Elephant-induced change in woody vegetation and its impact on elephant movements out of a protected area in Zimbabwe

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Abstract

In Zimbabwe, changes in woodlands caused by elephants and other factors motivate elephants to leave refuges to forage on wild tree species still abundant outside these areas. A vegetation survey was conducted using transects and aerial photo interpretation to test the hypothesis that the vegetation structure and relative abundance of certain plants in remnant forest fragments differ from forests found within protected areas. Tree species that elephants browse on outside the protected area were monitored over a three-year period. The results suggest that historically, high densities of elephants have altered forest structures, and elephants are now moving into areas occupied by humans to feed on certain woody plant species now uncommon in protected areas. This may be a factor in understanding conflict between elephants and people.

Additional key words: elephant–habitat interaction, human–elephant conflict, vegetation change

Résumé

Au Zimbabwe, les changements causés aux forêts par les éléphants, et par d'autres facteurs, poussent ces animaux à quitter leurs refuges pour se nourrir des espèces d'arbres sauvages qui sont encore abondantes en dehors de ces zones. On a mené une étude de la végétation en se servant de transects et d'interprétations de photos aériennes pour tester l'hypothèse selon laquelle la structure de la végétation et l'abondance relative de certaines plantes dans les derniers petits morceaux de forêt seraient différentes de celles des forêts que l'on trouve à l'intérieur des aires protégées. Pendant trois ans, on a contrôlé de façon continue les espèces d'arbres dont les éléphants se nourrissent hors de l'aire protégée. Les résultats suggèrent que, depuis toujours, les fortes densités d'éléphants ont altéré la structure des forêts et que les éléphants se déplacent maintenant vers des zones occupées par les hommes pour se nourrir d'espèces végétales qui sont devenues rares dans les aires protégées. Ceci peut constituer un facteur de meilleure compréhension dans les conflits qui opposent les hommes et les pachydermes.

Introduction

Changes in woodlands in regions with elephants have been extensively documented in Africa (for example, Afolayan 1975; Laws et al. 1975; Malpas 1977; Coetzee et al. 1979; Jachmann and Bell 1979; Barnes 1983; Conybeare 1991). In the 1960s, wildlife managers of newly gazetted protected areas noted substantial changes in woody vegetation caused by the destructive nature of elephant feeding. Although considered generalist feeders, elephants can be very selective and are able to eliminate preferred woody species locally (Wing and Buss 1970; Anderson 1973; Barnes 1983). An elephant's preference for certain species appears to be an important factor dictating its movements in some habitats. Elephants consume the bark of woody plants that can result in the death of these trees (Thomson 1975). There is evidence to suggest that this selective elimination of trees has occurred within protected areas in Zimbabwe and that tree species that elephants favour have declined in number, while some mature individual trees that elephants prefer have remained intact in areas now inhabited by people (Guy 1989).

The goal of this study was to determine if changes in woodlands caused by elephants and other factors motivate elephants to leave a protected area to forage on tree species still abundant outside these areas. If this is the case, management of elephants to control the effect they have on woodlands may be important in controlling elephant incursions into areas inhabited by humans.

Study area

The study area is situated in the Sebungwe region of Zimbabwe, in and around the Sengwa Wildlife Research Area (SWRA) and the surrounding communal lands (CLs) (fig. 1). During the mid-1970s, the elephant population within SWRA was estimated to be over 1000 animals. Damage to the woodlands was deemed unacceptable and a series of culls were carried out in an effort to keep the density under 3 animals per km^2. (Martin and Conybeare 1995).

The vegetation is generally deciduous and dry deciduous savannah woodland. The main vegetation associations are *Brachystegia*/*Julbernardia* woodland, *Colophospermum* mopane woodland, *Acacia* spp. riparian woodland, riverine grasslands and *Combretum* spp. thickets. A single rainy season usually occurs between November and April, but it is highly variable in timing and quantity. The mean annual rainfall is 668 mm (n = 30) (DNPW 1997).

Between 1940 and 1960, there was an attempt to eliminate all large game in CLs as part of a tsetse fly control scheme. A wire fence 2.5-metre high with eight strands was erected in 1968 along the southern and eastern boundary to prevent game from moving south into CLs. The fence line does not follow ecozonal boundaries and the woodlands inside and out were identical in 1966 (D. Cumming, pers comm.). Effectively, large game animals did not use the vegetation in CLs for 30 years (Guy 1989). This fence fell into disrepair during the late 1980s and was removed in 1990.

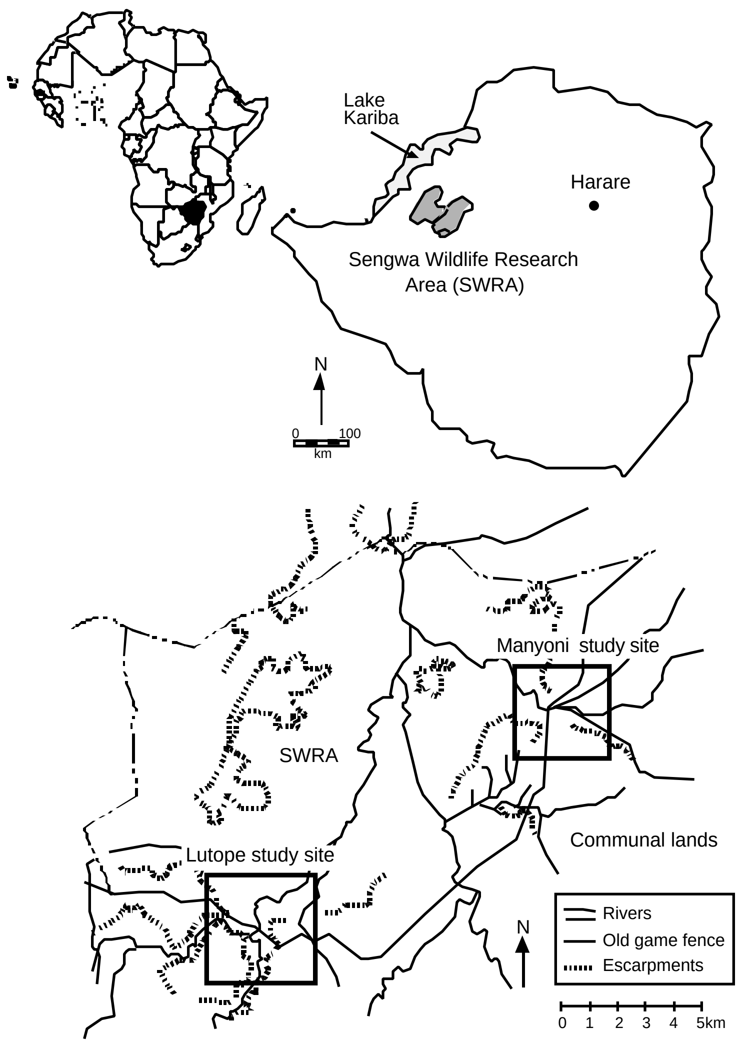

Figure 1. Location of the study area in Zimbabwe (Sengwa Wildlife Research Area—SWRA) and sites where study was conducted.

Materials and methods

Guy (1989) noted that exclosures had been useful for examining changes that occur in woodlands isolated from the effects of fire or grazers, or both. When exclosures are constructed, an area is cordoned off to ensure that fires do not occur and animals do not enter the plots.

When a reserve is fenced, a different situation occurs: wild animals are enclosed, keeping them from the woodlands outside the reserve. A comparison can be made between the woodlands inside and outside the fence. This technique has been used by Penzhorn et al. (1974) in Addo National Park in South Africa and by Murindagomo (1984), and Ford (1987) and Guy (1989) in the miombo woodlands around SWRA to study elephant impact on vegetation.

Two assumptions were made about the history of the riverine woodlands examined in this study. The first is that there was no difference in the woodland structure and composition of vegetation before the boundary fence was erected. The second is that changes to the vegetation in SWRA were caused by elephants and fire, and changes in CLs were due to human cultivation, domestic livestock and fire.

Three types of data were collected. First, vegetation transects were conducted to identify differences in woodland structure and composition. Second, aerial photographs taken between 1966 and 1993 were used to plot trends in woody vegetation cover in the riverine woodlands inside and outside the park. Finally, indirect observations of trees consumed by elephants in CLs were recorded.

From a survey of aerial photographs and vegetation and soil maps, two regions of riverine vegetation with similar physical features were identified for sampling. After experimenting with permanent plots and transects of different sizes, a 50 m x 10 m non-permanent belt transect (Brower and Zar 1977) was determined to be the most efficient sampling system. Transects were sited in SWRA and CLs in the Lutope and Manyoni riverine woodlands within 2 km of the boundary fence (fig. 1). In CLs, transects were sited in riverine fragments greater than 0.5 ha and selected from 1993 aerial photographs.

Anderson and Walker (1974) defined trees as woody plants taller than 3 m with a stem diameter greater than 6 cm (measured above the buttress swelling). Damaged by elephants, the shapes of many trees were distorted. For this study, a woody plant with a stem diameter greater than 5 cm was considered to be a ‘tree’. Plants were either identified in the field or a sample was collected for later identification at the SWRA herbarium. Multi-stem or coppicing plants were measured from ground level if the original stem was greater than 5 cm. The height was measured to the nearest half metre using a graduated pole. Dead trees were excluded. Damage was estimated using four categories: old elephant, old unknown, new elephant, and new unknown. Obvious fire or human damage was also noted. Data were recorded on data sheets designed by Anderson and Walker (1974). No recent fires had passed through the four transect areas, two of which are in CLs and two in SWRA.

Aerial photographs of the Lutope study area used in this analysis were taken five times over a 30-year period: 1966, 1971, 1977, 1983 and 1993. All photographs were taken in the mid- to late dry season when many of the deciduous trees in the miombo and mopane woodlands had lost their leaves. Most trees in the riverine woodlands are evergreen, making interpretation less susceptible to seasonal effects.

Research assistants tracked elephants from the SWRA boundary into CLs in the Lutope study area from June 1993 to June 1996. The fence line was patrolled six days a week and all elephants entering CLs were tracked. The location where elephants left SWRA was identified and the route taken by these elephants the previous night was followed. Assistants were trained to identify plants consumed by elephants, and each time a plant that an elephant had browsed on the previous night was encountered, the plant part consumed was recorded and was scored as one ‘browse event’. No effort was made to distinguish the amount of plant material removed.

Each browse event involved an interaction between elephants and an individual tree. Even if more than one elephant fed on a tree, the interaction was scored as one incident. However, as the group size of the study elephants in CLs varied from day to day, a bias exists in the browse event as an index. A group of 10 elephants moving through a woodland are more likely to feed on the same species of trees than a group of unassociated animals. Assistants patrolled the fence line six days a week so the number of days the elephants were tracked is an accurate measure of the number of times the elephants entered CLs.

Analysis

Although 33 transects were conducted in the study area, 4 were not used in the analysis because they crossed from one vegetation type to another. Two-tailed *t*-tests were used to compare the differences between tree height, species composition, and damage classes as the data appeared to be normally distributed. To compare the height of the trees, data were partitioned into three categories. An *A* classification was assigned to trees measuring 0.5–2.5 m in height, *B* was given to trees 2.6–10 m, and *C* to trees over 10 m. Two-tailed *t*-tests were used to compare the differences between tree heights and the number of species, as the data appeared to be normally distributed. Simpson's diversity index was used to compare the CL and the SWRA riverine forest. This index takes into account both the abundance (biomass) patterns and the species richness. It is calculated by determining, for each species, the proportion of individuals that it contributes to the total in the sample (Begon et al. 1990).

If two individuals are taken at random from a sample the probability that the two will belong to the same species is

$$l = \frac{\sum n_i (n_i - 1)}{N(N-1)}$$

where n_i is the total number of species $_i$ in the sample and *N* is the total number of individuals in the sample.

The quantity *l* is, therefore, a measure of dominance. A large *l* implies an aggregation of individuals in only a few species, whereas a small value of *l* denotes a more uniform distribution of individuals among species (Brower and Zar 1977). A collection of species with high diversity will show low dominance, and, $D_s = 1 - l$:

$$\text{Simpson's index } D_s = 1 - \frac{\sum n_i (n_i - 1)}{N(N-1)}$$

Brower and Zar (1977) state that if the data comprise an entire sub-community, then the result of the above analysis may be compared by inspection instead of statistically.

Photographs of the Lutope study area were selected from the five samples taken over the 30 years. The scale of the photographs varied from 1:10,000 to 1:70,000. To make a comparison between years, the scale of all the photographs was adjusted to 1:10,000 with the use of a Grant light table. This light table projected the image onto a piece of glass on which a 100 x 100 grid of squares measuring 1 cm^2 was positioned. Another grid of the same dimensions was placed on the photograph and by adjusting the height of projected image, the scale of all the images was standardized.

Each 1-cm^2 square cell was the equivalent of 20 x 20 m on the ground at the 1:10,000 scale used for analysis. The contents of each cell were examined and coded with either a percentage of the vegetation filling the cell or given a value of *F* for field or *R* for river. If a cell contained both wild vegetation and either 'field' or 'river', the cell was allocated to whichever type covered more than 50% of the cell. Wild cover classes were as follows:

- 0 = areas in CLs that had been cleared and not cultivated, or were bare ground in SWRA
- 1 = 5–24% cover
- 2 = 25–49% cover
- 3 = 50–75% cover
- 4 = 76–100% cover

Results

The difference between the number of individual trees in CLs and SWRA in the Lutope woodland was not significant ($t = 0.09$, df = 14, $p = 0.931$). The difference between the number of species was also not significant ($t = 1.05$, df =14, $p = 0.310$) nor was the difference between the stem diameters ($t = 0.85$, df = 14, $p = 0.408$).

There was a significant difference between the percentage of trees in height class *A* ($t = –2.86$, df = 14, $p = 0.013$). Figure 2a shows that 72% of the trees in SWRA measured below 2.5 m whereas only 48% of the trees in CLs were below this height (fig. 2b). There was also a significant difference between the percentage of trees in height class *B* ($t = 3.03$, df = 14, $p = 0.009$). Figure 2a shows that in SWRA only 19% of the trees were in the 2.5–5-m class whereas 39% were in this category in CLs. The difference in the percentage of trees greater than 10 m was not significant, with 9% in SWRA and 13% in CLs ($t = 0.74$, df = 14, $p = 0.474$).

The difference between the number of individual trees in CLs and SWRA in the Manyoni riverine was not significant ($t = 1.9$, df = 13, $p = 0.8$). The difference between the number of species was significant ($t = 5.03$, df = 13, $p = 0.0001$) as was the difference between the stem diameters ($t = 2.22$, df = 13, $p = 0.045$).

There was a significant difference between the percentage of trees in height class *A* ($t = –5.41$, df = 13, $p = 0.0001$). Figure 3a shows that in SWRA 86% of the trees measured were below 2.5 m whereas only 58% of the trees in CLs were below this height. There was also a significant difference between the percentage of trees in height class *B* ($t = 3.87$, df = 13, $p =$

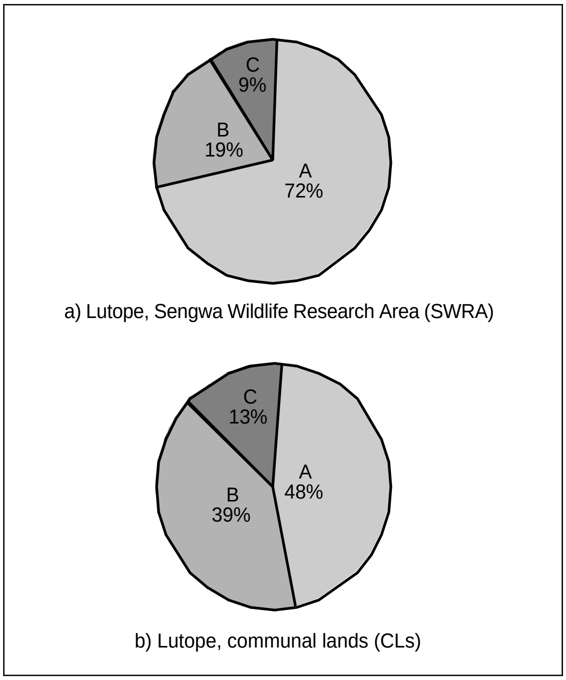

Figure 2. The percentage of trees in the Lutope study site in height classes A (0.5–2.5 m), B (2.6–10 m) or C (> 10 m).

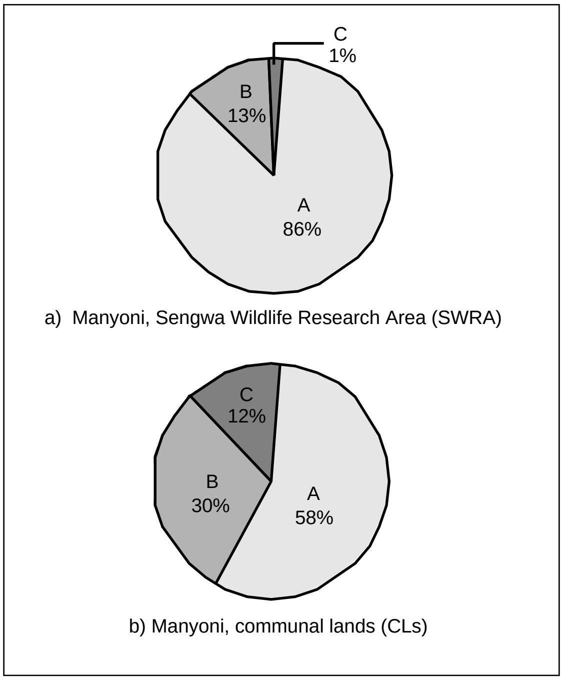

Figure 3. The percentage of trees in the Manyoni study site in height class A (0.5–2.5 m), B (2.5–10 m) or C (> 10 m).

0.002). In SWRA 13% of the trees were in the *B* class whereas 30% of the trees were in this category in CLs (fig. 3b). The difference in the percentage of trees in the > 10-m class was also significant with 1% in SWRA and 12% in CLs (t = 4.62, df = 13, p = 0.001).

Figure 4 shows the results of the aerial photo analysis for the five years sampled. The 1966 photos show little difference between the percentage of cover in the riverine vegetation inside and outside of SWRA. In the 1971 photos, the first few fields in CLs appear and there is a decline in category 4 and an increase in 1, which could be due to clearance of land in preparation for cultivation. The shift in the number of cells inside SWRA classified as 4 between 1966 and 1977 is due mostly to elephants and, to a lesser degree, fire (Anderson and Walker 1974). The shift is not as marked in CLs but there is a slow erosion of the number 4 class in favour of the other categories during the period between 1966 and 1977. This decline could be caused by cover variation at the time the photo was taken. The 1983 photos show a substantial shift from the 4 and the 1 cells to fields.

The routes elephants travelled in CLs were tracked on 784 occasions in the Lutope study area. Table 1 rates the 12 species most commonly browsed by elephants in CLs. As noted earlier, this method gives only a rough estimation of browse selection and is biased. The species they most heavily selected was *Combretum fragrans,* which is reported to be highly preferred by elephants within SWRA (Anderson and Walker 1974; Guy 1989).

Both *Combretum fragrans* and *Colophospermum mopane* are common in SWRA, and the fact that they are selected outside the park is not surprising. However, species such as *Bauhinia inscines* and *Grewia monticola* are no longer common in SWRA.

Discussion

The main difference between the woodlands in CLs and in SWRA is in the size of the trees. The woodlands in SWRA are younger and generally more homogeneous. It does not appear from these data that there are fewer preferred species in SWRA. In fact, in the Manyoni riverine woodland inside the park, some of the transects were sited in nearly pure stands of species

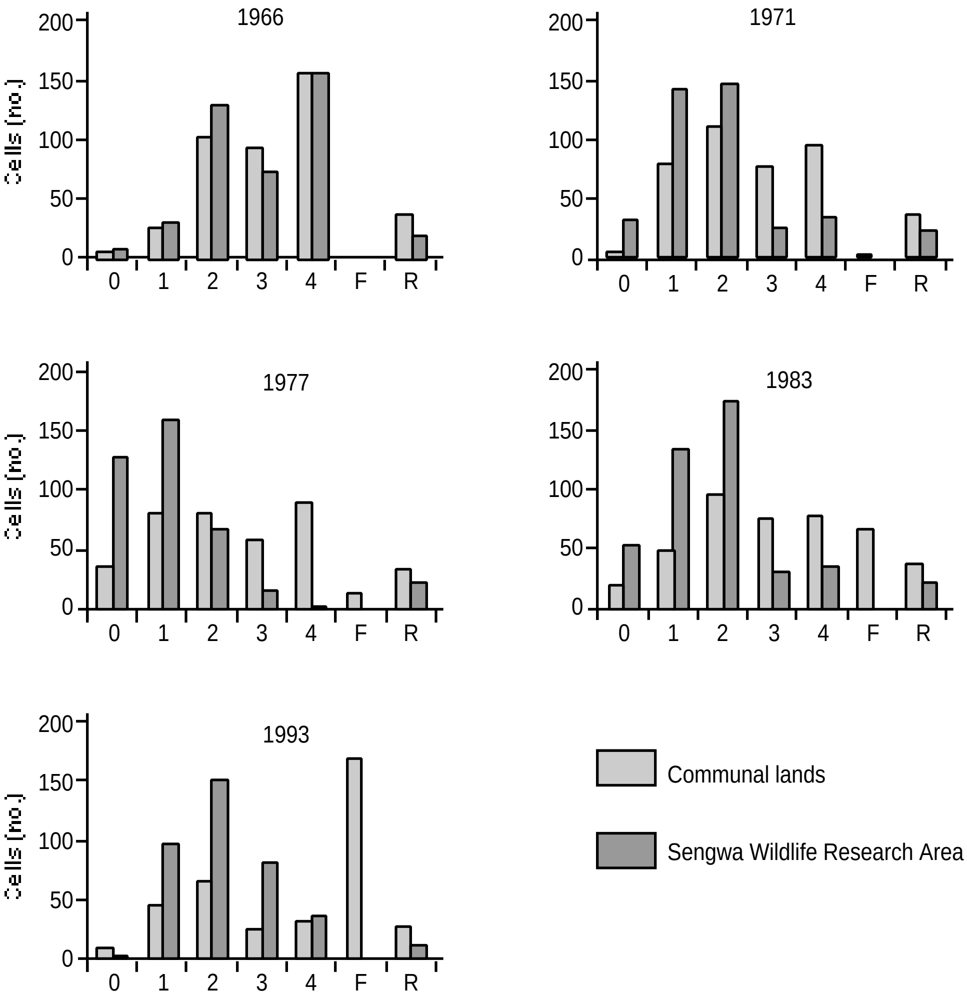

Figure 4. Aerial photo analysis of the vegetation. The 1-cm^2 cells in the photos indicated on the *Y* axis each cover an area 20 x 20 m on the ground. 0 = areas that had been either cleared and not cultivated or were bare ground, 1 = 5–24% woody cover, 2 = 25–49% woody cover, 3 = 50–75% woody cover, 4 = 76–100% woody cover, F = field and R = riverine.

that elephants seem to prefer. However, if elephants need to eat a small portion of many different trees to minimize the effect of any one secondary defence chemical, then the elephants may not find these pure stands of 'preferred' species particularly attractive. The relationship between secondary chemicals and elephant selection of food plants was beyond the scope of this study but does need to be investigated.

The results of the air photo interpretation suggests that before the fence was erected the woodlands inside and outside the park had approximately the same canopy cover. The shift in the number of cells classified as 4 from 1966 to 1977 is due mostly to elephants and fire. The shift is not as pronounced in CLs until 1983, when the photos show large areas cleared for farming. The shift from category 0 and 1 to 3 and 4 in SWRA suggests that there was substantial regeneration of the woodland after the culling in the late 1970s and early 1980s.

The browse selection analysis for CLs indicates that the two species selected most frequently there are very common in SWRA—*Combretum fragrans* and *Colophospermum mopane*. Elephants and fire have severely denuded the rest of the species in

Table 1. The order of importance of tree species selected in CLs by elephants using Simpson's index *D*

Rank	Species
1	*Combretum fragrans*
2	*Colophospermum mopane*
3	*Diplorhynchus condylocarpon*
4	*Bauhinia inscines*
5	*Terminalia sericea*
6	*Pseudolachnostylis maprouneifolia*
7	*Grewia monticola*
8	*Acacia tortilis*
9	*Bauhinia petersiana*
10	*Diospyros lycioides*
11	*Acacia polyacantha*
12	*Dichrostachys cinerea*

SWRA that were selected in CLs, with the exception of *Acacia tortilis*. This suggests that one reason why elephants move into CLs is to feed on those species that are now uncommon in SWRA.

The contrast between the vegetation inside SWRA and in CLs was already noticeable four years after the game fence along the southern boundary was erected. Guy (1989) noted that the difference between the density of canopy trees in CLs and SWRA was pronounced and attributed this to a decline in woody biomass in the major vegetation types within SWRA, especially the miombo woodlands. Ford (1987) concluded that the woody plant cover in CLs was significantly higher than in SWRA and attributed the differences to the selective feeding habits of elephants. Observations from this study suggest that elephants feed primarily, but not exclusively, in the riverine woodlands in CLs. Some typical miombo tree species, such as *Brachystegia boehmii* and *Afzelia quanzensis* were, however, also heavily browsed by elephant in CLs. Both of these species are now rare in the SWRA (Guy 1989).

The elephants' motivation to leave SWRA appears to be influenced by a variety of factors. The data presented suggest that the woodlands in CLs are different from those in SWRA, and this is probably the result of elephant feeding in SWRA. Although not demonstrated by this study, past vegetation studies in SWRA suggest that its vegetation may be considerably less diverse than that in the relatively unbrowsed CLs because of the high density of elephants in the 1970s and 1980s.

The high densities of elephants in many national parks are due to a combination of factors. In East Africa, human habitation and poaching have restricted elephants to relatively small areas. Compression or immigration of elephants from outside a protected area is an important factor contributing to over-population of elephants in many national parks (Eltringham 1979). In southern Africa, elephants were hunted to near extinction around the turn of the century and the currently high densities in protected areas are mostly due to natural reproductive increase. Lewis (1986) notes that human pressures have disrupted, or in some cases eliminated, patterns of dispersal for elephants and altered their use of food resources. Historically elephants regulated their effect on woodlands by moving from over-used areas. It therefore seems reasonable to view the movement of elephants into CLs to feed on wild browse as a normal reaction to over-used habitat within the protected areas.

Conclusion

In this paper, some of the causes behind the apparent attractiveness to elephants of the wild browse in forests outside protected areas have been examined. Elephants may be feeding on browse in CLs because of lower secondary chemicals or because of the abundance of favoured plants in CLs that are now uncommon in SWRA. In the past, elephants would have dispersed as the food resources became depleted in an area. This may be, in effect, what these elephants are doing when they move into the remnant forest mosaics outside of protected areas. While this study has not established a causal link between elephants and degraded woodlands, allowing elephants to degrade them may exacerbate conflict between elephants and farmers. Policies allowing elephant populations to increase unchecked, thereby removing preferred tree species, may motivate elephants to move into areas where crops are grown to find wild plants. Management of protected areas where elephants occur in abundance is, therefore, necessary if conflict with humans is to be reduced.

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