Browsing impact of large herbivores on *Acacia xanthophloea* Benth in Lake Nakuru National Park, Kenya

N. Dharani[1]*, J. I. Kinyamario[2], Peter W. Wagacha[3] and Anthony J. Rodrigues[3]

[1]*World Agroforestry Centre, PO Box 13800-00800, Nairobi, Kenya, [2]School of Biological Sciences and [3]School of Computing & Informatics, University of Nairobi, PO Box 30197-00100, Nairobi, Kenya*

Abstract

Significant differences ($P<0.05$) were found in growth of plant height, canopy cover and stem diameter of *Acacia xanthophloea* trees in fenced plot as compared with unfenced plot both in the wet and in the dry seasons. Finding of this study showed that although heavy browsing reduced the height and canopy of trees, it did not kill any trees and seedling regeneration took place simultaneously. Despite the presence of large herbivores that impact some considerable browsing pressure results indicate that the *A. xanthophloea* habitat type would continue to remain in balance in the presence of recruitment of seedlings and saplings. The conditions at the time of study indicate that the browsing on *A. xanthophloea* was not significant and was not serious enough to warrant management intervention at present.

Key words: Acacia, browsing, herbivores, Lake Nakuru

Résumé

Des différences significatives ($P<0,05$) ont été relevées dans la croissance en hauteur, le couvert de la canopée et le diamètre des tiges d'*Acacia xanthophloea* dans des parcelles clôturées, comparées à des parcelles non clôturées, en saison sèche comme en saison des pluies. Les résultats de cette étude ont montré que, même si un pâturage intense réduisait la hauteur et la canopée des arbres, il n'en tuait aucun et que la régénération des jeunes plants se faisait simultanément. Malgré la présence de grands herbivores qui exercent une pression considérable, les résultats indiquent que le type d'habitat à *A. xanthophloea* resterait équilibré grâce au recrutement de jeunes plants et de repousses. Les conditions prévalant au moment de l'étude indiquaient que la consommation d'*A. xanthophloea* n'était pas significative et qu'elle n'était pas assez grave pour justifier pour le moment une intervention en matière de gestion.

Introduction

Several *Acacia* woodland habitats occur in Lake Nakuru National Park and are associated with areas of high water table (Mutangah, 1994; Mutangah & Agnew, 1996). The *Acacia xanthophloea* woodland is an important habitat for many animals by providing nesting places and shelter for many resident and migratory birds in the park. The woodlands provide feed for large herbivores, mainly Rothschilds giraffe (*Giraffa camelopardalis rothschildi*), black rhinoceros (*Diceros bicornis*), Olive baboon (*Papio anubis*), Vervet monkey [*Cercopithecus(a.) pygerythrus*] and several other mammals and insects. The woodlands also contribute to aesthetic value and tourist attraction of the National Park.

The habitat in this enclosed park is being influenced by the presence of two re-introduced large herbivore browsers, Black Rhinoceros and Rothschild's Giraffe. Previous studies have examined the effect of large herbivores on woodlands. Generally, these studies have focused on elephant and fire impact (Dublin, Sinclair & Mcglade, 1990; Ben-Shaher, 1996) but some have also included the effect of giraffes (Pellew, 1983; Ruess & Halter, 1990), others have also studied the combined impact of elephants (*Loxodonta africana*), giraffes and rhinos on the habitat change (Birkett, 2002). Nearly, all these studies based their measurements on a large-scale analysis of damage, but one studied the effect of giraffes on the growth rates of individually marked trees (Pellew, 1983).

This study, however, focused mainly on determining the impact of large herbivores on *A. xanthophloea* trees that had been quantified by direct measurement of the growth

Correspondence: E-mail: ndharani@cgiar.org

rate in plant height, canopy and stem diameter. Currently, the *A. xanthophloea* woodland provides one of the principal feeds for the large herbivores in Lake Nakuru National Park. The main aim of the study was to find out the impacts of re-introduced large herbivore browsers on the *A. xanthophloea* woodland habitats in Lake Nakuru National Park. Results of this study can be used to better manage the population of browsers to be maintained in these habitats to maintain the ecological integrity of the park.

Materials and methods

Lake Nakuru National Park lies approximately between latitudes 0°18′ and 0°29′ South and longitude 36°03′ and 36°09′ East in the Rift Valley of Kenya. It covers an area of about 188 km^2. The altitude ranges from *c.* 1760 to 2080 m a.s.1. The park is located about 150 km from Nairobi. It is only 3 km south of Nakuru Town. The Lake has significant ecological and management contribution to the fragile ecosystem and to the national economy through tourism because of its unique biodiversity. This lake is home to flamingoes that attracts tourists and is also a Ramsar (International Wetland Treaty) site. The park is also declared as Rhino and birds sanctuaries.

Study sites were chosen in the western shoreline of Lake Nakuru National Park based on the criteria that *Acacia* trees were previously heavily browsed and the area has been regularly visited by large herbivores and experienced continuous browsing.

The impact of large herbivores browsing on the *A. xanthophloea* trees had been quantified in sampling area. Sampling was carried out within a 30 × 30 m square plot for the unfenced plot, and a 30 × 30 m enclosure for the fenced plot shown in Fig. 1, where the plant height, canopy cover and stem diameter of woody species were estimated (Eshete, 2000).

Plant height was determined using a clinometer (optical reading clinometer, PM-5/360 PC; SUUNTO, Finland), following the method used by Rosenschein, Tietema & Hall (1999) for trees. Woody plants <5 m in height were measured using a sliding or folding marked pole. Stem basal area was measured using calipers and a steel tape 3-m long. Where diameter at breast height could not be measured (due to stem was forked below the breast height), the diameter at the ground level was taken. Canopy diameter measurements were taken at the extremes of the tree canopy (to the tips of the longest branches) with a tape measure.

Data analysis of large herbivores browsing impact on A. xanthophloea *trees*

Different growth measures were developed from the initial growth data collected for plant height (*h*), canopy (*c*) and stem diameter at breast height (*d*) for unfenced and fenced plots, at an interval of 3 months over a 2-year time period. Initial parameters were classified into different height, canopy and diameter breast height classes, i.e. N_h, N_c and N_d respectively. The following sets of formulae were used to calculate these:

The corresponding incremental growth due to an incremental growth. *Δh,Δc* and *Δd*, respectively, each time *t* averaged over all trees in each set of initial N_h, N_c and N_d classes respectively for unfenced and fenced plots respectively.

$$\Delta h_j(t, N_h) = \frac{1}{N_h} \sum_{i=1}^{N_h} \Delta h_{i,t}, \forall t, \text{ in each} N_h \text{ class}$$
$$j = f(\text{fenced area}) or \; j = u(\text{unfenced area})$$

$$\Delta c_j(t, N_c) = \frac{1}{N_c} \sum_{i=1}^{N_c} \Delta c_{i,t}, \forall t, \text{ in each } N_c \text{ class}$$
$$j = f(\text{fenced area}) or \; j = u(\text{unfenced area})$$

$$\Delta d_j(t, N_d) = \frac{1}{N_d} \sum_{i=1}^{N_d} \Delta d_{i,t}, \forall t, \text{in each } N_d \text{ class}$$
$$j = f(\text{fenced area}) or \; j = u(\text{unfenced area})$$

Statistical difference in the growth rate measurement in plant height, canopy and stem diameter were tested using Tukey's procedure (HSD) and Analysis of Variance at 0.05 significance level (Steel, Torrie & Bodickey, 1997).

Results

Impact of herbivorous browsing on the growth rate in plant height, canopy and stem diameter at breast height (d) of A. xanthophloea *trees*

The mean growth rate measurement in plant height, canopy and stem diameter for *A. xanthophloea* trees was performed in the months of November 2002, May 2003, November 2003 and May 2004, which are in the rainy season as compared with tree growth in the dry season in the months of August 2002, February 2003, August 2003 and February 2004. The initial data for growth in tree
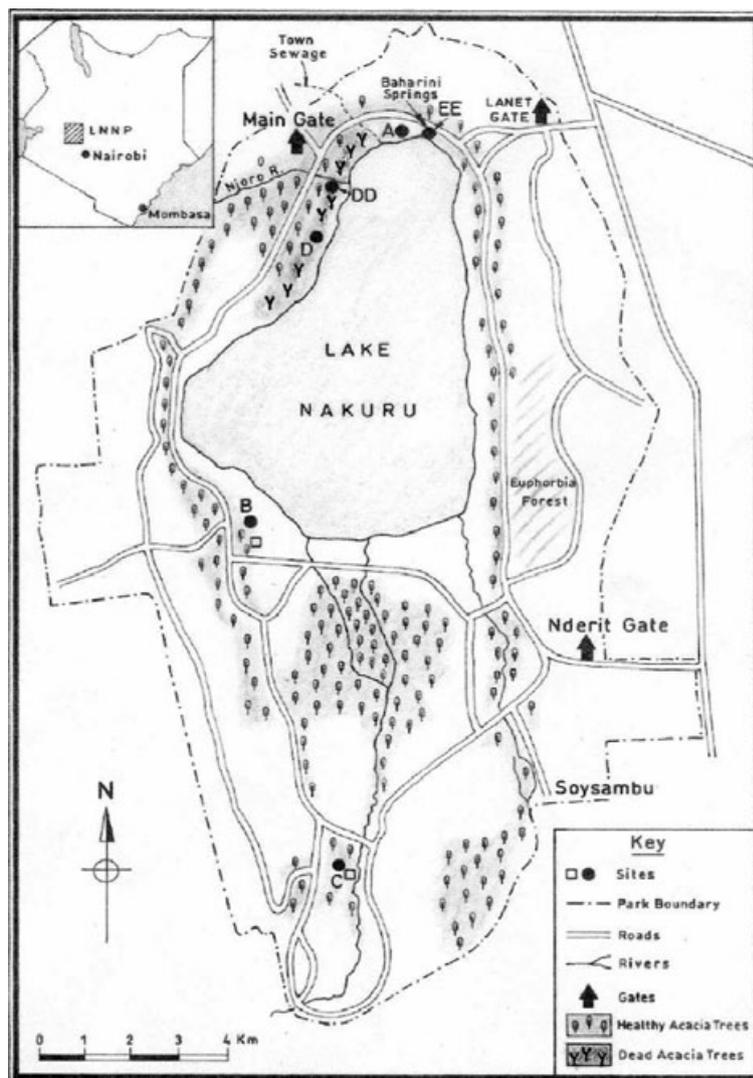
Fig 1 Map of Lake Nakuru National Park, Kenya, illustrating the study sites

height, canopy cover and stem diameter for previously browsed trees were taken in May 2002 in an unfenced plot with 49 trees and a fenced plot with 38 trees. Significant differences were found in growth rate for height, canopy and stem diameter of *Acacia* trees in the unfenced as compared with the fenced plots for the both rainy and dry seasons.

Impact of browsing on the growth rate in height of A. xanthophloea *trees in both rainy and dry seasons for unfenced and fenced plots*

Growth in height with respect to time and average rainfall, in *A. xanthophloea* trees for unfenced as compared with

fenced plots are presented in Fig. 2a,b. Measurements of growth rate in height were classified into three initial height classes; 150–250, 250–450 and 450–600 cm. Sampled trees in the unfenced plot had a lower incremental mean growth rate in height at 6.1 ± 2.4 cm year^{-1} as compared with trees in the fenced plot, where mean growth rate in height of the trees was very high at 16.1 ± 1.4 cm year^{-1}, as shown in Fig. 2a,b.

The mean growth rate in all the height classes indicated significantly ($P<0.05$) lower growth rate in height of the *Acacia* trees in the unfenced plot as compared to the fenced plot. However, this was no significant ($P>0.05$) increase in the 450–600 cm height class during the dry season for both plots.
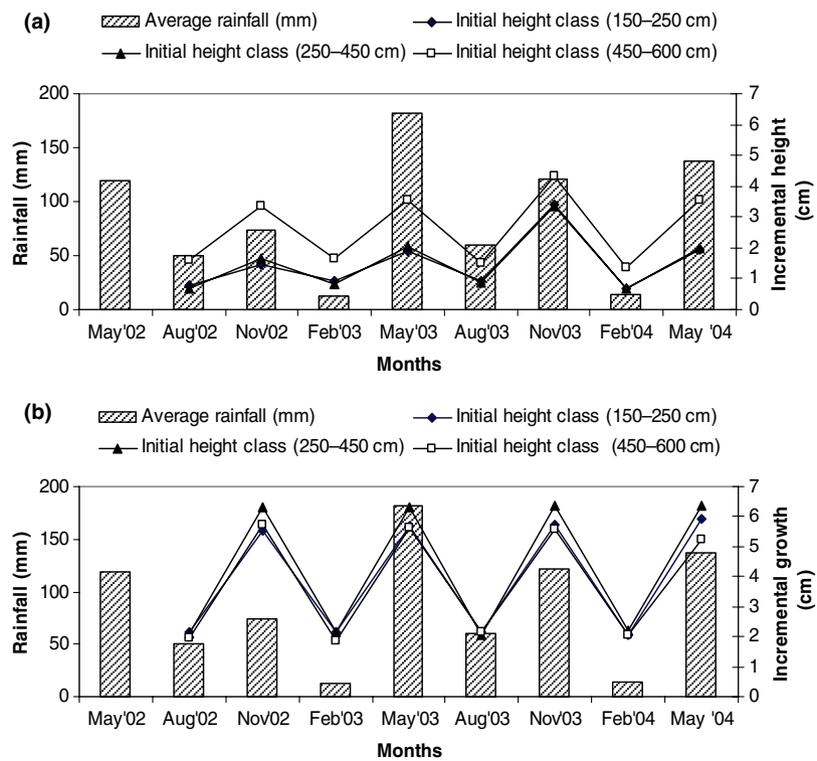
Fig 2 Incremental growth in height: (a) unfenced plot: incremental growth in height at each time averaged over an initial height class; (b) fenced plot: incremental growth in height at each time averaged over an initial height class

Impact of browsing on the growth rate in canopy of A. xanthophloea *trees in both rainy and dry seasons for unfenced and fenced plots*

Growth in canopy with respect to time and average rainfall, in *A. xanthophloea* trees for unfenced as compared with fenced plots are presented in Fig. 3a,b. Measurement of growth rate in canopy was classified into three initial canopy classes; 100–250, 250–350 and 550–500 cm. Trees in the unfenced plot had lower incremental mean growth rate in canopy at 4.2 ± 1.7 cm year^{-1} as compared with trees in the fenced plot where mean growth rate in canopy of the trees was very high at 12.4 ± 1.0 cm year^{-1}, as presented in Fig. 3a,b.

Results indicate that in the rainy season, mean canopy growth rate of *Acacia* trees in all the classes include 100–250, 250–350, 350–500 cm showed significantly lower growth rate of the canopy in the unfenced plot as compared to the trees in the fenced plot ($P<0.05$). Mean canopy growth rate in all the classes was significantly ($P<0.05$) lower in the unfenced plot than in the fenced plot.

Impact of browsing on the growth rate in stem diameter at breast height of A. xanthophloea *trees in both rainy and dry seasons for unfenced and fenced plots*

Growth in stem diameter in *A. xanthophloea* trees for unfenced as compared with fenced plots is presented in Fig. 4a,b. There was a higher growth rate of stem diameter at 1.5 ± 0.3 cm year^{-1} in the unfenced plot as compared to 0.4 ± 0.1 cm year^{-1} in fenced plot. Results indicate that in the wet season, mean growth rate showed significantly ($P<0.05$) higher mean growth rate for the unfenced plot as compared to the fenced plot on the average.

Discussion

Woodland–grassland ecosystems are inherently dynamic (Dublin, 1995) with factors such as browsing, fire and rainfall being critical in determining whether the habitat will be stable or subject to change (Walter, 1971; Walker *et al.*, 1981; Walker & Noy-Meir, 1982). Norton-Griffiths (1979) and Dublin (1995) reported that fire and browsing pressure impact the vegetation structure of Serengeti-Mara ecosystem and limit the natural regeneration of
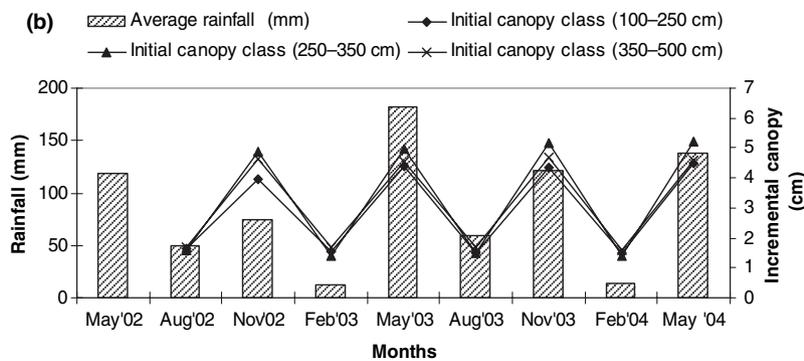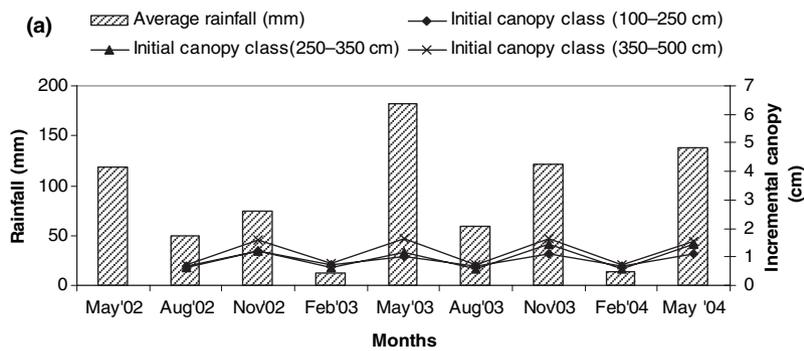
Fig 3 Incremental growth in canopy: (a) unfenced plot: incremental growth in canopy at each time averaged over an initial canopy classes; (b) fenced plot: incremental growth in canopy at each time averaged over an initial canopy classes
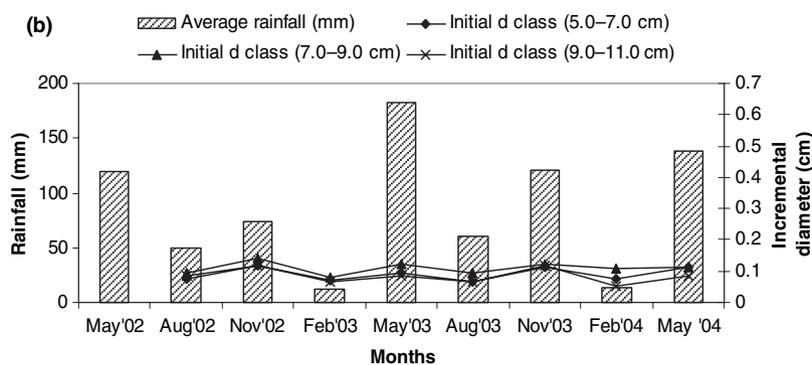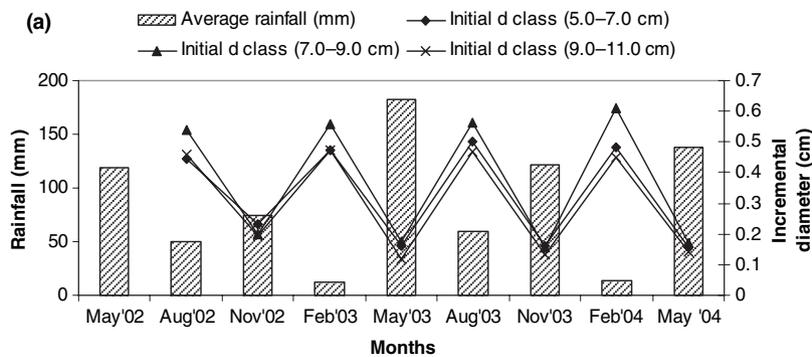

Fig 4 Incremental growth in diameter at breast height: (a) unfenced plot: incremental growth in diameter at each time averaged over an initial diameter classes; (b) fenced plot: incremental growth in diameter at each time averaged over an initial diameter classes

East African woodlands. Elephants have been reported to cause spectacular changes in vegetation structure and incomposition of savannahs in Africa (Barnes & Douglas, 1982; Cumming, 1982; Ruess & Halter, 1990). Furthermore, elephants have been reported to kill large Acacia trees (Western & Praet, 1973; Croze, 1974), resulting in of woodland disappearance. However, Western & Praet (1973) recognized that some trees in Amboseli were dying without appreciable elephant damage, while apparently healthy trees were able to tolerate significant amounts of debarking and branch removal. Their study suggested that long-term climatic change was also a more fundamental cause of tree mortality. They provided evidence that increased soil salinity, associated with a period of higher rainfall and a rising ground water-table in the closed drainage basin of Amboseli, resulted in killing stress to many trees. Elephants then accelerated the process, as they fed in the groves of dead weakened trees.

In this study, the *A. xanthophloea* woodland was exposed to the conditions of wet and dry seasons and different levels of browsing by large herbivores (mainly giraffes and black rhinoceros) but was not subject to fire and elephant browsing. These impacts appeared to be sufficient to cause rapid reductions in tree height and canopy. Dry season, low rainfall and intense browsing pressure reduced tree growth. Growth retardation was height and canopy specific, whereas growth increment was diameter specific. The present study has found that in the unfenced plot, there was a low average growth rate in plant height and canopy compared with the trees in the fenced plot.

Our results show that heavy browsing pressure on *Acacia* trees resulted in lower average incremental growth rates in the height and canopy cover of the trees in the unfenced plot as compared to the fenced and protected plot. Hence, the impact of heavy browsing pressure on *Acacia* trees in the unfenced plot resulted in a higher average growth rate in *d* as compared to the fenced plot where average growth rate in stem diameter was low. Therefore, some browsing pressure increased growth in stem diameters of the trees but decreased growth of tree height and canopy. Although the impact of browsing on the height and canopy of *Acacia* trees was considered to be high, it did not kill any trees, and seedlings and saplings were found growing in both plots.

Birkett (2002) studying the impacts of giraffes, rhinos and elephants within the black rhino sanctuary habitat in the Sweet Waters Game Reserve in Kenya found that *Acacia drepanolobium* trees subject to high levels of giraffe browsing and low rainfall grew by only 7.5 ± 0.5 cm year^{-1} in an unprotected area as compared to 19.1 ± 2.1 cm year^{-1} in a protected area. The study also reported extensive damage of trees due to elephant destruction. Ruess & Halter (1990) observed vegetation changes in Serengeti National Park due to the combined effects of fire, elephants and giraffes, reporting a high degree of stem and branch damage that resulted in high mortalities among trees.

In our study, significant differences were found in the average incremental growth rate in *Acacia* trees in the unfenced plot as compared with the fenced plot in both rainy and dry seasons. This indicates that rainfall plays an important role in the growth in height of these trees. Trees grew in height at a faster rate in the rainy season than in the dry season, even in the unfenced plot where browsing took place. Our results clearly indicate that most of the browsing took place in the height classes 150–250 and 250–450 cm in the unfenced plot. Pellew (1983)) in Serengeti National Park, reported more giraffe browsing impact on *Acacia tortilis* trees of 200–300 cm height class, but Birkett (2002) observed that giraffes browsed extensively in the 250–450 cm height class, whereas black rhino concentrated on lower <200 cm height class.

Significant differences were found in the average growth rate in each canopy class of *A. xanthophloea* trees in the unfenced as compared with the fenced plots in both rainy and dry seasons. It was also found that a significantly ($P<0.05$) high average incremental growth rate of trees in all three canopy classes occurred during the rainy seasons as compared to in the dry season for the fenced plot. This implies that rainfall plays an important role in the growth in canopy of the trees.

Significant differences were found in the average incremental growth rate in stem diameter class of *A. xanthophloea* trees in the unfenced as compared to fenced plots in both rainy and dry seasons. It was observed that the average incremental growth rate in tree stem diameter was significantly ($P<0.05$) higher during the dry seasons for the unfenced plot than during the rainy seasons. This could be a strategy by Acacia trees to avoid browsing damage by allocating more resources to stems than to aerial plant parts.

This indicates that herbivore browsing stimulate compensatory responses in the tree growth, especially in the stems, during heavy browsing in the dry season.

Danderfield & Modukanele (1996) suggested that stimulation of moderate browsing as a once-only event, in an otherwise browse-free environment, induced a compensatory response in *Acacia erubescens*. The compensatory responses, according to Danderfield & Modukanele (1996) were an increase in the number of shoots and shoot length that occurred within the same growing season as the disturbance event. Similar results were obtained from studies on *A. xanthopholoea* (Pellew, 1984), *A. tortilis* and *Acacia nigrenscens* (du Toit, Bryant & Frisby, 1990). In an open savannah, this may be infrequent and other pressures may be important. For example, overcompensation following a random browse event may allow an individual shrub or tree to reach reproductive size more rapidly or, perhaps reach a size where the impact of fire is tolerable (Danderfield & Modukanele, 1996).

It is noted that the current browser population of 75 giraffes and 67 rhinoceros has not reached a critical level to cause much negative impacts on the *A. xanthophloea* trees. Findings of this study showed that although heavy browsing reduced the height and canopy of *Acacia* trees, it did not kill any trees and seedling regeneration took place simultaneously. Even in the dry season, the heavy browsing pressure by large herbivores did not appear to have a negative impact on *Acacia* woodland. In conclusion, despite the presence and impacts of large herbivore browsers, results indicate that this *A. xanthophloea* habitat type is still in balance with the addition of recruitment seedlings and saplings. The conditions at the time of study indicate that the browsing in *A. xanthophloea* habitat was not significant, and is not serious enough to warrant management intervention at present levels.

Acknowledgement

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