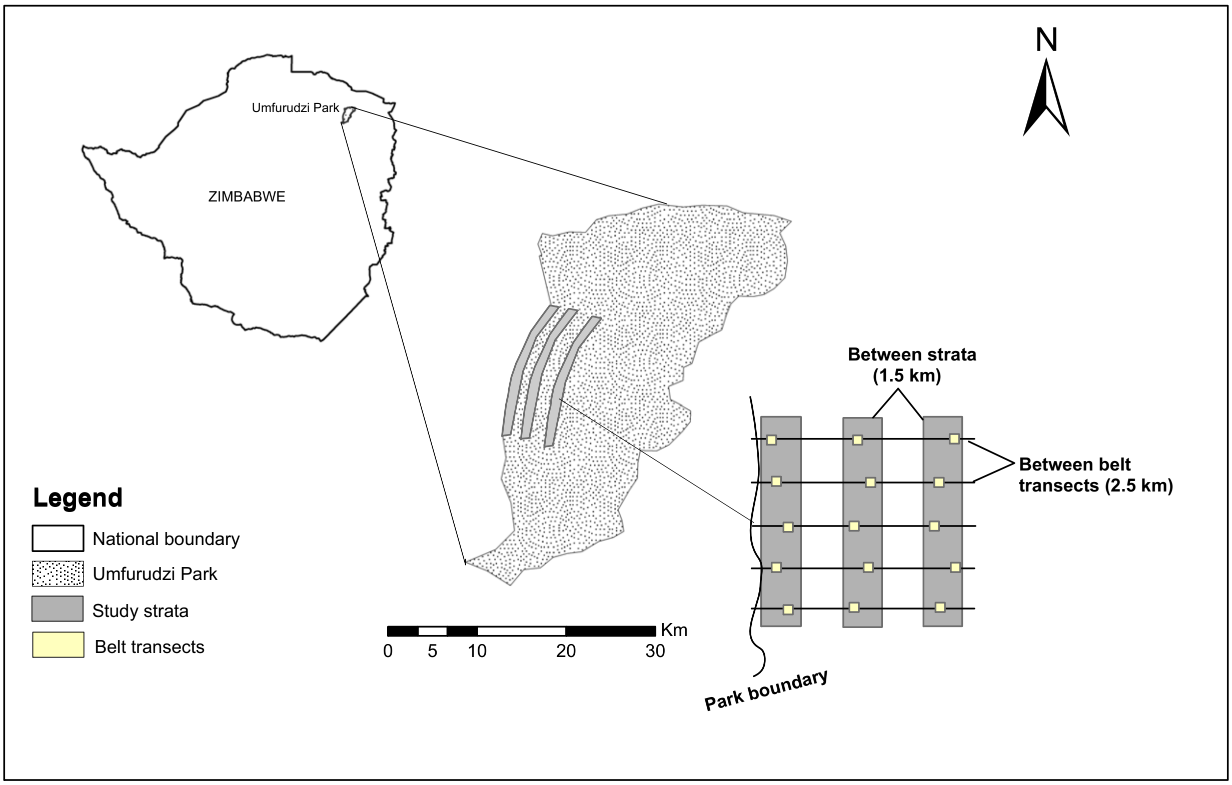

Fig 1 Map showing location of Umfurudzi Park and the three study strata established in the western boundary of the park. Notes: Boundary strata (within 1 km of park boundary), middle strata (2.5 km from park boundary) and inner strata (4.5 km from park boundary)

whereas those < 3 m were considered as shrubs (Witkowski & O'Connor, 1996). Only the woody plants rooted within sample plots were identified and assessed (Gandiwa *et al.*, 2014). We used Coates-Pelgrave (1997) and Frits (2012) field vegetation identification guides for woody and grass species, respectively.

Anthropogenic disturbance assessment

Anthropogenic disturbances emanating from utilization of the western section of Umfurudzi Park by local communities along the boundary were assessed. The following aspects were assessed: fire, fuel wood collection and pole harvesting, livestock grazing, ring barking for making bee hives and tree logging for tobacco curing. The anthropogenic disturbances were qualitatively assessed in each 300 × 30 m belt transect following methods adapted from Mligo, Lyaruu & Ndangalasi (2011) using a six-point scale (0–5) to represent the percentage of the belt transect disturbed as follows: 0 = no disturbance; 1 = 0–20% of the quadrat disturbed; 2 = 21–40% of the quadrat disturbed; 3 = 41–60% of the quadrat disturbed; 4 = 61–80% of the quadrat disturbed; and 5 = 81–100% of the quadrat disturbed.

Data analysis

Collected data on woody vegetation (basal area and density) were summarized as described by Gandiwa & Kativu (2009):

Basal area = ($c^2/4\pi$), where C is the stem circumference.

Density (y/ha) = [($x \times 10\,000$ m^2)/(plot area m^2)], where y denotes any of the trees or shrubs and x is the recorded number of trees and shrubs.

Canopy cover = $(D1 + D2)/2$, where D1 and D2 are the canopy dimensions at 90^0.

Relative density (%), relative dominance and important value index of each species were computed following the formulae after Brashears, Fajvan & Schuler (2004):

RD (%) = $(n_i/N) \times 100$, where, RD is the relative density of the species; n_i is the number of individuals of species i and N is the total number of all individual trees.

RDo (%) = $(\Sigma Ba_i \times 100)/(\Sigma Ba_n)$, where, RDo is the relative dominance of the species; Ba_i is the basal area of all individual trees belonging to a particular species *i*; Ba_n is the basal area of the stand.

IVI = (RD × RDo)/2, where, IVI is the Important Value Index, RD is the relative density and RDo is the relative dominance.

Woody vegetation and grass species diversity were established using the Shannon–Weiner diversity index (H′) (Ludwig & Reynolds, 1988). Vegetation data were tested for normality and homogeneity of variance using Kolmogorov–Smirnov test and Levene's test for homogeneity of variance, respectively. All vegetation data were found to be conforming to the normality assumptions. A one-way analysis of variance (ANOVA) was computed to test whether there were any differences in the vegetation attributes across the three study strata at 5% level of significance. Were significant differences were noted ($P < 0.05$), Tukey's Honestly Significant Differences (HSD) was computed. To assess the differences in the level of disturbances across strata, we used Kruskal–Wallis (Chi-square) test using SPSS Version 20 for windows (SPSS Inc, Chicago, USA).

To determine the association of study plots across the strata based on the vegetation attributes, a multivariate analysis using an ordination technique was carried out. We performed a linear method ordination technique, principal component analysis (PCA) using CANOCO Version 5.0 software for windows (Ter Braak & Smilauer, 2002). Principal Component Analysis was used because the data were compositional and had a gradient length of 2.4 SD units and is the recommended technique under such circumstances (Ter Braak & Smilauer, 2002). We further performed a hierarchical cluster analysis (HCA) using weighted average linkage using a matrix of 15 sampling plots and woody species abundance data to classify sampling plots on the basis of their species diversity.

Results

Vegetation structure and diversity

A total of 661 individual woody plants were assessed, 48% of these were trees, 48% shrubs and 4% were saplings. We recorded 36 woody plant species and 17 grass species in the three study strata. Although most vegetation structural and diversity attributes were different ($P < 0.05$) across the three study strata, there were no significant differences in tree basal area ($F_{(2, 12)} = 1.38$, $P = 0.289$) and grass species diversity ($F_{(2, 12)} = 2.89$, $P = 0.095$, Table 1).

Table 1 Vegetation species attributes for 15 sample plots (mean ± SD) across the study strata in western Umfurudzi Park and significant levels from ANOVA with equal sample size tests

	Strata				
Variable	Boundary	Middle	Inner	$F_{(2, 12)}$	*P* value
Woody plant height (m)	1.84 ± 2.66[a]	5.40 ± 0.94[b]	5.17 ± 0.45[b]	7.31	**0.008**
Tree basal area (m^2/ha^{-1})	0.12 ± 0.14[a]	0.33 ± 0.17[a]	0.18 ± 0.01[a]	1.38	0.289
Tree canopy cover (m^2/ha^{-1})	2.32 ± 2.34[a]	8.68 ± 1.34[b]	8.35 ± 1.16[b]	8.01	**0.006**
Tree density (trees ha^{-1})	77.78.67 ± 58.84[a]	883.33 ± 368.20[b]	794.44 ± 215.70[b]	14.11	**0.001**
Tree species diversity (H′)	0.41 ± 0.91[a]	2.00 ± 0.38[b]	1.66 ± 0.35[b]	9.72	**0.003**
Shrub density (shrubs ha^{-1})	961.12 ± 244.55[a]	327.78 ± 106.33[b]	461.12 ± 104.48[b]	7.34	**0.008**
Shrub diversity (H′)	2.27 ± 0.33[a]	1.64 ± 0.34[b]	1.72 ± 0.28[b]	5.90	**0.016**
Stump density (stumps ha^{-1})	473.00 ± 216.52[a]	54.33 ± 19.81[b]	20.67 ± 13.17[b]	19.92	**0.000**
Grass species height (m)	0.76 ± 0.24[a]	0.50 ± 0.07[b]	0.52 ± 0.09[b]	4.53	**0.034**
Grass species diversity (H′)	0.96 ± 0.33[a]	0.88 ± 0.13[a]	0.87 ± 0.09[a]	2.89	0.095
Grass sward width (cm)	0.22 ± 0.12[a]	0.11 ± 0.03[b]	0.09 ± 0.02[b]	5.07	**0.025**

Significant values are indicated in bold; values with different superscript letters (a, b) within rows differ significantly (Tukey's HSD; ***P*** < 0.05).
Boundary strata (within 1 km of park boundary), middle strata (2.5 km form park boundary) and inner strata (4.5 km from park boundary).

Significant differences were noted in grass height ($F_{(2, 12)} = 4.53$, $P = 0.034$) and grass sward width ($F_{(2, 12)} = 5.07$, $P = 0.025$). However, Tukey's HSD post hoc tests showed that grass height and sward width observed in middle and core strata were not significantly different ($P > 0.05$). No significant differences were noted for the grass species diversity ($F_{(2, 12)} = 2.89$, $P = 0.095$) and grass density ($F_{(2, 12)} = 0.25$, $P = 0.951$) across strata (Table 1).

From the PCA, we present principal component 1 and 2, explaining about 66.88% of the cumulative variation in vegetation attributes across the three study strata. Here, Axis 1 (eigenvalue = 0.50) defines a gradient from plots and sites with greater tree canopy cover, tree density, that is those in the middle and inner strata, to sites with high grass diversity and shrub diversity, occurring along the boundary. Axis 2 (eigenvalue = 0.17) defines a gradient from plots and sites with low shrub canopy cover to areas with greater grass density and diversity which were mainly found in boundary strata (Fig. 2). There was a clear separation of sample plots occurring along the boundary from those in middle and inner strata. Three broad clusters on the basis of species diversity and abundance in the strata. Cluster one consisted of two sample plots with high species diversity and abundance. Cluster two had six sample plots from which one was an outlier, belonging to the boundary strata. The third cluster had 7 sample plots with low species diversity and abundance (Fig. 3).

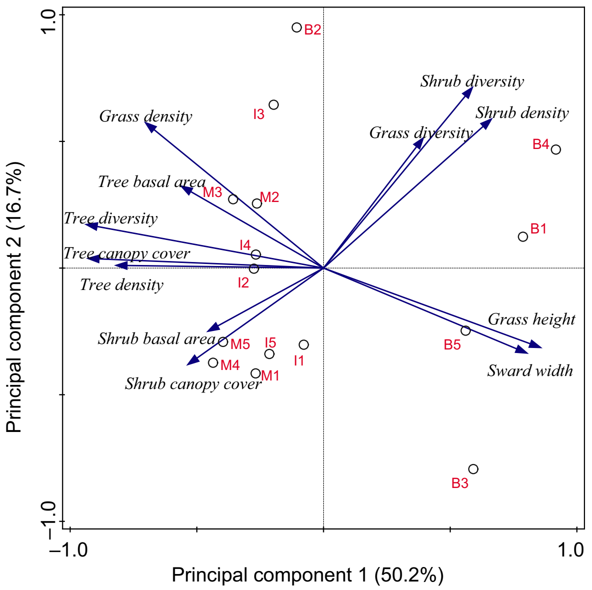

Fig 2 Principal component analysis biplot of vegetation variables from 15 sample plots in western section of Umfurudzi Park, Zimbabwe. Notes: B represents boundary strata, M represents middle strata and I represent inner strata

The most dominance and least important woody species across the three strata using the important value index

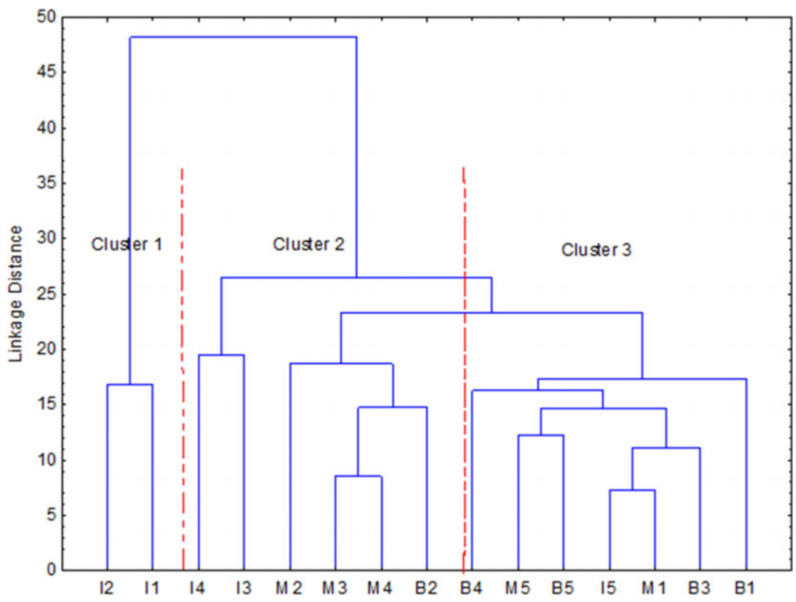

Fig 3 Hierarchical cluster analysis dendrogram showing classification of sample plots into three clusters based on species diversity measures from 15 sample plots in western section of Umfurudzi Park. Notes: I denotes inner strata plots, M denotes middle strata plots, B denotes boundary strata plots

(IVI) are shown in Table 2. Woody species composition and the importance of each of the species varied from one stratum to the other with some overlaps. The most dominant species with the highest IVI for the boundary, middle and core strata were *Monotes glaber*, *Pterocarpus rotundifolius* and *Brachystegia utilis*, respectively. However, *Bauhinia petersiana*, *Pterocarpus angolensis* and *Gardenia ternifolia* were the least important species for the three strata, respectively.

Anthropogenic disturbances

The main disturbances observed in the study strata were livestock grazing, fire, land clearing and poles, and firewood collection. Of these, we noted significant differences in level of livestock grazing ($\chi^2 = 11.67$, df = 2, $P = 0.003$), land clearing ($\chi^2 = 15.00$, df = 2, $P = 0.001$) and firewood collection ($\chi^2 = 6.96$, df = 2, $P = 0.030$) across the three study strata. However, multiple comparison tests showed no significant differences in the level of these disturbances between middle and inner strata (Table 3). More so, the three strata seemed to have experienced the same levels of fire disturbances ($\chi^2 = 0.54$, df = 0.768) during the study period.

Discussion

The results of this study show differences in tree and shrub species diversity and canopy cover across the three study strata. Woody species composition and importance value index differed by strata. The levels of anthropogenic disturbances were more pronounced within the boundary strata compared to the middle and inner strata of the park. The study shows a disturbance gradient from the park boundary into the inner sections of the park.

The differences in structural and compositional attributes in this study could be related to the level of disturbances in each strata such as fire, livestock grazing, land clearing and firewood collection as reported in other studies (Gandiwa & Kativu, 2009; Collantes *et al.*, 2013; Muboko *et al.*, 2014). Our findings are similar to those recorded by Zisadza-Gandiwa *et al.* (2013a) in the northern Gonarezhou National Park and adjacent areas where structural and compositional diversity of vegetation communities across different land uses differed. However, in this study, we did not consider other factors such as altitude (Eisenlohr *et al.*, 2013; Lee *et al.*, 2013), soil type (Tessema *et al.*, 2011; Bansal, James & Sheley, 2014; Gandiwa *et al.*, 2014) and geology (Smit *et al.*, 2013). Nonetheless, we note that the variations in soil type in western Umfurudzi Park as influenced by the geology and

Table 2 The dominant and least important woody species (IV 300) recorded for the three study strata

Strata	Species	R.Do	R. Freq	R. De	IVI
Boundary	*Monotes glaber*	100.00	100.00	100.00	300.00
	Brachystegia boehmii	78.86	44.44	30.77	154.07
	Terminalia stenostachya	5.17	22.22	15.38	42.78
	Acacia nigrescens	6.35	11.11	7.69	25.15
	Philenoptera violacea	3.33	11.11	7.69	22.13
	Diospyros mespiliformis	2.45	11.11	7.69	21.25
	Lannea discolour	2.45	11.11	7.69	21.25
	Acacia karroo	0.61	11.11	7.69	19.41
	Pterocarpus rotundifolius	0.42	11.11	7.69	19.23
	Bauhinia petersiana	0.37	11.11	7.69	19.17
Middle	*Pterocarpus rotundifolius*	6.15	81.82	20.45	108.42
	Brachystegia boehmii	43.08	82.23	25.98	151.29
	Terminalia stenostachya	18.56	59.48	16.10	94.14
	Brachystegia utilis	17.37	42.86	14.63	74.86
	Terminalia brachystemma	4.16	35.71	12.20	52.06
	Combretum psidioides	0.44	9.09	2.27	11.81
	Acacia karroo	0.26	9.09	2.27	11.63
	Strychnos madagascariensis	1.26	7.74	2.54	11.53
	Flacourtia indica	0.50	8.33	2.63	11.47
	Pterocarpus angolensis	0.25	7.14	2.44	9.83
Inner	*Brachystegia utilis*	76.86	183.33	44.00	304.19
	Brachystegia boehmii	42.22	77.41	20.13	139.76
	Combretum collinum	13.88	100.00	32.26	146.14
	Terminalia stenostachya	5.27	87.5	23.33	116.10
	Monotes glaber	13.00	71.4	27.78	112.20
	Crossopteryx febrifuga	5.79	31.67	7.40	44.86
	Bridelia cathartica	1.59	17.53	4.31	23.43
	Pseudolachnostylis maprouneifolia	0.51	16.67	2.56	19.74
	Combretum psidioides	0.67	10.00	3.23	13.90
	Gardenia ternifolia	0.67	10.00	3.23	13.90

R. De: denotes Relative density, R. Do: Relative dominance, Re. Freq frequency and IVI: Importance value index.

Table 3 Summary of statistical analyses from Kruskal–Wallis (Median test) results of the study disturbance variables across the three study strata in western section of Umfurudzi Park, Zimbabwe

	Strata			
Disturbance	Boundary	Middle	Inner	*P* value
Grazing	5 (13.0)[a]	1 (7.3)[b]	0 (3.5)[b]	**0.002**
Fire	3 (9.6)[a]	2 (7.5)[a]	2 (6.9)[a]	0.604
Land clearing	5 (13)[a]	0 (5.5)[b]	0 (5.5)[b]	**0.001**
Firewood	4 (10.9)[a]	3 (9.1)[a, b]	0 (4.0)[b]	**0.028**

Values in bold indicate significant differences, and those in brackets indicate the range. Different superscripts (a, b) in the same row indicate significant differences ($P < 0.05$).

termite mounds is more distinct (Muposhi *et al.*, 2014b). Termite mounds induced changes in soil parameters especially clay enrichment, and increased cation concentrations may induce heterogeneity in the vegetation structure and composition (Erpenbach *et al.*, 2013; Støen *et al.*, 2013). In other areas, altitude has been observed to influence vegetation structure and diversity (Aynekulu *et al.*, 2012; Pokhriyal, Chauhan & Todaria, 2012; Eisenlohr *et al.*, 2013). The variation in altitude in the study area (Muposhi *et al.*, 2014a) may be contributing to the observed patterns in vegetation structure and composition in western Umfurudzi Park other than the issue of anthropogenic disturbances.

In this study, anthropogenic disturbances have been observed to be higher closer to the park boundary compared to inside the park as observed elsewhere (Mligo, Lyaruu & Ndangalasi, 2011; Zisadza-Gandiwa *et al.*, 2013a). We argue that the Umfurudzi Park buffer zone of the western section has been completely fragmented due to human encroachment. Communities surrounding Umfurudzi Park have been previously observed to be heavily dependent on the park for several goods and services that may affect the vegetation structure and composition. (Mukwada, 2008). Human encroachment and disturbances in protected areas are common and seem to pose a threat to biodiversity conservation in southern Africa (Wolmer, 2005). In Mozambique's Limpopo National Park, over 27,000 people live in the park; 7000 of these are meant to be resettled to areas along the margins of the park (Lunstrum, 2008; Milgroom & Spierenburg, 2008). Similarly, in Gonarezhou National Park, livestock encroachment for pastures has affected up to 20 km deep into the park with serious implications on the vegetation and wildlife (Gandiwa *et al.*, 2011, 2013).

Our findings show a pattern of increasing species diversity with changing intensity of anthropogenic disturbances as reported by Chinuwo *et al.* (2010) in the buffer zone of western Umfurudzi Park. We argue that the patterns assumed by the vegetation diversity conform to the classical intermediate disturbance hypothesis (IDH) of Connell (1978). Nonetheless, a contrasting trend has been reported in the miombo ecoregion of central Zimbabwe by McKee (2012). Li *et al.* (2004) argues that the response of vegetation to disturbance gradients may show many patterns depending on how they are defined and modelled rather than the simple bell-shaped curve as depicted by the IDH. Several other ecological mechanisms may influence the patterns of vegetation structure and composition, resulting in several other patterns regardless of disturbance levels (Kiviat *et al.*, 2010; Gandiwa *et al.*, 2014). Although our results conform to the IDH and aspect of edge effects on ecosystems (Newmark, 2008; Balme, Slotow & Hunter, 2010), we argue that disturbance regimes are complex and responses of ecosystems are influenced by multiple mechanisms that interact in a dynamic way (Fox, 2013; Sheil & Burslem, 2013).

We expect the level of anthropogenic disturbances to decline with time given the establishment of a game fence along the Umfurudzi Park boundary in (Muposhi *et al.*, 2014a). The fence is a wildlife veterinary legal requirement in Zimbabwe especially when introducing buffalo (Taylor & Martin, 1987). However, fencing in itself should not be considered as a panacea to the human encroachment protected areas as these issues are highly contested in communal areas adjacent to protected areas (Muboko & Murindagomo, 2014). There is need to understand how the socio-economic transitions influence vegetation change and the existing relationships in human-impacted ecosystems (Twine, 2005). Ensuring that communities have access to the ecosystem goods and services should therefore be the concern of conservation agents to balance the trade-offs of conservation and societal needs (Palomo *et al.*, 2013).

Conclusion

The objectives of this study were to (i) determine vegetation diversity and structure in relation to distance from the park boundary into the inner strata of the park and (ii) establish the levels of anthropogenic disturbance from the park boundary into the inner strata of the park at different distance gradients. Based on our findings, we conclude that there is: (i) a difference in the vegetation structure and diversity as distance from the park boundary to the core of the park increases and (ii) an anthropogenic disturbance gradient as distance from the park boundary to the core of the park increases. To reduce the edge effects and associated impacts of anthropogenic disturbances on Umfurudzi Park ecosystem, we recommend the following: (i) revisit the buffer zone concept, policy measures and law enforcement associated with ecosystem services and goods provision for communities surrounding protected areas, (ii) engaging park authorities and communities on ecosystem goods and services derived from buffer zones and protected areas through a participatory park planning process and rangeland management and (iii) further studies on the regeneration and recovery of cleared patches along the boundary and their use by the reintroduced wildlife species in the park.

Acknowledgements

We are grateful to Umfurudzi Park management and Jan Stander for their support during this study. Comments and suggestions from two anonymous reviewers helped improve the earlier versions of this manuscript.

References

Aynekulu, E., Aerts, R., Moonen, P., Denich, M., Gebrehiwot, K., Vågen, T.-G., Mekuria, W. & Boehmer, H.J. (2012) Altitudinal variation and conservation priorities of vegetation along the Great Rift Valley escarpment, northern Ethiopia. *Biodivers. Conserv.* **21**, 2691–2707.

Balme, G., Slotow, R. & Hunter, L. (2010) Edge effects and the impact of non-protected areas in carnivore conservation: leopards in the Phinda–Mkhuze Complex, South Africa. *Anim. Conserv.* **13**, 315–323.

Banda, T., Schwartz, M.W. & Caro, T. (2006) Woody vegetation structure and composition along a protection gradient in a miombo ecosystem of western Tanzania. *Forest Ecol Manag.* **230**, 179–185.

Bansal, S., James, J.J. & Sheley, R.L. (2014) The effects of precipitation and soil type on three invasive annual grasses in the western United States. *J. Arid Environ.* **104**, 38–42.

Brashears, M.B., Fajvan, M.A. & Schuler, T.M. (2004) An assessment of canopy stratification and tree species diversity following clearcutting in central Appalachian hardwoods. *For. Sci.* **50**, 54–64.

Burkhard, B., Kroll, F., Nedkov, S. & Müller, F. (2012) Mapping ecosystem service supply, demand and budgets. *Ecol Indic.* **21** (1), 7–29.

Chambers, N., Simmons, C. & Wackernagel, M. (2014) *Sharing nature's interest: ecological footprints as an indicator of sustainability*. Earthscan, Routledge, New York.

Chinuwo, T., Gandiwa, E., Mugabe, P.H., Mpofu, I.D.T. & Timpong-Jones, E. (2010) Effects of previous cultivation on regeneration of Julbernadia globiflora and Brachystegia spiciformis in grazing areas of Mupfurudzi Resettlement Scheme, Zimbabwe. *Afr J Range Forage Sci.* **27**, 45–49.

Coates-Pelgrave, K. (1997) *Trees of southern Africa*. Struik Publishers, Cape Town.

Collantes, M.B., Escartín, C., Braun, K., Cingolani, A. & Anchorena, J. (2013) Grazing and Grazing Exclusion Along a Resource Gradient in Magellanic Meadows of Tierra del Fuego. *Rangeland Ecol. Manag.* **66**, 688–699.

Connell, J.H. (1978) Diversity in tropical rain forest and coral reefs. *Science* **199**, 1302–1310.

De-Groot, R.S., Alkemade, R., Braat, L., Hein, L. & Willemen, L. (2010) Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. *Ecol. Complex.* **7**, 260–272.

Eisenlohr, P.V., Alves, L.F., Bernacci, L.C., Padgurschi, M.C., Torres, R.B., Prata, E.M., Dos Santos, F.A.M., Assis, M.A., Ramos, E. & Rochelle, A.L.C. (2013) Disturbances, elevation, topography and spatial proximity drive vegetation patterns along an altitudinal gradient of a top biodiversity hotspot. *Biodivers. Conserv.* **22**, 2767–2783.

Erpenbach, A., Bernhardt-Römermann, M., Wittig, R., Thiombiano, A. & Hahn, K. (2013) The influence of termite-induced heterogeneity on savanna vegetation along a climatic gradient in West Africa. *J. Trop. Ecol.* **29**, 11–23.

Fischer, A., Marshall, P. & Camp, A. (2013) Disturbances in deciduous temperate forest ecosystems of the northern hemisphere: their effects on both recent and future forest development. *Biodivers. Conserv.* **22**, 1863–1893.

Fox, J. W. (2013) The intermediate disturbance hypothesis should be abandoned. *Trends Ecol. Evol.* **28**, 86–92.

Frits, O. (2012) *Guide to grasses of Southern Africa*. Briza, South Africa.

Gandiwa, E. (2013) *The Numbers Game in Wildlife Conservation: Changeability and framing of large mammal numbers in Zimbabwe*. PhD, Wageningen University, Wageningen.

Gandiwa, E. & Kativu, S. (2009) Influence of fire frequency on Colophospermum mopane and Combretum apiculatum woodland structure and composition in northern Gonarezhou National Park, Zimbabwe. *Koedoe.* **51**, Art.685, 613 DOI: 10.4102/koedoe.v51i1.685.

Gandiwa, P., Matsvayi, M., Ngwenya, M. M. & Gandiwa, E. (2011) Assessment of livestock and human settlement encroachment into northern Gonarezhou National Park, Zimbabwe. *JSDA.* **13**, 19–33.

Gandiwa, E., Heitkönig, I. M., Gandiwa, P., Matsvayi, W., Van Der, W. & Ngwenya, M. (2013) Large herbivore dynamics in northern Gonarezhou National Park, Zimbabwe. *Trop. Ecol.* **54**, 345–354.

Gandiwa, E., Zisadza-Gandiwa, P., Goza, D., Mashapa, C. & Muboko, N. (2014) Diversity and structure of woody vegetation across areas with different soils in Gonarezhou National Park, Zimbabwe. *Southern Forests.* **76**, 111–116.

Jax, K., Barton, D.N., Chan, K.M.A., Groot, R.D., Doyle, U., Eser, U., Görg, C., Gómez-Baggethun, E., Griewald, Y., Haber, W., Haines-Young, R., Heink, U., Jahn, T., Joosten, H., Kerschbaumer, L., Korn, H., Luck, G.W., Matzdorf, B., Muraca, B., Neßhöver, C., Norton, B., Ott, K., Potschin, M., Rauschmayer, F., Haaren, V.C. & Wichmann, S. (2013) Ecosystem services and ethics. *Ecol. Econ.* **93**, 260–268.

Kiviat, E., Mihocko, G., Stevens, G., Groffman, P. M. & Van Hoewyk, D. (2010) Vegetation, soils, and land use in calcareous fens of eastern New York and adjacent Connecticut. *Rhodora.* **112**, 335–354.

Lee, C. B., Chun, J. H., Song, H. K. & Cho, H. J. (2013) Altitudinal patterns of plant species richness on the Baekdudaegan Mountains, South Korea: mid-domain effect, area, climate, and Rapoport's rule. *Ecol. Res.* **28**, 67–79.

Li, J., Loneragan, W.A., Duggin, J.A. & Grant, C.D. (2004) Issues affecting the measurement of disturbance response patterns in herbaceous vegetation – A test of the intermediate disturbance hypothesis. *Plant Ecol.* **172**, 11–26.

Ludwig, J. A. & Reynolds, J. F. (1988) *Statistical ecology: a primer in methods and computing*. John Wiley & Sons, New York.

Lunstrum, E. (2008) Mozambique, Neoliberal land Reform and the Limpopo National Park. *Georg Rev.* **98**, 339–355.

McKee, C.J. (2012) *Spatial Patterns and Population Performance of Mule Deer: Responses to Water Provisioning in Mojave National Preserve*. Master of Science, University of Nevada, Reno, California.

Milgroom, J. & Spierenburg, M. (2008) Induced volition: Resettlement from the Limpopo National Park, Mozambique. *J Contemp Afr Stud.* **26**, 435–448.

Mligo, C. (2011) Anthropogenic disturbance on the vegetation in Makurunge Woodland, Bagamoyo district, Tanzania. *Tanz. J. Sci.* **37**, 94–108.

Mligo, C., Lyaruu, H. & Ndangalasi, H. (2011) The effect of anthropogenic disturbances on population structure and regeneration of Scorodophloeus fischeri and Manilkara sulcata in coastal forests of Tanzania. *Southern Forests.* **73**, 33–40.

Mligo, C., Lyaruu, H., Ndangalasi, H. & Marchant, R. (2009) Vegetation community structure, composition and distribution pattern in the Zaraninge forest, Bagamoyo District, Tanzania. *JEANH.* **98**, 223–239.

Muboko, N. & Murindagomo, F. (2014) Wildlife control, access and utilisation: Lessons from legislation, policy evolution and implementation in Zimbabwe. *J Nat Conserv.* **22**, 206–211.

Muboko, N., Chigumira, T., Mashapa, C., Gandiwa, E., Chibememe, G. & Muposhi, V.K. (2014) Impacts of Wood Poaching on Vegetation Structure and Composition in Mukuvisi Woodland, Zimbabwe. *JEP.* **5**, 156–163.

Mukwada, G. (2008) Voices from the Past and Echoes of the Future: Management of Forest and Woodland Resources by Local Religious Institutions within the Mufurudzi Resettlement Scheme in Zimbabwe. *JEA.* **12**, 39–53.

Muposhi, V.K., Chanyandura, A., Gandiwa, E., Muvengwi, J., Muboko, N., Taru, P. & Kupika, O. L. (2014a) Post-release monitoring of diet profile and diet quality of reintroduced African buffalo (*Syncerus caffer*) in Umfurudzi Park, Zimbabwe.. *TCS.* **7**, 440–456.

Muposhi, V.K., Ndlovu, M., Gandiwa, E., Muvengwi, J. & Muboko, N. (2014b) Vegetation structure and composition prior to wildlife reintroductions in southern Umfurudzi Park, Zimbabwe. *J. Ani. Plant. Sci.* **24**, 1680–1690.

Nesheim, I., Halvorsen, R. & Nordal, I. (2010) Plant composition in the Maya Biosphere Reserve: natural and anthropogenic influences. *Plant Ecol.* **208**, 93–122.

Newmark, W.D. (2008) Isolation of African protected areas. *Front. Ecol. Environ.* **6**, 321–328.

Palomo, I., Martín-López, B., Potschin, M., Haines-Young, R. & Montes, C. (2013) National Parks, buffer zones and surrounding lands: mapping ecosystem service flows. *Ecosystem Services.* **4**, 104–116.

Palomo, I., Montes, C., Martín-López, B., González, J. A., García-Llorente, M., Alcorlo, P. & Mora, M. R. G. (2014) Incorporating the Social–Ecological Approach in Protected Areas in the Anthropocene. *Bioscience.* **64**, 181–191.

Pokhriyal, P., Chauhan, D.S. & Todaria, N.P. (2012) Effect of altitude and disturbance on structure and species diversity of forest vegetation in a watershed of central Himalaya. *Trop. Ecol.* **53**, 307–315.

Rawal, R.S., Gairola, S. & Dhar, U. (2012) Effects of disturbance intensities on vegetation patterns in oak forests of Kumaun, west Himalaya. *J Mt Sci-Engl.* **9**, 157–165.

Schneiders, A., Daele, T.V., Landuyt, W.V. & Reeth, W.V. (2012) Biodiversity and ecosystem services: Complementary approaches for ecosystem management? *Ecol Indic.* **21**, 123–133.

Sheil, D. & Burslem, D. (2013) Defining and defending Connell's intermediate disturbance hypothesis: a response to Fox. *Trends Ecol. Evol.* **28**, 571–572.

Shrestha, K.B., Måren, I.E., Arneberg, E., Sah, J.P. & Vetaas, O.R. (2013) Effect of anthropogenic disturbance on plant species diversity in oak forests in Nepal, Central Himalaya. *IJBSM.* **9**, 21–29.

Singh, S.P. & Sharma, C.M. (2009) *Tropical ecology: An overview. Trop Ecol.* **50**, 7–21.

Smit, I.P.J., Smit, C.F., Govender, N., Linde, M. & Macfadyen, S. (2013) Rainfall, geology and landscape position generate large-scale spatiotemporal fire pattern heterogeneity in an African savanna. *Ecography* **36**, 447–459.

Støen, O.-G., Okullo, P., Eid, T. & Moe, S.R. (2013) Termites facilitate and ungulates limit savanna tree regeneration. *Oecologia* **172**, 1085–1093.

Taylor, R.D. & Martin, R.B. (1987) Effects of veterinary fences on wildlife conservation in Zimbabwe. *Environ. Manage.* **11**, 327–334.

Ter Braak, C. J. F. & Smilauer, P. (2002) CANOCO reference manual and CanoDraw for Windows user's guide: software for canonical community ordination (version 4.5).

Tessema, Z., De Boer, W., Baars, R. & Prins, H. (2011) Changes in soil nutrients, vegetation structure and herbaceous biomass in response to grazing in a semi-arid savanna of Ethiopia. *J. Arid Environ.* **75**, 662–670.

Twine, W. (2005) Socio-economic transitions influence vegetation change in the communal rangelands of the South African lowveld. *Afr J Range Forage Sci.* **22**, 93–99.

Witkowski, E.T.F. & O'Connor, T.G. (1996) Topo-edaphic, floristic and physiognomic gradients of woody plants in a semi-arid African savanna woodland. *Plant Ecol.* **124**, 9–23.

Wolmer, W. (2005) Wilderness gained, wilderness lost: wildlife management and land occupations in Zimbabwe's southeast lowveld. *J Hist Geogr.* **31**, 260–280.

Zhang, Y., Chen, H.Y. & Taylor, A. (2014) Multiple drivers of plant diversity in forest ecosystems. *Global Ecol Biogeogr.* **23**, 885–893.

Zisadza-Gandiwa, P., Mabika, C. T., Kupika, O. L., Gandiwa, E. & Murungweni, C. (2013a) Vegetation structure and composition across different land uses in a semiarid savanna of southern Zimbabwe. *Int. J. biodivers.* **2013**, Article ID 692564. 692565 pages.

Zisadza-Gandiwa, P., Mango, L., Gandiwa, E., Goza, D., Parakasingwa, C., Chinoitezvi, E., Shimbani, J. & Muvengwi, J. (2013b) Variation in woody vegetation structure and composition in a semi-arid savanna of Southern Zimbabwe. *Int. Biodivers. Conserv.* **5**, 71–77.

(*Manuscript accepted 27 January 2016*)

doi: 10.1111/aje.12300