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Structure and composition of woody vegetation around permanent-artificial and ephemeral-natural water points in northern Gonarezhou National Park, Zimbabwe

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Abstract: The main objective of this study was to compare woody vegetation structure and composition along a distance gradient from permanent-artificial and ephemeral-natural water points in northern Gonarezhou National Park (GNP), Zimbabwe. Woody plants were sampled in May 2010 using a stratified systematic design with plots systematically placed at 100, 500, 1000 and 2000 m from four selected water points. A total of 912 woody plants were assessed in 32 sampling plots and 63 woody plant species were recorded. There were no significant differences in mean height, number of stems per plant, density and diversity with distance from water points. Significant differences in basal areas were only recorded at 2000 m. Only one ephemeral-natural water pan showed a decrease in plant density with increase in distance from the water pan. Our results suggest that there has been some slight degradation of woody vegetation around water points in northern GNP.

Resumen: El objetivo principal de este estudio fue comparar la estructura y la composición de la vegetación leñosa a lo largo de un gradiente de distancia desde puntos de agua artificiales permanentes y efímeros naturales en el norte del Parque Nacional Gonarezhou (PNG), Zimbabue. Las plantas leñosas fueron muestreadas en mayo de 2010 usando un diseño estratificado sistemático con parcelas colocadas sistemáticamente a 100, 500, 1000 y 2000 m a partir del borde de cuatro puntos de agua seleccionados. En total se evaluaron 912 plantas leñosas en 32 parcelas de muestreo y se registraron 63 especies de plantas leñosas. No hubo diferencias significativas en la altura media, el número de tallos por planta, la densidad y la diversidad respecto a la distancia desde los puntos de agua. Sólo se registraron diferencias significativas en las áreas basales para una distancia de 2000 m. Solamente un depósito natural y efímero de agua mostró un decremento en la densidad de plantas conforme aumentó la distancia desde su orilla. Nuestros resultados sugieren que ha habido una degradación leve de la vegetación leñosa alrededor de los puntos de agua en la parte norte del PNG.

Resumo: O objectivo principal deste estudo foi o de comparar a estrutura e composição da vegetação lenhosa ao longo de um gradiente de distância de pontos de água artificiais--permanentes e naturais-temporários no norte do Parque Nacional de Gonarezhou (PNG), Zimbabwe. As plantas lenhosas foram amostradas em Maio de 2010 usando um delineamento

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estratificado sistemático colocado a 100, 500, 1000 e 2000 metros de quatro pontos de água selecionados. Foram avaliadas um total de 912 plantas lenhosas em 32 talhões amostra, tendo sido registadas 63 espécies de plantas lenhosas. Não foram encontradas diferenças significativas quanto à altura média, número de troncos por plantas, densidade e diversidade com a distância entre os pontos de água. Só a 2000 m foram registadas diferenças significativas nas áreas basais. Só num ponto de água temporário se verificou um decréscimo na densidade das plantas com o aumento de distância à poça de água. Os nossos resultados sugerem que tem havido uma ligeira degradação da vegetação lenhosa à volta dos pontos de água na zona norte do PNG.

Key words: Benji dam, browsing, Massasanya dam, piosphere, savanna.

Savannas are characterised by the co-existence of a herb layer, dominated by C_4 grasses, and variable densities of trees and shrubs, whose proportions are influenced by water availability, nutrients, fire and herbivores (Scholes & Archer 1997). Vegetation gradients developing around water sources (i.e. piospheres) are important features of arid and semi-arid ecosystems (Lange 1969). Studied extensively in pastoral areas (e.g. Andrew 1988; James *et al.* 1999; Todd 2006), piospheres are also increasingly being investigated in areas hosting rich herbivore diversity (e.g. Chamaillé-James *et al.* 2009; Gaugris & Van Rooyen 2009; Makhabu *et al.* 2002; Parker & Witkowski 1999; Thrash 1998; Thrash *et al.* 1991). Here we aim to contribute to the understanding of woody vegetation structure and composition in woodlands around water points in northern Gonarezhou National Park (GNP), Zimbabwe. The main objective of the present study was to compare density, height, number of stems per plant, basal area and species diversity of woody vegetation with distance from permanent-artificial and ephemeral-natural water points in northern GNP.

Established in the early 1930s as a Game Reserve, GNP was upgraded into a national park under the Parks and Wildlife Act of 1975. GNP has been part of the Great Limpopo Transfrontier Park since 2000. Covering an area of 5,053 km^2, GNP is located in southeast Zimbabwe, between 21° 00' - 22° 15' S and 30° 15' - 32° 30' E. Altitude varies between 165 and 575 m above sea level. GNP experiences two seasons, a wet season and a dry season, which are very contrasting. Annual average rainfall is about 466 mm, with October to March being the wettest months. The dry season normally lasts from April to September. Average monthly maximum temperatures are 25.9 °C in July and 36 °C in January. Average monthly minimum temperatures range between 9 °C in June and 24 °C in January (Gandiwa & Kativu 2009). The entire GNP constitutes the catchments of the Guluene, Chefu, Save, Runde and Mwenezi rivers. The river courses constitute special habitats in their riverine vegetation, surface waters and floodplain. Other natural water resources in GNP are the seasonal pans, which hold water to varying durations into the dry season (Tafangenyasha 1997a). A perception has been that greater use of the GNP could be made by the introduction of artificial water at strategic points, thus dispersing the game over a wider area (Tafangenyasha 1997b). To this effect, two dams (Benji and Massassanya) were constructed in the 1970s. The major vegetation type is mopane (*Colophospermum mopane* [Kirk ex Benth.] Kirk ex J. Léonard) woodland, which covers approximately 40 % of GNP. There is a wide variety of large herbivore species in GNP ecosystem and these include African buffalo (*Syncerus caffer* Sparrman, 1779), giraffe (*Giraffa camelopardalis* Linnaeus, 1758), waterbuck (*Kobus ellipsiprymnus* Ogilby, 1833), kudu (*Tragelaphus strepsiceros* Pallas, 1766), Burchell's zebra (*Equus burchelli* Gray, 1824), wildebeest (*Connochaetes taurinus* Burchell, 1823), African elephant (*Loxodonta africana* Blumenbach, 1797) and hippopotamus (*Hippopotamus amphibius* Linnaeus, 1758). The park has a variety of large carnivores such as lion (*Panthera leo* Linnaeus, 1758) and spotted hyena (*Crocuta crocuta* Erxleben, 1777).

A stratified systematic sampling procedure was adopted in this study. We selected four water points, two permanent-artificial (i.e. Benji and Massasanya dams) and two ephemeral-natural water points (i.e. Chidhlambani and Urombo pans). The ephemeral water points used in this study have similar characteristics. Both are natural pans and generally retain water for almost similar periods. Selected water points in this study occurred in mopane, Lebombo ironwood (*Androstachys johnsonii* Prain), red bushwillow (*Combretum apiculatum* Sond.) and tamboti (*Spirostachys africana* Sonder) mixed woodlands. The development of sampling technique used in this study followed that of Brits *et al.* (2002). At each selected water point, two line transects, each 2 km were traversed. Direction of each line transect from the water point was determined through a randomization procedure, using a random number table. Random numbers were used as angles that indicated the direction of the line transect from the true North. A plot size of 20 × 50 m was used in this study. This plot size was determined following Walker's (1976) method of having at least 15 to 20 trees of the dominant vegetation inside a plot. Two plots were systematically placed at 100, 500, 1000 and 2000 m distances along each line transect from each water point. This gave a total of eight plots for each water point.

Floristic composition and structure of woody vegetation component were assessed in May 2010. At this time of the year, species composition is most conspicuous. In each sample plot, the following variables were recorded or measured: tree height, stem circumference, woody vegetation species and number of stems per plant. Trees were defined as woody plants greater than 3 m in height and greater than 6 cm basal diameter, above buttress swelling (Ben-Shahar 1998). All woody plants rooted within a plot were recorded and measured. Woody plants occurring along plot margins were included if at least half of the rooted system was inside the plot (Walker 1976). For multi-stemmed plants located at edges of plots, only stems with more than half their base inside the plot were measured and recorded. Data collection procedures used in this study followed those outlined by Gandiwa & Kativu (2009).

We conducted statistical tests using STATISTICA for Windows, version 6 (StatSoft 2001). Vegetation survey data were tested for normality using the Shapiro-Wilk test (Shapiro & Wilk 1965) and were found to be normal. In order to test whether there were differences in vegetation structure between water points at selected distances, we performed one-way ANOVA tests. Significant effects were further analyzed using the Fisher's Least Significant Difference (LSD) *post-hoc* tests to detect significant differences between water points. Further, we performed simple linear regression analyses in order to determine the relationship between woody vegetation variables and distance from each water point. For regression analyses, distances from water points were taken as the independent variable and woody vegetation variables as the dependent variables. We considered to be no significance when the value of the probability of significance (P) was greater than 0.05.

A total of 912 woody plants were assessed in the 32 sampling plots and 63 woody plant species were recorded. There were no significant differences in: (1) mean height at 100 ($F_{3,4}$ = 2.88; P > 0.05), 500 ($F_{3,4}$ = 2.06; P > 0.05), 1,000 ($F_{3,4}$ = 3.41; P > 0.05) and 2,000 ($F_{3,4}$ = 2.26; P > 0.05) m between permanent-artificial and ephemeral-natural water points in northern GNP (Table 1); (2) no significant differences were recorded in the mean number of stems per plant at 100 ($F_{3,4}$ = 0.370; P > 0.05), 500 ($F_{3,4}$ = 2.980; P > 0.05), 1,000 ($F_{3,4}$ = 0.438; P > 0.05) and 2,000 ($F_{3,4}$ = 0.919; P > 0.05) m; (3) similarly, no significant differences were recorded in mean basal area at 100 ($F_{3,4}$ = 1.186; P > 0.05), 500 ($F_{3,4}$ = 0.616; P > 0.05) and 1,000 ($F_{3,4}$ = 5.955; P > 0.05) m; in contrast, there were significant differences in mean basal areas at 2,000 m from the water points ($F_{3,4}$ = 18.636; P = 0.008); LSD *post-hoc* for basal areas Chidhlambani *vs.* Massasanya (P < 0.01), Urombo *vs.* Massasanya (P < 0.05) and Benji *vs.* Massasanya P < 0.01); (4) no significant differences were recorded in mean density at 100 ($F_{3,4}$ = 0.99; P > 0.05), 500 ($F_{3,4}$ = 0.56; P > 0.05), 1,000 ($F_{3,4}$ = 3.04; P > 0.05) and 2,000 ($F_{3,4}$ = 0.51; P > 0.05) m; and (5) mean species diversity between permanent-artificial and ephemeral-natural water points did not differ significantly at 100 ($F_{3,4}$ = 3.89; P > 0.05), 500 ($F_{3,4}$ = 1.30; P > 0.05), 1,000 ($F_{3,4}$ = 2.50; P > 0.05) and 2,000 ($F_{3,4}$ = 4.15; P > 0.05) m. With the exception of mean density of woody vegetation in the Chidhlambani pan, which decreased with increasing distance from the water point (R^2 = 0.97; y = 480.24 - 0.04x; $F_{1,2}$ = 56.33; P = 0.017), there were no other significant relationship between distance and structural and compositional variables of woody vegetation in the four sampled water points (Table 1).

Our results suggest that permanent-artificial and ephemeral-natural water points in northern GNP have led to a slight degradation of woody vegetation structure adjacent to the water points. We only recorded changes in tree density and basal area with distance from water points, despite the increasing elephant population in GNP. The elephant population in GNP was first estimated at

Table 1. Attributes of woody vegetation structure and composition for plots (mean ± standard error) with distance from permanent-artificial (PA) and ephemeral-natural (EN) water points in northern Gonarezhou National Park (GNP), Zimbabwe and significance levels from one-way ANOVA tests and simple linear regression. Mean values with different superscript letters within column differ significantly (LSD; $P < 0.05$).

Variables	Name of water point	Water point category	Distance from water point (m)				Linear relationship
			100	500	1000	2000	
Height (m)	Benji	PA	2.91 ± 0.44^{a}	4.00 ± 0.15^{a}	3.52 ± 1.07^{a}	3.60 ± 0.11^{a}	$P = 0.615$
	Massasanya	PA	4.04 ± 0.21^{a}	3.32 ± 0.70^{a}	4.04 ± 0.10^{a}	4.96 ± 0.06^{a}	$P = 0.242$
	Chidhlambani	EN	5.12 ± 1.05^{a}	5.99 ± 1.39^{a}	5.48 ± 0.95^{a}	4.06 ± 0.18^{a}	$P = 0.296$
	Urombo	EN	5.09 ± 0.45^{a}	4.99 ± 0.47^{a}	6.54 ± 0.39^{a}	5.46 ± 1.10^{a}	$P = 0.651$
		One-way ANOVA	$P = 0.167$	$P = 0.248$	$P = 0.133$	$P = 0.224$	—
Number of stems per plant	Benji	PA	2.04 ± 0.66^{a}	4.24 ± 0.76^{a}	4.80 ± 3.55^{a}	2.82 ± 0.74^{a}	$P = 0.878$
	Massasanya	PA	1.96 ± 0.25^{a}	1.91 ± 0.50^{a}	2.80 ± 0.26^{a}	1.34 ± 0.16^{a}	$P = 0.628$
	Chidhlambani	EN	2.82 ± 0.85^{a}	2.79 ± 0.88^{a}	2.63 ± 0.95^{a}	2.64 ± 0.59^{a}	$P = 0.152$
	Urombo	EN	2.16 ± 0.67^{a}	1.90 ± 0.13^{a}	1.95 ± 0.41^{a}	3.45 ± 1.58^{a}	$P = 0.188$
		One-way ANOVA	$P = 0.780$	$P = 0.159$	$P = 0.738$	$P = 0.508$	—
Basal area ($m^2 ha^{-1}$)	Benji	PA	0.71 ± 0.11^{a}	3.03 ± 2.49^{a}	0.57 ± 0.08^{a}	0.91 ± 0.26^{a}	$P = 0.777$
	Massasanya	PA	1.89 ± 1.02^{a}	1.66 ± 0.11^{a}	1.41 ± 0.45^{a}	3.19 ± 0.14^{b}	$P = 0.267$
	Chidhlambani	EN	0.80 ± 0.25^{a}	0.81 ± 0.26^{a}	1.14 ± 0.01^{a}	0.91 ± 0.42^{a}	$P = 0.599$
	Urombo	EN	0.67 ± 0.18^{a}	1.08 ± 0.30^{a}	2.69 ± 0.58^{a}	0.95 ± 0.07^{a}	$P = 0.823$
		One-way ANOVA	$P = 0.421$	$P = 0.640$	$P = 0.059$	$P = 0.008$	—
Density (plants ha^{-1})	Benji	PA	366.67 ± 16.67^{a}	475.00 ± 191.67^{a}	633.33 ± 33.33^{a}	541.67 ± 91.67^{a}	$P = 0.341$
	Massasanya	PA	458.33 ± 175.00^{a}	341.67 ± 58.33^{a}	358.33 ± 75.00^{a}	425.00 ± 158.33^{a}	$P = 0.956$
	Chidhlambani	EN	466.67 ± 116.67^{a}	441.67 ± 91.67^{a}	416.67 ± 100.00^{a}	391.67 ± 41.67^{a}	$P = 0.010$
	Urombo	EN	791.67 ± 308.33^{a}	558.33 ± 91.67^{a}	458.33 ± 41.67^{a}	491.67 ± 8.33^{a}	$P = 0.242$
		One-way ANOVA	$P = 0.481$	$P = 0.667$	$P = 0.156$	$P = 0.696$	—
Diversity (Shannon-Weiner index, H')	Benji	PA	1.73 ± 0.01^{a}	1.89 ± 0.26^{a}	0.53 ± 0.41^{a}	0.55 ± 0.42^{a}	$P = 0.185$
	Massasanya	PA	0.11 ± 0.11^{a}	1.16 ± 0.12^{a}	1.93 ± 0.25^{a}	0.72 ± 0.14^{a}	$P = 0.735$
	Chidhlambani	EN	1.76 ± 0.08^{a}	1.54 ± 0.32^{a}	1.16 ± 0.51^{a}	1.97 ± 0.25^{a}	$P = 0.725$
	Urombo	EN	1.19 ± 0.77^{a}	1.45 ± 0.32^{a}	1.05 ± 0.21^{a}	1.12 ± 0.36^{a}	$P = 0.567$
		One-way ANOVA	$P = 0.111$	$P = 0.389$	$P = 0.199$	$P = 0.101$	—

3,100 in 1969. Recently, the elephant population was estimated at 9,100 in GNP during 2009 with a density of 1.84 per km^2 (Dunham *et al.* 2010). The existence of two major natural and perennial rivers in northern GNP, i.e. the Runde and Save rivers could also have an influence on habitat use by herbivores. The distances from the studied water points to the two major rivers in northern GNP are relatively small. Therefore, it is possible that most animals concentrate more on the major rivers as compared to the inland water points.

An earlier study by Bromwich (1972) found that the effect of large herbivores on natural watering point in GNP may be one of utilization rather than destruction, and woody vegetation may be utilized evenly with distance from water. Elsewhere, a recent study by Kalwij *et al.* (2010) reported an increase in tree density, canopy cover, and volume in central Chobe, Botswana, in spite of a growing elephant population. Another study by Makhabu *et al.* (2002) recorded no severe degradation of habitat around water points in Central Kalahari Game Reserve of Botswana.

Our findings are to a lesser extent consistent with the general assumption that water provision leads to the degradation of woodland structure in the influence range of water points or piospheres as a result of trampling and increased herbivory by large herbivores. Elsewhere, Brits *et al.* (2002) found a significant, though weak linear relationship between woody plant density and distance from watering point in the neighboring Kruger National Park, South Africa. Chamaillé-James *et al.* (2009) reported that woody cover was strongly affected within the first 2 km of the piospheres in Hwange National Park, Zimbabwe. Gaugris & Van Rooyen (2009) recorded a gradient of utilization away from permanent water in the Tembe Elephant Park, Maputaland, South Africa. Surface water availability has a strong influence on elephant movements at the habitat and landscape scale (Shannon *et al.* 2009). The greatest damage of the habitat by elephants is in the vicinity of rivers and permanent watering points (Laws 1970). It has been suggested that the aggregative response by elephants, and other smaller herbivores, around water points in the dry season results in increased browsing pressure and severe trampling around those areas, suppressing the regeneration of seedlings and shoot growth (Thrash & Derry 1999).

Other factors that may affect savanna woodland structure and composition are droughts, frost, fire, disease, herbivores, edaphic factors, topography and past human activities (e.g. Chafota & Owen-Smith 2009; Guldemond & Van Aarde 2008). These factors may be interrelated, and when they occur simultaneously they, probably, act in concert to exert a stronger effect. Fire frequency is usually low around watering points due to high browsing pressure and severe trampling by large herbivores, which reduces fuel loads. In northern Chobe National Park, Botswana, elephant browsing was high and fire occurrence low within 2 km from Chobe River and browsing was low and fire occurrence high beyond 7 km from the river (Mosugelo *et al.* 2002). Fire and herbivory are events that can interact and the consequences are not always easy to predict (Frost *et al.* 1986). In GNP, earlier studies have suggested that fire and elephant damage contributed to the general modification of habitats, leading to the decline of canopy woodlands and herbaceous plant cover in some habitats (Gandiwa & Kativu 2009; Tafangenyasha 1997a, 2001). Therefore, we recommend that continued monitoring using photopanoramas at water points should be given priority, and that future research should investigate the impact of herbivores around watering points on specific woodlands in GNP.

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