PRESCRIBED BURNING EFFECTS ON PLANT AND ANIMAL COMMUNITIES ON THE KIBOKO NATIONAL RANGE RESEARCH STATION, KENYA.

A THESIS SUBMITTED IN PART FULFILMENT FOR THE DEGREE OF MASTER OF SCIENCE IN BIOLOGY OF CONSERVATION IN THE ZOOLOGY DEPARTMENT, UNIVERSITY OF NAIROBI

BY

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AUGUST 1985

I hereby declare that this thesis is my original work and has not been presented for a degree in any other University.

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We hereby declare that this thesis has been submitted for examination with our approval as University Supervisors.

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ABSTRACT

This thesis presents results of responses of plant and animal communities to a late dry season prescribed burning. Comparisons are made between a paddock burnt in March 1984 and its unburnt neighbour. Comparisons in terms of density and biomass density of large herbivores between paddocks burnt at different dates are also made.

The fire was effective in reducing the number of plant species, the total density as well as the canopy area per hectare both for the understorey and overstorey species. Thus fire is a powerful tool in reducing bush encroachment at KNRRS. The burn induced an increase of 1.65% in total density of herbaceous species while the density of forbs increased by 23%. Similarly the number of herbaceous species increased by 50% while the number of forb species increased by 275%. Fire affected perennial grasses adversely. Grass mortality ranged between 7.79% for Botrichla insculpta and 98.03% for Microchloa kunthii. The Bray and Curtis (1957) community similarity coefficient showed more dissimilarity after the burn between the two paddocks at the herbaceous, understorey and overstorey strata, as one would expect. Ellenberg (1956) index of similarity showed more dissimilarity only for the herbaceous layer.

Fire was also effective in killing tagged plants of most species, irrespective of their height. There

was a general trend towards reduction of canopy area and height for most species. However the number of live stems increased in most of the tagged plants as a result of the burn.

Responses of mammals to the effect of fire were very varied even within a defined group such as large herbivores. The latter generally responded to one of the following factors: visibility, availability and/or nutrient content of food and changes in the structure of the habitat (vegetation). The immediate effect of reduction of food supply on the burnt area, particularly for grazers, was for them to leave the area. However other grazers too moved into the burnt area due to better visibility. The flush of green after the rains, attracted more animals and species which feed on a broader variety of plants, thus enhancing their nutritional benefits. It was also shown that burns of over one year old attracted large herbivores, mostly browsers. This study did not show any evidence of competition between wild herbivores and livestock for food resources. Dietary overlap between them is not excluded. However any wildlife/livestock conflict may arise from predation. It is suggested that killing of large herbivores at KNRRS must be based on scientific facts established by research. This has not yet been carried out.

The species composition of small mammal populations on the unburnt paddock was not very different from that on the burnt one. Also no significant differences emerged in trap success, population size and density between the burnt and the unburnt paddock. Presumably, the small mammal populations had crashed as a result of the persistent drought which already was effective prior to the start of the study.

Finally more research is recommended. Other aspects like responses of insects, birds etc.must be included in such an interdisciplinary research program if the response of the whole ecosystem to fire at KNRRS is to be known and documented.

INTRODUCTION

Kenya's rangelands represent 80% of the country's land. The Kiboko National Range Research Station (KNRRS) which covers 27,000 hectares of land is representative of about a quarter of Kenya's rangelands (Michieka and Van der Pouw 1977). Much of Kenya's Rangelands lies within Machakos, Kitui and Taita-Taveta Districts. Due to aridity, most of it is unsuitable for cultivation except in situations where a source of water other than rainfall is available (Fenner 1982). Used for grazing livestock, large tracts have been as well incorporated in the Tsavo and Amboseli National Parks for wildlife conservation. KNRRS itself was, until recently a game reserve. A prescribed burning policy has been implemented there since 1980 with the aim of reducing bush encroachment, subsequent to a decrease in burning frequency for about two decades.

Kinyamario (1982) has studied the effects of seasonal burnings on *Commiphora* - *Combretum* woodland in the Kiboko area. The burns took place in January, March, July, August and November. Woody species selected in that study were mostly different from those considered in this study. The responses differed from one species to another but in general, dry season burns were more effective in reducing the canopy cover and height while increasing stem mortality for most species. Early burns in the dry season induced a greater number of resprouts. No attempt was made to investigate the responses of the herbaceous species or wild herbivore populations to these seasonal burns.

Skovlin *et al.* (1984) pointed out that viable subsistence or commercial livestock operations become increasingly difficult on rangeland where wild ungulates represent 20% or more of the liveweight mammal biomass. Apart from significant disease and insect problems, the presence of wildlife complicates the management systems of maintaining and improving forage production. The attraction of wild ungulates to burnt areas is well documented (Pratt 1967, Harrington and Ross 1974, Drawe 1982, Rowe-Rowe 1982, Phillips 1965).

Afolayan (1978) has recommended early burning for narrow strips in game viewing tracts as a means of improving visibility and concentrating large mammals. There is a growing concern at the KNRRS, that wild ungulates make excessive use of recently burnt paddocks at the expense of livestock production and may even jeopardize the growth recovery of the herbaceous layer by grazing and trampling (Chappel et al. 1971, Onyeanusi 1983). However this phenomenon has not yet been studied and quantified. On the other hand, little is known about the abundance and distribution of small and inconspicuous mammals at the KNRRS. The effects of burning and grazing on their population dynamics has not yet been investigated.

The African rangelands grow under conditions that leave doubt about their origin (Vesey-Fitzgerald 1973). Some ecologists suggest they have replaced forests that have been destroyed by repeated man-made fires, i.e. they represent degraded vegetation produced by man's abuse of land. Such a generalization leaves many facts unexplained, as some grasslands occur under climatic conditions unfavourable to the growth of forest.

Fire has been part of natural ecosystems long before the advent of man on earth (Harris 1958, Wright and Bailey 1982) and has acted as a natural catalyst for diversity that provides stability to most ecosystems (Vogl 1971). West (1965) has reported results by some early observers in tropical Africa. Burchell (1822) recorded that Bushmen burnt old grass to attract game. Burton (1863) attributed the development of African savannas to "old and yearly burnings" which keep vegetation open. This was confirmed by Phillips (1930) who suggested that fire has been the primary cause of scattered trees and open grasslands in East Africa. Johnston (1884) described limits and reduction of forest by bush fire while Synnerton(1918, 1921) presented evidence of replacement of forest by wooded pasture land in southern Rhodesia (Zimbabwe) and Mozambique.

More recently, West (1943, 1951) showed experimentally that fire protection induces considerable changes in vegetation composition and structure, leading to bush encroachment in rangelands. Any attempt to eliminate fire from savanna grasslands has been shown to be detrimental to both the biotic and abiotic components of the ecosystem (Afolayan 1978). This could lead to the invasion of grasslands by shrubs and trees whereby shrublands become decadent and impenetrable thickets, (Wright 1974), with consequent decline in most cases of wildlife numbers and diversity.

West (1965) has proposed resumption of the use of fire in pasture management. Throughout tropical and subtropical Africa, the use of burning by traditional pastoralists in production and maintaining grazing land is a rule rather than an exception. Most burns are undertaken at the height of the dry season, when the herbage is at its driest and conditions more suitable for a hot fire. The pros and cons of use of fire in managing wildlife areas (national parks and game reserves) have been often disputed and no general agreement has been reached even at the scientific level (Eltringham 1976). The adverse effects have been stressed by Buechner and Dawkins (1961) whereas Lemon (1968) has emphasized beneficial aspects. In general, the scientific opinion initially opposed what was then termed a wasteful and destructive practice. The results of fire protection (Leopold et al 1963, Dodge 1972) brought more insight. The alternative vegetation management tools (herbicide and mechanical treatment) have proved environmentally harmful, not effective and at times too expensive and thus unacceptable (Wright and Bailey 1982). The financial consideration has favoured and will favour for some time, the use of fire in African rangelands, although no financial benefits of bush-control by burning are well established. All that precedes led towards tolerance and it is now generally admitted that there appears to be a place in management of natural grassland and savanna grazing for controlled or prescribed burning in which fire is used purposefully to achieve or in the attempt to achieve definite objectives (West 1965). Prescribed burning appears a seductive alternative to both "catastrophic management" options: burning every year and not burning at all. The objective is to create over time a mosaic of serial and climax stages of vegetation by a series of burnings. These successional stages will be attractive to the greatest diversity and numbers of wildlife and/or will provide sustained optimum forage to livestock. Prescribed burning takes into account the total animal species community, vegetation types, stages of plant succession, weather patterns and fire intensity.

Integrated studies are still lacking for African grasslands and the overall reactions of ecosystems to burning are little documented. Most studies on effects of burning are related to vegetation. Few scientists have looked simultaneously at effects on both animal and plant communities. Afolayan (1978) studied the effects in relation to large mammal management in Kainji National Park, Nigeria. Rowe-Rowe (1982) and Rowe-Rowe and Lowry (1982) observed effects on both large and small mammals in the Natal Drakensberg, South Africa. Ross and Harrington (1968, 1969) studied the practical aspects of implementing a controlled burning scheme in Kidepo National Park, Uganda, for conservation of both animals and plants. The study reported in this thesis aimed at bringing more insight on the burning at the KNRRS, by assessing quantitatively, the effects of a prescribed burning on plant and animal communities. The objectives of the study were to:

(1) Comparatively assess responses of some woody species and the herbaceous layer to prescribed burning.

(2) Assess effects of prescribed burning on the large herbivores' density, biomass and distribution.

(3) Assess effects of the burn on small mammal population by determining the population size, density, trap success and biomass density.

The principal hypotheses tested were:

(i) That fire has no effect on density of herbaceous vegetation and the height, canopy area, and number of live stems per plant for selected woody species.

(ii) That burning is not beneficial and does not attract large herbivore species.

(iii) That burning does not affect the population size, biomass-density and diversity of small mammals.

STUDY AREA

The KNRRS is situated approximately 170km southeast of Nairobi. The 27,000 hectare area is adjacent to Nairobi-Mombasa highway A109 and the railway line (Fig. 1). It is bounded by latitudes 2° 10' and 2° 25'S, longitudes 37° 40' and 37° 55'E. Elevation varies between 915 - 1055m. The highest point is the top of Mwailu hill, a volcanic cone which reaches 1,127m.

The geology of the area is summarized by Michieka and Van der Pouw (1977) as consisting of four major regions (Fig. 2):

(i) The area underlain by Basement system rocks of the semi-calcareous group.

(ii) The area underlain by Basement system rocks of the middle, semi-pelitic group.

(iii) The area consisting of recent lava flows and associated volcanic vents and cones which covers 40% of the KNRRS.

(iv) The area consisting of alluvium and recent limestones.

Michieka and Van der Pouw (1977) have made the most pertinent soil study of the area and classified the soils on the basis of geological and geomorphological features (Fig. 3). A summary of the soil classification is found in Ndegwa (1983):

(i) Soils of hills and footslopes.

Found on the volcanic cones of Mwailu, Duani, Dojini and Wakiamba among others. They are generally shallow, well drained, black to very dark greyish brown, friable and referred to as Regosols,

(ii) Soils of the lava flows.

Include both Lithosols and rock-out crops. They are well

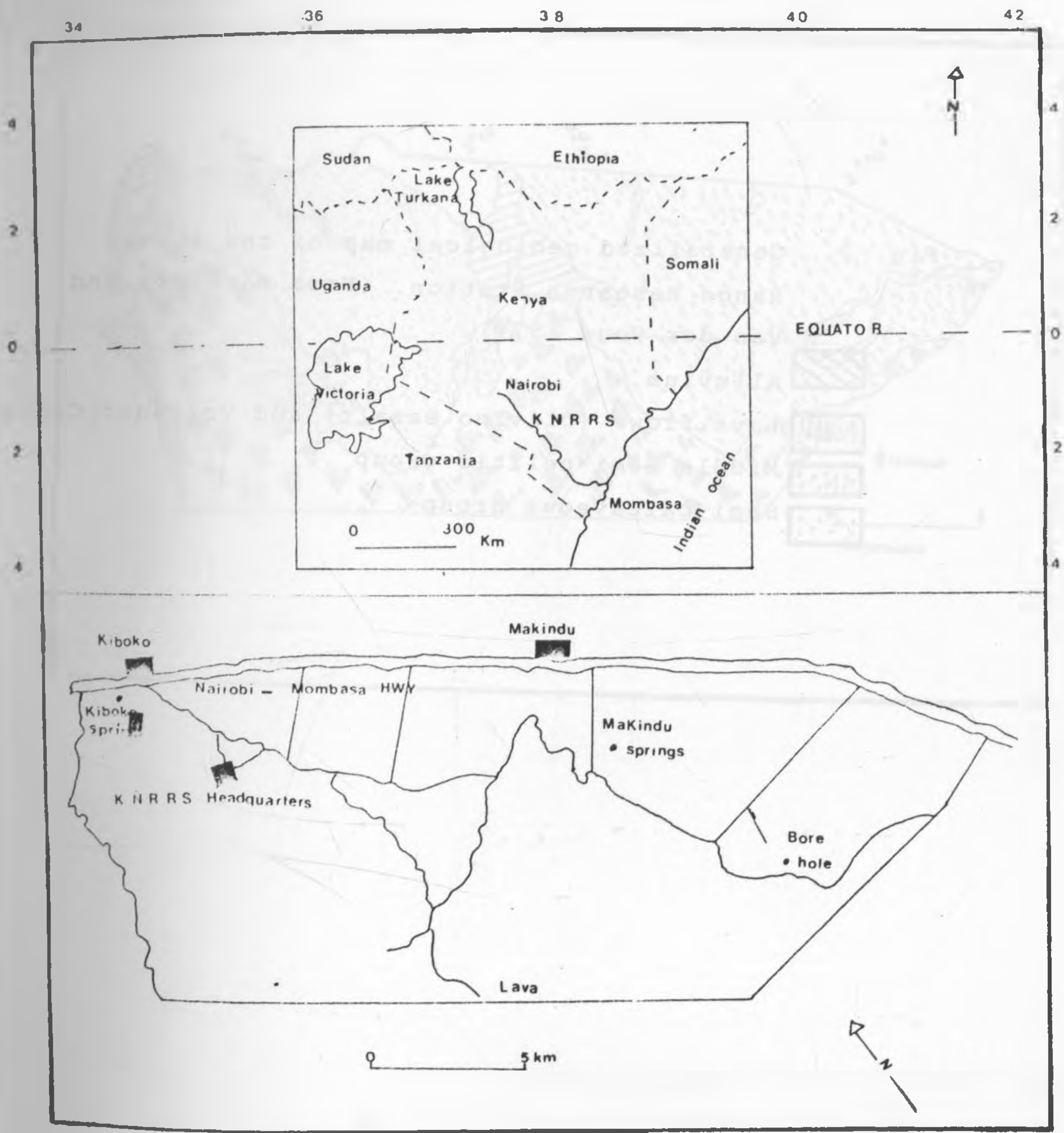


Fig. 1. Location map of the Kiboko Range Research Station and major roads network.

Fig. 2. Generalized geological map of the Kiboko Range Research Station. (From Michieka and Van der Pouw 1977).

- Alluvium
- Lava flows (Olivino Basalt) and Volcanic Cones
- Middle Semi-pelitic group
- Semi-calcaveous group

Fig. 2.

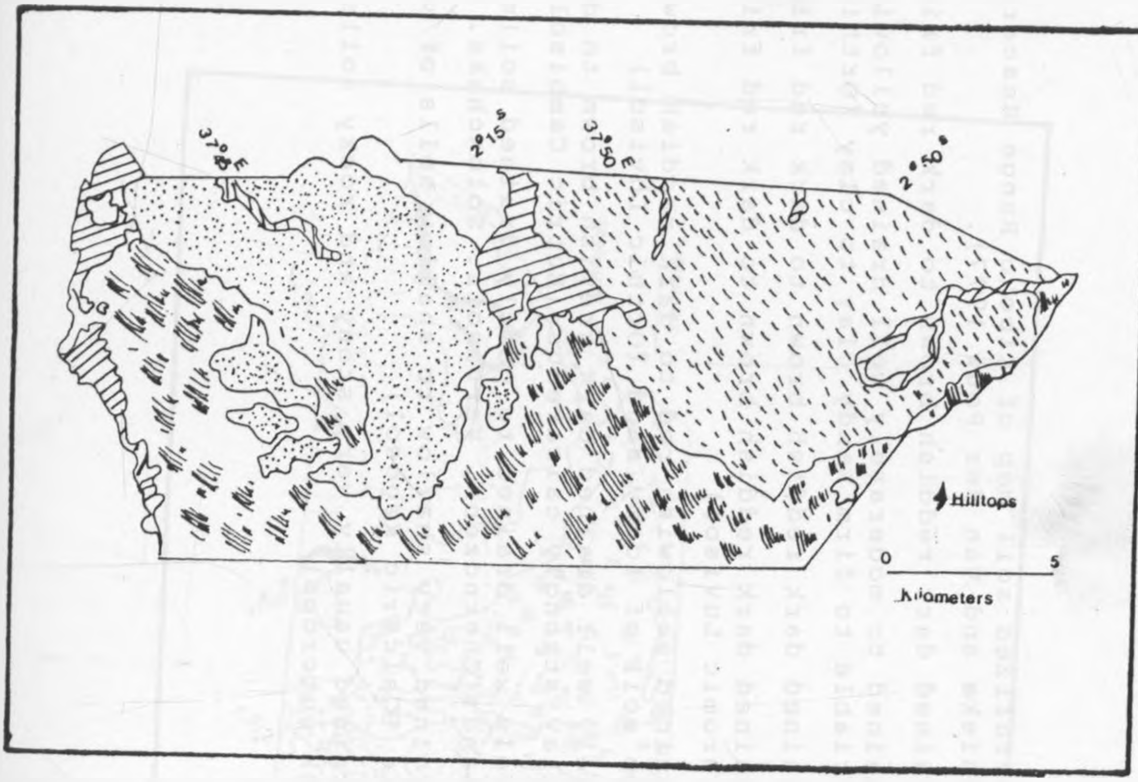
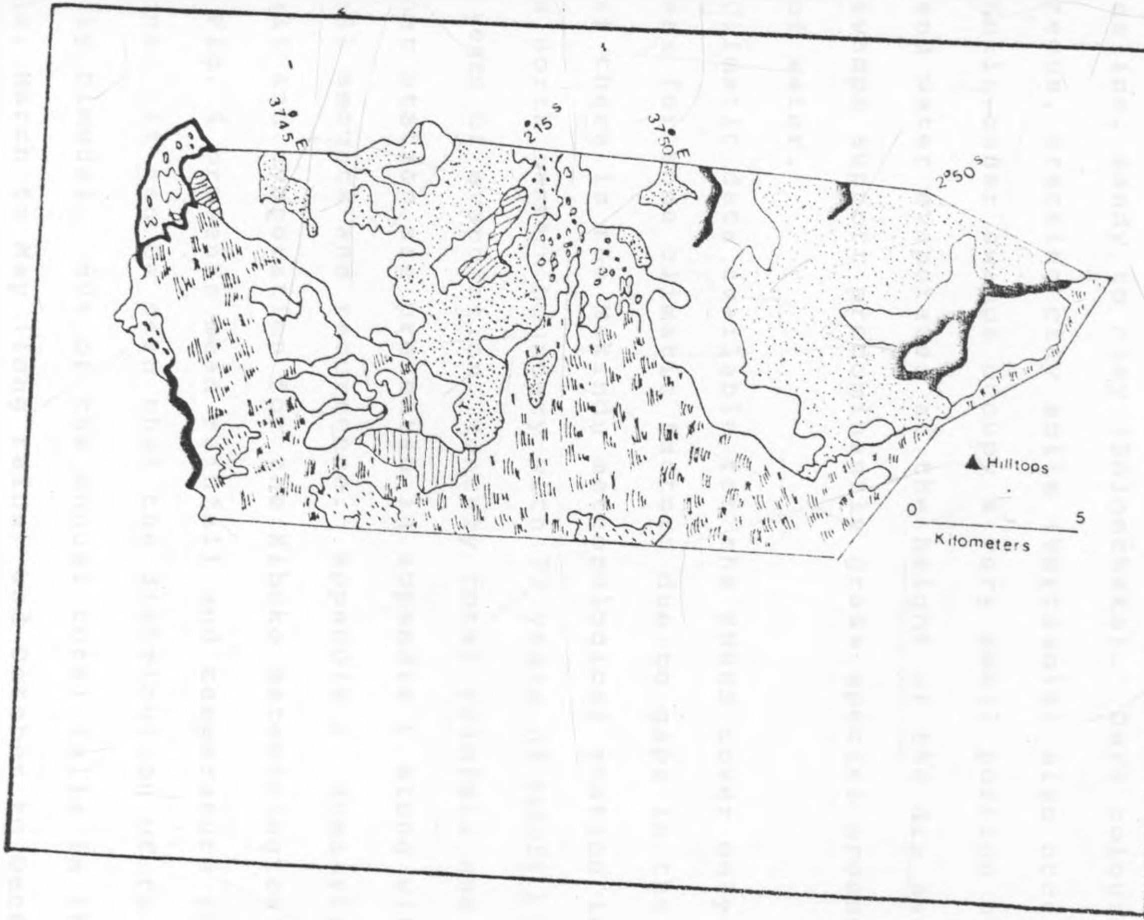


Fig. 3. Generalized soil map of Kiboko Range Research Station. (From Michieka and Van der Pouw 1977).

- Well drained dark reddish brown to dark red friable sandy clay to clay
- Well drained to moderately well drained yellowish red to dark reddish brown friable to firm sandy clay to clay (Orthic Ferralsol)
- Well drained dark reddish brown to dark red friable sandy clay to clay
- Well drained dark reddish brown to dark red friable to firm (compact) clay (Chromic Luvisol)
- Well drained yellowish red to dark reddish brown firm sandy clay to clay with top soil of loamy sand (Orthic Luvisol)
- Moderately well drained dark greyish brown to dark reddish brown friable, sandy clay strongly calcareous (Eutric Cambisol)
- Moderately well drained to poorly drained soils of floodplains and bottomlands(Chernozens. Vertisols. Solonchaks. Fluvisols)
- Well drained very shallow to shallow soils of volcanic cones and pumice deposits (Calcaric Regosol)
- Well drained usually very stony and rocky soils of Lava flows (Lithosols and Rock outcrops)

Fig. 3.



drained, very shallow, black to very dark greyish brown, stony to very rocky. They range from calcareous to strongly calcareous.

(iii) Soils of flood plains and bottomlands.

Slopes are less than 2%. They range from moderately well drained brown, strongly calcareous clays (calcic Chernozems) to imperfectly drained calcareous, stratified alluvial soils (Fluvisols) and poorly drained, greyish, strongly calcareous, very saline, sandy to clay (Solonchaks). Dark coloured, calcareous, cracking clay soils (Vertisols) also occur.

(iv) Soils under swamps occupy a very small portion of the area, and water evaporates at the height of the dry season. These swamps support predominantly grass species around the edges of water.

Climatic data available for the KNRRS cover only 9 years and less for some climatic factors due to gaps in the recording. However there is the Makindu meteorological station in the middle of the north western boundary with 73 years of rainfall records, and a few years of evaporation. Monthly total rainfall and evaporation for that station are presented in appendix 1 along with annual rainfall amounts and recurrence. Appendix 2 summarizes monthly rainfall and evaporation for the Kiboko meteorological station, while Fig. 4 presents mean rainfall and temperature for both stations. It can be seen that the distribution of rainfall is markedly bimodal. 80% of the annual total falls in the two wet seasons: March to May (long rains) and October to December (short rains). Variability of amount and temporal pattern is very high, and the unreliability of rainfall is one of the main limitations of the region from agricultural point of view

Fig. 4. Rainfall and temperature trends for Kiboko and Makindu Meteorological Stations.

Average Rainfall

1977-1985 Kiboko

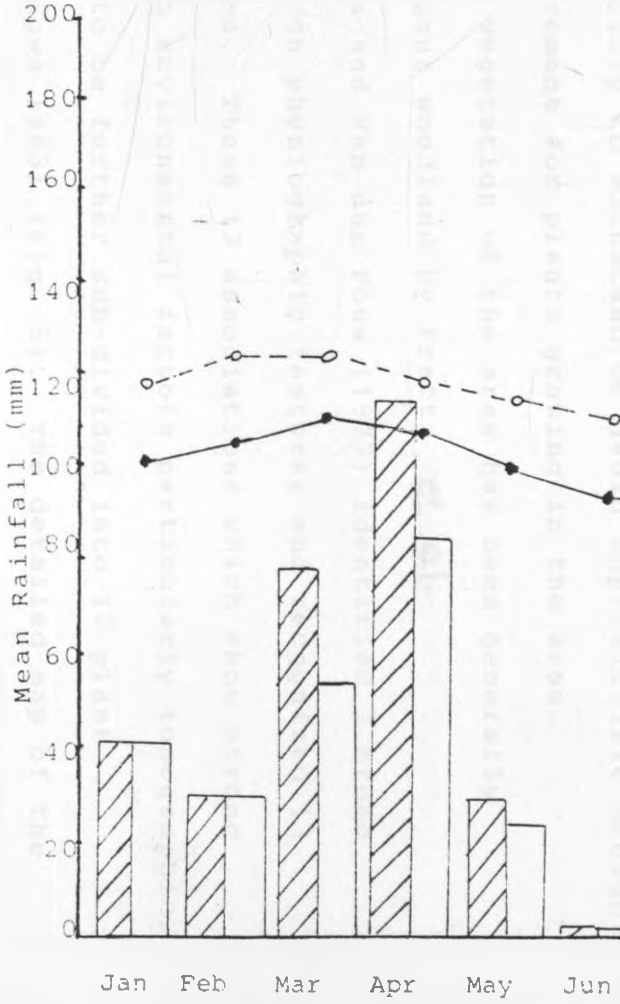
1904-1980 Makindu

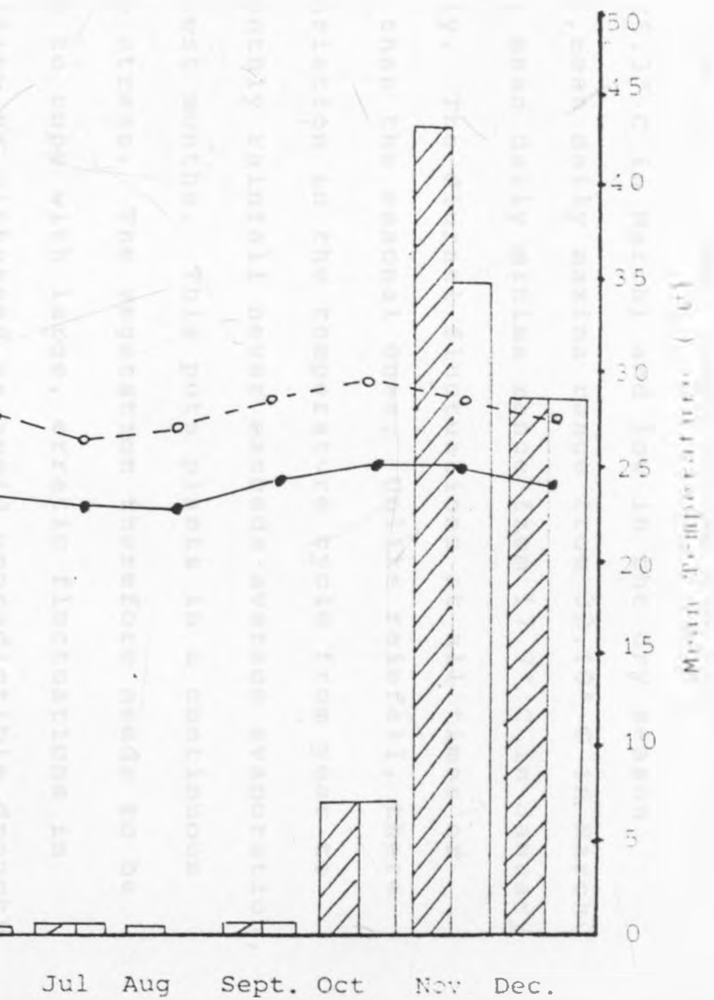
Average Temperature

● 1981-1985 Kiboko

○ 1937-1970 Makindu

Fig. 4.


200
180
160
140
120
100
80
60
40
20
0
Mean Rainfall (mm)
Jan
Feb
Mar
Apr
May
Jun



50
45
40
35
30
25
20
15
10
5
0
Mean Temperature (°C)
Jul
Aug
Sept.
Oct
Nov
Dec.

(Fenner 1982). The effectiveness of rainfall is much reduced by the high evaporation rate due to high temperatures which occur throughout the year. Mean temperatures are high during the wet season (25.3° C in March) and low in the dry season (21.7° C in July), mean daily maxima range from 32.10° C in March to 28° C in July; mean daily minima range from 17.7° C in January to 16.2° C in July. The diurnal fluctuations at all times of year are greater than the seaonal ones. Unlike rainfall, there is very little variation in the temperature cycle from year to year. Average monthly rainfall never exceeds average evaporation, even for the wettest months. This puts plants in a continuous state of moisture stress. The vegetation therefore needs to be adapted primarily to cope with large, erratic fluctuations in rainfall. An ability to withstand or avoid unpredictible drought would be a requirement for plants growing in the area.

The natural vegetation of the area has been generally defined as deciduous woodland by Pratt *et al.* [illegible] Michieka and Van der Pouw (1977) identified 3 broad categories based on physiographic features and recognized 13 plant associations. These 13 associations which show strong relationship with environmental factors particularly topographic and edaphic had to be further sub-divided into 17 plant associations (Ndegwa 1983) (Fig. 5). The detailed map of the study area is shown (Fig. 6) at a large scale.

The KNRRS started officially in 1971 in a former game reserve which had limited grazing by livestock because of the presence of tsetse flies. Today the area is used for grazing by cattle, goats and sheep belonging to KNRRS, and free ranging

1. Chrysopogon plumulosus - Sehima nervosum grassland.
2. Sehima nervosum - Digitaria macroblephara - Grewia bicolor bushed and/or wooded grassland.
3. Acacia brevispica - Commiphora baluensis bushland or woodland.
4. A. brevispica - Maerua sp. and Asparagus sp. bushland thicket.

5a. D. macroblephara - Acacia tortilis - Duosperma kilimandscharicum - Commiphora africana - Commiphora riparia bushed grassland.

5b. A. tortilis - D. macroblephara - Acacia senegal - G. bicolor - Acacia mellifera bushed grassland.

6. S. nervosum - C. riparia - A. tortilis - A. senegal bushed and/or grassland.
7. Chloris roxburghiana - A. senegal - Commiphora sp. woodland/dense bushland.
8. Cymbopogon pospischilii - D. macroblephara - C. riparia wooded grassland.
9. Cynodon dactylon - Eragrostis superba - Adansonia digitata - A. tortilis wooded grassland.
10. Cenchrus ciliaris - A. mellifera - A. tortilis bushland.
11. Aristida keniensis - C. dactylon - C. africana - Combretum apiculatum bushland thicket.
12. Sporobolus fimbriatus - C. ciliaris grassland.

13a. Themeda trianda - C. roxburghiana - C. apiculatum bushed grassland.

13b. Aristida keniensis and various annual weedy species grassland.

14. C. roxburghiana - D. macroblephara - A. tortilis - Grewia similis - C. africana - A. senegal complex bushland.
15. Pennisetum mezianum and other annuals grassland.
16. Echinochloa haplocada - Acacia drepanolobium bushed and/or wooded grassland.
17. Acacia xanthophloea - Phoenix reclinata - Cyperus alternifolius swampy grassland.

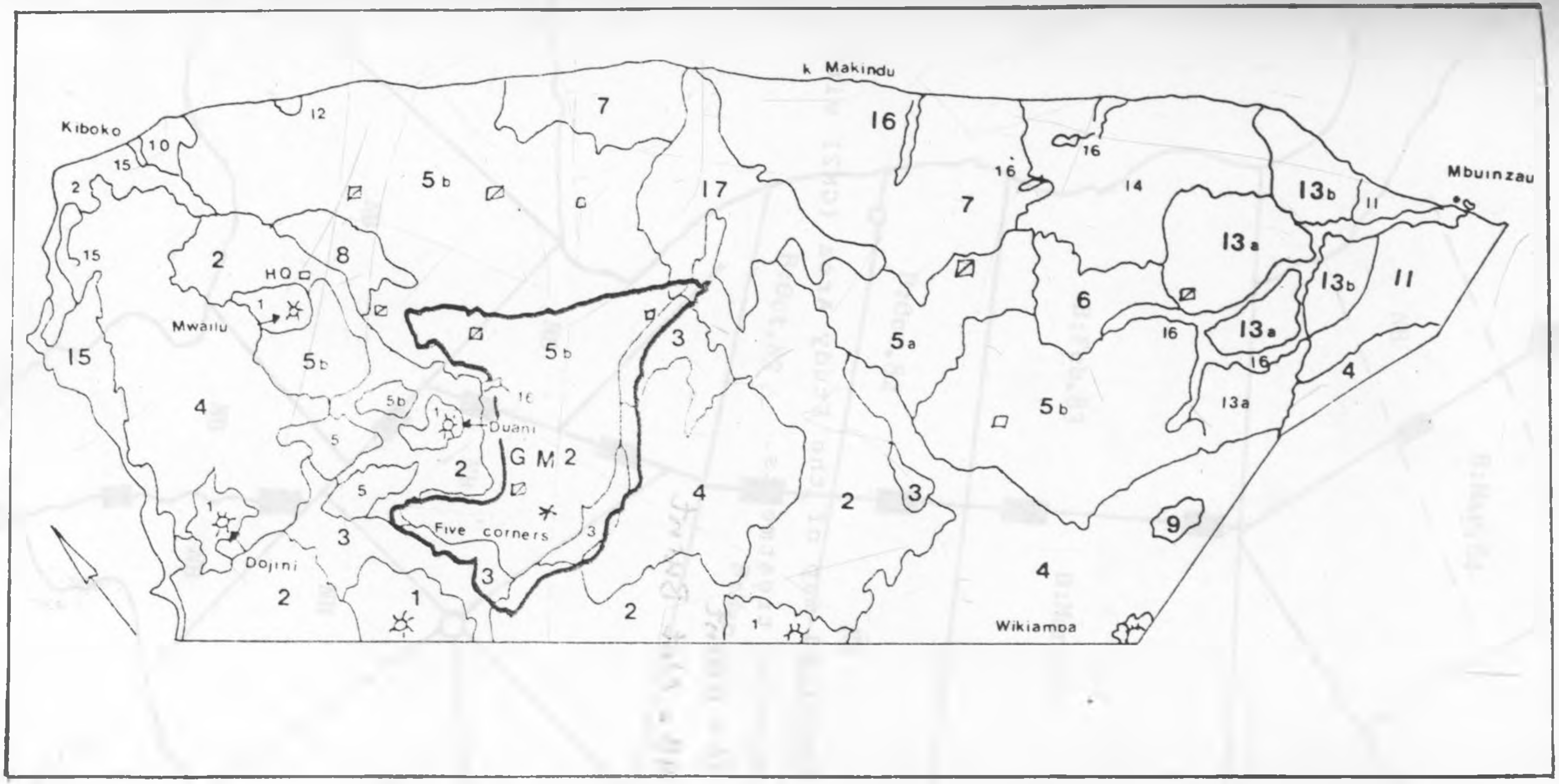
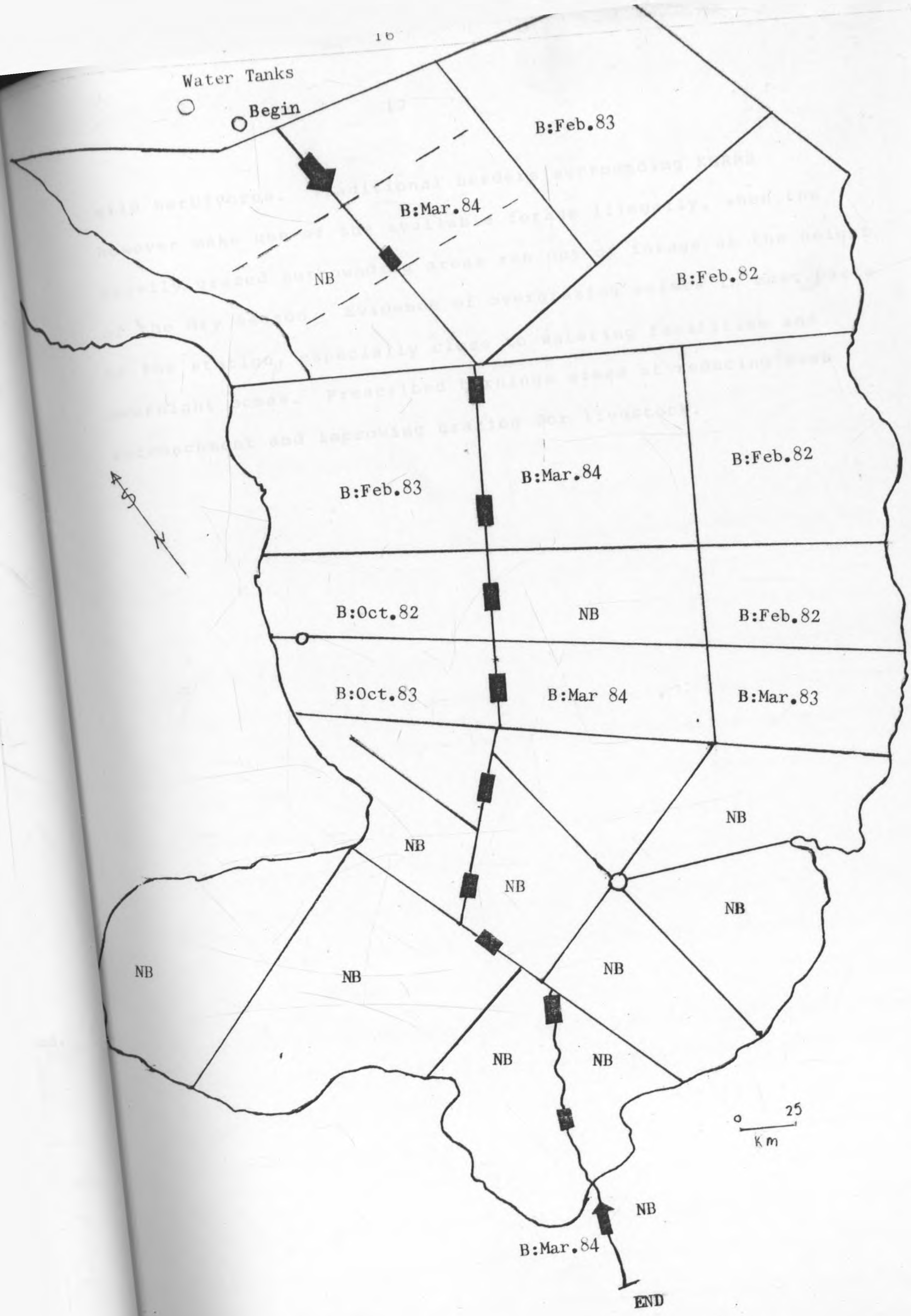


Fig. 5. Plant Associations : Kil[illegible] National Range Research Station, and Grazing Management Study Area (GM).

Fig. 6. Detailed map of the Study Area (GM2) with burning treatments.

B = Burnt

NB = Not Burnt


Water Tanks
Begin
B:Feb.83
B:Mar.84
NB
B:Feb.82
B:Feb.82
B:Mar.84
B:Feb.83
B:Oct.82
NB
B:Feb.82
B:Oct.83
B:Mar 84
B:Mar.83
NB
NB
NB
NB
NB
NB
NB
NB
NB
NB
0 25
Km
NB
B:Mar.84
END

wild herbivores. Traditional herders surrounding KNRRS however make use of the available forage illegally, when the heavily grazed surrounding areas run out of forage at the height of the dry season. Evidence of overgrazing exists in most parts of the station, especially close to watering facilities and overnight bomas. Prescribed burnings aimed at reducing bush encroachment and improving grazing for livestock.

MATERIALS AND METHODS

Sampling of woody vegetation.

The modified version of the point centered quadrant (PCQ) for grasslands studies (Dix 1961) was used. There were two adjacent paddocks. One was to be burnt and the other unburnt. Both were grazed by livestock under a continuous grazing schedule and by free ranging herbivores. Two permanent parallel lines were established about 450m apart in each paddock. The paddocks were about 1.6 km long while lines were 600m (Fig. 6). Along the line, sampling stations were established every 25m. Five of these sampling stations were selected randomly for setting permanent posts which served as markers of permanent transects. The direction of a transect from a marker was determined with a compass using random numbers between 0 and 360. Each transect was 100m long. Ten sampling points were selected systematically at 10m intervals. A 10m diameter zone around each marker was excluded from sampling in order to avoid effect of animals' concentration around the marker (Burzlaff pers. com.). At each sampling point four quadrants were established through a cross formed by two lines, one was parallel to the transect line and the other line was perpendicular to the first. Within each quadrant, the distance to the nearest woody plant was recorded in meters. Two height classes were predetermined: above and below 1 meter. This stratification was necessary to avoid under or oversampling one height class or the other (Burzlaff pers. com.). Other characteristics recorded on nearest plants were: the height, the number of live stems and canopy diameter (in meters). The canopy diameter was measured approximately along the transect direction using the line intercept method (Canfield 1941). The height was measured directly with a meter ruler for plants below or equal to 1 m, and indirectly using a telescoping fiber glass pole for those above 1 m.

Data derived from the 10 transects of each paddock were then pooled and the following variables calculated for each species: average height, average number of live stems, frequency, density, absolute density per hectare, relative frequency, relative density, canopy area per hectare and total density of woody species.

The assessment of effects of burning on the composition and structure of vegetation was made by using the index of similarity or community similarity coefficient before and after the burn. Preburn sampling was conducted on December 23rd 1982 for the paddock to be burnt while the control was sampled on June 28th 1983 by KNRRS ecology section. Both paddocks were resampled in February 1985 after the burn which was scheduled on March 9th 1984. It is difficult to establish a generally acceptable degree of similarity or dissimilarity. However, similarity relations can be expressed mathematically, and the investigator can set arbitrary limits on a mathematical basis Mueller-Dombois and Ellenberg (1974). Two similarity indices involving species quantitative values like density, biomass, cover were selected i.e. the Ellenberg (1956) index of similarity (IS_E), and the Bray and Curtis (1957) similarity coefficient (C).

(i) The Ellenberg index of similarity (IS_E) is given by:

$$IS_E = \frac{Mc \div 2}{Ma + Mb + Mc \div 2} \times 100$$

Where Mc is the sum of quantitative values for species common to both paddocks.

Ma is the sum of quantitative values of species restricted to paddock A (burnt).

Mb is the corresponding sum of species restricted to paddock B (unburnt).

(ii) The community similarity coefficient or index of similarity of Bray and Curtis (C) as defined in this thesis differs slightly from the original one proposed by the authors in 1957. In their original work, the range from no resemblance to complete identity was approximately covered by the range from 0 to 1. In this study, the index was multiplied by 100 in order to express the similarity in percent and make comparisons with Ellenberg's index possible and meaningful. The formula is:

$$C = \frac{2\sum W}{A + B} \times 100$$

Where $\sum W$ is the sum of the lower of the two quantitative values for species common to both paddocks.

A is the sum of the quantitative values for all species in paddock A (burnt).

B is the corresponding sum for all species in paddock B (unburnt).

The canopy area per hectare was used for calculations of similarity index. The choice was based on the assumption that cover gives a better measure of plant biomass than does the number of individuals (Rice 1967). Plant cover also has a major influence on the vegetation stand in terms of light and temperature relations. It influences water relations through rainfall interception and also influences transpiration rate per unit area. Moreover, the amount and characteristics of plant cover are of direct importance to the wild animals which depend on the vegetation for shelter and food. Finally, the canopy area directly influences the biomass productivity of the herbaceous layer, which burning aims to increase.

A tagging procedure was used to study responses of plant species to a burning treatment. Some species with greater absolute densities or canopy area per hectare were selected; Acacia senegal, Acacia tortilis, Acacia mellifera, Balanites aegyptiaca, Grewia villosa, Hermania alhensis and Solanum incanum. Two height classes were chosen: above and below 1.80 m with the assumption that fire will hardly affect (kill) plants above 1.80 m in height. The first five species were represented in both height classes whereas the last two species were only represented in the lower one. Ten plants per species and height class were selected randomly and tagged in each paddock. Caution was taken that enough fuel was around tagged plants in the paddock to be burnt. A total of 120 plants were tagged in each paddock, between February 25th-26th 1984 for the paddock to be burnt and between March 28th-29th 1984 for the unburnt one. The height, canopy diameter and number of live stems were recorded for each individual. The same characteristics were measured towards the end of the growing season following the burn (February 1985). A series of Mann-Whitney U-tests (Siegel 1956) were carried out to check differences. The assumption was that significant differences in canopy area, mortality of tagged plants or height may be indicative of the efficiency of the burn. This is likely to increase the biomass productivity of herbaceous layer. All statements concerning differences refer to significance at the 95% level of confidence unless otherwise stated.

Sampling of Herbaceous Vegetation.

The PCQ as described for woody vegetation (Dix 1961) was applied along the same permanent lines for herbaceous vegetation. Though transects had the same markers as those of woody vegetation and were determined randomly, directions never coincided. The transects were 25m long and the first 5m excluded from sampling for the same reasons given for woody species. Sampling points were established systematically at 1m intervals. The distance from the sampling point to the nearest grass or forb stem was measured in centimeters. The frequency, density, total density (per square meter), absolute density (per square meter), relative density and relative frequency for each species were calculated as for woody species by combining ten transects of the same paddock. Preburn sampling was conducted in 1981 by KNRRS ecology section and postburn sampling in February 1985. Bray and Curtis (1957) and Ellenberg (1956) similarity indices were also applied to herbaceous vegetation for assessing changes that may arise from the burn, using absolute density as the quantitative value.

Herbage biomass productivity was measured along the permanent lines set for trapping small mammals (see sampling of small mammals). The aim was to link any difference that may have occurred after burning with the population dynamics of small mammals. Data were collected between November 29th and December 1st, 1984, during the growing season. The method employed was that used by Rowe-Rowe and Lowry (1982), and involved clipping all herbage within a 20 x 20cm quadrat at about 1cm above the ground level. Quadrats were about 4m apart along the line and 25 quadrats were clipped on each line giving a total of 125 per paddock. Each quadrat harvest was weighed with a hand spring balance and forage from each line was mixed in a big paper bag.

Only new growth (green matter) was harvested from the burnt paddock and represented total wet biomass (in kg per hectare). The total wet biomass for the unburnt paddock was composed of old growth (dry matter) and new growth (green matter). The greeness was expressed as percent of ratio wet new growth over total wet biomass weight. The two fractions were separated and their respective weights recorded. The samples were then dried in an oven at about 75 - 80° C for 5 - 7 days depending on the moisture content of each sample and also the daily supply of electricity by the generator. The dried samples were ground in a Wiley mill and analysed for the percent of monocotyledon and dicotyledon material, as well as for protein and ash.

The percent of monocotyledon material was determined using a Multiple-Tally denominator (counter). The shape and arrangement of cells as observed from prepared slides were used as identification characters. Five slides from each small mammal trapping line were observed through twenty different fields. Thus 100 observations were made per sample and the percent of monocotyledonous material was calculated.

The protein content was derived from a Macrokjeldahl nitrogen analysis in use at KNRRS by multiplying percent nitrogen by 6.25. Ash was obtained after burning dry samples in a Muffle furnace at 600° C for 4 hours and expressed as percent of ash weight over dry sample weight.

Sampling of Mammals.

Large herbivores: Two methods were applied for counting large herbivores; ground sample counting by foot and sample counting by vehicle. The first method was restricted to the two paddocks around the water tanks on which vegetation studies were carried out, i.e. the paddock burnt in March 1984 and its adjacent unburnt neighbour. Densities of large herbivores were determined and differences between them tested. The second method was applied to the whole GM2 along the census route (Fig. 6). Along that census route there were 14 paddocks. One paddock was burnt on each of the following dates: October 1982, February and October 1983. Four paddocks were burnt in March 1984 while seven were unburnt. The objective was to determine density and distribution of large mammals for each treatment and to test for differences. All statements concerning differences refer to significance at the 95% level of confidence unless otherwise stated.

For counts conducted by foot, parallel belt transects crossing a paddock from one extremity to the other (about 1.6km) were established using natural and artificial markings. The burnt paddock had 4 transects while the unburnt one had 3 transects (a portion was excluded from sampling due to its irregular shape). The widths of transects were fixed, about 100m and 150m, respectively, for the unburnt and the burnt paddocks due to differences in visibility. The count entailed one observer/ recorder walking along a randomly selected transect centre and counting animals observed within the transect. Where applicable, they were aged, sexed and the activity of the animal or the group recorded according to Altmann (1974).

All counts and observations were conducted in the morning between 07:00 and 11:00 hrs and in late afternoon between 17:00 and 19:00 hrs, but about 80% were made during the morning period. Repeated recording of the same animals in the course of a count was avoided, for most species could be recognized from their group size and also due to the short time interval in sampling the adjacent paddocks. The method is very laborious but ideal for small areas (Van Lavieren 1976, Norton-Griffiths 1978). The area censused each month in a paddock as already described was variable depending on the number of transects sampled that month. Each month's census in either the burnt paddock or the unburnt one was considered to be one large area sampled once. The density of large herbivores was then estimated and no standard deviation attached to it. Differences between monthly and seasonal densities were investigated by a series of t-tests. Biomass densities derived from counts were also calculated and tested for differences. Population structure of major species, their activity pattern and sex-ratio were analysed.

Roadside counting from vehicle has been used and described by many wildlife biologists (Field and Laws 1970, Leuthold and Leuthold 1976, Western 1973, Van Lavieren 1976, Norton-Griffiths 1978). Fixed strip widths were used according to visibility: 400m for burnt paddocks (old or recent burn) and 200m for unburnt ones. Both sides of the track were searched simultaneously. All the observations were made between 17:00 and 19:00 hrs by one observer/driver and one observer/recorder. The speed of the Land Rover was kept constant at about 20km per hour, except for occasional stops to count animals or check the perpendicular distance of animals seen from the vehicle. The number of animals and the perpendicular distance of the focus of the animals from the transect direction were recorded. The spot point was located in a map of the GM2 (Fig. 6) from October 1984 though counting in vehicle started four months earlier. The distance at which animals were seen was checked with a range finger or estimated visually. The transect began at the water tanks and ended at the lava flows, i.e. 1km out of the GM2. From the beginning to the end and back were considered as two distinct transects on each sampling day. Thus, recording of the same animals was possible when they were resighted on the return trip.

Cobb (1976) has reviewed a number of methods for computing density from ground counts of animals from a vehicle. The estimator of density proposed by Gates et al. (1968) and tested by Hemingway (1971) in Tsavo National Park was adapted for this study, and the formula is:

$$\Delta = \frac{n}{2L\frac{(n\bar{y})}{n-1}}$$

Where Δ = density

n = number of animals seen

L = total transect length

$\bar{y}$ = mean distances of the animals from the transect line.

Densities were calculated on monthly basis per species for each treatment. The average densities for dry and wet months were determined for each treatment as well. These densities formed a basis for comparing densities and distribution between treatments. An analysis of variance (Bailey 1981) was carried out to test the treatment effect after which a series of Duncan multiple range tests (Steel and Torrie 1980) were used to test differences between each two treatments.

The biomass or biomass density (Leuthold and Leuthold 1976) derived from density and unit mass of species, is the total live-weight per unit area. It is a convenient measure allowing comparisons between different areas. A major difficulty in calculating accurate biomass figures is that there is no easy way to determine the "unit mass" i.e. the mean mass of all individuals of a species in a given population. This may vary considerably within a species depending on age structure, nutritional status, location and/or elevation (where mean mass differs in different parts of a species' range) Leuthold and Leuthold (1976). It is therefore imperative that unit mass be indicated whenever biomass figures are presented, so that other workers can calculate them according to their own criteria. In this study, unit masses were derived from various sources in the available literature for East Africa (Table 1). Biomasses were calculated on monthly basis as were densities. Wet and dry season biomasses were also calculated. The importance of each species was stressed by expressing its biomass as percent of total biomass in each treatment.

Small mammals: Sherman folding live traps (9 x 9 x 30cm) were used for trapping small mammals along permanent lines in two adjacent paddocks. One had been burnt in March 1984 and the other one had not been treated. Five paired lines of 30 traps each were laid on opposite sides of the firebreak. The lines were numbered and odd numbers were in the unburnt paddock and even numbers in the burnt. Two adjacent lines within a treatment were 100 m apart and traps numbered from 1 to 300 were about 4 m apart along a line. The effective trapping area per treatment was approximately 4.64 hectares. Traps were set between 17:30 and 19:00 hrs. The traps were checked the following morning between 07:00 and 08:30 hrs. The traps were then closed till setting time. This was repeated for four consecutive nights (a trapping session). The term "trap night" was used to describe a trap set for a 12-hour period, about 19:00 to 07:00 hrs. There were 600 trap nights per trapping session in each treatment. Small mammal abundance was expressed as number of captures per 100 trap nights and termed trap success or percent success. Species richness was established on the basis of number of different species trapped in one treatment or the other or in both.

Table 1. Average weights of large herbivores used for calculating biomass densities.

Species	Mass (Kg)	Source
Grant's gazelle	40	Leuthold (1976)
Warthog	50	Leuthold (1976)
Kongoni	125	Leuthold (1976)
Impala	40	Leuthold (1976)
Dik dik	5.20	Sachs (1967)
Zebra	200	Leuthold (1976)
Giraffe	750	Leuthold (1976)
Buffalo	450	Leuthold (1976)
Wildebeest	190	Sachs (1967)
Thomson's gazelle	18	Sachs (1967)
Ostrich	100	Khaurananga (1981)
Eland	300	Leuthold (1976)
Gerenuk	25	Leuthold (1976)
Oryx	150	Leuthold (1976)
Lesser Kudu	70	Leuthold (1976)
Bushbuck	60	Sinange (1982)
Suni	7	Kingdon (1982)

Five trapping sessions were conducted in May, September and December 1984, and February and April 1985. Repeated marking and recapture, known as the Schnabel Method (Cox 1985) was used. On the first day, a sample of small mammals was captured, marked by clipping toes and released. Animals were identified, weighed, sexed, and marked unless marked previously and released at the capture site. Where possible, the escape route of the animal, whether to cover or into burrows, was noted.

The population estimates and their standard errors were calculated according to Cox (1985). The density was calculated as the ratio of the population estimate on each trapping session over the effective trapping area. Trap success was also calculated on each trapping session. The t-test was then used to test for differences in population size, density and trap success between the two paddocks. All statements concerning differences refer to significance at the 95% level of confidence unless otherwise stated.

RESULTS

Response of Woody Vegetation to Burning.

Overstorey species: Before burning, the vegetation of the paddock to be burnt had 28 species, a total density of 412 plants per hectare and a canopy area of 2529.83 m^2 per hectare (Table 2). Similarily, there were 28 species in the control paddock and the total density and the canopy area were 615.02 plants and 3499.69 m^2, respectively.

There were 19 species common to both paddocks (Table 2). Boscia angustifolia, Grewia similis, Hermenia alhensis, Hibiscus aponeurus and Solanum incanum heights ranged between 1.10 to 1.40 m, but most species were above 1.80 m. Common species accounted for 95.22% relative density and 98.06% canopy area in the paddock to be burnt. Acacia senegal was the dominant species with 39.69% relative density and 64.09% canopy area per hectare. Subdominant species in terms of canopy area were Acacia mellifera (5.34%),Acacia tortilis (4.09%), Balanites aegyptiaca (3.54%), Grewia hexameta (3.19%) and Grewia villosa (3.09%). The common species accounted for 89.75% relative density and 96.07% canopy area in the control paddock. Acacia senegal was also the dominant species with 31.75% relative density and 64.09% canopy area. Subdominant species in the control paddock in terms of canopy area were B. aegyptiaca (8.39%), G. villosa (5.37%), A. mellifera (4.98%) and G. hexameta (2.50%).

Nine species were recorded exclusively in the paddock to be burnt (Table 2). They accounted for 4.78% relative density and 1.94% canopy area. Heights ranged from 1.10 m

Table 2 . Woody vegetation characteristics of the research area as determined from preburn and postburn surveys for species above 1 meter high.

Treatments	Preburn										Postburn									
	Burnt 1/					Control 2/					Burnt 3/					Control 3				
	H 4/	AD 5/	RD 6/	RF 7/	CA 8/	H	AD	RD	RF	CA	H	AD	RD	RF	CA	H	AD	RD	RF	CA
Acacia brevispica						2.8	3.08	0.5	1.0	12.51						1.6	1.40	0.3	1.0	0.90
Acacia drepanolobium	2.7	4.14	1.0	4.0	17.87						5.5	1.21	0.5	2.0	0.20					
Acacia mellifera	2.5	12.42	3.01	11.0	135.05	2.5	19.99	3.3	11.0	174.17	2.9	1.82	0.8	3.0	4.87	2.19	22.40	4.0	14.0	161.99
Acacia senegal	3.3	163.53	39.69	81.0	1621.33	3.3	195.26	31.8	70.0	2243.10	3.6	141.57	58.5	92.0	223.79	3.71	151.20	27.0	68.0	1892.71
Acacia tortilis	2.3	27.95	6.78	24.0	103.41	2.0	13.54	2.3	8.0	29.13	3.0	4.84	2.0	8.0	8.13	2.34	15.40	2.8	10.0	48.98
Albizia amara	1.5	2.07	0.5	2.0	2.30											2.15	7.0	1.3	5.0	26.76
Albizia anthelmintica						2.1	3.08	0.5	2.0	9.72										
Balanites aegyptiaca	3.7	13.46	3.27	11.0	89.58	3.4	47.66	7.8	26.0	293.66	5.5	12.10	5.0	15.0	16.43	3.27	37.80	6.8	24.0	597.20
Boscia angustifolia	1.0	1.04	0.25	1.0	0.98	1.3	1.54	0.3	1.0	4.52										
Cordia abyssinica						1.9	24.60	4.0	16.0	74.45										
Commiphora africana	1.9	25.88	6.28	22.0	66.97	2.0	26.14	4.3	14.0	62.57	1.9	7.26	3.0	12.0	5.03	1.97	26.60	4.8	16.0	84.28
Commiphora baluensis						2.5	10.76	1.8	7.0	6.40	2.5	1.82	0.8	3.0	1.24	2.64	15.40	2.8	9.0	98.41
Commiphora riparia	1.8	23.81	5.78	20.0	79.31	1.9	24.60	4.0	14.0	79.03	2.5	13.31	5.5	17.0	11.74	2.32	26.60	4.8	18.0	112.27
Commiphora rostrata	2.4	2.07	0.5	2.0	13.81	2.6	10.76	1.8	7.0	48.64										
Cordia crenata											3.1	11.50	4.8	19.0	20.87	2.12	18.20	3.3	12.0	85.34
Cordia gharaf	2.4	15.53	3.77	14.0	55.13	1.5	1.54	0.3	1.0	1.11						1.48	2.80	0.5	2.0	2.06
Cordia ovalis						2.1	1.54	0.3	1.0	11.12						2.30	2.80	0.5	2.0	37.79
Cordia sp.											2.7	1.21	0.5	2.0	0.88	2.66	12.60	2.3	9.0	62.30
Dalberghia melanoxylon	2.3	1.04	0.25	1.0	3.30	1.4	1.54	0.3	1.0	3.01	2.6	2.42	1.0	4.0	2.41					
Dicrostachys cinera	1.6	3.11	0.75	3.0	10.78											1.30	1.40	0.3	1.0	0.54
Grewia bicolor	1.4	4.14	1.0	4.0	32.18	2.2	10.76	1.8	6.0	87.41	1.8	0.61	0.3	1.0	0.06	1.98	23.80	4.3	14.0	113.52
Grewia hexameta	2.7	5.18	1.26	5.0	80.63	2.1	10.76	1.8	7.0	46.87	2.5	4.24	1.8	7.0	5.36	2.54	9.80	1.8	7.0	125.63
Grewia similis	1.3	15.53	3.77	12.0	30.85	1.5	12.30	2.0	6.0	10.46	1.4	1.82	0.8	2.0	0.36	1.59	16.80	3.0	8.0	18.69
Grewia villosa	1.8	20.70	5.02	19.0	78.15	1.8	44.59	7.3	28.0	200.42	2.0	4.24	1.8	7.0	8.88	1.98	23.80	4.3	15.0	124.29
Hermania alhensis	1.4	10.35	2.51	8.0	27.88	1.1	18.45	3.0	12.0	21.89	1.2	3.03	1.3	4.0	0.31	1.14	33.60	6.0	20.0	54.51
Hibiscus aponeurus	1.2	5.18	1.26	5.0	1.04	1.6	26.14	4.3	15.0	6.57						1.38	16.80	3.0	12.0	4.43
Hoslundia opposita	1.5	2.07	0.50	2.0	5.38	1.4	15.38	2.5	8.0	18.50	1.5	3.63	1.5	6.0	0.80	1.55	19.60	3.5	12.0	21.80
Indigofera spinosa																1.53	1.40	0.3	1.0	5.77
Lannea flucosa																2.09	4.20	0.8	3.0	3.58
Lannea stuhlmannia						1.3	6.15	1.0	4.0	5.48						1.47	4.20	0.8	3.0	8.34
Lantana viburnoides	2.8	12.42	3.01	9.0	15.96	1.5	10.76	1.8	6.0	5.59						1.57	7.00	1.3	4.0	5.27

Lippia sp.	1.1	1.04	0.25	1.0	0.27															
Maerua sp.						2.8	1.54		1.0	8.26						1.02	1.40	0.3	1.0	0.26
Milletia leucantha																1.27	5.60	1.0	4.0	4.92
Ormocarpum kirkii	2.3	2.07	0.50	2.0	4.49															
Phyllanthus sp.																1.64	1.40	0.3	1.0	0.53
Premna oligostriga	1.6	1.04	0.25	1.0	10.33						1.7	0.61	0.3	1.0	0.84	1.60	2.80	0.5	2.0	6.11
Solanum incanum	1.2	31.05	7.54	21.0	39.73	1.3	59.96	9.8	24.0	25.56	1.2	22.99	9.5	31.0	2.29	1.30	36.40	6.5	17.0	51.54
Solanum renschi	1.1	2.07	0.50	2.0	0.71						2.1	1.21	0.5	3.0	0.77					
Sterculia africana	1.5	1.04	0.25	1.0	1.46															
Tephrosia sp.																1.40	1.40	0.3	1.0	1.42
Tinnea aethiopica						1.4	6.15	1.0	4.0	0.85										
Triomfetta flavescens						1.4	6.15	1.0	4.0	8.69						1.27	1.40	0.3	1.0	0.54
Unidentified sp.	1.4	2.07	0.50	2.0	0.95						2.2	0.61	0.3	1.0	0.57	1.45	4.20	0.8	3.0	3.83
Vernonia wakefieldii																1.33	2.80	0.5	2.0	1.85
Total	-	412.0	99.95	-	2529.83	-	615.02	100.9	-	3499.69	-	242.05	100.5	-	315.83	-	560	101	-	3763.99
IS_E 9/						93.99										94.95				
C 10/						75.05										15.29				

1/ Survey Dec. 82
2/ Survey June 83
3/ Survey Feb. 85

4/ H = Height
5/ AD = Absolute density
6/ RD = Relative density

7/ RF = Relative frequency
8/ CA = Canopy area
9/ IS_E = Ellenberg index of similarity (%)
10/ C = Bray and Curtis community similarity coefficient (%)

(*Solanum renschi*) to 2.70 m (*Acacia drepanolobium*). Important species in decreasing order of canopy area were *A. drepanolobium*, *Dicrostachys cinera* and *Premna oligostriga*. There were also nine species found only in the control paddock, representing 10.25% relative density (Table 2). Two species, *Cordia abyssinica* and *Commiphora baluensis*, accounted for more than half of that percent. This was also true for the canopy area for which the nine species represented about 3.93%. Heights ranged from 1.30 m for *Lannea stulhmannia* to 2.80 m for *Maerua* sp. and *A. drepanolobium*.

Ellenberg's index and the Bray and Curtis community similarity coefficient showed a very high similarity between overstoreys of both paddocks before the burn (Table 2): IS_E = 93.99% and C = 75.05%.

After burning the number of species in the burnt paddock decreased by 25%, the total density by 41.26% and the canopy area per hectare by 87.52% (Table 2). The number of species increased by 14.28% in the unburnt paddock, the density decreased by 8.94% and the canopy area increased by 7.50%.

Three additional species were recorded in the burnt paddock: *Cordia* sp., *C. baluensis* and *Cordia crenata*. They accounted for 6% relative density with *C. crenata* alone representing 4.75%. Ten species recorded in the preburn survey were missing from the postburn. Except *Cordia gharaf* and *L. viburnoides*, the rest of missing species had very low absolute densities (1 to 5 plants per hectare) as well as low relative frequencies (Table 2).

Eleven additional species were recorded in the unburnt paddock. They represented 9.75% relative density with three of them, Albizia amara, C. crenata and Cordia sp. accounting for 6.7%. Six species which were not recorded after the postburn survey represented 8.51% on the preburn one. Except for C. abyssinica and Commiphora rostrata, the other missing species had the lowest absolute densities in that paddock.

There were 18 species common to both paddocks (Table 2) which represented 97.76% relative density and 98.75% canopy area in the burnt paddock. Among the 18 species, 13 had been recorded during the preburn survey. Acacia senegal remained the dominant species in the burnt paddock with a relative density of 58.49% and 70.86% canopy area. Subdominant species in decreasing order of canopy area were C. crenata (6.61%), B. aegyptiaca (5.20%), and C. riparia (3.72%). Balanites aegyptiaca survived the burn better and remained among subdominants as opposed to A. mellifera, A. tortilis, G. hexameta and G. villosa which lost ground and did not appear among subdominants as before the burn. The species common to both paddocks accounted for 88% relative density and 97.22% canopy area in the unburnt paddock. Acacia senegal also remained the dominant species with a relative density of 27% and 50.28% canopy area. Balanites aegyptiaca was the first subdominant species. Following, in decreasing order of canopy area, were A. mellifera, G. hexameta, G. villosa,

C. riparia and G. bicolor (Table 2).

Acacia drepanolobium, D. melanoxylon, S. renschi and an unidentified species were recorded only in the burnt paddock. They represented 2.25% relative density and 1.25% canopy area. Dalberghia melanoxylon was present in the unburnt paddock on the preburn survey but was not recorded on the postburn one. Acacia drepanolobium and S. renschi were recorded only in that paddock on the preburn survey and resisted the burn, presumably as a result of their heights.

Fifteen species were recorded only in the unburnt paddock (Table 2). They accounted for 11% of the relative density and 2.77% of the canopy area per hectare. Hoslundia aponeurus at 3% had the highest relative density, while both Albizia amara and Cordia ovalis accounted for 62% of the total canopy area of these species. Lannea stulhmannia and Maerua sp. were already recorded only in the unburnt paddock during the preburn survey. Cordia gharaf, H. aponeurus and L. viburnoides which were species common to both paddocks on the preburn survey were only found in the unburnt one. They may have been killed by fire in the burnt paddock.

The Bray and Curtis community similarity coefficient (C = 15.29%) decreased tremendously, suggesting as expected very low similarity between the overstoreys of the two paddocks. On the contrary Ellenberg's index (IS_E = 94.95) increased as compared to the preburn value suggesting more similarity between the overstoreys of the two paddocks (Table 2).

Understorey species: Before burning the paddock to be burnt had 26 species of shrubs and trees below 1 m high. The total density was 6,907 plants per hectare and the canopy area was 1147.74 m^2 (Table 3). Twenty one species were recorded in the control with a total density of 11,392 plants per hectare and canopy area of 859.65 m^2.

There were 12 species common to both paddocks (Table 3). Among them only Balanites aegyptiaca and Grewia similis averaged more than 0.5 m in height. Five major species S. incanum, Sida ovata, Ocimum americanum, H. aponeurus and Hermania alhensis represented 64.75% of the total plant density in the paddock to be burnt and 81.25% in the control paddock. Hermania alhensis and S. incanum accounted for 67.91% canopy area in the paddock to be burnt. Talinum caffrum and B. aegyptiaca followed with 10.24% and 8.50% canopy area, respectively. In the control paddock, H. alhensis and S. incanum accounted for 70.36% of the total canopy area. The former dominated the canopy with a canopy area of 419.64 m^2. Sub-dominant species in that paddock were G. villosa (4.49%) area and Lantana viburnoides (2.60%).

Fifteen species were endemic to the paddock to be burnt (Table 3). These species covered 164.50 m^2, 14.33% of the total canopy area in that paddock. Most important species in the group, in decreasing order of canopy area per hectare were T. caffrum, the unidentified species and Pavonia elegans. Some species like Hibiscus sp. with a relatively high absolute density had such a small canopy area per plant that they were not important in

Table 3 . Woody vegetation characteristics of research area as determined from preburn and postburn surveys for species below 1 meter high.

	Preburn										Postburn									
Treatments	Burnt					Control					Burnt					Control				
	H	AD	RD	RF	CA	H	AD	RD	RF	CA	H	AD	RD	RF	CA	H	AD	RD	RF	CA
Abutilon mauritaneum						0.1	85.44	0.8	2.0	1.52	0.41	1326.80	7.8	21.0	11.81	0.22	847.45	2.5	6.0	19.28
Acacia senegal	0.5	155.41	2.3	4.0	1.90	0.4	199.36	1.8	6.0	4.65	0.48	128.40	0.8	3.0	2.30	0.47	254.24	0.8	3.0	21.92
Acacia tortilis											0.42	42.80	0.3	1.0	0.33					
Balanites aegyptiaca	0.6	86.34	1.3	4.0	97.57	0.8	56.96	0.5	2.0	3.59	0.23	42.80	0.3	1.0	0.14					
Boscia angustifolia	0.7	17.24	0.3	1.0	4.30															
Commiphora africana	0.3	51.80	0.8	3.0	0.52						0.67	85.60	0.5	2.0	3.39					
Commiphora baluensis						0.2	56.96	0.5	1.0	1.05	0.75	42.80	0.3	1.0	0.37					
Commiphora madagariensis	0.2	17.27	0.3	1.0	0.11															
Commiphora riparia	0.4	17.27	1.0	0.36		0.4	28.48	0.3	1.0	2.76	0.59	171.20	1.0	3.0	4.45					
Cordia abyssinica						0.3	28.48	0.3	1.0	0.88										
Cordia crenata											0.53	128.40	0.8	3.0	1.14					
Cordia gharaf	0.4	17.27	0.3	1.0	0.20															
Cordia ovalis											0.50	42.80	0.3	1.0	1.57					
Grewia bicolor	0.5	34.54	0.5	1.0	1.69															
Grewia hexameta	0.3	17.27	0.3	1.0	1.36															
Grewia similis	0.4	103.61	1.5	5.0	30.98	0.9	28.48	0.3	1.0	5.46	0.54	171.20	1.0	3.0	5.38	0.1	84.75	0.3	1.0	0.44
Grewia villosa	0.4	103.61	1.5	5.0	11.87	0.4	256.32	2.3	8.0	38.63	0.34	214.0	1.3	4.0	2.37	0.3	254.24	0.8	2.0	26.49
Hermania alhensis	0.4	1502.27	21.8	47.0	419.64	0.6	2848.0	25.0	55.0	529.34	0.56	1968.80	11.5	27.0	76.17	0.37	4067.76	12.0	30.0	1208.85
Hibiscus aponeurus	0.3	500.76	7.3	19.0	34.90	0.5	1196.16	10.5	24.0	18.02	0.37	898.80	5.3	12.0	1.52	0.24	4745.72	14.0	29.0	32.35
Hibiscus sp.	0.4	155.41	2.3	9.0	5.98											0.91	84.75	0.3	1.0	28.54
Hoslundia opposita						0.7	85.44	0.8	2.0	5.22										
Indigofera spinosa						0.6	56.96	0.5	1.0	0.41										
Lantana sp.	0.5	17.27	0.3	1.0	0.44						0.35	42.80	0.3	1.0	0.10					
Ocimum suave	0.3	34.05	0.5	2.0	1.05															

Lantana viburnoides	0.4	103.61	1.5	6.0	20.35	0.3	284.80	2.5	8.0	22.32						0.27	593.22	1.8	7.0	2.33
Lippia sp.	0.6	34.54	0.5	2.0	0.38															
Maerua crassifolia						0.7	28.48	0.3	1.0	0.22										
Milletia leucantha																0.74	84.75	0.3	1.0	19.68
Ocimum americanum	0.3	207.21	3.0	7.0	1.56	0.3	3132.8	27.5	54.0	36.02	0.42	1540.80	9.0	19.0	3.71	0.29	16440.53	48.5	74.0	174.24
Ocimum sp.	0.3	34.54	0.5	2.0	1.05															
Ormocarpum kirkii	0.3	17.27	0.3	1.0	0.02															
Pavonia elegans	0.3	120.87	1.8	7.0	12.09															
Sida ovata	0.1	431.69	6.3	14.0	4.26	0.3	398.72	3.5	12.0	34.74	0.34	4665.2	27.3	52.0	4.98	0.21	4660.98	13.8	27.0	32.67
Solanum incanum	0.4	1830.36	26.5	52.0	359.81	0.4	1680.32	14.8	33.0	75.56	0.53	4451.2	26.0	46.0	147.45	0.37	1271.18	3.8	13.0	192.48
Solanum renschi	0.4	86.34	1.3	5.0	1.32											0.85	84.75	0.3	1.0	0.92
Talinum caffrum	0.3	725.23	10.6	25.0	117.52															
Talinum portulacifolium						0.4	569.60	5.0	14.0	58.53										
Tinnea aethiopica						0.5	313.28	2.8	7.0	11.26										
Triumfetta flavescens						0.7	28.48	0.3	1.0	5.74										
Unidentified species	0.3	518.03	7.6	18.0	17.56						0.53	1155.6	6.8	13.0	14.77	0.64	84.75	0.3	1.0	27.30
Vernonia cinera						0.7	28.48	0.3	1.0	3.73										
Total	-	6907.06	101	-	1147.74	-	11,392	100.6	-	859.65	-	17,120	100.6	-	281.95	-	33898.05	100.5	-	1788.44
IS_E						77.61										94.01				
C						56.05										25.65				

terms of canopy area per hectare. With exception of Boscia angustifolia and Lippia sp. which were 0.70 and 0.60 m high respectively, heights of most species ranged between 0.10 to 0.40 m.

There were 10 species recorded only in the control paddock (Table 3). Hoslundia opposita, Maerua crassifolia, Triomfetta flauescens and Vernonia cinera were tallest at about 0.70 m height. The 10 species accounted for 11% relative density. Talinum portulacifolium and Tinnea aethiopica were the dominant species with absolute densities of 569.6 and 313.28 plants per hectare, respectively. The 10 species totalled 10.30% of the canopy area. Talinum portulacifolium and T. aethiopica accounted for 78.80% of that value.

The Bray and Curtis community similarity coefficient showed an average similarity of 56.05% between understorey species of the two paddocks, whereas the Ellenberg similarity index was 77.61%.

After burning the number of plant species decreased by 30.77% and the canopy area by 75.44%, while the total density increased by 167.51% plants per hectare (Table 3). Similarily, the number of species decreased also in the unburnt paddock by 28.57%. The canopy area increased by 3.49% as well as the total density by 193.17%.

Five additional species were recorded in the burnt paddock; Abutilon maviritaneum, Acacia tortilis, Commiphora baluensis, Cordia crenata and Cordia ovalis . Thirteen species recorded before the burn were not noted in the postburn survey. All the species which were not recorded after the burn, except T. caffrum, were of lower absolute densities prior to the burn. Talinum caffrum may have succumbed to the burn as a result of its height, 0.25 m.

Four additional species were recorded in the unburnt paddock while ten others were not recorded. The additional species were, Milletia leucantha, Ocimum sp., Solanum renschi and an unidentified species. The absolute density of all species not recorded, except two, was low on the preburn survey. There were 10 species common to both paddocks after the burn as compared to eleven prior to the burn. The absolute density of all species except one (Acacia senegal) increased with the burning treatment. The greater increases were observed for O. americanum, 643.59% in the burnt paddock and 424.79% in the unburnt, and S. ovata, 980.68% in the burnt paddock and 1068.99% in the unburnt (Table 3). This was considered to be a reflection of the exceptional precipitation which occured from October 1984 through February 1985. Fire obviously impacted these species in a favourable way. The canopy area per hectare decreased for all species in both paddocks except for the two species mentioned above.

The common species represented 94.49% relative density and 95.92% canopy area in the burnt paddock. Hermania alhensis and S. incanum combined, decreased by 27.25% in relative density. The relative density of both species decreased by 65.50% in the unburnt paddock. The canopy area per hectare for H. alhensis and S. incanum increased by 11.40% in the burnt paddock and by 7.99% in the unburnt one. The sharp decrease in relative density of both species might have been related to the tremendous increase of _O. americanum_.

Eight species ocurred only in the burnt paddock (Table 3). All were different from those recorded on the preburn survey. They accounted for 3.50% relative density and 3.52% canopy area per hectare. Similarly, five species were recorded exclusively in the unburnt paddock. All were also different from those found during the preburn survey except _H. opposita_. They accounted for 3.50% relative density and 2.93% canopy area per hectare.

The burn resulted in reduction of species richness in the understorey of the burnt paddock. The burn seemed to trigger germination and sprouting as suggested by the 167.5% increase in total density of woody species below 1m. The increase in total density, however, hid a sharp reduction of 75.44% of canopy area per hectare. The canopy area per hectare increased by 3.49% in the unburnt paddock though the number of species decreased by 28.57%. Despite all these changes in canopy area (Table 3), Ellenberg's index of similarity increased from 77.61% to 94.01% showing more similarity between the two paddocks contrary to what one would have expected. Bray and Curtis' similarity coefficient decreased by 30.40%, displaying more dissimilarity between both understoreys than one would expect.

Acacia senegal. Twenty percent and 50% mortality were recorded for plants above and below 1.80 m, respectively after the burn. There was a highly significant ($p < .01$) decrease in canopy area and height but a significant decrease in number of live stems for individuals above

1.80 m (Table 4) as a result of burning. The burn also resulted in a significant reduction of canopy area and height of individuals below 1.80 m. On the contrary a significant increase in number of live stems was observed (Table 5) in plants below 1.80 m following the burn.

Acacia tortilis. There was 20% and 10% mortality for individuals above and below 1.80 m, respectively. There was a highly significant ($p < .01$) decrease of canopy area and height for plants above 1.80 m on the burnt paddock. No significant reduction in number of live stems was observed on that height class (Table 6). However the burn induced an increase in number of live stems for plants below 1.80 m (Table 7). Data showed a highly significant ($p < .01$) decrease of canopy area and height for plants below 1.80 m.

Acacia mellifera. There was 50% and 30% mortality for plants above and below 1.80 m, respectively, as a result of the burn. Reductions were highly significant ($p < .01$) in canopy area and height of plants above 1.80 m (Table 8). But there was a significant reduction of the number of live stems. Highly significant ($p < .01$) reductions in canopy area and height were also recorded on individuals below 1.80 m (Table 9). No reduction in number of live stems was observed on these individuals, on the contrary the burn induced a greater number of live stems.

Balanites aegyptiaca. Only 10% mortality was observed on individuals below 1.80 m as a result of the burn. There were highly significant ($p < .01$) reductions in canopy area

Table 4: Effects of fire on canopy area, height and number of live stems of *Acacia senegal* above 1.80 m .

U - Values were calculated using actual numbers.

PRB = Preburn

PSB = Postburn

B = Burnt March 1984

NB = Non burnt

* p<.05

** p<.01

n.s.= Non Significant

	Canopy area (m^2)				Height (m)				Number of Stems			
No. of ind.	PRB		PSB		PRB		PSB		PRB		PSB	
	B	NB	B	NB	B	NB	B	NB	B	NB	B	NB
1	11.70	8.65	7.79	11.33	3.81	2.61	4.05	3.30	1	1	1	1
2	13.07	14.45	6.38	16.04	3.17	3.92	3.53	4.07	1	1	1	1
3	9.18	20.90	6.60	–	3.42	3.31	3.25	–	1	4	1	–
4	12.31	6.83	0.86	6.83	3.17	3.53	3.09	3.72	2	1	1	1
5	15.47	10.29	11.04	10.75	3.27	2.23	3.28	2.53	1	2	1	2
6	5.68	13.32	2.69	16.11	3.45	3.33	3.20	3.72	1	1	1	1
7	8.55	8.70	–	11.94	3.05	4.20	–	4.15	1	3	–	3
8	5.81	10.75	2.00	10.52	2.67	3.77	2.60	3.82	3	2	1	2
9	17.12	9.62	–	10.17	3.43	3.29	–	3.69	2	3	–	3
10	7.64	13.85	2.69	14.18	3.05	3.59	3.15	3.75	2	2	2	2
Total	106.53	117.36	40.05	107.87	32.49	33.78	26.15	32.75	15	20	9	16
Mean	10.65	11.74	5.00	11.98	3.25	3.38	3.27	3.64	1.50	2.00	1.12	1.78
S.d	2.98	4.06	2.53	3.06	0.31	0.59	0.41	0.48	0.71	1.05	0.35	0.5
U				**				**				*

Table 5: Effects of fire on canopy area, height and number of live stems of _A_. _senegal_ below 1.80m.

U - Values were calculated using actual numbers

	Canopy area (m^2)				Height (m)				Number of Stems			
No. of ind.	PRB		PSB		PRB		PSB		PRB		PSB	
	B	NB	B	NB	B	NB	B	NB	B	NB	B	NB
1	5.14	1.27	–	1.47	1.29	1.04	–	1.28	5	2	–	1
2	2.92	4.91	0.86	–	1.06	1.20	0.43	–	4	1	8	–
3	1.47	2.21	–	2.54	1.32	1.27	–	1.50	1	1	–	1
4	4.26	1.77	2.54	2.01	1.52	1.52	1.62	1.55	1	2	1	1
5	0.85	2.11	–	2.21	1.21	1.51	–	1.80	1	1	–	1
6	2.21	2.89	–	3.14	1.55	1.61	–	1.69	1	1	–	1
7	1.93	1.91	0.54	3.63	1.75	1.58	0.28	1.55	1	1	12	1
8	4.75	2.27	0.69	2.32	1.70	1.69	0.68	1.70	1	1	6	1
9	4.37	1.13	–	1.47	1.75	1.46	–	1.77	2	1	–	1
10	1.27	3.49	0.78	–	0.99	1.73	0.23	–	1	1	5	–
Total	29.17	23.96	5.41	18.79	14.14	14.61	3.24	12.84	20	12	32	8
Mean	2.92	2.40	1.08	1.88	1.41	1.46	0.65	1.60	2.00	1.20	6.40	1.00
S.d	1.59	1.12	0.82	0.75	0.28	0.22	0.57	0.17	1.15	0.42	4.04	0.
U			*				*				n.s.	

Table 6: Effects of fire on canopy area, height and number of live stems of <u>Acacia tortilis</u> above 1.80m .

U - Values were calculated using actual numbers.

	Canopy area (m^2)				Height (m)				Number of Stems			
No. of ind.	PRB		PSB		PRB		PSB		PRB		PSB	
	B	NB	B	NB	B	NB	B	NB	B	NB	B	NB
1	5.89	13.65	0.28	13.85	2.84	3.40	0.20	3.70	1	1	7	1
2	12.12	5.94	5.51	8.14	2.92	2.59	3.50	2.69	2	1	2	1
3	8.29	7.54	–	9.89	3.07	2.89	–	3.17	7	4	–	4
4	7.40	8.55	2.14	11.33	2.48	2.91	2.49	3.54	1	1	1	1
5	10.17	7.30	12.87	7.54	3.81	2.84	3.62	3.02	2	1	2	1
6	27.05	11.10	0.98	9.29	2.90	2.40	0.11	2.40	8	5	10	5
7	12.31	3.70	0.68	3.56	3.23	2.43	1.82	2.60	1	2	1	2
8	19.23	26.41	0.54	28.26	3.20	4.39	0.90	4.25	5	1	8	1
9	9.67	10.75	–	12.75	2.79	2.34	–	2.39	1	1	–	1
10	6.60	12.37	1.23	12.87	2.95	3.96	3.04	3.96	1	3	2	3
Total	118.73	107.31	24.23	117.48	30.19	30.15	15.68	31.72	29	20	33	20
Mean	11.87	10.73	3.03	11.75	3.02	3.01	1.57	3.17	2.90	2.00	4.12	2.00
S.d	6.57	6.29	4.29	6.55	0.35	0.69	1.43	0.66	2.70	1.49	3.37	1.49
U			**				**				n.s	

Table 7: Effects of fire on canopy area, height and number of live stems of *A. tortilis* below 1.80m .

U - Values were calculated using actual numbers.

	Canopy area (m^2)				Height (m)				Number of Stems			
No. of ind.	PRB		PSB		PRB		PSB		PRB		PSB	
	B	NB	B	NB	B	NB	B	NB	B	NB	B	NB
1	2.60	1.91	0.68	1.47	1.47	1.60	0.24	1.66	1	1	10	1
2	2.74	2.27	–	2.27	1.57	1.47	–	1.58	1	1	–	1
3	2.46	0.75	0.34	1.04	1.60	1.25	0.24	1.35	1	1	8	1
4	1.52	4.45	0.45	4.48	1.01	1.62	0.52	1.84	1	2	21	2
5	1.10	1.54	0.71	1.77	1.16	1.11	1.15	1.29	1	2	1	1
6	2.77	0.86	0.57	1.54	1.30	1.03	0.58	1.00	2	1	14	1
7	1.93	2.27	0.50	3.14	1.52	1.75	0.50	1.80	2	1	10	1
8	3.94	1.21	3.46	1.31	1.55	1.50	1.74	1.55	2	1	2	1
9	4.75	1.70	0.86	1.27	1.80	1.70	0.71	1.80	1	1	4	1
10	2.14	2.16	1.43	1.65	1.55	1.26	0.23	1.09	2	1	27	1
Total	25.95	19.12	9.00	19.94	14.53	14.29	5.91	14.96	14	12	97	11
Mean	2.59	1.91	1.00	1.99	1.45	1.43	0.66	1.50	1.40	1.20	10.78	1.10
S.d	1.62	0.72	0.97	1.06	0.23	0.25	0.5	0.30	0.52	0.42	8.70	0.32
U			**				**				n.s.	

Table 8: Effects of fire on canopy area, height and number of live stems of *Acacia mellifera* above 1.80m .

U - Values were calculated using actual numbers.

	Canopy area (m^2)				Height (m)				Number of Stems			
No. of ind.	PRB		PSB		PRB		PSB		PRB		PSB	
	B	NB	B	NB	B	NB	B	NB	B	NB	B	NB
1	16.04	12.43	-	14.51	2.28	2.37	-	2.50	4	3	-	3
2	27.23	28.73	-	29.69	2.87	2.41	-	2.64	10	5	-	5
3	14.78	7.74	14.18	9.62	2.15	2.43	2.13	2.42	13	5	8	5
4	18.24	21.23	9.89	18.85	3.14	2.98	2.65	3.20	6	5	6	5
5	0.93	21.23	3.97	16.97	1.85	3.26	1.85	2.98	3	3	4	3
6	7.16	8.55	-	7.79	2.11	1.86	-	2.00	3	6	-	6
7	25.86	17.34	0.07	16.97	3.07	2.43	0.84	2.56	5	18	3	16
8	15.34	14.45	-	15.90	2.36	2.65	-	2.73	5	10	-	9
9	19.23	27.32	35.98	28.07	3.05	3.63	0.62	3.70	5	6	8	6
10	17.12	15.68	-	21.64	2.72	2.56	-	2.56	9	9	-	9
Total	161.93	174.70	64.09	180.01	25.60	26.58	8.09	27.29	63	70	29	67
Mean	16.19	17.47	12.82	18.00	2.56	2.66	1.62	2.73	6.30	7.00	5.80	6.70
S.d	7.79	7.18	14.03	7.03	0.46	0.51	0.86	0.47	3.30	4.47	1.09	3.86
U				**				**				*

Table 9: Effects of fire on canopy area, height and number of live stems of *A. mellifera* below 1.80m .

U = Values were calculated using actual numbers.

	Canopy (m^2)				Height (m)				Number of Stems			
No. of ind.	PRB		PSB		PRB		PSB		PRB		PSB	
	B	NB	B	NB	B	NB	B	NB	B	NB	B	NB
1	3.23	2.00	0.48	2.32	1.32	1.15	0.22	1.30	2	1	9	1
2	5.47	5.31	-	7.30	1.06	1.43	-	1.62	5	5	-	5
3	1.74	3.17	0.46	2.95	1.37	1.34	0.46	1.45	8	4	7	4
4	3.23	6.46	0.51	6.83	0.78	1.62	0.38	1.72	5	5	6	5
5	1.21	2.69	0.18	1.96	1.60	1.25	0.18	1.44	1	7	5	7
6	3.73	2.35	0.50	2.54	0.84	1.46	0.55	1.54	2	1	12	1
7	3.14	5.06	0.37	5.68	1.14	1.41	0.40	1.61	4	5	13	5
8	0.51	2.19	0.12	1.96	0.84	1.15	0.43	1.11	2	10	5	10
9	0.98	1.88	-	2.54	1.02	1.46	-	1.59	2	3	-	3
10	0.82	3.14	-	3.76	0.76	1.38	-	1.50	3	4	-	4
Total	24.06	34.25	2.62	37.84	10.76	13.65	2.62	14.88	34	45	57	50
Mean	2.41	3.42	0.37	3.78	1.08	1.36	0.37	1.49	3.40	4.50	8.14	5.00
S.d	1.58	1.22	0.16	2.05	0.77	0.15	0.13	0.18	2.12	2.68	3.29	1.37
U			**				**				n.s.	

and average height of individuals above and below 1.80 m (Tables 10 and 11). This species did not show significant reduction in the number of live stems as a result of burning both for plants above and below 1.80 m. Instead the average number of live stems increased at both height classes.

Grewia villosa. The burn had a marked effect on this multi-stemmed species. There was 90% mortality of the above ground parts in either height class but all individuals resprouted. Subsequently, reductions in canopy area and height for plants in both height classes were highly significant ($p < .01$) (Tables 12 and 13). Burning resulted in no significant reduction of number of live stems for individuals above and below 1.80 m respectively, but instead, increased slightly their average number.

Hermania alhensis. The burn was very effective in damaging this species whose average height was below 1.00 m. There was 20% mortality among the burnt individuals. The remaining individuals had their above ground parts killed but readily resprouted. Only 3 individuals were relocated in the unburnt paddock among the 10 which were tagged before the other paddock was burnt. Data from these few individuals showed significant reductions in canopy area, height but a significant increase in number of live stems (Table 14).

Solanum incanum. Forty percent mortality was observed on burnt plants. There was no significant reduction in number of live stems but instead an increase following the burn on the remaining individuals. However the canopy area and the height showed small but significant reductions (Table 15).

Table 10: Effects of fire on canopy area, height and number of live stems of *Balanites aegyptiaca* above 1.80m .

U - Values were calculated using actual numbers.

	Canopy area (m^2)				Height (m)				Number of Stems			
No. of ind	PRB		PSB		PRB		PSB		PRB		PSB	
	B	NB	B	NB	B	NB	B	NB	B	NB	B	NB
1	7.25	4.08	3.30	4.91	3.42	3.36	3.01	3.69	1	1	1	1
2	9.07	3.08	1.88	3.90	3.53	2.70	2.95	2.86	1	1	1	1
3	15.47	5.43	4.91	5.64	4.36	2.49	3.45	2.94	3	1	1	1
4	10.46	4.15	4.45	5.72	3.47	2.97	2.80	3.06	1	2	1	1
5	7.74	9.62	5.72	8.29	2.74	3.09	2.82	3.37	2	1	2	1
6	4.75	10.40	0.78	10.46	3.10	2.41	3.25	2.41	1	1	11	1
7	3.40	5.31	2.03	3.14	2.54	2.87	2.29	3.21	1	1	2	1
8	3.40	7.54	0.003	8.04	2.82	2.91	0.23	3.10	1	1	1	1
9	6.33	10.34	3.14	9.62	3.45	3.69	2.83	3.77	1	1	1	1
10	13.26	11.33	3.97	12.19	2.64	3.42	2.40	3.80	1	1	1	1
Total	81.13	71.28	30.18	71.91	32.07	29.91	26.03	32.21	13	11	22	10
Mean	8.11	7.13	3.02	7.20	3.21	2.99	2.60	3.22	1.30	1.10	2.20	1.00
S.d	3.88	3.09	1.27	2.99	0.55	0.41	0.42	0.44	0.67	0.32	3.12	0.00
U				**				**				n.s

Table 11: Effects of fire on canopy area, height and number of live stems of *B. aegyptiaca* below 1.80m .

U - Values were calculated using actual numbers.

	Canopy area (m^2)				Height (m)				Number of Stems			
No. of ind.	PRB		PSB		PRB		PSB		PRB		PSB	
	B	NB	B	NB	B	NB	B	NB	B	NB	B	NB
1	0.61	0.16	-	0.33	1.27	0.93	-	0.33	1	1	-	1
2	2.06	1.17	0.68	2.14	1.34	0.91	0.52	1.22	1	1	1	1
3	1.47	0.74	0.26	0.93	1.39	1.70	0.45	1.85	1	1	5	1
4	0.88	1.13	0.12	1.23	1.04	1.09	0.33	1.35	1	1	3	1
5	0.31	1.63	1.54	1.89	1.16	0.96	1.07	0.96	1	1	1	1
6	1.65	1.77	0.28	1.77	1.19	1.43	0.58	1.50	1	1	1	1
7	1.43	1.04	0.26	0.82	1.27	0.96	0.38	0.96	2	1	15	1
8	1.93	3.05	0.68	2.63	1.65	1.67	0.53	1.78	1	1	13	1
9	1.27	1.93	0.008	2.16	1.30	1.58	0.28	1.63	1	1	7	1
10	1.17	1.52	0.23	1.65	1.04	1.02	0.39	1.34	2	1	4	1
Total	12.78	14.14	4.06	15.55	12.65	12.25	4.53	13.64	12	10	50	10
Mean	1.28	1.41	0.45	1.55	1.26	1.22	0.50	1.36	1.20	1.00	5.00	1.00
S.d	0.56	0.78	0.61	0.40	0.18	0.33	0.19	0.32	0.42	0.00	5.22	0.00
U			**				**					n.s.

Table 12: Effects of fire on canopy area, height and number of live stems of Grewia villosa above 1.80m .

U - Values were calculated using actual numbers.

	Canopy area (m^2)				Height (m)				Number of Stems			
No. of ind.	PRB		PSB		PRB		PSB		PRB		PSB	
	B	NB	B	NB	B	NB	B	NB	B	NB	B	NB
1	7.25	11.88	1.33	9.34	2.51	2.19	0.68	2.33	11	32	36	24
2	5.26	9.56	1.43	11.94	2.18	2.25	0.71	2.24	13	59	18	42
3	9.78	11.45	0.57	12.25	2.38	2.12	1.25	2.43	15	28	13	24
4	3.56	5.85	1.04	7.69	1.82	2.14	0.68	2.00	12	13	7	9
5	2.14	11.51	9.62	10.57	1.95	2.45	2.15	2.52	6	22	18	15
6	5.06	6.11	1.88	8.81	2.00	2.17	0.80	2.07	35	9	34	8
7	6.46	11.16	0.82	9.89	2.20	2.48	0.87	2.60	5	22	20	20
8	7.79	9.07	0.58	13.52	2.08	2.87	0,66	3.34	16	14	28	13
9	3.08	7.79	0.45	8.81	1.83	2.25	0.63	2.30	15	19	33	14
10	5.18	6.69	1.54	8.97	1.83	2.41	1.33	2.61	32	13	28	11
Total	55.56	91.07	19.26	101.79	20.78	23.33	9.76	24.44	160	231	235	180
Mean	5.56	9.11	1.93	10.18	2.08	2.33	0.98	2.44	16.0	23.10	23.50	18.0
S.d	1.56	2.37	2.74	1.85	0.24	0.23	0.48	0.38	9.94	14.52	9.73	10.18
U				**				**				n.s.

Table 13: Effects of fire on canopy area, height and number of live stems of *G. villosa* below 1.80m .

U - Values were calculated using actual numbers.

	Canopy area (m^2)				Height (m)				Number of Stems			
No. of ind	PRB		PSB		PRB		PSB		PRB		PSB	
	B	NB	B	NB	B	NB	B	NB	B	NB	B	NB
1	3.23	4.56	1.65	6.69	1.21	1.54	0.75	1.55	14	44	19	39
2	2.60	1.35	1.65	1.77	0.91	0.65	0.91	0.84	14	25	12	16
3	1.47	1.36	0.46	1.65	0.78	1.00	0.47	1.00	7	7	15	5
4	3.90	3.14	0.32	3.33	1.29	1.26	0.49	1.41	11	14	14	9
5	1.27	2.27	2.69	2.27	0.78	1.06	1.28	1.06	6	14	11	12
6	2.21	2.11	1.04	1.84	0.97	1.43	0.48	1.50	10	18	24	15
7	1.94	2.77	0.72	6.11	1.42	1.20	0.60	1.72	6	10	13	12
8	3.73	1.04	0.63	1.39	1.52	1.00	0.40	1.05	24	17	17	23
9	1.65	1.77	0.24	2.01	1.35	0.84	0.72	0.91	7	7	6	9
10	2.77	4.45	0.26	7.16	1.09	1.32	0.53	1.22	5	6	7	8
Total	24.37	24.82	9.66	34.22	11.32	11.30	6.63	12.26	104	162	138	148
Mean	2.44	2.48	0.97	3.42	1.13	1.13	0.66	1.23	10.40	16.20	13.80	14.80
S.d	0.96	1.25	0.80	2.30	0.27	0.27	0.27	0.30	5.80	11.43	5.39	9.88
U			**				**				*	

Table 14: Effects of fire on canopy area, height and number of live stems of <u>Hermania alhensis</u> below 1.80m .

U - Values were calculated using actual numbers.

	Canopy area (m^2)				Height (m)				Number of Stems			
No. of ind.	PRB		PSB		PRB		PSB		PRB		PSB	
	B	NB	B	NB	B	NB	B	NB	B	NB	B	NB
1	1.93	0.93	1.02		0.93	0.68	0.93		8	9	16	
2	1.37	0.46	0.78	3.14	1.01	0.61	0.52	0.69	7	24	14	25
3	0.93	1.77	0.75		0.86	0.72	0.59		9	43	19	
4	1.02	0.95	0.82		0.78	0.90	0.66		10	21	21	
5	1.15	1.00	1.77	1.84	0.81	0.88	0.89	0.94	12	18	30	19
6	0.85	1.54	0.55		0.74	0.58	0.55		7	13	10	
7	0.49	1.47	1.13		0.56	1.13	0.88		11	18	25	
8	2.08	0.31	-		0.89	0.90	-		12	26	-	
9	0.85	0.95	-		0.76	0.74	-		4	24	-	
10	0.43	1.58	0.35	2.14	0.51	0.79	0.76	0.83	12	14	11	18
Total	11.10	10.96	7.17	7.12	7.85	7.93	5.78	2.43	92	210.	146	62
Mean	1.11	1.11	0.90	2.37	0.78	0.79	0.72	0.82	9.20	2.10	18.25	20.67
S.d	0.55	0.49	0.43	0.68	0.15	0.16	0.16	0.12	2.70	9.44	8.29	3.78
U				*				*				*

Table 15: Effects of fire on canopy area, height and number of live stems of <u>Solanum incanum</u> below 1.80m .

U - Values were calculated using actual numbers

	Canopy area (m^2)				Height (m)				Number of Stems			
No. of ind.	PRB		PSB		PRB		PSB		PRB		PSB	
	B	NB	B	NB	B	NB	B	NB	B	NB	B	NB
1	0.54	0.37	–		1.06	1.14	–		1	1	–	
2	0.51	0.38	1.04	0.86	1.06	0.91	0.91	1.02	1	1	4	1
3	0.42	0.63	0.003		0.83	1.25	0.07		1	1	1	
4	0.24	0.44	0.37		0.88	0.86	0.81		1	1	1	
5	0.28	0.38	–	0.50	0.93	0.78	–		1	1	–	
6	0.34	0.75	0.01		0.89	0.89	0.18	0.98	1	1	1	1
7	0.69	0.78	0.27	0.27	0.91	1.27	0.87	0.85	1	1	1	1
8	0.34	0.83	–		1.12	1.26	–		1	1	–	
9	0.35	0.39	0.75		0.94	0.90	0.79		1	1	2	
10	0.34	0.28	–	0.19	1.02	0.83	–	0.47	1	1	–	2
Total	4.05	5.23	2.44	1.82	9.64	10.09	3.63	3.32	10	10	10	5
Mean	0.40	0.52	0.41	0.45	0.96	1.00	0.60	0.83	1.00	1.00	1.67	1.25
S.d.	0.14	0.20	0.41	0.28	0.09	0.20	0.37	0.25	0.00	0.00	1.21	0.50

Response of Herbaceous Vegetation to Burning.

Before burning twelve grass species and nine forbs were recorded in the paddock to be burnt whereas eleven species of grass and seven forbs were found in the control paddock. Sixteen species were common to both paddocks of which ten were grasses (Table 16). All grasses were perennial except one, Aristida keniensis. Digitaria macroblephara was the dominant grass with relative densities of 55.26% and 48.51% in the paddock to be burnt and the control paddock, respectively. Its relative frequencies for both paddocks were 87.51% and 77.20%, respectively.

Subdominant grasses in the paddock to be burnt, in decreasing order of absolute density, were Microchloa kunthii, Bothrichloa insculpta and Bothrichloa glabra. In the control paddock subdominant grasses were B. glabra, M. kunthii and B. insculpta. Sehima nervosum was the grass found only in the paddock to be burnt whereas Cynodon dactylon was recorded in the control paddock. Both grasses were perennials.

Forbs represented 12% and 8.11% of relative density in the paddock to be burnt and the control paddock, respectively. There were 6 forb species common to both paddocks (Table 16). Carex sp. was the dominant species in both paddocks in terms of absolute density. Forb species found only in the paddock to be burnt were Barleria sp., Ocimum americanum and Scillia indica. All had very low absolute densities. The forb recorded only in the control paddock was a perennial climber, Asparagus africanus. Total density for herbaceous

Table 16. Herbaceous vegetation characteristics of research area as determined from preburn and postburn surveys.

	Preburn						Postburn					
Treatments	Burnt 1/			Control 1/			Burnt 2/			Control 2/		
	AD	RD	RF	AD	RD	RF	AD	RD	RF	AD	RD	RF
Acanthospermum hispidum (HA)							0.14	0.2	0.4			
Aristida keniensis (GA)	0.36	0.5	2.0	1.77	2.5	6.4	0.37	0.5	2.0	8.69	11.7	31.2
Asparagus africanus (CP)				0.07	0.1	0.4	0.22	0.3	1.2			
Asparagus sp. (CP)							0.07	0.1	0.4			
Athroisma psylloides (HA)	1.87	2.6	7.6	1.48	2.1	5.6						
Barleria sp. (HA)	0.07	0.1	0.4				0.07	0.1	0.4			
Bothrichloa glabra (GP)	3.02	4.2	10.8	9.82	13.7	30.0						
Bothrichloa insculpta (GP)	5.39	7.5	21.6	4.06	5.7	14.0	4.97	6.8	17.2	8.10	10.9	26.0
Brachiaria sp. (GA)							4.97	6.8	20.0	5.35	7.2	18.0
Carex sp. (H)	2.59	3.6	11.6	1.77	2.5	7.6						
Cenchrus ciliaris (GP)	1.08	1.5	4.0	0.81	1.1	2.4	0.37	0.5	1.6	0.07	0.1	0.4
Chloris roxburghiana (GP)	1.36	1.9	6.0	1.03	1.4	6.4	0.80	1.1	3.6	6.46	8.7	26.4
Chloris virgata (GA)							0.88	1.2	4.0	1.19	1.6	5.6
Cleome hirta (HA)							4.02	5.5	16.4			
Clerodendrum sp. (HP)							0.07	0.1	0.4			
Commelina benghalensis (HA)	0.57	0.8	3.2	0.96	1.3	4.8	2.56	3.5	10.0	4.31	5.8	16.4
Cynodon dactylon (GP)				1.03	1.4	2.0				0.07	0.1	0.4
Cynodon sp. (G)	1.51	2.1	6.0				1.17	1.6	4.4			
Cyphostema lentianum (HA)							0.07	0.1	0.4			
Cyperus rotundus (HA)							1.17	1.6	5.6	1.56	2.1	6.8
Dactyloctenium aegyptiacum (GA)							0.44	0.6	2.4	0.07	0.1	0.4
Digitaria macroblephara (GP)	39.65	55.2	87.2	34.79	48.5	77.2	24.03	32.9	72.4	29.27	39.4	75.6
Eleusine aegyptiaca (GA)							0.22	0.3	0.8			
Eragrostis aethiopica (GA)							3.51	4.8	16.0			
Eragrostis caespitosa (GP)	0.65	0.9	1.2	0.89	1.2	4.0	0.29	0.4	1.6	0.74	1.0	1.6
Eragrostis cilianensis (GA)							3.36	4.6	14.0	0.07	0.1	0.4
Eragrostis sp. (G)							0.15	0.2	0.8			
Heliotropium aegyptiaca (HA)							0.73	1.0	2.8			
Heliotropium strigosum (HA)							3.07	4.2	11.6			
Hibiscus sp. (H)							0.22	0.3	1.2			
Indigofera sp. (HA)							1.53	2.1	6.8			
							0.07	0.1	0.4			

Ipomea sp. (CA/P)							1.53	2.1	6.8			
Justicia sp. (HA)	0.93	1.3	5.2	1.11	1.5	5.6	1.53	2.1	6.8			
Leucas sp. (HA)							1.03	1.4	5.2	0.67	0.9	2.4
Microchloa kunthii (GP)	7.61	10.6	21.6	9.53	13.3	31.2	0.15	0.2	0.8	4.09	5.5	14.0
Ocimum americanum (H)	0.07	0.1	0.4									
Ocimum basilicum (HA)							0.15	0.2	0.4			
Oxygonum sinuatum (HA)							0.51	0.7	2.8			
Panicum maximum (GP)							0.88	1.2	3.2	0.59	0.8	2.0
Pennisetum massaicum (GP)							0.15	0.2	0.4	0.07	0.1	0.4
Scillia indica (H)	0.07	0.1	0.4									
Sehima nervosum (GP)	0.57	0.8	1.6									
Sporobolus sp.										0.30	0.4	1.2
Sporobolus pellucidus (GP)	0.86	1.2	3.2	0.52	0.7	2.4	0.22	0.3	1.2	0.07	0.1	0.4
Talinum caffrum (S)										0.15	0.2	0.8
Talinum portulacifolium (SP)										0.74	1.0	3.2
Tephrosia villosa (HA/P)	1.87	2.6	7.6	0.74	1.0	4.4	5.70	7.8	21.2	0.30	0.4	1.6
Themeda trianda (GP)	1.08	1.5	4.8	0.30	0.4	0.8	0.29	0.4	0.8	0.74	1.0	3.6
Tragus berteronianus (GA)							0.15	0.2	0.8			
Unidentified species (H)	0.57	0.8	2.4	1.03	1.4	2.0	2.12	2.9	9.6	0.59	0.8	1.2
Vernonia sp. (HA)							0.07	0.1	0.4			
Vigna sp. (H)							0.44	0.6	1.2			
Total	71.75	99.9	–	71.71	99.8	–	72.93	99.8	–	74.26	100	–
IS_E			95.38						76.67			
C			82.54						58.40			

1/ Survey Nov. 81

2/ Survey Feb. 85

(HA) = Annual herb (CP) = Perennial climber (S) = Shrub

(GA) = Annual grass (GP) = Perennial grass (SP) = Perennial Shrub.

species was 71.75 plants per square meter in the paddock to be burnt and 71.71 for the control paddock. Bray and Curtis' community similarity coefficient showed a high similarity between both paddocks (C = 82.54%). Ellenberg's index showed an even higher similarity between herbaceous layers of both paddocks (IS_E = 95.38%).

After burning there were forty two species of which seventeen were grasses in the burnt paddock. Similarly twenty four species were found in the unburnt paddock of which sixteen were grasses. Fifteen grass species and five forb species were common to both paddocks (Table 16). Five of the ten grasses were annuals: Eragrostis cilianensis, Dactyloctenium aegypticum, Chloris virgata, Brachiaria sp. and A. keniensis that was the only preburn annual. Table 16 showed that B. glabra was missing from the list of postburn common perennials, while Panicum maximum and Pennisetum massaicum were additional species recorded. The remaining perennials were already common to both paddocks on the preburn survey. Digitaria macroblephara remained the dominant grass in both paddocks but decreased in terms of relative density by 22.31% and 9.11% in the burnt and the unburnt paddock, respectively (Table 16).

Subdominant species in the burnt paddock were B. insculpta and Brachiaria sp. Both had the same relative density of 6.80%. The relative density of M. kunthii decreased by 10.4%. In the unburnt paddock, subdominant grasses in terms of relative density were, A. keniensis (11.70%), B. insculpta (10.90%), C. roxburghiana (8.70%) and Brachiaria sp. (7.20%). Bothrichloa glabra was missing from both paddocks on the postburn survey.

Grasses found only in the burnt paddock were all annuals: Eleusine aegyptiaca, Eragrostis sp., Tragus barteronianus and Eragrostis aethiopica. Absolute density of the latter was 3.51 plants per square meter while those of the remaining species were below 1 plant per square meter. Two perennial grasses, C. dactylon and Sporobolus sp., were found only in the burnt paddock but had very low absolute densities.

The relative density of forbs increased by 23% in the burnt paddock and by 1.89% in the unburnt one. Five forbs were common to both paddocks (Table 16). Leucas sp. and Cyperus rotundus were additional common species recruited and accounted for 3% relative density in both paddocks. The relative density of Tephrosia villosa increased by 5.20% in the burnt paddock but decreased in the unburnt one. The relative density of Commelina benghalensis increased by 2.70% and 4.50% in the burnt and unburnt paddock, respectively (Table 16).

There were 18 forb species found only in the burnt paddock, representing a 500% increase (Table 16). Two forbs were recorded only in the unburnt paddock as compared to one on the preburn survey, these were Talinum caffrum and Talinum portulacifolium.

An increase of 16.72% in number of forb species in the burnt paddock was noted. Changes in total density were minor, 1.64% and 3.55% in the burnt and unburnt paddocks, respectively. Both Ellenberg's index and the Bray and Curtis community similarity coefficient decreased by 18.71% and 24.14%, respectively. Thus, less similarity between herbaceous layers of the two paddocks was displayed as a result of burn, as one would expect.

Response of Mammal Populations to Burning.

Ground Count of Large Mammals: Overall mean densities of herbivore species derived from ground count for the burnt and unburnt paddock with their standard deviations are given in Table 17. The latter are rather high in all cases probably because of the small sample sizes. Significant differences between the burnt and the unburnt paddocks emerged for several species including Grant's gazelle and dik dik. The burnt paddock was more attractive to Grant's gazelle while the unburnt one attracted dik dik. Other species that showed significant differences by virtue of occuring in the burnt paddock alone were zebra, suni and eland. For warthog, kongoni, impala, giraffe and buffalo, overall mean densities did not differ significantly between the two areas. However densities were slightly higher in the burnt paddock for warthog and kongoni but were lower for giraffe, buffalo and impala.

Mean densities for wet and dry months are given in Table 18. Only Grant's gazelle showed significant differences in both seasons between the burnt and unburnt paddock. Differences in density were significant during wet months, between the burnt and the unburnt paddock, for dik dik, zebra, suni and eland. They were significant on dry months for impala, zebra and ostrich. Seasonal

Table 17 . Overall mean densities (d) per km² and their standard deviations as derived from a 12-month ground count for a burnt and unburnt paddock at KNRRS.

Species	Burnt		Non burnt		Difference
	d	s.d.	d	s.d.	
Grant's gazelle	3.53	± 4.54	0.21	± 0.52	**
Warthog	1.99	± 2.19	1.91	± 2.77	n.s.
Kongoni	1.80	± 3.07	1.16	± 2.05	n.s.
Impala	1.79	± 2.19	4.85	± 5.83	n.s
Dik dik	1.65	± 1.95	4.65	± 4.09	*
Zebra	0.41	± 0.75	0		*
Giraffe	1.17	± 2.34	3.20	± 6.10	n.s.
Buffalo	0.26	± 0.00	0.36	± 0.61	n.s.
Suni	1.19	± 0.00	0		*
Eland	0.30	± 0.00	0		*
Ostrich	0.34	± 0.60	0.30	± 0.0	n.s.

* = $p < .05$

** = $p < .01$

n.s. = Non significant

Table 18. Average densities per Km^2 and their standard deviations from a 12-month ground count and seasonal differences between a March 1984 burnt paddock and an unburnt paddock at KNRRS.

Species	Burnt		Unburnt		Difference	
	Wet	Dry	Wet	Dry	Wet v Wet	Dry v Dry
Grant's gazelle	3.27 ± 2.76	3.71 ± 5.70	0.26 ± 0.00	0.11 ± 0.00	*	*
Warthog	1.01 ± 1.78	2.55 ± 2.45	2.20 ± 1.71	1.69 ± 3.36	n.s.	n.s.
Kongoni	2.57 ± 4.47	1.25 ± 1.78	0	1.16 ± 2.05	n.s.	n.s.
Impala	1.07 ± 1.48	1.61 ± 1.58	2.32 ± 3.31	6.20 ± 6.91	n.s.	**
Dik dik	1.31 ± 2.76	1.89 ± 1.30	5.91 ± 4.27	3.75 ± 2.53	*	n.s.
Zebra	0.28 ± 0.00	0.51 ± 0.87	0	0	*	*
Giraffe	1.96 ± 3.31	0.62 ± 1.36	1.36 ± 0.0	4.51 ± 7.50	n.s.	n.s.
Buffalo	0	0.04 ± 0.00	0	0.36 ± 0.61	n.s.	n.s.
Suni	0.24 ± 0.00	0	0	0	*	n.s.
Eland	0.06 ± 0.0	0	0	0	*	n.s.
Ostrich	0.34 ± 0.60	0	0	0.30 ± 0.00	n.s.	*

* $p<.05$

** $p<.01$

densities for warthog, kongoni, giraffe and buffalo did not differ significantly, though most were slightly higher in the burnt paddock. Dry month densities were higher than wet ones in the burnt paddock for Grant's gazelle, warthog, impala, zebra, dik dik but were lower for giraffe and kongoni.

The biomass densities (Table 19) are based on mean animal unit mass. Many animals were not aged (Table 20) and the unit mass was assigned equally to all individuals, irrespective of their age. Thus figures in Table 19 are subject to wide margin of error and must be taken as indicating the order of magnitude only rather than exact values. In any one area, biomass density fluctuated considerably as a result of local movements of animals. Giraffe was the dominant species with 50% and 78.73% total biomass in the burnt and the unburnt paddocks, respectively. In decreasing order of percent biomass in the burnt paddock, it was followed by kongoni (12.82%), Grant's gazelle (8.05%) and buffalo (6.67%). Subdominant species in the unburnt area were impala (6%), buffalo (5.31%) and kongoni (4.76%).

Claims have been made that wild ungulates invade recently burnt paddocks (Burzlaff, pers. com.) and compete for food resources with livestock. Data on activity patterns of major species were recorded (Table 21). Giraffe, Grant's gazelle, warthog, kongoni, impala and dik dik were the 6 ungulates regularly counted. Zebra,

Table 19 . Estimates of biomass density over the study period and percent biomass of each species in the burnt and unburnt paddocks.

Species		Burnt			Unburnt		
	Unit Mass	Density	Biomass (Kg/Km^2)	%Total	Density	Biomass (Kg/Km^2)	%Total
Grantis gazelle 3/	40	3.53	141.20	8.05	0.21	8.40	0.28
Warthog 1/	50	1.99	99.50	5.67	1.91	95.50	3.13
Kongoni 1/	125	1.80	225	12.82	1.16	145	4.76
Impala 3/	40	1.79	71.60	4.08	4.58	183.2	6.00
Dikdik 2/	5.20	1.65	8.60	0.49	4.65	24.2	0.79
Zebra 1/	200	0.41	82	4.67	–	–	–
Giraffe 2/	750	1.17	877.50	50.00	3.20	2400	78.73
Buffalo 1/	450	0.26	117	6.67	0.36	1.62	5.31
Suni 2/	7.00	1.19	8.30	0.47	–	–	–
Eland 3/	300	0.30	90	5.13	–	–	–
Ostrich 1/	100	0.34	34	1.94	0.30	30	0.98
Total biomass			1754.70	99.99		3048.30	99.98

1/ = Grazer

2/ = Browser

3/ = Mixed feeder

Table 20. Age structure of major herbivore species determined from ground count in the study area

Species	Sample size	% Adult	% Juvenile	% Young	% Undetermined	Calving season
Grant's gazelle	98	46.9 (46)	31.6 (31)	9.2 (9)	12.2 (12)	October-March
Warthog	77	59.7 (46)	7.8 (6)	11.7 (9)	20.8 (16)	October-February
Kongoni	64	45.3 (29)	14.1 (9)	15.6 (10)	25.0 (16)	Year round
Impala	109	71.5 (78)	8.2 (9)	2.7 (3)	17.4 (19)	Year round
Dik dik	97	85.6 (83)	0.0 (0)	1.0 (1)	13.4 (13)	Not obvious
Zebra	16	12.5 (2)	25.0 (4)	18.7 (3)	43.7 (7)	Not obvious
Giraffe	85	42.3 (36)	21.2 (18)	18.8 (16)	17.6 (15)	Year round
Buffalo	3	66.7 (2)	33.3 (1)	-	-	Not obvious
Suni	4	-	-	-	100 (4)	Not obvious

( ) = number of individuals of the species aged in the course of the study

Table 21. Large herbivores sighted and their main activities as percent of number of sightings during the 12-month ground count in the burnt paddock and the unburnt one.

	Burnt				Unburnt			
Species	No of sightings	feeding	running	standing	No of sightings	feeding	running	standing
Grant's gazelle	16	25	12.5	12.5	14	21.4	7.1	21.4
Warthog	14	35.7	42.8	-	22	4.5	40.9	18.2
Kongoni	10	10	40	40	14	-	21.4	25.6
Impala	4	-	25	-	13	30.7	7.7	30.7
Dik dik	9	22.2	44.4	11.1	51	3.9	47.0	29.4
Zebra	3	-	-	-	0	-	-	-
Giraffe	6	50	16.6	16.6	9	77.8	-	-
Buffalo	1	-	100	-	2	50	-	-
Suni	3	66.6	33.4	-	-	-	-	-
Eland	-	-	-	-	1	-	-	100
Ostrich	-	-	-	-	1	-	100	-
Gerenuk	-	-	-	-	2	-	-	100
Total	66				129			

suni, eland, buffalo, gerenuk and ostrich were occasionally encountered. Data suggest that most animals were more involved in activities other than feeding. Running was the major activity for most species. This may be due to the fact animals are harassed at KNRRS and when they first detected the investigator, they escaped into the cover.

For most species the sex and age of most of the individuals could not be determined for reasons given above (Tables 20 and 22). For dik dik, whenever two adults were seen together, it was assumed one was a male and the other a female. For warthog, kongoni and buffalo, males were observed in considerably higher proportions than females. The inverse was observed for Grant's gazelle and impala while dik dik and giraffe were at equal proportions. Except for impala and dik dik there was 10% young for most species populations. The recruitment of young in relation to the number of adult females was generally low (Table 20). Production of young year round was observed for kongoni, impala and giraffe. Impala, zebra and dik dik did not show a definite calving season but appeared also to breed the year round. For Grant's gazelle and warthog, production of young seemed to coincide with the rainy season.

Random observations were made when I was involved in other activities in both paddocks. The seven most abundant ungulate species preferred the burnt paddock (Table 23). Differences were more marked in warthog and wildebeest but were less for zebra and kongoni. Unselective mixed feeders like Grant's gazelle and impala showed also marked preferences for the burnt paddock. The trend was pronounced particularly six months after the burn and thereafter when

Table 22. Sex ratio of major herbivore species observed from a ground count (March 1984-March 1985)

Species	Sample size	Male	Female	Undetermined	Young/Female
Grant's gazelle	98	1.0 (27)	1.3 (35)	0.6 (36)	0.3
Warthog	77	1.0 (23)	0.7 (17)	0.9 (37)	0.5
Kongoni	64	1.0 (19)	0.7 (14)	0.9 (31)	0.7
Impala	109	1.0 (22)	2.9 (64)	0.3 (23)	0.05
Dik dik	97	1.0 (33)	1.0 (33)	0.5 (31)	0.03
Zebra	16	0.0 (0)	4.0 (4)	3.0 (12)	0.8
Giraffe	85	1.0 (10)	1.0 (10)	3.2 (65)	1.6
Buffalo	3	1.0 (2)	0.5 (1)	-	-
Suni	4	-	-	4.0 (4)	-
Gerenuk	2	0.0 (0)	2.0 (2)	-	-

( ) = number of individuals sexed

Table 23. Numbers of individuals of each herbivore species and percent of random observations made in the burnt and the unburnt paddocks during the study period.

Species	Time since burn				N	% Total
	< 6 months		> 6 months			
	B	NB	B	NB		
Grant's gazelle	15	1	14	-	30	14.28
Giraffe	-	-	14	13	27	12.86
Zebra	7	2	-	-	9	4.28
Warthog	8	-	2	2	12	5.71
Kongoni	-	9	13	-	22	10.48
Wildebeest	12	-	-	-	12	5.71
Impala	-	-	59	28	87	41.43
Dik dik	-	-	8	3	11	5.24
Total	42	12	110	46	210	
% Total	20	5.71	52.38	21.90		99.99

the rains came.

Vehicle Count of Large Mammals:

Results from the vehicle count indicated that both burning and grazing treatments had effects on overall densities of large herbivores (Table 24). Densities were also higher during wet months than during dry ones for most species and in all treatments (Table 25) except Thomson's gazelle (March 1984 burn), ostrich (unburnt), impala and giraffe (February 1983 burn). The magnitude of increase was more important for all species in the March 1984 burn. Regardless of the year of burn, paddocks burnt at the height of December to March dry season showed significant differences from those, burnt, during the June t October dry season, or the unburnt ones (Table 26). The density in the March 1984 burn was significantly lower than that of the February 1983 burn, but the higher species diversity was recorded in the former (Table 24). The difference was, mainly due to giraffe (a browser) which accounted for 96.69% of total biomass in that treatment and also by mixed feeders Grant's gazelle and impala (Table 27). The only grazer recorded in the February 1983 burn, and which accounted for 1.31% of total biomass only, was kongoni. The February 1983 burn showed also significant differences, in overall and dry season densities with each of the other treatments (Table 26). There was no significant difference during wet months. However the March 1984 burn showed significant difference with the October 1982 burn, and also the unburnt during wet months.

Table 24. Overall mean densities (animal/Km^2) and standard deviations of each species in the 5 burning treatments during the study period.

Species	B:March 84	Unburnt	B:Oct. 83	B:Feb. 83	B:Oct. 82
Dik dik	0.38 ± 0.26	0.12 ± 0.21	-	-	-
Kongoni	2.57 ± 4.51	-	-	2.02 ± 0.0	1.44 ± 0.0
Impala	4.66 ± 2.15	1.18 ± 2.15	-	8.59 ± 3.45	-
Zebra	1.70 ± 1.71	0.75 ± 0.47	-	-	-
Warthog	0.11 ± 0.15	1.04 ± 0.49	-	-	-
Grant's gazelle	4.31 ± 3.84	0.41 ± 0.43	0.38 ± 0.0	1.01 ± 0.0	-
Thomson's gazelle	5.44 ± 0.45	-	-	-	-
Ostrich	1.99 ± 3.13	1.84 ± 3.08	1.79 ± 0.0	-	1.73 ± 0.0
Giraffe	0.06 ± 0.07	2.08 ± 2.43	-	24.79 ± 30.95	-
Suni	-	0.40 ± 0.0	-	-	-
Gerenuk	0.19 ± 0.0	-	-	-	-
Wildebeest	5.86 ± 0.59	-	-	-	1.51 ± 0.0
Oryx	-	1.19 ± 0.0	-	-	-
Bushbuck	-	0.08 ± 0.0	-	-	-

Table 25. Dry and wet months mean densities ($/Km^2$) and standard deviations of each species in the 5 burning treatments during the study period

DRY MONTHS (June, July, August and September 1984, and January and March 1985)						WET MONTHS (October, November and December 1984 and February 1985)				
Species	B:March 84	Unburnt	B:Oct. 83	B:Feb.83	B:Oct.82	B:March 84	Unburnt	B:Oct.83	B:Feb.83	B:Oct. 82
Dik dik	0.38 ± 0.26	0.08 ± 0.15	-	-	-	-	0.19 ± 0.33	-	-	-
Kongoni	0.58 ± 0.93	-	-	2.02 ± 0.0	1.44 ± 0.0	10.53 ± 0.0	-	-	-	-
Impala	3.35 ± 5.94	0.74 ± 1.53	-	11.03 ± 0.0	-	6.83 ± 4.06	1.90 ± 3.20	-	6.15 ± 0.0	-
Zebra	0.71 ± 0.05	0.71 ± 0.05	-	-	-	3.67 ± 0.0	0.96 ± 0.0	-	-	-
Warthog	0.11 ± 0.15	0.78 ± 0.38	-	-	-	-	1.30 ± 0.57	-	-	-
Grant's gazelle	2.34 ± 0.0	0.41 ± 0.43	0.38 ± 0.0	1.01 ± 0.0	-	4.70 ± 4.14	-	-	-	-
Thomson's gazelle	5.76 ± 0.0	-	-	-	-	5.12 ± 0.0	-	-	-	-
Ostrich	0.40 ± 0.69	2.73 ± 4.36	-	-	-	2.94 ± 3.72	0.05 ± 0.0	1.79 ± 0.0	-	-
Giraffe	0.06 ± 0.07	1.57 ± 2.26	-	46.68 ± 0.0	-	-	4.15 ± 2.57	-	2.90 ± 0.0	1.73 ± 0.0
Suni	-	-	-	-	-	-	0.40 ± 0.0	-	-	-
Gerenuk	0.19 ± 0.0	-	-	-	-	-	-	-	-	-
Wildebeest	-	-	-	-	-	5.86 ± 0.59	-	-	-	1.51 ± 0.0
Oryx	-	1.19 ± 0.0	-	-	-	-	-	-	-	-
Bushbuck	-	-	-	-	-	-	-	0.08 ± 0.0	-	-

Table 26. Results of Duncan's multiple range test applied to overall, wet and dry months mean densities between 5 burning treatments.

Treatments compared			Significance		
			overall	wet	dry
B: Feb. 83	v	Unburnt	*	n.s.	*
B: Feb. 83	v	B: Oct. 83	*	n.s.	*
B: Feb. 83	v	B:Oct. 82	*	n.s.	*
B: Feb. 83	v	B: March 84	*	n.s.[1]	*
B: March 84	v	Unburnt	n.s.	*	n.s.
B: March 84	v	B: Oct. 83	n.s.	n.s.	n.s.
B: March 84	v	B: Oct. 82	n.s.	*	n.s.[1]
B: Oct. 82	v	Unburnt	n.s.	n.s.	n.s.[1]
B: Oct. 82	v	B: Oct. 83	n.s.	n.s.[1]	n.s.
B: Oct. 83	v	Unburnt	n.s.	n.s.	n.s.

* = $p < .05$

** = $p < .01$

n.s.= Non significant

n.s.[1]= Mean density in second treatment greater than the first

Except for the March 1984 burn, there were more herbivore species in the unburnt than in any other treatment. As one would expect most were browsers. The ranking of the five treatments in decreasing order of total biomass was February 1983 burn, March 1984 burn, unburnt, October 1982 and October 1983 burn (Table 27).

The distribution maps are consistent throughout. The increasing size of dot corresponds to increase in numbers of animals seen (see legend).

Grant's gazelle, are animals of open grasslands, and this is clearly shown in their distribution (Fig. 7). They preferred paddocks that had been burnt already. The highest densities were recorded in the most recently burnt paddocks. However, the distribution was not static. Unlike in the dry season, almost all Grant's gazelles were seen in paddocks burnt in March 1984, during the wet season. The biomass density fluctuated accordingly (Table. 28). Higher densities and biomass densities were recorded in March 1984 burn. (Tables 24 and 27). The highest percent of total biomass for Grant's gazelles in any treatment was recorded in October 1983.

Kongoni. The distribution of kongoni was remarkable in the sense that the maps displayed two features (Fig. 8):

- the species was totally absent during dry months,
- it concentrated in only one of the paddocks burnt in 1984, during wet months.

However kongoni were also seen in paddocks burnt in February 1983 and October 1982 (Table 24). The mean

Table 27. Mean biomass densities (Kg/Km^2) and % total biomass of each species in 5 burning treatments.

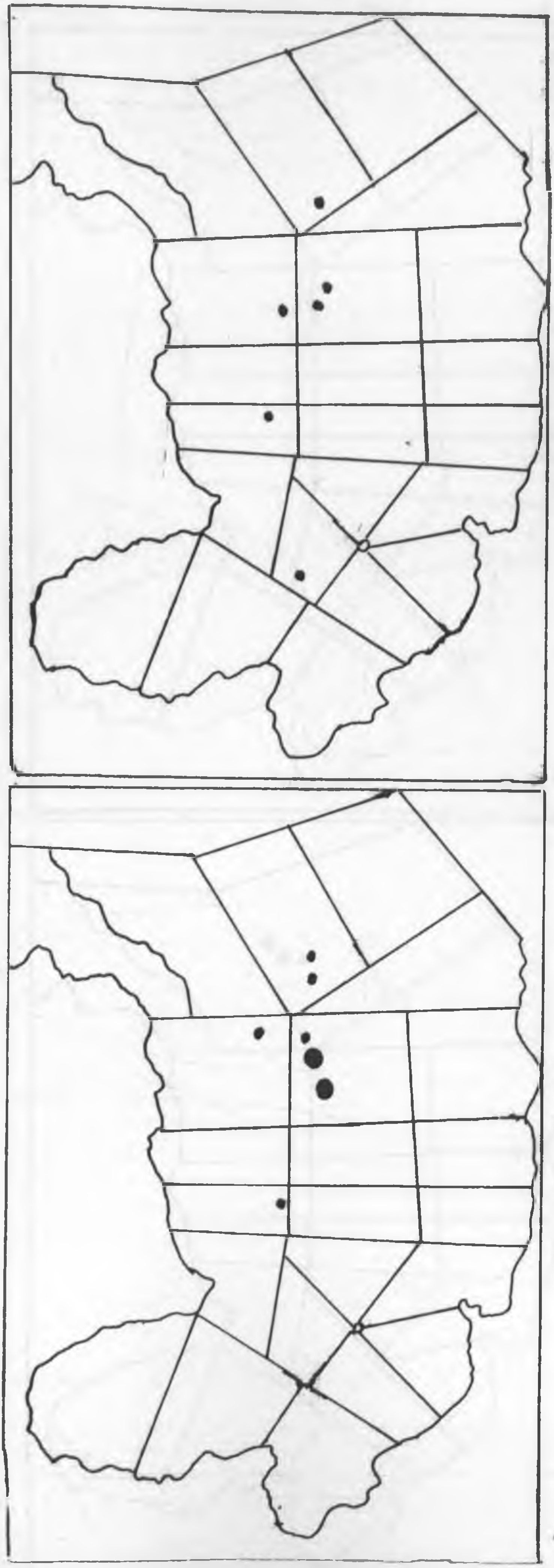
Species	B:March 84	%Total	Unburnt	%Total	B:Oct. 83	%Total	B:Feb. 83	%Total	B:Oct. 82	%Total
Dik dik	1.98	0.08	0.62	0.03	–		–		–	
Kongoni	321.25	12.91	–		–		252.50	1.31	180	28.13
Impala	186.40	7.49	47.20	2.15	–		343.60	1.79	–	
Zebra	340	13.67	150	6.83	–		–		–	
Warthog	5.50	0.22	52	2.37	–		–		–	
Grant's gazelle	172.40	6.93	16.40	0.75	15.20	7.83	40.40	0.21	–	
Thomson's gazelle	97.92	3.94	–		–		–		–	
Ostrich	199	8.00	184	8.38	179	92.17	–		173	27.04
Giraffe	45	1.81	1560	71.03	–		18592.50	96.69	–	
Suni	–		2.8	0.13	–		–		–	
Gerenuk	4.75	0.19	–		–		–		–	
Wildebeest	1113.40	44.76	–		–		–		286.90	44.83
Oryx	–		178.50	8.13	–		–		–	
Bushbuck	–		4.8	0.22	–		–		–	
Total	2487.60	100	2196.32	100	194.20	100	19229	100	639.9	100

Table 28. Dry and Wet months biomass densities (Kg/Km^2) and % total biomass of each species in 5 burning treatments

Species	B:March84	%	Unburnt	%	B:Oct.83	%	B:Feb.83	%	B:Oct.82	%	B:March84	%	Unburnt	%	B:Oct.83	%	B:Feb.83	%	B:Oct82	%
Dik dik	1.98	0.26	0.42	0.02	-		-		-		-		0.99	0.03	-		-		-	
Kongoni	72.50	9.42	-		-		252.50	0.71	180	100	1316.25	31.92	-		-		-		-	
Impala	134	17.41	29.60	1.59	-		441.20	1.23	-		273.20	6.62	76	2.20	-		246	10.16	-	
Zebra	142	18.44	142	7.65	-		-		-		-		-		-		-		-	
Warthog	5.50	0.71	39	2.10	-		-		-		-		65	1.88	-		-		-	
G. Gazelle	93.60	12.16	16.40	0.88	15.20	100	40.40	0.11	-		188	4.56	-		-		-		-	
T. Gazelle	230.40	29.93	-		-		-		-		204.80	4.97	-		-		-		-	
Ostrich	40	5.20	273	14.71	-		-		-		294	7.13	5.00	0.14	179	100	-		-	
Giraffe	45	5.85	1177.50	63.43	-		35010	97.95	-		-		3112.50	89.98	-		2175	89.84	1297.50	81.89
Suni	-	-	-		-		-		-		-		2.80							
Geremuk	4.75	0.68	-		-		-		-		-		-	-	-		-		[illegible]	[illegible]
Wildebeest	-		-		-		-		-		1113.40	27.00	-		-		-		286.90	18.11
Oryx	-		178.50	9.62	-		-		-		-		-		-		-		-	
Bushbuck	-		-		-		-		-		-		4.80	0.14	-		-		-	
Total	769.73	100	1856.42	100	15.20	100	35744.00	100	180	100	4123.65	100	3459.09	100	179	100	2421	100	1584.40	100

Figures 7 to 12: Distribution of Large Herbivores in the Study Area (GM2). 0 — 50 Km

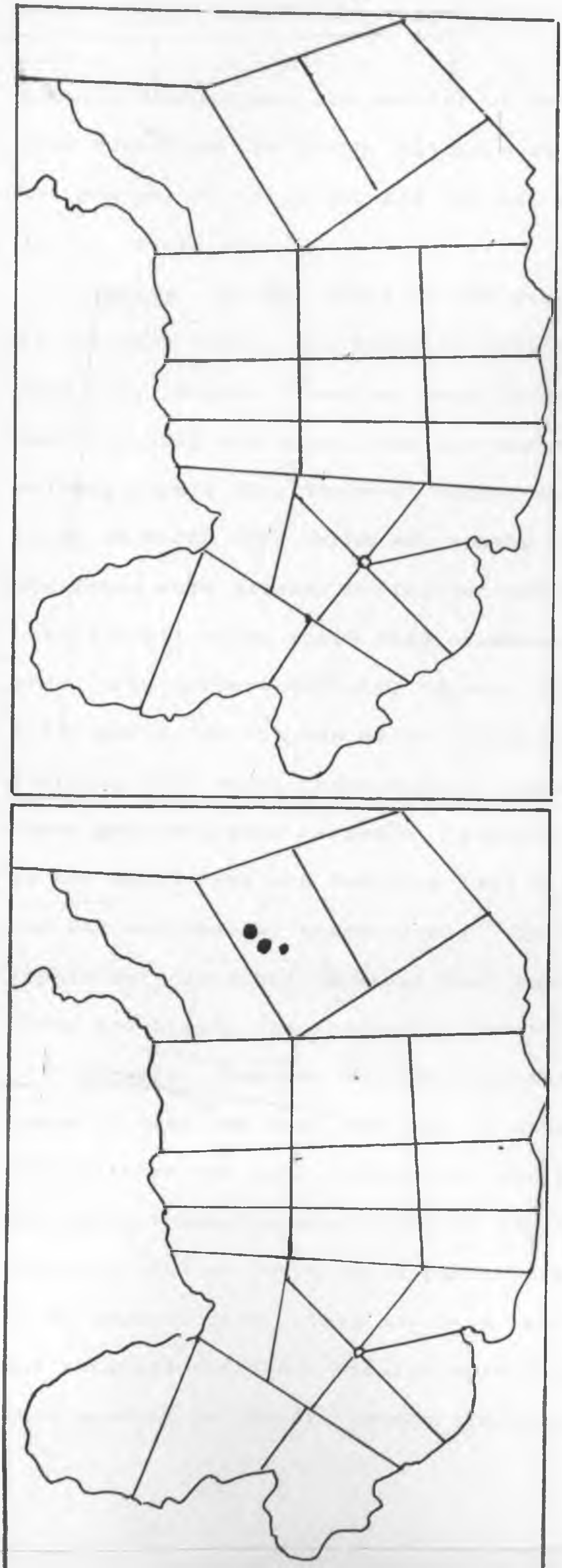
- ● 1 to 5 animals
- ● 5 to 10 animals
- ● 10 to 15 animals
- ● 15 to 20 animals
- ● > 20 animals.



Dry

Wet

FIG. 7 DISTRIBUTION OF <u>Grant's gazelle</u>



Dry

Wet

FIG. 8 DISTRIBUTION OF <u>Kongoni</u>

biomass density and the percent of total biomass of kongoni were higher in the March 1984 burn as one would expect. The percent of total biomass for wet months was even higher: 31.92% (Table 28).

Impala. At all times of the year, impala were seen in recently burnt, old burnt as well as in unburnt areas (Fig. 9). Higher densities were recorded in paddocks burnt in February 1983 and March 1984 for the dry and wet months, respectively (Table 25). The next higher densities were in the paddocks burnt in March 1984 during wet months and then the unburnt ones. The densities were greater during wet months than during dry ones for all burns where they occurred, except February 1983. The percent of total biomass densities were 7.49%, 2.15% and 1.79% for the March 1984 burn, unburnt and the February 1983 burn, respectively (Table 27). However these percents were variable. Highest ones were recorded in the March 1984 and February 1983 burns, in the dry and the wet season, respectively. Quite clearly it seemed impala were attached to areas that could provide sufficient graze and browse simultaneously (burnt areas).

Giraffe. Centres of high densities for giraffe were areas of over one year old burn or unburnt ones (Fig. 10). This pattern was more conspicuous during the dry season. The overall density was higher in the paddock burnt in February 1983 as compared to paddocks burnt in March 1984 or to unburnt ones. This may have been due to the open and unragged terrain. Giraffe were more concentrated in that paddock in the dry season (Table 25). The density

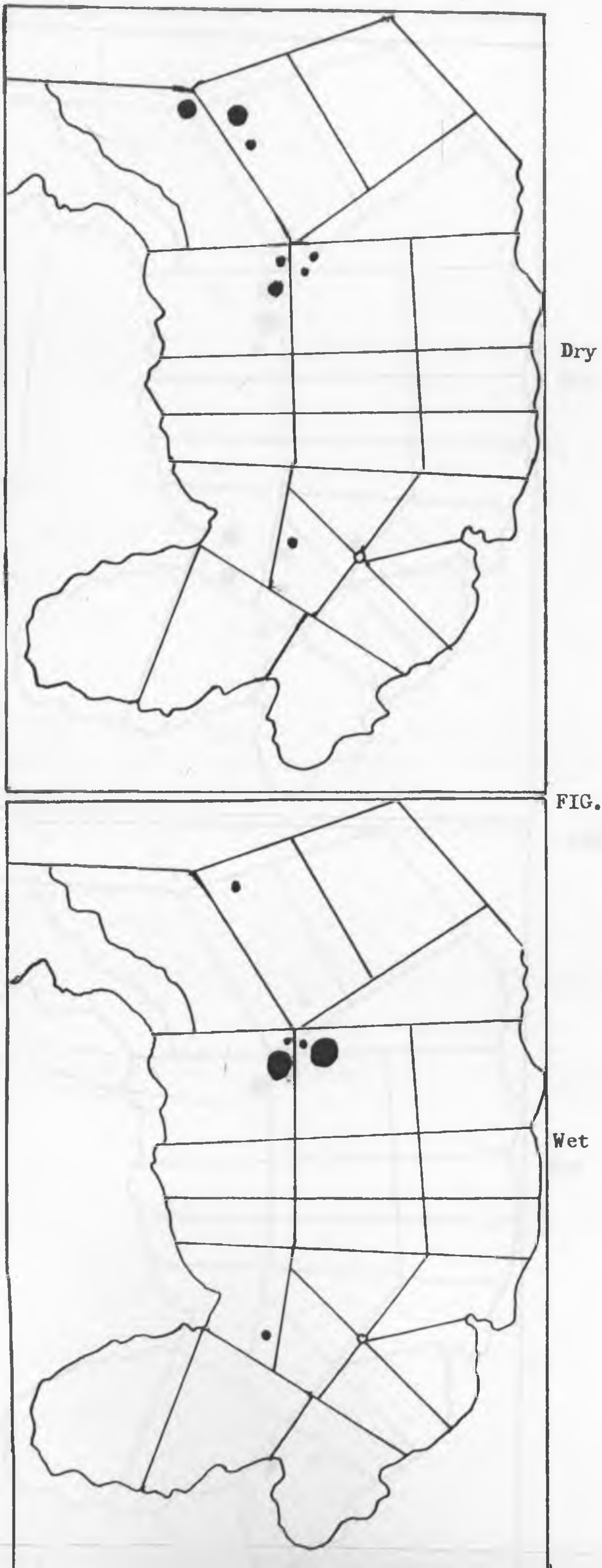
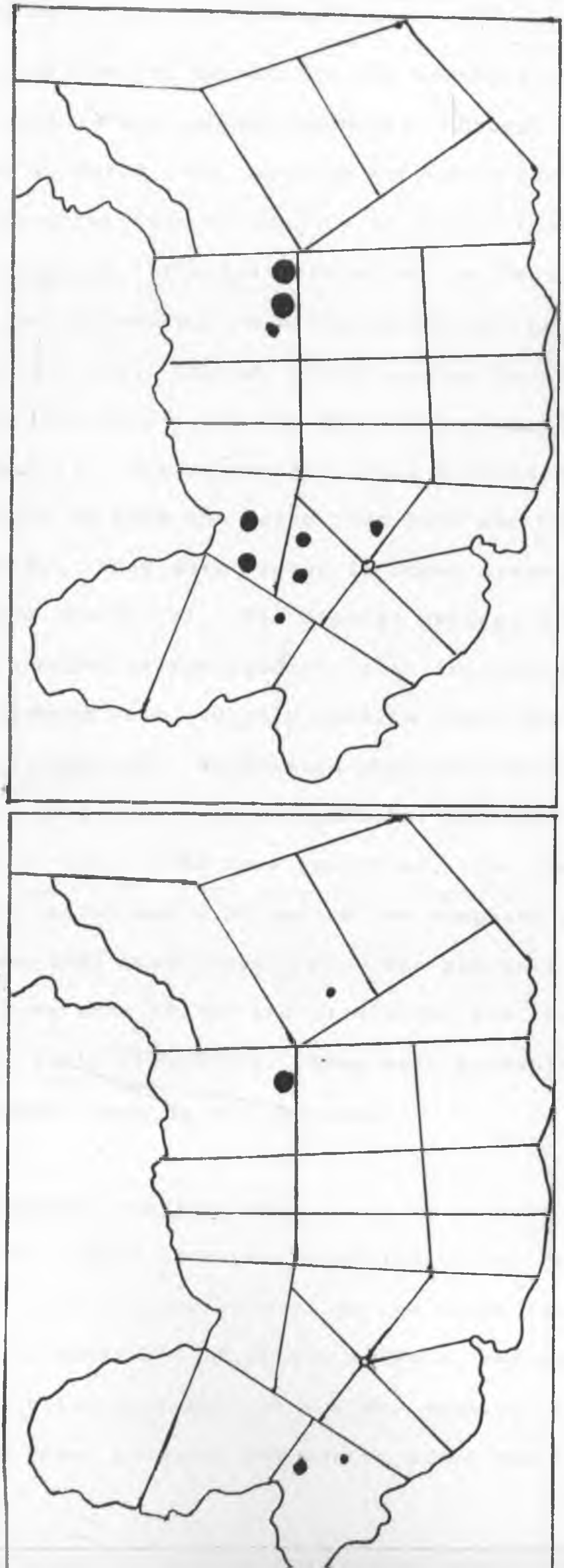


FIG. 9 DISTRIBUTION OF <u>Impala</u>



Dry

Wet

FIG. 10 DISTRIBUTION OF <u>Giraffe</u>

was also greater during the wet months as compared to the dry ones in the unburnt paddocks. Except for paddocks burnt in March 1984, giraffe accounted for more than 60% of the total biomass density in other treatments (Table 27).

Ostrich. They were found at low density in burnt as well as in unburnt areas during the dry season (Fig. 11). It is not clear whether there was any preference for the March 1984 burn, from the dry and wet season mean densities (Table 25). The percent of total biomass densities were about 8% in both the March 1984 burn and the unburnt paddocks. They were higher in other areas where ostriches occurred (Table 27). The highest percent of total biomass was recorded in the paddock burnt in October 1983, where ostrich and bushbuck were the only species found during the wet months.

Wildebeest. Wildbeests were only seen during the wet season (Fig. 12). Burnt paddocks, and particularly those burnt in March 1984 were preferred. The overall density in the latter was 5.86 per Km^2 as compared to 1.51 in October 1982 burn (Table 24). The percents of total biomass densities were 44.76% and 44.83% for the above areas, respectively (Table 27). They were probably lower in the wet months than in the dry ones.

Small Mammal Populations:

The number of captures of individual species trapped during each session as well as the total trap success are given in Table 29. Eighteen rodents, representing 41.87% of the total captures for the May session, were caught in the burnt paddock, two months after the burn. The

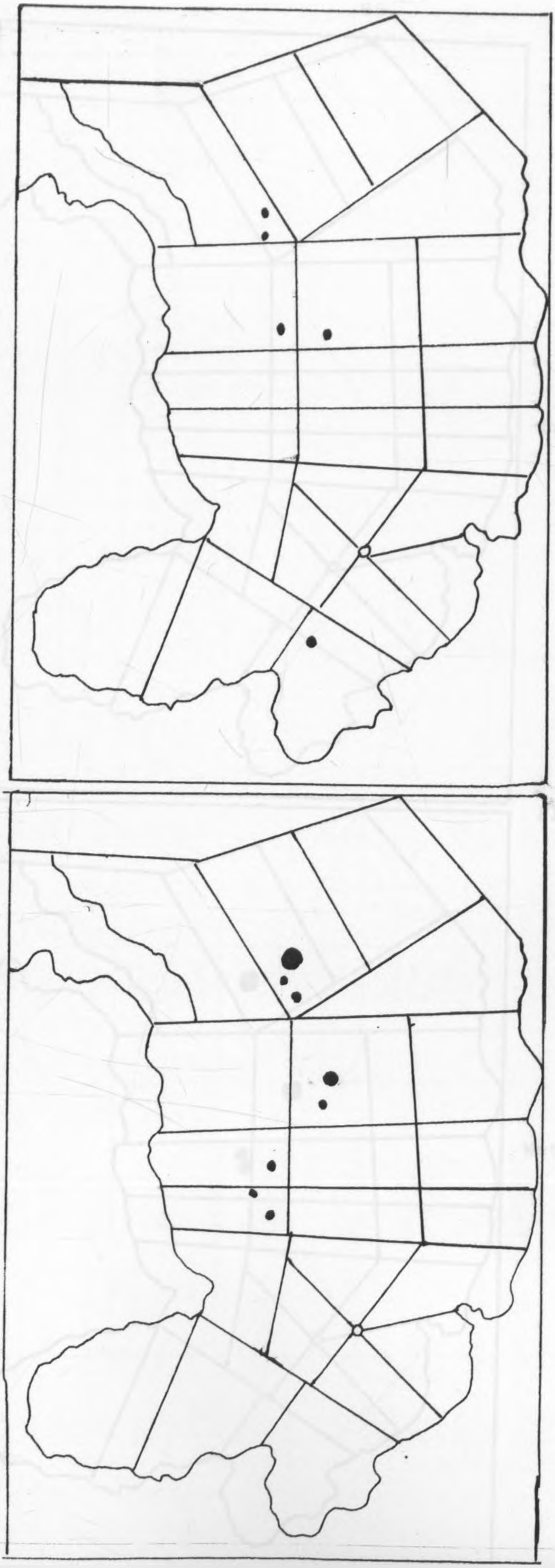
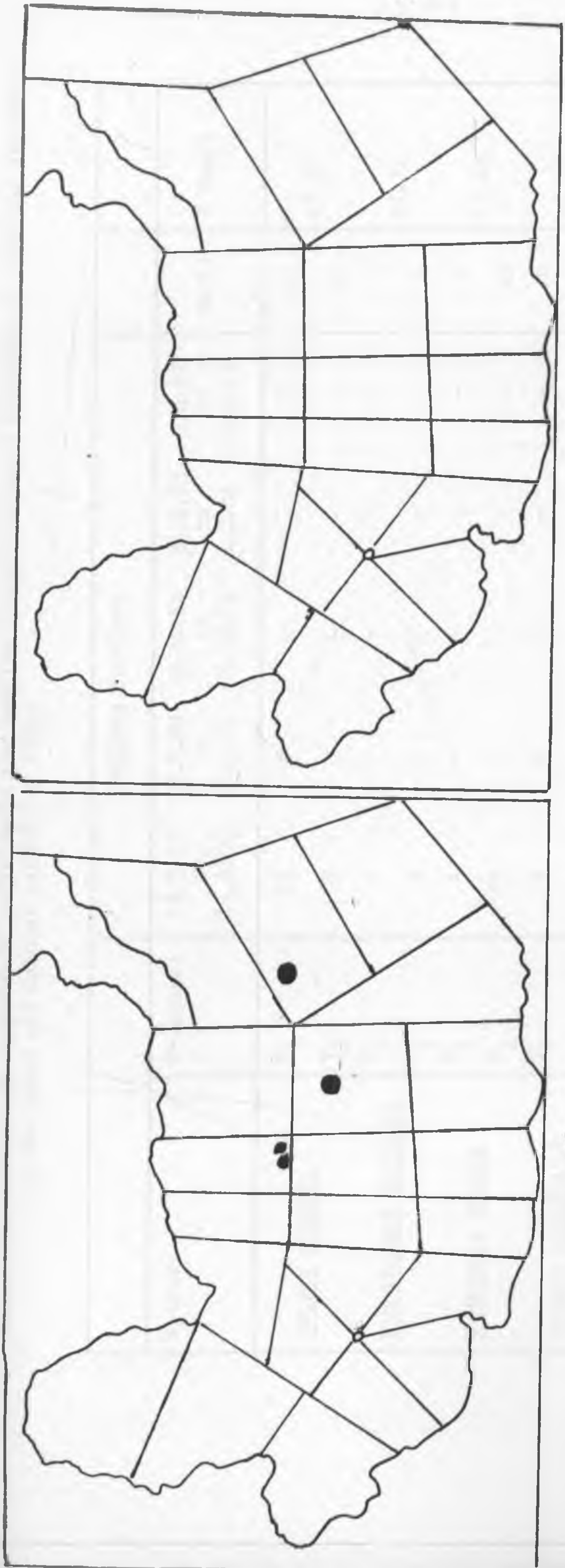


FIG.11 DISTRIBUTION OF <u>Ostrich</u>



Dry

Wet

FIG.12 DISTRIBUTION OF Wildebeest

Table 29. Numbers of captures of individuals per species trapped during 5 consecutive trapping sessions in the burnt and unburnt paddocks at KNRRS

Species	Treatment	Trapping sessions: 10.5.84 to 13.5.84	25.9.84 to 28.9.84	4.12.84 to 7.12.84	26.2.85 to 1.3.85	5.4.85 to 8.4.85	Total	% Total
Tatera robusta	T_1	13	9	-	-	-	22	45.83
	T_2	8	3	-	-	-	11	
Lemniscomys barbarus	T_1	-	-	-	-	3	3	11.11
	T_2	4	1	-	-	-	5	
Steatomys parvus	T_1	1	-	-	-	-	1	19.44
	T_2	12	1	-	-	-	13	
Acomys dimidiatus	T_1	1	4	1	-	-	6	11.11
	T_2	1	1	-	-	-	2	
Mus sp.	T_1	3	4	-	-	-	7	11.11
	T_2	-	-	-	1	-	1	
Tatera nigricauda	T_1	-	1	-	-	-	1	1.39
	T_2	-	-	-	-	-	-	
Total		43	24	1	1	3	72	99.99
Trap nights		1200	1200	1200	1200	1200	6000	
Trap success (%)		3.58	2.00	0.08	0.08	0.25	5.99	

T_1 = treatment$_1$ (burnt) T_2 = treatment$_2$ (unburnt) grass cover was poor since there was little regrowth in the absence of rains. The grass height was about 2 to 4 cm but most had started dying off. Twenty rodents (58.31%) were caught in the unburnt paddock in May. The overall trap success for the May session was 3.58% and five species of rodents were captured (Table 30). They were: Tatera robusta, Steatomys parvus, Acomys dimidiatus (trapped in both paddocks), Lemniscomys barbarus (only in the unburnt) and one Mus sp. in the burnt paddock. Population estimates of small mammals were 36 ± 7.44 and 25 ± 4.17 for the burnt and the unburnt paddock, respectively (May session). They decreased to 25.2 ± 4.19 and 8.31 ± 2.35, respectively, in September. Further decreases were recorded on subsequent trapping sessions (Table 31). Densities of small mammals followed the same trend. The number of captures from the burnt paddock remained the same in September as during May trapping session. It sharply decreased in the unburnt one where trap success fell from 4.16% to 1% (Fig. 13). From May to September, no rain was recorded. The little green flush observed in May in the burnt paddock and the few green leaves found then in the unburnt paddock grasses had completely dried up. In September one new species, Tatera nigricauda, was trapped in the burnt paddock. Tatera robusta and Acomys dimidiatus were captured in both paddocks. Lemniscomys barbarus and Steatomys parvus were only caught in the unburnt area. Mus sp. and Tatera nigricauda were only caught in the burnt area. A total of 6 rodent species were trapped

Table 30 . Trap success per trapping session and species caught, used as crude indicator of richness of the burnt and unburnt paddocks.

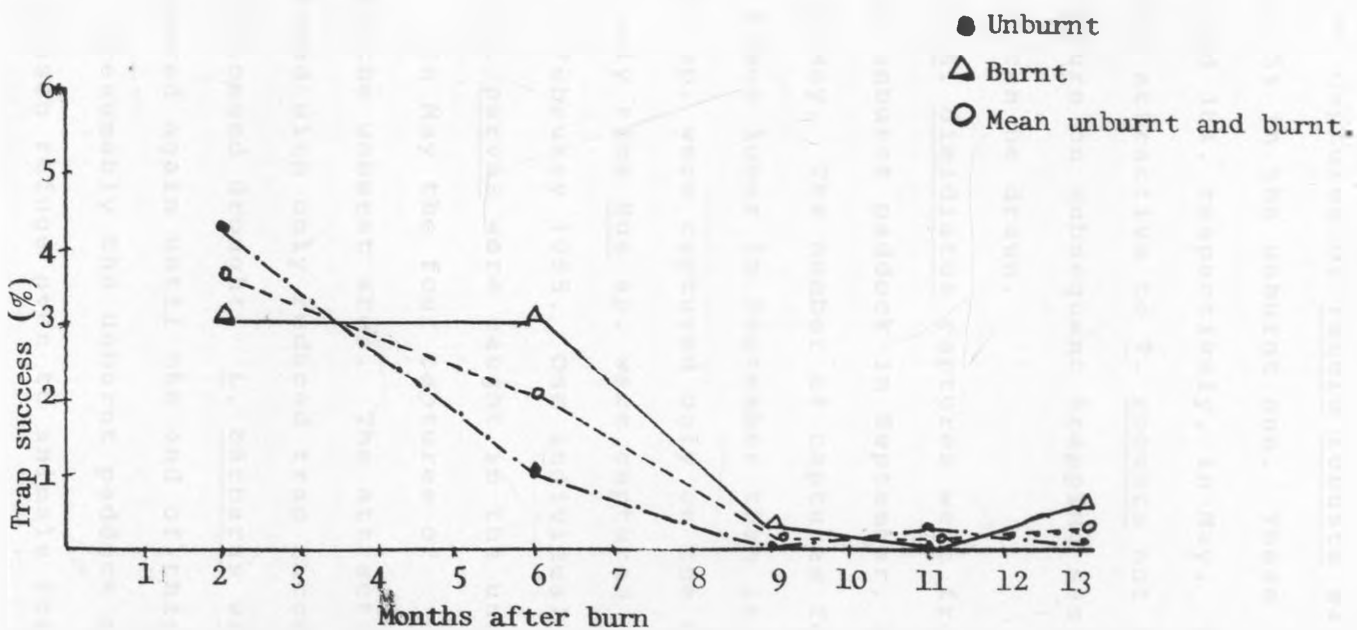
	Trap success							
Sessions / Treatment	10.5.84 to 13.5.84	25.9.84 to 28.9.84	4.12.84 to 7.12.84	26.2.85 to 1.3.85	5.4.85 to 8.4.85	Total	$\bar{x}$ s.d.	Significance
Burnt	3.00(4)	3.00(4)	0.16(1)	-	0.56(1)	6.66	1.33 ± 1.53	n.s.
Unburnt	4.16(4)	1.00(4)	-	0.16(1)	-	5.32	1.06 ± 1.78	
Total species richness	(5)	(6)	(1)	(1)	(1)			

( ) = Number of species caught

Table 31. Population estimates and densities of small mammals in the burnt and the unburnt areas for the 5 consecutive trapping sessions.

	Treatment	Trapping sessions: 10.5.84 to 13.5.84	25.9.84 to 28.5.84	4.12.84 to 7.12.84	26.2.85 to 1.3.85	5.4.85 to 8.4.85	Total	$\bar{x}$ s.d.	Significance
Population estimate	Burnt	36 $\pm$ 7.44	25.2 $\pm$ 4.19	1.47 $\pm$ 1.71	-	1.53 $\pm$ 0.72	64.20	12.84 $\pm$ 16.66	
	Unburnt	25 $\pm$ 4.17	8.31 $\pm$ 2.35	-	1.46 $\pm$ 1.38	-	34.77	6.95 $\pm$ 10.70	n.s.
Density (/ha)	Burnt	7.76	5.43	0.32	-	0.33	13.84	2.98 $\pm$ 3.59	
	Unburnt	5.39	1.79	-	0.31	-	7.49	1.61 $\pm$ 2.30	n.s.
Monthly rainfall (mm)		0.0	0.0	113.6	129.6	34.7			

Fig. 13 Small mammal trap success after burn in the burnt and unburnt paddock at KNRRS



during the September session as opposed to five in May. Seventy-five percent of captures of *Tatera robusta* was in the burnt area and 25% in the unburnt one. These proportions were 62% and 38%, respectively, in May. Thus the burnt area remained attractive to *T. robusta* but in the absence of any capture on subsequent trapping sessions, no reliable conclusion can be drawn.

Eighty percent of *A. dimidiatus* captures were from the burnt and 20% from the unburnt paddock in September, but the ratio was 50/50 in May. The number of captures for that species was 2.5 times lower in September than in May. All individuals of *Mus* sp. were captured only on the burnt paddock in May. The only time *Mus* sp. were captured in the unburnt area was in February 1985. One individual each of *L. barbarus* and of *S. parvus* were caught in the unburnt paddock in September. In May the four captures of *L. barbarus* occured in the unburnt area. The attraction to that paddock persisted with only reduced trap success, probably due to the prolonged drought. *L. barbarus* was not captured or recaptured again until the end of this study in April 1985. Presumably the unburnt paddock may have served as a dry season refuge even to animals from the burnt paddock. The same can be suggested for *S. parvus*. One *T. robusta* was captured in September 25th and 28th on the burnt paddock and it had already been trapped twice in May in the same area and may have been a resident. Similarly one *Mus* sp. captured in the same paddock in May once, was also captured twice in September and appeared to have been a resident for the 6 months following the burn. No individual was captured twice in September in the unburnt area. Three individuals were first captured in the unburnt paddock and were later recaptured in the burnt one. These were two T. robusta and one A. dimidiatus More could have been known on these species behaviour if they were caught on subsequent sessions. This was not the case, instead one new Acomys was captured in December.

Rains started in late October 1984 and it rained regularly until February 1985 with a short break in January Total trap successes in December 1984, and in February and April 1985 were very low (0.08% to 0.25%). There was no significant difference in small mammal trap success between the burnt and the unburnt paddock (Table 30). Similarly the difference was not significant in population and density estimates between the two paddocks (Table 31). Thus, it is difficult to draw reliable conclusions about the parameters for any species of small mammal. Presumably burning had no effect on their populations.

Responses of Individual Species to Burning:

Tatera robusta (common gerbil) was the most common small mammal after the burn and it accounted for 48.83% and 50% of total captures during May and September trapping sessions, respectively. The species was never captured on subsequent sessions but still represented 45.83% of total captures during the study period. Thirteen and 9 T. robusta were from the unburnt area during May and

September, respectively, compared to 8 and 3 for the unburnt area. There was no significant difference in mean number of captures, between the two areas in May and September, but more individuals were captured in the burnt area. T. robusta are burrowers, and opportunistic feeders (Kingdon 1974) and therefore were able to survive in the recently burnt area. They could stay in burrows by day time to avoid predators (mainly golden backed jackals) and feed on roots, dry bases and stems of burnt grasses and dead insects killed by fire which were plentiful during the dry season. On release almost all individuals were seen entering burrows. A total of 17 individuals were marked during the study and the sex ratio was 1.0 males 1.12 females. The male to female ratio in the burnt area was 1.0 to 0.83 and 1.0 to 2.0 in the unburnt paddock (Tables 32 and 33).

Lemniscomys barbarus (zebra mouse) represented 11.11% of the captures of small mammals during the study period. Only two individuals were marked, one male and one female. The first individual was captured 4 consecutive times in the unburnt area in May 1984 and once in September 1984. The other individual was captured 3 times in the burnt paddock and even on the same trap line in April 1985. L. barbarus feeds on grass stems, leaves and seeds and makes nests of grass (Kingdon 1974). Swanepoel (1981) reported that another species of the same genus, L. griselda, tended to run for spots with some degree of

Table 32. Number and sex-ratio of species trapped in the burnt paddock

Species \ Sessions	10.5.84 to 13.5.84	25.9.84 to 28.9.84	4.12.84 to 7.12.84	26.2.85 to 1.3.85	5.4.85 to 8.4.85	Total
Tatera robusta	7(4:3)	4(2:2)	-	-	-	11(6:5)
Lemniscomys barbarus	-	-	-	-	1(0:1)	1(0:1)
Steatomys parvus	1(1:0)	-	-	-	-	1(1:0)
Acomys dimidiatus	1(0:1)	3(2:1)	1(0:1)	-	-	5(2:3)
Mus sp.	3(1:2)	1(0:1)	-	-	-	4(1:3)
Tatera nigricauda	-	1 (+)	-	-	-	1(+)

+ = one individual unsexed (too young)

(x:y) = sex-ratio, x = male, y = male

Table 33. Number and sex-ratio of species trapped in the unburnt paddock

Sessions / Species	10.5.84 to 13.5.84	25.9.84 to 28.9.84	4.12.84 to 7.12.84	26.2.85 to 1.3.85	5.4.85 to 8.4.85	Total
Tatera robusta	4(1:3)	2(1:1)	–	–	–	6(2:4)
Lemniscomys barbarus	1(0:1)	–	–	–	–	1(0:1)
Steatomys parvus	9(2:7)	–	–	–	–	9(2:7)
Acomys dimidiatus	1(+)	1(0:1)	–	–	–	2(0:1)+
Mus sp.	–	–	–	1(1:0)	–	1(1:0)
Tatera nigricauda	–	–	–	–	–	–

aerial cover on burnt areas. He noted that zebra mice utilized burrows in Farm Marton Park, Zimbabwe. In September 1984, the zebra mice trapped in the unburnt paddock retreated to a burrow when released. The poor ground cover of the burnt paddock in May and September probably explains why the species was never caught on those dates.

Though its population trend was similar to that of other rodents (Table 31), cover appears to be of paramount importance for the distribution of L. barbarus. The literature suggests that only a light cover is preferred by the species (Kingdon 1974).

Steatomys parvus (fat mouse) was trapped in May and September 1984. Fat mice represented 30.23% of captures in May, of which 92.30% were from the unburnt paddock and 7.79% were from the burnt paddock. Nine individuals were marked in the unburnt paddock and one in the burnt one (Tables 32 and 33). The sex-ratio was 1 male to 2.33 females. One individual was recaptured one time in September but died during the handling. Fat mice were not otherwise trapped until the end of the study, following the general trend of the catches of other rodents. The small sample size precludes any firm conclusion but suggests that fat mice prefer unburnt areas. According to Kingdon (1974), S. parvus inhabits deep burrows on which they are extremely dependent. The distribution of fat mice may be limited by the compactness of soil. The last point is unlikely to explain the discrepancy observed in trapping between the two treatments. The species may have preferred the food items in the unburnt area (seeds and bulbs).

Acomys dimidiatus (spiny mouse). Nine were trapped in May, September and December 1984, representing 11.11% of the total captures during this study. One individual was trapped in each paddock in May, but in September 4 new individuals (3 in the burnt paddock and the other one in both treatments due to recapture) were trapped. There were 3 males and 3 females. The spiny mice are known to be opportunistic feeders and food was probably equally abundant for them in the unburnt and burnt paddocks.

Mus sp. was trapped in May, September 1984 and February 1985. A total of five individuals were caught (2 males and 3 females). Three individuals were captured once each in the burnt paddock in May. There were 4 captures in September and only one new individual was caught, in the burnt area. The only time Mus sp. was captured during this study in the unburnt area was in February 1985. Low trap success in the other trapping sessions precludes reliable conclusions. Perhaps they may have a preference for the burnt area.

One Tatera nigricauda (blacktail gerbil) was captured in September in the burnt paddock. It was so young that the sex could not be determined. Very little can be said about the species on the study area.

Effects of Productivity, Botanical Composition and Quality of Forage on Small Mammals Response to Burning: Rowe-Rowe and Lowry (1982) have reported differences in herbage production and grass species composition as primary factors responsible for differences in small mammal species richness and trap success in the Natal Drakensberg. The ideal would have been to measure these factors on each trapping session in order to test if small mammal recolonization was affected by vegetation structure, composition and nutrient content. There was little regrowth if any in the burnt paddock between May and September as a result of persistent drought. The plant data were collected once at the time of optimum growth (between November 29th and December 1st 1984), i.e. only 3 days before the third (December) trapping session .

Data collected along the trapping lines in both paddocks on herbage productivity, greenness and percentage of monocotyledon material are given in Table 34. There was no significant difference in herbage productivity between the two paddocks but, there was a significant difference in the percentage of monocotyledon material between the two paddocks. Greenness was highly significant ($p<.01$) between the burnt and unburnt paddock. Protein and ash contents were compared along the same lines (Table 35). There was no significant difference in protein content for the new growth between the recently burnt paddock and the unburnt one. There was a highly significant ($p<.01$) difference in protein content between the two paddocks for total above ground herbage (new and old growth). Data on ash content show a highly significant ($p<.01$) difference between the burnt and the unburnt for the new growth and also when new and old growths were pooled together for the unburnt paddock.

Table 34 . Biomass of the herbaceous layer (kg/ha), and greenness expressed as percent of total wet weight and percent monocotyledon material from growing season samples.

Sampling lines	Biomass productivity (Kg/ha)		Greenness (%)		Monocotyledon material (%)	
	Unburnt	Burnt	Unburnt	Burnt	Unburnt	Burnt
1 - 2	370	220.40	84	100	58	42.50
3 - 4	507.60	224.40	73.36	100	55.50	43
5 - 6	575.20	416.50	73.02	100	55.50	47.50
7 - 8	496.80	447.60	83.65	100	49	58.50
9 - 10	450	480	82.84	100	66	52
$\bar{x}$	479.92	357.78	79.37	100	56.80	48.70
s.d.	76.00	125.61	5.66	0.00	6.13	4.29
Significance	n.s		**		*	

Sampling lines: odd numbers for unburnt and even numbers for burnt.

* = p< .05

** = p< .01

Table 35. Protein and ash contents of the herbaceous layer (%) for the burnt and unburnt paddock

Sampling lines	New growth protein		New growth & old growth protein		New growth ash		New growth & old growth ash	
	Unburnt	Burnt	Unburnt	Burnt	Unburnt	Burnt	Unburnt	Burnt
1 – 2	14.97	16.29	8.88	16.29	12.82	19.50	11.78	19.50
3 – 4	7.92	14.93	5.21	14.93	11.58	14.30	11.97	14.30
5 – 6	17.38	13.26	10.81	13.26	10.92	13.45	11.04	13.45
7 – 8	8.24	10.23	5.81	10.23	11.83	14.25	11.30	14.25
9 – 10	9.59	14.44	6.41	14.44	11.84	15.15	12.01	15.15
$\bar{x}$	11.62	13.83	7.42	13.83	11.80	15.33	11.62	15.33
s.d.	4.29	2.29	2.35	2.29	0.68	2.41	0.43	2.41
significance	n.s.		**		**		**	

* = $p < .05$

** = $p < .01$

Despite the highly significant differences between the two areas in greenness, protein and ash contents, no significant differene in trap success was observed between them. The plant productivity evidently could not have acted as a factor susceptible to bring differences in trap success between the 2 paddocks.

GENERAL DISCUSSION AND RECOMMENDATIONS

The PCQ is reputed to be the most efficient available distance method for sampling tree sapling composition of woodlands (Cottam Curtis 1956, Mueller - Dombois and Ellenberg 1974), but it is not completely free from error. The method yields greater information per sampling point and does not require laying out of plot boundaries. This saves considerable time and also eliminates to some extent the personal error in judging whether boundary individuals are inside or outside the quadrat . Mueller Dombois and Ellenberg (1974) recommended its use in mixed species stands especially where species are randomly distributed. The KNRRS vegetation has been classified into associations (Michieka and Van der Pouw 1977, Kipkech 1982, Ndegwa 1983), and error from that source is not excluded from the results. Dix (1961) predicted that since the measured distances of nearest plants are relatively small (true for herbaceous species in this study), minor differences in the vegetation are readily detected whether these are changes in time caused by livestock and wildlife grazing, climatic shifts or fire. Greigh-Smith (1964) has cautioned against applying the PCQ method to grassland vegetation since this will result in inaccurate densities where individuals are clumped. That was the case at some sampling points in this study. Whatever the case two independent sets of data are collected when the method is used. The unreliability does not apply to frequencies and measurements of individual characteristics such as height, canopy diameter, or number of stems (for woody species), which are independent of the accurate distance. In this study, the canopy area per hectare was derived from absolute density and may have been affected by any error arising from absolute density estimates.

The preburn samplings were conducted in 1981 for the herbaceous vegetation, and in 1982 and 1983 for the woody vegetation. One paddock was burnt in March 1984 and postburn samplings were conducted in 1985. Both paddocks were equally disturbed prior to the burn i.e. grazed by livestock and free ranging wild herbivores. It is believed that under these conditions the population densities of plant species did not vary greatly from those which would normally be produced by natural mortality. Data analysed in this study were collected in paddocks, lines and even transects using different investigators in the preburn and the postburn samplings. This resulted in some confusion in the classification of some species. For example Ocimum americanum although a herb has been consistently classified both as herbaceous species and woody species below 1 m. Talinum caffrum and T. portulacifolium which are normally perennial shrubs were recorded as herbs during the 1985 sampling. Obviously this alters the exactness of results particularly where the species was endemic to one paddock. Improved supervision of vegetation sampling with specific instructions given to investigators when they are going to the field is essential. The presence of a plant taxonomist with the team in the field for rapid identification of species particularly new ones that tend to be labelled "unknown" is highly recommended.

The application of the Ellenberg index of similarity (IS_E) and the Bray and Curtis community similarity coefficient (C) did not show similar results in vegetation response to burning. Both indices showed more dissimilarity of the herbaceous layer between the two paddocks after one was burnt. For the shrubs and trees (understorey and overstorey), (C) still showed more dissimilarity following the burn as expected, but (IS_E) instead displayed more similarity between the two paddocks. The main difference between the two indices is that while both the numerator and the denominator change simultaneously in (IS_E), the denominator in (C) is independent of the numerator. (C) gives greater weight than (IS_E) to species that occur in both paddocks (Mueller-Dombois and Ellenberg 1974). On the contrary IS_E gives more emphasis to species restricted to one paddock or the other. Since such species in this study had very small values either as a result of burn and/or drought or because they were at their establishing phase, the denominators in (IS_E) were relatively low, thus showing a greater similarity between the paddocks after the burn than before the burn.

The responses of selected woody species showed that the burn was effective in killing individuals of most species, irrespective of their height. The most affected species in decreasing order of percent mortality for both height classes were *A. mellifera*, *A. senegal*, *S. incanum*, *A. tortilis*, *H. alhensis* and *B. aegyptiaca*. There was 90% mortality for above ground part of *G. villosa* but all individuals resprouted. In general, individuals below 1.80 m were more susceptible to the burn, except for A. tortilis and A. mellifera. The mortality was caused by the level of damage inflicted on plants (Appendix 3). The level of damage was related to the amount of combustible fuel around the plants (pers. obs.) Thomas and Pratt (1967) assessed the relative susceptibility of species according to the percent of plants killed following the burn. Their study was conducted at Katumani, Machakos district, the same ecological zone that Kiboko is in. The burn took place at the height of the dry season, and species selected were all different from those in the present study. They classified them as follows: tolerant 10%, semi-tolerant 10 - 39%, sensitive 40 - 70%, intolerant 70%. On this basis species considered in this study, can be classified as follows;

(a) A. senegal above 1.80 m semi-tolerant, but sensitive below 1.80 m.

(b) A. tortilis semi-tolerant at both height classes.

(c) A. mellifera sensitive above 1.80 m but semi-tolerant below 1.80 m.

(d) B. aegyptiaca tolerant

(e) H. alhensis semi-tolerant and S. incanum sensitive.

There was no clear indication of what controlled susceptibility to fire. However, Thomas and Pratt (1967) postulated that thick or fissured bark and possession of large root reserves, combined with ability to sprout from below ground were important factors. This study suggests height and amount of combustible fuel (pers.obs.) around the plant as additional factors. My results, on the other hand, showed that not all species were tolerant to a single burn as generally claimed (- Pratt and Gwynne 1977). If mortality of a species with great canopy area, like A. senegal, A. tortilis and A. mellifera, could occur on a large scale, fire can be a very effective means in reducing bush encroachment. There was a general trend towards canopy reduction for most species after burning. Greater reductions were recorded on plants above 1.80 m. This study also showed that average woody plant heights were reduced by the burn. The reduction was greater for plants below 1.80 m. The reduction was even more pronounced for species whose above ground parts were killed but which resprouted like, G. villosa. Because the burn was scheduled at the height of the dry season, these results can be attributed to favourable weather conditions, e.g. high wind speed and temperature and low relative humidity (Pratt and Gwynne 1977). Kinyamario (1982) obtained similar results on different plant species in the Kiboko area and reported that other investigators obtained similar results. The burn induced greater numbers of live stems in most species. Many had their above ground parts killed, but after the rains they responded with greater numbers of resprouts which in most cases exceeded preburn number of live stems. This was the case for A. tortilis and G. villosa at both height classes, A. senegal and A. mellifera below 1.80 m, H. alhensis and to some extent B. aegyptiaca. The burn induced an increase of total density of herbaceous species by 1.65%. The increase in absolute density for forbs was even more important (23%) and the number of herbaceous species increased by 50%. The increase in number of forb species was 275%. B. glabra was the only grass that was not recorded after the burn while A. keniensis maintained its absolute density. In terms of absolute density, grasses reacted differently to the burn as indicated by the following survival rates; B. insculpta (92.21%), Cynodon sp. (77.48%), D. macroblephara (60.60%), C. roxburghiana (58.82%), E. caespitosa (44.61%), C. ciliaris (34.26%), T. trianda (26.85%), S. pellucidus (25.58%) and M. kunthii (1.97%). These results differ from those obtained by Skovlin (1971) on 6 important grasses on 3 consecutive burning seasons, also in the Kiboko area. No mortality was recorded as a result of first late dry season burn for C. roxburghiana, D, milanjiana, Hyparrhenia lintonii, Panicum maximum, Pennisetum mezianum and T. trianda. Even under conditions of repeated burning, grass survival was generally high. Apart from C. roxburghiana which suffered 10% mortality, all species maintained at least 97% survival following the second burning season and 95% survival after the third one in that study.

Results reported in this study only concern one burn and one should refrain from anticipating too much. However these results indicate that burning can be a powerful tool in reducing bush encroachment at KNRRS. Three to four burns at 3 years interval are likely to transform most bushed and/or wooded grassland paddocks into pure grassland. However since these burns affect wild mammals the latter deserved attention.

All large mammal species recorded during the ground count were also counted during the vehicle count except buffalo and eland. Additional species recorded from the vehicle count were oryx, bushbuck and Thomson's gazelle.

The young of the year/female ratios for most species were higher than those calculated by Drawe (1982) at the KNRRS, except for impala, warthog and dik dik. Sample sizes were small in Drawe's study. In that study and the present one, a high proportion of animals was neither aged nor sexed. Actual ratios for most species are probably somewhere between the two estimates.

Large herbivore densities in burnt areas from ground count were higher than those derived from the vehicle count for dik dik, warthog and suni. However, they were lower for kongoni, impala, zebra, ostrich and Grant's gazelle. Densities in unburnt areas were also higher from ground count as compared to vehicle ones for dik dik, warthog, kongoni, impala, giraffe and Grant's gazelle. Both ground and vehicle count densities were higher for most species than those calculated by Sinange (1982), from an aerial count in the Kiboko area in September. Estimate of densities from belt transects on foot is very laborious but gives more accurate results (Van Lavieren 1976, Norton Griffiths 1978), when applied to small areas. Gates et al. (1968) estimator appeared unsuitable for solitary and rare species. In the course of this study, species whose only one individual was seen in a month had a null density that month. Thus the formula tends to underestimate densities for such species. It is my belief that the distribution maps based on numbers of individuals of each species seen, corrects this bias. Consequently they give a more accurate picture of the reality. Unfortunately distribution maps cover only 6 months out of ten. On the other hand, strip widths were kept fixed throughout the vehicle counts despite obvious changes in the visibility. Cover was relatively denser during the rainy season. This may have added a further bias. Presumably, the poor visibility also explains lower densities of small herbivores like dik dik and warthog, during the rainy season. Many animals might not have been distinguished or seen from the aircraft by Sinange (1982). The densities estimated from the ground count method are likely to be the most accurate. As pointed out above this method is only suitable for small areas. Therefore the acceptable method for estimating population and density at the KNRRS GM2, may be the vehicle count. This method can be supplemented eventually by aerial counts.

Overall densities of large herbivores derived from ground count showed significant differences between the burnt and the unburnt paddock for species like, Grant's gazelle, eland, dik dik, suni and zebra. Suni and dik dik are browsers; eland and Grant's gazelle mixed feeders and zebra a grazer. Dietary overlap between heavy grazers (buffalo, wildebeest and zebra) with livestock, has been reported in some parts of East Africa (Talbot and Talbot 1961, Casebeer and Koss 1970, Ngethe 1976). This overlap does not necessarily imply competition. A lengthy debate on this aspect is not within the scope of this study. However, it is clear that the success of increase of livestock production combined with conservation of wildlife at KNRRS depends on thorough knowledge, of food preferences and forage selectivity of animals involved. Such data are still lacking. Data on activity pattern gathered in the course of this study showed that even though the burn attracted ungulates, the animals were involved more in other activities than feeding. This allows a further rejection of resource competition. Probably herbivores preferred burnt areas which are more open to monitor their predators better. The few zebras counted, were seen at the time when there was no grass regrowth in the burnt paddock. Moreover, all grazers accounted for 31.77% of total biomass in the burnt paddock as compared to 14.18% in the unburnt one. This confirms they were attracted to the burnt paddock but also indicates that browsers remained predominant in that paddock with 54.55% of total biomass. Giraffe alone represented 50% of total biomass in the burnt paddock and 78.73% in the unburnt one. Since densities of shrubs and trees, particularly Acacia sp. on which giraffe feed mostly (Ngog 1981) are very high at KNRRS, potential competition with livestock (goats) is ruled out in the near future.

Results from vehicle count gave more insight on the attraction of large herbivores to burnt areas. Data indicated that the highest diversity of large herbivore species was found in recently burnt areas (March 1984). It was also shown that the difference in density between the February 1983 and March 1984 burns, was mainly due to browsers and mixed feeders rather than grazers. Most herbivore species in this study, probably preferred recently burnt paddocks because of their higher nutritional value. Results of Table 34, if representative of the burnt (March 1984) and unburnt paddocks confirm this assertion. Similar results were found by Rowe-Rowe (1982) in the Natal Drakensberg veld. In addition to favouring recently burnt areas for higher nutritional content, herbivores probably also preferred them to unburnt ones or old burnt because living material (green new growth) is more exposed and available, and not mixed with dry grass which has a much lower crude protein content (Dougall et al. 1964).

The magnitude of densities and biomass densities in the study area was compared with those in other areas of East Africa (Appendix 4). Data from these other areas had been derived by a variety of methods in areas of different sizes and at different periods. All these factors may have had some impact on the results. We recalculated biomass densities for all areas using unit masses in Table 1 to make data more comparable. Rainfall data are attached to each area. Probably figures do not reflect the total herbivore biomass density of these areas. Some like Isiolo, Loita Mara and Kiboko carried substantial numbers of livestock that were not included in the calculations. Similarly Tsavo National Park carried a large number of elephants and rhino not included in the calculations. Large wild herbivores represent at most 30% of total biomass at KNRRS though accurate comparative figures for cattle, goats and sheep were difficult to obtain. In considering wild herbivores alone, our densities and biomass density figures fall within the general range of the areas listed in Appendix 4. The figures of Sinange (1982) are likely to be somewhat below the reality since aerial count over large areas tend to underestimate densities due to poor visibility (Norton Griffiths 1978). The comparison of total biomass density at KNRRS with Tarangire which has almost the same annual rainfall suggests that the former can still accommodate more wild herbivores without deterioration of the habitat. There is therefore very little evidence from this study to support actual or potential competition on food resource between livestock and wildlife at KNRRS. Consequently there is no sound ecological argument why the ongoing killing of wild herbivores at KNRRS by the Wildlife Conservation and Management Department (WCMD) should continue. Cropping will be welcome if necessary on the basis of sound research which has not yet been done. At a recent conference for wildlife/ livestock interfaces, participants recognized that wildlife and livestock have been coexisting and can still coexist in Kenya's rangelands (see Proceedings Conf.). They stressed the parasite/disease perspective and said blame for wildlife transmission of disease to livestock, in many instances,was uncomfirmed by scientific facts. My conviction is that any livestock-wildlife conflict at KNRRS originates from predation (Appendix 5). It is therefore surprising that the attention of WCMD is focused on "innocent" herbivores rather than large carnivores. During the study period I never heard of any shooting of carnivores. The problem of predation can be minimized and overcome by building bomas as suggested by Kruuk (1980). However, if wildlife is to survive at KNRRS as in most of Kenya's rangeland, it must compensate and even outweigh losses inflicted to livestock and people living in rangelands. Wildlife must be a marketable commodity. KNRRS is not a national park, it is possible to allow sport hunting (if this becomes necessary) to generate income, cropped meat, hides and trophies could be sold. The controversy is around the status of wildlife at KNRRS, and this must be clarified by the relevant authorities.

Wildlife conservationists always show more concern and emotion on big game. Western (1983) speculated that if we cannot save the biggest and more dramatic of Africa's mammals (elephant and rhino) there is no hope for the rest i.e. small ones. Indeed very little has been done so far for the conservation of small and inconspicuous mammals. It may be difficult to justify their economic value as compared to large ones but they are part of the ecosystem and conservation deals with the whole ecosystem and its diversity.The above mentioned conference on wildlife/livestock interfaces stressed the need of an interdisciplinary ecosystem approach research program.

The number of species of small mammals captured in the course of this study was fewer than those reported by Hansen et al. (1984) at the KNRRS. All of the species of small mammals trapped in this study were recorded by Hansen et al. and in addition they recorded Mus minutordes, Mus tenellus, Mus setulosus, Arvicanthus niloticus and Elephantulus rufescens.

The May and September trapping sessions were fairly productive. Too few specimens were caught at other times for reliable conclusions to be drawn regarding the biology of different species and their distribution. Generally the time and habitats in which the various species were found were in agreement with their food and habitat preferences as indicated in Kingdon (1974). Tatera robusta was found mostly in the burnt paddock where it had found refuge in burrows after the controlled burn. Lemniscorys barbarus was found only when and where there was some good plant cover. Cover was adequate for them in May and September 1984 in the control (but not when the cover became too dense), and in April 1985 in the burnt paddock. Steatomys parvus showed preference for the burnt area whereas no preference was shown by Acomys dimidiatus.

Rowe-Rowe and Lowry (1982) reported on seven studies on the responses of small mammals to range fires.

Generally, immediately after a fire, there was a drastic decrease in the numbers of individuals. There was a fairly rapid recovery and numbers reached pre-burn or the unburnt area's densities in 6 to 15 months. Species richness on burnt and unburnt areas were reported to be similar in 6 of these studies. Observations made during this study confirm the similarity in species richness at least for the first 2 trapping sessions (Table 29). In May Tatera robusta, Steatomys parvus and Acomys dimidiatus were common to both treatments, but Lemniscomys barbarus was only found in the unburnt paddock and Mus species in the burnt area. In September Tatera robusta and Acomys dimidiatus were found in both treatments. One cannot draw a reliable conclusion for December. Though no pre-burn trapping was conducted, the population trends suggested a drastic decrease and they never recovered up to the end of this study (13 months after the burn).

Presumably the abundance of small mammals became extremely low in the burnt area during the wet season as suggested by Hansen et al. (1984): yield was 0.35% in 1983. The wet season trapping success in the burnt paddock was 0.16% in December and zero in February 1985. But the trap success remained low even during the following dry season with 0.5% in April 1985. Presumably, populations crashed between September and the onset of rains in October 1984. The trapping success remained very low on subsequent trapping sessions compared to May and September

1984 (Fig.13).

The trapping results were similar to those obtained by Martin et al. (1981) in Mt. Kulal forest with live traps (0.2%) but lower than that achieved in the montane grassland of the same region (5.4%). By all standards they were lower compared to successes obtained by Rowe-Rowe and Lowry (1982) in the Natal Drakensberg. These authors recorded 5.8% as the lower mean trapping success in forest but achieved 20% in a woodland 13 months after a burn and 10.8% and 21.6% success in a tall grassland at 6 and 11 months after a burn, respectively.

Estimates of densities of small mammals are normally based on population estimates drawn from animals captured and/or recaptured. The mean densities per hectare for this study are 2.98 ± 3.59 and 1.61 ± 2.30 for the burnt area and the unburnt area, respectively. The average density calculated by Martin et al. (1981) for 6 unburnt habitats of Mt. Kulal in 1979 was 2.4 rodents/ha. They concluded that low trap success was indicative of low population density. Some of the factors that can lead to a low success have been identified: (i) inadequate trapping technique, (ii) large proportion of population not trappable, and (iii) low population density.

In this study the animals present were frequently trapped. The types of bait and trap employed have been used successfully worldwide by many workers and in Kenya and even at the KNRRS. Hansen in 1983 obtained more small mammals per trap night. The positioning of traps was not a contributing factor to low success because there was higher success in May and September sessions with the same design. Though some of the species are known to store food in their burrows like Tatera robusta, Steatomys parvus and Acomys dimidiatus, it is hardly believable they can do so for 7 months without coming out in search for food. Martin et al. (1981) argued that though population densities of small mammals may be generally low in Kenya's arid savannahs, most studies were undertaken in the dry season,when populations are likely to be low and thus yield low trap success. The results of the current study do not support this concept. Higher trap successes were achieved during the dry season (3.58% in May and 2.00% in September). Rain came frequently from October to February and despite an abundance of forage and insects of high protein content and eventually more suitable conditions for breeding, the trap success remained very low (0.08% in December 1984 and February 1985), suggesting a low population density as the most obvious reason for low trapping success. Presumably the populations had crashed. In order to ascertain the extent to which burning, bush control and grazing affect the dynamics of small mammal populations at the KNRRS, we I recommend a new study using the results of this study as basic data and determining small mammal abundance for one year on a nonburnt area and on the other areas to be burnt.

This study leaves many questions unanswered. But the results do add to the understanding of fire and its effects on plant and animals communities at KNRRS. Similar studies should be extended for longer periods and cover other aspects not considered in this study, like birds, insects and soil. My hope is that such studies can bring more insight on the way fire affects the whole ecosystem.

APPENDIX 1

a) Rainfall and evaporation data for Makindu Met. Station

Month	Rainfall (1904-1962)mm				Evaporation (1958-1963)		
	Monthly total				Type 15" pn		
	Average	Highest	Lowest	Max in 24 hours	Average	Highest	Lowest
January	40	214	0	54.6	177	215	153
February	28	175	0	73.7	197	257	155
March	79	650	0	94.0	209	256	181
April	111	822	0	86.4	183	234	149
May	31	203	0	55.6	172	217	135
June	2	41	0	10.2	171	206	124
July	1	8	0	8.4	165	188	139
August	1	7	0	1.5	186	235	167
September	1	39	0	9.7	205	258	164
October	29	327	0	165.1	229	271	182
November	168	518	0	112.5	177	213	170
December	120	603	0	88.9	141	170	114
Year	611	1964	67	165.1	2212	2456	1923

Source: East African Meteorlogical Department.

b) Annual rainfall amounts and recurrence period at Makindu (adapted from Michieka and POUW 1977)

Recurrence period and probability	Annual rainfall (mm)	
	Amount exceeded	Amount non-exceeded
Once per 2 years (50%)	500	500
Once per 5 years (20%)	720	420
Once per 10 years (10%)	880	360
Once per 20 years (5%)	1040	300
Once per 50 years (2%)	1250	220
Once per 100 years (1%)	1420	160

APPENDIX 2. Rainfall and evaporation for Kiboko Met. Station

Month	Rainfall (1977-1985)mm			Evaporation (1981-1985)mm		
	Monthly total			Monthly total		
	Average	Highest	Lowest	Average	Highest	Lowest
January	40.0	171.8	0	210.6	279.9	159
February	29.9	129.6	0	200.8	242.5	164.9
March	41.2	124.7	0	236.1	279.0	193.8
April	83.1	154.2	19.0	176.4	204.0	156.5
May	22.8	50.5	0	146.3	187.4	77.4
*June	0.2	1.8	0	144.2	167.0	115.5
*July	1.8	13.5	0	142.6	162.8	117.5
*August	0	0	0	164.3	176.5	107.0
*September	1.2	9.5	0	193.2	195.5	189.5
*October	43.3	132.7	0	210.8	229.4	193.0
*November	143.7	245.6	31.8	177.0	201.4	150.8
*December	129.7	205.8	47.1	151.9	160.1	133.9
Year	536.9	1239.7	78.9	2154.0	2485.5	1758.8

*Months for which data for 1985 are not included.

Appendix 3 – Assessment of immediate damage of burning on tagged plants, one day after the burn.

1. Undamaged by fire.
2. Slight damage: lower leaves singed, some damage to lower branches.
3. Lower branches and leaves burned, some damage to upper branches and leaves.
4. Upper leaves and branches burned.
5. Extensive damage and complete burning.

sp / No. ind	111	211	311	411	511	121	221	321	421	521	621	721
1	3	3	4*	2	3	4*	3	4	3*	3	5	4*
2	3	2	3*	3	4	4	3*	4*	4	4	5	5
3	2	4*	1	4	3	2*	3	4	2	5	3	2
4	2	2	1	2	3	2	3	3	2	3	3	2
5	1	1	1	1	1	1*	1	1	1	1	1	1*
6	3	4	3*	2	4	3*	3	3	4	4	4	5
7	3*	3	2	3	3	4	4	4	3	4	4	5
8	3	2	3*	3	2	4	3	3	3	5	4	5*
9	2*	2*	2	2	2	3*	4	4*	2	2	4*	2
10	2	2	2*	3	2	3	3	4*	3	2	4*	3*

*Dead.

111 = Acacia senegal above 1.80m

221 = A. tortilis below 1.80m

1 = A. senegal, 2 = A. tortilis, 3 = A. mellifera, 4 = Balanites aegyptiaca

5 = Grewia villosa, 6 = Hermania alhensis 7 = Solanum incanum.

Appendix. 4 . Comparison of densities (animals per km^2) and biomass densities (kg/km^2) at KNRRS, with some ungulate species in different areas of East Africa.

Speices	Kiboko			Isiolo (Kenya)	Loita-Mara (Kenya)	Tsavo West N.p	Tarangire (Tanzania)
	Burnt 1984	Unburnt	Aerial				
Dik dik	0.38	0.12	-	-	-	-	-
Kongoni	2.57	-	0.43	-	0.19	0.82	-
Impala	4.66	1.18	0.45	-	-	0.87	20.95
Zebra	1.18	0.75	0.41	3.40	4.09	0.93	8.54
Warthog	0.11	1.04	0.01	-	-	0.12	-
Grant's gazelle	4.31	0.41	0.07	0.73	-	1.12	0.029
Thomson's gazelle	5.44	-	-	-	-	-	-
Ostrich	1.99	1.84	0.08	-	-	0.11	-
Giraffe	0.06	2.08	1.03	0.93	-	0.19	1.13
Suni	-	0.40	-	-	-	-	-
Gerenuk	0.19	-	-	-	-	0.12	-
Wildebeest	5.86	-	0.06	-	4.87	-	3.49
Oryx	-	1.19	0.04	-	-	0.39	-
Bushbuck	-	0.08	-	0.54	-	-	-
Biomass density (recalculated)	2383.60	2195.15	951.35	1439.10	1767.05	589.10	4068.20
Annual rainfall (mm)		537		300-600	700	300-600	600
Reference	This study		Sinange (1982)	Leuthold (1976)	Leuthold (1976)	Cobb (1976)	Lamprey (1964)

Appendix 5 . Effects of large carnivores on livestock at KNRRS

Date	Number domestic animals killed	Predator
February 1981	1 Cow	Hyena
July 1981	1 Cow	Hyena
August 1981	1 Male caf	Hyena
September 1981	1 Young Cow	Hyena
December 1981	1 Bull	Lion
March 1982	1 Female calf/1 Male calf	Wild dogs/Lion
April 1982	1 Cow	Lion
August 1982	1 Female calf	Wild dogs
November 1982	1 Cow	Lion
December 1982	1 Female calf	Wild dogs
March 1983	1 Young Cow	Hyena
February 1984	1 Male calf	Lion
March 1984	53 Sheep and 38 Goats	Leopard
April 1984	21 Sheep and 4 Goats	Leopard
February 1985	1 Cow	Lion
June 1985	17 Goats and 45 Sheep	Leopard/Cheetah.

Source: KNRRS Livestock section.

Appendix 6. Scientific and common names of mammals encountered on the Kiboko National Range Research Station.

Common name	Scientific name
HERBIVORES	
Giraffe	Giraffa camelopardis L.
Grant's gazelle	Gazella granti Brooke
Impala	Aepyceros melampus Lichtenstein
Kongoni	Alcelaphus buselaphus Pallas
Dik dik	Rynchotragus kirki Gunther
Wildebeest	Connochaetes taurinus Burchell
Warthog	Phacocerus aethiopicus Pallas
Waterbuck	Kobus ellipsiprymnus Ogilby
Zebra	Equus burchelli Bray
Eland	Taurotragus oryx Pallas
Steinbock	Raphicerus campestris Thumberg
Thomson's gazelle	Gazelle thomsoni Gunther
Greater kudu	Tragelaphus strepsiceros Pallas
Lesser kudu	Tragelaphus imberbis Blyth
Oryx	Oryx beisa Ruppell
Suni	Nesotragus moschatus Von Dueben
Buffalo	Syncerus caffer Sparrman
Bushbuck	Tragelaphus scriptus Pallas
Gerenuk	Litocranius walleri Brooke
Ostrich	Struthio camelus
Klispringer	Orestragus orestragus Zimmermann
Elephant (faeces)	Loxodonta africana africana Blumenbach

Baboon	Papio anubis Fischer
Vervet monkey	Arcopithecus aethiops L.

CARNIVORES AND OTHERS

Hyena	Crocuta crocuta Erxleben
Leopard	Panthera pardus L.
Lion	Panthera leo L.
Cheetah	Acinonyx jubatus Schreber
Wild dog	Lycaon pictus Temminck
Golden backed Jackal	Canis aureus L.
Black backed Jackal	Canis mesomelas Schreber
Crested porcupine	Hystrix sp.
African wild cat	Felis libyca Forster

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