A VEGETATION AND LARGE HERBIVORE SPECIES SURVEY IN HELL'S GATE NATIONAL PARK, NAIVASHA - KENYA

A THESIS SUBMITTED IN PARTIAL FULFILMENT
FOR
MASTER OF SCIENCE DEGREE IN ZOOLOGY,
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By J. W. KIRINGE

1990

DECLARATION

[redacted]

I, **JOHN WARUI KIRINGE** hereby declare that this is my original work, and has not been presented for a degree in any other University.

J .W. KIRINGE

This thesis has been submitted for examination with my approval as the University supervisor.

Dr. W. K. KARANJA **Date**

26/11/90

[redacted]

"Without the kind of understanding which ecological monitoring provides, a protected area cannot be properly managed ......and this means a protected area will not long survive" (Croze, 1983).

DEDICATION

Dedicated to my parents, **KIRINGE AND WANJIRU**, whose idea to take me to school was noble.

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ACKNOWLEDGEMENTS

Thanks to all those who made this project a success. I am indebted to Dr. David Harper of the University of Leicester, England who made it possible for the project to be sponsored by the Centre for Field Research (Earthwatch) of Boston, U.S.A.

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Various Earthwatch Research team volunteers greatly helped in various ways. Lastly, though not least, I thank Mrs. Jean Hayes of crescent Island, Naivasha for allowing me to use her computer facilities during the correction of the thesis. Mrs. Muriuki typed the tables. To her I extend my sincere gratitude.

ABSTRACT

Vegetation, soil and large herbivores of Hell's Gate National Park were studied between October 1988 and June 1989. The latter were also studied in two adjoining areas, Kedong and Kongoni Ranches.

Three hundred and sixty six plant species belonging to seventy three families were collected and identified. Herbaceous species were more represented in terms of numbers. Woody species were poorly represented, with *Tarchonanthus camphoratus* and *Acacia drepanolobium* being the most common, the former dominating. Thirteen vegetation communities were mapped. These were categorised into three vegetation types; *Cynodon*/ *Digitaria* grassland and *Digitaria*/ *Acacia* dwarf shrub grassland, dense *T. camphoratus*/ *A. drepanolobium* shrubland and open *T. camphoratus*/ *A. drepanolobium* shrubland. The last two were the most common and covered the largest part of the park. They were physiognomically (structurally) different but their species composition were similar. Ground cover was dominated by herbaceous species, mainly *T. triandra*, *D. scalarum* and *Hyparrhenia* sp. In the grassland vegetation type, *D. scalarum*, *C. dactylon*, *T. triandra* and *Felicia muricata* dominated, and contributed the highest proportion of the ground cover.

Soil chemical and physical properties were determined for each community. These similar among the communities, and the soils were generally poor in exchangeable cations. Cation Exchange Capacity (C.E.C.) was low and did not differ significantly between communities. Amount of sand was higher than silt and clay in all the communities. Each textural property did not significantly differ from one community to another.

The soil properties alone could not explain the observed distribution of the communities. The distribution could have been under an interplay of factors. Since communities correlated with variations in topography, it was considered as the major factor affecting their distribution. Other factors such as human activities were considered secondary modifying factors although their influence could not be ignored.

Population sizes for the large herbivores were estimated by the road strip transect and total count methods. Road counts were only carried out in the park, and were found to overestimate the animal populations.

Zebras Equus burchelli and Kongoni Alcephalus buselaphus were the most common, and had the highest density in all the three census areas. Buffalo Syncerus caffer in the park, Thomson's gazelle Gazella thomsonii in the park and Kedong Ranch, Grant's gazelle Gazella granti and Impala Aepyceros melampus in Kongoni Ranch had a high density.

Population structures and sex ratios (of all adults, sub-adult male and females) were determined. Adults dominated in most species, and the sex ratios showed a significant difference from unity. A distribution map of the herbivores for the herbivores in the park was produced by combining their distribution for each month. They mostly occupied approximately 12.5 km^2 of the total area (mostly the Njorowa Gorge), and exhibited a contagious distribution pattern.

Habitat preference for each species was also determined. Most species were habitat specific and preferred open flat areas. Dense vegetation and rugged terrain were frequently avoided.

Topography, nature of the vegetation, availability and distribution of food resources were considered as the factors influencing the herbivores' movements and distribution. Other factors, especially the Olkaria Geothermal activities, Masai livestock and large predators seemed to have no significant influence, although their effects were not evaluated. Water availability was poor in the entire study area and affected the herbivores' movement and distribution on a daily basis.

CHAPTER 1

1.0 INTRODUCTION AND STUDY AREA

Wildlife conservation has become a global concern. It contributes to man's enjoyment and pleasure, and plays a key role in a variety of aesthetic, cultural, recreational, scientific and educational activities. The economic value of wildlife, especially in Africa is well known (Ajayi et al, 1981), and it is a major natural resource contributing to the income of East African counties (Lamprey, 1962, Eltringham, 1984). In Kenya it forms the backbone of the tourist industry (Ajayi, 1972), making it a leading foreign exchange earner second to agricultural and industrial exports (Kenya Ministry of Finance and Planning, 1983). Prior to the 1973 oil crisis, tourism earned about ten per cent of Kenya's foreign exchange (Myers, 1975). Annual foreign revenues derived from wildlife resources in Nigeria and Ghana is quite high (Ajayi, 1973). Tanzania's tourism is based on wildlife, making it an important foreign exchange earner after agriculture (Ajayi, 1972).

There is an increasing recognition of the fact that wildlife conservation is a varied and important form of land-use, not only for tourist attraction, but also a potential source of food (Eltringham, 1984, Ramade, 1984). Approximately 75% of Africa's population relies on traditional sources of protein, particularly wildlife (Asibey, 1974). A variety of animals, including various species of rodents, reptiles, bats, primates, anteaters and birds provide food for several tribes in West Africa (Asibey, 1974). In Nigeria, wildlife is an important source of meat (Ajayi et al 1981), and Botswana's 60 per cent of annual protein consumption comes from wildlife (Von Richter, 1970). Cremoux (1963) reported a minimal consumption of 373, 631 metric tons of game meat per year in Senegal, composed of 26 and 74 per cent animals and birds respectively.

Many authors have investigated the advantages of game ranching in Africa as an alternative land-use system (Crawford, 1972; Hopcraft, 1975; 1980; Stelfox, 1985; Sinnary, 1987). In South Africa and Zimbabwe, game ranching has emerged as an economically profitable land- use system (Bauer, 1983). As early as 1964, 4,000 ranches in Transvaal, South Africa, were practising commercial game production (Riney and Kettlitz, 1964). Its advancement has however been slow in East Africa. Africa's tourist industry, directly or indirectly, provides employment for the local people, promotes demand for local products, and to an extent promotes the development of the infrastructure, basic services such as transport and communication (Phillip, 1972).

There is already a world concern for the future of Africa's wildlife (Eltringham, 1984; Ramade, 1984). In spite of its great importance, it has suffered depletion through poaching and habitat destruction (Asibey, 1974; Myers, 1975; Ajayi et al, 1981; Eltringham, 1984; Osemeobo, 1988), and unless serious steps are taken to conserve it and the wild habitats upon which it depends, its existence in future is threatened (Lamprey, 1962). For example, in Uganda, poaching reduced the elephant, Loxodonta africana Blumenbach populations of Ruwenzori and Kabalega National Parks to five per cent of their original numbers (Malpas, 1981), while in Kenya there was a two thirds reduction between 1973 and 1980 (Anon, 1980). In the last few years there has been a decline in the number of elephants and both rhino species, the black Diceros bicornis L. and the white Ceratotherium sinum Cottoni in Africa, including Kenya. The elephant population has been reduced from an estimated 1.3 million in 1979 (Douglas- Hamilton, 1979) to about 625,000 by 1989 (ITRG,1989, quoted in Poole and Thomsen, 1989), while the black rhino was reduced to 9,000 by 1984 from an estimated population of 14,000 in 1980 (Western and Vigne, 1985). International trade has been singled out as the major factor responsible for this decline (Pilgram and Western, 1986; Caughley, 1988; RRAG, 1989). This has further been accelerated by the ever increasing human population in most African countries, which has meant acquiring more land for agriculture, settlement, urban areas, infrastructure and industry at the expense of wildlife (Laws, 1970; Asibey, 1974; Osemeobo, 1988). Large herds of domestic livestock are also a big threat to wildlife as they compete for the same habitats (Okaeme et al, 1988; Mordi, 1989).

Most of the wild animals have therefore either completely lost their habitat or been displaced, confining them to relatively small patchy areas while others have become extinct. Habitat alterations which affect home range size, amount and availability of food will have a direct effect on an animals survival. Destruction and modification of food supply and habitat are presently the major threats to vertebrate populations (Caughley, 1977), and this is a serious conservation problem.

In an attempt to conserve Africa's wildlife, conservationists have advocated the delimitation of parks and game reserves (Ramade, 1984). Nairobi National Park was the first conservation area (in Kenya) to be declared a park in 1946. Since then, the Government has delimited several wild habitats into game reserves and national parks. These are remnants of the large habitats previously occupied by wildlife and for some species have proved insufficient in meeting their habitat and food requirements and have brought their own management problems. Human encroachment is worsening the situation, and is currently a threat to conservation efforts in Africa and other developing countries of the world (Hough, 1988). For instance, in Nigeria all game reserves are surrounded by or have isolated human settlements within them (Osemeobo, 1988). Most national parks and game reserves are situated in marginal areas. such arid areas which receive even less than 500mm of rainfall are characterised by frequent prolonged droughts and food resources can be a big problem. This has led to the death of large numbers of wild animals (Mordi, 1989). Approximately 4,700 elephants in Tsavo National Park died during the 1970 - 71 drought (Myers, 1973).

With delimitation of parks and game reserves in East Africa, all forms of animal hunting and migration were reduced (Caughley, 1977). Animals were concentrated in too small areas to support them, and this has been the cause of conservation problems experienced in many of these areas (Caughley, 1977). The most frequently cited causes of landscape changes in these and adjacent areas are agriculture, fire (Glover, 1963) and elephants (Laws, 1970).

By confining the animals, especially herbivores, their seasonal migratory behaviour to other feeding areas is curtailed, and large populations build up in these limited spaces. This also limits the animal's ability to cope up with any climatic or seasonal variations. It is due to this situation that conservation and management of herbivores has proved difficult, and many national peaks in East Africa are presently undergoing major habitat changes (Western, 1973).

East Africa's tourism heavily depends on wildlife. Although tourism appears to have attained a "boom" stage, several serious ecological and social problems currently face the national parks and game reserves which might result in their collapse, unless serious management strategies are adopted (Ajayi et al, 1981). With the present high rate of human population growth, a lot of pressure is mounting in and around these conservation areas, as people seek more land to settle, cultivate and keep livestock (Eltringham, 1984). This has continuously decreased the animals habitats, home range, food and water resources which can be dangerous, especially during prolonged droughts. For instance, in Narok District, over 59 percent of the land is suitable for agriculture (Kenya, Ministry of Finance and Planning, 1984). Annual population growth rate is about 3.2 per cent, with the result that most of the former Masai occupied areas are being converted into agricultural land at an alarming rate (Doute et al, 1980; Amuyunzu, 1984; Lamprey, 1984; Lusigi, 1986). Various Masai group ranches have been developed in important cattle and wildlife grazing zones, while wheat farms are expanding at a high rate (Lamprey, 1984). The situation has been made critical by the Kenya government, which allowed the reduction of the Masai- Mara Game Reserve by 200 Km^2 in 1983, and the Masai pastoralists who have penetrated the Mara at the rate of 7.5 per cent per year in the last fifteen years (Lamprey, 1984). These human activities will have undesirable on the future conservation of wildlife in in Narok, and if not checked, a number of irreversible ecological changes might occur such as:

(a) Masai-Mara Game Reserve will eventually suffer degradation due to overgrazing,

(b) several wildlife species will disappear due to habitat loss,

(c) the wildlife oriented industry in the district will decline,

(d) migratory routes of the Serengeti- Masai-Mara wildlife will be cut,

(e) the Loita plains which are important animal concentration areas will be lost to wheat farming.

Other human related development activities are in conflict with conservation efforts in East Africa and equally threaten the future of wildlife (Mwalyosi, 1988).

Tourism itself is becoming a management problem where tourist vehicles have caused soil compaction and vegetation changes. Predator species, mainly the lion Panthera leo, leopard Panthera pardus and cheetah Acinonyx jubatus are frequently disturbed to an extent of interfering with their ecology, which might finally affect their feeding and breeding behaviour. This led the East African Wildlife Society to sponsor an inquiry of the situation in certain parks such as Nakuru and Nairobi National Parks (Anon, 1973). Henry (1977) reported a similar problem in Amboseli National Park. There is an ongoing project in Masai-Mara Game Reserve, whose objective is to look into the effects of tourism on big predators, vegetation and soils.

The most well studied herbivore/ habitat interaction in East Africa is that of elephants, and can serve as an example of the damage that can be caused by large herbivore populations. These herbivores are destructive feeders (when in high numbers) and have caused serious effects on the whole ecosystem. The ultimate cause of this damage has been attributed to a reduction in the their home range through human encroachment and the resultant increase in their density (Laws, 1970; Ramade 1984). Many national parks in East Africa have comparable levels of woodland decline, such as Murchison National Park, Uganda (Buechner and Dawkins, 1961; Salvige, 1968), Lake Manyara National Park, Tanzania (Douglas-Hamilton, 1972), and Tsavo National Park (Glover, 1963; Laws, 1970; Owegegha- Afunadula, 1984).

If these conservation areas are to retain their integrity and continue to support the present animal populations, their dynamics need to be studied. Animal numbers, density, distribution and fluctuation through time need careful monitoring. Habitat alteration should also be monitored since this can have serious side effects. For example, between 1962 and 1972, the Serengeti National Park, Tanzania, lost 13 percent of its woody vegetation due to high herbivore densities (Norton-Griffiths, 1973). Such changes in habitat need frequent monitoring in order to institute appropriate management of the herbivore population.

Even with such studies, the negative attitudes held by a number of local people, who see conservation areas as a nuisance (since wild herbivores occasionally raid their farms) and a waste of human resources, should not be ignored. There is therefore a need to educate them on the importance of wildlife so that they can appreciate and understand the benefits to them and the state. This is being encouraged in Kenya through various school and college wildlife clubs and by the East African Wildlife Society. Local people living within the radius of the conservation areas should be given a chance to participate in their administration and general running, as is already happening in the Masai-Mara Game reserve, where the local Masai are responsible for its management. Unless this is encouraged country-wide, conservation efforts will always be in conflict with the local people.

The aim of this study was to investigate the different large herbivore species in Hell's Gate National Park and at the same time understand the vegetation of the area. A vegetation study was carried out as part of the animals' habitat. The specific objectives were:

(a) to establish the numbers, density and distribution of large herbivore species,

(b) to identify plant communities and determine their species composition, distribution and condition.

1·1 LOCATION WITHIN THE RIFT VALLEY

Hell's Gate National Park lies within the eastern Rift Valley. To the north east are the Nyandarua Ranges (Aberdares) and the Kinangop Plateau; to the west are the Mau escarpment and Eburu mountains (Fig. 1). To the south east and north are Mt. Longonot and Lake Naivasha, respectively. It is on the leeward side of Lake Naivasha catchment area. Although it lies adjacent to the basin, there are no rivers or streams supplying water. The two major rivers from the catchment, Malewa and Gilgil end up in the lake.

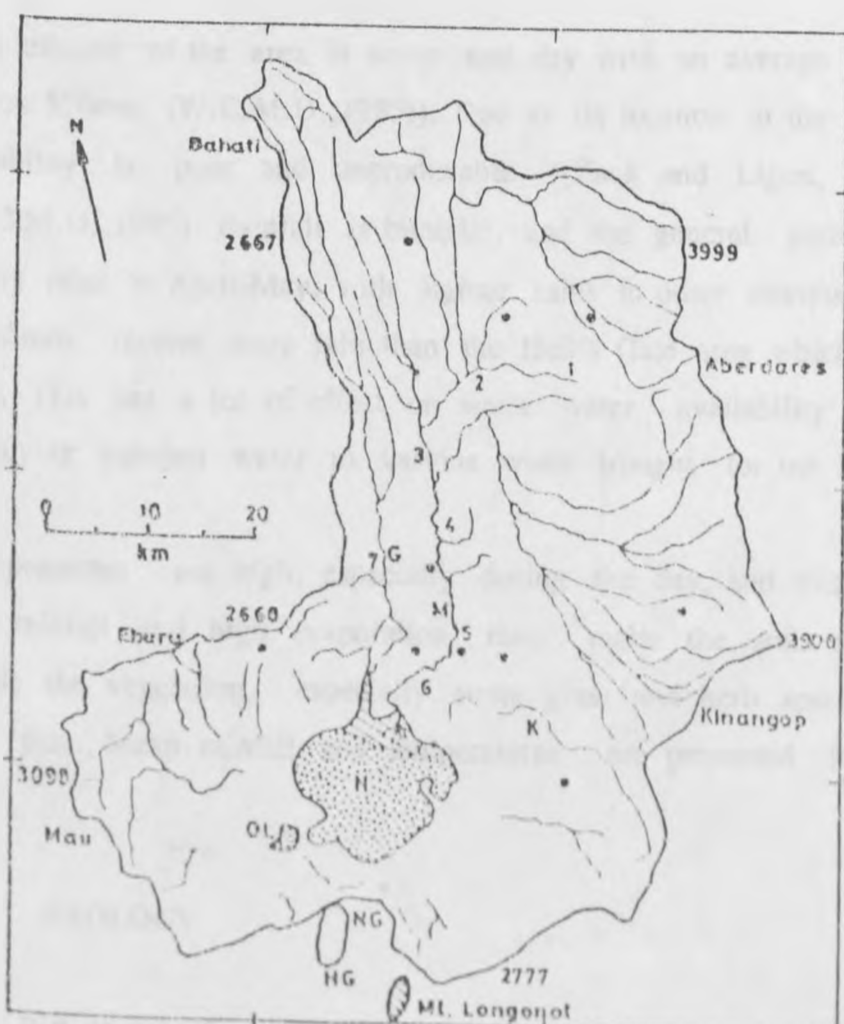


FIG. 1. Naivasha drainage basin. Lake Naivasha (N); Oloidien Lake (OL); Gilgil River (G); Malewa River (M); Karati River (K); Njorowa Gorge (NG); Hell's Gate National Park (HG). (Modified from Gaudet and Melack, 1981)

The Njorowa Gorge which was an outlet of Lake Naivasha during the Holocene period or era (Gaudet and Melack, 1981), passes through the eastern section of the park, dissecting it into two unequal parts (Fig.2). The Rift Valley floor in the region is extensively broken by faulting and is still volcanically active as indicated by steam vents, fumaroles and hot springs. Steam vents are very common in the western section of the park.

1.2 CLIMATE

The climate of the area is warm and dry with an average annual rainfall of about 550mm (W.C.M.D.,1985)). Due to its location in the Rift Valley, rainfall reliability is poor and unpredictable (Zack and Ligon, 1985, quoted in W.C.M.D.,1985). Rainfall is bimodal, and the general pattern is of relatively heavy rains in April-May, with lighter rains in other months. The surrounding highlands receive more rain than the Hell's Gate area which is on the leeward side. This has a lot of effect on water water availability which necessiates supplying pumped water to various water troughs for use by wildlife (Fig. 2).

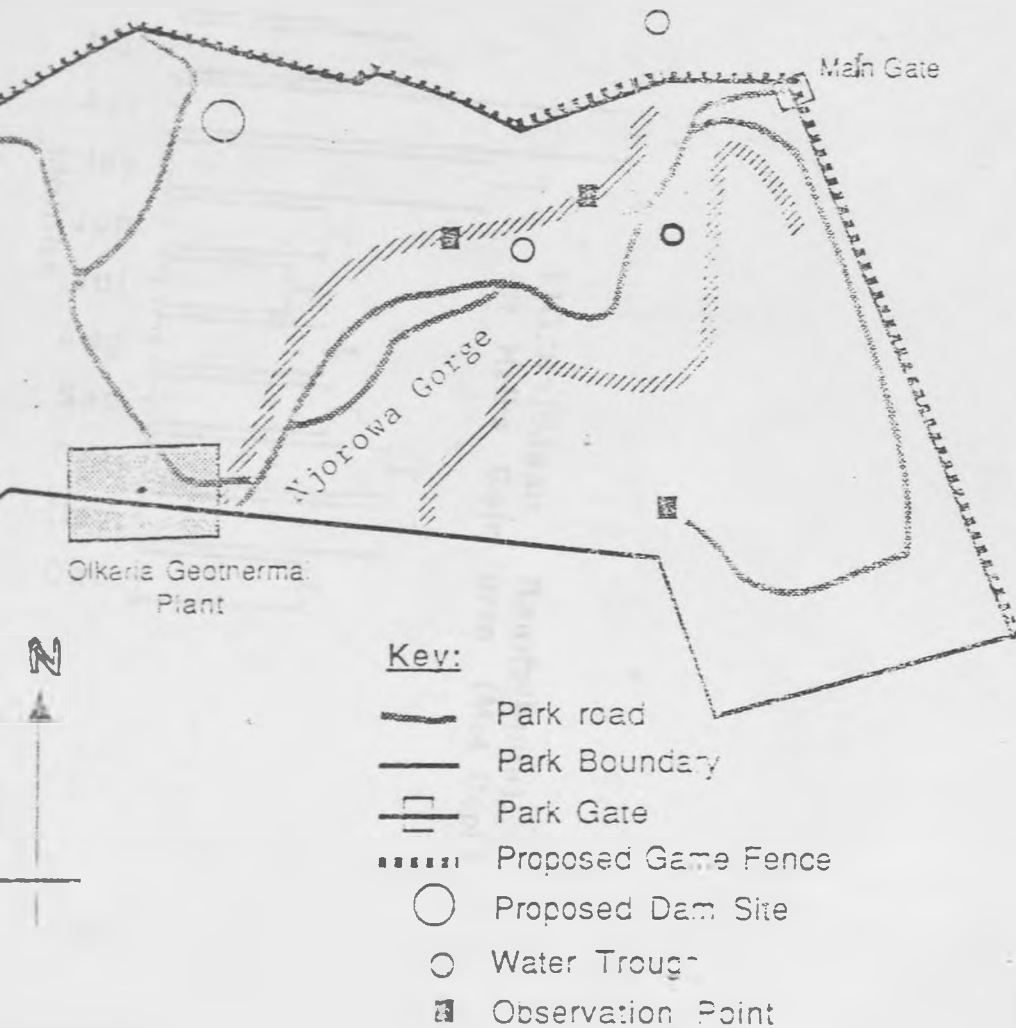
Temperatures are high, especially during the day, and this coupled with the low rainfall and high evaporation rate, make the soils relatively dry. As a result the vegetation, especially some grass and herb species are dry most of the year. Mean rainfall and temperatures are presented in figures 3 (a) and (b).

1.3 GEOLOGY

The Rift Valley floor in Hell's Gate area is largely covered with sediments which accumulated in lakes during the Pleistocene period. The rocks vary from under- saturated tephrites to highly acid rocks such as rhyolites and sodic rhyolites. Underlying the commendite sediments in the Njorowa Gorge are grey and white pumicious ashes.

FIG. 2: Hel

's Gate National Park: Water Troughs.Dam Sites and Proposed Game Fence



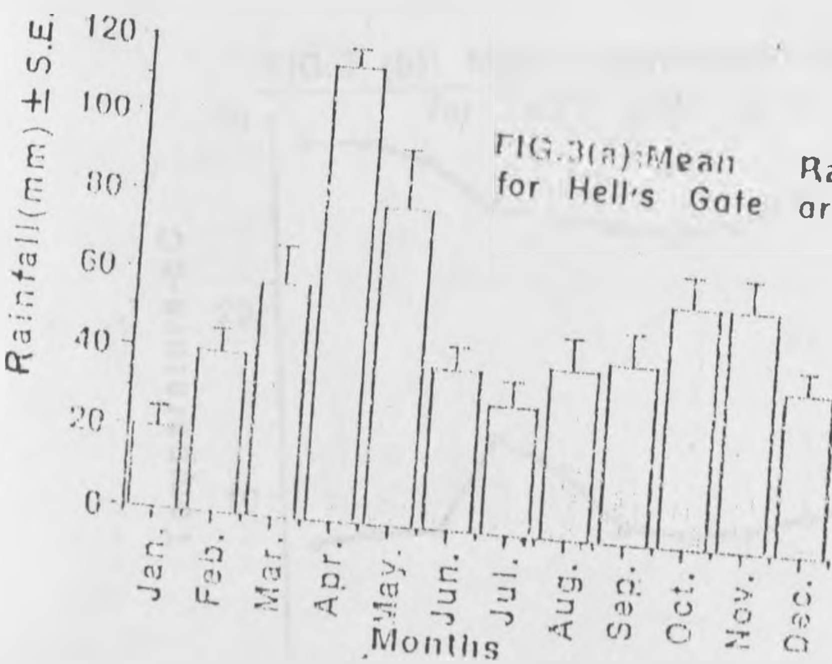
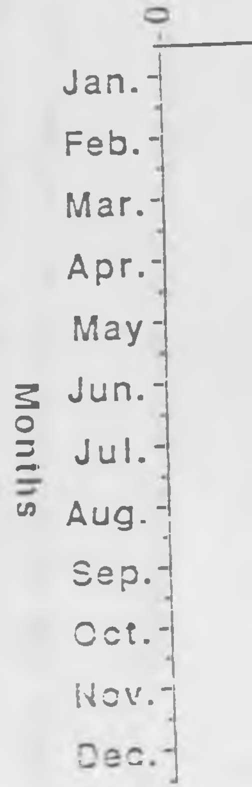


FIG.3(a):Mean Rainfall(mm) for Hell's Gate area (Met. Dept.)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Jan.
Feb.
Mar.
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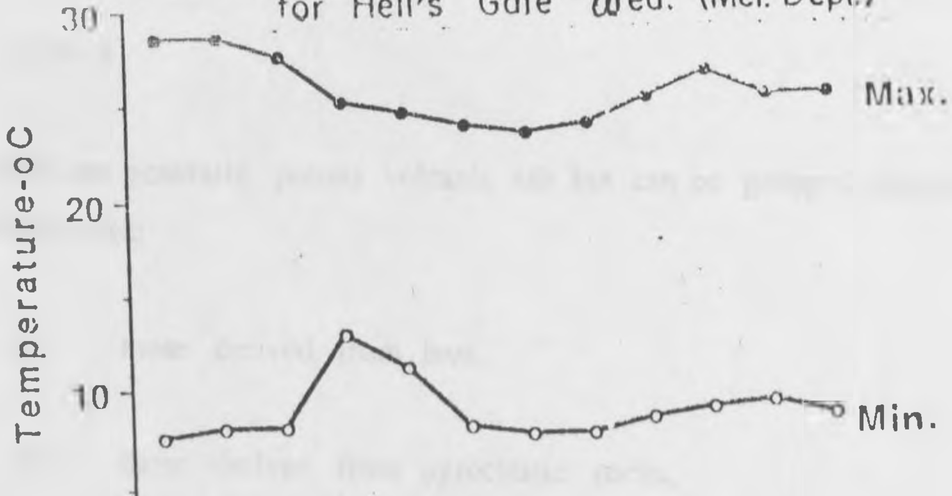
Months

FIG.3 (b): Mean Temperature(oC) for Hell's Gate area. (Met. Dept.)



Most parts of the park are replete with ashes which were sprinkled during the volcanic eruption of Mt. Longonot and its predecessors, and Olkaria most recently. The volcanic rocks found in this area consist of tephrites, basalts, trachytes, phonolites, tuffs, agglomerates and acid lava such as rhyolite, commendite and obsidian. The lake beds are mainly composed of reworked volcanic material and pyroclastic. Faulting has occurred in various sections of the area with slight faulting in the Njorowa Gorge.

1.4 SOILS

The soils are generally porous volcanic ash but can be grouped into three main rock categories;

a) those derived from lava,

b) those derived from pyroclastic rocks,

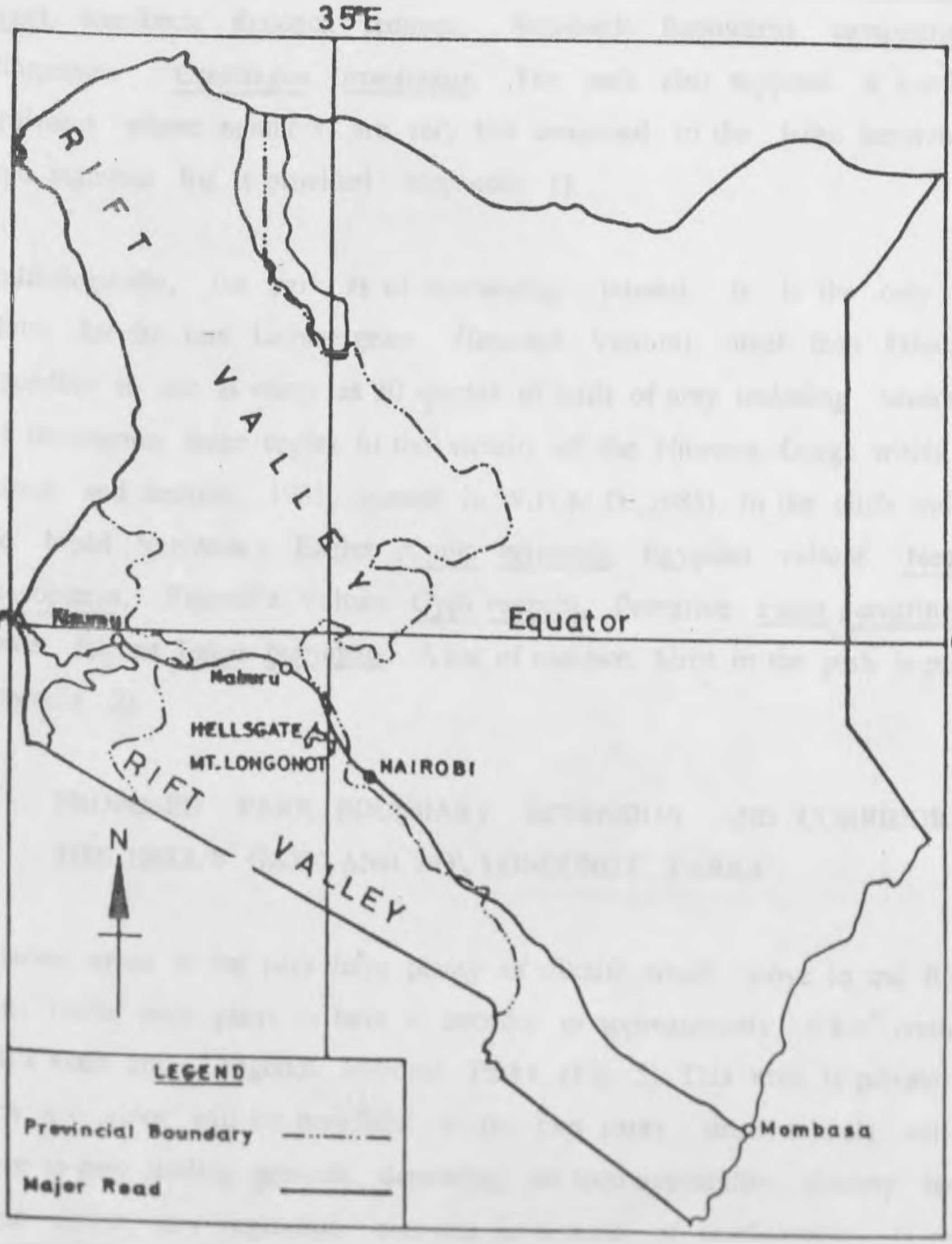
c) those derived from lacustrine lake deposits.

Ongweny (1973) described the soils occupying the Rift Valley floor starting from Naivasha area to Baringo as light grey or brown to pinkish non-calcareous soils.

1.5 STUDY AREA

Hell's Gate National Park is located in Nakuru District, Rift Valley Province, about 100 km north-west of Nairobi and 19 km south of Naivasha town (Fig. 4). It lies between longitude, 36° 30'E and between latitudes 0° 30'E and 1° 00'S. It is ecological zone IV of Pratt et al (1966), where Tarchonanthus - Acacia bushland dominates, and annual indices of available water are -30 to -40 (Woodhead, 1970). Its area is 68.25 km^2.

FIG. 4 HELL'S GATE AND MT. LONGONOT NATIONAL PARKS: NATIONAL SETTING



1.6 FAUNA

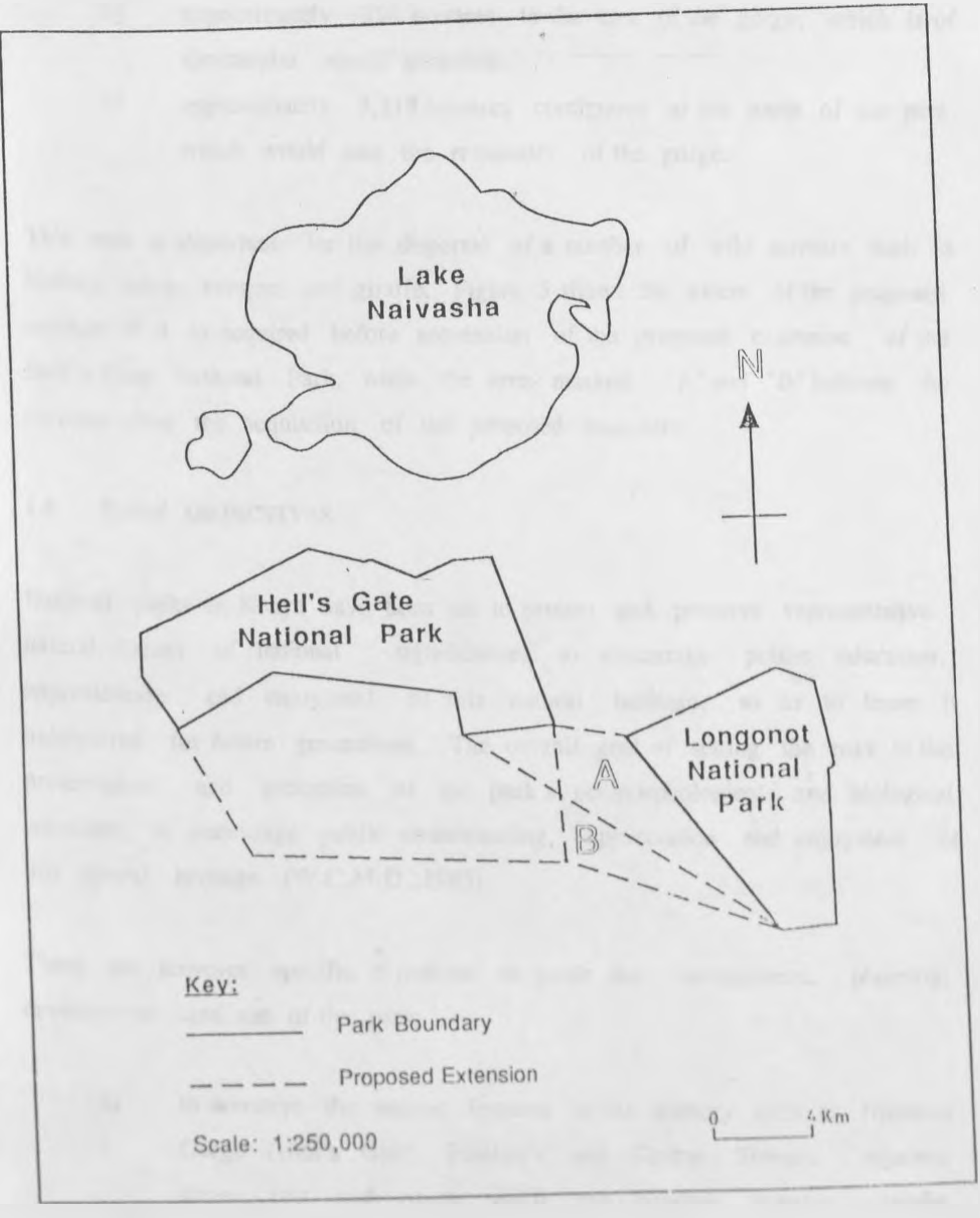
Most wildlife species in the park and adjoining areas are plains game such as Kongoni Alcephalus buselaphus coki, Buffalo Syncerus caffer. Thomson's Gazelle Gazella thomsonii, Grant's Gazelle Gazella grantii, and Zebra Equus burchelli. Others of particular interest include the rock hyrax Heteropharyx brucei, Reedbuck Redunca redunca, Steinbuck Raphicerus campestris and Klipspringer Oreotragus oreotragus. The park also supports a number of carnivores whose numbers are very low compared to the large herbivores. A large mammal list is provided (appendix 1).

Ornithologically, the park is of outstanding interest. It is the only known habitat for the rare Lammergeirs (Bearded Vulture), other than Ethiopia. It is possible to see as many as 30 species of birds of prey including several rare and uncommon large eagles in the vicinity of the Njorowa Gorge within a day (Barrah and Jenkins, 1981, quoted in W.C.M.D.,1985). In the cliffs and gorge also breed Verreaux's Eagles Aquila verrauxii, Egyptian vulture Neophron perenopterus, Ruppell's Vulture Gyps ruppelli, Peregrine Falco peregrinus and Lanner falcons Falco biarmicus. A list of common birds in the park is provided (appendix 2).

1.7 PROPOSED PARK BOUNDARY EXTENSION AND CORRIDOR FOR THE HELL'S GATE AND MT. LONGONOT PARKS

Adjacent areas to the park have plenty of wildlife which move to and from the park. There were plans to have a corridor of approximately 8 km^2 connecting Hell's Gate and Longonot National Parks (Fig. 5). This area is private land. Such a corridor will be beneficial to the two parks since animals will easily move to new feeding grounds depending on food availability, thereby reducing to an extent, any vegetation over-use as a result of confinement. In order to fully exploit the enormous potential of the park, it has been proposed that the

FIG. 5: Hell's Gate and Longonot National Parks, showing Proposed extension corridors



present boundary be extended southward (Fig. 6) to include the following adjacent areas:

a) approximately 850 hectares to the east of the gorge, which is of spectacular scenic attraction,

b) approximately 3,218 hectares contiguous to the south of the park which would take the remainder of the gorge.

This area is important for the dispersal of a number of wild animals such as buffalo, zebra, kongoni and giraffe. Figure 5 shows the extent of the proposed corridor if it is acquired before acquisition of the proposed extension of the Hell's Gate National Park, while the area marked "A" and "B" indicate the corridor after the acquisition of the proposed boundary.

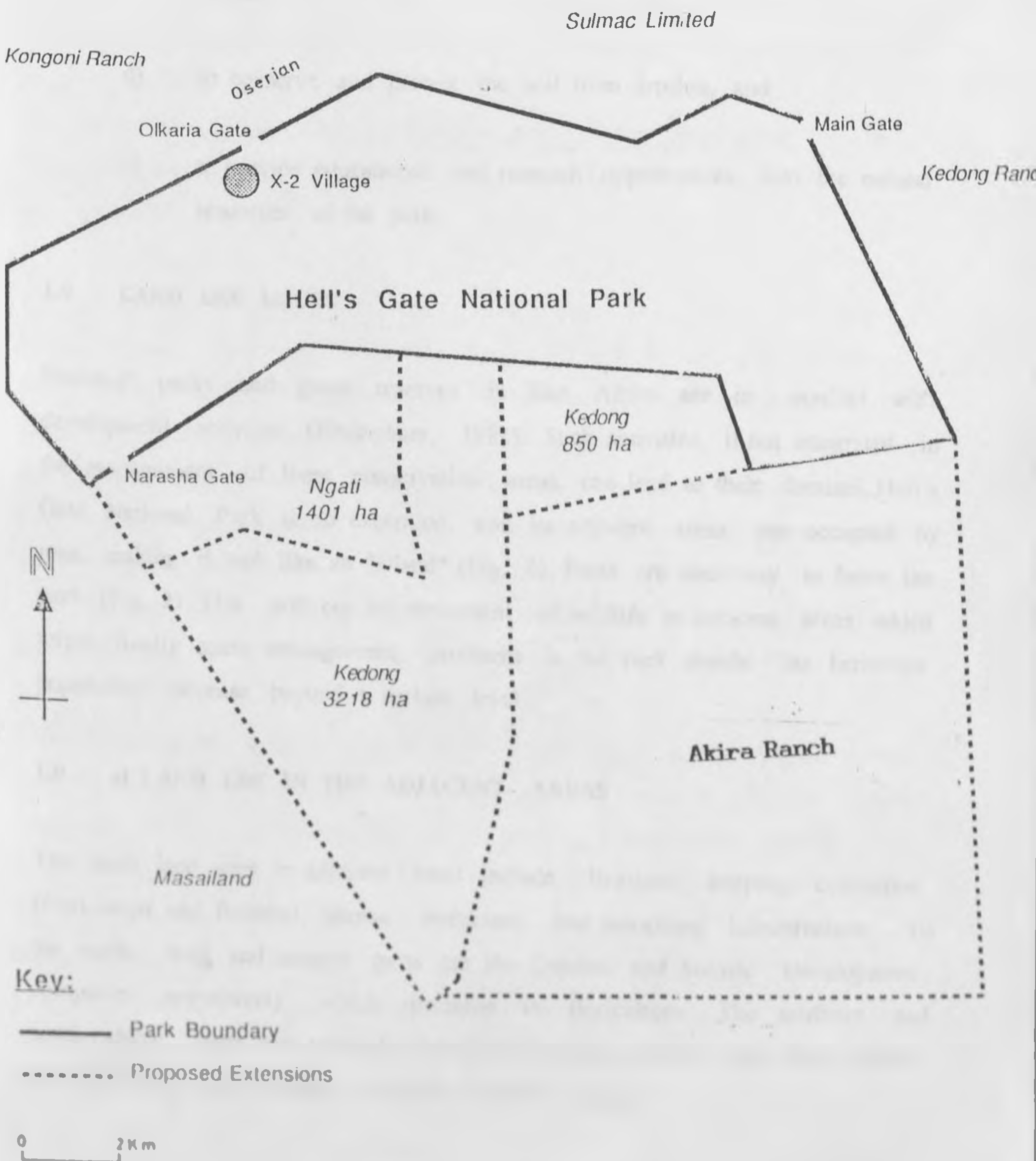
1.8 PARK OBJECTIVES

National parks in Kenya have been set to protect and preserve representative natural areas of national significance, to encourage public education, appreciation and enjoyment of this natural heritage, so as to leave it unimpaired for future generations. The overall goal of setting the park is the preservation and protection of the park's geomorphological and biological resources, to encourage public understanding, appreciation and enjoyment of this natural heritage (W.C.M.D., 1985).

There are however specific objectives to guide the management, planning, development and use of the park;

a) to conserve the unique features of the scenery such as Njorowa Gorge (Hell's Gate), Fischer's and Central Towers, adjacent steam jets and caves which can become popular tourist attractions,

FIG. 6: Hell's Gate National Park: Proposed Boundary Extensions



b) to conserve and protect the rare Lammergeirs (Bearded) Vulture and other wildlife in the ecosystem,

c) to conserve and protect the enormous variety of succulent plants and the Leleshwa (Tarchonanthus camphoratus) bushland habitats,

d) to conserve and protect the soil from erosion, and

e) to provide educational and research opportunities into the natural resources of the park.

1.9 LAND USE ISSUES

National parks and game reserves in East Africa are in conflict with development activities (Eltringham, 1984). Such activities, if not integrated in the management of these conservation areas, can lead to their demise. Hell's Gate National Park is no exception, and its adjacent areas are occupied by man, making it look like an "island" (Fig. 6). Plans are underway to fence the park (Fig. 2). This will cut off movement of wildlife to adjacent areas which might finally cause management problems in the park should the herbivore population increase beyond a certain level.

1.9 a) LAND USE IN THE ADJACENT AREAS

The main land uses in adjacent areas include : livestock keeping, cultivation (food crops and flowers), human settlement and associated infrastructure. To the north- west and eastern parts are the Oserian and Sulmac Development companies respectively, which specialise in floriculture. The southern and south-eastern parts are privately owned by Kedong and the Ngati Co-operative Societies, and are important wildlife dispersal areas.

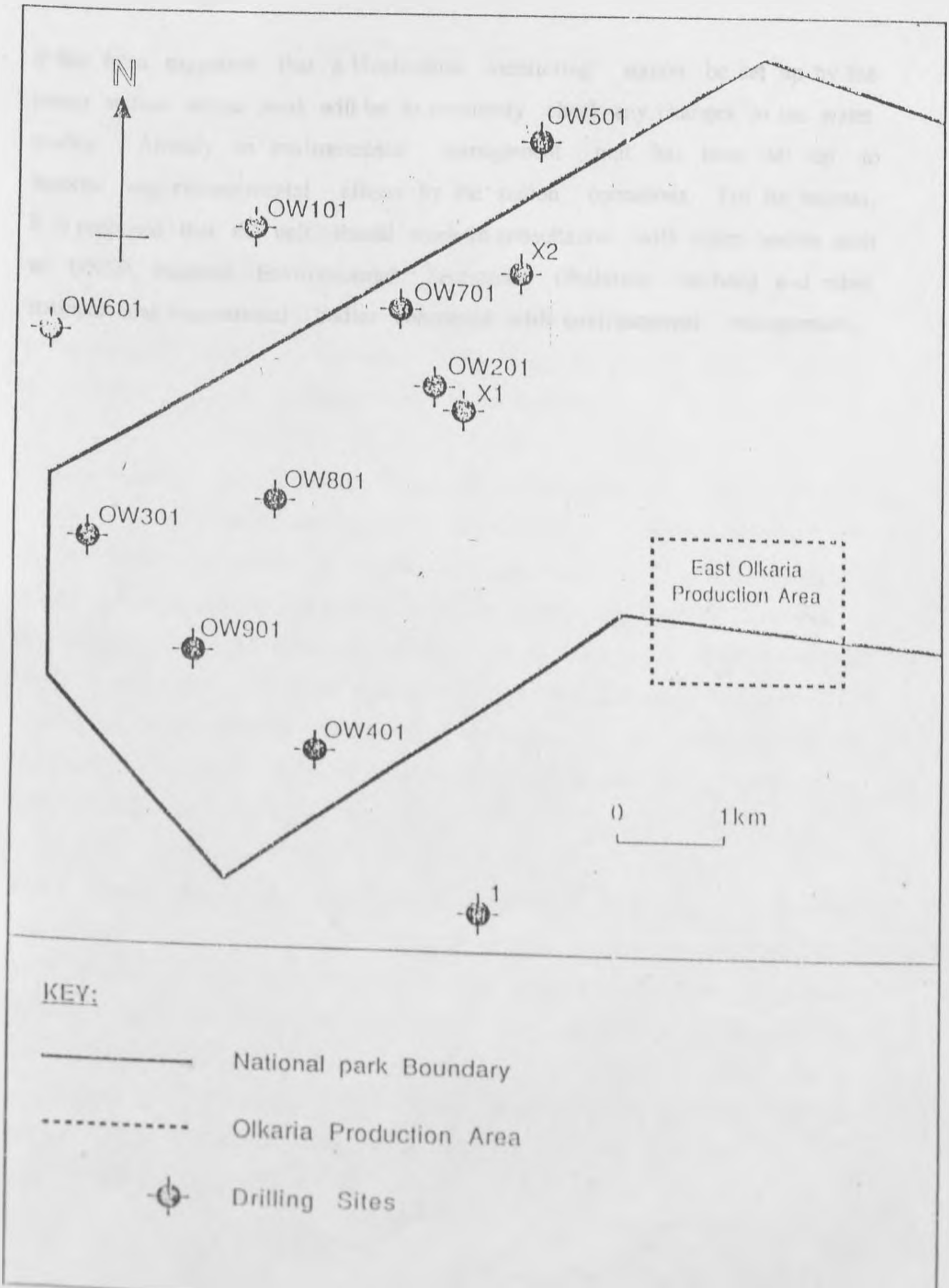
1.9 b) LAND USE WITHIN THE PARK

Before the park was gazetted in 1984, the Masai people were using the area for grazing purposes. Initially, it was difficult to make them move out, and for some time they continued grazing their animals in the park. The park authority managed to force them out, but they occasionally enter to graze and water their animals, especially during the dry months. The government, in conjunction with the Geothermal Power authority, was encouraging them to keep their animals out of the park by providing pumped clean water from lake Naivasha (Warden pers. comm.). Charcoal burning was also prevalent but is now minimal.

While it is easy to reduce the above two activities, the Olkaria Geothermal Power Station which operates within the park, will be very difficult to deal with at the moment. Approximately 2 km^2 of the land is already under production, while additional areas for further exploration cover nearly half of the proposed park extension area (Fig. 7). The development activity, though beneficial to the government and the local people, poses a big threat to the viability of the park, such as wildlife displacement, air and water pollution, destabilisation of the landscape and floral communities through site clearing and drilling.

There is therefore a need to look into the ecological impact of the power station, especially with regard to noise pollution, gaseous emission, waste water disposal,and landscape clearing. At present approximately 24,000 litres of waste water are disposed off daily (W.C.M.D, 1985), and this is bound to increase in future when the station expands. When drilling, large volumes of bentonistic mud and cement grout are gushed out; and these need to be carefully dumped. The impact of the turbine exhaust emissions and the "test" wells to the surrounding is of concern, especially from sulphurous gases. Adverse impact of the acidic emission on surrounding flora cannot also be

FIG: 7 : Hell's Gate National Park: Western Region showing Drilling Sites



overlooked. The vegetation around the "test" wells, especially the grasses and herbs show some damage(pers.obs.).

It has been suggested that a biochemical monitoring station be set up by the power station whose work will be to constantly check any changes in the water quality. Already an environmental management unit has been set up to monitor any environmental effects by the station operations. For its success, it is proposed that the unit should work in consultation with other bodies such as UNEP, National Environmental Secretariat (Pollution Section) and other national and international bodies concerned with environmental management.

CHAPTER II

2.0 VEGETATION AND SOILS

2.1 INTRODUCTION

The disappearance of vegetation patterns through changes in plant species composition may theoretically lead to a reduction in the number of animal species through loss of habitat or an increase in the population of a species whose preferred habitat is increased. Plants being the primary food consumers are naturally subjected to depredation by animals.

Grazing/browsing is an important factor, particularly when its intensity reaches a level as to injure or prevent successful growth and reproduction of plants. Its general effect is to reduce the proportion of those plants less able to withstand certain grazing/browsing intensity, resulting in the reduction of plant variety in a habitat, more so those species that are used as food. Overgrazing can result in elimination of certain species, a decline in soil fertility and removal of vegetation cover, exposing soils to agents of erosion. Many species, though not necessarily eliminated, are reduced in number, vigour and vitality, while others totally disappear.

Many studies have been carried out in an attempt to account for observed distribution of plant communities (Bunting and Lea, 1962; Anderson and Talbot, 1965; Packham et al, 1966; Whittaker, 1967; Greenway and Vesey-Fitzgerald, 1969; Anderson and Herlocker, 1973; Taiti, 1973; Wells et al, 1976; Ball et al, 1981; quoted in Moore and Chapman, 1986). Human activities such as industry, agriculture and urbanisation have greatly influenced and modified plant and animal species distribution (Cox et al, 1973).

Soil texture is a function of the size and proportion of the various constituent particles. In any given soil, the amount of clay, silt and sand is relatively constant and stable, and has significant effects on its ecological, physical and chemical properties (Faniran and Areola, 1978). They affect soil consistency, structure, degree of compaction and stability, aeration, drainage and root penetration ability (Jarvis and Jarvis, 1972; Briggs, 1981; Landon, 1984). Water retention capacity is also affected (Fitzpatrick, 1971; Jarvis and Jarvis, 1972).

Soil chemical properties can have many effects on plant growth, survival and hence their spatial distribution. Plants are naturally adapted to survive in soils of varying chemical properties. Nutrient availability is determined by the supply characteristics of the soil and the absorption properties of the roots. There is a direct relationship between availability of specific nutrients in the soil and primary production (Kanwar, 1978). There could be a lack of essential nutrient(s) in a soil due to factors related to the parent material. pH is however crucial, and can alter the proportion of nutrients. It is in turn affected by aeration, leaching, organic matter content, biological activities and amount of carbon dioxide in the soil water phase. At pH 6.5, the soil reaction is just about neutral and all nutrients are sufficiently available to satisfy plant requirements. Increasing alkaline conditions render certain minerals insoluble. Extremely acid conditions can promote the solubility of aluminium and iron to an extent of being toxic to some plant species, and phosphorus can become unavailable since it tends to combine with these minerals forming insoluble compounds. Plants, thus vary in their ability to tolerate certain degrees of pH (Stalfelt, 1972).

For long term management of parks and game reserves, there is a need to study the population dynamics of herbivores, the vegetation upon which they depend for food and habitat, and possibly, get an insight into the interaction between the two. Hell's Gate National Park requires a sound management strategy in order to retain its present integrity. There is a need to understand the animal populations, vegetation communities, their distribution, condition and interaction. A comprehensive record of the flora is essential for routine ecological practical purposes aimed at formulating conservation measures of the vegetation. To make an inference about soil/vegetation relationships, soils were collected from different vegetation communities and their physical and chemical properties studied.

2.2 METHODS

2.2.1 Mapping vegetation communities

To map out the different vegetation communities, a 1:50,000 topographic map of the park was used. The study area was transversed using a vehicle when necessary. Most of the area was covered on foot in order to ascertain the the boundaries of the vegetation communities. During this time, the different vegetation communities were noted and drawn to scale. These were named according to Pratt et al (1966) with modifications. If the vegetation of Hell's Gate area was considered (including the park), it would have fallen under one vegetation type, Tarchonanthus camphoratus/ Acacia drepanolobium shrubland. In order to understand the vegetation of the park, the classification of Pratt et al (1966) was applied at a smaller scale (to fit the size of the park). This resulted in similar vegetation communities. All the communities were then categorised into three major vegetation types. The word open and dense were used to refer to the physiognomic or structural appearance of the vegetation.

2.2.2 Plant specimen collection

By the start of this study, the only available information on the flora was done by Page and Reiley (1978). They collected 169 plants belonging to 54 families. There was a need to carry out further plant species collection before any quantitative analysis of the vegetation could be carried out. In each vegetation community, intensive plant species collection was done. Specimens were dried in a plant press and latter identified at the University of Nairobi herbarium.

2.2.3 Quantitative vegetation sampling

Various authors have extensively discussed and described the different quantitative methods available for vegetation sampling (Greig-Smith, 1957, 1983; Cain and Castrol, 1959; Kershaw, 1969, 1973; Mueller-Dumbois and Ellenberg, 1974). Vegetation communities have characteristic plant species composition. For any quantitative comparison purposes, a standard plot size or the minimal plot (area) has to be used in all the stands (Mueller-Dumbois and Ellenberg, 1974). Several authors have defined and discussed the determination of minimal plot in vegetation sampling (Braun-Blanquet, 1913, 1924, 1928; Du-Rietz, 1920, 1922; Nardhagen, 1928; all quoted in Hopkins, 1957); Cain, 1932, 1938; Vestal and Heserman, 1945; Vestal, 1949; Goodall, 1952; Cain and Castrol, 1959). Sampling methods will depend on the aims and objectives of the study. The size of the sample unit used in each vegetation community was the minimal plot (area), determined from the species/area curve, plotted from the number of species counted in a progressively increased area of a plot (quadrat) (Moravec, 1973).

For this study, I chose the quadrat sampling method and determined the quadrat sizes that were appropriate for the study situation. Quadrats of varying sizes were placed in the vegetation stands, each time recording the number of species present, until further enlargement of the quadrats resulted in insignificant changes in the species composition. With this data, two species/area curves were drawn (Fig. 8 and 9). A 2m x 2m quadrat was found suitable for grass/herbs sampling, while a 20m x 20m quadrat was found appropriate for sampling trees and shrubs.

Fig. 8: Species/area curve for herbaceous species

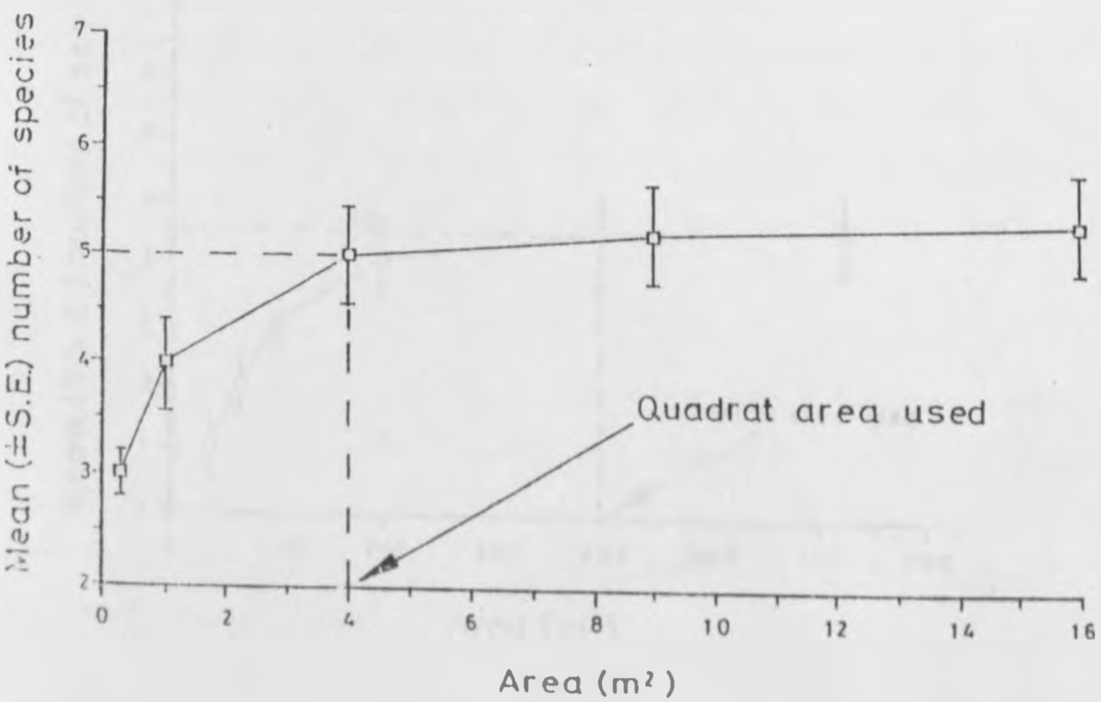
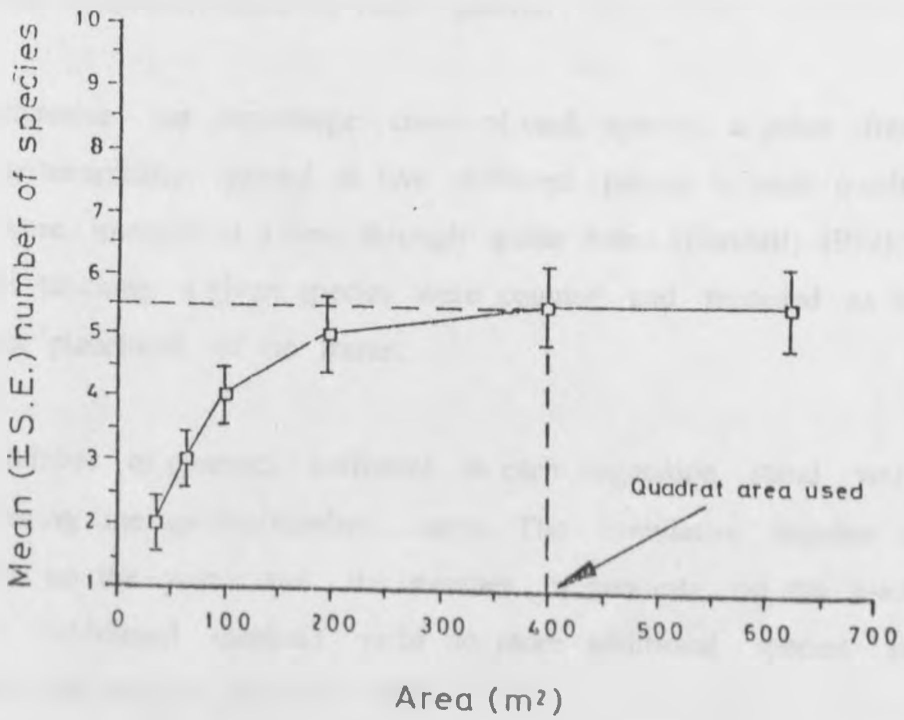


Fig 9: Species/area curve for woody species



2.2.4 Grass/Herbs sampling

Using a table of random numbers, transects (300 m long) were randomly selected in each vegetation community. Quadrats were then placed on the ground along these transects at 20m intervals. The number of plants of a given species within each quadrat were recorded. Due to the growth nature of Themeda triandra, Digitaria scalarum and Cynodon dactylon, it was not practical to count individual plants, but they had a high density. The latter had extensive stolons, and D. scalarum had numerous shoots from underground rhizomes, making counting individual shoots impractical. Their presence was only noted in each quadrat.

To determine the percentage cover of each species, a point frequency frame was systematically placed at five different points in each quadrat. Ten wire pins were lowered at a time through guide holes (Goodall, 1952). The number of pins touching a given species were counted and recorded as number of hits at each placement of the frame.

The number of quadrats sufficient in each vegetation stand were determined by drawing the species/number curve. The cumulative number of species was plotted on the y-axis and the number of quadrats on the x-axis. The point where additional quadrats yield no more additional species represents the number of quadrats (Odum, 1959).

From the data, frequency, density and percentage cover, and relative cover were calculate as:

$$\text{Frequency} = \frac{\text{number of quadrats in which a species occurs}}{\text{total number of quadrats}}$$

$$\text{Density} = \frac{\text{total number of plants of each species}}{\text{area } (m^2)}$$

$$\% \text{ cover} = \frac{\text{number of pins (hits) touching a species}}{\text{total number of pins}} \times 100$$

$$\% \text{ relative cover} = \frac{\% \text{ cover of a species}}{\text{total } \% \text{ cover of all species}} \times 100$$

2.2.5 Trees/Shrubs sampling

Along the line transects selected for grass/ herbs sampling, quadrats of 20m x 20m were placed at 20m intervals. The different woody species were recorded and counted in each quadrat. Their basal diameter rather than diameter at breast height (dbh) was measured. It gives a better measure of true diameter (Mueller-Dombois and Ellenberg, 1974). All diameters of each species were converted to basal area using a conversion table. Frequency and density were calculated as shown above. Percentage composition was calculated as:

$$\% \text{ species composition} = \frac{\text{number of plants of a species}}{\text{total number of all plant species}} \times 100$$

2.2.6 Soil sampling

Soils wre sampled in the various vegetation communities, except community L (sparsely vegetated rocky zone) where the rocks were little weathered, hence there was no soil. In each stand, line transects wre randomly selected and soil core samples, 30cm below the surface taken at 20m intervals. Samples of each transect were thoroughly mixed to make a composite sample (the assumption was that soil properties were homogenous in each community), homogenised and air dried. These were then sub-sampled (for analysis), sieved using a 2 mm x 2 mm sieve and put in polythene bags.

Analysis for chemical and physical properties of the soils was done at the Kenya soil survey section in the National Agricultural Laboratories. Soil reaction (pH) was determined by electrical conductivity method, exchangeable bases (K^+, Na^+, Mg^{2+} and Ca^{2+}) by leaching in Ammonium acetate at pH = 7. Potassium and Sodium were then determined using a flame photometer. For Magnesium and Calcium the extract was analysed using the EDTA method. Total percentage Nitrogen and Carbon were determined using the Kjeldhal and Walkley-Black methods respectively. The hydrometer method was used to determine soil texture. To determine the soil exchange capacity (C.E.C), soils samples were leached in 1 N Sodium acetate at pH = 8.2, and the total amount of cations measured.

2.3 RESULTS

2.3.1 Vegetation

Thirteen vegetation communities were mapped (Fig. 10). Each is described and a summary of the collected data on the herbaceous and woody species provided in tables. All the communities were categorised into three major vegetation types:

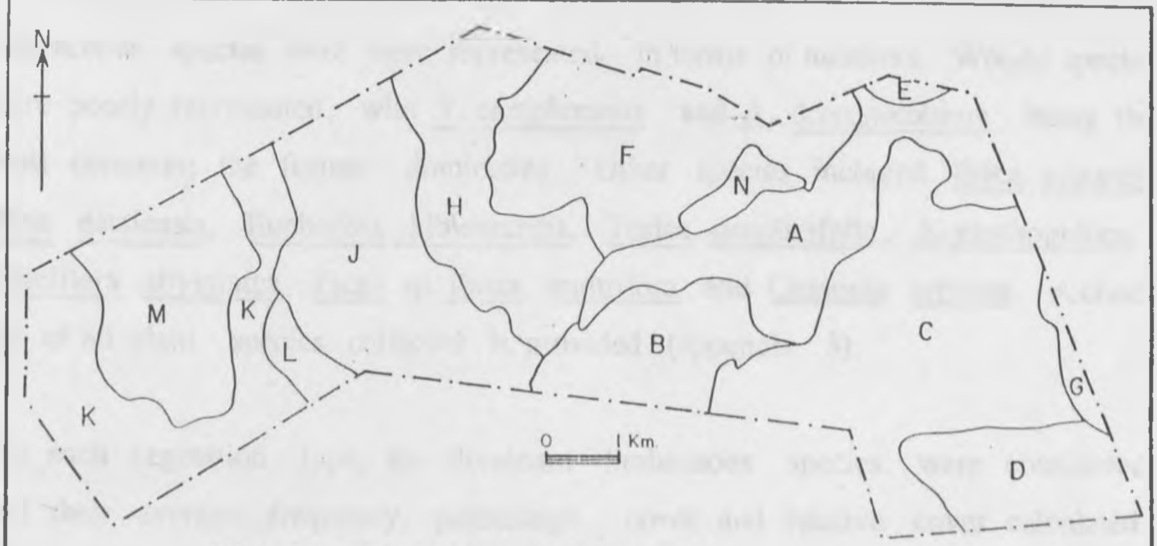
a) *Cynodon/Digitaria* grassland and *Digitaria/Acacia* dwarf shrub grassland (community A and G),

b) Dense *Tarchonanthus camphoratus/Acacia drepanolobium* shrubland (community B, D, H, E, K and N),

c) Open *T. camphoratus/A. drepanolobium* shrubland (community C, F, J, and M).

Three hundred and sixty six plant species belonging to seventy three families were collected and identified. Most of them were collected from valleys.

FIG 10 : HELL'S GATE NATIONAL PARK : VEGETATION COMMUNITIES 1988/89



KEY TO VEGETATION COMMUNITIES

A	Cynodon / Digitaria grassland
B	Hyparrhenia / Digitaria / Tarchonanthus / Acacia shrubland.
C	Themeda / Tarchonanthus / Acacia dwarf shrubland
D	Themeda / Digitaria / Tarchonanthus / Acacia shrubland
E	Digitaria / Hyparrhenia / Tarchonanthus / Dodonea shrubland
F	Digitaria / Tarchonanthus / Acacia dwarf shrubland.
G	Digitaria / Acacia dwarf shrubland grassland
H	Themeda / Digitaria / Tarchonanthus / Acacia shrubland
J	Hyparrhenia / Acacia / Tarchonanthus dwarf shrubland
K	Hyparrhenia / Tarchonanthus / Acacia shrubland
L	Sparsely vegetated rocky zone.
M	Digitaria / Themeda / Tarchonanthus / Acacia dwarf shrubland
N	Digitaria / Tarchonanthus / Acacia shrubland.

Herbaceous species were more represented in terms of numbers. Woody species were poorly represented with T. camphoratus and A. drepanolobium being the most common; the former dominating. Other species included Erica arborea, Rhus natalensis, Euphorbia kibwezensis, Teclea simplicifolia, A. xanthophloea, Schefflera abyssinica, Ficus sp. Iboza multiflora and Cussonia arborea. A check list of all plant species collected is provided (appendix 3).

For each vegetation type, the dominant herbaceous species were considered and their average frequency, percentage cover and relative cover calculated. These were not significantly different among the species (ANOVA, $p > 0.05$, see table 1, 2 and 3). Densities of Tarchonanthus camphoratus and Acacia drepanolobium between the dense and open vegetation types were compared (table 4). There was significant difference in each case (Mann Whitney U one tailed test, $U = 11$, d.f. = (6, 4), $p < 0.05$, respectively). T. camphoratus density was high in the dense vegetation communities than in the open communities, while A. drepanolobium density was high in the latter than in the former.

The dominant herbaceous species in all the twelve communities were pooled. There was no significant difference in their average frequency, percentage cover and relative cover (ANOVA and t-test, $p > 0.05$, see table 5 for data summary and statistics). Digitaria scalarum, Themeda triandra and Hyparrhenia sp. were the most dominant species.

Table 6 shows the average frequency, density, percentage species composition and basal area of the three common woody species in the park. There was no siginificant difference in the frequency, density and species composition of T. camphoratus and A. drepanolobium ($t = 1.150$, $t = 1.758$ and $t = 1.640$ respectively, two tailed t- test, d.f. = 22, $p > 0.05$ in all cases). There was significant difference between T. camphoratus vs Rhus natalensis and A. drepanolobium vs Rhus natalensis (two tailed t-test, d.f. = 19, $p < 0.05$

Table 1: Mean (±S.E.) percentage cover, relative cover and frequency of the dominant herbaceous species in the grassland vegetation type — Community A and G

Species	frequency	%cover	% relative cover	n
Digitaria scalarum	0.87	20.50±3.77	34.44±4.25	2
Cynodon dactylon	0.44	11.70±7.66	19.07±11.79	2
Themeda triandra	0.54	6.05±2.25	10.51± 4.47	2
Felicia muricata	0.82	9.24±2.60	15.97± 5.38	2
F	1.444 ns	1.608 ns	1.743 ns	
d.f	(3,4)	(3,4)	(3,4)	

F values are calculated after angular transformation of the data

ns = no significant difference $P>0.05$

S.E = standard error

Table 2 and 3: Mean (±S.E.) percentage cover, relative cover and frequency of the dominant herbaceous species in the open and dense Tarchananthus camphoratus/ Acacia drepanolobium **Shrubland,** vegetation type **respectively.**

Table 2:-

Species	frequency	%cover	% relative cover	n
Digitaria scalarum	0.59	17.39±3.94	24.68±4.02	4
Themeda triandra	0.73	19.56±5.66	28.58±9.09	4
Hyparrhenia Sp.	0.53	14.39±4.04	23.22±8.77	4
Hyparrhenia lintonii	0.35	9.81±0.94	14.48±2.46	3
F	2.314 ns	0.717 ns	0.604 ns	
d.f	(3,11)	(3,11)	(3,11)	

ns = no significant difference P>0.05

S.E. = standard error

Table 3:-

Species	frequency	%cover	% relative cover	n
Digitaria scalarum	0.77	22.75±2.52	35.98±4.83	5
Themeda triandra	0.87	19.05±6.95	25.19±7.34	4
Hyparrhenia Sp.	0.58	26.34±6.89	41.24±11.95	4
F	1.997 ns	0.519 ns	0.965 ns	
d.f	(2,10)	(2,10)	(2,10)	

F values are calculated after angular transformation of the data (for both tables)

ns = no significant difference P>0.05

Table 4: Density of Tarchonanthus camphoratus and Acacia drepanolobium in the dense and open Shrubland vegetation types

Vegetation type	species	density/ha
Dense T. camphoratus/ A. drepanolobium shrubland	T. camphoratus	578.23
		581.63
		430.74
		460.46
		646.86
		320.40
Open T. camphoratus/ A. drepanolobium shrubland	T. camphoratus	443.40
		386.05
		188.78
		380.40

U - test (d.f = 6,4), U = 11*

Vegetation type	species	density/ha
Dense T. camphoratus/ A. drepanolobium shrubland	A. drepanolobium	154.86
		748.29
		243.62
		187.50
		17.86
		180.02
Open T. camphoratus/ A. drepanolobium shrubland	A. drepanolobium	296.94
		319.73
		330.36
		293.37

U- test (d.f = 6,4), U = 11*

* Significant difference P<0.05

Table 5: Mean (±S.E.) percentage cover, relative cover and frequency of the dominant herbaceous species in the whole park

Species	frequency	%cover	%relative cover	n
Digitaria scalarum	0.72	20.39±1.92	31.63±3.02	11
Themeda triandra	0.74	16.65±3.73	23.62±4.87	10
Hyparrhenia Sp.	0.55	20.36±4.33	32.23±7.65	8
F	1.895 ns	1.443 ns	1.067 ns	
d.f	(2,26)	(2,26)	(2,26)	

F values are calculated after angular transformation of the data

ns = no significant difference P>0.05

S.E. = standard error

Table 6: Mean frequency, density, basal area and percentage composition of the dominant woody species in the park

Acacia drepanolobium and *Rhus natalensis*		*T. camphoratus* and *Rhus natalensis*		*T. camphoratus* and *Acacia drepanolobium*		
12	9	12	9	12	12	n
19		19		22		d.f.
0.70	0.18	0.82	0.18	0.82	0.70	frequency
4.805*		5.690*		1.510 ns		t-test
237.60	25.80	377.60	25.80	377.60	237.60	density/ha
3.171*		5.312*		1.758 ns		t-test
39.64	3.11	55.20	3.11	55.20	39.64	%species composition
5.461*		8.594*		1.640 ns		t-test
1.09	0.23	11.26	0.23	11.26	1.09	basal area M^2/ha
3.440*		3.322*		3.556*		t-test

ns = no significant difference P>0.05

t-test for frequency and percentage composition are calcualted after angular transformation of the data.

* Significant difference $P < 0.05$

respectively, table 6). The basal areas of the three species were significantly different (t-test, d.f. = 22, $p < 0.05$, two tailed test).

2.3.1 (a) Vegetation community A: *Cynodon/ Digitaria* grassland

This was the biggest open grassland in the whole park and occupied the Njorowa Gorge. It was flat and low in relation to other parts which were relatively hilly. The dominant plant species were Cynodon dactylon and Digitaria scalarum as indicated by their frequency and cover value (table 7a). They occurred throughout the zone, had a high density, although it was not possible to count them during the sampling due to their growth nature. C. dactylon frequently occurred in dense tall clumps such as around the Fischer's tower. Other common species included Themeda triandra, Indigofera tanganyikensis, Harpachne schimperi, Justicia sp., Euphorbia inaequliatera and Felicia muricata. T. triandra had a patchy distribution. Where grazing was frequent, the grass was short, less than 20cm. Total herbaceous cover was 62 per cent, and no overgrazing was evident. F. muricata, a short perennial herb was widely distributed throughout the zone with a high density. In those areas where it was dense, such as around Fischer's tower, it had displaced most of the other plant species , thus assuming dominance.

Tarchonanthus camphoratus and Acacia drepanolobium occasionally occurred in clumps, but were sparsely distributed. T. camphoratus was the most common (table 7b). Their overall contribution to the vegetation cover was not significant. There were two water troughs for wildlife use, and the vegetation around them had been trampled on. However, this was not serious, but might deteriorate if herbivore populations increase to a certain level.

Table 7a: The density, frequency, percentage cover and relative cover of herbaceous species in Community A

Species	density/m2	frequency	%cover	%rel. cover
Cynodon dactylon	-	0.56	19.33	31.14
Digitaria scalarum	-	0.85	24.25	39.06
Themeda triandra	-	0.21	3.80	6.12
Euphorbia inaequilatera	1.72	0.43	0.18	0.29
Felicia muricata	10.91	0.78	6.65	10.71
Indigofera tanganyikensis	6.79	0.66	1.38	2.20
Indigofera spicata	0.17	0.10	0.08	0.13
Aristida keniensis	0.22	0.21	0.18	0.29
Plectranthus barbatus	1.16	0.25	0.60	0.97
Crotalaria incana	0.11	0.15	0.03	0.05
Crotalaria vallicola	0.01	0.03	-	-
Harpachne schimperi	2.78	0.45	1.43	2.30
Crotalaria tanganyikensis	0.48	0.20	0.43	0.69
Cassia hildebrandtii	0.01	0.01	-	-
Oldenlandia scopulorum	0.32	0.06	0.05	0.08
Conyza stricta	0.17	0.04	-	-
Eragrostis tenuifolia	1.07	0.26	0.85	1.37
Cyperus rigidifolius	0.54	0.09	0.05	0.08
Eragrostis inamoena	0.75	0.36	0.08	0.13
Conyza schimperi	0.06	0.05	-	-
Heliotropium steudneri	0.29	0.01	0.10	0.16
Justicia sp.	1.08	0.44	0.23	0.37
Cassia mimosoides	0.08	0.45	0.03	0.05
Helichrysum glumaceum	0.01	0.01	-	-

Species	density/m2	frequency	%cover	% rel. cover
Cynoglossum coeruleum	0.03	0.05	-	-
Kyllinga sp.	0.42	0.25	0.40	0.64
Phyllanthus rotundifolius	0.14	0.01	-	-
Sida arneifolia	0.21	0.16	0.35	0.56
Commelina benghalensis	0.25	0.23	0.10	0.16
Chloris gayana	0.49	0.19	0.50	0.82
Monsonia angustifolia	0.01	0.03	-	-
Oxygonum sinuatum	0.03	0.04	-	-
Amaranthus sp.	0.04	0.03	-	-
Portulacca kermesina	0.09	0.06	0.03	0.05
Achryanthes aspera	0.02	0.03	0.05	0.08
Aerva lanata	0.13	0.14	0.03	0.05
Chenopodium schraderianum	0.01	0.03	-	-
Solanum incanum	0.78	0.31	0.50	0.82
Dyschoriste radicans	0.01	0.01	-	-
Tagetes minuta	0.01	0.01	-	-
Psiadia punctulata	0.14	0.03	0.13	0.21
Ocimum suave	0.04	0.04	0.03	0.05
Setaria sphacelata	0.03	0.01	-	-
Abutilon mauritianum	0.04	0.03	-	-
Commelina africana	0.04	0.03	-	-
Polygala sphenoptera	0.01	0.01	-	-
Wahlenbergia abyssinica	0.02	0.01	-	-
Hypoestes verticillaris	0.04	0.03	-	-
Fuerstia africana	0.04	0.01	0 08	0.13
Setaria verticillata	0.01	0.01	-	-

Species	density/m2	frequency	%cover	% rel. cover
Indigofera bogidanii	0.01	0.01	-	-
Rhynchelytrum repens	0.01	0.01	-	-
Plectranthus sp.	0.01	0.01	-	-
Panicum maximum	0.04	0.01	-	-
Aspilia pluriseta	0.26	0.16	0.15	0.24
Total			62.08%	100.00%

Table 7b: The frequency, density, percentage species composition and basal area for the woody species in community A

Species	frequency	density/ha	%composition	basal m²/ha
Tarchonanthus camphoratus	0.30	90.01	80.36	2.50
Acacia drepanolobium	0.20	28.16	19.64	0.01

2.3.1 (b) Vegetation community B: *Hyparrhenia/ Digitaria/Tarchonanthus/ Acacia* shrubland

This occurred around the central tower as one moved from the flat deep section of the Njorowa Gorge. The vegetation was dense with T. camphoratus and A. drepanolobium being the common woody species (table 8b), though the former dominated. Both had a height of about 3 - 4m. Hyparrhenia sp. and Digitaria scalarum were the dominant herbaceous species, with high frequency and per cent relative cover (table 8a). Cynodon dactylon, Themeda triandra, Felicia muricata, Indigofera tanganyikensis, Eragrostis inamoena and Oldenlandia scopulorum were common as indicated by their frequency values. Other species had lower densities and frequency values. Between this community and community C was a large open area dominated by tall dense C. dactylon, and, in some places, by D. scalarum mixed with a variety of herbaceous species.

2.3.1 (c) Vegetation community C: *Themeda/ Tarchonanthus/Acacia* dwarf shrubland

An extensive open shrubland with varying topography which included several valleys opening into vegetation community A. Most of the plant species in this community were collected from these valleys which formed micro - habitats. A. drepanolobium and T. camphoratus were the frequent woody species with the latter constituting the highest percentage (table 9b). Rhus natalensis was also present but its frequency and density were low. It was dominated by Themeda triandra, Digitaria scalarum and Hyparrhenia sp. (Table 9a). Cynodon dactylon and Felicia muricata were common, and frequently occurred in clumps. Hyparrhenia sp. was the dominant species on the slopes with shallow, partially weathered soils. T. triandra was widely distributed and had grown to a height of greater than 60cm in certain areas, but less than 20 cm where it was heavily grazed. Open areas covered by grass species mainly C.

Table 8a : The density, frequency, percentage cover and relative cover of herbaceous species in Community B

Species	density/m2	frequency	%cover	%rel. cover
Felicia muricata	0.06	0.59	0.67	1.29
Digitaria scalarum	–	0.89	16.50	31.96
Indigofera tanganyikensis	1.65	0.67	–	–
Themeda triandra	–	0.60	1.25	2.42
Chloris gayana	0.07	0.16	–	–
Kyllinga sp.	0.32	0.26	–	–
Eragrostis mamoena	0.45	0.50	0.40	0.77
Indigofera spicata	0.04	0.03	–	–
Aerva lanata	0.01	0.03	–	–
Justicia sp.	0.04	0.30	–	–
Phyllanthus ratundifolius	0.01	0.02	–	–
Oldenlandia scopulorum	0.92	0.45	–	–
Panicum maximum	0.04	0.39	0.01	0.02
Cassia mimosoides	0.01	0.04	–	–
Hyparrhenia sp.	1.10	0.89	32.06	62.10
Linum volkensii	0.02	0.04	–	–
Polygala sphenoptera	0.01	0.02	–	–
Aristida adoensis	0.02	0.01	–	–
Harpachne schimperi	0.10	0.50	0.06	0.12
Euphorbia inaequlatera	0.01	0.04	–	–

Species	density/m^2	frequency	%cover	%rel. cover
Aristida keniesis	0.21	0.23	0.03	0.06
Satureia bifrola	0.01	0.02	–	–
Zornia setosa	0.01	0.02	–	–
Oxygonum sinuatum	0.01	0.03	–	–
Heliotropium steudneri	0.16	0.26	–	–
Plectranthus barbatus	0.02	0.04	–	–
Cynodon dactylon	–	0.40	0.65	1.26
Total			51.63%	100.00%

Table 8b: The frequency, density, percentage species composition and basal area for the woody species in community B

Species	frequency	density/ha	%composition	basal area m^2/ha
Tarchonanthus camphoratus	1.00	578.23	58.40	38.55
Acacia drepanolobium	0.83	154.86	41.60	2.44

Table 9a: The mean density, frequency, percentage cover and relative cover of herbaceous species in Community C

Species	density/m2	frequency	%cover	%rel. cover
Digitaria scalarum	-	0.75	15.95	26.46
Cynodon dactylon	-	0.35	1.28	2.12
Themeda triandra	-	0.90	31.62	52.45
Solanum incanum	0.01	0.10	-	-
Justicia sp.	0.01	0.13	-	-
Hyparrhenia sp.	1.09	0.64	10.45	17.33
Harpachne schimperi	0.01	0.02	-	-
Indigofera tanganyikensis	0.02	0.04	-	-
Eragrostis inamoena	0.10	0.03	-	-
Felicia muricata	0.60	0.35	0.89	1.48
Aristida keniensis	0.02	0.12	-	-
Kyllinga sp.	0.01	0.05	-	-
Eragrostis tenuifolia	0.06	0.11	0.05	0.08
Cassia mimosoides	0.03	0.06	-	-
Oldenlandia scopulorum	0.62	0.14	-	-
Helichrysum glumaceum	0.01	0.06	-	-
Chloris gayana	0.05	0.16	0.05	0.08
Ocimum suave	0.30	0.07	-	-
Euphorbia inaequilatera	0.10	0.17	-	-
Abutilon mauritianum	0.02	0.09	-	-
Walhenbergia abyssinica	0.09	0.05	-	-
Linum volkensii	0.08	0.05	-	-
Indigofera spicata	0.06	0.08	-	-

Species	density/m2	frequency	%cover	%rel. cover
Dyschoriste radicans	0.07	0.11	-	-
Monsonia angustifolia	0.01	0.01	-	-
Plectranthus barbatus	0.09	0.10	-	-
Helichrysum cymosum	0.05	0.10	-	-
Bulbine abyssinica	0.02	0.04	-	-
Crotalaria tanganyikensis	0.02	0.09	-	-
Total			60.29	100.00%

Table 9b: The frequency, density, percentage species composition and basal area for the woody species in community C

Species	frequency	density/ha	%composition	basal area m²/ha
Acacia drepanolobium	0.98	296.94	34.89	0.46
Tarchonanthus camphoratus	0.82	443.40	62.59	5.07
Rhus natalensis	0.12	21.43	2.52	0.12

dactylon and D. scalarum were common and some of them were abandoned Masai homesteads. Overall vegetation cover was 60 percent and woody species did not contribute significantly to the cover.

The zone appeared to have had periodic burning in the past as evidenced by partially burnt T. camphoratus stumps. During the study, an extensive portion of the vegetation was burnt. The fire had spread from a neighbouring area outside the park where the Masai had set the vegetation on fire presumably to have it sprout afresh during the rains. Such fires, if frequent, can cause considerable changes in the vegetation, especially eliminating the fire intolerant species. It has been postulated that annual fires are responsible for maintaining Themeda, both in East and South Africa (Phillips, 1930; Edwards, 1951; Heady, 1966, quoted in Kahurananga, 1979). In the absence of fire, the species declines. If it is true that the zone had been subjected to frequent burning, then fire could be responsible for the high abundance of this species.

2.3.1 (d) Vegetation Community D: *Themeda/Digitaria/Tarchonanthus/Acacia* shrubland

This occurred at the south eastern part of the park, bordering Kedong Ranch and facing Mt. Longonot National Park. Vegetation was dominated by tall T. camphoratus 2.5 -3m). A. drepanolobium constituted 56 percent of the woody species composition (table 10b). Rhus natalensis though present, was rare with low frequency and density values.

Digitaria scalarum and Themeda triandra were the dominant herbaceous species (table 10a), and contributed significantly to the overall herbaceous cover. In certain areas, they had grown to a height of 60 - 80cm, forming thick mats on the ground. Other common species included Kyllinga sp., Indigofera tanganyikensis, Crotalaria tanganyikensis, Justicia sp., Harpachne schimperi, Polygala sphenoptera, Eragrostis inamoena, Oldenlandia scopulorum and

Table10a: The density, frequency, percentage cover and relative cover of herbaceous species in Community D

Species	density/m2	frequency	% cover	%rel. cover
Digitaria scalarum	-	0.80	21.82	31.06
Cynodon dactylon	-	0.13	3.51	5.00
Themeda triandra	-	0.91	30.53	43.47
Harpachne schimperi	0.57	0.42	0.8	1.14
Felicia muricata	0.18	0.16	0.53	0.76
Justicia sp.	0.47	0.56	0.31	0.44
Eragrostis inamoena	2.03	0.6	3.11	4.43
Aristida keniensis	0.33	0.29	0.13	0.18
Kyllinga sp.	0.49	0.58	1.07	1.52
Indigofera tanganyikensis	2.64	0.91	2.50	3.56
Euphorbia inaequilatera	0.38	0.49	0.18	0.26
Polygala sphenoptera	0.43	0.53	0.09	0.13
Crotalaria tanganyikensis	0.37	0.62	0.36	0.51
Indigofera spicata	0.08	0.16	0.18	0.26
Monsonia angustifolia	0.11	0.33	0.04	0.06
Solanum incanum	0.02	0.02	-	-
Satureia biflora	0.02	0.04	-	-
Eragrostis tenuifolia	0.06	0.04	0.36	0.51
Bulbine abyssinica	0.08	0.18	0.04	0.06
Helichrysum glumaceum	0.29	0.29	0.31	0.44
Chloris gayana	0.12	0.22	0.53	0.76

Species	density/m2	frequency	% cover	%rel. cover
Microchloa kunthii	0.25	0.02	0.36	0.51
Oldenlandia scopulorum	1.65	0.58	0.71	1.01
Sida arneifolia	0.02	0.02	-	-
Dyschoriste radicans	0.01	0.02	-	-
Portulacca kermesina	0.01	0.02	-	-
Cyperus rigidifolius	0.01	0.04	-	-
Heliotropium steudneri	0.01	0.02	-	-
Hyparrhenia lintonii	0.36	0.18	2.76	3.93
Plectranthus barbatus	0.01	0.02	-	-
Aristida adoensis	0.01	0.02	-	-
Commmelina benghalensis	0.02	0.07	-	-
Zornia setosa	0.04	0.09	-	-
Total			70.23	100.00%

Table 10b: The frequency, density, percentage species composition and basal area for the woody species in community D

Species	frequency	density/ha	%composition	basal area m^2/ha
Acacia drepanolobium	0.97	748.29	55.98	1.15
Tarchonanthus camphoratus	1.00	581.63	43.51	11.71
Rhus natalensis	0.13	6.80	0.51	0.06

Euphorbia inaequliatera. Cynodon dactylon was a common grass species with a high density, but its contribution to the herbaceous cover was low compared with D. scalarum and T. triandra. Total herbaceous cover was high, 70 per cent.

2.3.1 (e) **Vegetation community E: *Digitaria/Hyparrhenia Tarchonanthus/Dodonea* shrubland**

The zone was separated from other vegetation zones by the Njorowa Gorge, thus standing distinctively on its own next to the Elsa Gate (Fig. 10). T. camphoratus was the dominant woody species with a 52 per cent species composition (table 11b). A. drepanolobium and Dodonea latifolia were the next dominant species. D. latifolia had a patchy distribution with high concentrations in those areas where soils were shallow with a lot of gravel. Rhus natalensis was present but in low density and frequency. Towards Sulmac were relatively open grass dominated areas which appeared to have been cleared by man (pers. obs.).

Total herbaceous cover was 52 per cent. The dominant herbaceous species were Hyparrhenia sp., Themeda triandra and Digitaria scalarum (table 11a). Eragrostis inamoena, Crotalaria tanganyikensis, Indigofera tanganyikensis, Kyllinga sp., Chloris gayana, Euphorbia inacquilatera, Felicia muricata, Harpachne schimperi and Oldenlandia scopulorum were frequent as indicated by their frequency values. Their individual cover were however lower than those of the dominant species. Cynodon dactylon was sparsely distributed with low frequency values. Hyparrhenia sp. contributed significantly to the ground cover and appeared to favour gently sloping areas, where it was the dominant species.

Table 11a: The density, frequency, percentage cover and relative cover of herbaceous species in Community E

Species	density/m2	frequency	% cover	% rel. cover
Digitaria scalarum	-	0.60	18.4	32.96
Themeda triandra	-	0.77	7.60	13.61
Cynodon dactylon	-	0.03	0.33	0.59
Eragrostis inamoena	0.79	0.47	1.07	1.92
Hyparrhenia sp.	0.91	0.33	16.07	28.78
Cyperus rigidifolius	0.03	0.07	-	-
Chloris gayana	0.63	0.60	2.60	4.66
Kyllinga sp.	0.58	0.60	0.60	1.07
Eragrostis racemosa	0.08	0.13	-	-
Harpachne schimperi	0.53	0.53	1.00	1.79
Rhynchelytrum repens	0.43	0.27	1.47	2.63
Aristida keniensis	0.08	0.17	0.07	0.13
Dyschoriste radicans	0.04	0.01	-	-
Commelina africana	0.16	0.33	0.20	0.35
Indigofera tanganyikensis	2.25	0.70	0.60	1.07
Helichrysum glumaceum	0.36	0.27	0.27	0.48
Satureia biflora	0.14	0.23	-	-
Crotalaria tanganyikensis	0.68	0.63	0.40	0.72
Bulbine abyssinica	0.05	0.47	0.07	0.13
Cassia mimosoides	0.16	0.40	-	-
Plectranthus barbatus	0.48	0.27	0.27	0.48

Species	density/m2	frequency	% cover	% rel. cover
Euphorbia inaequilatera	0.48	0.67	0.2	0.35
Felicia muricata	0.75	0.47	2.47	4.42
Polygala sphenoptera	0.19	0.37	0.07	0.13
Oldenlandia scopulorum	0.76	0.50	0.27	0.48
Walhenbergia abyssinica	0.08	0.13	0.07	0.13
Hirpicium diffusum	0.05	0.03	-	-
Solanum incanum	0.01	0.03	-	-
Rhamphicarpa montana	0.07	0.13	-	-
Linum volkensii	0.01	0.03	-	-
Crotalaria incana	0.03	0.03	-	-
Justicia sp.	0.34	0.17	0.07	0.13
Monsonia angustifolia	0.09	0.27	0.13	0.25
Helichrysum cymosum	0.02	0.67	-	-
Hyharrhenia lintonii	0.13	0.13	1.53	2.74
Eragrostis tenuifolia	0.01	0.03	-	-
Total			55.83	100.00%

Table 11b: The frequency, density, percentage species composition and basal area for the woody species in community E

Species	frequency	density/ha	%composition	basal area m^2/ha
Acacia drepanolobium	0.76	243.62	19.55	0.83
Tarchonanthus camphoratus	1.00	430.74	51.89	6.89
Dodonea latifolia	0.45	285.71	22.93	0.20
Rhus natalensis	0.42	70.15	5.63	0.51

2.3.1. (f) Vegetation community F: *Digitaria/Tarchonanthus/Acacia* dwarf shrubland

This community occurred next to Sulmac and was hilly with steep slopes. To the east and south east were the dense T. camphoratus/ A. drepanolobium (community N) and open grassland (community A) respectively. Ground vegetation cover was mainly dominated by Themeda triandra, Digitaria scalarum and Hyparrhenia sp. (table 12a). Rhynchelytrum repens also contributed to the vegetation cover, although it was not evenly distributed like the other two species. Other common species included Harpachne schimperi, Justicia sp.,Indigofera tanganyikensis, Chloris gayana, Eragrostis inamoena, Microchloa kunthii and Euphorbia inaequilatera, but individual species cover were low compared with the three dominant grass species.

Like in other communities where it occurred, Hyparrhenia sp. was the most dominant species on the steep slopes. Certain steep areas were sparsely vegetated and the soils had slightly been eroded. The valleys had a good vegetation cover with common species such as Cynodon dactylon, Solanum incanum and a variety of other species. T. camphoratus was the dominant woody species with a high percentage composition value (table 12b). A. drepanolobium was the next dominant species and Rhus natalensis was rare.

2.3.1. (g) Vegetation Community G: *Digitaria/Acacia* dwarf shrub grassland

A small flat area between Kedong Ranch and the open shrubland community C (Fig 10). Felicia muricata, Digitaria scalarum and Themeda triandra were the dominant species with high frequency, per cent cover values (table 13a). The latter two had high density but it was not possible to count individual plants. Harpachne schimperi, Indigofera spicata, Chloris gayana, Justicia sp., Oldenlandia scopulorum, Indigofera tanganyikensis and Cynodon dactylon were

Table 12a: The density, frequency, percentage cover and relative cover of herbaceous species in Community F

Species	density/m2	frequency	% cover	% rel. cover
Digitaria scalarum	-	0.53	21.80	28.24
Themeda triandra	-	0.63	19.20	24.87
Harpachne schimperi	0.37	0.37	1.67	2.16
Felicia muricata	0.13	0.23	0.40	0.52
Justicia sp.	0.40	0.53	0.27	0.35
Crotalaria tanganyikensis	0.35	0.46	0.80	1.04
Oldenlandia scopulorum	0.63	0.27	0.13	0.17
Eragrostis inamoena	0.35	0.37	1.27	1.65
Indigofera tanganyikensis	1.02	0.53	1.13	1.46
Euphorbia inaequilatera	0.38	0.40	0.13	0.17
Cassia mimosoides	0.12	0.27	-	-
Hyparrhenia sp.	0.44	0.23	9.60	12.43
Satureia biflora	0.22	0.23	0.40	0.52
Kyllinga sp.	0.12	0.27	0.20	0.26
Commelina benghalensis	0.06	0.13	-	-
Rhynchelytrum repens	-	0.23	5.13	6.64
Crotolaria incana	0.02	0.03	-	-
Cyperus rigidifolius	0.01	0.03	-	-
Chloris gayana	0.16	0.37	0.40	0.52
Euphorbia crotonoides	0.02	0.07	-	-
Helichrysum glumaceum	0.13	0.13	-	-

Species	density/m2	frequency	% cover	% rel. cover
Microchloa kunthii	0.09	0.33	0.53	0.69
Bulbine abyssinica	0.03	0.10	-	-
Plectranthus barbatus	0.26	0.07	0.07	0.09
Aerva lanata	0.10	0.07	0.27	0.35
Aristida keniensis	0.28	0.23	0.80	1.04
Heliotropium steudneri	0.04	0.07	-	-
Commelina africana	0.07	0.07	0.13	0.17
Brachiaria serrata	0.16	0.13	1.53	1.98
Hyparrhenia lintoniii	-	0.27	11.33	14.68
Polygala sphenoptera	0.11	0.20	-	-
Dyschoriste radicans	0.02	0.07	-	-
Total			77.19%	100.00%

Table 12b: The frequency, density, percentage species composition and basal area for the woody species in community F

Species	frequency	density/ha	%composition	basal area m²/ha
Tarchonanthus camphoratus	0.93	386.05	54.18	7.99
Acacia drepanolobium	0.83	319.73	44.87	1.57
Rhus natalensis	0.13	6.80	0.95	0.56

Table13a: The density, frequency, percentage cover and relative cover of herbaceous species in Community G

Species	density/m2	frequency	% cover	% rel. cover
Digitaria scalarum	-	0.89	16.74	30.20
Cynodon dactylon	-	0.31	4.06	7.32
Themeda triandra	-	0.86	8.29	14.96
Crotalaria tanganyikensis	0.13	0.26	-	-
Cyperus rigidifolius	0.34	0.23	0.21	0.41
Monsonia angustifolia	0.01	0.06	-	-
Helichrysum glumaceum	0.54	0.29	0.17	0.31
Oldenlandia scopulorum	3.74	0.77	1.54	2.78
Eragrostis inamoena	0.02	0.09	-	-
Polygala sphenoptera	0.19	0.20	0.06	0.11
Solanum incanum	0.04	0.06	-	-
Bulbine abyssinica	0.05	0.11	0.06	0.11
Conyza schimperi	0.01	0.03	-	-
Portulacca kermesina	0.09	0.03	-	-
Rhamphicarpa montana	0.01	0.03	-	-
Heliotropium steudneri	0.03	0.03	-	-
Felicia muricata	3.54	0.86	11.83	21.34
Harpachne schimperi	2.69	0.97	3.26	5.88
Indigofera tanganyikensis	3.95	0.80	0.74	1.34
Indigofera spicata	1.09	0.66	3.54	6.39
Justicia sp.	1.94	0.66	1.54	2.78
Sida schimperiana	0.01	0.06	-	-

Species	density/m2	frequency	% cover	% rel. cover
Eragrostis tenuifolia	0.35	0.29	0.40	0.72
Chloris gayana	0.30	0.49	1.31	2.36
Aristida keniensis	0.16	0.17	0.29	0.53
Kyllinga sp.	0.31	0.34	0.11	0.19
Euphorbia inaequilatera	0.30	0.40	0.06	0.11
Crotalaria massaiensis	0.46	0.51	1.09	1.97
Plectranthus barbatus	0.52	0.34	0.11	0.19
Total			55.41%	100.00%

also common and had high densities. The latter had uneven distribution. Crotalaria massaiensis was also frequent. Other herbaceous species had low density and frequency. Total herbaceous cover was 55 per cent.

Acacia drepanolobium was more abundant than Tarchonanthus camphoratus, and had a high per cent species composition value (table 13b). They were however sparsely distributed and their contribution to the ground cover was small.

2.3.1 (h) Vegetation Community H: *Themeda/Digitaria/Tarchonanthus/Acacia* shrubland

Between community F and J was an expanse of dense shrubland dominated by dense T. camphoratus which constituted 71 per cent of the woody species (table 14b). A. drepanolobium and Rhus natalensis were present but the latter was rare. Certain areas had been cleared for geothermal exploration. Digitaria scalarum, D. milanjiana and Themeda triandra were widely distributed and dominated the ground vegetation cover. T. triandra had grown to a height of 60 - 70 cm in certain areas. Hyparrhenia sp. was common with a relative cover of 14 per cent (table 14a). Although it was not as abundant as the other two species, it dominated on the steep slopes. C. tanganyikensis, I. tanganyikensis, E. inaequilatera, Chloris gayana, Hyparrhenia lintonii, Harpachne schimperi, Conyza stricta and Eragrostis inamoena were frequent though their densities and contribution to ground cover were low (table 14a).

2.3.1 (i) Vegetation Community J: *Hyparrhenia/Acacia/Tarchonanthus* dwarf shrubland

An extensive open shrubland with varying topography. It extended from Olkaria gate to the geothermal power station, ending at the sparsely vegetated rocky community L. Steam vents with diversified plant species were common.

Table 13b: The frequency, density, percentage species composition and basal area for the woody species in community G

Species	Frequency	density/ha	%composition	basal area m^2/ha
Tarchonanthus camphoratus	0.20	24.23	7.34	1.50
Acacia drepanolobium	0.50	51.60	92.66	0.12

Table 14a: The density, frequency, percentage cover and relative cover of herbaceous species in Community H

Species	density/m2	frequency	%cover	%rel. cover
Digitaria scalarum	-	0.61	29.66	28.78
Themeda triandra	-	0.96	31.61	30.69
Crotalaria tanganyikensis	0.18	0.42	0.28	0.27
Indigofera tanganyikensis	0.60	0.64	1.11	1.08
Kyllinga sp.	0.01	0.03	0.06	0.06
Cyperus rigidifolius	0.52	0.53	2.33	2.26
Euphorbia inaequilatera	0.47	0.47	0.11	0.10
Oldenlandia scopulorum	0.28	0.31	0.06	0.06
Eragrostis blepharoglumis	0.24	0.06	0.83	0.81
Harpachne schimperi	0.35	0.28	0.78	0.76
Abutilon mauritianum	0.08	0.14	-	-
Hyparrhenia sp.	0.49	0.31	14.11	13.71
Hypoestes verticillaris	0.19	0.11	1.50	1.46
Crotalaria incana	0.01	0.03	-	-
Eragrostis tenuifolia	0.34	0.19	1.61	1.56
Chloris gayana	0.19	0.36	1.50	1.46
Solanum incanum	0.06	0.14	-	-
Aristida keniensis	0.11	0.08	0.67	0.65
Aerva lanata	0.01	0.03	-	-
Harparrhenia lintonii	0.26	0.31	2.78	2.70
Cassia mimosoides	0.06	0.14	-	-
Polygala sphenoptera	0.03	0.14	-	-
Satureia biflora	0.15	0.19	-	-

Species	density/m2	frequency	%cover	%rel. cover
Conyza schimperi	0.01	0.03	-	-
Justicia sp.	0.13	0.11	0.11	0.10
Helichrysum cymosum	0.03	0.08	-	-
Eragrostis inamoena	1.20	0.36	1.16	1.13
Cyperus laevigatus	0.08	0.14	0.22	0.21
Rhychelytrum repens	-	0.19	7.94	7.71
Aristida adoensis	0.03	0.11	0.06	0.06
Dyschoriste radicans	0.07	0.14	0.06	0.06
Indigofera spicata	0.03	0.06	0.11	0.10
Conyza newii	0.87	0.36	3.28	3.18
Crotalaria deserticola	0.08	0.17	0.17	0.17
Cyperus rigidifolius	0.14	0.03	0.50	0.49
Felicia muricata	0.02	0.06	0.06	0.06
Monsonia angustifolia	0.01	0.03	-	-
Setaria sphacelata	0.01	0.03	0.33	0.32
Total			103.00%	100.00%

Table 14b: The frequency, density, percentage species composition and basal area for the woody species in community H

Species	frequency	density/ha	%composition	basal area m^2/ha
Tarchonanthus camphoratus	0.83	460.46	70.78	12.30
Acacia drepanolobium	0.73	187.50	28.82	2.17
Rhus natalensis	0.03	2.55	0.40	0.01

The zone was the main centre for the geothermal operations, and had therefore been cleared for power exploration purposes.

At the Olkaria gate was the geothermal village (X-2), where most of the natural vegetation particularly woody species had been cleared and were being replaced with exotic species under the geothermal vegetation rehabilitation programme. Hyparrhenia sp. was the dominant herbaceous species and contributed considerably to the herbaceous cover (table 15a).
T. triandra, C. gayana, D. scalarum and H. lintonii were the next common species and contributed significantly to the vegetation cover in relation to the rest of the herbaceous species.

A. drepanolobium constituted 63 per cent of the woody species, and T. camphoratus 36 per cent, but the latter dominate (table 15b). R. natalensis, T. camphoratus and other shrub species were frequently found in valleys.

2.3.1 (j) Vegetation Community K : *Hyparrhenia/Tarchonanthus/Acacia* shrubland.

This community extended from the Geothermal village to the north western and south western parts of the park near Elkariani Hill including Narasha area. T. camphoratus dominated the woody species with a high density and per cent species composition compared to other woody species (table 16b), and in certain areas had grown to a height of 3 - 4m. The undergrowth in such areas was well developed with species like Commelina africana, C. benghalensis, Oxygonum sinuatum and Setaria verticillata being common. Rhus natalensis was the second dominant species. Erica arborea was concentrated on a small rocky area but its overall abundance was low as indicated by the frequency value. This was the only community of the park with such a high concentration of this species. A. drepanolobium, Dodonea latifolia and Osyris compressa were less abundant.

Table 15a: The density, frequency, percentage cover and relative cover of herbaceous species in Community J

Species	density/m2	frequency	%cover	%rel. cover
Themeda triandra	-	0.48	4.50	8.38
Oldenlandia scopulorum	0.16	0.20	-	-
Chloris gayana	0.08	0.78	2.45	4.56
Eragrostis inamoena	0.10	0.60	1.10	2.06
Hyparrhenia lintonii	-	0.40	10.00	18.64
Indigofera tanganyikensis	0.09	0.23	-	-
Kyllinga sp.	0.26	0.15	0.05	0.09
Digitaria scalarum	-	0.38	6.96	12.96
Hyparrhenia sp.	1.28	0.80	26.48	49.32
Crotalaria tanganyikensis	0.03	0.10	-	-
Justicia sp.	0.28	0.33	-	-
Monsonia angustifolia	0.01	0.03	-	-
Dyschoriste radicans	0.10	0.05	0.50	0.93
Harpachne schimperi	0.58	0.28	0.60	1.11
Euphorbia inaequilatera	0.08	0.15	-	-
Polygala sphenoptera	0.09	0.25	-	-
Cassia mimosoides	0.08	0.15	-	-
Achyranthes aspera	0.09	0.13	-	-
Crotalaria deserticola	0.03	0.08	-	-
Linum volkensii	0.24	0.08	-	-
Solanum incanum	0.04	0.08	-	-
Plectranthus barbatus	0.06	0.10	-	-

Species	density/m2	frequency	%cover	%rel. cover
Bulbine abyssinica	0.01	0.03	-	-
Commelina benghalensis	0.04	0.08	-	-
Eragrostis cilianensis	0.45	0.33	0.95	1.77
Cyperus rigidifolius	0.04	0.13	-	-
Eragrostis tenuifolia	0.06	0.10	-	-
Satureia biflora	0.24	0.30	-	-
Felicia muricata	0.16	0.08	0.05	0.09
Commelina africana	0.03	0.08	-	-
Crotalaria chrysochlora	0.38	0.03	-	-
Cyperus laevigatus	0.10	0.10	-	-
Indigofera spicata	0.08	0.03	-	-
Hypoestes verticillaris	0.02	0.05	-	-
Helichrysum glumaceum	0.05	0.03	-	-
H. cymosum	0.03	0.08	-	-
Aristida adoensis	0.03	0.13	-	-
Setaria sphacelata	0.21	0.03	0.05	0.09
Rhamphicarpa montana	0.02	0.03	-	-
Total			53.69%	100.00%

Table 15b: The frequency, density, percentage species composition and basal area for the woody species in community J

Species	frequency	density/ha	%composition	basal area m^2/ha
Tarchonanthus camphoratus	0.83	188.78	36.19	8.22
Acacia drepanolobium	0.88	330.36	63.33	0.97
Rhus natalensis	0.05	2.55	0.48	0.01

Herbaceous species cover was about 71 per cent with Hyparrhenia sp. contributing the highest proportion (table 16a). It was the dominant herbaceous species. In certain areas, it assumed dominance over other species and grew as tall as 1 - 1.5 m. Digitaria scalarum, Themeda triandra and Cynodon dactylon were rare. This area seemed to have had a lot of human impact as indicated by abandoned Masai homesteads and Geothermal exploration sites. These open areas were heavily grazed by Masai domestic animals mainly Zebu cattle Bos taurus L., goats Cappra hirc.us L., sheep Ovis aries and donkeys Equus asinus L.

2.3.1 (k) Vegetation Community L. Sparsely Vegetated Rocky Zone

An extensive mass of unweathered rocks mainly of volcanic origin, with sparse vegetation. Most plant species were growing from crevices. A number of plant species such as Tarchonanthus camphoratus, Harpachne schimperi, Helichrysum glumaceum, Anselia gigantea, Ficus thoningii, Erica arborea, Anthospermum usambarensis, Euclea divinorum, Agauria salicifolia, Dissotis iruingiana, Dicranopteris linearis, Cymbopogon caesus, Dodonea latifolia and Rhus natalensis had managed to colonise certain areas. Massive rock outcrops made sampling impractical, hence only the common species were noted.

2.3.1 (l) Vegetation Community M: *Digitaria/Themeda/Tarchonanthus/Acacia* dwarf shrubland

This community occupied the highest part of the park including the Elkariani hill which was > 2240m high. It covered most of the western parts of the park bordering Kongoni Ranch. Certain areas had been cleared for Geothermal operations and by the Masai. In one abandoned Masai homestead near Elkariani hill, T. camphoratus had been cut clear leaving an extensive open area.

Table 16a: The density, frequency, percentage cover and relative cover of herbaceous species in Community K

Species	density/m^2	frequency	%cover	%rel. cover
Digitaria scalarum	-	0.18	1.70	2.38
Cynodon dactylon	-	0.03	-	-
Themeda triandra	-	0.05	0.30	0.42
Ramphicarpa montana	0.04	0.05	-	-
Eragrostis tenuifolia	0.25	0.15	0.80	1.12
Justicia sp.	0.42	0.18	0.60	0.84
Oldenlandia scopulorum	0.21	0.08	0.35	0.49
Felicia muricata	0.04	0.10	0.80	1.12
Harpache schimperi	1.83	0.28	3.15	4.41
Indigofera spicata	0.06	0.10	-	-
Abutilon mauritianum	0.01	0.05	-	-
Oxygonum sinuatum	0.01	0.03	-	-
Eragrostis inamoena	2.88	0.83	2.85	3.99
Pennisetum clandestinum	-	0.05	2.50	3.50
Hypoestes verticillaris	0.03	0.05	0.55	0.77
Chloris gayana	0.04	0.35	3.55	4.98
Setaria sphacelata	0.02	0.08	0.15	0.21
Solanum incanum	0.03	0.03	0.10	0.14
Satureia biflora	0.64	0.73	0.65	0.91
Plectranthus barbatus	0.06	0.18	0.05	0.07
Cyperus rigidifolius	0.08	0.15	0.20	0.28
Monsonia agustifolia	0.03	0.10	-	-
Commelina africana	0.02	0.03	-	-

Species	density/m2	frequency	%cover	%rel. cover
Euphorbia inaequilatera	0.01	0.05	-	-
Crotalaria incana	0.01	0.03	-	-
Rhynchelytrum repens	-	0.33	1.95	2.73
Indigofera tanganyikensis	0.08	0.15	0.10	0.14
Commelina benghalensis	0.09	0.23	0.05	0.07
Kyllinga sp.	0.08	0.13	0.05	0.07
Hyparrhenia sp.	1.33	0.80	43.10	60.36
Crotalaria chrysochloa	0.74	0.33	0.20	0.28
Brachiaria serrata	0.09	0.20	0.55	0.77
Crotalaria deserticola	0.04	0.13	0.05	0.07
Helichrysum cymosum	0.04	0.15	-	-
Walhenbergia abyssinica	0.04	0.10	-	-
Conyza newii	0.06	0.15	0.10	0.14
Zornia setosa	0.01	0.03	0.10	0.14
Dyschoriste radicans	0.01	0.05	0.05	0.07
Conyza schimperi	0.06	0.03	0.05	0.07
Achyranthrus aspera	0.02	0.03	0.10	0.14
Hyparrhenia lintonii	0.96	0.75	6.65	9.32
Total			71.40%	100.00%

Table 16b: The frequency, density, percentage species composition and basal area for the woody species in community K

Species	frequency	density/ha	%composition	basal area m²/ha
Tarchonanthus camphoratus	0.98	646.86	69.24	19.54
Acacia drepanolobium	0.23	17.86	2.58	1.13
Dodonaea latifolia	0.05	2.55	0.37	0.02
Rhus natalensis	0.68	118.62	17.13	0.27
Osyris compressa	0.05	2.55	0.55	0.26
Erica arborea	0.20	71.43	10.31	1.97

Digitaria scalarum and Themeda triandra were the dominant grass species (table 17a). Hyparrhenia sp., Eragrostis inamoena and Hyparrhenia lintonii were the next common species. Euphorbia inaequilatera, Polygala sphenoptera, Harpachne schimperi, and Setaria sphacelata were abundant but did not contribute significantly to the ground cover compared with other species.

Both A. drepanolobium and T. camphoratus were common. They occurred in low densities (table 17b), but T. camphoratus was dominant and occurred in dense clumps in certain areas. Rhus natalensis was present but rare.

2.3.1 (m) Vegetation Community N : *Digitaria/Tarchonanthus/Acacia* shrubland

A small vegetation community between the open grassland A and the open scrubland community F (Fig. 10). It was relatively flat, and appeared to be an "arm" of the Njorowa Gorge. Compared with community B, D, and K, it was relatively open particularly at the transition zone between it and the open grassland. Digitaria scalarum was the dominant herbaceous species (table 18a). Themeda triandra and Hyparrhenia lintonii were the next dominant species. Other common species included Indigofera tanganyikensis, Euphorbia inaequilatera, Oldenlandia scopulorum, Harpachne schimperi and Crotalaria tanganyikensis. Cynodon dactylon occurred in small widely spaced dense clumps. In the heavily grazed open areas, D. scalarum and T. triandra were short but attained a height of 20 - 30 cm where they were ungrazed. T. camphoratus was the dominant species (table 18b). A. drepanolobium was the next dominant species while Rhus natalensis was rare.

Table 17a: The density, frequency, percentage cover and relative cover of herbaceous species in Community M

Species	density/m2	frequency	%cover	%rel. cover
Digitaria scalarum	-	0.69	24.86	31.05
Eragrostis racemosa	0.19	0.26	0.97	1.21
Crotalaria incana	0.01	0.03	-	-
Eragrostis tenuifolia	0.34	0.14	2.34	2.92
Oldenlandia scopulorum	0.31	0.29	-	-
Harpachne schimperi	0.46	0.40	0.40	0.50
Justicia sp.	0.11	0.04	-	-
Euphorbia inaequilatera	0.52	0.40	-	-
Themeda triandra	-	0.89	22.91	28.62
Commelina africana	0.09	0.14	-	-
Aristida adoensis	0.14	0.20	0.69	0.86
Kyllinga sp.	0.03	0.03	-	-
Eragrostis inamoena	3.59	0.71	5.89	7.36
Crotalaria tanganyikensis	0.09	0.23	-	-
Dyschoriste radicans	0.2	0.29	-	-
Hyparrhenia sp.	0.54	0.43	11.03	13.78
Polygala sphenoptera	0.20	0.37	-	-
Setaria sphacelata	0.23	0.40	-	-
Hyparrhenia lintonii	-	0.37	8.11	10.13
Satureia biflora	0.10	0.23	-	-
Plectranthus barbatus	0.06	0.09	-	-
Felicia muricata	0.03	0.09	-	-

Species	density/m^2	frequency	%cover	%rel. cover
Chloris gayana	0.12	0.3	2.86	3.57
Walhenbergia abyssinica	0.03	0.06	-	-
Commelina benghalensis	0.01	0.06	-	-
Solanum incanum	0.29	0.14	-	-
Achyranthes aspera	0.66	0.09	-	-
Monsonia angustifolia	0.01	0.06	-	-
Oxygonum sinuatum	0.01	0.03	-	-
Cyperus laevigatus	0.04	0.03	-	-
Cynodon dactylon	-	0.03	-	-
Cyperus rigidifolius	0.02	0.03	-	-
Abutilon mauritianum	0.01	0.03	-	-
Conyza schimperi	0.01	0.06	-	-
Aristida keniensis	0.01	0.03	-	-
Hypoestes verticillaris	0.01	0.03	-	-
Total			80.06%	100.00%

Table 17b: The frequency, density, percentage species composition and basal area for the woody species in community M

Species	frequency	density/ha	%composition	basal area m^2/ha
Tarchonanthus camphoratus	0.96	380.40	60.10	8.92
Acacia drepanolobium	0.90	293.37	39.72	1.28
Rhus natalensis	0.03	1.46	0.18	0.51

Table 18a: The density, frequency, percentage cover and relative cover of herbaceous species in Community N

Species	density/m^2	frequency	%cover	%rel. cover
Digitaria scalarum	-	0.94	27.35	55.15
Themeda triandra	-	0.83	6.45	13.01
Cynodon dactylon	-	0.03	0.06	0.12
Chloris gayana	0.15	0.32	0.19	0.38
Kyllinga sp.	0.15	0.29	-	-
Harpachne schimperi	0.89	0.58	1.03	2.08
Aristida keniensis	0.13	0.32	-	-
rhynchelytrum repens	0.02	0.03	-	-
Hyparrhenia lintonii	1.32	0.65	7.09	14.3
Eragrostis tenuifolia	0.03	0.03	0.13	0.26
Justicia sp.	0.26	0.29	0.32	0.65
Oldenlandia scopulorum	0.43	0.55	0.32	0.65
Polygala sphenoptera	0.13	0.23	-	-
Cassia mimosoides	0.29	0.29	0.39	0.79
Felicia muricata	0.10	0.16	1.29	2.60
Euphorbia inaequilatera	0.38	0.64	0.13	0.26
Commelina benghalensis	0.01	0.03	-	-
Helichrysum glumaceum	0.15	0.13	0.06	0.12
Indigofera spicata	0.01	0.03	-	-
Aerva lanata	0.08	0.03	-	-
Phyllanthus rotundifolius	0.02	0.06	-	-
Abutilon mauritianum	0.06	0.06	-	-

Species	density/m2	frequency	%cover	%rel. cover
Solanum incanum	0.05	0.03	-	-
Eragrostis inamoena	0.12	0.29	0.13	0.26
Indigofera taganyikensis	8.49	0.96	3.29	6.63
Crotalaria tanganyikensis	0.67	0.74	0.39	0.79
C .chrysochlora	0.04	0.06	-	-
Plectranthus barbatus	0.01	0.03	-	-
Linum volkensii	0.01	0.03	-	-
Bulbine abyssinica	0.01	0.03	-	-
Cyperus rigidifolius	0.10	0.09	0.13	0.26
Hyparrhenia sp.	0.02	0.03	0.84	1.69
Hirpicium diffusum	0.06	0.03	-	-
Rhamphicarpa montana	0.04	0.03	-	-
Total			49.59%	100.00%

Table 18b: The frequency, density, percentage species composition and basal area for woody species in community N

Species	frequency	density/ha	%composition	basal area m^2/ha
Tarchonanthus camphoratus	1.00	320.40	67.81	9.95
Acacia drepanolobium	0.58	180.02	32.00	0.94
Rhus natalensis	0.03	1.28	0.19	0.01

2.3.2 SUMMARY OF VEGETATION COMMUNITIES

2.3.2 (a) *Cynodon/Digitaria* grassland and *Digitaria/Acacia* dwarf shrub grassland (Community A and G)

Compared with the other two vegetation types, the grassland occupied a small proportion of the park. It occurred in two main areas, the Njorowa Gorge (vegetation community A) and Vegetation community G. The two were separated by a small stretch of open Tarchonanthus camphoratus/ Acacia drepanolobium shrubland. The dominant species were D. scalarum, C. dactylon, T. triandra and Felicia muricata. These species had a high density and contributed the largest proportion of the ground cover. Other common species included Harpachne schimperi, Chloris gayana, Justicia sp., Indigofera tanganyikensis, Euphorbia inaequilatera, Eragrostis tenuifolia, Oldenlandia scopulorum and Indigofera spicata, but their density and cover were lower than those of the dominant species.

Cynodon dactylon was more abundant in community A than G, and grew to a height of 40 -70cm in certain areas. Felicia muricata was widely distributed with a high density. T. camphoratus and A. drepanolobium were the common woody species, but sparsely distributed with low densities compared with the open and dense communities.

2.3.2 (b) Dense and Open *Tarchonanthus camphoratus/Acacia drepanolobium* vegetation types - community B,C,D,E,F,H,J,K,M and N

These were the common vegetation types and covered the largest part of the park. T. camphoratus and A. drepanolobium were the common woody species. They had a high density and the former was dominant. Other woody species such as Rhus natalensis, Erica arborea were present but in low frequency and density and were rare. In the dense community, T. camphoratus had higher densities than the open communities. In such areas, it had grown tall and variously branched at the base, forming a relatively closed crown cover, with well developed herbaceous undergrowth. A. drepanolobium was the next dominant species with higher density in the open community than in the dense communities. The ground cover was high in most communities, and was dominated by herbaceous species mainly Themeda triandra, Digitaria scalarum and Hyparrhenia sp. (table 2 and 3). Hyparrhenia lintonii was also dominant in the open T. camphoratus/ A. drepanolobium shrubland vegetation type. Cynodon dactylon, Felicia muricata, Indigofera tanganyikensis, Harpachne schimperi and Rhynchelytrum repens were the next dominant species. Other species were rare and had low density, frequency, percentage cover and relative cover. The communities were physiognomically different but their species composition were similar, although the species varied in density, frequency, cover and relative cover.

2.3.3 SOILS

A summary of the soil chemical and physical properties for each vegetation type are given in table 19 and 20 respectively. The amount of exchangeable bases (Na^+, Ca^{++} and Mg^{++}) were not significantly different (ANOVA, d.f. = 11,24, $p > 0.05$, in each case, table 19). There were no significant difference in the amount of percent total Nitrogen and Carbon among the communities (ANOVA, d.f. = 11, 24, $p > 0.05$ in each case, table 19). Both were however low in amount. pH ranged between 5.02 - 7.04, with most soils showing a tendency towards neutrality. C.E.C. was in general low, and its variation from community to community was slight. It was not significantly different among the communities (ANOVA, d.f. = 11, 24 $p > 0.05$ in each case, table 19). Overall, the soils were poor in exchangeable cations, and their amount did not vary significantly among the communities.

Table 19: *Soil chemical properties - Mean (±S.E.) exchangeable bases, per cent total Nitrogen and Carbon, C.E.C and pH*

Community	K^+ (meq/100g)	Na^+ (meq./100g)	Ca^{++} (meq./100g)	Mg^{++} (meq./100g)	total % N	total % C	C.E.C (meq./100g)
A	0.15±0.03	2.20±0.64	6.20±1.39	0.80±0.14	0.17±0.06	3.02±0.58	10.60±1.01
B	0.41±0.07	1.98±0.16	5.80±0.60	0.60±0.17	0.14±0.17	1.50±0.21	8.79±0.73
C	0.19±0.01	1.21±0.06	4.60±0.23	0.75±0.12	0.14±0.05	2.29±0.44	6.73±0.24
D	0.24±0.05	1.36±0.10	4.80±0.38	3.40±0.50	0.28±0.04	2.54±0.40	9.80±0.42
E	0.18±0.02	1.12±0.08	4.20±0.21	2.00±0.41	0.14±0.03	1.00±0.26	7.75±0.61
F	0.48±0.05	1.96±0.40	5.27±0.36	1.60±0.36	0.11±0.01	2.68±0.27	9.87±0.61
G	0.23±0.05	1.62±0.21	2.60±0.10	5.80±1.34	0.22±0.03	3.12±0.47	10.40±0.81
H	0.59±0.20	1.88±0.35	5.80±0.46	0.30±0.06	0.09±0.65	3.46±0.65	8.63±0.14
J	1.18±0.25	2.96±0.69	5.40±1.18	1.87±0.51	0.10±0.81	2.49±0.07	11.50±1.97
K	0.37±0.09	1.56±0.47	7.27±0.43	1.67±0.20	0.21±0.06	2.80±0.24	10.65±0.61
M	0.41±0.06	2.15±0.38	5.60±0.92	1.50±0.06	0.31±0.05	2.59±0.33	9.79±0.60
N	0.65±0.18	1.75±0.27	2.80±0.55	4.20±0.73	0.09±0.02	2.00±0.28	9.40±0.61
F	2.872 ns	1.897 ns	3.081 ns	2.596 ns	2.518 ns	2.521 ns	2.331 ns
n	36	36	36	36	36	36	36

d.f (11,24), p = 0.05 in each case, ns = no significant difference, S.E = standard error

F values for percentage total Nitrogen and Carbon are calculated after angular transformation of data

Community	pH	community	pH
A	6.49	F	7.04
B	6.33	G	6.86
C	6.66	H	5.43
D	6.20	J	5.02
E	6.23	K	6.16
M	6.43	N	5.78

Table 19: Soil chemical properties - Mean (±S.E.) exchangeable bases, per cent total Nitrogen and Carbon, C.E.C and pH

Community	K+ (meq/100g)	Na+(meq./100g)	Ca++(meq./100g)	Mg++(meq./100g)	total % N	total % C	C.E.C (meq./100g)
A	0.1[illegible]±0.03	2.20±0.64	6.20±1.39	0.80±0.14	0.17±0.06	3.02±0.58	10.60±1.01
B	0.41±0.07	1.98±0.16	5.80±0.60	0.60±0.17	0.14±0.17	1.50±0.21	8.79±0.73
C	0.19±0.01	1.21±0.06	4.60±0.23	0.75±0.12	0.14±0.05	2.29±0.44	6.73±0.24
D	0.24±0.05	1.36±0.10	4.80±0.38	3.40±0.50	0.28±0.04	2.54±0.40	9.80±0.42
E	0.18±0.02	1.12±0.08	4.20±0.21	2.00±0.41	0.14±0.03	1.00±0.26	7.75±0.61
F	0.48±0.05	1.96±0.40	5.27±0.36	1.60±0.36	0.11±0.01	2.68±0.27	9.87±0.61
G	0.23±0.05	1.62±0.21	2.60±0.10	5.80±1.34	0.22±0.03	3.12±0.47	10.40±0.81
H	0.59±0.20	1.88±0.35	5.80±0.46	0.30±0.06	0.09±0.65	3.46±0.65	8.63±0.14
J	1.18±0.25	2.96±0.69	5.40±1.18	1.87±0.51	0.10±0.81	2.49±0.07	11.50±1.97
K	0.37±0.09	1.56±0.47	7.27±0.43	1.67±0.20	0.21±0.06	2.80±0.24	10.65±0.61
M	0.41±0.06	2.15±0.38	5.60±0.92	1.50±0.06	0.31±0.05	2.59±0.33	9.79±0.60
N	0.65±0.118	1.75±0.27	2.80±0.55	4.20±0.73	0.09±0.02	2.00±0.28	9.40±0.61
F	2.872 ns	1.897 ns	3.081 ns	2.596 ns	2.518 ns	2.521 ns	2.331 ns
n	36	36	36	36	36	36	36

d.f (11,24), $p = 0.05$ in each case, ns = no significant difference, S.E = standard error

F values for percentage total Nitrogen and Carbon are calculated after angular transformation of data

Community	pH	community	pH
A	6.49	F	7.04
B	6.33	G	6.86
C	6.66	H	5.43
D	6.20	J	5.02
E	6.23	K	6.16
M	6.43	N	5.78

Table 20: Soil Texture-Mean (±S.E.) percentage sand, clay and silt for each community

Community	%Sand	%Clay	%Silt
A	52.52±0.26	12.02±0.41	35.46±0.14
B	60.74±1.38	5.22±0.77	34.04±1.83
C	56.40±3.36	12.78±2.58	30.83±1.19
D	61.56±0.82	5.16±0.82	33.28±1.64
E	61.88±0.55	10.48±0.55	27.64±1.11
F	54.73±0.99	14.07±0.83	31.21±0.75
G	57.56±0.82	10.66±0.41	31.78±1.23
H	45.27±3.89	15.45±2.69	39.28±1.64
J	50.87±1.76	12.11±1.42	37.02±2.33
K	49.85±7.35	14.45±3.43	35.70±4.19
M	43.54±9.38	13.34±3.56	43.12±5.83
N	54.02±0.14	7.16±0.29	38.82±0.44
F	2.684 ns	2.150 ns	2.383 ns
n	36	36	36

F values are calculated after angular transformation of the data
d.f = 11,24 in each case

ns = no significant difference P>0.05

each community

Community	%Sand	%Clay	%Silt
A	52.52±0.26	12.02±0.41	35.46±0.14
B	60.74±1.38	5.22±0.77	34.04±1.83
C	56.40±3.36	12.78±2.58	30.83±1.19
D	61.56±0.82	5.16±0.82	33.28±1.64
E	61.88±0.55	10.48±0.55	27.64±1.11
F	54.73±0.99	14.07±0.83	31.21±0.75
G	57.56±0.82	10.66±0.41	31.78±1.23
H	45.27±3.89	15.45±2.69	39.28±1.64
J	50.87±1.76	12.11±1.42	37.02±2.33
K	49.85±7.35	14.45±3.43	35.70±4.19
M	43.54±9.38	13.34±3.56	43.12±5.83
N	54.02±0.14	7.16±0.29	38.82±0.44
F	2.684 ns	2.150 ns	2.383 ns
n	36	36	36

F values are calculated after angular transformation of the data
d.f = 11,24 in each case

ns = no significant difference P>0.05

The three textural characteristics of the soils varied in all the communities (Mann Whitney U one tailed test, per cent sand vs per cent clay, per cent silt and per cent clay, U = 144, d.f. = 12, 12 $p < 0.05$ respectively). Sand was the highest followed by silt and clay the least. However, there was no significant difference in the amount of per cent sand, clay and silt among the communities (ANOVA, d.f. = 11, 24, $p > 0.05$ in each case, table 20).

2.4 DISCUSSION

2.4.1 Vegetation

Most communities had similar species composition. Herbaceous species were the most abundant and contributed significantly to the vegetation cover. They were more represented in terms of species numbers than the woody species. Only thirty six grass species were collected, which was low compared to other East African parks. Talbot (1956) collected one hundred grass species in the Serengeti Plains, Tanzania. The grass species composition of the grassland (in Hell's Gate) did not show any similarity to other important grasslands of East Africa. It was dominated by Themeda triandra, Cynodon dactylon, Digitaria scalarum and D. milaniiana. T. triandra, D. scalarum, D. milanjiana and Hyperrhenia sp. were the dominant grass species. They were widely distributed throughout the park and contributed the highest proportion of the ground cover in relation to other species, and were the most abundant grass species. Other herbaceous species varied in their density, frequency, percentage cover and relative cover among the communities. Plectranthus barbatus, Felicia muricata, C. dactylon, Eragrostis inamoena, Indigofera spicata, I. tanganyikensis and Harpachne schimperi were common species in many communities.

Hyparrhenia sp., usually occurred in extensive stands often mixed with a variety of herbs, and occasionally, D. scalarum and D. milanjiana but not T. triandra. It was common on steep and gentle slopes, and was not recorded on the flat areas. Such areas possibly provided the necessary soil conditions, thus influencing its spatial distribution. T. triandra, D. milanjiana and D. scalarum were growing together, occasionally intermingled with various herbs. They however showed a tendency of growing in extensive stands in certain areas. Their height, cover, and density varied from locality to locality. Where grazing intensity was high, either by wildlife or livestock, they were short, approximately 10-20 cm, and in moderate and less grazed areas, they were approximately 40-60 cm. They were common on gentle sloping flat areas, which could have been as a result of their soil condition requirements. Cynodon dactylon was the next common grass species, but had a patchy distribution unlike the other three species and preferred sites of fertile soils, especially the abandoned Masai homesteads. On such sites, it assumed dominance and grew tall to about 40-70 cm in certain areas. It was occasionally mixed with other herbs, Digitaria scalarum, D. milanjiana but not Hyparrhenia sp. and T. triandra. Competition was the likely cause for spatial ecological separation of the species from other grasses. Heavy grazing reduced the vigour of the species, forcing it to decline and disappear, giving way for other species especially T. triandra, D. milanjiana and D. scalarum. Similar soil preference observations of the species were made in Simanjiro Plains, Northern Tanzania (Kahurananga, 1979).

Tarchonanthus camphoratus and Acacia drepanolobium were the common woody species as indicated by their frequency and density values, with the former being dominant. They were widely distributed, occurring in all the communities, and contributed the highest proportion of the woody plants as indicated by their percentage species composition. As such, most of the mapped vegetation communities were dominated by the two species, where they occurred in high densities. Within the communities, there were spatial distribution and density variations corresponding to environmental heterogeneity, and they frequently occurred in clumps. Rhus natalensis was recorded in nine of the communities, but its overall density, frequency and percentage species composition were low compared to the other two species. Other trees and shrubs were rare and mostly occurred in valleys and in low densities.

Open and dense T. camphoratus/ A. drepanolobium vegetation types covered the largest part of the park, leaving only a small section which was covered by the grassland vegetation type. The latter occupied the Njorowa Gorge and a small area bordering Kedong Ranch, towards mount Longonot. According to Mueller-Dombois and Ellenberg (1974) no two communities, even adjacent vegetation stands' are similar in their species composition, but all mapped communities were very similar in their species composition. The species only varied in their frequency, density, percentage cover and relative cover. This indicated that the overall soil conditions were similar since climatic effects were equally felt in all the areas of the park. The only difference between them was the woody species density, and the physiognomic or structural appearance. In general , the dense communities had high and low density of T. camphoratus and A. drepanolobium respectively, and vice versa for the open communities. This was responsible for their structural differences. The two species had low densities in the grassland vegetation type which could have been as a result of topographic differences from the rest of the communities, but herbaceous species composition was very similar to other communities. Within communities there were repeated plant species assemblages corresponding to localised soils and topographic differences. Stalfelt (1972) and Whittaker (1967) suggested that spatial plant species distribution vary according to soil conditions.

Most communities had a good vegetation cover. Human interference in the form of Masai livestock and Olkaria Geothermal exploration activities had to a certain extent modified the vegetation cover and structure in certain areas. The vegetation had been subjected to previous human pressure as indicated by numerous recently abandoned Masai homesteads and frequent burnt T. camphoratus stumps.

Valleys were important habitat and had more species in relation to open areas. Their soils were better developed and being sheltered by steep slopes the soils remained moist even during dry months. Various steam vents occurred within the western part of the park. The soils and relative humidity were different from the surroundings and the vegetation was unique with common species such as Lycopodium cernum, Dissotis senegambiensis and Ophioglossum vulgatum. It is important to note that the comparatively small size of the park may have obscured any expected vegetation differences, with the result that the communities were very similar.

2.4.2. Soil Texture and Chemical Properties

All the vegetation communities had a high amount of sand which was to be expected since the study area lies in the Rift valley floor where the soil parent materials are predominantly volcanic in origin. In most areas, the soils were shallow, parent material was partially unweathered and the amount of gravel was high, suggesting that they were not fully developed. Much higher silt and clay contents and low sand fraction normally indicate greater soil maturity.

Climate, topography and the parent material were the factors influencing soil development, and were responsible for the soil characteristics of the communities. Annual rainfall amount was low, and temperatures were high, making weathering processes slow. Physical weathering was dominant over chemical and biological weathering which resulted in high amounts of sand, silt, gravel and a lot of unweathered material. Effects of biological weathering were localised and modified soils depending on the nature of the vegetation at a given site. Areas with thick vegetation, especially bushes, had better developed soils.

Topography, affected soil processes and development down the slopes, producing soil units with different properties. These varied in their particle sizes, consistency, structure and degree of compaction. This affected drainage, aeration, root growth and penetration ability. Soils on the lower sections of the slopes were deep and more weathered than the upper parts. Those at the middle were moderately developed. Very steep slopes had shallow poorly developed soils and in certain places little weathered. Flat areas such as the Njorowa Gorge had deep weathered soils with occasional unweathered materials.

The textural characteristic influenced the physical and chemical properties of the soil. Leaching and pH were not responsible for the low nutrients in the soils. The amount of rainfall per year was not significant for any nutrient leaching processes to occur, and the pH approached neutrality in most soils, and did not therefore affect nutrient availability. Heavy rain storms were rare, even when they occurred, the amount may not have been significant for any short-term leaching process to take place. High rainfall amounts affect leaching process and consequently the quantity of nutrients in a soil (Scott, 1962); Lind and Morrison, 1974). They were influenced by the nature of the parent material composition (chemical and mineralogical), its degree of weathering and the soil textural properties. The high amounts of sand, silt (which are mineralogically similar) and gravel made the soil- available nutrients to be low. Much sand in the soil improves aeration and drainage, but due to their low chemical activity, they provide low amounts of nutrients (Fitzpatrick, 1971). Gravel is generally slow weathered, provides few plant nutrients, holds insignificant amount of water, and is of low biological activity (Olivier and Boyd, 1973; Faniran and Areola, 1978; Kanwar, 1978). The clay proportion is important in that it provides colloidal particles to which water and soil nutrients can adhere, thus regulating their release (Fitzpatrick, 1971). Its amount in the soils was less than clay and silt.

Total percentage Nitrogen and Carbon were low, an indication of less organic matter in the soils. Scarcity of nodule leguminous plant species could also have caused the low Nitrogen amounts. Humus content in a soil is important because it affects both the physical and chemical properties of the soil, such as amount of Nitrogen, Carbon, soil texture, supply of bases, pH, water retention capacity and the cation exchange capacity (Braun-Blanquet, 1932). Climate and the nature of vegetation in turn affect the kind and quantity of humus. The humus content of arid soils is low, approximately one per cent (Hilgard, 1914). In the moist tropics, temperature and high moisture content favour complete decomposition and little humus accumulates. Most of the dead plant material in the park was partially or fully undecomposed. This was due to low water availability in the soils and hence less biological activity for any decomposition to occur. Where moisture content was high, such as under thick bushes, plant material was decomposed and the soils had high amounts of organic matter compared to adjacent areas.

The low C.E.C. values indicated the low potential of the soil to supply plant nutrients. It was affected by the soil texture and low organic matter content of the soils. Water availability is important for plant growth. The park lies in a dry zone which receives little rainfall. Due to the high amounts of sand, gravel and low clays contents, most of the rain water quickly percolated, leaving very little in the soils. If this was followed by a short spell of no rain, even a few days, the soils quickly dried up and this had profound effects on plant growth.

2.4.3 Distribution of Plant Communities

Soil patterns were not studied in order to produce a soil/vegetation map. The aim of analysing the soil physical and chemical properties was to help account for the distribution of the various identified plant communities. Soil properties were similar in all the communities and could not explain the distribution pattern on their own. This could have been due to the few replicates used during soil analysis (where $n_i = 3$ in each community). The distribution of the communities could have therefore been under the influence of an interplay of factors. This is supported by similar findings elsewhere. In the Serengeti plains, Tanzania, climate, grazing, burning and soil factors interacted differentially to influence the distribution of grassland types (Anderson and Talbot, 1965). Ball et al (1962, quoted in Moore and Chapman, 1986) found that soil description correlated with vegetation, but chemical analysis on its own did not fully account for the differences. Plant species can therefore develop ecotypes adapted to particular soil conditions and thus confuse simplistic association between species and soil chemical properties (Moore and Chapman, 1986).

Climate by influencing soil development produces different soil types and influence vegetation distribution. Areas with similar climatic conditions would thus be expected to have similar vegetation types. At the regional and local level, modifying factors such as biotic, aspect, elevation and topography become more important and in most cases account for the observed vegetation communities (Lind and Morrison, 1974; Fitzpatrick, 1983). Such natural and localised environmental factors can cause apparently identical vegetation (Phillips and Goodier, 1962; Greenway and Vessey-Fitzgearld, 1969; Moore and Chapman, 1986). Since there was no differential rainfall distribution, and considering the park size, the park should have one community type. This was not the case. Localised topographic and geologic differences may have been the factors influencing the distribution of the communities.

Topography, by influencing soil development and processes down a slope, produces compound soil units, whose properties are different. In most cases, each of these units has its characteristic vegetation community (Milne, 1935, 1947; Burtt, 1942; Radwanski and Ollier, 1959; Lang- Brown and Harrap, 1962; Calton, 1963). The park had a varied topography, and most parts were hilly with either gentle or steep slopes. The vegetation communities correlated with variation in topography. Areas with similar topography had similar vegetation communities, hence the similarity in most communities. Within a community, there were spatial variations in species composition and distribution, corresponding to small scale localised topographic and soil differences, such that the community could be viewed as being made up of micro- communities.

There were variations in soil physical properties along the slopes. With a few exceptions, most steep areas had shallow soils with a lot of gravel and unweathered rock material, while flat areas had relatively deep soils with little unweathered material. This affected soil drainage, aeration, root growth, root penetration ability and other related factors, and therefore influenced species distribution. There was a change in species composition down the slopes correlating with changes in soils. T. camphoratus which was the dominant woody species was site specific, although it was widely distributed. It appeared in high densities on gentle sloping areas with better developed soils but low in steep areas. On the flat ground, such as the grassland communities (A and G), it appeared towards the periphery at the transition zones where the slope was gentle. Other dominant species including T. triandra, D. milanjiana and D. scalarum and many other herbs were abundant on flat areas, less common in gentle sloping areas and almost absent on steep slopes. Cynodon dactylon had a patchy distribution, favouring abandoned Masai homesteads with deep, fertile soils and a lot soil moisture. Woody species like Scheffler abyssinica, Acacia xanthophloea and Euphobia kibwensis were common in valleys, where the soils were well developed, deep and of good drainage. Most of the mapped dense T. camphoratus/ A. drepanolobium communities therefore appeared on gentle sloping areas while open T. camphoratus/ A. drepanolobium types occurred on relatively steep ground. Grassland communities A and G were on flat ground where soils were deep and of good drainage.

Existing environmental variables may fail to explain the vegetation distribution due to past environmental changes and historical factors may account better for the observed distribution (Greig-Smith, 1983). The past history of the park before it was gazetted is therefore important. Masai people in the past used the area for livestock for livestock grazing. Grazing/browsing intensity by their animals, and frequent fires may have changed the vegetation communities by altering their structure and species composition. Throughout the park, there were several abandoned Masai homesteads, for example around the central tower between communities B and C, in communities M, C and H. In such areas, the soils were different from the surrounding, resulting in different vegetation types which were dominated by tall C. dactylon. Partially burnt T. camphoratus stumps were frequent in certain communities indicating fire outbreaks in the past. The operations of the Geothermal Station may have contributed to vegetation modification through clearing, especially around the "test wells". Some of them were abandoned, and their vegetation was different from the surrounding. While the effects of Masai livestock on vegetation modification may be decreasing, the expansion of the power station will inevitably continue to change the vegetation composition and structure.

CHAPTER III

3.0 POPULATION ESTIMATES OF LARGE HERBIVORES

3.1 INTRODUCTION

No form of wildlife management is possible without reliable information on the numbers , population dynamics and movement of animals concerned [Norton-Griffiths, 1978]. It is important to know the numbers in a population and how they are changing since effective wildlife management can be determined and assessed [Bull, 1981]. An idea of a species population size and its associated parameters is an important step in understanding its structure and dynamics [Seber, 1982].

Different authors have investigated different aspects of ground sampling methods and designs [Hayne, 1949; Dasmann and Mossman, 1962; Eberhardt, 1968; Gates, 1969; Hirst, 1969; Robinette et al., 1974]. Norton-Griffiths [1978] has given an account of various methods commonly used for animal census including factors that should be considered.

There are basically two methods of estimating the numbers in a population in any given area:

(a) determine the absolute number of individuals [total count], where the whole study area is searched and all animals counted.

This method has its associated disadvantages:

(i) actual counting is a problem depending on the herd size and behaviour of animal[s] in question. For example, a total count of a large herd of migratory wildebeest is next to impossible;

(ii) it is expensive and time consuming,

(iii) it is not suitable for large areas, and where vegetation and topography is such as to hinder accessibility and visibility, thus locating some of the animals is a problem.

Assumptions of the method include:

(i) all animals are located and accurately counted,

(ii) the whole area is searched.

(b) estimate the number of individuals [sample count], where representative parts of the study area are selected, searched and animals counted. Using the values obtained, the numbers of animals in the whole area is estimated. This method has several advantages and is the most widely used. It saves time, allows large census areas to be covered quickly, and if properly done, it can fulfil the objectives of the census. It is suitable where vegetation and topography hinder accessibility and visibility. It is cheaper, depending on the available resources, and is appropriate in censusing large migratory herbivore herds, where a total count is almost impossible.

Assumptions of this method are similar to those of total count method.

The choice of any counting method is a compromise between a number of factors including the size of the census area, vegetation type, the nature of the species being counted, terrain and availability of resources [Norton-Grifiths, 1978]. Since each technique has its own weakness and limitations, the use of several independent methods is important as checks of each other [Southwood, 1978]. The decision to use either a total count or sample count is not really choosing the "best" method but rather avoiding the "worst" [Norton-Grifiths, 1978].

Both total and road strip count [sample count] methods were used for animal censuses in this study. Censuses were done every first week of the month for a period of nine months.

3.2 METHODS

3.2.1 Total counts-park

Monthly total counts were carried out from October 1988 to June 1989. Counting began between 06.00 and 07.00 hours, subject to field logistic constraints. Due to the nature of the terrain, the park was divided into three major blocks in which census was done separately. These were further sub-divided into sub-blocks depending on the vegetation thickness and topography, thus facilitating counting. Each block/sub-block was scanned with an 8 x 30 pair of binoculars standing on top of a vehicle in order to have a better view. Every time a herd/individual of a large herbivore * was sighted, the following were recorded:

(a) the species name and number [n],
(b) sex [where possible],
(c) age class [either adult, sub-adult or juvenile],
(d) location on a 1 km x 1 km grid reference map of the park. * Dikdik was considered as the smallest herbivore.

Areas of rugged terrain and thick vegetation were combed on foot making sure minimal animal disturbance was made in order to count them before fleeing. Results of all blocks were pooled to make a single count per month.
Sexing was done by sighting either the sex organs, absence or presence of horns, body colouration and colour patterns, size and shape of horns or a combination of them. Juveniles were not easy to sex, and neither were sub-adults of kongoni, zebra, Thomson's gazelle and eland. Individual animals were categorised into age classes using either the size and shape of horns, body

size and body colouration or a combination of them. However, the small antelopes such dikdik, klipspringer, Thomson's gazelle, steinbuck and reedbuck were difficult to categorise. One could easily confuse sub-adults with adults depending on the age at which the former were.

The following assumptions were made:

(a) each block/sub-block was fully searched. The accuracy of this was difficult to assess, but was done to the best of the observer's ability.

(b) all individuals of a given species were located and accurately counted. This was also difficult to assess.

(c) animals did not move before detection, and none was counted more than once. Most animals were fleeing when approached, but due to the nature of the terrain and the numbers encountered at any single sighting, counting more than once was probably not done.

(d) sequential sampling took place in uniform habitats and weather conditions, there was a random distribution of individuals in the habitats, and the animals were uniformly conspicuous to the observer. The latter was not obvious depending on the colour and size of the animals. Dikdiks and warthogs were less conspicuous. So were klipspringers whose body colour matched with that of their rocky habitat. Since the park is situated in a semi-arid area, weather conditions did not change appreciably as to any effects on census success.

3.2.2 Road Strip Counts-Park

3.2.3 INTRODUCTION

Road counts are widely used in Africa as a method for indicating the relative abundance of game, and in some cases obtaining abundance of animal numbers [Dasmann and Mossman, 1962] However, they are open to bias and must be carried out carefully [Norton-Grifiths, 1978]. Transects have even been used to estimate population of birds [Gichuki, 1982; Collar and Goriup, 1983; Kamweya, 1986; Thomson, 1987; Mwangi, 1988]. Literature on this method has continued to expand [Hayne, 1949; Hirst, 1969; Anderson and Phosphala, 1970; Franzerb, 1981; Seber, 1982, 1986].

Many authors agree that the fixed transect width provides the best design if a reasonably large transect can be covered and all the animals within it detected [Norton- Grifiths, 1978]. It is efficient in censusing large areas [Jarvinen and Vaisanen, 1975; Emlen, 1977], distance estimation is less critical than if using variable width transect methods [Franzreb, 1981], thus avoiding the use of tape measures or range finders [Scott et al., 1981 quoted in Kamweya, 1986]. Further more, it is suitable for narrow habitat strips or patchy habitats, while recording observations and data analysis is relatively easy [Franzreb, 1981].

The greatest difficulty in making an accurate count of animals in any area using the road strip method is to prevent them leaving before they are counted and preventing others from coming in. It is not safe to assume that the out-going and in-coming animals will balance each other [Lee, 1938]. Dawson [1981] has reviewed the characteristics and limitations of strip and line transects as methods for estimating animal abundance. For example, the transects' width, distance between them and length of the counting period have profound influence on the counts obtained and consequently the density of wild animals, particularly game birds. Since then, many methods of estimating the density of non-game birds have been developed.

The theory of the transect strip sampling in estimating population of animals depends on certain basic assumptions [Emlen, 1977; Burhiam et al., 1980].

(a) animals are fixed at the initial sighting position, that is, they do not move before detection and none is counted more than once. Although no animals were counted twice, the kongoni, eland, warthog and Thomson's gazelle were fleeing at the sight of the observer and had to be approached carefully.

(b) The behaviour of animals in one portion of the strip does not influence those in another. This was a problem with the animals mentioned in (a) above, which fled upon seeing the observer, thus making other animals run out of or into the strip. They had to be approached carefully, and if necessary counted from a reasonable distance.

(c) animals directly on the strip boundaries are never missed. Such a situation never occurred.

(d) distances are measured without error, thus avoiding measurement and rounding errors,

(e) sightings are independent events,

(f) sequential sampling takes place in uniform habitat and weather conditions, there is a random distribution of individuals in the habitats and the animals are uniformly conspicuous to the observer,

(g) the response behaviour of the animals does not change appreciably throughout the study period. This was difficult to assess but the animals appeared to behave in the same way during the study.

(h) The response behaviour of individual of a species is similar regardless of sex and age. Again this was difficult to assess but individuals of agiven species seemed to behave in the same way irrespective of their sex or age.

3.2.4 Method

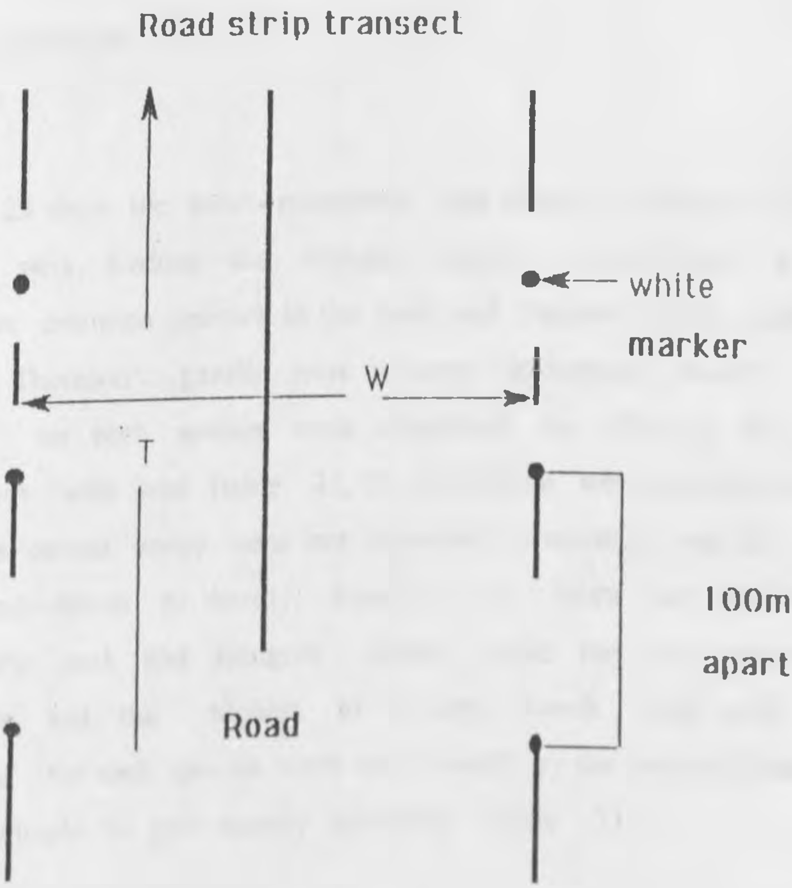
Road counts were carried out concurrently with the total counts. Due to the park terrain and vegetation thickness, the variable fixed width strip was considered appropriate [Norton-Grifiths, 1978]. Permanent transects of variable width [W] were selected at the beginning of the study using the existing road network, and their length [T] determined. White painted markers 100 m apart were then erected either 200m, 250m or 300m on either side of the road of the transects. These were constantly repainted to ensure that they were visible during each census.

The observer rode on top of a vehicle while another person did the driving. This enabled him to have a better view and concentrate on scanning and counting the animals using an 8 x 30 pair of binoculars. When a herd/individual of a large herbivore was encountered along the transects and within its boundaries the species and number[s] [n] were noted.

3.2.5 Census Outside the Park

3.2.6 Total Counts

Since the park was unfenced, there was a lot of animal movement between it and its adjacent areas [pers. obs.]. I therefore decided to carry out herbivore censuses outside the park in order to obtain an idea of their wildlife abundance I chose two areas which were favoured by wildlife, Kendong and Kongoni ranches [Fig. 6], and carried out total counts of large herbivore species for nine months. These were done concurrently with park counts on different days, but within the same week. The methods and assumptions were similar to those of total counts carried out in the park. Road counts were not done.



Where;

W = Width of the transect

T = Length of the transect

Total population estimate, N, for each species, for the entire census zone, Z, was calculated as;

$$N = nZ/TW$$

n = number of animals, recorded for each species

The population estimates for each species using the two methods were subjected to appropriate statistical test in order to test for any significant differences.

3.3 RESULTS

3.3.1 Population Estimates

3.3.2 Total Counts

Table 21, 22 and 23 show the mean population and density estimates of large herbivores in the park, Kedong and Kongoni Ranches respectively. Kongoni and zebra were the common species in the park and Kongoni Ranch, while the same species and Thomson's gazelle were common in Kedong Ranch.
Density estimates for each species were calculated by dividing the mean population estimates with area [table 21, 22, 23]. These were quite low, since large areas of the census zones were not occupied by animals yet they were included in the calculation of density. Kongoni and zebra had the highest density in both the park and Kongoni Ranch, while the two species and Thomson's gazelle had the highest in Kedong Ranch. The park mean population estimate for each species were also divided by the approximate area occupied by the animals to give density estimates [table 21].

Statistical test between the density of the park vs Kedong, park vs Kongoni Ranch and Kedong vs Kongoni Ranches showed no significant difference [Mann-Whitney U two tailed test, U = 78, d.f = [13, 11], U = 47, d.f = [13, 9], U = 37, d.f. = (11, 9), P > 0.05, respectively]. Animal movement between the park and Kedong Ranch was high but low for the park and Kongoni Ranch [pers. obs.].

3.3.3 Total vs Road Counts

Mean population estimates of large herbivores using total and road counts are given in table 24. Buffalo, klipsringer, reedbuck and dikdik were secretive and were therefore not estimated using the road strip method. The student's-t was used to test the accuracy of the two counting methods. There was a significant difference between mean population estimates of each species [two tailed t-test, P < 0.05].

Table 21: Mean ($\pm$S.E) population and density estimates of large herbivores in the park

Species	Mean	S.E	n	Density/Km^2 (total area) 68.25 Km^2	Density/Km^2 (utilised area) 12.5 Km^2
Kongoni	274	25	9	4.00	21.92
Zebra	128	7	9	1.91	10.24
Thomsons's gazelle	62	10	9	0.91	5.00
Grant's gazelle	21	9	8	0.31	1.70
Eland	36	7	6	0.53	2.88
Warthog	13	2	8	0.20	1.00
Buffalo	90	12	6	1.32	7.20
Steinbuck	10	1	8	0.15	0.80
Reedbuck	15	2	9	0.22	1.20
Klipspringer	8	2	6	0.12	0.64
Dikdik	10	1	6	0.15	0.80
Giraffe	8	1	8	0.12	0.64
Impala	3	1	3	0.04	0.24

Overall mean of herbivores = 587 S.E = 27

n = number of months a species was counted

S.E. = Standard error

Table 22: Mean (± S.E) population and density estimates of large herbivores in Kedong ranch (80 Km^2)

Species	Mean	S.E.	n	Density/Km^2
Kongoni	424	39	9	5.30
Zebra	333	43	9	4.16
Thomson´s gazelle	979	71	9	12.24
Grant´s gazelle	59	7	9	0.74
Eland	101	17	9	1.26
Giraffe	11	2	9	0.14
Impala	36	5	9	0.45
Warthog	8	1	6	0.10
Reedbuck	10	1	9	0.13
Wildebeest	1	0.1	5	0.01
Dikdik	10	2	6	0.13

Overall mean of herbivores= 1964   S.E = 12.0

n = number of months a species was counted

S.E = standard error

Table 23: Mean (± S.E) population and density estimates of large herbivores in Kongoni Ranch (54.63 Km^2)

Species	Mean	S.E	n	Density/Km^2
Kongoni	241	27	9	4.41
Zebra	402	35	9	7.36
Grant's gazzele	117	13	9	2.14
Thomson's gazzele	33	5	9	0.60
Eland	39	7	9	0.71
Impala	102	16	9	1.87
Giraffe	17	3	9	0.31
Reedbuck	8	2	6	0.15
Steinbuck	7	1	5	0.13

Overall mean of herbivores = 953

S.E = 75

n = number of months a species was counted

S.E = standard error

Table 24: Mean population estimates of large herbivores in the park using total and road counts

	Total Counts			Road counts				
Species	Mean	S.E	n	Mean	S.E.	n	d.f	t-test
Kongoni	274	25	9	544	43	6	13	2.632*
Zebra	128	7	9	313	40	6	13	3.220*
Thomson's gazelle	62	10	9	190	35	4	11	2.674*
Grant's gazelle	21	3	8	180	48	4	10	5.618*
Giraffe	8	1	8	78	18	5	11	2.745*
Eland	36	7	6	128	36	4	8	2.876*
Reedbuck	15	2	7	41	20	1	6	3.227*
Warthog	13	2	8	62	25	2	8	7.607*
Impala	3	1	3	22	10	1	5	4.336*

*· significant difference P<0.05

n = number of months a species was counted

S.E = standard error

3.3.4 Population Structure and Sex Ratios

A summary of population structure and sex ratios of the herbivores in the park, Kedong and Kongoni ranches is given in tables 25, 26, 27, 28, 29 and 30, respectively. Adults were dominant in most species except for the eland in Kedong Ranch and warthog in the park where juveniles featured prominently.

Only adult and sub-adult males and females were considered when calculating the sex ratios. These were subjected to G-test based on the expected 1:1 sex ratio hypothesis. Most species showed a significant difference from the expected ratio [table 28, 29 and 30]. Reedbuck, steinbuck, klispringer, dikdik and juveniles were hard to sex in the field, hence their sex ratios were not considered.

3.3.5 Distribution and Habitat Preference

The herbivores' distribution for all months were combined to produce a distribution map [Fig. 11]. Approximately 12.5 km^2 of the park was occupied by the large herbivores. Both the Poisson series and Chi-square were used to test the distribution type based on the hypothesis that the animals were randomly distributed. For the Poisson series, the mean is always equal to the variance [S^2]. Therefore, if:

a) mean $= S^2$, the distribution is random,

b) mean $> S^2$, the distribution is regular,

c) mean $< S^2$, the distribution is contiguous,

d) $S^2 = 0$, the distribution is perfectly regular.

Table 25: Percentage population structure of large herbivores in the park

Species	Adults	Sub-adults	Juveniles
Kongoni	76.6	7	16.4
Zebra	78.9	10.2	10.9
Thomson's gazelle	83.9	9.7	6.4
Grant's gazelle	52	36	12
Giraffe	62.5	25	12.5
Buffalo	51.7	25.9	22.4
Eland	36	42	22
Warthog	38.5	*	61.5

* not sighted

For Impala, Dikdik, Klipspringer and Reedbuck, only adults were sighted

Table 26: Percentage population structure of large herbivores in Kedong Ranch

Species	Adults	Sub-adults	Juveniles
Kongoni	78.3	6.6	15.1
Zebra	85.9	8.6	5.4
Thomson's gazelle	87.8	9.9	2.3
Grant's gazelle	74.6	22	3.4
Eland	19	31	50
Giraffe	78.6	14.3	7.1
Impala	66.7	26.2	7.1

For Reedbuck, Warthog and Dikdik, only adults were sighted

Table 27: Percentage population structure of large herbivores in Kongoni Ranch

Species	Adults	Sub-adults	Juveniles
Kongoni	81.9	5.8	12.3
Zebra	87.7	6.4	5.9
Thomson's gazelle	81.1	8.1	10.8
Grant's gazelle	69.7	20.2	10.1
Eland	44.7	30.6	24.5
Impala	71.3	20.4	8.3
Giraffe	50	30	20

For Steinbuck and Reedbuck, only adults were sighted

Table 28: Sex ratios of large herbivores in the park

Species	Adults F	Adults M	Sub-adults F	Sub-adults M	n	G test
Kongoni	70	140	8	11	229	23.678*
Zebra	27	74	5	8	144	22.694*
Eland	4	9	5	10	28	3.651 ns
Grant's gazelle	4	7	2	6	19	2.641 ns
Buffalo	15	32	16	7	70	0.915 ns
Thomson's gazelle	10	42	4	2	58	16.298*
Giraffe	2	3	-	2	7	1.328 ns
Warthog	2	3	-	-	5	0.201 ns
Impala	3	-	-	-	3	-

G-test is for all males compared to all females

* Significant difference P<0.05

ns no significant difference P>0.05

d.f = I in each case

Table 29: Sex ratios of large herbivores in Kedong Ranch

Species	Adults		Sub-adult		n	G test
	F :	M :	F	M		
Kongoni	132	200	10	18	360	16.175*
Zebra	106	18	10	19	315	22.129*
Eland	5	14	11	20	50	6.628*
Thomson's gazelle	260	600	35	62	957	144.423*
Grant's gazelle	10	34	4	9	57	15.469*
Giraffe	3	5	-	2	10	1.645 ns
Impala	7	17	3	6	33	5.225*
Warthog	3	5	-	-	8	0.505 ns
Wildebeest	1	-	-	-	1	-

G-test is for all males compared to all females

* Significant difference P<0.05

ns no significant difference P>0.05

d.f. = 1 in each case

Table 30: Sex ratios of large herbivores in Kongoni Ranch

Species	Adults		Sub-adults		n	G test
	F :	M	F :	M		
Kongoni	73	124	6	8	211	13.458*
Zebra	149	203	7	19	378	11.580*
Eland	4	13	4	8	29	6.040*
Giraffe	3	6	3	2	14	0.287 ns
Impala	23	50	10	11	94	8.471*
Thomson's gazelle	11	16	-	3	30	2.159 ns
Grant's gazelle	20	61	10	14	105	19.923*

G-test is for all males compared to all females

* Significant difference P<0.05

ns no significant difference P>0.05

d.f = 1 in each case

FIG 11: HELL'S GATE NATIONAL PARK: WILDLIFE DISTRIBUTION 1988/89

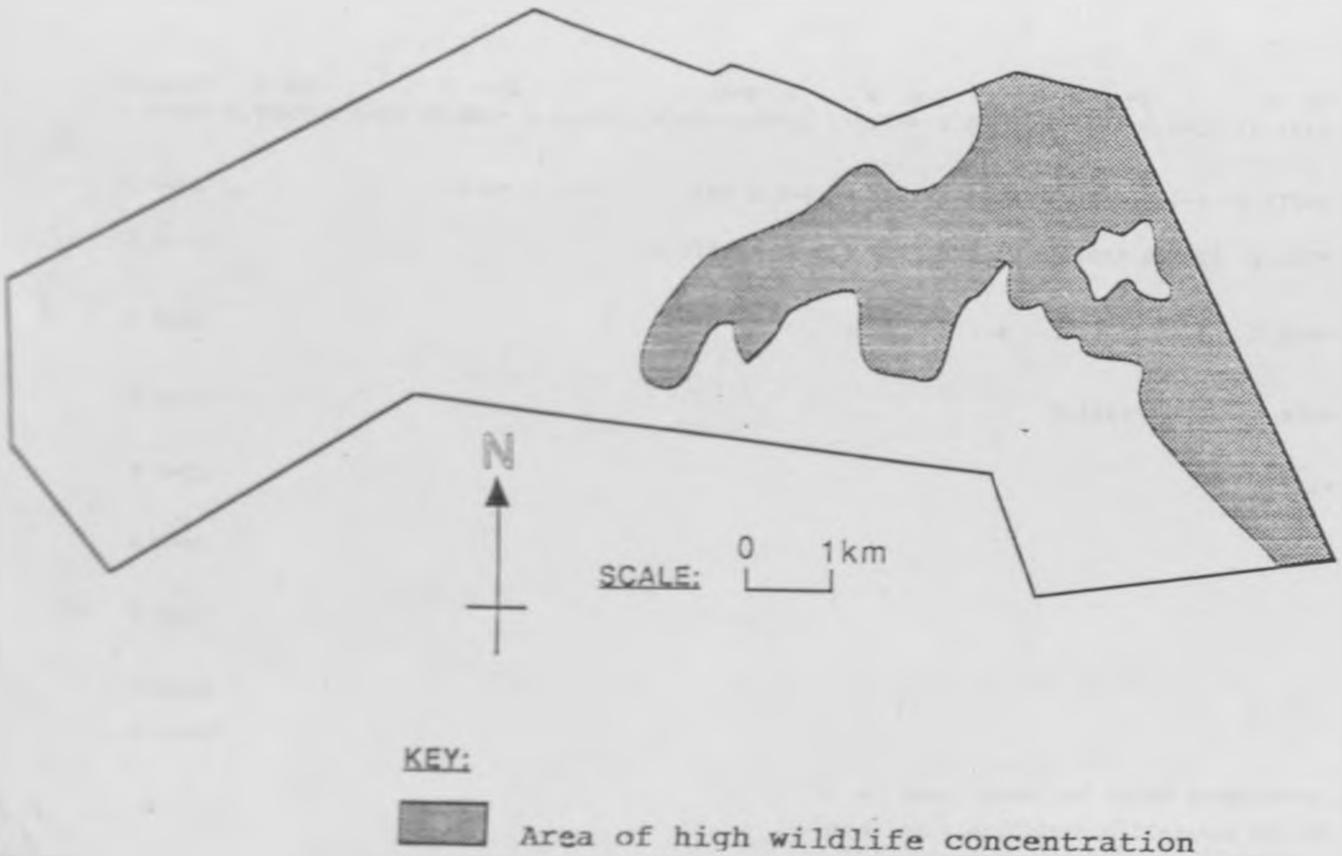


Table 31: Habitat Preference by large herbivores t-test

Habitat	B N=5	C n=12	D N=5	E N=5	F n=5	G n=7	H n=2	J n=4	N n=5
A N=250	8.984* d.f=12	12.484* d.f.=19	12.599* d.f=12	13.230* d.f=12	13.009* d.f=12	12.423* d.f=14	8.361* d.f=9	11.686* d.f=11	13.142* d.f=12
B N=[illegible]		2.632* d.f=10	4.745* d.f=8	5.735* d.f=12	5.368* d.f=8	1.575ns d.f=10	3.744* d.f=7	5.000* d.f=7	5.588* d.f=12
C N=121			12.025* d.f15	13.846* d.f=15	13.205* d.f=15	6.667* d.f=17	9.200* d.f=12	12.159* d.f=1	13.589* d.f=15
D N=39				5.417* d.f=8	3.478* d.f=8	7.258* d.f=10	5.128* d.f=5	4.138* d.f=7	1.58?ns d.f=8
E N=1[illegible]					5.556* d.f=8	9.831* d.f=10	0.667* d.f=5	4.667* d.f=7	4.905* d.f=8
F N=12						8.983* d.f=10	10.00* d.f=5	1.857*nsd.f=7	3.333* d.f=8
G N=[illegible]							5.701* d.f=7	8.382* d.f=9	9.412* d.f=10
H N=[illegible]								3.333* d.f=4	6.000* d.f=5
J N=10									3.667* d.f=7
N. N=37									

N = Mean number of large herbivores recorded in each habitat
ns = no significant difference P>0.05
* = significant difference P<0.05
n = number of large herbivore species sighted in each habitat

Table 32: Habitat Preference by large herbivores

Species	Number of habitats where sighted	Prefered Habitat(s)
Kongoni	7 (A,B,C,D,E,G,N)	A , G and C.
Zebra	10 (A,B,C,D,E,F,G,H, J,N)	A, G and C.
Thomson's Gazelle	4 (A, C, G, N)	A
Eland	5 (A,C,E,F,G)	C
Buffalo	2 (B,C) ,rarely in A	B
Grant's Gazelle	3 (A,C,G)	A and G
Klipspringer	4 (C,F,A,E)	C and F
Impala	2 (A,J)	rarely seen in the park
Giraffe	6 (A,C,D,G,H,J)	A , G, D and H.
Warthog	4 (A, B, C and N)	A and N.
Steinbuck	4 (C,D,F,J)	F and J.
Reedbuck	4 (C,D,E,N)	N and C.
Dikdik	3 (B,C,F)	B

Under the hypothesis, the observed distribution differed significantly from the expected [mean = 0.77, S^2 = 7.6588, chi-square = 37.938, d.f = 5, P < 0.05], thus having a contiguous dispersion.

During census, the location of each individual/group of herbivore[s] was recorded against the vegetation community. Total number of animals sighted in each vegetation community for all months were summed and a mean calculated. The data was subjected to a t-test in order to obtain an idea of habitat preference [table 31]. Vegetation community A had the highest number of animals followed by community C, with communities J and F being the least preferred. Very few animals were sighted in communities K and M. The order of preference was A > C > B and G > N and D > E and H > J and F. Most species were habitat specific and appeared to prefer relatively open flat areas. A summary of habitat preference for each species is given in table 32.

3.4 Discussion

3.4.1 Population Estimates

3.4.2 Total Counts

Population estimates in this study are an indication of wildlife abundance in the Hell's Gate National Park ecosystem. Their numbers were low compared to other parks in East Africa such as Nairobi National Park [1961 - 1974 game count records], Maasai-Mara Game Reserve, [Stewart and Talbot, 1962; Stelfox et al., 1980]; Tsavo [Western, 1973]; Ruaha, Tanzania [Barnes and Douglas-Hamiliton, 1982] and Kidepo Valley National Park, Uganda [Ross et al., 1976]. Ramade [1984] reports high numbers of five ungulate species in the Serengeti National Park, Tanzania [counted in 1971], of, 42,000 buffaloes, 220,000 Grant's zebra, 330,000 wildebeest, 20,000 topis Damaliscus korrigum and 150,000 Thomson's gazelle, with an overall density of 33 animals per km^2. MacNaughton [1976] also reports high numbers of ungulates [counted in 1974] in the same park, of, one million wildebeest, 600,000 Thomson's gazelle, 200,000 zebra and 65,000 buffaloes within an area of 23,000 km^2.

Lack of diversified food resources which would allow ecological separation, and thus more variety of species, may be one of the factors which was responsible for the observed low species diversity, variety and numbers. Most species were grazers, with the giraffe being the main browser. The dominant vegetation in the park and its environs was Tarchonanthus camphoratus/Acacia drepanolobium shrubland which covered extensive areas. T. camphoratus unlike A. drepanolobium was not an important food source, although the giraffe were occasionally seen feeding on it. Other palatable trees and shrubs were not abundant. Areas covered by herbaceous species especially grasses were small, and only three species, Themeda triandra, Digitaria scalarum and Cynodon dactylon were major food sources. Hyperrhenia sp. though abundant was rarely or not fed on due to its fibrous nature.

Only 12.5 km^2 of the total park area, covering most of the grassland was under utilisation by wildlife. Although Kongoni and Kedong Ranches provided extensive grazing areas [possibly that is why they had higher animal concentrations than the park], the food resources were similar to those of the park, though the total plant biomass may have been higher. Food was therefore possibly less to support a large number of animals, and both intra- and inter-specific competition may have occurred. Low amount of rainfall may also have limited primary production, thus influencing plant standing biomass and subsequently food availability. Since large herbivore communities are ultimately limited by their food resource [Lack, 1954; Hairston et al., 1960; Wynne Edwards, 1962; Sinclair, 1974a], the link between rainfall and large herbivore biomass is most likely to operate through the effects of rainfall on primary production. Predator numbers were too low to have any influence on the population sizes, through predation of the juveniles or sub adults. Climatic variations especially precipitation affect primary production [Walter, 1954; Whittaker, 1970] and indirectly the "carrying capacity" [Phillipson, 1975; Coe et al., 1976]. Some authors [Watson, 1972; Leuthold, 1973; Sinclair, 1974a; Western, 1975, quoted in Coe et al., 1976] reported a relationship between

Considering the total size of the three census areas, animal densities were high, although they were low compared to those reported for other East Africa parks. Ross et al., [1976] recorded mean densities of giraffe ranging between 0.17 - 0.28 km^2 in Kidepo National Park, Uganda. Nairobi National Park had a giraffe density of 0.72 km^2 [quoted in Ross et al., 1976]. Blankenship and Field [1972] recorded a giraffe density of 0.98 km^2 for Akira Ranch [Fig. 6].

There was no seasonal migration into or out of the whole area hence the population sizes remained fairly constant every month. Most species showed a potential of increasing their numbers with time, although their recruitment rates [reproduction rates] were low as indicated by the low number of juveniles recorded [except for the eland in Kedong Ranch and the warthog in the park].

Fourteen species of ungulates were counted. Seven of the species were medium sized [impala, klipspringer, Thomson's gazelle, Grant's gazelle, reedbuck, steinbuck and warthog], and six were large [buffaloes, wildebeest, eland, kongoni, giraffe and zebra]. Dikdik was the smallest species. The variety of species was low, and "important" species such as elephant Loxodonta africana Blumenbach, black rhinoceros Diceros bicornis L. and white rhinoceros Ceratotherium sinum Cottoni, were absent. Stewart and Talbot [19762] reported thirty species of wild ungulates and eight of wild carnivores, in the Serengeti National Park. In Akira Ranch [Fig. 6], Blankenship and Field [1972] recovered seventeen large herbivore species [kongoni-coke's hartebeest, Grant's gazelle, Thomson's gazelle, eland, giraffe, buffalo, bushbuck Tragelaphus scriptus, bushduicker Sylvicarpa grimmia, dikdik, impala, Bohor reedbuck, Chanler's mountain reedbuck Redunca fulvorufula, steinbuck, waterbuck Kobus defassa [or ellipsiprymus], warthog and Burchell's zebra. Kongoni, Grant's gazelle, Thomson's gazelle, eland and giraffe had large population sizes. Total number of game in the ranch was higher than that of either the park, Kedong or Kongoni Ranches.

annual rainfall and large African herbivore biomass. Sinclair [1972] also reported a positive relationship between buffalo density and rainfall in a number of East African habitats. According to Coe et al., [1976] variation in total large mammal biomass in Africa savannas is both a reflection of the primary production, ecological separation of the communities and availability of diversified habitats. Ross et al., [1976] suggested that the low giraffe density observed in Kidepo Valley National Park, Uganda, was a result of competition from elephants, which were also destroying trees which the giraffes were using as food.

The past history of the area may have had an influence on the populations. A few decades ago, game hunting was prevalent and species such as bushduicker, bushbuck, wildebeest and a variety of other antelopes were abundant [Grant pers. comm.]. These were not sighted during census which might explain why only one wildebeest was sighted in Kedong Ranch. Hunting may have reduced the populations while certain species disappeared. The high human encroachment rate in the ecosystem may have also accerelated species loss, as more land was put into crop farming, floriculture, livestock keeping and settlement, compressing the animals habitat and food resources.

The high primary productivity of Central and East Africa savannas, and the ecologically diversified ungulate populations enable them to support the highest secondary production [Bourliere, 1963; Bourliere and Hadley, 1970]. Coe et al [1976] has given a summary of large herbivore standing biomass for various parks of Africa, such as:

(a)	Nakuru National Park	6,688 Kg/km^2
(b)	Amboseli Game Reserve [now a park]	4,848 Kg/Km^2
(c)	Nairobi National Park	4,824 Kg/Km^2
(d)	Tsavo National Park [East] north of Voi river	4,033 Kg/Km^2

(e)	Tsavo National Park [East]-south of Voi river	4,388 Kg/Km^2
(f)	Serengeti National Park, Tanzania	8,352 Kg/Km^2
(g)	Ruwenzoris National Park, Uganda	19,928 Kg/Km^2

An accurate estimate of standing animal biomass for the Hell's Gate National Park ecosystem was not made. Using documented weight of similar species elsewhere [eg. Coe et al., 1976], I roughly estimated it to be 926 - 1147 Kg/Km^2. It was likely to be lower than other reported biomass in East Africa due to the low population sizes coupled by the fact that most species were medium sized, and large heavy species like rhinoceros and elephant which would significantly increase the biomass were absent. Animal biomass may have remained fairly constant since there were no seasonal migrations into or out of the ecosystem.

3.4.3 Road Counts

Using road counts, I was expecting to get estimates close to those obtained using total count method, but this was not the case. A number of potential sources of bias may have affected the counts. Large portions of the park were hilly and thickly vegetated with few flat and open areas where most of the wildlife was concentrated. The road system was constructed in these areas of high wildlife concentration for better game viewing, and did not provide an equal representation of the different habitats. This system seemed to directly or indirectly influence the distribution of certain species like the Thomson's gazelle, Grant's gazelle, zebra and Kongoni, which tended to graze near the roads. The results was to increase the number of animals [n] counted for each species in the transects. The strip widths used were small, reducing the TW values, and this combined with the high [n] values considerably increased the N values in the population estimation equation $N = nZ/TW$. The variable fixed width strip although initially considered appropriate for for this study, proved inefficient in estimating the populations. Vegetation thickness and topography did not affect the efficiency of total counts, and were better in estimating the population sizes of the various species. However, so long as the inherent biases in road counts are corrected for, the method can give good results [Norton- Grifiths, 1978].

3.4.4 Population Structure and Sex Ratios

Animal populations have a structure and sex which is characteristic of a species. The ratio may not be 1:1, but at a fixed proportion dependent on the conception rate of the two sexes or their survival rates. An idea of the structure and and sex ratio characteristic of a population is a major step in understanding its dynamics and trend. Various hypothesis have been proposed to explain the sex ration modifications [Trivers and Willard, 1973; Meyers, 1978; Warren and Charnor, 1978], but the subject remains controversial.

Pyramids are often used to represent information collected on population structure of a species, and can enable one to make probable future trends based on its history (Dasmann, 1964). Rapidly growing populations normally have broad based pyramids due to high young rate production. Those with a relatively stable but slower growth rate have a narrower pyramid base tapering sharply towards the top, while declining population will show even narrower base as production of young declines. Any irregularities in the pyramid often indicate the occurrence of past favourable or unfavourable conditions for breeding and subsequent survival (Dasmann, 1964).

Population structure and sex ratio can be affected by both intrinsic and extrinsic factors. Factors such as predation, density, natality, differential mortality, diseases, nutrition and migration are important. For example, Sinclair (1974a, b, c) found that the buffalo population structure in the Serengeti National Park, Tanzania, was regulated through adult mortality due to under nutrition as a result of food shortage and not through fertility or juvenile mortality. On controlled studies on penned deer, Verme (1965, 1969) found that adults on poor nutrition prior to breeding produced more males fawns than did females at low densities. MacCullough (1979) confirmed this relationship for penned deer existing under high and low densities, thus differing nutritional planes. Maternal age has been shown to affect the sex of the young ones at birth (Lowe and MacKeown, 1950; Ludwig and boost, 1951).

The plane of nutrition may influence pre-natal mortality and possibly the sex ratio at birth (Bernstein, 1948). Parkers (1921) quoted in Bernstein, (1948) reported that the secondary sex ratio in mice would fall considerably when he artificially increased abortion rate creating unfavourable environmental conditions. Differential sex mortality of individuals and even age class(es) may occur in species, thus modifying both the sex ratio and the population structure.

Results of this study have reviewed the present population structure and sex ratios of the different herbivore species. Proportion of adults was higher in relation to sub-adults and juveniles in most species. The sex ratios deviated significantly from the expected 1:1 ratio except for a few cases. It was not possible to establish the factor(s) affecting the structure and sex ratios but the past conditions could be responsible. Due to lack of past detailed information, their trend cannot be easily predicted. It is only possible to draw conclusions about data of this kind if there are many records of similar populations of the species and if their history is thoroughly understood (Lloyd, 1980).

3.4.5 Animal distribution and habitat preference

Populations exhibited a distribution pattern which varies from species to species. Contiguous distribution is the most common due to spatial heterogeneity in the environment. Random and regular distributions are rare in nature. An animal will show preference of a habitat over another if food, survival chances and habitat requirements are perfectly met. For wildlife management, knowledge of the distribution and habitat utilisation by animals in conservation areas is important. Any management plans such as road construction and water supply for wildlife use (if required) will depend on this kind of information. Both intrinsic and extrinsic factors influence a species distribution pattern but the latter are more important. Topography, food quality and availability, habitat quality, rainfall pattern, water resources, nature of vegetation, fire, predators and man have been found to influence animal distribution (Field and Laws, 1970; Jarman, 1972; Leuthold and Sale, 1973; WEstern, 1973; Barnes and Douglas-Hamiliton, 1982; Western and Lindsay, 1984; Stelfox, 1985).

In all three census areas, most of the animals preferred open flat landscape (Njorowa Gorge in case of the park), and avoided steep areas and thick vegetation. These flat landscapes were dominated by grasses mainly Cynodon dactylon, Digitaria scalarum and Themeda triandra, and had high wildlife concentrations. Vegetation characteristics varied spatially, and influenced animal preference and distribution. Thomson's gazelle and warthog were common where grass was short, while zebra, Grant's gazelle and kongoni were abundant in areas of tall grass. The latter were highly mobile and had a wide distribution. Within the park, steinbuck and klipsringer preferred steep landscape covered with bushes. Buffalo, reedbuck and dikdik preferred dense but relatively open vegetation. Eland were rarely seen in the open and spent most of the hot hours of the day in open T. camphoratus/ A. drepanolobium bushes. This possibly helped them regulate their body temperature. Giraffes were very mobile, and common where A. drepanolobium (their preferred food) was abundant. Very few animals were counted in thick vegetation, suggesting that they were not preferred habitats by most species.

Similar vegetation preferences were obtained for the ungulate community in adjoining Akira Ranch (Fig. 6 - Blankenship and Field, (1972). Vegetation was the major factor influencing the animals' distribution, which was in turn affected by fire, rainfall and cattle grazing intensities. Other important factors including hunting, animal behaviour (feeding and breeding behaviour) and water. Thomson's gazelle were attracted to short grass areas around water troughs, overgrazed sites and cattle bomas. Burnt areas also attracted large numbers of the species. Thomson's gazelle were found to prefer areas grazed by cattle. This also applied in Kedong and Kongoni Ranches. Kongoni preferred tall grass areas such as T. triandra and were rarely seen close to water troughs; water did not influence their distribution. Eland avoided areas of intensive cattle grazing. Rangeland deterioration due to prolonged dry spells also forced them to seek better vegetation areas for food.

Wildlife distribution in the whole ecosystem was uneven, and their movements were influenced by temporal and spatial variation in food resources. Their movements, distribution and density in the park, the two ranches and between Kedong and the park varied both on a daily and monthly basis. Overall densities in the three areas remained fairly stable throughout.

Animal movement from Kongoni Ranch to the park was minimal, except for some occasional impala, kongoni, giraffe, zebra and eland. Vegetation thickness and steep topography at the boundary may have hindered movements. No movements were observed between the populations of Kedong and Kongoni Ranches. The land between them was under cultivation (mainly floriculture) by Oseiran and Sulmac Development Companies, preventing possible movements. The populations were therefore isolated. A lot of movement occurred between the park and the Kedong Ranch particularly the grassland communities (A and G) and community C. The population existed as a whole unit. Eland, impala and Thomson's gazelle rarely moved out of the ranch to the park and remained in the former for most of the time.

Other studies in various parts of East Africa have shown that environmental factors (biotic and abiotic), influence animal habitat preference, movement, distribution and their overall temporal and spatial variation in density. In Queen Elizabeth National Park, Uganda, Field and Laws (1970) found that the large herbivore species showed habitat preference, and their spatial distribution was influenced by vegetation, fire, water predators and man. Elephants preferred areas of Capparis tomentosa bush and Sporobolus pyramidalis, and avoided vegetation stands of short grass species such as Microchloa kunthii and coarse species like Cymbopogon afronardus. During the wet season reedbuck preferred areas of M. kunthii and S. pyramidalis. Wet and areas of occasional fires were also preferred, but Imperta cylindrica and Indigofera arrecta dominated stands were avoided. Buffalo were common where H. filipendula, S. pyramidalis and T. triandra were abundant, especially during the wet seasons. They shifted their preferences during the dry seasons to areas dominated by S. pyramidalis and to an extent C. tomentosa, Heteropogon contortus and M. kunthii. They also showed preference for wallows in the wet season but more permanent water in the dry season. Fire indirectly influenced animal distribution. Burning facilitated new growth, replacing tall mature, unpalatable vegetation of low quality. Such areas were suitable feeding grounds, but changed the vegetation structure, risking predation of species which used cover to avoid predation such as the bushbuck, duicker Sylricarpa grimmia and reedbuck.

The seasonal migration of animals within the Serengeti- Masai Mara ecosystem is closely related to seasonal variation in water and food, particularly the latter. When it is wet season in the Mara region, large herds of wildebeest and zebra migrate from Serengeti as the dry season advances and vice versa. Even when in Mara, the animals occupy the park and adjoining areas especially the Loita plains in large numbers. Density of the herbivore within the ecosystem therefore fluctuates seasonally depending on the rainfall pattern, and subsequently food availability.

Animal movement between Nairobi National Park and the Athi-Kapiti plains is influenced by vegetation characteristics (Gichohi pers. comm.; Keiyoro, 1982). During the wet season, most of the ungulates move into adjoining areas where vegetation is short. When water and food become scarce (during the dry season), they return to the park and take advantage of the less grazed vegetation. Fire also influences their movements. Areas burnt in the dry season (either in or outside the park) attract large herds of herbivores. Animal movements, distribution and densities in the park and the adjoining areas therefore change seasonally depending on food availability.
Western (1973), Western and Lindsay (1984) reported habitat preference and differential spatial distribution pattern among the ungulate communities of Amboseli National Park. This was determined by water, food quality and availability which in turn depended on rainfall distribution. Eland were the most habitat specific. Sheep and goats were less habitat specific than cattle. Buffalo and elephant in Kidepo National Park, Uganda, were influenced by water availability (Ross et al., 1976). In Ruaha National Park, Tanzania, Barnes and Douglas-Hamilton (1982) found that human pressure (poaching and animal harassment) at the peripheral areas forced the elephants to concentrate within the park where they were safer. Their densities decreased from the park to the adjoining areas. Water and vegetation characteristics also influenced their distribution. The latter affected the distribution patterns of the zebra, eland, hartebeest, kudu Tragelaphus strepticeros and sable Hippotragus niger Harris. Similar factors influenced the distribution and movements of elephants in Tsavo National Park (Laws, 1970; Meyers, 1973).

In the Hell's Gate National Park ecosystem, animal harassment (hunting) was minimal, and did not affect the distribution patterns of the animals. Disturbances from tourists, geothermal activities and the maasai livestock were not evaluated, but did not appear to have any significant influence. Predators effect on animal distribution was difficult to assess. Large predators such as lion Panthera leo, leopard Panthera pardus and spotted hyena Crocuta

crocuta were not abundant. Water availability was poor. Only two water troughs and three watering points were available for wildlife use in the park. Zebra were the most frequently sighted around the troughs, but kongoni and other species were rare. Water only affected the herbivores' movement and distribution on a daily basis. Fire was also rare. Topography, nature of vegetation and food resources were the main factors affecting distribution of animals in the entire ecosystem. The general appearance was "pockets" of populations separated by steep or vegetated landscape, exhibiting a contiguous distribution pattern.

CHAPTER IV

4.0 GENERAL DISCUSSION

The goal of setting up conservation areas such as national parks and game reserves is to protect wildlife, vegetation and the landscape in order to maintain ecosystem processes and fuctions, at the same time permitting man to benefit through recreation. Human threat to such areas cannot be understood in isolation from the political, socio-economic and ecological processes which face them.

Information obtained in this study has given a picture of the ecology of Hell's Gate National Park ecosystem. It provides a base-line for further studies since time did not allow all the various ecosystem aspects and components of the park to be studied. Primary production, animal biomass and potential "carrying capacity" of the range land and the associated environmental limitations would be worth studying in future. Even with this rather limited information, the future of the ecosystem can be addressed.

Conservation of wildlife in the ecosystem is of great concern, since human pressure is inevitable. Any changes of present human activities or ownership in Kedong and Kongoni Ranches, which are important wildlife concentration areas will directly determine the future trend of the populations. Before the end of the study, plans were underway to convert Kedong into a game ranch where tourists will pay to view the game on horse backs (Grant pers. comm.). This will ensure wildlife safety but the fate of those in Kongoni Ranch might be different. If it is sub-divided for human settlement, the animals' feeding areas will get compressed, at the same time increase their contact with human beings. Assuming such changes will not occur, the wildlife in the entire ecosystem will be safe (except for occasional inevitable small scale illegal hunting by the local people) since species like rhinoceros D. bicornis and elephant L. africana which encourage poaching elsewhere were absent.

Park fencing will equally determine the fate of the animals. If it is done, the chances are that most of the wildlife will be in the adjoining areas, while their movements to and from the park will be cut. The effects of this are two fold. It will prevent the animals from seeking refuge in the park in case of human harrasment outside. Secondly, it might eventually lead to overgrazing in the park in future should the enclosed population increase beyond the "carrying capacity", considering that only 12.5 Km^2 of the total area was being utilised by the animals. Such a proposal requires careful planning and should be done in such a way as not to impair the present dispersal characteristic of the animals within the ecosystem.

In the 1985 management plan for Mount Longonot and Hell's Gate National Parks (W.C.M.D, 1985), it is suggested that the latter provides an ideal habitat for introduction of endangered species such as the rhinoceros D. bicornis and Rothschild giraffe Giraffa camelopardalis rothschildi. Before such an introduction, a detailed study is essential in order to ascertain that the habitat and food requirements of the species will be adequately met. Their possible interaction with the existing species should also be studied bearing in mind most of the vegetation is dominated by T. camphoratus/ A. drepanolobium shrubland which is not an imporatant food source.

Expansion of the Geothermal Power Station will inevitably be a threat to the future of the park. Associated with the expansion will be changes in vegetation and landscape through clearing which might compress the animals habitat and food resources. Vegetation changes due to chemical pollution may accerelate the process. Apart from affecting large animals, invertebrate species diversity might be altered. Water pollution and the likely effects of the station to the sarrounding agriculture, particularly floriculture should not be overlooked, nor the possible geological instabilities. It should be possible through environmental management for the government to safeguard the park and at the same time benefit from the underground steam potential. Environmental studies should therefoe address themselves to the socio-economic aspects, tourism and visual aesthetics, climatic parameters (since a lot of excess heat and gases are already being emitted into the atmosphere), soils and geology, water supply and hydrology, air pollution, seismicity and ground subsidence.

Further effects will come from the expansion of the X-2 village as more people become employed to meet the man power demands of the station. These are bound to bring their own families and relatives which will necessitate expanding the present housing and social amenities at the expense of the park.

Domestic waste disposal might eventually become unmanageable increasing the chances of such wastes ending up in undesired areas. Moreover, the place will attract business such as kiosks, shops and butcheries to cater for the growing population. Human to wildlife contact will increase. Fuel wood collection might also increase to satisfy energy demands. During the study, I uncovered a rock "mining" racket not far from the village, where pumice rocks were being dug and transported in lorries to Nakuru, Kisumu and Nairobi for sale. T. camphoratus and other herbaceous species were seriously being damaged. Investigations proved that those involved lived in the village and were relatives of some of the station workers. Current Geothermal traffic flow through the park will increase as the station and infra-structure expand, thus endangering the life of animals which can be very sensitve to vehicle disturbances (e.g kongoni, warthog and eland).

Tourist impact on vegetation and wildlife is being felt in other parks like Masai-Mara Game reserve, Nairobi and Amboseli National Parks. It has therefore become increasingly important to monitor their numbers and vehicles, vegetation changes and animals harassment in order to arrest and revert the situation. Hell's Gate National Park, being relatively new, and the fact that it lacks tourists' popular species like rhinoceros, elephant, cheetah, lion and leopard (these predators are present but in low numbers and rare), has not gained much popularity. Tourist load was low, and its impact had not been identified. To avoid similar mistakes being repeated as has happened elsewhere, it is important to monitor the tourists' numbers and any impacts that could be going undetected. Excess vegetation trampling (by human or livestock), generally results in changes in soil compaction and water retention capacity, vegetation structure, species composition, root growth and penetration, plant biomass and percentage cover (Bates, 1934; Lutz, 1945; Burden and Randerson, 1972; Chappell et al., 1971; Liddle and Greig-Smith, 1975). Fragile parts of the park should be protected and a programme to educate such tourists on the waste disposal started.

The park ecosystem has experienced insignificant human pressure for quite sometime. T. camphoratus shrubland which covers most of the park and its environs is gradually disappearing in most of the Rift Valley as more land is cleared to give way for settlement and agriculture. Around Mt. Longonot area, including Mai- Mahiu, new settlement and cultivated land have come up in the last few decades. This is being accerelated by overgrazing due to high Masai livestock densities and frequent fires started by the local people to stimulate vegetation regrowth during the rains. Livestock grazing in the park was still prevalent, and it was not unusual to find cattle roaming in the Geothermal Station unattended. Vegetation changes are eminent if their entry is not checked, wildlife displacement and the spread of ecto- and endoparasites and other cattle associated diseases are likely to occur. Charcoal burning for sale was still carried out in deep valleys where the park authority was not likely to find those involved.

All these activities are a potential threat to the vegetation and soils of the park. Patrols by rangers should be regular although transport is a problem due to constant breakdown of the vehicles. A campaign by the administration to educate the local people and the Geothermal staff on the local and national importance of the park and conservation in general can be useful. The latter should also be briefed on the importance of proper waste disposal around abandoned "test" wells. If possible the local people, like Masai should be given a chance to participate in the running of the park. By doing so, they will feel it is their responsibility to protect the wildlife, since they will be benefiting directly. Harrassment of the local people by rangers will only increase their antagonism towards the existence of the park. The present programme by the government and Geothermal authority, to provide water for livestock should be expanded, so as to discourage the Masai from watering their animals in the park.

Wildlife is not likely to cause vegetation changes in the next few years. Population sizes were low, and elephants which have caused serious vegetation changes in other East African parks were absent. Giraffes which were the main browsers were too low in numbers and density to have any serious browsing effects on the vegetation. Vegetation around existing and proposed water troughs should be monitored to prevent excess trampling.

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APPENDIX 1:
MAMMALS OF HELL'S GATE AND ADJOINING AREAS

Large Carnivores

African hunting dog	*Lycaon pictus*
African Wildcat	*Felis lybica*
Bat Eared Fox	*Otooyon megalotis*
Cheetah	*Acinonyx jubatus*
Golden Jackal	*Canis aureus*
Honey Badger	*Mellivora capensis*
Leopard	*Panthera pardus*
Lion	*Panthera leo*
Serval Cat	*Felis serval*
Silver Backed Jackal	*Canis mesomelas*
Spotted Hyaena	*Crocuta crocuta*
Caracal	*Felis caracal*

Large Herbivores

Bohor Reedbuck	*Rendunca redunca*
Buffalo	*Syncerus caffer*
Dikdik	*Rhynchotragus kirkii*
Eland	*Taurotragus oryx*
Masai Giraffe	*Giraffa camelopardalis*
Reticulated Giraffe	*G. reticulata*
Grant's Gazelle	*Gazella grantii rosevelti*
Thomson's Gazelle	*G.thomsonii thomsonii*
Impala	*Aepyceros melampus*
Klipspringer	*Oreotragus oreotragus*

Kongoni [Coke's Hartebeest]	*Alcephalus buselaphus coki*
Steinbuck	*Raphicerus campestris*
Warthog	*Phacochoerus aethiopicus*
Zebra	*Equus burchelli grantii*
Wildebeest	*Connochaetes taurinus*
Others	
Aardvark	*Orycteropus afer*
Olive baboon	*Papio anubis*
Rock hyrax	*Heterophyrax brucei*
Hare	*Lepus capensis*

APPENDIX 2
BIRDS OF HELL'S GATE

Ostrich	*Struthio camelus*
White Pelican	*Pelicanus onocrotalus*
Secretary Bird	*Saggitarius serpentarius*
Rupell's Vulture	*Gyps ruppellii*
White-backed Vulture	*Gyps bengalensis*
Nubian Vulture	*Torgos tracheliotus*
Egyptian Vulture	*Neophron percnopterus*
Lammergeyer	*Gypaetus barbatus*
Harrier Hawk	*Polybariodes radiatus*
Batleur	*Terathopius ecaudatus*
Auger Buzzard	*Buteo rufofuscus*
Long-crested Eagle	*Lophaetus occipitalis*
African Hawk Eagle	*Hieraaetus spilogaster*
Tawny Eagle	*Aquila rapax*
Verreaux's Eagle	*Aquila verrauxii*
Whalberg's Eagle	*Aquila wahlbergi*
African Fish Eagle	*Haliaeetus vocifer*
Lanner	*Falco biarmicus*
Peregrine	*Falco peregrinus*
African Hobby	*Falco cuvieri*
Fox Kestrel	*Falco alopex*
Spotted Eagle Owl	*Bubo africanus*
Cocqui Francolin	*Francolinus coqui*
Hildebrandt's Francolin	*Francolinus hildebranti*
Scaly Francolin	*Francolinus squamatus*
Helmeted Guinea Fowl	*Numida meleagris*
Kori Bustard	*Ardeotis kori*
Crowned Plover	*Vanellus coronatus*
Common Sandpiper	*Tringa hypoleucos*
Temminck's Courser	*Cursorius temminckii*
Speckled Pigeon	*Columba guinea*
Red-eyed Dove	*Streptopelia semitorquata*
Ring necked Dove	*Streptopelia capicola*
Laughing Dove	*Streptopelia senegalensis*
Red-chested Cuckoo	*Cuculus solitarius*
Didric Cuckoo	*Chrysococcyx caprius*
Klaas's Cockoo	*Chrysococcyx klaas*
White-browed Coucal	*Centropus superciliosus*
Nightjar sp.	*Caprimulgus sp.*
Mottled Swift	*Apus aequatorialis*
Nyanza Swift	*Apus niansae*
Little Swift	*Apus affinis*
Horus Swift	*Apus horus*
Speckled Mousebird	*Colius striatus*
White-fronted Bee Eater	*Merops bullockoides*
African Hoopoe	*Upupa epops*
Abyssinian Scimitarbill	*Phoeniculus minor*
Gold-tailed Woodpecker	*Campethera cailliautii*
Bearded Woodpecker	*Thripias namaquus*
Plain-backed pipit	*Anthus leucophrys*
Rufus-naped Lark	*Mirafra africana*
Redwing Bush Lark	*Mirafra hypermetra*
African Rock Martin	*Hirundo fuligula*
European Swallow	*Hirundo rustica*
Red-rumped Swallow	*Hirundo daurica*
Grey-rumped Swallow	*Hirundo griseopyga*
Grey Wagtail	*Motacilla clara*

African Pied Wagtail	*Moticilla aquimp*
Richard's Pipit	*Anthus novaeseelandiae*
Yellow-vented Bulbul	*Pycnonotus barbatus*
Black-backed Puffback	*Dryoscopus cubla*
Brown-headed Tchagra	*Tchagra australis*
Tropical Boubou	*Laniarius ferruineu.*
Fiscal Shrike	*Lanius collaris*
Grey-backed Fiscal Shrike	*Lanius excubitorius*
Stone Chat	*Saxicola torquata*
Schalow's Wheatear	*Oenanthe lugubris*
Anteater Chat	*Myrmecocichla aethiops*
Robin Chat	*Cossypha caffra*
White-browed Robin Chat	*Coccypha heuglini*
Black-lored Babbler	*Turdoides melanops*
Wood Warbler	*Phylloscopus sibilatrix*
Brown Woodland Warbler	*Phylloscopus umbrovirens*
Willow Warbler	*Phylloscopus trochilus*
Rattling Cisticola	*Cisticola chiniana*
Tawny-flanked Prinia	*Prinia sublava*
Black-breasted Apalis	*Apalis flavida*
Red-faced Apalis	*Apalis rufifrons*
Buff-bellied Warbler	*Phyllolais pulchella*
Grey-backed Camaroptera	*Camaroptera brevicaudata*
Crombec	*Sylvietta brachyura*
Dusky Flycatcher	*Alsenax adustus*
White-eyed Slaty Flycatcher	*Dioptornis fischeri*
Grey Flycatcher	*Bradornis microrhynchus*
Chin-spot Flycatcher	*Batis molitor*
Hunter's Sunbird	*Nectarina hunteri*
Scarlet-chested Sunbird	*Nectarinia senegalensis*
Variable Sunbird	*Necterinia venusta*
Bronze Sunbird	*Nectarinia kilimensis*
Golden brested Bunting	*Emberiza flaviventris*
Cinnamon-breasted Rock Bunting	*Emberiza tahapisi*
Yellow-rumped Seed Eater	*Serinus atrogularis*
Brimstone Canary	*Serinus sulphuratus*
Crimson-rumped Waxbill	*Estrilda rhodopyga*
Common Waxbill	*Estrilda astrild*
Purple Grenadier	*Uraeginthus ianthinogaster*
Pin tailed Whydah	*Vidua macroura*
Richenow's Weaver	*Ploceus baglafeht*
Vitteline Masked Wever	*Ploceus velatus*
Yellow Bishop	*Euplectes capensis*
Rufous Sparrow	*Passer motitensis*
Grey-headed Sparrow	*Passer griseus*
Redwing Starling	*Onychognathus morio*
Blue-eared Glossy Starling	*Lamprotornis chalybaeus*
Superb Starling	*Spreo superbus*
Red-billed Oxpecker	*Buphagus erythrorhynchus*
Black-headed Oriole	*Oriolus larvatus*
Drongo	*Dicurus adsimilis*

Appendix 3: Check List of Plant Species

FAMILY

1. Acanthaceae

Barleria micrantha
Dyschoriste radicans
Hypoestes aristata
H. verticillaris
Justicia sp.
Monechma debile
Thunbergia alata

2. Adiantaceae

Actiniopteris semiflabellata
Adiantum thalictroides
Pellaea adiantoides

3. Agavaceae

Sansevieria ehrenbergii
S. intermedia
S. suffruticosa

4. Aizoaceae

Delosperma nakuruense
Trianthema triquetra

5. Amaranthaceae

Achyranthes aspera
Aerva lanata
Alternanthera peploides
A. pungens
Amaranthus hybridus
Cyathula cylindrica
Gomphrena celosioides

6. Anacardiaceae

Ozoroa insignis
Rhus natalensis
Rhus vulgaris

7. Apocynaceae

Acokanthera schimperi
Carissa edulis

8. Araliaceae

Cussonia holstii
C. spicata
C. arborea
Schefflera abyssinica

9. Asclepiadaceae

Cyananchum altiscandens
Sarcostemma viminale
Stapelia gigantea

10. Boraginaceae

Cordia ovalis
Cynoglossum coeruleum
Echiochilon lithospermoides
Heliotropium somalense
H. steudneri

11. Cactaceae

Opuntia vulgaris

12. Capparaceae

Maerua triphylla

13. Chenopodiaceae

Atripex semibaccata
Chenopodium opulifolium
C. pungens

C. schraderianum

14. Caesalpiniaceae

Cassia didymobotrya
C. grantii
C. hildebrandtii
C. mimosoides
C. tomentosa

15. Commelinaceae

Commelina benghalensis
C. africana
C. purpurea

16. Campanulaceae

Lobelia holstii
Wahlenbergia abyssinica
W. denticulata
W. krebsii
W. virgata

17. Caryophllaceae

Pollichia campestris
Silene burchellii
S. macrosolen

18. Compositae

Artemesia afra
Aspilia pluriseta
Athroisma psyllioides
Bidens pilosa
B. ruepelli
Cinareria grandiflora
Conyza floribunda
C. newii
C .schimperi
C. stricta
C. volkensii
Crassocephalum montuosum
C. picridifolium

Circium vulgure
Dichrocephala integrifolia
Emilia diseifolius
Erlangea cordifolia
E. fusca
Felicia muricata
Galinsoga parviflora
Gnaphalium luteo-album
Gutenbergia cordifolia
G. fischeri
Gynura scandens
Helichrysum cymosum
H. gerberaefolium
H. globosum
H. glumaceum
H. odoratissimum
H. schimperi
Hirpicium diffusum
Lactuca capensis
Laggera brevipes
Launea cornuta
Notonia gregorii
N. hildebrandtii
N. petraea
Osteospermum vaillantii
Pluchea nitens
P. ovalis
Psiadia punctulata
Senecio petitianus
Solanecio angulatus
Solanecio manii
Sonchus luxurians
S. oleraceus
Sphaeranthus napierae
S. confertifolius
Tagetes minuta
Tarchonanthus camphoratus
Vernonia lasiopus

19. Coniferae

Juniperus procera

20. Convolvulaceae

Ipomoea whytei

21. Crassulaceae

Bryphyllum sp.
Cotyledon barbeyi
Crassula alba
C. alsinoides
C. pentandra
C. volkensii
Kalanchoe densiflora
K. glaucescens
Umbilicus botryoides

22. Cruciferae

Crambe abyssinica
Erucastrum arabicum
Farsetia undulicarpa
Lepidium bonariense

23. Cucurbitaceae

Cucumis aculeatus
C. figarei
Peponium vogelii

24. Cyperaceae

Abildgaardia hispidula
Kyllinga sp.
Cyperus amauropus
C. immensus
C. laevigatus
C. obtusiflorus
C. papyrus
C. rigidifolius
Fimbristylis hispidula
Mariscus leptophyllus

25. Denstaediae

Pteridium aquilinum

26. Ebenaceae

Euclea divinorum

27. Ericaceae

Erica arborea
Agauria salicifolia

28. Euphorbiaceae

Acalypha volkensii
Elutia abyssinica
Euphorbia crotonoides
E. kibwezensis
E. inaequilatera
E. nyikae
E. schimperana
Jatropha sp.
Phyllanthus rotundifolius
P. sepialis
Ricinus communis

29. Flacourtiaceae

Doryalis abyssinica

30. Geraniaceae

Geranium aculeolatum
G. elamellatum
G. ocellatum
Monsonia angustifolia
Pelargonium quinguelobatum

31. Graminae

Aristida keniensis
A. adoensis
Athroisma gracile

Brachiaria serrata
Chloris gayana
C. roxburghiana
Cymbopogon afronardus
Cynodon dactylon
C. plechtostachyus
Dactyloctenium aegyptium
Digitaria scalarum
Dichanthium papillosum
Echinochloa colona
Eleusine africana
Eragrostis blepharoglumis
E. cilianensis
E. inamoena
E. racemosa
E. tenuifolia
Harpachne schimperi
Hyparrhenia sp.
H. collina
H. filipendula
H. hirta
H. lintonii
Microchloa kunthii
Panicum maximum
Pennisetum clandestinum
Rhynchelytrum repens
Setaria plicatilis
S. pumila
S. sphacelata
Sporobolus fimbriatus
S. pylamidalis
S. stapfianus
Themeda triandra

32. Hypericaceae

Hypericum sp.

33. Iridaceae

Aristea angolensis
Gladiolus natalensis

34. Labiatae

Becium obesum
Fuerstia africana
Iboza multiflora
Leonotis mollisima
L. nepetiflolia
Leucas pratensis
Ocimum suave
Plectranthus barbatus
P. caninus
P. longipes
P. pubescens
Satureia biflora

35. Liliaceae

Aloe kedongensis
A. myriacantha
A. secundiflora
Asparagus africanus
A. racemosus
Bulbine abyssinica
Gloriosa superba
Kniphofia thomsonii

36. Linaceae

Linum volkensii

37. Loranthaceae

Loranthus fischeri
L. heckmannianus
L. ziziphifolius
Odentella fischeri
Viscum tuberculatum

38. Malvaceae

Abutilon mauritianum
Hibiscus flavifolius
H. cannabinus
H. fuscus
H. macranthus

H. calyophyllus
H. aponeurus
Malva verticillata
Pavonia patens
Sida cuneifolia
S. rhombifolia
S. schimperiana

39 Melastomaceae

Dissotis senegambiensis
D. incana

40. Menispermaceae

Cissampelos pareira

41. Mimosaceae

Acacia drepanolobium
A. xanthophloea

42. Moraceae

Ficus pretoriae
F. thonningii

43. Myricaceae

Myrica meyeri-johannis

44. Myrsinaceae

Myrsine africana

45. Oleaceae

Jasminum floribundum
Olea africana
O. europaea
O. hochstetteri
Schrebera alata

46. Orchidaceae

Angraecum humile
Ansellia gigantea var. *nilotica*
Cyrtorchis arcuata
Pteroglossaspis ruwenzoriensis

47. Oxalidaceae

Oxalis obliquifolia

48. Papilionaceae

Argyrolobium rupestre
Astragalus ostropilosulus
Crotalaria. agatiflora
C. chrysochlora
C. deserticola
C. dewildemaniana
C. incana
C. lachnophora
C. massaiensis
C. spinosa
C. tanganyikensis
Dolichos formosus
Eriosema sparsiflorum
Indigofera tanganyikenses
Lotus becquetii
L. goetzei
Macrotyloma axillare
Neonotonia wightii
Ormocarpum kirkii
Rhynchosia minima
Rhynchosia usambarensis
Rhynchosia wightii
Sesbania sesban
Tephrosia emeroides
T. interrupta
T. linearis
Teramnus labialis
Trifolium cryptopodium
T. semipilosum
Vigna schimperi
Zornia pratensis
Z. setosa

49. Phytolacaceae

Phytolacca dodecandra
P. octandra

50. Pittosporaceae

Pittosporum viridiflorum

51. Polygalaceae

Polygala abyssinica
P. amboniensis
P. sphenoptera

52. Polygonaceae

Oxygonum sinuatum
Polygonum salicifolium
Rumex usambarensis

53. Portulacaceae

Portulaca kermesina
P. quadrifida

54. Proteaceae

Protea gaguedi

55. Pteridophyta

Actiniopteris radiata
Asplenium aethiopicum
Dicranopteris linearis
Ophioglossum vulgatum
Pellaea adiantoides
P. calomelanos
Pleopeltis macrocarpa

56. Ranunculaceae

Clematis sinensis

57. Rhamnaceae

Rhamnus staddo

58. Rosaceae

Rubus keniensis

59. Rubiaceae

Anthospermum usambarensis
A. herbaceum
Canthium phyllanthoideum
Galium spurium
Oldenlandia fastigiata
O. scopulorum
O. corymbosa
O. wiedemanii
Pentanisia ouranogyne
Pentas lanceolata
P. parvifolia
P. zanzibarica
Psydrax schimperiana
Rubia cordifolia
Tarena graveoleus

60. Rutaceae

Teclea simplicifolia
Clausena anisata

61. Santalaceae

Thesium schweinfurthii
Osyris compressa

62. Sapindaceae

Dodonaea latifolia
D. viscosa
Pappea capensis

63. Scrophulariaceae

Alectra sessiliflora
Craterostigma plantagineum
Hebenstretia dentata
Pseudosopubia hildebrandtii
Ramphicarpa asperrima
R. montana
Striga linearifolia
Veronica abyssinica

64. Solanaceae

Datura stramonium
Lycium europaeum
Nicotiana glauca
Solanum incanum
S. maunse
S. nigrum
Withania somnifera

65. Sterculiaceae

Dombeya burgessiae
Melhania velutina
Peponium vogelii

66. Tiliaceae

Grewia similis

67. Typhaceae

Typha latifolia

68. Ulmaceae

Trema guineensis
Trema orietalis

69. Umbelliferae

Ferula communis
Heteromorpha trifoliata

70. Urticaceae

Droguetia iners

71. Verbenaceae

Clerodendron fastigiata
Lippia javanica

72. Vitaceae

Cyphostemma nierense
Cyphostemma nodiglandulosum

73. Zygophyllaceae

Tribulus terrestris