# SEASONAL DIET AND HABITAT PREFERENCES OF CATTLE (*Bos indicus*), KONGONI (*Alcephalus buselaphus*) AND WILDEBEEST (*Connochaetes taurinus*) GRAZING ON A COMMON RANGE.

BY

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# DECLARATION

THIS IS MY ORIGINAL WORK AND HAS NOT BEEN PRESENTED FOR A DEGREE IN ANY OTHER UNIVERSITY.

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## DEDICATION

To my parents who thought I could do better than to look after cattle, brothers, sisters and grandmother and all who have encouraged me and contributed to my academic achievements since 1970 and to my grandfather, who dearly loved me, but could not live long to see this thesis.

Special dedication to my wife, Damaris, my children Jerotich and Kokwo and to all those who cherish the beauty of the African bush.

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# ABSTRACT

The feeding habits of cattle (*Bos indicus*), kongoni (*Alcephalus buselaphus*) and wildebeest (*Connochaetes taurinus*) whether as single species or in combination with other animal species on the same range have been studied by several researchers in different environments. Generally these studies conclude that animals do select their diets from an of array plants depending on what is available to them and the prevailing conditions.

This thesis is the result of a study conducted at Game Ranching Ltd. situated at the Athi Kapiti Plains, Kenya, between January and August 1993, to determine the diet and habitat preferences of cattle, kongoni and wildebeest. The following six vegetation types (habitats) occur in the ranch; *Themeda* grassland, *Balanites glabra* tree grassland, *Balanites - Acacia* tree grassland, *Acacia drepanolobium* dwarf tree grassland, *Acacia* woodland and *Acacia xanthophloea* bushland.

The diet preference by the three herbivores was determined by using microhistological analysis technique. The three dominant grasses in the ranch *Themeda triandra*, *Digitaria macroblephara* and *Penisetum mezianum* also formed the major diets of the animals. The browse component of the diets increased during the dry season by about 100% irrespective of the animal species, with cattle always having twice as much browse as the wild herbivores. The animals, however, selected similar diets in terms of plant species during both seasons. Dietary overlaps were always above 75%, but higher during the dry season, than during the wet season. The overlaps were lower between cattle and wild herbivores than between the wild herbivores.

During the wet season *Balanites glabra* tree grassland was the most preferred while all other habitats had negative preference indices, with *Acacia* woodland and *Acacia xanthophloea* bushland habitats being avoided completely by kongoni and wildebeest. During the dry season the two herbivores shifted their habitat preferences to *Balanites - Acacia* tree grassland habitat, with *Acacia xanthophloea* being avoided completely. *Balanites - Acacia* grassland seem to be the best available habitat in the ranch as it is the habitat upon which kongoni and wildebeest depend for their survival during the dry season. *Balanites glabra* grassland, however is the most preferred habitat but is only available during the wet season.

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# CHAPTER ONE

# GENERAL INTRODUCTION

## 1.1 Introduction

Kenya's rangelands are in demand for various competing land uses due to the expanding population, eg settlement, agriculture, pastoralism, conservation and tourism. These land uses have caused conflicts in the rangelands. The expansion of human population has created the need for greater agricultural production, forcing agricultural people to move to prime rangelands. This has forced the traditional pastoralists to poorer rangelands, previously occupied solely by wildlife. The latter has been forced into small pockets and sometimes important migratory routes have been blocked.

Governments have established Wildlife Reserves and National Parks to facilitate tourism and to protect wildlife. However wildlife migrates from these Reserves and National Parks into neighbouring pastoral areas and ranches. As a result wildlife in some areas moves to neighbouring agricultural lands destroying crops and thus causing friction between man and wildlife. With the foregoing, a key issue is the future role of wildlife in the rangelands. Further, several countries have imposed complete restriction on consumptive use of certain wildlife species to avoid their extinction leaving tourism as the only legitimate use. These policies have promoted increase of wildlife populations with resultant conflicts with those of livestock producers being in the forefront. Wildlife destroy fences, compete for food resources and are carriers of diseases to the detriment of livestock producers. Compensation schemes have never been adequate for such damages.

Natural forage is the main source of feed for both wild and domestic herbivores in the arid and semi-arid rangelands. Pratt and Gwynne (1977) stated that grass will remain the cheapest source of livestock feed in Kenya in the foreseeable future due to limited supply of grain and the cost of manufactured feed. Ruminants (bovids) are highly efficient compared to simple stomached herbivores (equids) in the conversion of forage to meat (Church 1975). Duncan *et al.* (1990), however argues that equids compared to similarly sized grazing bovids have higher rates of food intake, which more than compensates for their lesser ability to digest plant material and are capable of extracting more nutrients from at libitum forage diets than bovids, especially from very high and very low fibre diets. This implies that given an equal amount of feed, bovids would efficiently convert it to meat than equids but the equids can extract more nutrients from an ad libitum diet than bovids. However, maximum livestock production is dependent upon proper management of the resources. The most fundamental of these is stocking the range with the correct kinds/class and numbers of animals (Heady 1975).

Unlike stall-fed animals that receive their rations in amounts and proportions dictated by the livestock owners, free ranging animals choose their diets from the complex variety of available forage plant species in the plant communities they utilize. Man therefore exerts only limited managerial control through such decisions as stocking rates, herd composition and size, and location of grazing areas. The diet that an animal will ultimately select in a particular situation and location is a function of many interacting plant and animal related factors (Malechek and Provenza 1983). Certain characteristics of individual plants which influence their acceptance or rejection therefore play a major role. Further unique morphological, physiological and other characteristics of a particular plant species interact to determine the animal's feeding strategy as they exploit the available food resources. The aggregate effect of all these is manifested in the feeding behaviour termed "selectivity", that is the consumption of some plant species or plant parts to the exclusion of others (Heady 1975, Malechek and Provenza, 1983).

## 1.2 Objectives

The objectives of this study were;

a) to determine seasonal diet preferences and dietary overlaps of cattle, kongoni and wildebeest, grazing on the same range and

b) to determine the seasonal habitat preferences of the cattle, kongoni and wildebeest.

## 1.3 Justification

East African rangelands have highly seasonal growing conditions and periodic fluctuation of large herbivore populations. This results from periodic shortage and replenishment of feed resource due to seasonality of rainfall. Foraging is an important component of fitness and many aspects of behaviour and morphology are shaped by the need to gather food. Foraging efficiency in part determines the inclusive fitness of an individual, and though food acquisition is central to activities, it competes for time with other activities such as mating, territory defence and predator vigilance (Krebs 1978). As natural selection favours individuals with highest inclusive fitness, animals are under pressure to forage efficiently. This notion of foraging efficiency has led to studies that investigate diet preference, competition and habitat preference. Problems arise from the nature of herbivore diet and constraints it imposes on the digestive process which include those of animal physiology which dictate the diet selection, foraging time limitations and nutritional constraints from food (Belovsky and Jordan 1978, Demment *et al.* 1986 and Van Soest 1982).

The degree of diet selection determines the dispersion and availability of food items for a herbivore. Highly selective herbivores have their diets compost of buds and flowers, which are highly digestible but making up only a tiny fraction of the plant biomass.

This type of food is highly dispersed, relatively rare and only small amounts can be harvested (Geist 1974, Githaiga 1991). By lowering its acceptance threshold, a larger proportion of the plant community becomes available as food for a grazer, bites are almost continuous and search time is reduced (Jarman 1974). The patterning of the nutrient content and its distribution in the vegetation is therefore critical in feeding strategy of a ruminant grazer depending on its selectivity regime.

Field (1968) noted that in some parts of Uganda and East Africa as a whole, overstocking of domestic animals by pastoralists, leads to overgrazing and range destruction. He concluded that in many such cases the value of wildlife is neglected and it is the first to suffer following degradation of its habitat. Thus the management of domestic animals do affect the survival of wildlife. It is therefore important that the influences of interrelated multiple use of grazing strategies should be considered in range management to successfully meet the objectives of finding optimal use of the range, for livestock or for wildlife or a combination of livestock and wildlife.

Knowledge of feeding habits and habitat preference of both wild and domestic animals is necessary in order to solve problems arising from the issue of preservation and food requirement of wild animals. Information on dietary habits of both wild and domestic herbivores is therefore an important tool to a range manager in determining what competition exists among different range animals and in balancing wildlife and livestock numbers with available forage (Holechek *et al.* 1982a, Wangoi 1984). An indication of the plant species consumed enables a manager to know what the key plant species are and animal performance (Holechek *et al.* 1981). Further information on the feeding habits of animals utilizing a common range is important in offering a basis for assessing the usefulness of the range to the animals dependent on it. Consequently data and information on food habits and habitat preferences are important in making management decisions, like the manipulation of the vegetation to achieve the desired objective(s).

## 1.4 Hypothesis

The following hypothesis were formulated in trying to test this problem

$H0_1$ - Cattle, wildebeest and kongoni have similar diet preferences,

$H0_2$ - Cattle, kongoni and wildebeest prefer similar habitats irrespective of seasons.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 General feeding strategies of wild and domestic ruminants

The way in which ruminant species select their diet is termed the feeding strategy (Hanley 1982). The selectivity of each ruminant diet is expressed by; the amount of grass versus browse, the choice of plant species within each forage consumed and the amount of each plant part consumed. Pregastric fermentation of ingested plant material supplies ruminants with energy and nutrients in the form of microbial products (Hungate 1966). In ruminants, the initial consumer of plant primary production is the anaerobic microbial population of the rumen. This buffered anaerobic fermentation, supplies nutrients to ruminants in the form of volatile fatty acids, the end products of fermentation. The growth of microbial cells produce proteins and vitamins which are harvested from the rumen by passage to the abomasum where peptic digestion occurs. This gives the advantage to the ruminants over simple stomach mammals with hind gut fermentation, where most microbial cells are lost in the faeces. This advantage is especially important when plant products, such as cell wall carbohydrates, which are not digested by enzymes secreted by mammals, are a large portion of ingested food. Another advantage is that plant

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Van Soest (1982) reported that intake is the most important parameter in the nutritional status of all mammals. He also concluded that the rumen has a limited capacity and rumen fill is considered an important factor regulating intake. The turnover and capacity of the rumen must therefore place limits to intake as it is the major site of digestion. Welch and Smith (1969) in their studies concluded that as plant cell wall increases in the ruminant diet, rumination time increases to a limit at which point intake must decrease. Rumination, which reduces ingesta to a size that will pass through the reticulo-omasal orifice, is therefore an important factor. Hofmann (1973) suggested that the omasum plays an important role in regulating rumen turnover and that its structure and place in the digestive tract suggest a sieving and pumping function. Therefore, the omasum also regulate the passage rate of digesta to the lower tract. In contrast, mammals such as zebra and elephants have no blockage to the passage of ingesta. This gives them the ability to increase intake in response to decreased quality of food beyond the capabilities of ruminants.

These relationships suggest that ruminant herbivores need to select diets that correspond to the limitations inherent in the functional anatomy of the digestive tract of each species.

## 2.2 Feeding strategies of cattle, kongoni and wildebeest

The prehensile capabilities of cattle, kongoni and wildebeest is related to their feeding strategies (Jarman and Sinclair 1979). Dentition, muzzle width and manner of grazing or browsing are important in the ease with which herbivores can select plants with different morphological attributes. The most important aspect of the feeding strategy of cattle is that they are domesticated. Their grazing patterns and habitats in which they feed are controlled by man. Traditional methods of keeping cattle in bomas at night severely restrict their feeding time. This would force cattle to be less selective when feeding because of time limit. On the other hand, the ability of cattle as well as sheep and goats to increase fill under conditions of restricted feeding time (Hoppe 1977) may be an important feature in their adaptation to domestication.

The relatively broad muzzles and efficient use of tongues in wildebeest and cattle allow rapid and efficient harvesting of grass leaves from dense leafy swards. However in tall grass communities kongoni with a long, narrow, flat muzzle is more capable of selecting for grass leaves than cattle (Jarman and Sinclair 1979). Kongoni are classified as "bulk feeders and roughage eaters" in the subclass of the "roughage grazers" (Hofmann 1973). Jarman (1974) described kongoni as being rather unselective for grass species but more selective for plant parts or growth stages. Kongoni select for maximum intake of grass leaves in the wet season, but in the dry season grass sheath is selected over grass stem (Stanley-Price 1977). Kongoni appear to be able to select for grass leaf in tall grass vegetation types (Stewart and Stewart 1970, Talbot and Talbot 1962). Wildebeest are classified by Hofmann (1973) as "bulk and roughage eaters" in the subclass "fresh grass grazers dependant upon water". In Jarman's (1974) classification scheme, wildebeest are in the same class as kongoni, unselective for grass species but more selective for plant parts and growth stages. Wildebeest show preference for short grass vegetation types (Mentis and Duke 1976). Unlike kongoni, wildebeest do not seem capable of selecting for grass leaf in tall grass vegetation types. Instead, they maximize intake of grass leaves by migration or association with less selective ungulates (especially zebra) in grazing succession (Bell 1971). Zebra create a more acceptable sward structure for wildebeest in the grazing succession along the catena change from tall grass to short grass vegetation types. This process is also repeated across the rainfall gradients which create short and tall grass vegetation types as occurs in the Serengeti plains (Bell 1971).

## 2.3 Relationship between feeding strategy and body size

A number of authors have related feeding strategies of African ungulates to their body weight (Vessey-Fitzgerald 1960, Jarman 1974, Van Soest 1982). The concept that very small ruminants (<15Kg) are selective feeders and very large ruminants (>200Kg) are relatively unselective is generally accepted. The relationship between energy requirements, body weight and digestive tract capacity supports this conclusion (Van Soest 1982, Mentis 1977). The consequence of this relationship is very important to the feeding strategies of ruminants differing in body weight (Van Soest 1982). Very small ruminants such as duikers, suni and dik-dik need to select for diets that have both high rates of digestion and high digestive tract passage rates to maintain rumen turnover and intake levels necessary to meet their nutrient requirements. Plants that meet this criteria are very low in abundance (Jarman 1974, Mentis 1977). Consequently these animals are restricted in specific habitats.

## 2.4 Role of special senses in grazing

The senses of sight, smell, taste and touch are involved in diet selection (Arnold and Dudzinki 1978, Arnold 1966a, Krueger *et al.* 1974). Sight is the most important in orientating the animal to other animals and its environment. Sheep do recognize conspicuous food plants by sight but do not use sight to help them graze selectively. This was documented by Arnold (1966a) who found that blind folded sheep ate similar diets to those of sheep that could see under a wide range of conditions. Arnold (1966b), in a series of studies with surgically treated sheep to produce single and multiple sensory impairments showed that, not only were there marked changes in acceptability of plant species when each of the senses were impaired, but that total food intake was affected. He found that inability to taste had the effect of improving the acceptability of more species than did the inability to smell or feel them.

Arnold and Dudzinki (1978) indicated that chemical signals influence food selection. These are received at receptors for taste and smell. Stimuli are transmitted to the brain and the animal responds behaviourally or physiologically to the messages they contain (Krueger *et al.* 1974). The animal then responds by integrating these messages with others, such as feedbacks on the current nutritional state of the animal. The desire to eat may then result in lowering either taste or smell thresholds of rejection (Goatcher and Church 1970, Arnold and Dudzinki 1978).

## 2.5 Influence of standing biomass on forage utilization by herbivores

One of the most important properties of the East African rangelands is the abundance of plant biomass on a temporal and spatial basis, which is mainly dependent largely on rainfall. Rainfall is the major determinant of the quality and quantity of the forage available for consumption by herbivores, thereby determining the abundance of both plant and animal components of which the East African grasslands support a greater biomass and diversity of herbivores than any other terrestrial ecosystem (Van Dyne *et al.* 1980). This combination may result from high degree of resource partitioning among these herbivores, with large populations and high diversity permitted by relatively efficient use of available food and space (Lamprey 1963, Jarman and Sinclair 1979).

The growth form (i.e. height, leaf/stem ratio and crown structure) of tropical grasses has an important effect on the eating time, bite size and intake (Stobbs 1973, Chacon and Stobbs 1976). They concluded that in general tall growth of tropical grasses leads to a longer eating time, smaller bite size and lower intake by cattle when compared to short leafy growth of the same grasses. Herbage yield is also negatively related to bite size and intake. These relationships indicate that the presence of large amount of grass biomass would be deleterious to ruminant utilization. The ability of grazing ruminants to maximize forage intake on short grass swards may be a factor in migratory patterns and choice of vegetation types of wild ruminants in East Africa. The grazing succession described by Bell (1971), in which Zebra create a short grass sward more acceptable to wildebeest and Thomson's gazelle, fits this concept. Wildebeest also migrate to the short grass plains in the Serengeti ecosystem in their period of peak demands during parturition and early lactation (Sinclair and Norton-Griffiths 1979).

Concomitant with large seasonal changes in plant standing biomass are equally large and important changes in nutrient contents and digestibility. Although there are infinite variations in nutritive value among plant species, there are some similarities among plant groups. Generally the grasses and forbs of the herb layer, have relatively high digestibility (French 1957) and high concentrations of nitrogen, phosphorus and other nutrients (Bredon and Wilson 1963, Taerum 1970) soon after growth resumes at the onset of rainy season. During the period of early growth, concentration of crude protein in grass leaves is approximately 8-20%, while forbs have a higher concentration ranging from 15-30% (Dougall *et al.* 1964). As the growth ages, its nutritional quality declines as a result of increases in structural carbohydrates, so that both nutrient concentration and digestibility decrease (French 1957, Kilcher 1981). By contrast, browse plants in tropical grasslands generally have deeper root system which exploit a less ephemeral moisture supply and store food reserves in stems and leaves rather than in roots (Lawton 1968, Owen-Smith 1982). Browse, therefore do not decrease much in protein and carbohydrates, with advancing maturity as much as grasses do (Heady 1975).

## 2.6 Forage preference by domestic and wild herbivores

Numerous studies geared towards understanding the feeding habits of both wild and domestic herbivores have been conducted. The evidence assembled todate indicate that ungulates are selective in their diet for at least part of the year, involving habitat selection, plant species selection, and selection for plant parts (Jarman and Sinclair 1979). As diet quality declines, with higher incidence of fibrous material, more time at the expense of feeding must be set aside for rumination which is thus a critical component of foraging. Thus what a grazer does when not foraging is as important as it does in overall feeding strategy (Demment *et al.* 1986). The fibrous material content of the diet ultimately controls ingestion and assimilation of other nutrients (Van Soest 1967). The constraints imposed by the digestive physiology dictate that ruminants select an easily digestible diet of high quality. This selectivity with a preference for green grass parts, has been documented by several studies in domestic and wild herbivores (Sinclair 1972, Stobbs 1975, Talbot and Talbot 1962, Gakahu 1982).

Ruminants have been found to display different selectivity regimes closely associated with body size with profound effects on the ecology and behaviour of the species. Gwynne and Bell (1968) showed that larger animals tolerate coarser, lower quality food, and smaller ungulates can coexist with larger species by using scattered remnants of high quality food. Larger species therefore facilitate plant/forage utilization by smaller species by removing coarser material and exposing the higher quality portions. However reduction of resources below a critical level can trigger competition (Field 1972). Hillman and Hillman (1977) concluded that food resource shortages are so intense in drought years as to cause high mortality among ungulates. Further evidence of resource shortage comes from observations of a shift in diet composition among plant parts. Andere (1981) concluded that if resource abundance varies with season and there is evidence of seasonal shortage, then niche overlap may be construed as actual competition.

Wildebeest and zebra are virtually pure grazers and select leaves, which have the highest ratio of protein and soluble carbohydrates to cellulose (Gwynne and Bell, 1968). In the dry season there is a decrease in the intake of leaves, at the expenses of leave sheath and stem. Similarly Owaga (1975) found that both wildebeest and zebra are almost pure grazers, taking little forbs (about 1-2%) during the wet periods and almost none at other times. The proportions in zebra diet were usually close to the availability and therefore seemed to be relatively random feeders. In his experiment in Kruger National Park, South Africa, Ben-Shahar (1991) showed that there was a considerable overlap of grass species composition in the diets of zebra and wildebeest. However wildebeest diet alternated with seasons, showing high preferences during the winter for grasses which were rejected during the summer.

Field (1975) noted that cattle, buffalo, eland and oryx grazed within the grass/herb layer during the early growth period. He also noted that annual and drought tolerant grasses form the main diet of oryx, while buffalo and cattle feed on bulky perennial grasses. A study of goat and eland diets on the Kiboko Research Station, Kenya by Ng'ethe and Box (1976) showed that the bulk of diets of both animal species consisted of leaves from relatively few plant species. Although elands utilized a wide variety of plants, they consumed a larger proportion of grasses than goats. Elands are mixed feeders. Van Zyl (1965) reported that elands browsed 76.5% and grazed 23.5% of their time in the field, while Lamprey (1963) concluded that elands selected 70% grasses and 30% browse species. Kerr *et al.* (1970) reported that grasses were minor forage components for elands. These conflicting conclusions imply that intake could be largely dictated by the nutritional status of the animal, locality and availability of forage. Further they confirm the observation that elands are capable of utilizing a wide variety of plant species.

Field and Potere (1972) have documented that cattle prefer grazing to browsing and that sheep like fine grass, forbs and shrubs while goats are mainly browsers. In a study on the feeding behaviour of cattle in a semi-arid part of Tanganyika, Payne and MacFarlane (1963) noted that cattle were browsing more frequently as the dry season advanced. Holechek *et al.* (1982b) investigated the seasonal diets of cattle in the Oregon forests, United States of America. The study showed that grasses, forbs and shrubs averaged 61%, 16% and 23% of the diet respectively. Composition of the diet differed with advancement of the season. Forbs were heavily used in the early part of the growing season before maturation. Browse comprised as much as 47% of the diet when green grass was unavailable. They concluded that cattle were opportunistic grazers and did not limit their selection to grass species. Kayongo Male (1986) studying the seasonal variability in cattle diets in Marsabit District, Kenya, concluded that during the wet season, annual and perennial grasses made up the bulk of cattle diets. When the dry season become severe the herbs, dwarf shrubs, trees and litter constituted major portion of cattle diets. This was in general agreement with other studies by Payne and MacFarlane (1963). Wangoi and Hansen (1987) investigating the seasonal dietary habits of camels, cattle, sheep and goats grazing a common range in Marsabit District, Kenya, concluded that although cattle predominantly ate grasses, the browse component of their diet was higher in the wet season than in the dry season. More than 50% of the sheep diet consisted of grasses for all except one season, when the browse component of their diet tended to increase during the very dry and very wet season. Goats also tended to browse relatively more during the driest season. However, for camels which have mouth parts adapted for browsing just like sheep and goats, the grass component was highest during the dry season.

From most of the studies done so far, there is a general conclusion, that grazing animals do select their diet from an array of plants depending on what is available to them and prevailing conditions. The animals tend to be opportunists utilizing whatever is available thereby showing great variation in feeding habits in different ecological regions and certain seasonal variation of these habits within the same region. To consider dietary data as forage classes (grass, forbs and shrubs) overlooks in general the important fact that animals select their diets on a plant species basis and even plant parts. It is important therefore that dietary selection studies consider analysis and reporting of diets at species level. Seasonal dietary shifts can be abrupt particularly in areas having distinct wet and dry seasons like in the temperate areas. The nutritional consequences of these shifts are probably great in terms of competition among animals on a common range.

Generalization from these diet selection studies are difficult because all have been conducted under conditions of different plant availabilities. Consequently, the results tend to be location specific in terms of applicability to management. However, such studies when applied to the site from which the data originated, can provide range managers with some basis for making management decisions.

## 2.7 Determination of range herbivore diets

The procedures that have been used to determine the botanical composition of grazing animal diets include;

- utilization technique,
- direct observation of the animal(s),
- stomach content analysis,
- microhistological technique and
- fistula techniques.

### 2.7.1 Utilization technique

Utilization is one of the oldest approaches used to evaluate grazing animal's diet (Holechek *et al.* 1982a). Approaches to determining utilization (Holechek *et al.* 1982a) have involved;

- evaluating differences between grazed and ungrazed plots,
- evaluating differences before and after grazing,
- measurements involving correlation and regression of factors related to utilization,
- general observation and comparison with predetermined standards of use and
- ocular estimate methods which involve comparing the amount of herbage inside and outside cages.

The advantages of this approach include the speed and the fact that it provides information on location and the degree a range is used in a given time period. Its major disadvantage is that it does not indicate when a forage species was used and how often it is used. This technique does not account for large scale losses of plant parts from weathering and trampling by animals other than those of interest (Cook and Stoddart, 1953). Further still, for actively growing forage, and regrowth after defoliation can make accurate determination of utilization difficult. Cook and Stoddart (1953) indicated that when forage is actively growing and/or being used by more than one herbivore, any utilization technique has severe limitations. Under these conditions other procedures should be selected for determination of botanical composition of diet.

### 2.7.2 Direct observation

Direct observation of the grazing animal is a widely used procedure in studies of botanical composition of a herbivore diet. The major advantages of direct observation include simplicity, minor equipment requirements and ease of use (Holechek *et al.* 1982a). The problem associated with this method include difficulties in species identification and quantifying information from direct observation obtained from bite-count and feeding minutes approaches. When the feeding minute technique is employed, time spent grazing each species is quantified and assumed to be proportional to the importance of the species in the diet (Bjugstad *et al.* 1970). The bite-count procedure differs in that number of bites taken from each species, rather than the length of grazing time, is recorded. This method may not apply to wild ungulates which are often difficult to locate and approach closely enough for accurate observations. These problems do not occur in studies if tame animals are used for study. It may be difficult to differentiate between mere nibbling and active grazing, and only one animal can be observed at a time even with tame animals.

Results from direct observation studies of tame animals have been shown to be consistent with data from esophageal fistulated animals (Sanders *et al.* 1980). Sanders *et al.* (1980) reported that direct observation was not practical for use on large brush infested pasture with rough terrain. Factors that may influence the accuracy and precision of direct observation procedure include the degree of training of the observer, complexity of the plant community present, and/or phenological development of individual plants.

Diet selection is a complex behaviuoral act that is influenced by several factors (Krueger *et al.* 1974). Physiological condition, degree of hunger, topography, other animals present and past experience, all influence which and how much of individual plant species are consumed. Therefore the previously mentioned factors can be greatly altered by using artificially reared and maintained animals.

### 2.7.3 Stomach content analysis

Stomach content analysis method of determining botanical composition of animal diets is a common procedure among wildlife researchers (Chippendale 1962, Chamrad and Box 1964). Stomach content analysis provides information on what species are being consumed and gives an indication of relative proportions consumed. The main disadvantage of this procedure is that it involves killing of animals and therefore, is restricted primarily to wild animals with large populations. Difficulties also arise from the fact the complete or partial digestion of some material may alter the original proportions in the diet and also make plant identification fragments difficult. Tabulation of food item numbers, tabulations of frequency of food item occurrences, volumetric measurement, and weight measurement are methods that have been used to evaluate stomach contents. Chamrad and Box (1964) described a method which appears to be superior to other methods in speed, accuracy and precision. The microhistological technique by Spark and Malechek (1968), and microscope point technique by Heady and Van Dyne (1965) can be used to evaluate species composition by weight.

A modification of this procedure has been reported by Wilson *et al.* (1977) to avoid the problem of animal sacrifice when stomach analysis is used to sample large ruminant's diet. Tranquilization is used to immobilize animals and rumen samples are taken with a trochar. The resulting wound is sewn shut. However, layering of rumen contents, effective tranquilization of animals and infection by bacteria are problems associated with trochar sampling. Further, due to the danger of death from parasites, diseases and overdosing occurring often, the technique may not be liberally applied to rare or endangered species (Holechek *et al.* 1982a).

### 2.7.4 Microhistological technique

Microhistological technique has received greater use for evaluating range herbivore food habits. The procedure has several unique advantages that account for its popularity in research (Croker 1959, Scother 1979). These include;

- non interference with the normal habits of animals,
- it permits practically unlimited sampling,
- there is no restriction on animal movement,
- it is of great value where animals graze over mixed plant communities and
- actual sampling requires very little equipment.

Important disadvantages noted by Slater and Jones (1971), Scother (1979), Vavra and Holechek (1980), Sanders *et al.* (1980) include;

- accuracy may be a problem because forage species passed in faeces are often not proportional to those consumed,
- considerable equipment and labour are required for actual analysis,
- an extensive reference plant collection is required,
- an observer must have considerable experience or

training in order to accurately identify plant fragments,
- some plant species are difficult to separate at the species level and sometimes even at the genus level,
- plant identification is tedious and time consuming,
- procedures of sample collection may bias the results,
- some species of plants may become unidentifiable in faeces and
- identification can be complicated by aging of faecal material before sample collection.

Major points of interest concerning microhistological techniques have been the influence of digestion, frequency of observation and degree of training of observer on the accuracy of diet composition determination. Hansen (1971) reported good agreement between composition of ingested and faecal material. Todd and Hansen (1973) indicated that the relative number of plant fragments of each kind of plant, remains similar in passing through the digestive process. They suggest that digestion reduce the mean weight of fragments rather than eliminating the whole fragment. Sanders *et al.* (1980) compared the microhistological technique and bite count method for range animal diets. The experiment indicated that the two methods gave similar results for estimating major components of cattle diets. It was further noted that the bite-count method could not be used on large bush-infested areas with rough terrain whereas the other method could be used under such conditions. Holechek and Gross (1982) used seventeen forage species to determine the effects of stage of maturity and skill of observation on the accuracy of microhistological analysis for species composition of hand compounded samples. Results indicated that growth stage had little effect on the accuracy of estimation. Five observers with specialized training and experience obtained similarity indices for estimates of diets composition of 95%, 88%, 85%, 93% and 75%. Poor accuracy was recorded for the observer without specialized training. The effect of observer was the most important of the factors examined. Observers with specialized training most accurately evaluated botanical composition of each diet. In an experiment to study mastication effects on cattle diets determined by microhistological analysis, Bryan *et al.* (1983) reported that mastication had no overall effect on diet composition. None of the individual species was affected by mastication, considerable variation occurred between observers in this study. In general, the experiments pointed out that fragments of plants survive the chewing and the digestive process and can be identified and quantified in herbivore faeces by microhistological technique. This method thus remains the one of choice in the study of dietary composition of free-ranging animals in mixed plant communities.

### 2.7.5 Fistula technique

Esophageal and rumen fistula techniques have considerable advantages over some of the above methods in that fistula enable the investigator to obtain naturally grazed samples. Both fistula are popular in research but esophageal fistula is generally preferred to the rumen fistula because rumen evacuation subjects animals to abnormal conditions, is mainly limited to large animals and is more laborious (Holechek *et al.* 1982a). Problems associated with the use of the esophageal fistula include contamination by rumen contents, incomplete recoveries, high cost, and low sampling precision for individual species in the diet.

# CHAPTER THREE

# STUDY AREA

## 3.1 Location and physiography

Game Ranching Ltd (GRL), Athi River, is a privately owned, mixed game and cattle ranch. GRL was initiated to demonstrate the economic and environmental viability as well as the social acceptability of game ranching. The ranch occupies an area of 8,100 Ha. and is located 40 Km South - East of Nairobi on the Athi Kapiti plains (Figure 1). Elevation varies between 1600 and 1700 M above sea-level, latitude 0.1 30"S, and longitude 37 02"E (Stelfox 1985, MacDowell *et al*. 1988). The ranch is only 5 Km to the North of Kajiado District, which is mainly used for pastoralism and is bordered by unfenced private ranches. It is separated from Nairobi National Park by Portland Cement Ranch and the Nairobi - Namanga road.

Prior to 1981, GRL was operated as a cattle and sheep ranch. Following the findings of research by Hopcraft (1975) on productivity comparison between Thomson Gazelle and cattle, and their relation to the ecosystem, GRL applied to the Kenya Government for a permit to operate it as a game ranch. To meet the government regulations GRL had to complete several modifications including a 50 Km chain-link fence, 2.6 M in height along the perimeter to ensure the existence of a closed system. This closed system was used in this study to investigate the diets and habitat preferences of cattle, and kongoni wildebeest.

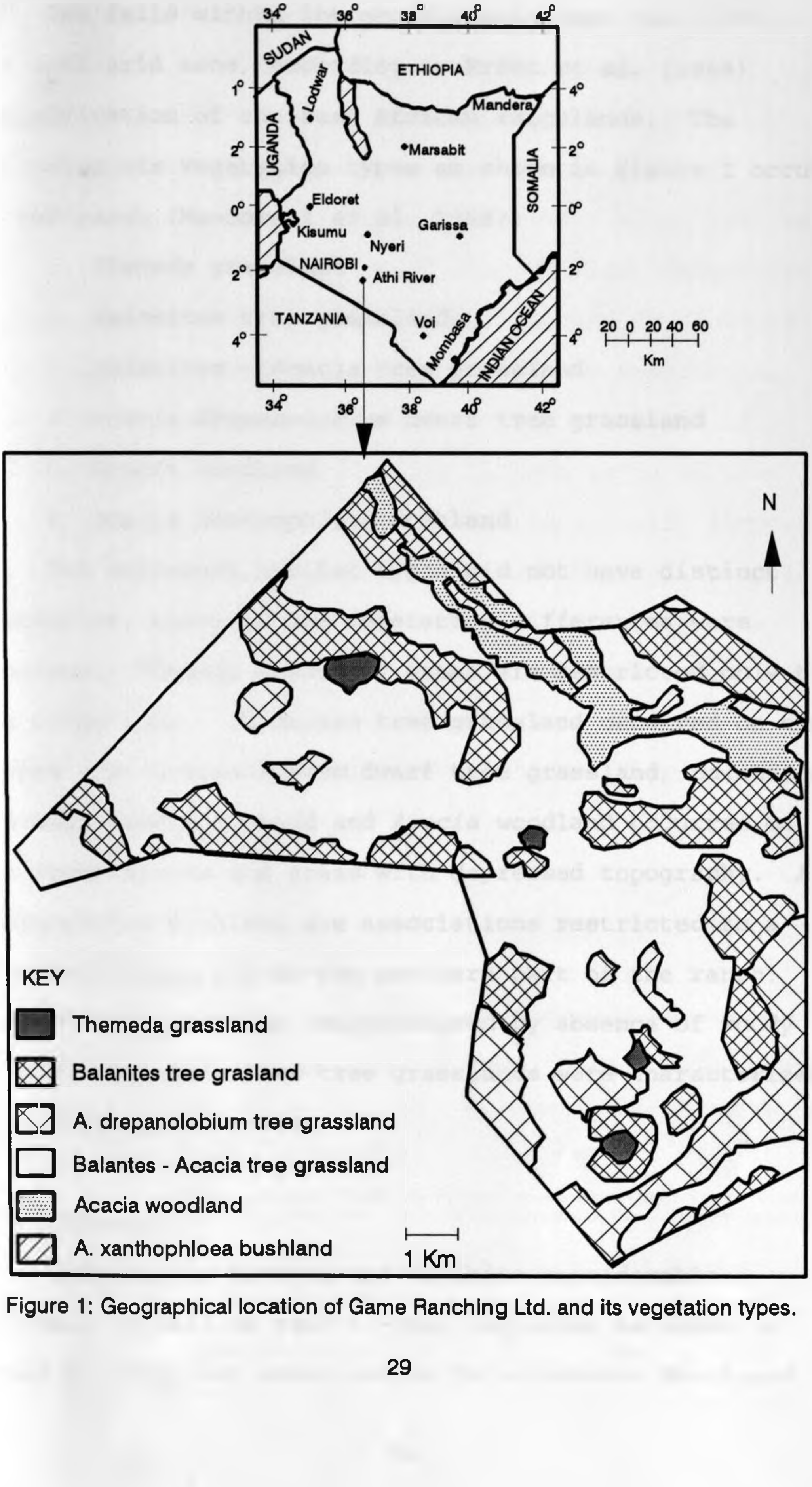

Figure 1: Geographical location of Game Ranching Ltd. and its vegetation types.

GRL falls within the eco-climatic zone four (IV), the semi-arid zone, according to Pratt *et al.* (1966) classification of the East African rangelands. The following six vegetation types as shown in Figure 1 occur in the ranch (MacDowell *et al.* 1988);

1. *Themeda* grassland
2. *Balanites* tree grassland
3. *Balanites* - *Acacia* tree grassland
4. *Acacia drepanolobium* dwarf tree grassland
5. *Acacia* woodland
6. *Acacia xanthophloea* bushland

The different habitat types did not have distinct boundaries, however, the vegetation differences were apparent. *Themeda* grassland areas are restricted only to the ridge tops. *Balanites* tree grassland occurred on the slopes. *A. drepanolobium* dwarf tree grassland, *Balanites* - *Acacia* tree grassland and *Acacia* woodland occurred on the lower slopes and areas with depressed topography. *A. xanthophloea* bushland are associations restricted to a seasonal stream bed at the northern part of the ranch. *Themeda* grassland was characterized by absence of woody plants. The *Balanites* tree grasslands were characterized by widely spaced trees.

### 3.2 Climate

Rainfall is bimodal and exhibits considerable seasonal as well as year-to-year variation as shown in Table 1. The long rainy season falls between March and

May, followed by a cool, cloudy and dry season from June to September. The short rainy season extends from October to December and is followed by a hot and sunny dry period, which continues to the middle of March. Average annual rainfall for 12 years starting in 1981 was 502 mm. During the eight month study period, January to August the short rains extended to February as shown in Figure 2. It should be noted however that despite the fact that no rains were recorded during the month of March, there were a lot of rains in some parts of the ranch through to early April when rains actually stopped. The usual long rains failed and as such January to April and May to August were considered wet and dry seasons respectively in this study. Due to the elevation, temperature is characterized by warm days and cool nights, maximum 24.9°C and minimum 13.7°C (MacDowell *et al.* 1988).

Table 1: Mean and annual rainfall (mm) for the period 1981 to 1992.

| Year | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|---|
| Rainfall | 422 | 473 | 435 | 349 | 698 | 468 | 345 |

| Year | 1988 | 1989 | 1990 | 1991 | 1992 | mean |
|---|---|---|---|---|---|---|
| Rainfall | 702 | 627 | 687 | 449 | 372 | 502 |

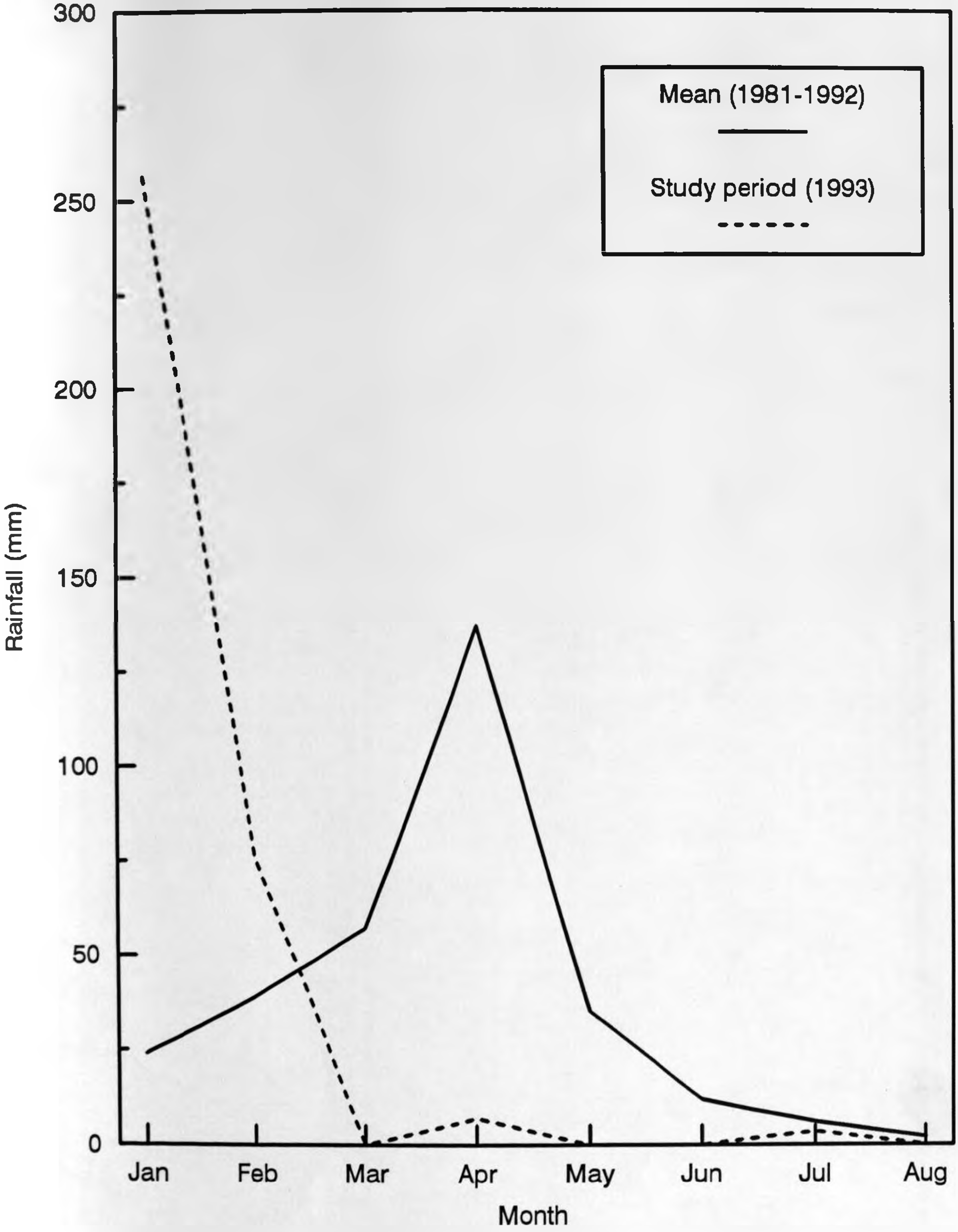

Figure 2: Monthly rainfall during the study period compared to the mean monthly rainfall for 12 years (1981 - 1992).

### 3.3 Animals

The wild herbivores of GRL include; kongoni, Thomson's gazelle, grants' gazelle, Maasai giraffe, impala, fringe-eared oryx, wildebeest and burchells zebra. Results of a census conducted in the ranch during the month of August by the ranch management are shown in Table 2 below.

Table 2: Wild herbivore numbers and density per Km$^2$ in the study area.

| Animal species | Total | Percentage | Density/Km$^2$ |
|---|---|---|---|
| Wildebeest | 949 | 34.3 | 11.7 |
| Kongoni | 583 | 21.1 | 7.2 |
| Grants' gazelle | 392 | 14.2 | 4.8 |
| Thomson's gazelle | 324 | 11.7 | 4.0 |
| Burchells zebra | 128 | 4.6 | 1.6 |
| Fringe-eared oryx | 109 | 3.9 | 1.3 |
| Impala | 96 | 3.5 | 1.2 |
| Maasai giraffe | 85 | 3.1 | 1.0 |
| Ostrich | 75 | 2.7 | 0.9 |
| Eland | 25 | 0.9 | 0.3 |
| TOTAL* | 2766 | 100.0 | 34.1 |

* - Livestock were excluded from the census, Dairy herd 250, Penta herd 2360 (April-September) and Sheep 250.

# CHAPTER FOUR

# MATERIALS AND METHODS

## 4.1 Vegetation inventory and animal diets

### 4.1.1 Herb layer biomass sampling

During the eight month study period, the sampling was done six times, once every month except during the months of March and July. Herb layer standing biomass was obtained by clipping thirty 0.5 $M^2$ circular quadrats along 300 M transects in each vegetation type. Quadrats were placed after every 10 M along the transects. This process was repeated each time clipping was done, but on a transect parallel and 4 M away from the previous one. The herb layer was clipped to the ground level and separated into species. Forbs were grouped together. The clipped samples of each plant species were weighed in the field and packed in paper bags. They were later dried to a constant weight at 60°C and weighed. Dry weights were determined for each habitat type and converted to Kilogrammes per hectare.

### 4.1.2 Woody plant density and canopy cover sampling

Woody plant density was estimated using the Point Centred Quarter Method (PCQ) (Dieter and Heinz 1974) in five habitat types. In each habitat two transects were sampled. Themeda grassland was not sampled because it was devoid of woody plants. A transect perpendicular to the contours was established in each plot. A point 15 M along each transect was selected for placing the PCQ stick. Four sampling quarters was established by making two lines, one parallel to the transect and the other perpendicular to the transect at the PCQ stick. In each quarter the distance between the nearest woody plant and the stick was measured. Each plant was sampled for stem diameter, and two perpendicular crown diameters. Canopy cover was determined by calculating the means of the crown diameters of each tree and hence their area. The crown cover area of all the trees were totaled to give the total cover and hence percentage cover calculated. The mean area occupied by each tree was determined by using the mean distance from the PCQ stick. Total area was then calculated by multiplying the mean area by 120, the number of quadrats sampled (4 x 30) in each vegetation type. The density of the trees per hectare was then determined.

## 4.2 Dietary sampling

### 4.2.1 Preparation of plant reference slides

In this study microhistological technique was used in the analysis of dietary samples from the study animals. Reference slides were prepared from plant species collected from the study area. The plants were identified in the field, collected, oven dried and finely ground using a Willey Mill with 1 mm sieve. Slides were made from the materials following the procedures described by Cavender and Hansen (1970). A 5-10 gm sub-sample of the reference material was soaked in a bleaching agent for about 15 minutes. Soaking helped bleach the plant pigments and softened the tissues during slide preparation. Following this treatment the bleached samples were then washed with running tap water over a 212 μm sieve for about 3 minutes to remove smaller plant fragments, bleaching agent and any dirt. A small amount of the material was then put near the end of a glass microscope slide using a spatula and a template. Hoyer's solution (Cavender and Hansen 1970) was added in small quantities so as to cover the sample. A teasing needle was used to mix the sample material with the solution. The mixture was then spread evenly over an area large enough to be covered by a 22 x 40 mm glass cover slip. The cover slip was affixed and the slide was slowly heated over an alcohol burner till the solution started to bubble. The bottom part of the slide was immediately pressed onto a wet cloth material to drive out air bubbles. The cover slip was then gently, sealed to the slide using a few drops of Hoyer's solution. Five slides were prepared for each sample. The prepared slides were then placed in a rack and dried at 60°C for 48 hours and stored.

### 4.2.2 Preparation of slides from faecal material

For each of the animal species and for each month, faecal samples were collected for 3 days each week during a three week collection period from randomly selected fresh dung/faeces in the field. Faecal samples for each animal species were compounded from the weekly samples to form one composite sample. Each composite sample was then crushed, washed over a 600 μm and 212 μm sieves with running tap water. The sample retained by the 212 μm sieve was then dried and stored in sealed plastic bags. For each composite sample five slides were made using the procedures described above.

### 4.2.3 Slide quantification

Faecal slides were quantified as described by Hansen *et al.* (1984) and Foppe (1984). Twenty identifiable fields were used in the quantification. A 100x magnification was used on a movable stage microscope. The recorded identifiable plant fragments were converted to percent relative density, using the Hewlet-Packard frequency/density tables, assuming that the relationship between relative density and dry weight is highly correlated (Sparks and Malechek 1968, Hansen *et al.* 1984, Foppe 1984). The percent relative density gives an indication of the relative amount of different plant species consumed (Hansen *et al.* 1984). The frequency of different plant species in each of the faecal slides was determined and Relative Density (R.D) was calculated using the formula (Hansen *et al.* 1984) below:

$$R.D = \frac{\textit{density of discerned fragments for a species}}{\textit{densities of discerned fragments of all species}} \times 100$$

Tissue characteristics that were used in the identification process included the characteristics of epidermal cells, cell walls, stomatal shape, size and arrangement of silica cells, druses, silica suberose, trichomes and microhairs.

### 4.3 Animal density and habitat preferences

Animal censuses were conducted once every month during the study period (January to August, 1993). Table 3 shows the areas covered by each habitat and their respective areas that were sampled during the animal censuses. In the *Themeda* grassland, Acacia woodland and *A. xanthophloea* bushland habitat types which occupied less than 10% of the Ranch each, one block was identified in each, where total animal counts were done. In the other habitat types that occupied more than 10%, each, of the ranch (*Balanites - Acacia* tree, *Balanites* and *A. drepanolobium* dwarf tree grasslands) two blocks were used as shown in Figure 3. Each month, the censuses were conducted for three consecutive days. The fieldwork was done twice each day (in the morning and in the evening). The morning census started at 6.30 am and ended at 9.30 am, while in the evening it started at 3.30 pm and ended at 6.30 pm. The data recorded at the sites included animal species, number, block (habitat type), date and time of observation. Due to absence of clear boundaries between the different habitat types, herds whose group members appeared in transitional areas were assumed to have been utilizing the block, hence counted. The areas covered during the animal censuses were calculated by using a map overlaid with grids and showing all the locations of each vegetation type in the Ranch. The grids on the map demarcated an area of 2.5 $Km^2$.

Table 3: Total area in hectares covered by each habitat, and their respective areas that were sampled during the animal census.

| Habitat | Total area | | Area sampled | |
|---|---|---|---|---|
| | (Ha) | (%) | (Ha) | (%) |
| Balacc[3] | 3937.50 | 48.61 | 275.00 | 6.98 |
| Baltre[2] | 2187.50 | 27.01 | 337.50 | 15.43 |
| Accdrf[4] | 1100.00 | 13.58 | 200.00 | 18.18 |
| Accwdl[5] | 500.00 | 6.17 | 112.50 | 22.50 |
| Accxan[6] | 225.00 | 2.78 | 75.00 | 33.33 |
| Thtgsl[1] | 150.00 | 1.85 | 75.00 | 50.00 |
| Total | 8100.00 | | 975.00 | |

[1]*Themeda* grassland, [2]*Balanites* tree grassland, [3]*Balanites - Acacia* tree grassland, [4]*A. drepanolobium* dwarf tree grassland, [5]*Acacia* woodland and [6]*A. xanthophloea* bushland.

## 4.4 Data analysis

### 4.4.1 Seasonal diet preference

For each animal species and for each sampling period, the dietary components at species level was tabulated

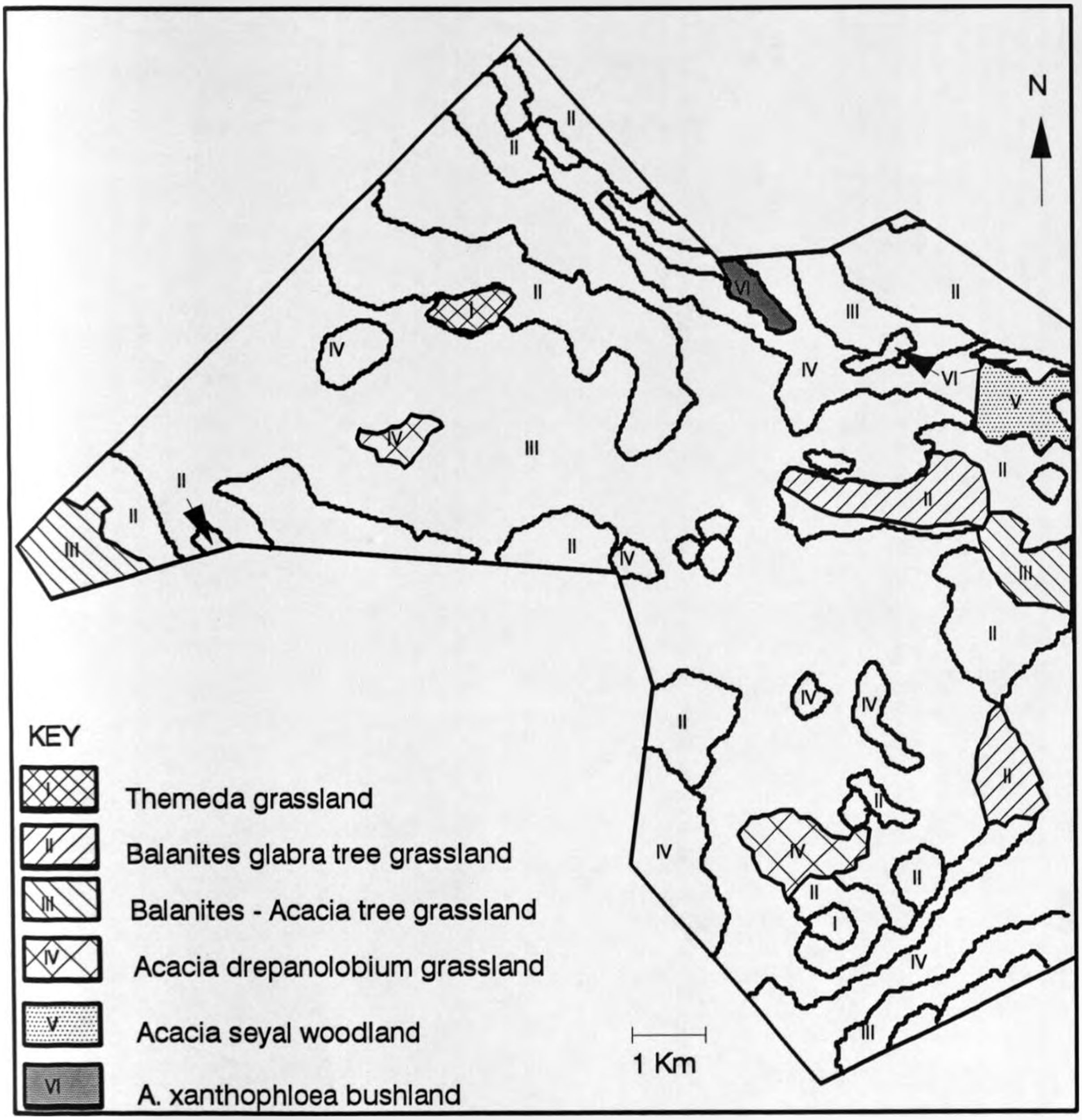

Figure 3: Map showing the areas sampled in each vegetation type for animals.

together with relative density and any changes in density due to season. This was compared with plant species available in the range so as to determine animal diet preference by calculating their preference indices. Diet preference indices were then calculated by using the following equation adapted from Viljoen (1989).

$$\textit{Diet preference index} = \frac{\textit{Percentage in animal diet}}{\textit{Percentage availability}}$$

### 4.4.2 Dietary overlaps

Dietary overlaps between animal species were calculated using percent similarity index (S.I) (Oosting, 1956).

$$S.I. = \frac{\sum_{i=1}^{n} 2Wi}{\sum_{i=1}^{n} (ai+bi)} * 100$$

Where; Wi = Lesser percentage of food category in the two diets being compared and

ai + bi = Sum of the percentages of food category in the two diets.

Comparisons were made between animals within seasons using the above formula. The similarity index represents the percentage of the diets that is identical or the percentage of diets that is shared by two herbivores. It shows the potential for competition between two herbivores. Snedecor and Cochran (1967) and Hansen *et al.* (1984) calculated a coefficient, Rs, as shown in the equation below from the relative densities of the plant species common in the diets of two animals being compared (Pair-wise comparisons).

$$Rs=\frac{1-6\sum_{i=1}^{n} d^2}{n(n^3-1)}$$

Where; d = differences between paired ranks of common plant species,
n = number of pairs of observation
and Rs = Spearman's rank correlation coefficient.

Comparisons were made between animals within seasons. A high Rs value (close to 1) indicates a strong correlation for the order in which different plant species are selected by the animals. A strong negative Rs value shows a low potential for food competition by the animals being compared. Test of significance for a positive Rs value was by way of comparison with table values at n-2 degrees of freedom (Snedecor and Cochran 1967). Using the above two methods, animal diets were compared two at a time for each season. Significant positive values were interpreted to mean strong correlations for the order in which any two herbivores select the same plant species that constitute their diets. Trophic diversity indices (H") were calculated using the formula below to indicate food niche breadth using Shannon's diversity index (1948).

$$H''=-\sum_{n=i}^{s} Ni\ln Ni$$

where Ni is the proportion of the $i^{th}$ food item in the diet.

Trophic diversity index indicates variety and evenness of components in the diet. The index decreases as an animal relies on fewer food categories for most of their diets (Hurtubia 1973). High trophic diversity indices indicate that an animal does not rely of fewer major food categories for most of their diets, but is able to feed on many categories. Therefore, the herbivore with high trophic diversities is potentially better able to adopt its diets to changes in plant composition.

### 4.4.3 Animal density and habitat preferences

Animal density per Km² was calculated as shown below:

$$\text{Animal density } (N/Km^2) = \frac{\text{Animals counted in each block}}{\text{Total block area (Ha)}} \times 100$$

The total number of each species was obtained by multiplying its density in each vegetation type by the total area occupied by the vegetation type and summing up the totals of each vegetation type. The distribution of kongoni and wildebeest in all the habitat types were determined by monthly ground sample counts. To evaluate the animals' habitat preference, the relative densities of each animal species were calculated on seasonal basis. A Preference Index (P.I) was calculated for each species in each habitat type using an equation adopted from Hillman (1979) as shown below;

$$1.\ If, \frac{nx}{Nt} > \frac{ax}{At}, then, P.I(x) = \frac{1}{1-\frac{ax}{At}} \times \left(\frac{nx}{Nt} - \frac{ax}{At}\right)$$

$$2.\ If, \frac{nx}{Nt} < \frac{ax}{At}, then, P.I(x) = \frac{1}{\frac{ax}{At}} \times \left(\frac{nx}{Nt} - \frac{ax}{At}\right)$$

Where; P.I = Habitat Preference Index,
nx = the number of animal species expected in habitat "X",
Nt = the total number of each animal species expected in the ranch,
ax = the surface area of habitat "X" (Km²),
At = area (Km²) covered during the census in habitat "X',
nx/Nt = proportion of animal species expected in habitat "X" and
ax/At = the proportion of the total area covered by habitat "X".

The values obtained range from -1.0 to +1.0, indicating the least and the most preferred habitats respectively. A value of zero indicates a random association and a value of -1.0 indicates that the habitat was not utilized at all.

The data was analyzed using a split-split plot design. Treatment means were separated using Duncan's Multiple Range Test and statistical analysis were done using SAS procedures (SAS Inc.,1987) and graphics enhanced using Freelance Program (Lotus Development Corporation 1991).

# CHAPTER FIVE

# RESULTS AND DISCUSSION

## 5.1 Vegetation and animal diets

### 5.1.1 Woody plant cover and density

The results of the ten PCQ transects showed clear differences in canopy cover and tree density between transects representing the different vegetation types (habitats). In the *Balanites* tree grassland the canopy cover was below 2% (Table 4). In this vegetation type

Table 4: Mean absolute and relative canopy cover (%) and density (number of plants per hectare) for *Balanites* tree grassland.

| Dominant species | Density | | Cover | |
|---|---|---|---|---|
| | Absolute | Relative | Absolute | Relative |
| *B. glabra* | 13.67 | 92.92 | 1.37 | 97.89 |
| *A. drepanolobium* | 0.76 | 5.42 | 0.02 | 1.31 |
| *A. xanthophloea* | 0.21 | 0.72 | 0.01 | 0.78 |
| *A. Stuhlmanii* | 0.07 | 0.42 | 0.01 | 0.02 |
| All species | 14.70 | 100.00 | 1.40 | 100.00 |

Balanites *glabra* contributed 97.89% of the woody plant cover while the other species contributed only 2.11%. This vegetation type had a lower density of trees (14.7 trees per hectare) with *B. glabra* contributing the highest percentage 92.92%.

As shown in Table 5 the *Balanites - Acacia* tree grassland canopy cover was dominated by *A. drepanolobium* contributing 69.17% while *A. stuhlmanii* and *B. glabra* each contributed 15.14% and 15.47%, respectively. This vegetation type had the highest tree density of 603.98 trees per hectare, with *A. drepanolobium* contributing the highest density (86.67%).

Table 5: Mean absolute and relative canopy cover (%) and density (number of plants per hectare) for *Balanites - Acacia* tree grassland.

| Dominant species | Density | | Cover | |
|---|---|---|---|---|
| | Absolute | Relative | Absolute | Absolute |
| *A. drepanolobium* | 523.44 | 86.67 | 7.62 | 69.17 |
| *B. glabra* | 60.41 | 10.00 | 1.73 | 15.47 |
| *A. stuhlmanii* | 17.62 | 2.92 | 1.71 | 15.14 |
| *Commiphora* spp | 2.51 | 0.42 | 0.02 | 0.23 |
| All species | 603.98 | 100.00 | 11.07 | 100.00 |

The *A. drepanolobium* dwarf tree grassland was dominated by *A. drepanolobium* which contributed 94.15% (Table 6) and 91.25% cover and trees per hectare, respectively, while *A. stuhlmanii* contributed 5.79% cover and 7.92% trees per hectare. The *Acacia* woodland had the highest number of dominant trees, with a total cover of 12.63% and high tree density of 456.41 trees per hectare as shown in Table 7. *A. drepanolobium* contributed 47.09%

of the cover and 41.67% of tree density. The *A. xanthophloea* bushland had the highest woody cover of 122.92% and tree density of 215.33 tree per hectare (Table 8). Tall trees above 8 M occurred in this vegetation type. This area occurred long a watercourse, where the ground water was close to the surface. *A. xanthophloea* contributed the highest percentage both in cover and density, 95.40% and 72.92%, respectively.

Table 6: Mean absolute and relative canopy cover (%) and density (number of plants per hectare) for *A. drepanolobium* dwarf tree grassland.

| Dominant species | Density | | Cover | |
|---|---|---|---|---|
| | Absolute | Relative | Absolute | Relative |
| *A. drepanolobium* | 168.04 | 91.25 | 2.56 | 94.15 |
| *A. stuhlmanii* | 14.98 | 7.92 | 0.15 | 5.79 |
| *B. glabra* | 1.49 | 0.83 | 0.01 | 0.06 |
| All species | 184.52 | 100.00 | 2.72 | 100.00 |

Table 7: Mean absolute and relative canopy cover (%) and density (number of plants per hectare) for Acacia woodland.

| Dominant species | Density | | Cover | |
|---|---|---|---|---|
| | Absolute | Relative | Absolute | Relative |
| *A. drepanolobium* | 187.49 | 41.67 | 5.93 | 47.09 |
| *A. xanthophloea* | 177.03 | 38.33 | 4.66 | 36.88 |
| *A. seyal* | 57.64 | 12.50 | 1.02 | 8.06 |
| *B. glabra* | 26.62 | 5.83 | 0.92 | 7.32 |
| *Commiphora* spp | 7.61 | 1.67 | 0.09 | 0.72 |
| All species | 456.41 | 100.00 | 12.63 | 100.00 |

Table 8: Mean absolute and relative canopy cover (%) and density (number of plants per hectare) for *A. xanthophloea* bushland

| Dominant species | Density | | Cover | |
|---|---|---|---|---|
| | Absolute | Relative | Absolute | Relative |
| *A. xanthophloea* | 157.04 | 72.92 | 117.07 | 95.40 |
| *B. glabra* | 38.70 | 17.92 | 3.96 | 3.08 |
| *Dombeya* spp | 9.78 | 4.58 | 0.88 | 0.73 |
| *A. seyal* | 7.34 | 3.34 | 0.88 | 0.67 |
| *A. stuhlmanii* | 1.76 | 0.83 | 0.12 | 0.11 |
| *Commiphora* spp | 0.88 | 0.42 | 0.01 | 0.01 |
| All species | 215.33 | 100.00 | 122.92 | 100.00 |

Analysis of variance of the density and percent canopy cover of the trees in all the habitats sampled, revealed that both the density and canopy cover was dependent upon the habitat (environment), tree species and their interactions. Evidence for this is shown by a significant differences in density between habitats ($F_{4,45}$=92.49 df=4 $p<0.05$), trees ($F_{6,45}$=237.06 df=6 $p<0.05$) and habitat - tree interaction ($F_{24,45}$=93.81 df=24 $p<0.05$) in the analysis as shown in Table 9. Similarly there were significant differences in percent canopy cover between habitats ($F_{4,45}$=429.10 df=4 $p<0.05$), trees ($F_{6,45}$=439.24 df=6 $p<0.05$) and habitat - tree interaction ($F_{24,45}$=427.54 df=24 $p<0.05$) (Table 10).

Table 9: Analysis of variance of density of trees per hectare in the study area.

| Source | F | SS | MS | F Value |
|---|---|---|---|---|
| CORRECTED TOTAL | 69 | 687932.24 | | |
| PLOT | 1 | 29.35 | 29.35 | 0.17ns |
| HABITAT | 4 | 62460.70 | 15615.17 | 92.49* |
| TREE | 6 | 240128.41 | 40021.40 | 237.06* |
| PLOT*HABITAT | 4 | 351.17 | 87.79 | 0.52ns |
| PLOT*TREE | 6 | 825.13 | 137.52 | 0.81ns |
| HABITAT*TREE | 24 | 380085.66 | 15836.90 | 93.81* |

* - significant ($p<0.05$), ns - non significant.

Table 10: Analysis of variance of percent canopy cover of woody plants in the study area.

| Source | DF | SS | MS | F Value |
|---|---|---|---|---|
| CORRECTED TOTAL | 69 | 26472.04 | | |
| PLOT | 1 | 4.11 | 4.11 | 2.28ns |
| HABITAT | 4 | 3101.96 | 775.49 | 429.10* |
| TREE | 6 | 4762.94 | 793.82 | 439.24* |
| PLOT*HABITAT | 4 | 11.37 | 2.84 | 1.57ns |
| PLOT*TREE | 6 | 3.84 | 0.64 | 0.35ns |
| HABITAT*TREE | 24 | 18544.43 | 772.68 | 427.54* |

* - significant ($p<0.05$), ns - non significant.

The mean percent canopy cover varied greatly from habitat to habitat and from tree to tree. It ranged from 0.20 to 17.56 for *Balanites* tree grassland and *A. xanthophloea* bushland habitats respectively (Table 11), and from 0.02 to 24.35 for *Commiphora* spp and *A. xanthophloea* tree species respectively (Table 12). The tree density per hectare likewise varied greatly from habitat to habitat. It ranged from 2.10 in the *B. glabra* tree grassland to 86.28 in *Balanites* - *Acacia* tree grassland (Table 11). The same phenomenon likewise varied from tree to tree. It ranged from 1.96 for *Dombeya spp.* to 175.95 for *A. drepanolobium* (Table 12).

Table 11: Mean density per hectare and percent canopy cover of trees in each habitat in the study area.

| Habitat | Density | Canopy Cover | n |
|---|---|---|---|
| Baltre[2] | 2.101d* | 0.200c* | 14 |
| Balacc[3] | 86.284a | 1.581b | 14 |
| Accdrf[4] | 26.359c | 0.388c | 14 |
| Accwdl[5] | 65.200b | 1.804b | 14 |
| Accxan[6] | 30.786c | 17.560a | 14 |

* means followed by the same letter in the same column are not significantly different at $P<0.05$. [1] *Themeda* grassland, [2] *Balanites* tree grassland, [3] *Balanites* - Acacia tree grassland, [4] *A. drepanolobium* dwarf tree grassland, [5] *Acacia* woodland and [6] *A. xanthophloea* bushland.

Table 12: Mean density per hectare and percent canopy cover of each tree species in the study area.

| Species | Density | Cover | n |
|---|---|---|---|
| *A . drepanolobium* | 175.949a* | 3.226b* | 10 |
| *A . seyal* | 12.996d | 0.379cd | 10 |
| *A. xanthophloea* | 66.856b | 24.348a | 10 |
| *B. glabra* | 28.178c | 1.596c | 10 |
| *Commiphora* spp | 2.200d | 0.024d | 10 |
| *A. stuhlmanii* | 6.886d | 0.396cd | 10 |
| *Dombeya* spp. | 1.956d | 0.176d | 10 |

* means followed by the same letter in the same column are not significantly different at $P<0.05$.

### 5.1.2 Herb layer

The herbaceous standing biomass remained high during the study period (Table 13). All the habitats, except *Themeda* grassland, had very high standing biomass both during the wet and dry seasons, but were generally lower during the dry season. *Themeda* grassland had the lowest mean standing biomass of 789 and 495 Kg/ha. during the wet and dry seasons, respectively. *Balanites* tree grassland, which was heavily utilized by the study animals, had 1838 and 1386 Kg/ha. mean standing biomass during the wet and dry seasons, respectively. Other habitats had higher mean standing biomass than *Balanites* tree grassland irrespective of the season, with *Acacia* woodland always having the highest. The change in percentage standing biomass of dominant grass species varied with habitat type. Grasses with more than 10% standing biomass were termed dominant, while those with between 1% and 10% were termed subdominant.

Table 13: Mean herbaceous standing biomass in Kilogrammes per hectare for each habitat during the wet and dry seasons.

| Habitat | Thtgsl[1] | Baltre[2] | Balacc[3] | Accdrf[4] | Accwdl[5] | Accxan[6] |
|---|---|---|---|---|---|---|
| Wet | 789 | 1838 | 2005 | 2456 | 3130 | 2585 |
| Dry | 495 | 1386 | 1836 | 2218 | 2458 | 1768 |

[1] *Themeda* grassland, [2] *Balanites* tree grassland, [3] *Balanites - Acacia* tree grassland, [4] *A. drepanolobium* dwarf tree grassland, [5] *Acacia* woodland and [6] *A. xanthophloea* bushland.

*Themeda triandra*, *Digitaria macroblephara* and *Penisetum mezianum* were the three most dominant species in the *Themeda* grassland, *Balanites* tree grassland, *Balanites - Acacia* tree grassland and in *Acacia* woodland vegetation types (tables 14, 15, 16 and 18). *Ischaemum afrum*, *Lintonia nutans*, and *P. mezianum* were the dominant species in the *A. drepanolobium* dwarf tree grassland (Table 17). In the *A. xanthophloea* bushland *Penisetum stramineum*, *P. mezianum*, *D. macroblephara* and *P. maximum* were the dominant species, (Table 19). The subdominant species, unlike the dominant ones, varied from one vegetation type to another and showed no general pattern. They ranged from *D. macroblephara* in the *A.*

*drepanolobium* dwarf tree grassland in the depressed areas to *Cynodon dactylon* in *Themeda* grassland at the ridge tops (Tables 14 - 19).

Table 14: Seasonal percent standing biomass of dominant grasses (>1%) and forbs in the *Themeda* grassland.

| Plant Species | SEASON | | | |
|---|---|---|---|---|
| | Wet | | Dry | |
| | Mean | SD | Mean | SD |
| *D. macroblephara* | 29.90 | 5.18 | 22.00 | 5.70 |
| *T. triandra* | 11.40 | 2.46 | 12.10 | 1.98 |
| *P. mezianum* | 10.60 | 8.24 | 17.80 | 17.60 |
| *C. dactylon* | 9.90 | 8.74 | 10.60 | 5.17 |
| *Harpachne schimperi* | 7.13 | 1.69 | 5.20 | 3.67 |
| *Panicum* spp | 6.33 | 5.98 | 5.26 | 4.64 |
| *Bothriochloa inscupta* | 5.53 | 2.01 | 4.44 | 1.83 |
| *P. stramineum* | 2.50 | 3.12 | 9.74 | 4.38 |
| *Microchloa kunthii* | 1.26 | 1.64 | 0.00 | 0.00 |
| Sedges | 1.01 | 1.74 | 0.00 | 0.00 |
| *Chloris gayana* | 0.09 | 0.16 | 1.15 | 2.00 |
| *Penisetum masaicum* | 0.00 | 0.00 | 2.92 | 5.06 |
| Forbs | 12.70 | 2.62 | 7.43 | 5.73 |

Table 15: Seasonal percent standing biomass of dominant grasses (>1%) and forbs in the *Balanites* tree grassland.

| Plant Species | SEASON | | | |
|---|---|---|---|---|
| | Wet | | Dry | |
| | Mean | SD | Mean | SD |
| *T. triandra* | 42.40 | 4.77 | 36.10 | 1.88 |
| *D. macroblephara* | 21.00 | 4.35 | 18.40 | 1.64 |
| *P. mezianum* | 14.50 | 5.91 | 16.90 | 8.97 |
| *B. inscupta* | 3.69 | 1.09 | 2.79 | 1.08 |
| *Hyperrhenia* spp | 3.66 | 3.82 | 16.40 | 4.58 |
| *P. stramineum* | 1.61 | 2.80 | 0.00 | 0.00 |
| *Aristida* spp | 1.61 | 1.23 | 1.48 | 0.50 |
| *H. schimperi* | 1.39 | 1.32 | 0.16 | 0.29 |
| *I. afrum* | 1.00 | 0.88 | 0.00 | 0.00 |
| *C. dactylon* | 0.88 | 0.78 | 1.75 | 0.95 |
| Forbs | 5.26 | 1.78 | 5.30 | 3.67 |

Table 16: Seasonal percent standing biomass of dominant grassland (>1%) and forbs in the *Balanites - Acacia* tree grassland.

| Plant Species | SEASON | | | |
|---|---|---|---|---|
| | Wet | | Dry | |
| | Mean | SD | Mean | SD |
| *P. mezianum* | 26.80 | 7.49 | 36.80 | 5.44 |
| *T. triandra* | 25.10 | 4.42 | 21.20 | 0.19 |
| *D. macroblephara* | 15.40 | 4.33 | 17.10 | 1.48 |
| *P. masaicum* | 9.17 | 11.30 | 0.00 | 0.00 |
| *P. stramineum* | 7.60 | 7.53 | 8.18 | 2.43 |
| *B. inscupta* | 2.99 | 2.61 | 0.00 | 0.00 |
| *Hyperrhenia* spp | 2.15 | 3.73 | 0.00 | 0.00 |
| *C. gayana* | 1.83 | 2.95 | 0.00 | 0.00 |
| *L. nutans* | 1.66 | 2.69 | 8.05 | 3.40 |
| *C. dactylon* | 1.61 | 2.17 | 1.14 | 1.09 |
| *I. afrum* | 0.44 | 0.77 | 5.77 | 1.45 |
| Forbs | 3.83 | 1.19 | 1.55 | 0.77 |

Table 17: Seasonal percent standing biomass of dominant grasses (>1%) and forbs in the *A. drepanolobium* dwarf tree grassland.

| Plant Species | SEASON | | | |
|---|---|---|---|---|
| | Wet | | Dry | |
| | Mean | SD | Mean | SD |
| *D. macroblephara* | 15.60 | 15.80 | 3.42 | 1.41 |
| *P. mezianum* | 14.50 | 13.90 | 7.40 | 1.76 |
| *P. stramineum* | 13.80 | 7.67 | 11.70 | 6.26 |
| *L. nutans* | 12.50 | 12.20 | 14.70 | 0.25 |
| *I. afrum* | 11.40 | 8.15 | 30.00 | 2.68 |
| *P. masaicum* | 2.65 | 3.34 | 0.00 | 0.00 |
| *B. inscupta* | 1.22 | 1.82 | 0.00 | 0.00 |
| *Sporobolus pellucidus* | 1.07 | 1.29 | 0.00 | 0.00 |
| *C. dactylon* | 0.45 | 0.52 | 7.12 | 6.18 |
| Forbs | 25.10 | 9.61 | 24.70 | 3.36 |

Table 18: Seasonal percent standing biomass of dominant grasses (>1%) and forbs in the *Acacia* woodland.

| Plant Species | SEASON | | | |
|---|---|---|---|---|
| | Wet | | Dry | |
| | Mean | SD | Mean | SD |
| *D. macroblephara* | 20.80 | 1.97 | 29.70 | 3.12 |
| *P. mezianum* | 19.30 | 2.11 | 21.30 | 3.24 |
| *T. triandra* | 17.00 | 2.28 | 14.90 | 5.80 |
| *I. afrum* | 14.40 | 3.65 | 9.95 | 5.72 |
| *L. nutans* | 7.82 | 7.12 | 12.30 | 6.17 |
| *P. stramineum* | 4.99 | 4.45 | 4.31 | 3.80 |
| Forbs | 14.70 | 5.00 | 6.42 | 5.08 |

Table 19: Seasonal percent standing biomass of dominant grasses (>1%) and forbs in the *A. xanthophloea* bushland.

| Plant Species | SEASON | | | |
|---|---|---|---|---|
| | Wet | | Dry | |
| | Mean | SD | Mean | SD |
| *P. stramineum* | 29.40 | 7.88 | 24.00 | 4.47 |
| *P. mezianum* | 19.30 | 6.15 | 22.40 | 2.60 |
| *D. macroblephara* | 18.80 | 4.63 | 20.60 | 6.91 |
| *P. maximum* | 10.30 | 1.07 | 16.20 | 3.05 |
| *L. nutans* | 4.48 | 5.27 | 7.40 | 5.43 |
| *I. afrum* | 3.39 | 3.16 | 1.90 | 1.70 |
| *C. dactylon* | 0.75 | 0.33 | 1.90 | 0.90 |
| *C. gayana* | 0.00 | 0.00 | 1.07 | 0.93 |
| Forbs | 12.20 | 5.82 | 4.24 | 0.32 |

Table 20 shows the analysis of variance of seasonal herbaceous mean percent standing biomass above 1%. There was no significant variation in percent standing biomass among plant species between the wet and the dry season. However the percent standing biomass varied from habitat to habitat ($F_{5,62}=7.04$ df=5 $p<0.05$). It was highest in *Acacia* woodland and lowest in *Themeda* grassland (Table 21). The standing biomass varied greatly among the plant species ($F_{18,62}=24.25$ df=18 $p<0.05$). It was highest among three dominant grasses; *P. mezianum*, *D.*

*macroblephara* and *T. triandra*, where it ranged from 19% to 22.6% respectively. The standing biomass of forbs in general was lower (10.31%) than grasses, but was higher than for some individual grasses as shown in Table 22. The percent standing biomass of herbaceous plants is dependent on the interaction between the plant and the environment. Evidence for this is shown by a significant interaction term between habitat and herb in the analysis as shown in Table 20 ($F_{38,61}$=7.00 df=38 $p<0.05$).

Table 20: Analysis of variance of seasonal percent standing biomass of dominant grasses (>1%) and forbs.

| Source | DF | SS | MS | F Value |
|---|---|---|---|---|
| CORRECTED TOTAL | 123 | 11067.18 | | |
| SEASON | 1 | 0.22 | 0.23 | 0.02ns |
| HABITAT | 5 | 487.60 | 97.52 | 7.04* |
| PLANT | 18 | 6047.14 | 335.95 | 24.25* |
| HABITAT*PLANT | 38 | 3687.20 | 97.03 | 7.00* |

* - significant ($p<0.05$), ns - non significant.

Table 21: Mean percent standing biomass of dominant grasses (>1%) and forbs in each habitat.

| Habitat | Mean standing biomass | n |
|---|---|---|
| Accwdl[5] | 14.171a* | 14 |
| Accxan[6] | 11.052b | 18 |
| Accdrf[4] | 9.892bc | 20 |
| Baltre[2] | 8.943bc | 22 |
| Balacc[3] | 8.282c | 24 |
| Thtgsl[1] | 7.598c | 26 |

* Means followed by the same letter are not significantly different ($p<0.05$). [1]*Themeda* grassland, [2]*Balanites* tree grassland, [3]*Balanites - Acacia* tree grassland, [4]*A. drepanolobium* dwarf tree grassland, [5]*Acacia* woodland and [6]*A. xanthophloea* bushland.

Table 22: Mean seasonal percent standing biomass of dominant grasses (>1%) and forbs.

| Plant species | Mean | n |
|---|---|---|
| *T. triandra* | 22.582a* | 8 |
| *D. macroblephara* | 19.444a | 12 |
| *P. mezianum* | 19.026a | 12 |
| *P. maximum* | 13.310b | 2 |
| Forbs | 10.308b | 12 |
| *P. stramineum* | 9.840bc | 12 |
| *L. nutans* | 8.634bcd | 8 |
| *I. afrum* | 7.845bcde | 10 |
| *Panicum* spp | 5.800bcde | 2 |
| *Hyperrhenia* spp | 5.575cdef | 4 |
| *C. dactylon* | 3.618def | 10 |
| *H. schimperi* | 3.475def | 4 |
| *B. inscupta* | 2.586ef | 8 |
| *P. masaicum* | 2.460ef | 6 |
| *Aristida* spp | 1.545f | 2 |
| *C. gayana* | 0.693f | 6 |
| *M. kunthii* | 0.635f | 2 |
| *Sporobolus pellucidus* | 0.535f | 2 |
| Sedges | 0.505f | 2 |

* Means followed by the same letter are not significantly different ($p<0.05$).

### 5.1.3 Diet composition by plant species

The botanical composition in the animals' diets during the wet and dry seasons are shown in Tables 23 and 24. During the wet season, the three most prominent grass species in each animal species diet (Table 23 and Figure 4 (A)) and their means were as follows:

Cattle: *T. triandra*, *D. macroblephara* and *P. mezianum*, each contributed 29.5%, 24.7% and 15.9% respectively. Their combined contribution was 70.2%. Other monocot species combined contributed 25.8% while browse contribution was 4.0%.

Kongoni: *D. macroblephara*, *T. triandra* and *P. mezianum* were the prominent grass species. Each species made up 20.8%, 21.1% and 19.4% respectively. Their combined contribution to the diet was 61.3%. Other grass species' combined diet contribution was 37.4%, whereas browse contributed only 1.2%.

Wildebeest: *T. triandra*, *D. macroblephara* and *P. mezianum* made up 23.7%, 21.1%, and 18.7% of the diet respectively. Their combined contribution being 63.4%. Other grass species contributed 34.7% while browse component of the diet was only 1.9%.

Table 23: Mean percent relative densities of the botanical composition of the diets of the study animals during the wet season (January-April, 1993).

| Species | CATTLE |  |  |  | KONGONI |  |  |  | WILDEBEEST |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Jan | Feb | Mar | Apr | Jan | Feb | Mar | Apr | Jan | Feb | Mar | Apr |
| *T. triandra* | 33.56 | 30.32 | 26.73 | 27.32 | 19.76 | 21.10 | 21.22 | 22.30 | 28.00 | 26.24 | 21.85 | 18.71 |
| *D. macroblephara* | 25.79 | 27.59 | 27.44 | 18.17 | 26.13 | 18.21 | 16.37 | 22.60 | 20.38 | 15.74 | 20.62 | 27.48 |
| *P. mezianum* | 13.00 | 14.39 | 15.03 | 21.31 | 19.57 | 23.61 | 16.80 | 17.73 | 21.65 | 17.82 | 21.24 | 13.92 |
| *P. stramineum* | 2.60 | 2.30 | 3.68 | 2.33 | 6.39 | 7.15 | 15.70 | 8.96 | 1.59 | 5.16 | 5.03 | 5.11 |
| *I. afrum* | . | 1.64 | 2.08 | 8.05 | 6.58 | 6.51 | 4.46 | 5.44 | 1.25 | 3.68 | 7.40 | 10.47 |
| Other grasses* | 2.09 | 2.62 | 2.20 | 2.78 | 3.42 | 6.69 | 3.68 | 4.01 | 7.52 | 10.82 | 3.01 | 3.43 |
| *C. dactylon* | 4.25 | 4.01 | 4.45 | 6.29 | 2.66 | 2.74 | 3.43 | 3.49 | 3.07 | 2.97 | 3.25 | 1.97 |
| *L. nutans* | 0.08 | 1.67 | 1.49 | 1.61 | 4.25 | 4.65 | 4.28 | 5.35 | 1.96 | 2.70 | 6.37 | 3.88 |
| Browse | 2.80 | 2.39 | 5.20 | 5.76 | . | 1.18 | 1.78 | 1.90 | 2.93 | 0.98 | 0.86 | 2.83 |
| *B. inscupta* | 3.34 | 2.17 | 1.58 | 0.70 | 2.35 | 3.31 | 0.73 | 1.03 | 1.07 | 2.19 | 1.60 | 2.63 |
| *Aristida* spp | 3.45 | 2.76 | 0.80 | 0.49 | 1.78 | 0.86 | 1.21 | 0.60 | 1.27 | 1.67 | 0.75 | 1.17 |
| *C. gayana* | 1.65 | 0.74 | 0.93 | 0.78 | 1.85 | 1.01 | 0.69 | 0.18 | 3.09 | 0.85 | 2.90 | 0.60 |
| *Brachiaria* spp | 2.42 | 1.39 | 2.26 | 0.59 | 1.81 | 0.70 | 2.08 | 0.32 | 0.56 | 1.37 | 0.44 | 0.88 |
| *Hyperrhenia* spp | 0.67 | 0.46 | 0.25 | 0.41 | . | 0.19 | 0.98 | 1.15 | 1.72 | 0.49 | 0.90 | 4.51 |
| *P. masaicum* | 0.34 | 0.33 | 0.90 | 0.25 | 1.02 | . | 2.55 | 3.05 | 0.00 | 1.47 | 0.46 | 1.27 |
| *H. contortus* | 0.50 | 0.60 | 1.72 | 0.18 | 0.18 | 0.46 | 1.15 | 0.62 | 0.67 | 2.56 | 2.16 | . |
| *H. schimperi* | 0.90 | 1.17 | 1.86 | 0.63 | 0.83 | 0.47 | 0.81 | 0.32 | 1.24 | 1.32 | 0.09 | 0.43 |
| *C. ciliaris* | 1.14 | 0.60 | 0.95 | 0.69 | 1.34 | 0.42 | 1.48 | 0.52 | 0.89 | 0.51 | 0.37 | . |
| *S. pellucides* | 1.19 | 1.59 | 0.46 | 0.95 | 0.08 | 0.74 | 0.36 | 0.22 | . | 0.22 | . | . |
| Sedges | . | 0.74 | . | 0.71 | . | . | 0.23 | 0.23 | 0.45 | . | 0.74 | 0.72 |
| *Panicum* spp | 0.23 | 0.53 | . | . | . | . | . | . | . | . | . | . |

* - unidentified grasses in the diet and . (dot) not observed in the diet.

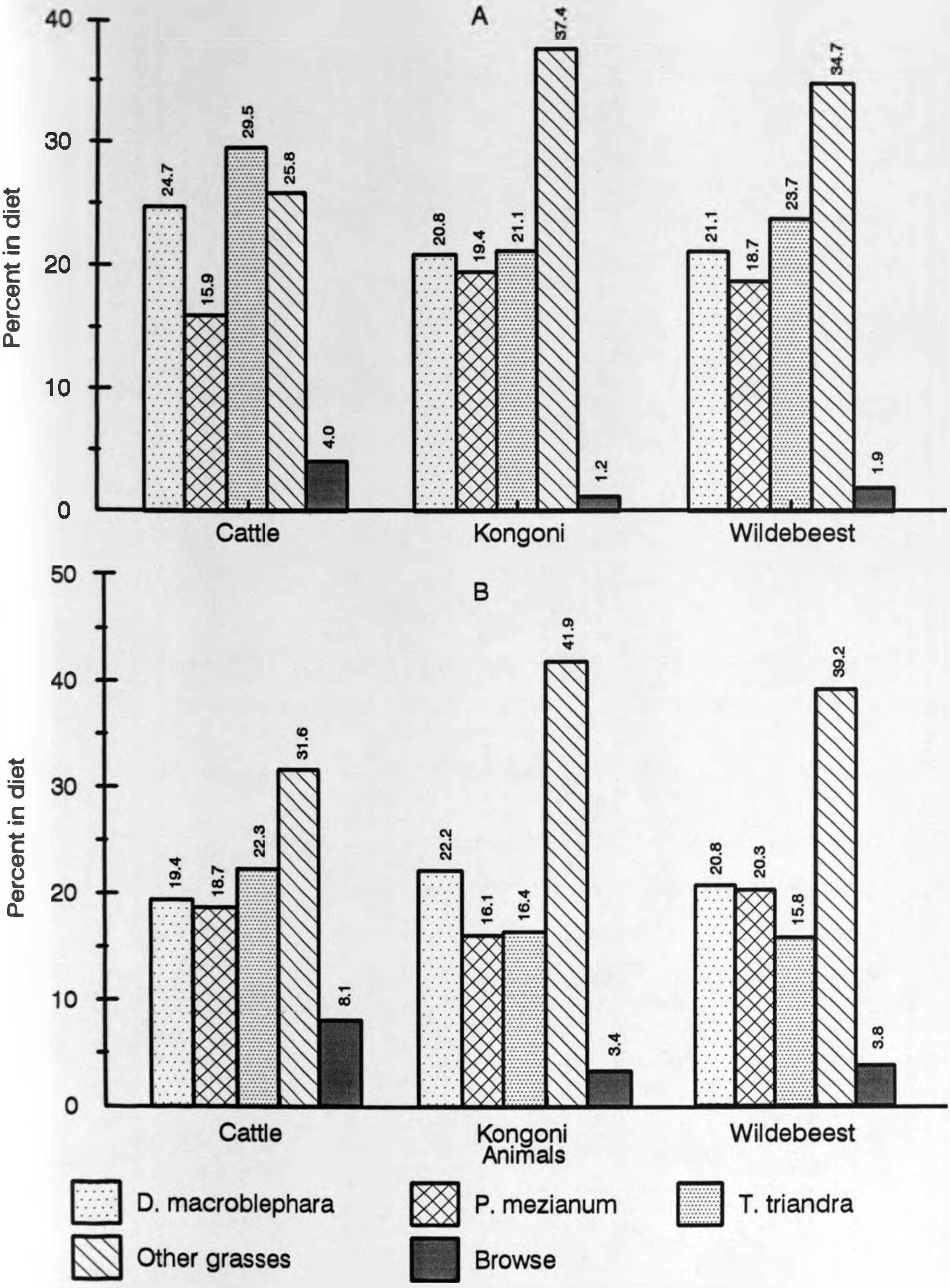

Figure 4: Prominent grass species and browse in animal diets during the wet (A) and dry (B) seasons at Game Ranching Ltd., Athi River, Kenya. 1993.

The mean percent relative densities of the botanical composition of animal diets during the dry season are shown in Table 24. The three most dominant grass species, other grasses and browse contribution to the diet (Figure 4 (B)) and their means were as follows;

Cattle: *T. triandra*, *D. macroblephara* and *P. mezianum* were prominent grass species. Their contribution to diets were 22.3%, 19.4% and 18.7%, respectively. The three made up 60.3% of the diet. Other grass and browse species each contributed 31.6% and 8.1% to the diet.

Kongoni: *D. macroblephara*, *T. triandra* and *P. mezianum* were the three most abundant plant species in the diet. These grasses contributed 22.2%, 16.4% and 16.1%, respectively thus constituting 54.7% of the diet. Other grasses contributed 41.9%, whereas browse component was 3.8% of the diet.

Wildebeest: *P. mezianum*, *D. macroblephara* and *T. triandra*, each contributed 20.3%, 20.8% and 15.8% respectively to the diet, thus making up 57.0% of the diet. Again browse contributed only 3.8%, whereas other grasses contributed 39.2% to the diet.

Table 24: Mean percent relative densities of the botanical composition of the diets of the study animals during the dry season (May - August, 1993).

| Species | CATTLE | | | | KONGONI | | | | WILDEBEEST | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | May | Jun | Jul | Aug | May | Jun | Jul | Aug | May | Jun | Jul | Aug |
| *D. macroblephara* | 20.79 | 18.85 | 19.19 | 18.76 | 22.39 | 22.62 | 23.21 | 20.59 | 24.63 | 19.71 | 21.82 | 16.91 |
| *P. mezianum* | 16.60 | 18.04 | 19.69 | 20.28 | 14.64 | 15.47 | 18.11 | 16.14 | 22.20 | 21.57 | 17.33 | 20.24 |
| *T. triandra* | 24.17 | 22.11 | 21.15 | 21.71 | 15.83 | 15.37 | 18.19 | 16.32 | 14.57 | 16.00 | 16.38 | 16.45 |
| *I. afrum* | 6.13 | 4.89 | 7.65 | 8.47 | 13.79 | 13.61 | 12.78 | 10.62 | 8.29 | 9.93 | 8.80 | 8.44 |
| *L. nutans* | 4.41 | 7.70 | 5.57 | 7.73 | 9.90 | 10.25 | 7.28 | 9.35 | 6.30 | 6.18 | 5.88 | 6.62 |
| *P. stramineum* | 7.33 | 8.72 | 4.36 | 3.88 | 4.08 | 9.30 | 6.08 | 8.04 | 3.19 | 6.93 | 8.59 | 7.32 |
| *C. dactylon* | 3.94 | 2.23 | 3.79 | 3.29 | 8.60 | 5.11 | 5.91 | 6.33 | 6.30 | 8.11 | 6.41 | 12.06 |
| Browse | 8.42 | 9.21 | 5.33 | 9.33 | 6.62 | 1.70 | 2.05 | 3.09 | 3.61 | 3.73 | 4.43 | 3.50 |
| Other grasses* | 3.52 | 3.60 | 4.83 | 4.57 | 2.69 | 4.57 | 3.05 | 4.29 | 2.94 | 4.25 | 6.70 | 5.64 |
| Sedges | 0.49 | 1.01 | 3.72 | . | 0.14 | 0.55 | . | 3.24 | 1.49 | 0.40 | . | 0.11 |
| *Hyperrhenia* spp | 1.58 | . | 1.78 | . | . | . | 0.21 | . | 1.22 | 0.20 | 1.56 | 1.13 |
| *Brachiaria* spp | 0.54 | 0.18 | 1.54 | 0.73 | 0.30 | . | 0.42 | . | 0.17 | 0.79 | 0.16 | . |
| *C. gayana* | 0.63 | 0.55 | 0.19 | 0.72 | 0.08 | 0.36 | 0.42 | 0.26 | 0.45 | 0.49 | 0.63 | . |
| *B. inscupta* | 0.26 | 0.45 | 0.29 | . | 0.14 | 0.19 | 1.37 | 0.27 | 0.45 | 0.80 | . | 0.09 |
| *C. ciliaris* | . | 0.47 | 0.92 | 0.55 | . | 0.09 | 0.10 | . | 0.35 | 0.45 | 0.17 | 0.72 |
| *&S. pellucides* | 0.49 | 1.50 | . | . | 0.23 | . | 0.21 | . | 0.86 | 0.34 | . | . |
| *Aristida* spp | 0.34 | . | . | . | 0.15 | . | 0.31 | . | 1.98 | . | 0.10 | 0.10 |
| *P. masaicum* | . | . | . | . | 0.16 | . | 0.21 | 1.37 | 0.47 | . | 0.35 | 0.36 |
| *H. contortus* | . | 0.48 | . | . | 0.26 | 0.54 | . | . | . | . | 0.70 | 0.29 |
| *H. schimperi* | 0.36 | . | . | . | . | 0.27 | 0.10 | 0.09 | 0.53 | 0.11 | . | . |

* - unidentified grasses in the diet and . (dot) not observed in the diet.

Table 25: Mean diet preference indices* of cattle, kongoni and wildebeest with percent plant availability (PA) during the wet and dry seasons, at GRL, Athi River 1993.

| Plant species | SEASON | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Wet | | | | Dry | | | |
| | Ct | Kg | Wb | PA | Ct | Kg | Wb | PA |
| *Brachiaria* spp | 10.72 | 6.30 | 12.38 | 0.30 | . | . | . | 0.07 |
| *H. schimperi* | 5.68 | 2.93 | 4.56 | 0.43 | 2.99 | 2.50 | 5.35 | 0.06 |
| *C. dactylon* | 5.68 | 3.39 | 2.71 | 1.18 | 1.36 | 2.91 | 4.10 | 2.35 |
| *C. gayana* | 3.27 | 4.39 | . | 0.97 | 10.40 | . | . | 0.04 |
| *Aristida* spp. | 4.23 | 2.54 | 4.28 | 0.56 | 0.29 | 0.13 | 1.81 | 0.31 |
| Sedges | 3.79 | 0.31 | 3.64 | 0.13 | . | . | . | 0.02 |
| *D. macroblephara* | 1.42 | 1.28 | 1.20 | 17.46 | 1.20 | 1.35 | 1.26 | 16.18 |
| *I. afrum* | 0.65 | 2.10 | 1.21 | 3.64 | 0.73 | 1.41 | 1.00 | 8.99 |
| *P. stramineum* | 0.85 | 2.28 | 0.80 | 6.67 | 0.94 | 1.05 | 0.87 | 6.88 |
| *S. pellucides* | 5.18 | 1.37 | 0.20 | 0.31 | . | . | . | 0.07 |
| *T. triandra* | 1.21 | 0.84 | 0.96 | 25.41 | 1.12 | 0.78 | 0.77 | 20.25 |
| *B. inscupta* | 0.87 | 1.07 | 1.62 | 2.54 | 0.34 | 0.37 | 0.66 | 0.61 |
| *P. mezianum* | 0.77 | 1.00 | 0.89 | 20.71 | 0.71 | 0.60 | 0.84 | 25.79 |
| *Panicum* spp. | 1.14 | 0.00 | 3.08 | 0.18 | . | . | . | 0.06 |
| Browse | 0.43 | 0.11 | 0.28 | 8.63 | 1.31 | 0.54 | 0.53 | 6.97 |
| *L. nutans* | . | . | . | 3.61 | 0.89 | 1.30 | 0.84 | 7.85 |
| *P. masaicum* | 0.19 | 0.55 | 0.83 | 4.79 | . | . | . | 0.02 |
| *Hyperrhenia* spp. | . | . | . | 1.98 | 0.15 | 0.00 | 0.29 | 3.47 |

*Preference index = Percent in diet/percent availability, Kg - kongoni, Wb - wildebeest, Ct - cattle and PA - plant availability.

The seasonal diet preference indices for cattle, kongoni and wildebeest with percent plant availability in the ranch are shown in Table 25. Analysis of variance of mean diet preference indices of the plant species eaten by the animals (Table 26) revealed that the diet preference indices differed significantly between the animals ($F_{2,18}=8.39$, df=2, $p<0.05$). *Brachiaria* species

Table 26: Analysis of variance of mean diet preferences of cattle, kongoni and wildebeest.

| Source | DF | SS | MS | F Value |
|---|---|---|---|---|
| CORRECTED TOTAL | 83 | 454.14 | | |
| SEASON | 1 | 20.68 | 20.68 | 33.72* |
| ANIMAL | 2 | 10.29 | 5.14 | 8.39* |
| DIET | 17 | 315.96 | 18.58 | 30.30* |
| ANIMAL*DIET | 33 | 53.02 | 1.60 | 2.62* |
| SEASON*DIET | 10 | 40.88 | 4.08 | 6.66* |
| SEASON*ANIMAL | 2 | 2.24 | 1.12 | 1.83ns |

* - significant ($p<0.05$), ns - non significant.

recorded the highest diet preference index, followed by *C. gayana*, while *Hyperrhenia* species had the lowest index (Table 27). The diet preference indices for animals differed from one season to the other ($F_{1,18}=33.72$, df=1, $p<0.05$). It tended to be high during the wet season and low during the dry season indicating that the degree of selectivity was low during the dry season. Similarly, the diet preference indices varied significantly from one plant species to another ($F_{17,18}=30.30$, df=17, $p<0.05$). The diet preferences seemed to be dependent on the interactions between season and plant species and on the interactions between animals and plant species and not on animal - season interaction. This is supported by a significant season - diet and animal - diet interaction terms in our model ($F_{10,18}=6.66$ df=10, $p=0.05$ and

$F_{33,18}$=2.62, df=33, $p<0.05$ respectively), while animal - season interaction was non significant.

Table 27: Mean diet preferences of cattle, kongoni and wildebeest.

| Diet | Mean diet preference | n |
|---|---|---|
| *Brachiaria* spp | 9.800a* | 3 |
| *C. gayana* | 6.020b | 3 |
| *H. schimperi* | 4.002c | 6 |
| *C. dactylon* | 3.358cd | 6 |
| Sedges | 2.580cde | 3 |
| *S. pellucidus* | 2.250cdef | 3 |
| *Aristida* spp | 2.213cdef | 6 |
| *Panicum* spp | 1.407edf | 3 |
| *D. macroblephara* | 1.285ef | 6 |
| *I. afrum* | 1.183ef | 6 |
| *P. stramineum* | 1.132ef | 6 |
| *L. nutans* | 1.010ef | 3 |
| *T. triandra* | 0.947ef | 6 |
| *B. inscupta* | 0.822ef | 6 |
| *P. mezianum* | 0.802ef | 6 |
| Browse | 0.533ef | 6 |
| *P. masaicum* | 0.523ef | 3 |
| *Hyperrhenia* spp | 0.147ef | 3 |

* Means followed by the same letter are not significantly different at $p<0.05$.

### 5.1.4 Seasonal dietary overlaps between animals

Dietary overlaps during the rainy season were all above 70% and significant ($P<0.05$), as shown in Table 28 and illustrated in Figure 5. Cattle and kongoni diets had overlaps ranging from 72.59% to 79.56% with a mean overlap of 76.06%. Correlation coefficients were significant ($p<0.05$) and ranged from +0.46 to +0.87. Cattle and wildebeest diet overlaps ranged from 74.56% to 78.74%, with a mean overlap of 77.30%. All correlation coefficients were significant ($P<0.05$) and ranged from +0.62 to +0.72. Diet overlaps between kongoni and wildebeest ranged from 77.24% to 82.06% with a mean overlap of 80.83%. Correlation coefficients were significant during all periods and ranged from +0.64 to +0.90 ($p<0.05$).

Table 28: Percent similarity indices (S.I) and correlation coefficients (Rs) between cattle and wildlife diets during the wet season.

| Animal combination | Period | S.I | Rs | n | t |
|---|---|---|---|---|---|
| Cattle Vs kongoni | Jan | 76.14 | 0.46 | 20 | 2.218* |
| | Feb | 72.59 | 0.87 | 21 | 7.683* |
| | Mar | 75.99 | 0.78 | 20 | 5.253* |
| | Apr | 79.56 | 0.66 | 20 | 3.699* |
| | Mean | 76.06 ± 2.46 | | | |
| Cattle Vs wildebeest | Jan | 78.74 | 0.62 | 21 | 3.405* |
| | Feb | 78.30 | 0.72 | 21 | 4.507* |
| | Mar | 77.64 | 0.62 | 20 | 3.383* |
| | Apr | 74.56 | 0.68 | 20 | 3.940* |
| | Mean | 77.30 ± 1.63 | | | |
| Kongoni Vs wildebeest | Jan | 77.24 | 0.64 | 21 | 3.669* |
| | Feb | 82.97 | 0.80 | 20 | 5.726* |
| | Mar | 81.08 | 0.76 | 20 | 5.031* |
| | Apr | 82.06 | 0.90 | 20 | 8.890* |
| | Mean | 80.83 ± 2.18 | | | |

* - significant ($p<0.05$).

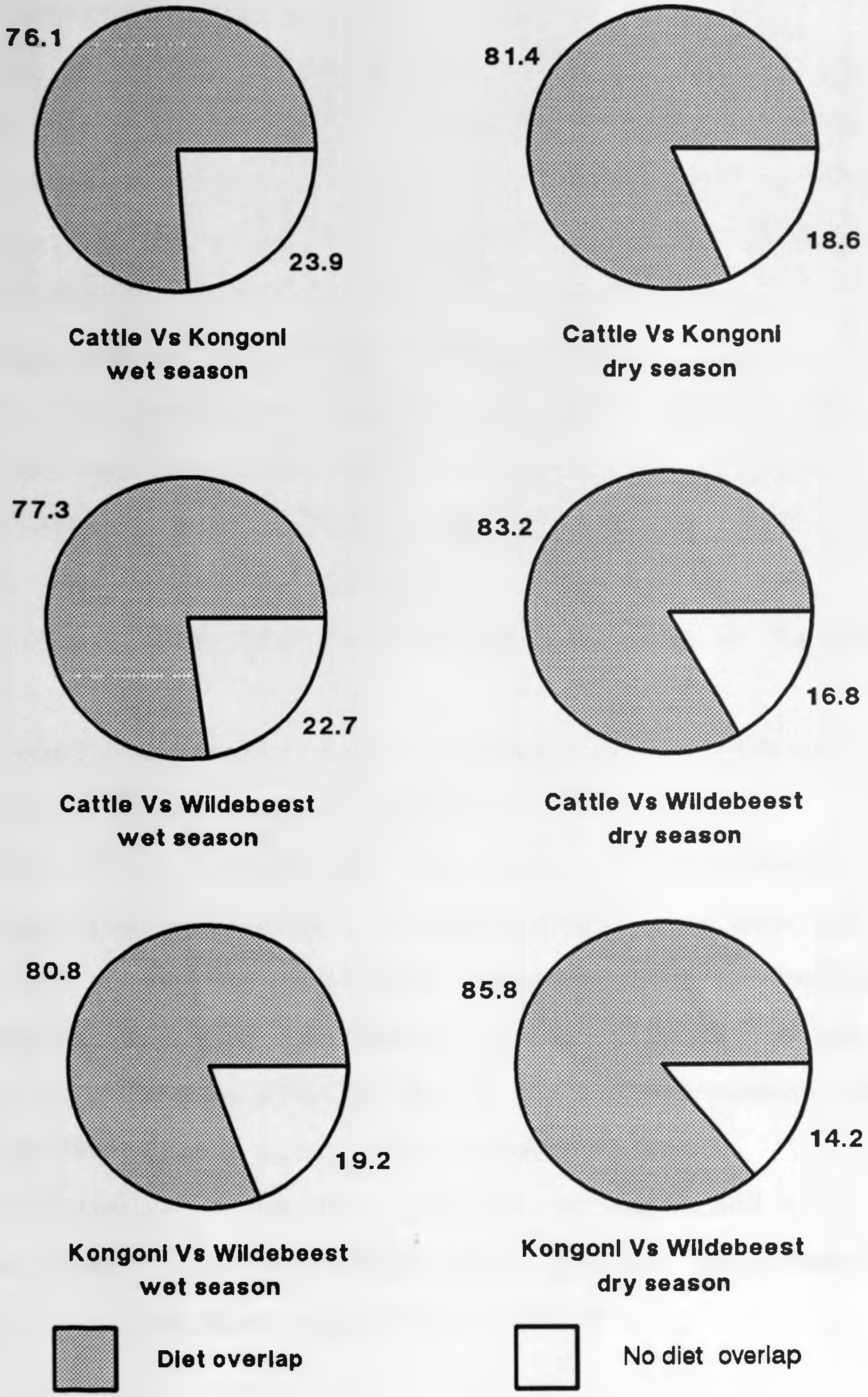

Figure 5: Percent animal diet overlaps during the wet ( January - April) and dry (May - August) seasons at Game Ranching Ltd. Athi River, Kenya. 1993.

Dietary overlaps exhibited during the dry season were all above 75%, (Table 29 and Figure 5). Cattle and Kongoni diets had overlaps ranging from 80.18% to 83.16% with a mean of 81.44%. All correlation coefficients were all positive and ranged from +0.78 to +0.86, and were all significant ($P<0.05$). Cattle and wildebeest diets overlaps ranged from 79.96% to 85.60% with a mean of 83.19%. All correlation coefficients were significantly high ($P<0.05$) and ranged from +0.78 to +0.84. Kongoni and wildebeest diet overlaps ranged from 83.06% to 88.49% with a mean of 85.84%. Correlation coefficients were significantly high ($P<0.05$) and ranged between +0.78, and +0.83.

Trophic diversity index measures niche breadth and it complements studies on overlap and competition (Hurtubia 1973). Generally, all animals in this study had high trophic diversity indicating that they were not dependent on any one particular plant species, but rather selected from a wide spectrum of plants. Cattle had the lowest trophic diversity (2.12 ± 0.06) and wildebeest had the highest (2.20 ± 0.05), while kongoni's was intermediate (2.16 ± 0.05). Overall, wildlife had a higher trophic diversity than cattle, but the difference was not statistically significant ($p=0.05$).

Table 29: Percent similarity indices (S.I) and correlation coefficients (Rs) between cattle and wildlife diets during the dry season.

| Animal combination | Period | S.I | Rs | n | t |
|---|---|---|---|---|---|
| Cattle Vs kongoni | May | 80.18 | 0.78 | 19 | 5.139* |
| | Jun | 80.21 | 0.86 | 17 | 6.444* |
| | Jul | 83.16 | 0.83 | 19 | 6.020* |
| | Aug | 82.22 | 0.79 | 16 | 4.877* |
| | Mean | 81.44 ± 1.292 | | | |
| Cattle Vs wildebeest | May | 79.96 | 0.84 | 19 | 6.403* |
| | Jun | 82.77 | 0.82 | 18 | 5.751* |
| | Jul | 85.60 | 0.81 | 18 | 5.622* |
| | Aug | 84.45 | 0.78 | 18 | 5.042* |
| | Mean | 83.19 ± 2.124 | | | |
| Kongoni Vs wildebeest | May | 83.06 | 0.78 | 20 | 5.331* |
| | Jun | 85.80 | 0.83 | 18 | 6.013* |
| | Jul | 88.49 | 0.81 | 19 | 5.836* |
| | Aug | 86.04 | 0.80 | 18 | 5.448* |
| | Mean | 85.84 ± 1.92 | | | |

* - significant ($P<0.05$).

### 5.1.5 Discussions

All the study animal species almost had similar plant varieties in their diets both during the wet and dry season. This observation however contradicted the results of Casebeer and Koss (1970) in the same general area. They found that the diets of the animals had a greater variety during the dry season than during the wet season, this is most likely explained in two ways. First this study was carried out in a closed system. This may have resulted in animals being limited in their preferred habitats and home ranges and therefore limited plant varieties to select from. Secondly the high abundance of forage in the ranch during the study period may have not necessitated a shift in the diets of the animals.

During the two seasons in 1993 three grass species; *D. macroblephara*, *P. mezianum* and *T. triandra* dominated the diets of the three animals. The preference for these species were probably by virtue of being perennial and having greater standing biomass than other grass species. Kibet (1984) has advanced similar reasons for selection of *D. macroblephara* by cattle. During the wet season the three most preferred plant species constituted about 70%, 61% and 63% for cattle, kongoni and wildebeest, respectively. Cattle had the highest browse component in their diet of about 4%, while kongoni and wildebeest diets constituted 1% and 2%, respectively. During the dry season, *T. triandra*, *D. macroblephara* and *P. mezianum* made up about 60%, 54% and 55% of cattle, kongoni and wildebeest diets, respectively. The browse component during the dry season increased to about 8%, 4% and 4% for cattle, kongoni and wildebeest respectively. The results clearly show an increased use of browse in the dry season. This is in general agreement with earlier studies by Payne and MacFarlane (1963) and Kayongo Male (1986) who found that browse component in cattle diets increased as the dry season progressed. This results, however contradict those of Wangoi and Hansen (1987) who concluded that cattle are predominantly grassers and the browse component of their diet was higher during the wet season than in the dry season. Whereas cattle in this study browsed more during the dry season, Wangoi (1984) working in Rendile part of Kenya observed that cattle browsed most during the wet season when browse shoots are most abundant. This difference is most likely due to differences in the vegetation in the two areas. Most of the trees and shrubs in the Rendile area which is in ecological zone six were reported (same study) to be devoid of leaves in the dry season. In the study area (GRL) most shrubs and trees retained their leaves long into the dry season (Personal observation), thereby offering browse to the animals. Owaga (1975) observed that wildebeest browsed about 1-2% of browse during the wet season and almost none, at other times. This was in contrast to the findings of this study, where wildebeest took more browse during the dry season but about the same amount during the wet season. This difference is most likely due to management. Whereas Owaga did her study on animals whose movement was unrestricted, this study was carried out in a closed system which did not allow for migration of the animals. This observation can be explained in four ways. During the wet season the animals utilized habitats which had less browse material than during the dry season. It seems clear therefore that the locality of the animals in relation to plant availability will affect the proportion of browse in the diet. Secondly, during the wet season, the new growth from all plants is high in crude protein, digestibility, has less fibre, and forage is abundant in general. There would be no nutritional advantage in animals walking from one shrub/tree to another in search of browse, whereas the grass at ground level was more abundant, and accessible. The energy cost involved would outweigh the benefits. Thirdly this can also be viewed as a resource utilization strategy whereby these animals make maximum use of the grass when still growing and high in nutrient contents before suddenly declining in quality with advancement of maturity. This may result in browse preservations, which declines less in quality, for the critical dry season. Fourth, it has also been reported (Van Soest, 1982) that young growing browse plants may contain high levels of secondary compounds (tannins, sapponins, etc). Some of these compounds interfere with the digestive mechanisms in the animal, among other effects. It is possible then, that these animals could simply be avoiding much of the browse growth which may contain the compounds. These explanations are however neither mutually exclusive nor exhaustive because diet selection under range condition is a complex process involving both animal related and plant related factors, as ameliorated by the environment.

During the wet and dry seasons, the dietary overlaps and Spearman Rank Correlation Coefficients were high among all the animal species. The findings of this study clearly indicate that cattle, kongoni and wildebeest most likely compete with each other for forage resources. Do overlaps indicate competition?. Not necessarily. Field, (1972) documented that competition only occurs when the resources being shared are limiting. Many researchers in East Africa have addressed the question of resource partitioning and coexistence of East African ungulates. Some of the theories on how coexistence is achieved include; spatial and temporal distribution, grazing at different herb layers, grazing of different plant parts, differences in mouth structure and differences in body size. Thus, it is possible that the study animals, despite having high dietary overlaps, may have had differential selectivity for plant parts. Talbot and Talbot (1963) pointed out that ecological separation was achieved by spatial separation. They also mentioned that diets of various plains ungulates were complementary and non duplicative. According to the findings of this study, many diets were duplicated and none were complementary. Spatial and temporal separation was exhibited partially by kongoni and wildebeest.

Bell (1969) observed that during the wet season all the species in the Serengeti plains occupy the same plain catena. At the GRL, the study animals concentrated on those habitats where grass was kept short and or in growing condition by trampling, mowing and grazing. The short grass was preferred as it was leafy and nutritious. Thus, in the wet season, the animals were limited by quality of food rather than the quantity. There was super abundance of forage resources during this study period hence critical levels that trigger competition may have not been attained. This may be one of the reasons why dietary overlaps were high. In conclusion the dietary overlaps were lower between cattle and wildlife than among wild animals.

Diet preference index for the animals differed from season to season, and from plant to plant. The animals were more selective during the wet season. This could be explained in various ways first, the presence of higher standing biomass during the wet season gave the animals an opportunity to select diets that they prefer most. During the dry season forage species that were not preferred by the animals during the wet season were also eaten resulting in lower diet preference. Secondly animals select plant parts that are more nutritious. It is possible therefore that the animals selected for those plant parts that were more nutritious during the dry season from those plants that were not preferred during the wet season. Finally different habitats had different proportions of standing biomass of each plant species. The seasonal changes in the habitat preferences of the animals therefore exposed them to those plants that were not equally accessible during the wet season. These seasonal changes in habitat preference by the animals were reflected by the changes in diet preferences.

The changes in the proportion of the standing biomass and variation in species of the herbaceous materials from habitat to habitat can be explained by the changes in cover, elevation, soils and utilization by the animals. Habitats on the ridgetops and on the higher slopes generally had a lower standing biomass, than those on the lower slopes and lowlying areas. Similarly habitats which had higher cover generally had higher standing biomass than those with lower cover. Interestingly habitats on the ridged tops and on the slopes had lower cover and received heavier animal utilization especially during the wet season. Habitats on the lower slopes had higher cover and were least utilized by the animals. This resulted in accumulation of dry matter in these habitats hence higher standing biomass.

## 5.2 Animal density and habitat preferences

### 5.2.1 Number and distribution of animals

This work was conducted to determine the preference of the study animals for the different habitat types during the wet and dry seasons. During the study period cattle were herded throughout. Cattle thus had no free choice of habitat. During wet months (January, February, March and April) they grazed mainly in the *Themeda* grassland and *Balanites* tree grassland. During this period there were only 250 heads of mainly dairy cattle[1] in the Ranch. From April onwards cattle numbers were increased to 2,500 as animals for fattening (Penta herd) were purchased. Cattle bomas were located at hill tops, resulting in heavy livestock pressures being exerted on these areas. On daily basis from April onwards cattle were always herded from their bomas at the hilltops to the low-lying areas where dams have been constructed for watering the animals. This resulted therefore in the animals utilizing most vegetation types. As the dry season progressed (July and August) they were herded into the *Acacia* woodland and *A. xanthophloea* bushland.

### 5.2.2 Animal density and habitat preference

The results of the habitat preference study were based on observations of the wild herbivores (kongoni and wildebeest) over a period of eight months. The seasonal habitat preference indices, percent frequencies and relative densities of all the six habitat types for kongoni and wildebeest are shown on Tables 30 and 31, respectively, and illustrated in Figure 6(A) and 6(B). It is evident that during the wet season, for kongoni and wildebeest, the highest and positive preference indices occurred in the *Balanites* tree grassland habitat on the higher slopes (0.44 and 0.50 for kongoni and wildebeest respectively). All other habitat types had negative

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[1] indigenous animals kept for milk production.

preference indices. *Themeda* grassland, *Balanites* - *Acacia* and *A. drepanolobium* dwarf tree grasslands had -0.82, -0.32 and -0.44 preference indices, respectively, for kongoni and -1.00, -0.34 and -0.65, respectively, for wildebeest. The *Acacia* woodland and *A. xanthophloea* bushland were avoided completely by the two animal species (Preference Index -1.00).

During the dry season the two animal species shifted their habitat preferences to the *Balanites* - *Acacia* grassland. Preference indices were 0.45 and 0.36 for kongoni and wildebeest respectively. *A. xanthophloea* bushland was avoided completely by both animals. *Themeda* grassland, and *Acacia* woodland had negative preference indices close to -1. Their respective indices were -0.92 and -0.76 for kongoni and -0.97 and -0.98 for wildebeest. *A. drepanolobium* dwarf tree grassland had lower but negative preference indices. They were -0.21 and -0.23 for kongoni and wildebeest respectively, while *Balanites* tree grassland had preference indices of -0.47 and -0.25 for kongoni and wildebeest respectively.

Table 30: Habitat utilization by the kongoni, showing relative densities (R.D) per Km$^2$, percentage frequencies (P.F) and preference indices (P.I) during the wet and dry seasons in 1993, at the GRL, Athi River, Kenya.

| Habitat | Wet Season | | | Dry Season | | |
|---|---|---|---|---|---|---|
| | R.D | P.F | P.I | R.D | P.F | P.I |
| Baltre[2] | 15.56 | 60.51 | 0.44 | 4.74 | 16.33 | -0.47 |
| Balacc[3] | 4.82 | 18.74 | -0.32 | 13.27 | 45.72 | 0.45 |
| Accdrf[4] | 4.00 | 15.56 | -0.44 | 8.13 | 27.99 | -0.21 |
| Thtgsl[1] | 1.33 | 5.19 | -0.82 | 0.67 | 2.30 | -0.92 |
| Accwdl[5] | 0.00 | 0.00 | -1.00 | 2.22 | 7.66 | -0.76 |
| Accxan[6] | 0.00 | 0.00 | -1.00 | 0.00 | 0.00 | -1.00 |
| Total | 25.71 | 100.00 | | 29.03 | 100.00 | |

[1]*Themeda* grassland, [2]*Balanites* tree grassland, [3]*Balanites - Acacia* tree grassland, [4]*A. drepanolobium* dwarf tree grassland, [5]*Acacia* woodland and [6]*A. xanthophloea* bushland.

Table 31: Habitat utilization by the wildebeest, showing relative density (R.D) per km², percentage frequencies (P.F) and preference indices (P.I) during the wet and dry seasons in 1993, at the GRL, Athi River, Kenya.

| Habitat | Wet Season | | | Dry Season | | |
|---|---|---|---|---|---|---|
| | R.D | P.F | P.I | R.D | P.F | P.I |
| Baltre[2] | 26.15 | 69.94 | 0.50 | 10.07 | 25.76 | -0.25 |
| Balacc[3] | 7.36 | 19.70 | -0.34 | 17.73 | 45.33 | 0.36 |
| Accdrf[4] | 3.88 | 10.36 | -0.65 | 10.75 | 27.49 | -0.23 |
| Thtgsl[1] | 0.00 | 0.00 | -1.00 | 0.33 | 0.85 | -0.97 |
| Accwdl[5] | 0.00 | 0.00 | -1.00 | 0.22 | 0.57 | -0.98 |
| Accxan[6] | 0.00 | 0.00 | -1.00 | 0.00 | 0.00 | -1.00 |
| Total | 37.39 | 100.00 | | 39.11 | 100.00 | |

[1] *Themeda* grassland, [2] *Balanites* tree grassland, [3] *Balanites - Acacia* tree grassland, [4] *A. drepanolobium* dwarf tree grassland, [5] *Acacia* woodland and [6] *A. xanthophloea* bushland.

An analysis of variance (Table 32) showed that there was no significant variation in habitat preference between the two animals (kongoni and wildebeest). This phenomenon did not vary with seasons, however there was a significant variation in habitat preference between the habitats ($F_{5,5}$=150.49, df=5, $p<0.05$).

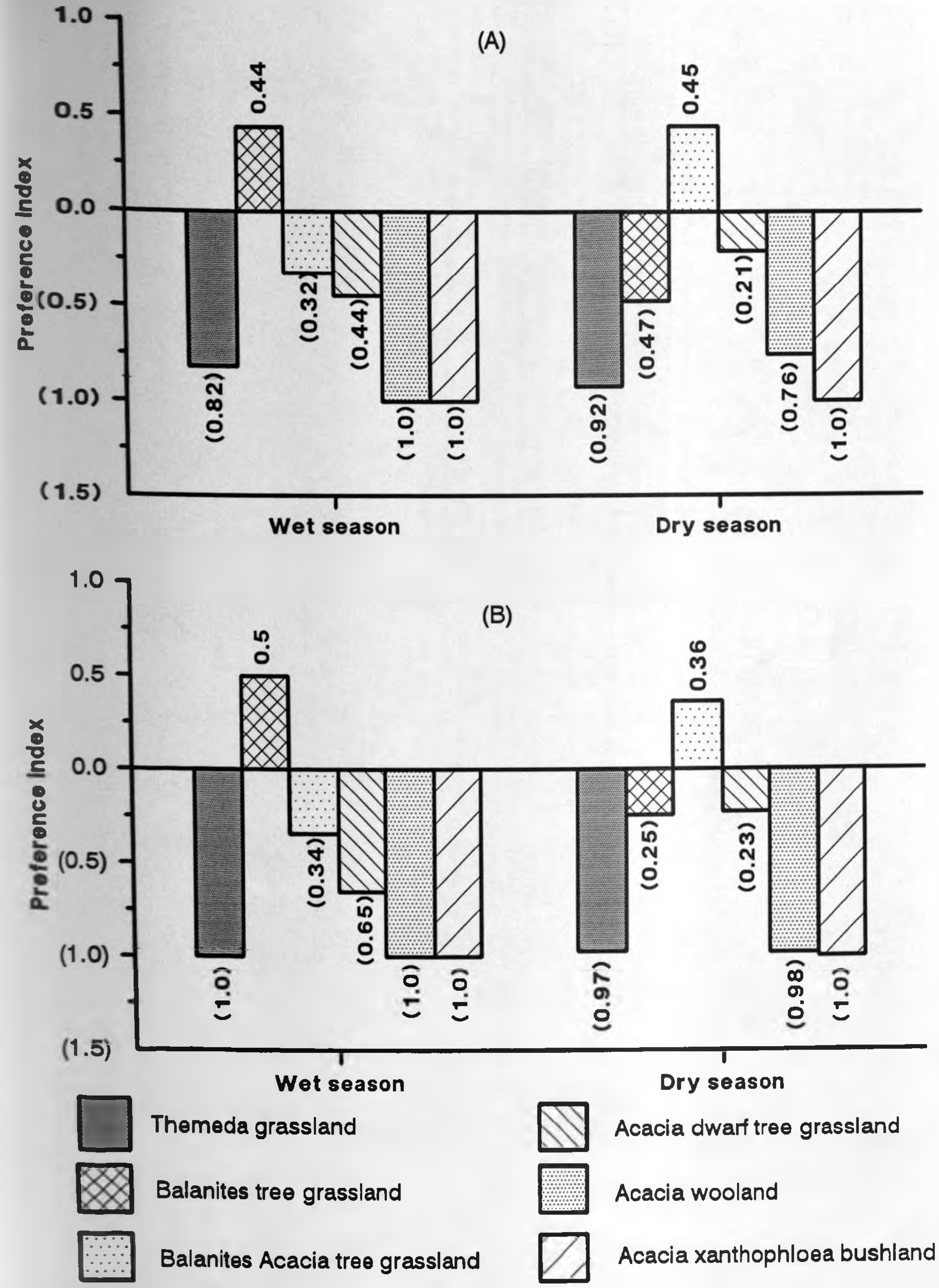

Figure 6: Seasonal changes in habitat preference for kongoni (A) and wildebeest (B) for the six different habitat types at GRL, Athi River, Kenya. 1993.

Table 32: Analysis of variance of mean habitat preferences of kongoni and wildebeest.

| Source | DF | SS | MS | F Value |
|---|---|---|---|---|
| CORRECTED TOTAL | 23 | 6.369 | | |
| ANIMAL | 1 | 0.011 | 0.011 | 1.74ns |
| SEASON | 1 | 0.018 | 0.018 | 2.83ns |
| HABITAT | 5 | 4.909 | 0.981 | 150.49* |
| ANIMAL*HABITAT | 5 | 0.052 | 0.010 | 1.60ns |
| ANIMAL*SEASON | 1 | 0.001 | 0.001 | 0.25ns |
| SEASON*HABITAT | 5 | 1.343 | 0.268 | 41.18* |

* - significant ($p<0.05$), ns - non significant.

Apparently the distribution of the animals seem to be neither dependent on the animal species and habitat type nor on animal species and season interactions. This is supported by the non significant animal - habitat and animal - season interactions in our model. Habitat preference was influenced by the interaction between seasons and the environment ($F_{5,5,}$=41.18, df=5, $p<0.05$). However, there was no apparent relationship between animal density (for both kongoni and wildebeest) and the standing biomass. Evidence for this is shown by a low Pearson's correlation coefficient (r=0.04, p=0.81 for kongoni and r=0.014, p=0.93 for wildebeest). The two animal species mostly preferred *Balanites* tree and *Balanites* - *Acacia* tree grasslands. *Balanites* - *Acacia* woodland was the least preferred habitat while the *A. xanthophloea* woodland was completely avoided as shown in Table 33.

Table 33: Mean habitat preferences of kongoni and wildebeest.

| Habitat | Mean Habitat Preference | n |
|---|---|---|
| Baltre[2] | 0.55a* | 4 |
| Balacc[3] | 0.037a | 4 |
| Accdrf[4] | -0.383a | 4 |
| Thtgsl[1] | -0.928b | 4 |
| Accwdl[5] | -0.934b | 4 |
| Accxan[6] | -1.00b | 4 |

* means followed by same letter are not significantly different at $P<0.05$. [1]*Themeda* grassland, [2]*Balanites* tree grassland, [3]*Balanites - Acacia* tree grassland, [4]*A. drepanolobium* dwarf tree grassland, [5]*Acacia* woodland and [6]*A. xanthophloea* bushland.

### 5.2.3 Discussions

Changes in habitat utilization by the two wild herbivores reflects preferred patterns of feeding habits and feeding strategies. The relative densities of kongoni and wildebeest in the *Balanites* tree grassland, at the upper slopes were higher during the wet season, than on the low-lying areas. At the beginning of the dry season in May, the higher density in the low-lying areas, (*Balanites - Acacia* and *A. drepanolobium* dwarf tree grassland) areas indicated that they were utilizing these areas in preference to the short grass areas at the upper slopes. At this time there was less green biomass at the upper slopes than on the low-lying areas. Kongoni appeared to use the low-lying areas to a greater extent than wildebeest both during the wet and dry seasons. Kongoni and wildebeest are selective grazers that try to maximize the amount of grass leaf in their diets. Kongoni are probably able to select grass leaves in tall grass area better than wildebeest. Wildebeest maximize grass leaf intake by feeding in the short grass areas with high leaf to stem ratio by feeding on the preferred short grass areas on the upper slopes. The two wild herbivores appeared not to occupy the *Acacia* woodland and *A. xanthophloea* bushland habitats.

Elements of the grazing succession on the ranch as described by Bell (1971) for the Serengeti ecosystem, were apparent on the ranch especially during the wet season. Short grass areas that received the heaviest cattle utilization were preferred by the kongoni and wildebeest. The low-lying areas were lightly utilized during the wet season. One reason for this lighter utilization could have been related to the uneven distribution of cattle grazing pressure, which was highest on the upper slopes (personal observation). Therefore, a grazing succession in the low lying areas of tall grass could not occur. The *Balanites* tree grassland habitat clearly is the most preferred by cattle, kongoni and wildebeest in the ranch only during the wet season while *Balanites* - *Acacia* tree grassland is the most preferred during the dry season. The seasonal habitat preferences by kongoni and wildebeest is probably an important mechanism of survival and optimum utilization of the available resources, which aims at reducing the impact on the dry season habitats during the wet season.

# CHAPTER SIX

## CONCLUSIONS AND RECOMMENDATIONS

The feeding habits of cattle, kongoni and wildebeest whether as single species or in combination with other animal species on the same range, have been studied by several researchers in different environments. Some findings concur, while others conflict. In the current study the animal species (kongoni, wildebeest and cattle) increased browse components in their diets by about 100% during the dry season. The animals, however, selected similar diets in terms of plant species during both seasons. The locality of the animals in relation to plant availability affects the diet preferences and the proportions of browse and grass in the diet.

The *Balanites - Acacia* tree grassland is the best available habitat. It is the habitat upon which kongoni and wildebeest depend on for their survival in the ranch during the dry season, when the forage resources are limiting. Without this habitat these animals would lose their body condition, which will eventually result in increased mortalities and reduced population size. *Balanites* tree grassland, however, is the most preferred habitat but is only available during the wet season.

Generally the proportion of herbaceous standing biomass, and cover of the woody species is dependent on the interactions between the plants and the environment. Diet preference is dependent on interactions between season and plant and on interaction between animal and plant. Therefore any changes of factors in the interactions will result in changes in the dependable factor. One therefore can manipulate any one of these habitat factors so as to achieve a desired objective. Such habitat manipulation when being implemented should take into consideration herbage production, habitat requirements and the diet preference of the animals in question. In a closed system animals are limited in their habitats and plant variety to select diets from. This therefore calls for proper management. This can be achieved by harvesting/cropping the animals and through habitat manipulation. Habitat manipulation should aim at increasing heterogeneity rather than homogeneity in habitats. This will allow the animals to maximize their habitat and diet selection and hence result in increased productivity.

Finally it is recommended that similar studies be undertaken on other animal species in the ranch. This will enable comprehensive management package to be developed. Such a package should take into consideration habitat and feed requirements of all the herbivores in the ranch while taking into consideration the management objective.

## REFERENCES

Andere, D.K. 1981. Wildebeest (*Connochaetes taurinus*) and its food supply in Amboseli Basin. *Afr. J. Ecol. 19:239-250.*

Arnold, G.W. 1966a. The special senses in grazing animals. I. Sight and dietary habits in sheep. *Aust. J. Agric. Res. 17:521-529.*

Arnold, G.W. 1966b. The special senses in grazing animals II: Smell, taste and touch and dietary habits in sheep. *Aust. J. Agric. Res. 17:531-542.*

Arnold, G.W. and M.C. Dudzinki. 1978. Ethology of free-ranging animals. *Elselvier Sci. Publ. Co. Netherlands.*

Bell, R.H.V. 1969. The use of the herb layer by grazing ungulates in Serengeti. In: *A. Watson, ed. Animal population in relation to food resources.* Symp. Brt. Ecol. Soc., Blackwell, Oxford, Edinborough.

Bell, R.H.V. 1971. A grazing ecosystem in Serengeti. *Scientific Americana, 225:86-93.*

Belovsky, G.E. and P.A. Jordan. 1978. Time-Energy budget of a moose. *Theor. pop biol. 14:76-104*

Ben-Shahar, R. 1991. Selectivity in large generalists herbivores; feeding patterns of African ungulates a semi-arid habitat. *Afr. J. Ecol. 29:302-315.*

Bjugstad, A.J., H.S. Crawford and I.N. Donald. 1970. Determining forage consumption by direct observation of domestic animals. In *Range Wildl. Habitat Eval-A Res. Symp. US. Dep. Pub. No. 1147, 220p.*(Quoted by Holechek et al. 1982b).

Bredon, R.M. and J. Wilson. 1963. The chemical composition and nutritive value of grasses from semi arid area of Karamoja as related to ecology and types of soils. *East Afr. Agric. For. J. 29:134-142.*

Bryan, D.G., M. Elfatih and J.L. Holechek. 1983. Mastication effect on cattle diets determined by microhistological analysis. *J. Range Manage. 36:475-478.*

Casebeer, R.L. and G. Koss. 1970. Food habits of wildebeest, zebra, hartebeest and cattle in Kenya, Masailand. *E. Afr. Wild. J. 8:25-36.*

Cavender, R.B. and R.M. Hansen. 1970. The microscope method used for herbivore diet estimates and botanical analysis of litter and mulch at Pawnee site. Grassl. *Biome, U.S. Int. Biol. Prog. Techn. Rep. No.18.*

Chacon, E. and T. H. Stobbs. 1976. Influence of progressive defoliation of a grass sward on the eating behaviour of cattle. *Aust. J. Agric. Res. 27:709-27.*

Church, D.C. 1975. Digestive physiology and nutrition of ruminants. *O & B books, Corvallis Ore.*

Chippendale, G. 1962. Botanical composition of Kangaroo and cattle stomach contents. *Aust. J. Sci. 25:21-22.*

Chamrad, A. D., and T.W. Box. 1964. A point frame for sampling rumen stomach contents. *Aust. J. Sci. 25:21-22.*

Cook, C.W. and L.A. Stoddart. 1953. The Quadry of utilization and preference. *J. Range Manage. 8:327-335.*

Croker, B.H. 1959. A method for estimating the botanical composition of the diet of sheep. *N.Z.J. Agr. Res. 2:72-85.* (Quoted by Holechek et al. 1982b).

Demment, M.W., E.A. Laca and G.B. Greenwood. 1986. Intake in grazing ruminants: *A conceptual framework, Feed, Intake Symposium. pp 208-225.*

Dieter Mueller-Domboise and Heinz Ellenberg. 1974. Aims and methods of vegetation ecology. John Willey and sons inc. Dougall, H.W., V.M., V.M. Drysdale, and P.E. Glover. 1964. The chemical composition of Kenya browse and pasture herbage. *E. Afr. Wildl. J. 2:86-11.*

Duncan, P., T.J. Foose, I.J. Gordon, C.G. Gakahu and M. Lloyd. 1990. Comparative nutrient extraction by grazing bovids and equids: a test of the nutritional model of equid/bovid competition and coexistence. *Oecologia, 84: 411 - 418.*

Field, C.R. 1968. The food habits of some wild ungulates in reaction to land use and management. *E. Afr. Agric. For. J. 33:159-162.*

Field, C.R. 1972. The food habits of wild ungulates in Uganda by analysis of stomach contents. *E. Afr. Wildl. J. 10:17-42.*

Field, C.R. 1975. Climate and food habits of ungulates on Galana Ranch. *E. Afr. Wildl. J. 13:203-220.*

Field, D.I. and J.K. Potere. 1972. The value of browse plants. In: Over-browsing of *Capparis tomentosa* bushes by goats in Ruwensori National Park, Uganda. *Afr. J. Ecol. 18:11-17.*

Foppe, F.M. 1984. Microhistological technique training program. *Misc. Publ. Composition analysis lab range science dept. Colorado State University.*

French, M.H. 1957. Nutritive value of tropical grasses and fodders. *Herb Abst. 27:1-9.*

Gakahu, C.G. 1982. Feeding strategies of plains Zebra, *Equus quaga boehmii* in Amboseli Ecosystem. PhD. Thesis, University of Nairobi.

Geist, V. 1974. On the relationship of social evolution and ecology in ungulates. *Am. Nat. 14:205-220.*

Githaiga, J.M. 1991. Grazing Speed: The test of a model. MSc. Thesis University of Nairobi.

Goatcher, W.D. and D.C. Church. 1970. Review of some nutritional aspects of the sense of taste. *J. Anim. Sci. 31:973-981.*

Gwynne, M.D. and R.H.V. Bell. 1968. Selection of vegetation components by grazing ungulates in the Serengeti National Park. *Nature. 220:390-393.*

Hanley, T.A. 1982. The nutritional basis for food selection by ungulates. *J. Range Manage. 35:146-151.*

Hansen, R.M. 1971. Composition in wild sheep diets. *First trans. N. Amer. Wild. Sheep Confr. pp180.*

Hansen, R.M., T.M. Foppe, M.B. Gilbert, R.C. Clark and H.W. Reynolds. 1984. The microhistological analyses of faeces as an estimator of herbivore dietary. *Misc. Pub. Composition analysis lab. Range Science Department.* Colorado State University.

Heady, H.F. 1975. "Range management". McGraw Hill book Co., New York.

Heady, H.F. and G.M. Van Dyne. 1965. Prediction of weight composition from point samples on clipped herbage. *J. Range Manage. 18:144-149.*

Hillman, C. and A.K.K. Hillman. 1977. Mortality of wildlife in Nairobi National Park During the drought of 1973-1974. *E. Afri. Wildl. J. 10:1-8.*

Hillman, J.C. 1979. The biology of the Eland (*Taurotragus oryx* Pallas) in the wild. PhD. Thesis, University of Nairobi.

Hofmann, R.R. 1973. The Ruminant stomach. *East African Monographs in Biology, volume 2.* East African literature bureau.

Holechek, J.L., J.M. Varva, J.M. Skovlin and R.L. Philips. 1981. Diet quality and performance of cattle on grassland and forest range. *J. Ani. Sci. 53:291-298.*

Holechek, J.L. and B.D. Gross. 1982. Evaluation of different procedures for microhistological analysis. *J. Range Manage. 35:541-542.*

Holechek, J.L., M. Varva and R.D. Pieper. 1982a. Botanical composition determination of range herbivore diets: A review. *J. Range Manage. 35:309-315.*

Holechek, J.L., M. Varva, J. Skovlin, W.C. Krueger. 1982b. Cattle diets in the Blue Mountains of Oregon II forests. *J. Range Manage. 35:239.*

Hopcraft, D. 1975. Productivity comparison between Thompson's Gazelle and cattle, and their Relation to the Ecosystem in Kenya. PhD. Thesis, Cornel University.

Hoppe, P.P. 1977. Rumen fermentation and food selection in East African sheep, goats, Thomson's gazelle, Grant's Gazelle and Impala. *J. agric. Sci., Camb. 89:129-135.*

Hungate, R.E. 1966. The Rumen and its Microbes. Academic press, New York.

Hurtubia, J. 1973. Tropic diversity measurement in sympatric predatory species. *Ecology, 54:885-890.*

Jarman, P.J. 1974. The Social organization of antelope in relation to their ecology. *Behaviour, 48:215-67.*

Jarman, P.J. and A.R.E. Sinclair. 1979. Feeding strategy and pattern of resource partitioning in ungulates. In: *Serengeti dynamics of an ecosystem.* University of Chicago Press, Chicago.

Kayongo Male, H. 1986. Feeding habits, forage quality and food intake by Zebu cattle grazing natural rangeland in IPAL, study area. *IPAL Technical Report No. E-8; 201.*

Kerr, J.A., V.J. Wilson and H.H. Roth. 1970. Studies on agricultural utilization of semi-domesticated Eland (*Taurotragus oryx*) in Rhodesia. *Rhod. J. Agr. Res. 8:71-71* (Quoted by Ng'ethe and Box. 1976).

Kibet, P.K. 1984. Influence of browse on cattle diets in Acacia savannah of East Africa. MSc. Thesis Texas A and M University, Texas.

Kilcher M.R. 1981. Plant development, stage of maturity, and nutrient composition. *J. Range manage. 34:363-364.*

Krebs, J.R. 1978. Rules for predators. In: *Behavioural ecology: An Evolutionary Approach. pp 23 - 68.* Eds.

Krueger, W.C., W.C. Lay Cock, and D.A. Price. 1974. Relationships of taste, smell, sight and touch to forage selection. *J. Range Manage. 27:258-262.*

Lamprey, H.F. 1963. Ecological separation of the large mammal species in Tarangire Game Reserve, Tanganyika. *E. Afr. Wildl. J. 1:63-92.*

Lawton, R.M. 1968. The value of browse in dry tropics. *East Afr. agric. For. J. 33:227-231.*

Lotus Development Corporation. 1991. Lotus Freelance Graphics, version 4.0. 55. Cambridge parkway, Cambridge.

MacDowell, R.E., D.G. Sister, E.C. Schemerhon, J.D. Reed and R.P. Bauer. 1988. Game or cattle for meat production on Kenya rangelands. Dept. of Anim. Sci., New York College of Agriculture and life sciences. Cornell University, Ithaca, New York.

Malechek, J.C. and F.D. Provenza. 1983. Feeding behaviour and nutritional characteristics of goats on rangelands. *World Animal Review, 47: P.38.*

Mentis, M.T. and R.R. Duke. 1976. Carrying capacities of natural veld in Netal for forage wild herbivores. *S. Afr. J. Wild. Res. 6:65-74.*

Mentis, M.T. 1977. Stocking rates and carrying capacities for ungulates on African rangelands. *S. Afr. J. Wildl. res. 7:89-98.*

Ng'ethe, J.C. and T.W. Box. 1976. Botanical composition of Eland and goat diets on an acacia-grassland community in Kenya. *J. Range Manage. 29:290-293.*

Oosting, J.H. 1956. The study of plant communities. W. H. Freeman and Company, San Francisco, California.

Owaga, M.L. 1975. The feeding ecology of the wildebeest and zebra in Athi Kapiti Plains. *E. Afr. Wildl. J. 13:375-383.*

Owen-Smith, N. 1982. Factors influencing the consumption of plant products by large herbivores. In: *Ecology of tropical Savannas.* (Eds B.J. Huntley and B.H. Walker) PP. 359-404. Springer-verlag, New York.

Payne, W.J.A. and J.S. Macfarlane. 1963. A brief study of cattle browsing behaviour in a semi-arid area of Tanganyika. *E. Afr. For. J. 29:131.*

Pratt, D.J. and M.D. Gwynne. 1977. "Rangeland management and ecology in East Africa". Robert E. Krueger Publ. Co. Huntington, New York.

Pratt, D.J., P.J. Greenway and M.D. Gwynne. 1966. A classification of East African Rangelands. *J. App. Ecology, 3:369-392.*

Sanders, K.D., B.E. and G. Scott. 1980. Bite count Vs fecal analysis for range animals diets. *J. Range Manage. 32:146-149.*

SAS Inc., 1987. SAS (r) Proprietary Software Release 6.04. Cary, NC 27512-8000, U.S.A.

Scother, J.S.B. 1979. A review of fecal analysis techniques for determination of the diet of wild grazing herbivores. *Proc. Grassld. Soc. Afr. 14:141-146.* (Quoted by Holechek et al. 1982a)

Shannon, C.E. 1948. A mathematical theory of communication. *Bell Systems Techn. J. 27:378-423.*

Sinclair, A.R.E. and M. Norton - Griffiths, 1979, Serengeti: *Dynamics of an ecosystem.* The University of Chicago press, Chicago and London.

Sinclair, A. R. E. 1972. Food selection and competition in East African Buffalo (*Syncerus cafer* Sparman). *E. Afri. Wildl. J. 10: 77-78.*

Slater, J. and R.J. Jonnes. 1971. Estimation of diets selected by grazing animals from microscopic analysis of faeces. *J. Aust. Inst. Agri. Sci. 37:238.* (Quoted by Holechek 1982a).

Snedecor, G.W. and W.G. Cochran. 1967. Statistical methods. The Iowa State University Press, Ames, Iowa, U.S.A.

Sparks, D.R., and J.C. Malechek. 1968. Estimating percentage in diets using a microscopic technique. *J. Range Manage. 21:264-265.*

Stanley - Price, M.R. 1977. The estimation of food intake and its seasonal variation, in the hartebeest. *E. Afr. Wildl. J. 15:107-124.*

Stelfox, J.B. 1985. Mixed species Game Ranching on the Athi Kapiti plains, Kenya. PhD. Thesis. University of Albert: In: Sinnary, A.S. and J.J. Hebrard. 1991. A new approach for detecting visibility bias. *Afr. J. Ecol. 29:222-28.*

Stewart, D.R.M. and J. Stewart. 1970. Food preference data analysis for african plains ungulates. *Zoologica Africana, 5:115-129.*

Stobbs, T.H. 1973. The effect of plant structure on intake of tropical pastures. *Aust. J. Agric. Res. 24:809-19.*

Stobbs, T.H. 1975. The effect of plant structure on the intake of Tropical pastures. III Influence of fertilizer nitrogen on the size of bite harvested by Jersey cows grazing *Setaria anceps* CV. Kazungula swards. *Aust. J. Agric. Res. 26:997-1007.*

Taerum, R. 1970. A note on the chemical contents of some East African grasses. *East Afr. Agric. For. J. 46:171-176.*

Talbot, L.M. and M.H. Talbot. 1962. Food preferences of some East African wild Ungulates. *E. Afr. Agric. For. J. 27:131-138.*

Talbot, L.M. and M.H. Talbot. 1963. The wildebeest in western Maasailand East Africa. *Wildlife Monograph, 2:88.*

Todd, J.W. and R.M. Hansen. 1973. Plant fragments in faeces of big horns as indicators of food habits. *J. Wild. Manage. 37:363-367.*

Van Dyne, G.M., N.R. Brockngton, Z. Szocs, J, Duek and C. A. Ribic. 1980. Large herbivore subsystem. In: *Grasslands System Analysis and Man*. (Edn A.I. Brey Meyer and G.M. Van Dyne) pp 269 - 537. I.B.P. Synthesis 19. Cambridge University Press, Cambridge.

Van Soest, P.J. 1982. Nutritional ecology of the ruminant. O&B Books Inc. Corvallis, Ore.

Van Soest, P.J. 1967. Development of a comprehensive system of feed analysis and its application to forage. *J. Anim. Sci. 26: 119 - 128*

Van Zyl, J.H.M. 1965. The vegetation of S.A. Lombard Nature Reserve and its utilization by certain antelopes. *Zoologica Africana, 1:55.* Quoted by Ng'ethe and Box 1976).

Vavra, M. and J.L. Holechek. 1980. Factors influencing microhistological analysis of herbivore diets. *J. Range Manage. 33:371-374.*

Vessey - Fitzgerald, D.F. 1960. Grazing succession among East African game animals. *J. Mammal. 41:161-72.*

Viljoen, P.J. 1989. Habitat selection and preferred food plants of a desert-dwelling elephant in the northern Namib Desert, South West Africa/Namimbia. *J. Afr. Ecol. 27:227-240.*

Wangoi, E. Migongo. 1984. The tropic relations of domestic animals in he central part of Rendile land in Northern Kenya. Ph.D Diss. Colorado State Univ. Fort Collins, Co.

Wangoi Migongo-Bake and R.M. Hansen. 1987. Seasonal diets of camels, cattle, sheep and goats in a common range in East Africa. *J. Range Manage. 40:76.*

Welch, J.G. and A.M. Smith. 1969. Influence of forage quality on rumination time in sheep. *J. Anim. Sci. 28:813-818.*

Wilson, A.E., S.M. Hirst and R.P. Ellis. 1977. Determination of feeding preferences in wild ruminants from fecal samples. *J. Wild. Manage. 41:70-75.*

# APPENDIX

## Scientific names and authorities for plants and animals species mentioned in the text

### 1. Grasses

*Digitaria macroblephara* (Hack.) Stapf
*Penisetum mezianum* Leeke
*Themeda triandra* Fork
*Cynodon dactylon* (L.) Pers.
*Harpachne schimperi* A. Rich.
*Penisetum stramineum* Peter
*Bothriochloa inscupta* (A. Rich) A. Camus
*Penisetum masaicum* Stapf
*Lintonia nutans* Stapf
*Ischaemum afrum* (J. F. Gmel.) Dandy
*Panicum maximum* Jacq.
*Cenchrus ciliaris* L.
*Chloris gayana* Kunth.
*Heteropogon contortus* (L.) Beauv. ex R. & S.
*Sporobolus pellucidus* Hochst.

### 2. Tress

*Acacia xanthophloea* Benth.
*Acacia drepanolobium* Harms ex Sjostedt
*Acacia seyal* Del.
*Acacia stuhlmanii* Taub
*Balanites glabra* Mildbr. & Schleht

### 3. Animals

| Common name | Scientific names and authority |
|---|---|
| Zebra | *Equus burchelli* Gray |
| Kongoni | *Alcephalus buselaphus* Pallas |
| Wildebeest | *Connochaetes taurinus* Burchell |
| Thomsons' gazelle | *Gazella thomsoni* Gunther |
| Grants' gazelle | *Gazella granti* Brooke |
| Eland | *Taurotrogus oryx* Pallas |
| Maasai giraffe | *Giraffa camelopardalis* L. |
| Impala | *Aepyceros melampus* Lichtenstein |
| Ostrich | *Structhio camelus* L. |
| Catlle | *Bos indicus* |