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Impact of African elephants on baobab (*Adansonia digitata* L.) population structure in northern Gonarezhou National Park, Zimbabwe

OLGA L. KUPIKA[1], SHAKKIE KATIVU[2] , EDSON GANDIWA[3*] & ANGELLA GUMBIE[4]

[1]Department of Wildlife and Safari Management, School of Hospitality and Tourism, Chinhoyi University of Technology, Private Bag 7724, Chinhoyi, Zimbabwe

[2]Tropical Resource Ecology Programme, University of Zimbabwe, P.O. Box MP167, Mt Pleasant, Harare, Zimbabwe

[3]Scientific Services, Gonarezhou National Park, Parks and Wildlife Management Authority, Private Bag 7003, Chiredzi, Zimbabwe

[4]Department of Forest Resources and Wildlife Management, Faculty of Applied Sciences, National University of Science and Technology, P.O. Box AC 939, Ascot, Bulawayo, Zimbabwe

Abstract: The impact of African elephant (*Loxodonta africana*) on population structure of baobab trees (*Adansonia digitata* L.) was assessed in northern Gonarezhou National Park (GNP), southeast Zimbabwe. Baobabs were sampled in March 2008 and September 2012 using 11 randomly laid belt transects of variable length within 1 km of the eastern and western sections of the Runde River and also away (> 1 km) from the water sources. A total of 223 baobabs, 130 near permanent water sources and 93 away from permanent water sources, were sampled. Baobab density did not significantly differ across the two study sites. Furthermore, there were no significant differences in girth at breast height between the two study sites. Results of the present study suggest that elephants target large baobabs (girth ≥ 5 m). In contrast, significant difference in baobab damage was recorded between the two sites. A single dead baobab tree was encountered at a site away from water sources. A larger proportion of elephant damaged baobabs was located closer to permanent water sources. However, baobab recruitment and regeneration was higher in areas close to permanent water sources than in distant areas. Management should come up with strategies to monitor vegetation changes in order to avoid loss of baobabs and other tree species.

Resumen: Se evaluóel impactodel elefante africano (*Loxodonta africana*) sobre la estructura poblacional de los árboles de baobab (*Adansonia digitata* L.) en la parte norte del Parque Nacional Gonarezhou (GNP), surestede Zimbabue. Los baobabs fueron muestreadosen marzode 2008 y septiembrede 2012 usando 11 transectos de banda de longitud variable, colocados al azara no más de 1 km de las secciones oriental y occidental del río Runde,y también lejos (> 1 km) de las fuentes de agua. Se muestrearon en total 223 baobabs, 130 cerca de fuentes de agua permanentes y 93 alejados de ellas. La densidad de los baobabsno difirió significativamente entre los dos sitiosde estudio. Además, no hubo diferencias significativasen el perímetro a la altura del pecho entre los dos sitios. Los resultados del estudio sugierenquelos blancos de los elefantes sonlos baobabs grandes (perímetro ≥ 5 m). Además, se registró una diferencia significativa en el daño producido a los baobabs entre los dos sitios. Sólo se encontró un baobab muerto en un sitio alejado de las fuentes de agua. Una proporción más grande de baobabs dañados por elefantes fue localizada más cerca de las fuentes de agua permanentes. Sin

[*]*Corresponding Author*; e-mail: egandiwa@gmail.com

embargo, el reclutamiento y laregeneracióndel baobab fueron mayoresen áreascercanasalas fuentes de agua permanentesqueen las áreas distantes. El manejo debería incluir estrategias para monitorearlos cambios en la vegetación a fin de evitarpérdidas de baobabs y de otras especies de árboles.

Resumo: O impacto do elefante Africano (*Loxodonta africana*) sobre a estrutura populacional dosimbondeiros (*Adansonia digitata* L.) foi avaliado no norte do Parque Nacional de Gonarezhou (PNB), sudeste Zimbabwe. Os imbondeiros foram coletados em março de 2008 e setembro 2012 com 11 transeptos pde comprimento variável e definidos aleatoriamente, dentro de uma faixa de 1 km das seções orientais e ocidentais do rio Runde e também afastados de (> 1 km)do curso de água. Foram amostrados um total de 223 imbondeiros, 130 perto de fontes de água permanentes e 93 longe dessas fontes de água. A densidade dos imbondeiros não diferiram significativamente entre os dois locais de estudo. Além disso, não foram observadas diferenças significativas no perímetro à altura do peito entre os dois locais de estudo. Os resultados do presente estudo sugerem que os elefantes visam os maiores imbondeiros (circunferência ≥ 5 m). Além disso, registaram-se diferenças significativasnos danos nos imbondeiros entre os dois sítios. Um únicoimbondeiro morto foi encontrado num local longe das fontes de água. A maior proporção de imbondeiros danificadas pelos elefantesfoi localizada mais perto de fontes de água permanentes. No entanto, a germinação e regeneração de imbondeiros foi maior em áreas próximas a fontes de água permanentes do que em áreas distantes. A gestão deve propor estratégias para monitorizar as mudanças de vegetação, a fim de evitar a perda de imbondeiros e outras espécies arbóreas.

Key words: Baobab, damage, elephant, Gonarezhou, population structure, vegetation, water sources.

Introduction

Large herbivores such as elephants (*Loxodonta africana*) and fire play an important role in shaping vegetation structure in African savannas (Bond & Keeley 2005; Gandiwa *et al.* 2011; Mapaure & Campbell 2002; Sankaran *et al.* 2005). In most protected areas, elephants utilize diverse tree species (Biru & Bekele 2012; Hayward & Zawadzka 2010; O'Connor *et al.* 2007), such as the baobab (*Adansonia digitata* L.), especially in times of resource scarcity (Owen-Smith 1988). Elephants are the only herbivores that have been reported to damage baobab trees leading to their mortality and reduction in their densities (Edkins *et al.* 2008; Mpofu *et al.* 2012; Sanchez *et al.* 2011; Swanepoel 1993). In a 10-year study in Tanzania, Barnes *et al.* (1994) observed that baobab populations declined as elephant numbers increased and the species recovered when elephant populations declined due to poaching. Impact of elephants on baobabs is confounded by interactions with drought, other herbivores and fire (Edkins *et al.* 2008). Severe damage to baobabs may indicate that elephant population, irrespective of its absolute density, has reached a level at which it has already initiated major vegetation changes in an area (Swanepoel & Swanepoel 1986).

The elephant population has been increasing in Gonarezhou National Park (GNP), southeast Zimbabwe, from an estimated number of 3,100 in 1969 (Department of National Parks and Wildlife Management 1998) to 9,100 in 2009 (Gandiwa 2012). This increase could have resulted in negative impacts on vegetation in the park. Excessive damage of baobab populations in some sections of the GNP has been recently reported (Mpofu *et al.* 2012). Elephant damage on baobab trees has been of concern to park managers in the GNP, especially given that excessive feeding on flowers, bark and immature fruit can lead to decreased fruit yield, damage to adult trees, and eventual death of the trees (Department of National Parks and Wildlife Management 1998). Thus, population structure of the baobabs in GNP could be influenced by herbivory, which may have long-term effects on species demography. While a recent study by Mpofu *et al.* (2012) has contributed to a general assessment of elephant impact on baobab in the southern section of GNP, this study aims to

Table 1. Survey effort, baobab population structure and elephant damage in relation to proximity to permanent water source in northern Gonarezhou National Park, Zimbabwe.
Note: Values in parentheses represents standard errors.

Attribute	Sites close to permanent water sources (≤ 1 km)	Sites away from permanent water sources (> 1 km)
Survey effort		
Number of transects	5	6
Number of baobabs	130	93
Baobab population structure		
Young baobabs (gbh < 5 m)	61	31
Adult baobabs (gbh ≥ 5 m)	69	62
Baobab density (ha^{-1})	0.45 (0.13)	0.51 (0.13)
Girth at breast height (gbh)	4.99 (3.50)	5.53 (3.02)
Elephant damage		
No damage	16	19
Slight	14	36
Moderate	21	18
Severe	79	19
Dead	0	1

assess the impact of elephants on baobab population structure in relation to distance from permanent water sources in northern GNP. Mpofu *et al.* (2012) reported that more baobabs were recorded in areas with rocky outcrops which acted as refugia for the baobabs in southern GNP. The present study focused on baobab population structure, recruitment and associated elephant damage in relation to distance from permanent water sources in northern GNP.

Materials and methods

Study area

GNP is located in the southeast lowveld of Zimbabwe, between latitudes 21° 00' to 22° 15' S and longitudes 30° 15' to 32° 30' E. The park is spread over an area of approximately 5,000 km^2. GNP has a semi-arid climate receiving annual rainfall ranging from 400 to 600 mm (Gandiwa & Kativu 2009). This study focused on baobabs found within the eastern and western sections of the Runde River in northern GNP. The study area was stratified into two categories based on proximity to permanent water sources, i.e. (i) sites close to permanent water which were located within 1 km of the eastern and western sections of Runde River in northern GNP, and (ii) sites further away from permanent water sources which were located at least 1 km from permanent water sources.

Data collection

Baobabs were sampled in March 2008 and September 2012 using 11 randomly laid belt transects of variable length. Five belt transects were placed in sites close to permanent water sources whereas six belt transects were placed in sites away from permanent water sources. Transect length was determined by number of baobab trees occurring in a particular belt transect. Measurements were recorded from between 10 and 15 individual baobabs encountered in each transect, those with at least half of the canopy falling within the transect following Campbell *et al.* (1996). Baobabs were categorized as small (girth < 5 m) and large (girth ≥ 5 m) according to Swanepoel & Swanepoel (1986). Both dead and live baobab trees were enumerated in each transect (Barnes 1980). The locations of all sampled baobabs were recorded using a hand-held Garmin Geographic Position System (GPS) unit. Girth at breast height (gbh) at 1.3 m was recorded using a flexible 20 m tape measure. For resprouting individuals, only the largest stem was recorded. Baobab damage by elephants was assessed on a 5-point scale, from 0 = no damage, 1 = slight damage with few scars: 2 = moderate damage with numerous scars; 3 = severe damage with the tree scarred deeply and 4 = tree dead or felled (Swanepoel 1993).

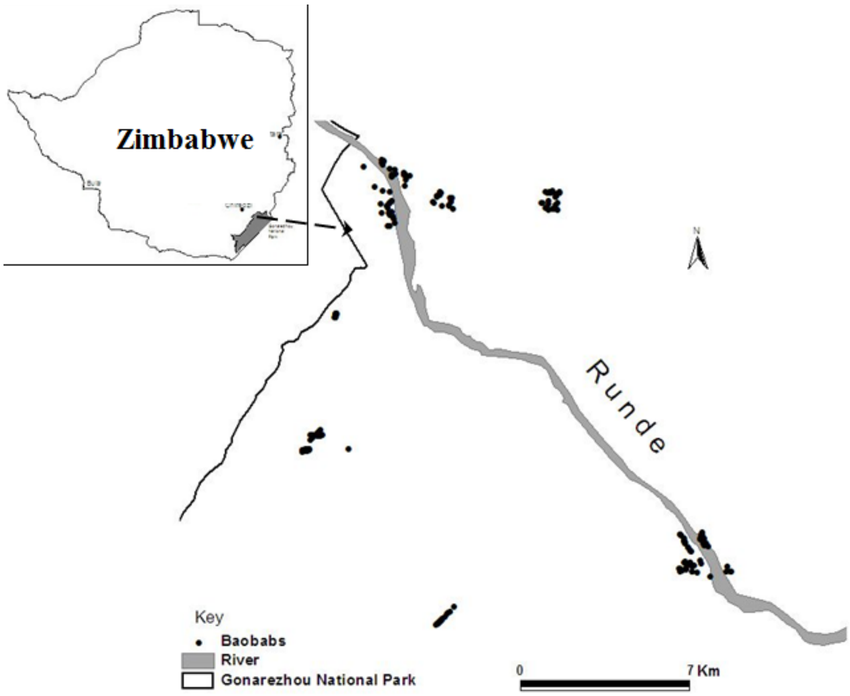

Fig. 1. The spatial distribution of sampled baobabs in northern Gonarezhou National Park, southeast Zimbabwe.

Data analysis

Density was calculated from the belt transect area within which the baobab trees were encountered along the transect and converted to per ha. Baobab location data were spatially represented using Arc View 3.2 software for Windows (ESRI, Redlands, CA). The number of baobabs within each girth interval was grouped according to damage classification. Baobab trees were classified into size class distributions based on 2.5 m girth intervals i.e. < 2.50; 2.51-5.00; 5.01-7.50; 7.51-10.0; 10.01-12.50; 12.51-15.00 m following Swanepoel & Swanepoel (1986). A two-tailed independent samples *t*-test with equal variance was used to compare mean baobab densities and gbh across the study sites using SPSS version 19 for Windows (SPSS Inc., Chicago, IL, USA). Chi-Square (χ^2) test of independence was used to determine the differences in elephant damaged baobabs between the two study sites.

Results

A total of 223 baobabs were randomly sampled along Runde River in the northern GNP. More baobabs were sampled in areas close to permanent water sources than in areas located away from permanent water sources (Table 1). Baobab density however, did not significantly differ between sites located close to and away from permanent water sources (*t*-test, t = - 0.37, df = 9, P = 0.719). Fig. 1 shows the distribution of sampled baobabs in relation to Runde River in northern GNP. Fewer baobabs (≥ 5 m) were recorded in sites located away from permanent water sources than in sites close to permanent water sources. There were no significant differences in gbh between the two study sites (*t*-test, t = -1.20, df = 221, P = 0.231). The size class distribution for sites located away from permanent water sources showed a bell-shaped distribution curve whilst those close to permanent water sources showed a reverse J-shaped curve (Fig. 2).

From a sample of 223 baobabs, 84 % were elephant damaged and 16 % were not damaged by elephants. The highest frequency of elephant damaged baobabs (60 %) was recorded in the large size classes (gbh ≥ 5 m) whilst fewer damaged baobabs (40 %) were in the smaller size classes (gbh ≤ 5 m). Only a single dead baobab was recorded away from permanent water source. A higher proportion of elephant damaged baobabs was encountered in sites located close to permanent water sources (88 %) than in sites away from permanent water sources (80 %; Table 1). Further-

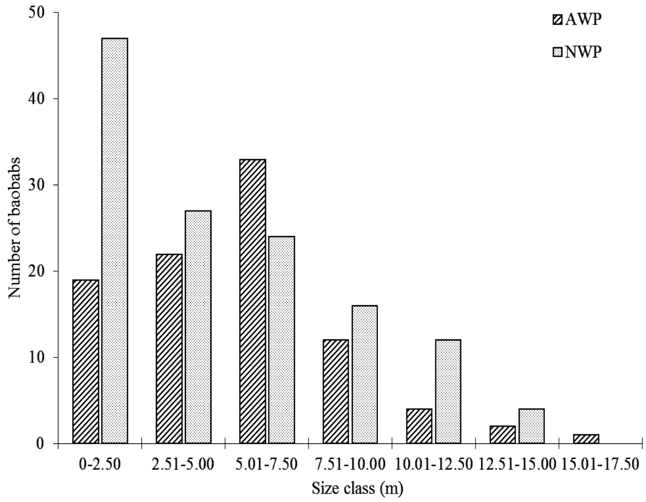

Fig. 2. Size class distribution for baobabs located in sites close to and far away from permanent water sources in northern Gonarezhou National Park, Zimbabwe. AWP = away from permanent water sources and NWP = near permanent water sources.

more, a higher proportion (73 %) of large baobabs (gbh ≥ 5 m) was elephant damaged in sites close to permanent water sources as compared to 47 % in sites located away from permanent water sources. Overall, there were significant differences in damage of baobab trees between the two study sites ($\chi^2 = 42.95$, df = 4, $P < 0.0001$; Table 1).

Discussion

Our results show that although baobab density did not significantly differ in relation to water sources, baobab distribution, however, varied across the two study sites in northern GNP. In terms of baobab distribution, more baobabs were located closer to water sources, largely in rocky outcrops as reported by Mpofu *et al.* (2012). Several factors could explain the recorded spatial variation in baobab distribution in natural environments. Baobab densities are variable in the landscape and are affected by a number of establishment factors, such as baboon (*Papio ursinus*) mediated seed dispersal, soil characteristics and topography (Edkins *et al.* 2008; Mpofu *et al.* 2012; Venter & Witkowski 2011; Wilson 1988). Furthermore, Dhillion & Gustad (2004) suggest that baobab distribution is influenced by management practices related to different land use types. Baobab densities in northern GNP appear to be within the range previously recorded in other protected areas (e.g. Barnes 1980).

Girth at breast height categories can be used to trace the growth pattern of the baobab population as they provide an indication of recruitment at any one particular stage in the population history (Mudavanhu 1997). Size class distribution of baobabs in sites located near permanent water sources showed a reverse J-shaped curve with many small baobabs. Edkins *et al.* (2008) made similar observations in the adjacent Kruger National Park, South Africa. More baobabs were recorded in the smaller size class than the larger size classes. This suggests that baobab regeneration within these study sites is high (Lykke 1998; Schumann *et al.* 2010), and represents a stable distribution and a healthy state of baobabs (Schumann *et al.* 2010). However, there appears to be low recruitment of baobabs into larger size classes likely as a result of herbivory. Other factors that could have influenced baobab population structure apart from elephant browsing in GNP include the 1991-92 drought, fires and human activities (Gandiwa & Kativu 2009; Tafangenyasha 1997, 1998).

The sites located away from permanent water sources displayed a bell-shaped size class distribution with a likely low recruitment as also recorded by Edkins *et al.* (2008). This low recruitment could indicate a decline of the baobab population in areas away from water sources in northern GNP. Wickens & Lowe (2008) suggest that recruitment can be affected by herbivory from animals, such as elephants, which eat, kill baobab seedlings and saplings. In the present study, elephants and other large herbivores were also observed foraging in the baobab communities during field data collection. It has been suggested that areas with low baobab recruitment are likely to be associated with local high elephant densities or other long-term environmental factors such as droughts or past land uses (De Smedt *et al.* 2012; Guy 1982; Wilson 1988). Climate change, rainfall and drought can also affect baobab recruitment thereby contributing towards the decline in baobab populations (Assogbadjo & Loo 2011; Sanchez 2010; Sanchez *et al.* 2011; Wickens & Lowe 2008). GNP is located in a drought prone region; hence, baobab seedlings and saplings could succumb to such natural disasters.

Local management practices and associated land uses also tend to affect the baobab recruitment (Dhillion & Gustad 2004). It has been reported that increased frequency of bush fires, grazing by livestock, intensification of agriculture and overexploitation for leaves, debarking and/or fruits (Assogbadjo & Loo 2011) which may be related to weak institutional structures to manage natural resources, often leads to overharvesting and poor management of baobab resources (Alelign *et al.* 2011; Mamo & Bekele 2011; Schumann *et al.* 2012; Venter 2012). In GNP, it has been observed that local people also harvest baobab fruits from the park (E. Gandiwa, *personal observation*); hence this could also be influencing baobab recruitment in the park. Human utilisation and elephant presence (Schumann *et al.* 2010) could, therefore, influence baobab recruitment in these sites.

Our results suggest that elephants mostly target large baobabs. The prevalence of moderate to severe elephant damage in larger classes supports the view that elephants prefer larger baobabs than smaller ones (Swanepoel & Swanepoel 1986). This contradicts with suggestions that elephants prefer to feed on small baobab trees (Barnes 1980; Weyerhaeuser 1985). Elephant utilization of baobabs in northern GNP does not seem to indicate that small trees, i.e. those with girth < 5 m, are in danger of excessive mortality since only one small dead baobab was recorded during the study. Sites close to permanent water source were characterized by rough terrain with however, a higher proportion of damaged baobab trees largely in areas that appeared easily accessible to elephants. However, baobabs that occurred on steep slopes were least affected by elephants. Baobab damage by elephants has been reported to be relatively low in steep areas, rocky outcrops and areas with human settlements (Duvall 2007; Edkins *et al.* 2008; Mpofu *et al.* 2012).

It has been suggested that damage incurred on any tree depends on its position relative to water, elephant population density, and timing of the initial damage, i.e. early or late in the dry season (Edkins *et al.* 2008). Elephants usually encounter baobabs close to permanent water sources, if they are easily accessible, more regularly before or after drinking water during the dry season. This increases the chances of bark stripping and vegetation damage since forage is scarce during the dry season as recorded in several earlier studies (Brits *et al.* 2002; Gandiwa *et al.* 2011; Gandiwa *et al.* 2012; Mukwashi *et al.* 2012; Swanepoel 1993; Tafangenyasha 1997).

Although diseases, such as sooty baobab disease, have been reported to also affect baobabs in similar ecosystems (Piearce *et al.* 1994), we, however, did not record any baobab affected by this disease in the present study. Long term monitoring of the baobab populations along with densities and habitat use by elephants would be needed to understand the future trends and vegetation dynamics as also suggested by Sanchez *et al.* (2011). Future studies should focus on comparison of baobab utilization, distribution and population structure within and outside the protected area so as to assess the potential for the species conservation in these areas.

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