Structure and composition of *Acacia xanthophloea* woodland in Lake Nakuru National Park, Kenya

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Abstract

The woody vegetation of Lake Nakuru National Park occurs along rivers, lakeshores and flood plains. Four different sites within the *Acacia xanthophloea* woodlands were selected for the study. Vegetation structure was not significantly different in the four woodlands used for the study, but these sites differed in the relative density of *Acacia* trees. Regeneration of *A. xanthophloea* differed in each site, with the highest regeneration rates found in the nonfenced plots where browsing took place.

Key words: Acacia, herbivores, Lake Nakuru, vegetation structure

Résumé

La végétation ligneuse du Parc National de Nakuru se trouve le long des cours d'eau, sur les berges du lac et dans les plaines inondables. Nous avons sélectionné quatre sites dans les zones arborées à *Acacia xanthophloea*. La structure da la végétation n'était pas significativement différente dans les quatre forêts sélectionnées pour l'étude, mais ces sites différaient quant à la densité relative d'acacias. La régénération des *Acacia xanthophloea* différait sur chaque site, et le taux de régénération était le plus élevé dans les plots non clôturés fréquentés par les herbivores.

Introduction

Lake Nakuru National Park lies approximately between latitudes 0°18′ and 0°29′ South and longitudes 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 approximately 1760–2080 m a.s.l. The park is located about 150 km from Nairobi along the Trans African Highway A104. 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 attract tourists and is also a RAMSAR (International Wetland Treaty) site. The park is also declared as a rhino and bird sanctuary.

A detailed vegetation study was conducted by Mutangah (1989) who divided the vegetation into three forests, namely *Acacia xanthophloea* Benth; *Euphorbia candelabrum* Kotschy; and *Olea erupaea* ssp. *africana* Mill forests. Several *Acacia* woodlands occur in the park and are associated with areas of a high water table (Mutangah, 1994; Mutangah & Agnew, 1996). The *A. xanthophloea* woodland is an important habitat for many animals by providing nesting places and shelter for many resident and migratory birds. The woodlands also provide food for large herbivores, mainly Rothschilds giraffes (*Giraffa camelopardalis rothschildi*), black rhinoceroses (*Diceros bicornis*), Olive baboons (*Papio anubis*), Vervet monkeys (*Cercopithecus pygerythrus*) and several other mammals and insects. The woodlands also contribute to the aesthetic value and tourist attraction of the national park.

Plant species composition, tree height, stem basal area, canopy cover and plant density of the *A. xanthophloea* woodlands were determined in the sample plots. Such ecological knowledge can be used in determining appropriate management practices and in promoting the maintenance of biodiversity, wildlife management and ecosystem rehabilitation.

The main objective of the study was to characterize the vegetation structure of various *Acacia* woodlands in Lake Nakuru National Park. This study forms a wider study initiated to find out the cause of the recent die-off of many *A. xanthophloea* trees in the Lake Nakuru National Park.

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Material and methods

In 2001, four sites (10 × 100 m) were randomly selected to represent the various areas where *A. xanthophloea* woodland is found, namely:

Site A: Baharini Springs area in the eastern shoreline;
Site B: Opposite pelican corner in the western shoreline;
Site C: Naishi Park Headquarters and the surrounding area in the southern part of the park;
Site D: Njoro River and its surrounding vegetation in the north-western part of the park.

A randomly placed belt transect of 10 × 100 m length was used at each site for vegetation sampling. Within the belt transects, plant density, height, canopy cover, and stem basal area of woody species were estimated (Eshete, 2000). Quantitative analysis was carried out to quantify species abundance (density), dominance (stem basal area) and cover (canopy cover) of the woody species. This was performed to determine floristic variations and find out the major woody species of the area (Mutangah, 1989). Moreover, the relative frequencies of woody trees and shrubs at a height above 1.5 m and stem diameter above the 2-cm class were also determined.

Plant height was determined using a clinometer (PM-5, SUUNTO) following the method used by Rosenschein, Tietema & Hall (1999). Woody plants of <5-m height were measured using a sliding or folding marked pole. Stem basal area at breast height (1.3 m above the ground) was measured using callipers and a steel diameter tape. Where the diameter at breast height could not be measured (because of stem forked below the breast height), the diameter at the ground level was taken. The canopy diameter measurements were taken at the extremes of the tree canopy (to the tips of the longest branches) with a tape measure.

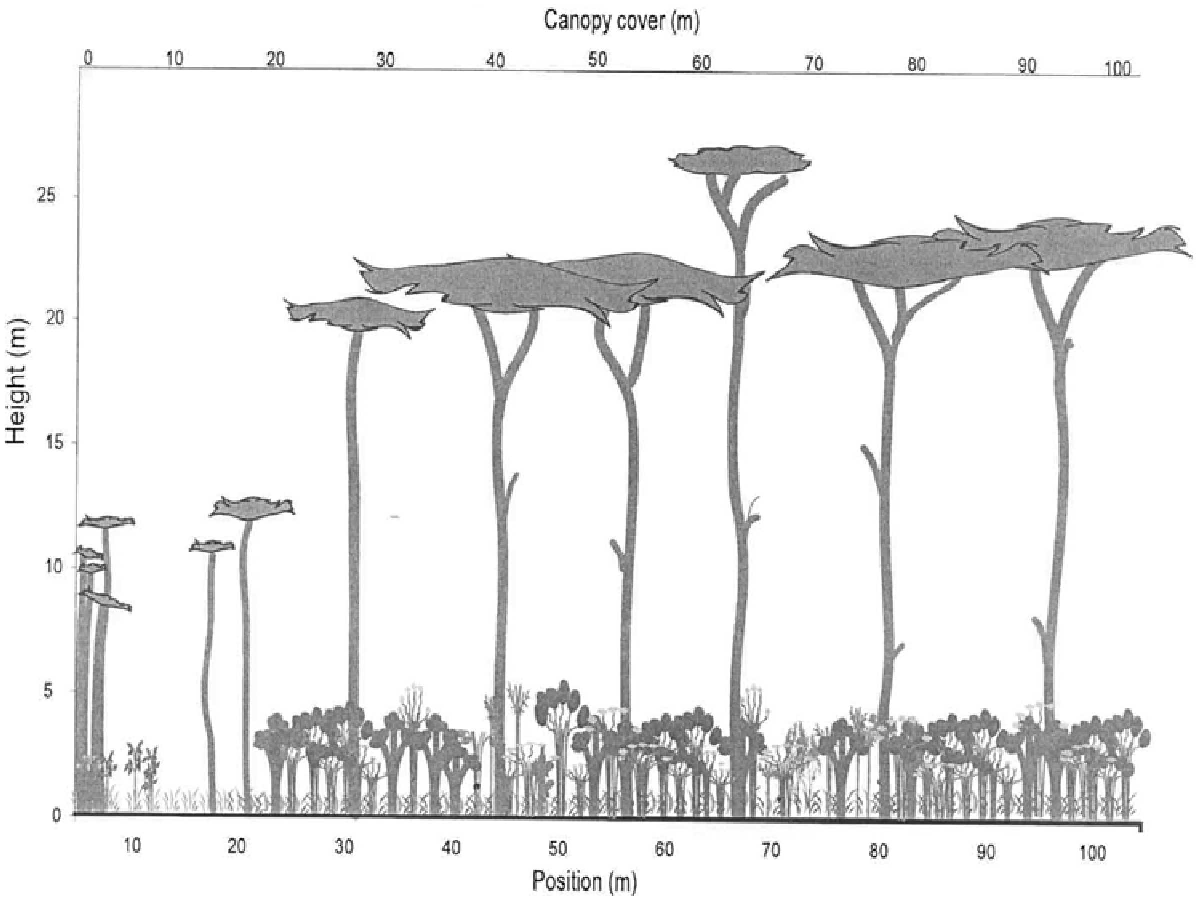

Fig 1 Profile diagram showing the vertical stratification of vegetation at Site A

Relative density, relative dominance, relative cover and Importance Value Index of the woody species were calculated as follows (Mutangah, 1989 and Kigomo, Savill & Woodell, 1990):

$$\text{Relative density} = \frac{\text{Number of individuals of species A}}{\text{Number of individuals of species B}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Total basal area of species A}}{\text{Total basal areas of all species}} \times 100$$

$$\text{Relative cover} = \frac{\text{Total cover of species A}}{\text{Total cover of all species}} \times 100$$

$$\text{Importance value (IV)} = \text{Relative density} + \text{Relative dominance} + \text{Relative cover}$$

From the stem diameter measurements, the basal area for each woody plant was calculated, together with height measurements. These were used to construct profile diagrams to show both vertical and horizontal vegetation structure of the plant communities sampled at the sites.

Statistical differences between the sites were tested using Tukey's procedure (HSD) and the analysis of variance at 0.05 significance level (Steel, Torrie & Dickey, 1997).

Results

Vegetation profile diagrams (Figs 1–4) were prepared, using plant position (m) along each transect, plant height (m) and canopy cover (m), and the floristic characteristics of each of these sites are given in Table 1. This list gives the status of each woody species in terms of spatial dominance, distribution, frequency and its ecological or importance value in the *Acacia* woodland.

Site A was made up of homogenous stands of *A. xanthophloea*, with the presence of dense undergrowth,

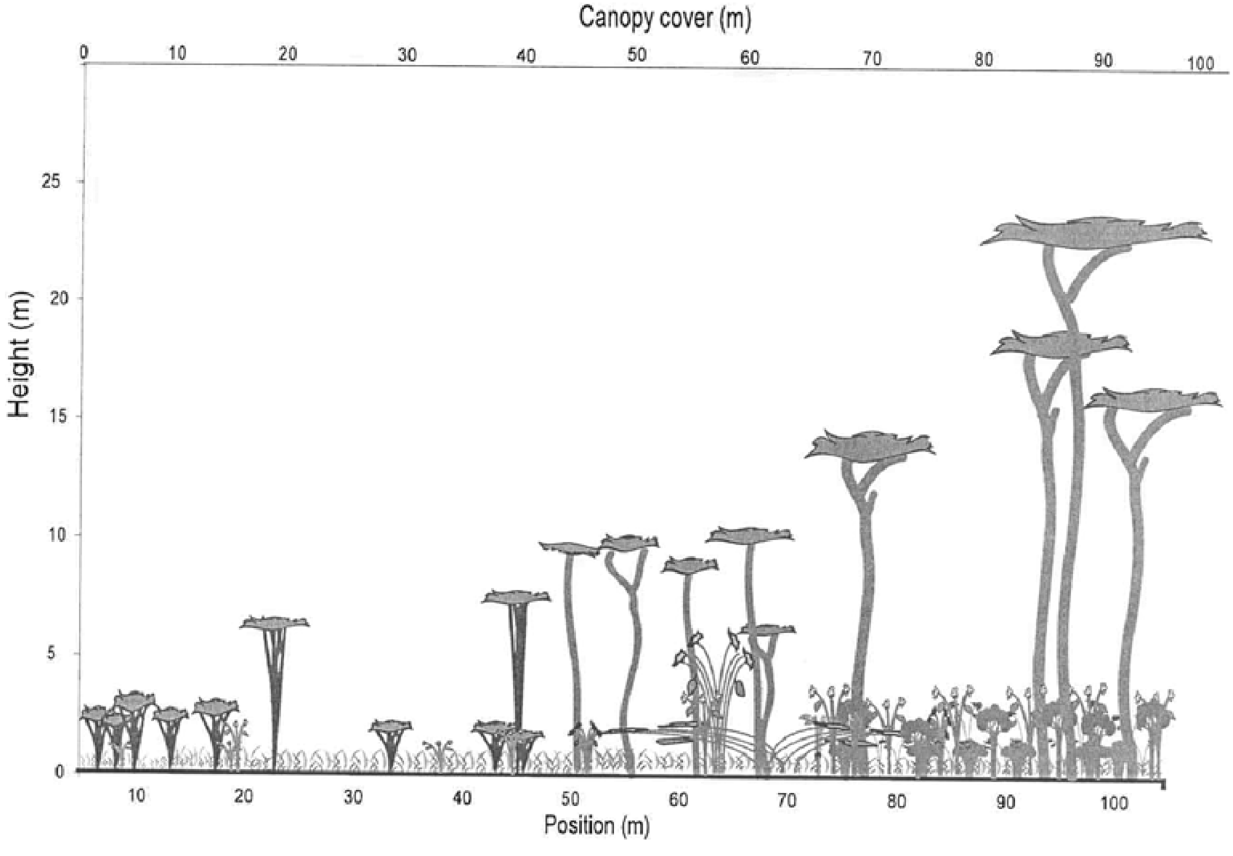

Fig 2 Profile diagram showing the vertical stratification of vegetation at Site B

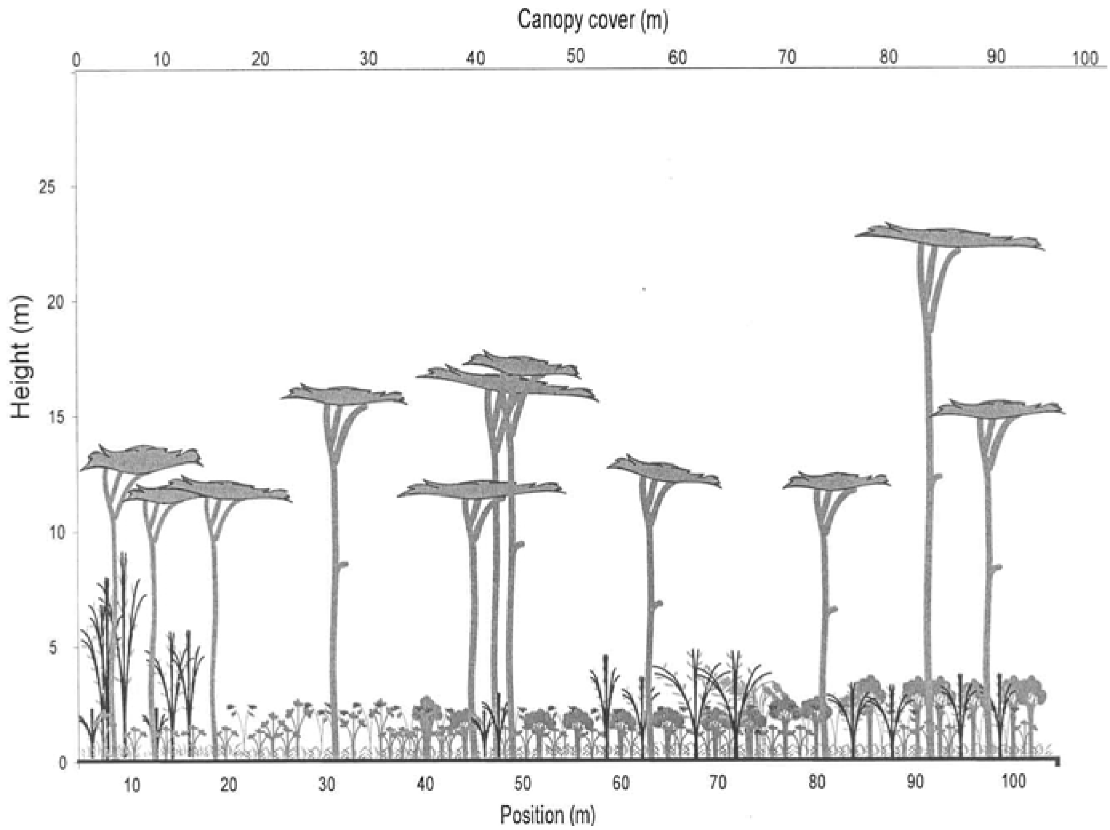

Fig 3 Profile diagram showing the vertical stratification of vegetation at Site C

mainly of *Lantana camara*, *Abutilon mauritianum* and *Achyranthus aspera* with a height up to 0.5 m but occasionally reached up to 1.0–1.3 m in height making a strong thick bush (Fig. 1). The *A. xanthophloea* trees had a high IV of 77%. These trees started to branch off beyond the height of 25.9 m, the zone where branches interlace together to form a closed canopy of about 30 m in height. As a result of the small size of the leaves and their leaflets, enough sunlight penetrates through the tree canopy to give life to the undergrowth (Fig. 1). The woody shrub layer was almost lacking, only a few shrubs that mainly comprised *Senna bicapsularis*, *Grewia similis*, *Toddalia asiatica*, *Microglossa pyrifolia* and *Maytenus heterophylla* but had significantly low IV between 3.5 and 24.8%. *Senna bicapsularis* with IV of 13.6%, *L. camara* with 3.38%, *M. pyrifolia* with IV of 3.5%, *G. similis* with IV of 10.4%, *T. asiatica* with IV of 24.8%, and *M. heterophylla* IV of 7.69% (Table 1).

The dominant woody tree species at site B was again *A. xanthophloea* that had the highest importance value (Table 1). *Acacia xanthophloea* occasionally formed a semi-closed canopy of about 26.4 m in height (Fig. 2). The characteristic of this site was that heavily browsed *A. xanthophloea* trees became bushy and multi-stemmed at a height of between 1.9 and 3 m at the periphery zone of the woodland. Unbrowsed trees were taller than browsed trees, single-stemmed with a height between 6 and 21.4 m and formed a semi-closed *Acacia* canopy more than the browsed trees. The few shrubs that were sparingly scattered comprised mainly *M. pyrifolia*, *Rhus natalensis* and *G. similis* and had low importance values (Table 1). This woodland also had the presence of climbers and lianas that hung on the trunks of big-sized *Acacia* trees. The undergrowth was dominated by *A. mauritianum*, *A. aspera*, *Solanum incanum* and *M. pyrifolia* that covered the area (Fig. 2).

The most common woody tree species at site C was *A. xanthophloea*. There were tall, even-sized stands of *A. xanthophloea* up to a height of 24 m with high IV (Table 1). The thick undergrowth layer was made up mainly of *A. mauritianum*. Other woody shrubs

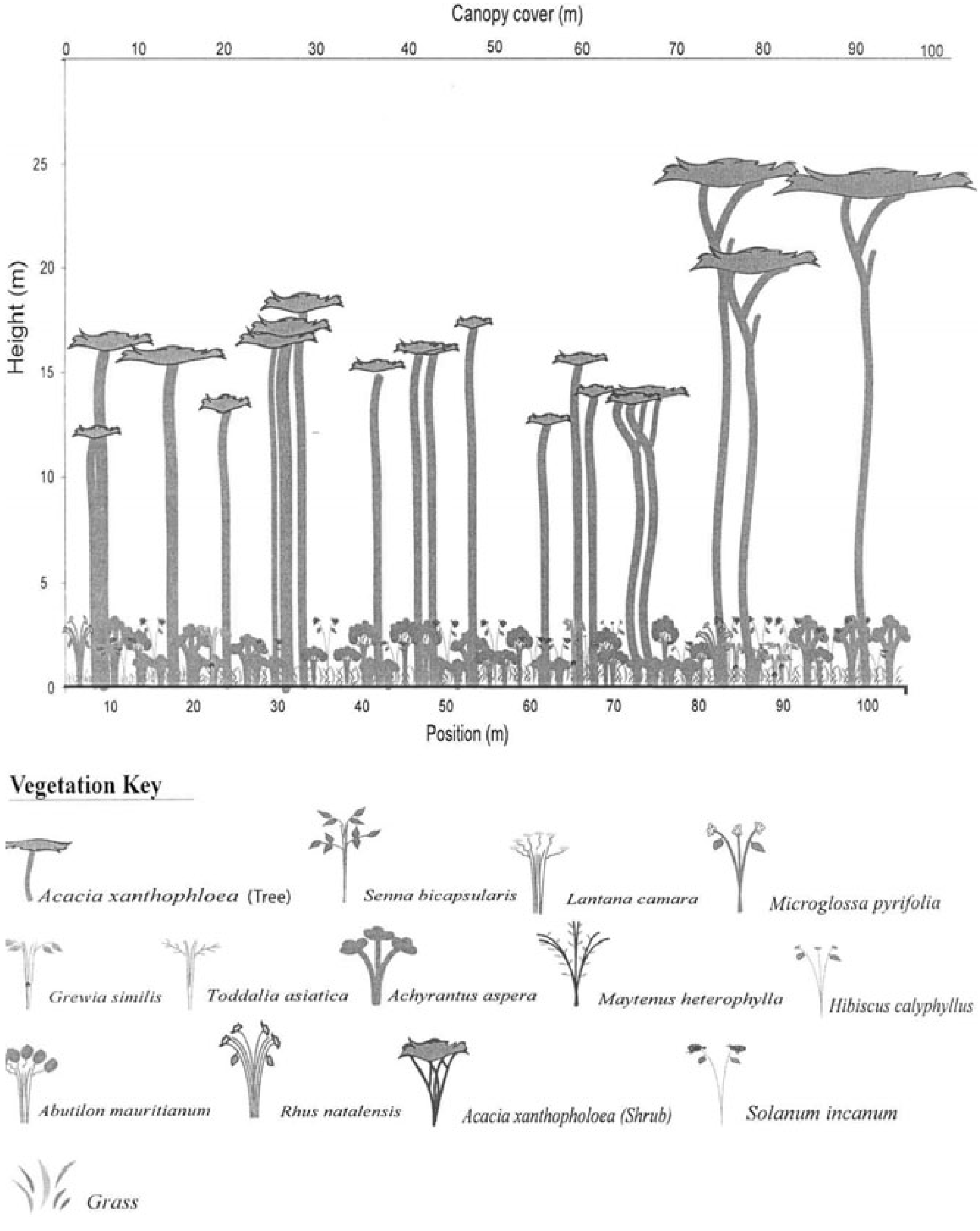

Fig 4 Profile diagram showing the vertical stratification of vegetation at Site D

occasionally found comprised only *M. heterophylla* and *G. similis* (Fig. 3).

Site D was characterized by tall, mature and homogenous stands of *A. xanthophloea* trees making an upper stratum up to a height of 26 m, the zone where the branches interlaced together to form a closed canopy. There was the presence of dense undergrowth formed mainly by *G. similis*, *R. natalensis*, *Hibiscus calyphyllus*, *A. mauritianum*, *S. incanum* and *A. aspera* with a height between 0.5 and 1.5 m, however, occasionally reaching up to 2 m in height (Fig. 4).

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Table 1 Overall relative importance of the common woody species at sites A, B, C and D (see text)

Species	Relative density (%)	Relative dominance (%)	Relative cover (%)	Importance value (IV)
Site A				
Acacia xanthophloea	35.3	99.8	89.6	225
Senna bicapsularis	11.76	0.006	1.82	13.6
Lantana camara	2.94	0.004	0.44	3.38
Microglossa pyrifolia	2.94	0.009	0.57	3.5
Grewia similis	8.82	0.02	1.6	10.4
Toddalia asiatica	20.6	0.08	4.13	24.8
Maytenus heterophylla	5.88	0.04	1.77	7.69
Site B				
Acacia xanthophloea	60	99.3	67.2	226.5
Microglossa pyrifolia	20	0.45	3.83	24.3
Rhus natalensis	16.7	0.2	22.5	39.41
Grewia similis	3	0.0001	0.64	3.94
Site C				
Acacia xanthophloea	37.93	98.2	81.2	217.3
Grewia similis	6.8	0.04	1.46	8.3
Maytenus heterophylla	55.17	1.75	17.3	74.3
Site D				
Acacia xanthophloea	51.4	99.6	92.9	243.9
Rhus natalensis	8.57	0.08	1.39	10.04
Grewia similis	17.14	0.238	2.08	19.46
Solanum incanum	5.71	0.005	0.67	6.39
Hibiscus calyphyllus	5.71	0.021	0.58	6.311
Abutilon mauritianum	11.43	0.025	2.37	13.8

Discussion

The woodland on the plains under study in the four sampling sites comprised mainly one tree genus, *Acacia*, that was predominantly represented by the *A. xanthophloea* species. Profile diagram at each site clearly shows *A. xanthophloea* as being the largest and the most dominant woody tree species in all the sites with a very high importance value. There were a few shorter shrubs found scattered here, mainly *S. bicapsularis*, *G. similis*, *T. asiatica*, *M. pyrifolia*, *M. heterophylla*, *R. natalensis*, *A. mauritianum* and *H. calyphyllus* with a low IV. The undergrowth was overwhelmingly formed by *L. camara*, *A. mauritianum*, *S. incanum* and *A. aspera*. This is typical of the *A. xanthophloea* woodlands in East Africa (Mutangah, 1989).

Although *A. xanthophloea* was the most dominant woody species of the study sites, other minor woody species were also associated with it. This is in line with data from other ecosystems, for example, Tsavo National Park, where Belsky (1989) found the *Acacia* species associated with other understory woody plants, mostly shrubs.

The four study sites were dominated by even-sized *Acacia* tree individuals. This is a common observation in East Africa. It is a consequence of successional oscillation under the control of climate and fire (Lamphery, 1984), herbivore population fluctuation (Prins & Van Der Jeudg, 1993) and perhaps human disturbance (Mutangah & Agnew, 1996) in some interdependent cycle. There are numerous descriptions of these processes in East Africa, for example, the studies by Belsky (1989) and Ruess & Halter (1990) in the Serengeti, where *A. xanthophloea* formed even-sized stands. Norton-Griths (1979) and Ruess & Halter (1990) in the Serengeti, where *A. xanthophloea* formed even-sized stands.

Clearly, therefore, density estimates and vegetation structure may change as the woodland matures. These relationships have also been studied in the *Acacia* woodlands of Seronera Valley, Serengeti National Park, Tanzania, in relation to the effects of fire, elephants and giraffes (Lamphery *et al.*, 1967; Croze, 1974; Norton-Griths, 1979; Pellew, 1983a–c). Elephants in Amboseli National Park in Kenya, as elsewhere (Croze, 1974), might have killed large fever trees (Western & Praet, 1973), and this activity was clearly the proximate cause 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 the long-term climatic change was the 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, produced a killing stress to many trees. Elephants then accelerated the process, as they fed in the groves of dead and weakened trees. These changes in the woodland have troubled both ecologists and management authorities. Again, the climatic and edaphic factors and the impact of large herbivores on the structure of the woodland should be considered. Stewart & Veblen (1982) suggested that the even-age stand structure of *A. xanthophloea* represented an even more fundamental cause of the sudden disappearance of fever-tree woodland. They also explained that when most of the adults of a population are of the same, or nearly of the same age, they will tend to senesce and die at around the same time. While senescent death in a mixed-aged stand is hardly noticeable, senescence is synchronous and the population exhibits a dramatic dieback.

However, long-term monitoring of changes in woodland composition is necessary to interpret these effects. Knowledge of the state and dynamics of the woodlands is required for parks and land managers to designed methods to achieve a sustainable use of these resources. In this regard, tree size, structure, species composition, and regeneration patterns are some of the elements to be addressed. Knowledge of this kind can be used, for example, in determining appropriate management practices, which include the maintenance of biodiversity and ecosystem rehabilitation and the uses of woodland resources. Lake Nakuru is also a very important protected ecosystem in Kenya that is inhabited by a very wide range of biodiversity. Research and monitoring are therefore required to maintain and manage this biodiversity for posterity.

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