SEASONAL DISTRIBUTIONS AND INTERACTIONS OF CATTLE AND WILD UNGULATES IN MAASAILAND, TANZANIA

by

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ABSTRACT

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INTRODUCTION

A Historical Perspective to Cattle and Wild Ungulate Coexistence

East Africa has recently attained world renown for its unrivaled concentrations of wildlife and the most notable of these Pleistocene concentrations are found within Maasailand. In sharp contrast to a reputation for intertribal combat, the Maasai attitude towards wildlife has been characterized as one of tolerance bordering on benign benevolence. Such a disposition is perhaps most poignantly depicted in an account by the early explorer Joseph Thomson (Miller 1971:107) in which he was nearly speared after shooting a zebra (*Equus burchelli*) in Maasailand.

In contrast to the pursuit of agriculture or hunting and gathering, a lifestyle of subsistence pastoralism is often characterized by a minimum of direct conflict with wildlife. A look at practical considerations from which a wildlife ethos may have evolved could warrant the conclusion that, to be successful, pastoralism had to utilize the total capability of the pastoralist. Activities resulting in a diversion of energies were therefore restricted, hence the "conservation mindedness" of the Maasai. A corollary to the foregoing would be that by following such a course, there was then no reason to exploit wildlife because pastoralism supplied all needs. This supposition is supported by the temporary adoption of a hunting and gathering existence by many Maasai when the rinderpest panzootic decimated their cattle (*Bos indicus*) herds in the latter 19th century (Ford 1971:191) and by the lifestyle of the impoverished Maasai or 'Balang'a' Dorobo referred to by Maguire (1948).

Archeological evidence of pastoralism in Maasailand traces the coexistence of cattle and wild ungulates back to 1000 B.C. (Jacobs 1975:410). The association is more directly linked by the hypothesis that pastoral peoples, through their use of fire and the impact of their cattle, helped to induce and maintain the environment necessary for the large populations of native grazers. Bell (1969) has presented evidence for the Serengeti region, correlating areas of most intensive use by plains game with those having a history of greatest human influence.

The point is that while on an evolutionary and geologic time scale cattle and wild ungulate coexistence is short, it is nonetheless of some antiquity relative to recent changes affecting that association. Presumably, up to the advent of the European in the last century, interspecific competition was minimized due to natural attrition (cattle and human) and the unhampered movement of both cattle and wild ungulates.

Recent Developments Affecting Cattle and Wild Ungulate Coexistence

Were this simplified historical backdrop unaltered, a study dealing with cattle and wild ungulate coexistence and interaction would be largely academic. However, beginning with the introduction of western medicine and a reduction of internecine tribal warfare, both human and domestic animal populations have increased and the mobility of both domesticated and wild ungulates has been drastically curtailed. Central to the attainment of Tanzania's aspirations for a better life materially for all her people are the expressed goals of socialism ('ujamaa') and self reliance (Nyerere 1977). A logical outcome of the latter has been the recognition of both the value of wildlife as a resource of economic potential and the need for livestock development in the traditional sector. Where livestock and wildlife overlap, as in the range areas of Maasailand, questions and conflicts have surfaced pertaining to the relative importance that each should play in present and future land development strategies.

Background to the Study

The status of wildlife in Tanzania is partly determined by the creation of National Parks set aside for wildlife preservation and the accompanying development of tourism in these Parks as the main form of economic land use. Due to socio-political and economic constraints, the National Parks are often not ecologically viable units. Rather they constitute the dry season concentration areas around permanent water, with wildlife annually dispersing from these areas. Exemplifying this pattern is the seasonal emigration of ungulate species from Tarangire National Park into the adjoining Simanjiro area of Maasailand.

In Simanjiro, livestock development is being encouraged by the formation of permanent ranching villages which are a legally registered form of land use cooperative involving all the Maasai cattle owners in a particular area. Furthermore, technical and capital input by the United States Agency for International Development (U.S.A.I.D.) through the Maasai Livestock and Range Development Project, is giving rise to at least the ostensible structure necessary for a production oriented livestock economy. While at present the majority of the Maasai people still ascribe to values and a life style of subsistence pastoralism, the Maasai Project and the Tanzania Government Livestock Department view wildlife as potentially conflicting with goals of livestock development. Expressed areas of concern include competition for forage and water and the problem of interspecific spread of disease.

Conversely, the Tarangire Park administration has been concerned that livestock development in Maasailand may conflict with the seasonal use of the area by many of the Park's wildlife species. An outgrowth of this concern was a preliminary proposal by the National Parks to create a new land use authority modelled after the Ngorongoro Conservation Authority. However, since the infrastructure for livestock development already existed at that time in Simanjiro, the Livestock Department took the view that, provided background information on game and livestock dual use could be obtained, it would be possible to use the existing Range Act regulations to encourage the coordinated development of both wildlife and livestock resources.

Consequently, the identification of areas of distributional overlap and an assessment of potential competition was needed to assist in rational planning. For these reasons the U.S.A.I.D. financed preliminary report (Gordon and O'Rourke 1973) which recommended a land capability survey of Arusha Region, included the suggestion that part of this survey should consist of an inventory of wildlife distribution in selected livestock areas.

Objectives, Study Duration and Hypotheses

Objectives of the study were:

(general)

1) To provide for development planners information pertaining to cattle and wild ungulate distributions in the Simanjiro-Loibor Sirret and encompassing areas of Maasailand adjacent to Tarangire National Park.

   (specific)

   a. To document the major concentrations of cattle and their seasonal distribution
   b. To determine the seasonal distributions of the major wild ungulates
   c. To define and map the major habitats
   d. To delineate areas subject to infestation by tsetse fly (Glossina spp.)

2) To relate patterns of cattle and wild ungulate distributions to each other, to habitats, tsetse infestation and other parameters affecting and affected by the observed distributions

3) To define aspects and areas of greatest actual and potential cattle-wildlife competition

4) To make recommendations with reference to the coordinated development of the livestock and wildlife resources.

Data on cattle and wild ungulate distributions and tsetse infestation were collected by the investigator from January 1975 through May 1976. Vegetative sampling was completed the following wet season, February to June, and August 1977. In fulfillment of the first objective, preliminary reports (Peterson 1975, 1976a and 1976b) and a series of map overlays (1:250,000 scale) depicting patterns of cattle and wild ungulate distributions and tsetse infestation were submitted to Regional (Arusha) and District (Kibaya) Livestock Departments as well as filed at the Regional Water Office in Arusha. This report deals with the remaining objectives, interpreting and analyzing the baseline data in the perspective of interactions between cattle and wild ungulates. Given the time framework, the large area, the resources allocated and consequent methods employed, the study was necessarily on a macro scale and designed to detect gross patterns of distributional overlap and habitat preferences. The interspecific competition referred to has been called the resource-use type (Odum 1971:211) in which a resource shared by two or more species is in short supply and results in inhibition of and by the interacting species. The following hypotheses were made in regard to competition: 1) for competition to occur there must be distributional (habitat) and ecological (niche) overlap between the competing species i.e., a common resource, 2) the resource must be limited at some time relative to the needs of the competing species and adverse environmental change as reflected by damage to that resource constitutes an expression of extreme resource limitation, 3) competition can be expected to be most severe during periods of resource scarcity. In the present study, competition as reflected by distributional displacement should be most evident during the dry season, 4) the significance of wet season distribution in terms of potential competition would most likely be in relation to the effect on resources in critical dry season areas.

LITERATURE REVIEW

Interspecific Competition

Darwin in his classic, On the Origin of Species, stresses the importance of interspecific competition to a species' struggle for survival and points to benign tropical environments as the most likely areas to witness this truism of nature (Diamond 1978). It wasn't until after Gause's well known laboratory experiments (Odum 1971) that the concept known as competitive exclusion (Hardin 1960) was appreciated by ecologists for its wide-ranging influence on species' distributions and niche characteristics.

Much of the evidence for interspecific competition in nature is circumstantial (Odum 1971) with the greatest contribution by ornithologists (Lack and Southern 1949, Crowell 1962, Willis 1966, MacArthur and Pianka 1966, Diamond 1973, Diamond and Marshall 1977). Studies in which competition is inferred on the basis of habitat occupancy include those of Pianka (1969), Cody (1974) and Lane (1975). Watson et al. (1969) inferred competition between cattle and wildebeest (*Connochaetes taurinus albojubatus*) by comparing their relative densities in the Serengeti National Park and adjacent livestock areas. Lamprey (1964) attributed the low density of wild ungulates in Maasailand to the lack of permanent water sources and competition for grazing with domestic animals. This approach assumes that there is a limited common resource and that consequent competition is a major determinant of species' distributions. Wiens (1977) validly pointed to the danger of interpreting distributional relationships solely in terms of competition for resources which fluctuate and are often not limiting. The role of interspecific competition in nature has been downplayed (Andrewartha and Birch 1954) and negated (Hairston et al. 1960, Slobodkin et al. 1967) by assertions that there is seldom a shortage of food in relation to animal numbers. However, Sinclair (1974, 1975) countered this hypothesis and presented evidence that resources are limiting for herbivore trophic levels in at least some terrestrial ecosystems.

Studies of African Ungulates

Numerous studies of African ungulates confirm Darwin's observations that interspecific competition would be most evident in the tropics. The tremendous diversity of coexisting ungulates lends itself to study of interspecific competition and resultant ecological separation. Studies which deal exclusively with wild ungulates, as well as with mixed domestic and wild herbivores, can be divided somewhat arbitrarily into two categories: 1) in which emphasis is on broader habitat and distributional stratification and 2) in which stress is on finer food habit or niche differentiation and overlap.

In the former, Lamprey (1963) demonstrated ungulate separation on the basis of spatial and temporal distribution differences and the use of different feeding levels. Herbivore distributions in Queen Elizabeth Park, Uganda were related chiefly to preference for vegetation types and accompanying floristic components (Field and Laws 1970). Partitioning of large wild herbivores by habitat type and temporal discontinuity was described by Harris (1972) in the

Mkomazi Reserve, Tanzania. Blankenship and Field (1972) on a ranch in Kenya showed that ungulate distributions were affected by vegetation communities as well as vegetation condition within the communities. They concluded that while localized influence of cattle on wild ungulate food supplies was evident, overall competition was not significant due to the low number of herbivores relative to the forage resources. In Rhodesia, wild ungulate distributions were associated with gross vegetative structure and topographic features (Ferrar and Walker 1974). Similarly, Hirst (1975) concluded that interspecific competition among wild ungulates in South Africa was avoided primarily by spatial separation.

Studies of ecological separation and overlap at the food habits level can be separated into those which concentrate on plant species selection, those which emphasize plant parts, and those which combine the two. Studies of selection for plant species include those of Talbot and Talbot (1962) and Casebeer and Koss (1970). Results of the latter work indicated a high degree of similarity in selection for grass species by wildebeest, zebra, hartebeest (_Alcelaphus buselaphus cokii_) and cattle. Overlap of buffalo (_Syncerus caffer_) and cattle grazing preferences led Field et al. (1973) to conclude that there was apparent food competition in the trial areas, but that buffalo utilized certain habitats (tree shade, standing water) which were minimally used by cattle. In a study which correlated selection of plant species with chemical composition of the plants (Field 1975), buffalo and cattle were categorized as coarse grass feeders as their large mouths rendered them relatively unselective for parts of plants. Eland (*Taurotragus oryx*) were unable to maintain themselves on low quality grass and were forced to switch to browse in the dry season. Among the four species studied, oryx (*Oryx beisa callotis*) seemed to be the most adaptable as their small mouths enabled them to select for nutrient rich parts of grasses. Recent work by McNaughton (1978) has shown how different groupings of grass species (plant guilds) may effect the separation of ungulates along lines of their varying food selectivity. Studies emphasizing structure and plant parts (Vesey-Fitzgerald 1960, 1965, Gwynne and Bell 1968, Bell 1970, McNaughton 1976) have demonstrated that the feeding relationships between wild ungulates are more facilitative than competitive. These studies showed how grazing and trampling by certain ungulate species favorably modified the vegetation structure for other species which followed. The characteristic sequence of movement by the different species has been coined the grazing succession.

A combined species and plant-part approach was taken by Sinclair and Gwynne (1972) which indicated a selection by buffalo both for grass leaf and for species with a high leaf:stem ratio. In this study considerable food habit overlap between wildebeest and buffalo was demonstrated, suggesting that competition was operating during the dry season when protein and other nutrients were limited. Blankenship and Qvortrup (1974) stated that Thomson's gazelle (*Gazella thomsonii*) and impala (*Aepyceros melampus*) were highly competitive for food with livestock on the Kekopey ranch in Kenya.

They based this conclusion on overlap of habitat as well as selection for plant species and parts. Owaga (1975) concluded that while wildebeest and zebra both were almost exclusively grazers, wildebeest were more selective for short grass and for leaf.

As an adjunct to the previous ecological studies, Hofmann (1973) furnished a detailed description of the stomach morphology of several wild ruminants. His division of ruminant stomachs on morphological grounds is correlated with information on food habits and is supportive of feeding ecology studies albeit on a level of broad differentiation. A synthesis of the socio-ecology of African antelope by Jarman (1974) presented a number of interesting hypotheses linking social, behavioral and ecological characteristics. The implication is that there both were social and behavioral bases of ecological separation.

Previous Work in the Study Area

General wet season dispersal patterns of Tarangire ungulates were determined by Lamprey (1964). The low density (0.97/sq. km) of wild ungulates in the Maasai dispersal area compared to that in the Serengeti wet season areas (30-54/sq. km) was attributed at least in part to human activity. He concluded that a decrease in dry season water sources was the foremost reason for low ungulate density, followed by competition for forage with domestic animals and a high incidence of hunting.

Kahurananga (1976) underscored the importance of the Simanjiro plains as wet season habitat for Tarangire ungulates, especially wildebeest and zebra. His work provided detailed information on herbivore densities related to habitat. Herbivore number and biomass estimates confirm the preponderance of cattle which was particularly pronounced in the dry season when there was a concomitant decrease of wild herbivores. The broader approach taken by the present study should prove complementary to the detailed work by Kahurananaanga in Simanjiro as Kahurananga investigated only 12% of the present study area.

A cursory description of the vegetation of Simanjiro was given by Van Voorthuizen (1971) who estimated the carrying capacity of the area to be 9-12 acres per Animal Unit. Also, the area was included in a broad phytosociological classification of all south Maasailand (Leippert 1968). Kametz (1962) provided a thorough listing of permanent water sources in the northern half of the study area. Comparison with present sources indicated little change in the status of dry season water.

THE STUDY AREA

Location and Boundary Delineation

Lolkisale mountain is located in the northern most part of the study area some 53 km ssw of Arusha in northern Tanzania (Fig. 1). The study area extends 100 km south and averages 48 km east/west to encompass an area of 4867 km^2. It lies between latitudes 3°46' and 4°55' S. and longitudes 36°08' and 36°48' E. Tarangire National Park borders the area on the west while the scarp rising from the Makami depression most prominently demarcates the eastern boundary. The primary criteria for delineating boundaries were inclusion of wet season habitats occupied by Tarangire ungulates and inclusion of areas traditionally utilized by Maasai belonging to the Simanjiro-Loibor Sirret ranching villages.

Physiography, Relief and Drainage

The study area is a flat to a mildly undulating upland plateau which varies altitudinally from 1585 m to 1097 m, north to south. Exceptions to the prevailing topography are rolling and moderately dissected lands along the northeast and east central portions including 18% (873 km^2) of the area, and the deeply dissected slope system (4%; 175 km^2) circumscribing Lolkisale in the north.

Several isolated hills which rise from 50 to 610 m above the surrounding country are found throughout the area but are concentrated in the northwest, west central and southeastern portions. Most conspicuous are Lolkisale (2132 m) in the north, Oldonyo Sambu (1881 m)

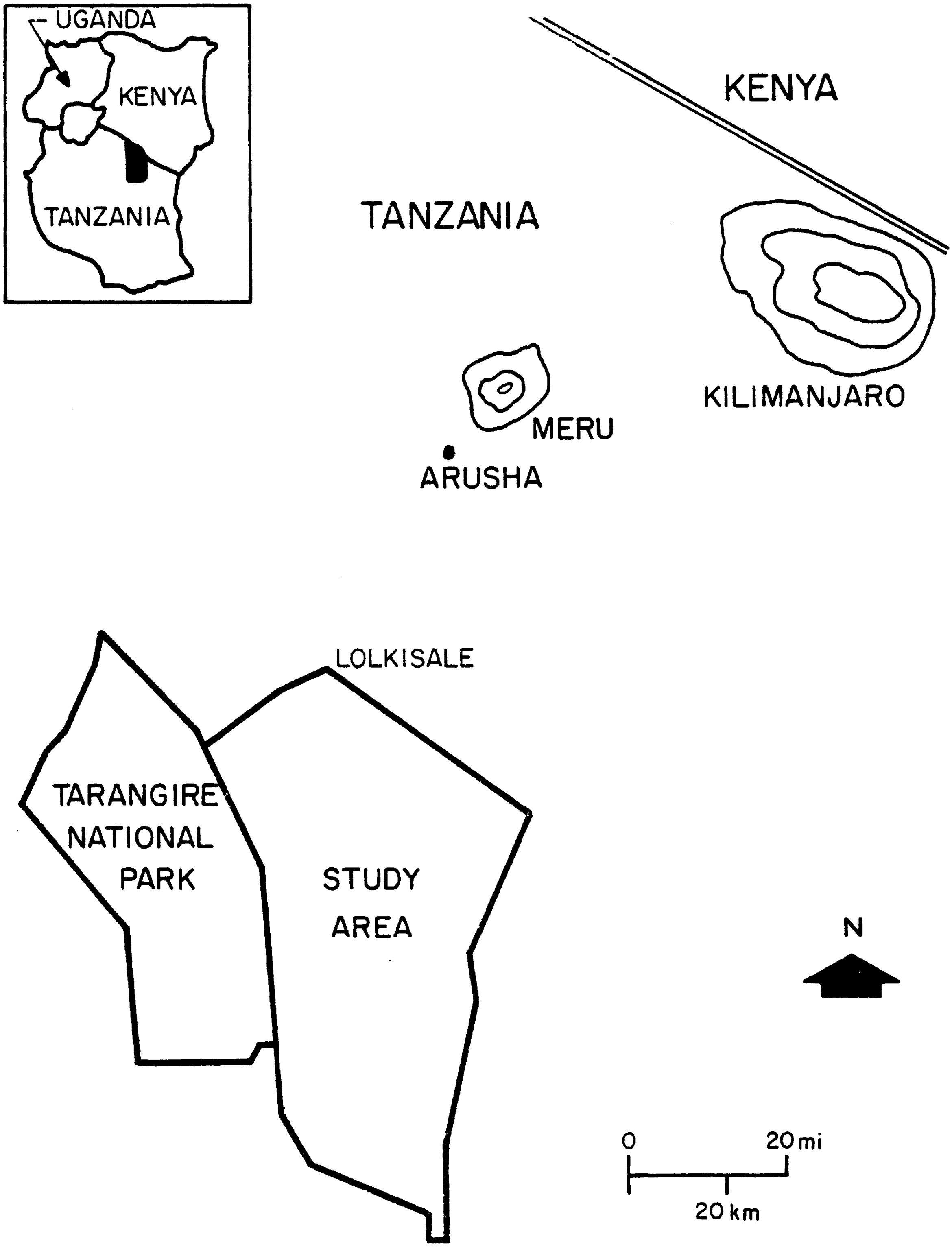

Fig. 1. Location of the study area, south Maasailand, Tanzania.

in the west, and Naibormurt (1601 m) in the east. The latter name means white neck in Maasai and refers to the massive volcanic plug which can be seen shimmering in the sun some 100 km distant.

The northern most dissected sections, including Terat and Lolkisale, drain north to the Pangani river and finally into the Indian Ocean. The remainder of the area is comprised of an internal drainage system. Drainage from the east and north central portions is southeasterly to the Ngamuriagi and Kitiangare seasonal river courses. A convergence of these terminates in the Makami depression. Seasonal runoff from northwest and west central sections flows southwest to the large edaphic grassland of Larmakau in Tarangire. Drainage from the central part of the area is southerly, ending up in the seasonally inundated grassland depressions of Njoro and Kimottorro within the study area. The lower elevated south is comparatively flat, as reflected by the localized drainage patterns. Surface runoff is to small seasonally inundated depressions and waterholes and two larger units (158 km^2; 50 km^2) which are slightly depressed and floristically and edaphically distinct from the surrounding bush.

Climate

Rainfall-Seasonality and Amount

In East Africa rainfall is the most important aspect of climate in terms of land use potential (Woodhead 1970). While rainfall patterns are complex and unpredictable they are associated with the Intertropical Convergence Zone (Sinclair 1975:13), which follows the sun's north/south oscillations. This low pressure zone is responsible for the varying degrees of bimodal rainfall distribution often occurring proximal to the equator. The study area is included (Pratt and Gwynne 1977:15) in a broad region which characteristically receives a single season rainfall from December to April. Interpretation of the meager records available for Loiborsoit in the north of the study area (E. Afr. Meteorological Department, Tanzania) confirm this and indicate that monthly peaks for any year can occur from December to April, but that January and April are the most likely months. Thus, a long term assessment indicates a single-season rainfall while on a yearly basis a bimodal distribution of rainfall may be observed. Maasai knowledge corroborates this as does the fact that they have a specific word (Aladalo) for the short dry interim period between rainfall peaks. Light rains may begin as early as September to October and continue into June. The arrival and departure of Tarangire wildebeest and zebra and concurrent presence and absence of ephemeral water and green grass ('74/'75: Jan-June, '75/'76: mid Dec-June), determined the partitioning of wet and dry seasons for purposes of this study.

The 11 year mean rainfall for the Loiborsoit records was 529 mm (max. 759 mm; min. 334 mm). The entire study area is included in the 400-600 mm isohyetal interval for mean annual rainfall (Atlas of Tanzania 1967). In terms of rainfall probability the area falls within the 250-500 mm isohyets (Ibid.). This means that the statistical probability of receiving more than 250-500 mm of precipitation in any year is 90% and of receiving less is 10%.

Although elevation is not always a reliable index of precipitation, in East Africa there is often a direct correlation between the two (Trapnell and Griffiths 1960, Pratt and Gwynne 1977:13). Thus it is probable that the lower elevation bush areas in the south receive on average less than 500 mm per annum. Such conjecture is supported by the dominance of dry bush and annual grasses in the south and the differential classification of northern and southern areas by the Maasai. The higher altitude north is considered to be between "osupuko" and "orpurkel" (ecological site classifications characterized primarily by higher and lower rainfall, respectively), whereas the south is decidedly "orpurkel."

Mean annual evaporation as presented in Pratt and Gwynne (1977:21) ranges from 1500 to 2500 mm. Correlated with precipitation, this suggests a general climatic description of the area as semi-arid to arid. The paucity and variability of rainfall in timing and amount is of significance to the study for the following reasons: a stable system of crop agriculture is precluded; ecological considerations prescribe emphasis on land use options involving livestock and/or wildlife resources; wildlife and livestock are prone to considerable nutritional stress during the long dry seasons when resources are limited and competition is potentially greatest.

Rainfall during the study period. Rain gauges were installed at Loibor Sirret, Mboret and Loiborsoit. In addition I hoped to obtain a record from the Tarangire Park camp south of Oldonyo Ngahari. Vandalism by warriors, movement and negligence by those entrusted to keep records and a hyena's variegated choice of menu, resulted in a complete record only for Mboret for the '75/'76 wet season. A total precipitation of 254 mm indicated a considerably drier than average year. On the basis of incomplete records and comparison with the above, '74/'75 precipitation was about average, whereas that for '76/'77 was above average. While observations in the latter year appeared to confirm ungulate distributional patterns as recorded in the previous drier years, it should be borne in mind that the data represent a somewhat drier than average period in the cycle, a time when competitive interaction would presumably be heightened.

Temperature and Wind

An approximation of mean temperatures can be gained by subtracting 5.3°C per 1000 m elevation from an average coastal temperature of 27°C (Glover and Kenworthy 1958 in Pratt and Gwynne 1977:19). Calculated as such, approximate mean temperatures for the study area range from 19 to 21°C. December to March and June to August, respectively, are the warmer and cooler months. As any good elephant hunter will confirm, dry season winds are fairly constant and blow westerly. Wind during the wet season is relatively minimal and directionally variable.

Geology and Soils

The geology and soils of the area have been subjected to minimal investigation. Regional geological mapping at a scale of 1:125,000 is ongoing in Tanzania but has not yet covered much of Maasailand. There are small scale geological maps of the entire country (Furcn 1963:320, Pratt and Gwynne 1977:6, Atlas of Tanzania 1967) which yield a general picture. Almost all of the area overlies Precambrian rocks of the Usagaran system. The latter source defines the rocks as metamorphosed sediments and volcanics and consisting of quartzite, graphitic schist, chlorite, amphibole, mica and kyanite, schist, hornblende, biotite and garnet gneiss, granulite and charnockite. Additionally, there are small areas of Tertiary and Quaternary sedimentary rocks consisting of sand, gravel, laterite, silcrete and calcrete. These correspond to the floristically and edaphically distinct units referred to in the section on physiography.

The three basic soil types which cover the majority of the area are summarized from the Atlas of Tanzania (1967) as follows:

1. Reddish brown soils of semi-arid regions; sandy loams to clay loams derived chiefly from gneisses
2. Lithosols on basic parent materials, chiefly lavas and gneisses; grey-brown gritty loams
3. Vertisols of topographic depressions derived from fine textured riverine and lacustrine alluvium and colluvium; grey to black clays

A small area over 1500 m in elevation, including the broad-leaved woodland around Lolkisale and the Simanjiro short grassland, is classified as having ferruginous tropical soils and ferrisols of high altitudes. These are dark brown to red loams and clay loams derived from gneisses, lavas, granites and ash. Apart from the vertisols and to a lesser extent the latter soil types, edaphic differences are largely masked or overridden by the climatic (altitude/moisture) regime. Hence, given reasonable topographical and management history similarity, areas of similar elevation have similar vegetation types. The gradient from higher to lower elevation is from open wooded and bushed grasslands and woodland dominated by perennial grasses to bushland and annual grasses.

Vegetation

Since the vegetation is discussed in detail under the habitat classification section of Results, a brief overview will suffice here. Floristic and physiognomic characteristics lead to placement of the northern 'savanna' like country into the *Acacia*-*Themeda* Scattered Tree Grassland type, whereas the southern bush areas are closest to the Desert-Grass-Bush type (Edwards and Bogdan 1951:6,10). The entire area falls within Heady's (1960:12) extensive *Themeda-Hyparrhenia* grassland zone.

The north central elevated areas, comprising about a third of the study area, fall within eco-climatic zone IV of Pratt and Gwynne (1977:42; revised from Pratt et al. 1966). Physiognomic categories within the zone consist of woodland, wooded grassland and grassland (Pratt and Gwynne 1977:44-50). Chief genera include *Acacia* and *Commiphora* for the overstory and *Themeda*, *Panicum* and *Digitaria* in the understory. Roughly a third of the area lies intermediate to zones IV and V and is composed of woodland, wooded grassland and bushed grassland. Primary generic constituents are *Acacia/Commiphora* with *Themeda* and *Aristida* in the understory. The southern bushland units represented by *Acacia*, *Commiphora* and *Grewia* species fall in zone V. In addition, scattered throughout, there are bushland units, grasslands and bush-herb grasslands of impeded drainage under edaphic control. Acacia mellifera, Pennisetum mezianum and the herb Cyathula erinacea best characterize these units.

History

According to oral tradition (Jacobs 1975:411-412), the Maasai originated west of Lake Rudolph and slowly moved south, entering the Rift Valley by A.D. 1400. In all the areas into which they expanded, they ousted semi-pastoralists and acquired use of existing water supplies. Elders confirm that the deep wells found throughout Maasailand, including Kimottorro wells in the study area, were in existence prior to the advent of the Maasai.

Oral tradition maintains that some 30 years before the rinderpest panzootic (ca. 1860), the Maasai drove the Kwavi (an off-shoot of the Maasai) from around the permanent water sources in the study area. During the panzootic and its aftermath (1891-1900) the area was largely abandoned, as the Maasai who endured the disaster had few stock and were forced to take up existence with neighboring agriculturalists or hunter-gatherers. Around 1900 the Loibor Sirret and Terat river springs and environs regained status as dry season livestock areas. The Kimottorro area was used for wet season grazing until population pressure and the '60-'61 drought necessitated re-excavation of the wells in 1961. Terat and Kimottorro have remained as dry season habitats up to the present.

Tsetse infestation has been associated with Loibor Sirret since

Maasai occupancy. The infestation, while fluctuating, was generally light and tended to restrict rather than preclude livestock use. (My interjection: restricted use = extra forage = fire = tsetse control?) An increase in tsetse in the mid-1940's resulted in partial emigration of the Maasai. Large scale (255 km^2) tsetse clearing in the late '40's to mid 50's by the colonial government (Annual Report of the Tsetse Survey and Reclamation Department 1958) effected an upsurge in occupancy which was magnified by immigration of drought-stricken Maasai from other areas. Ensuing intensive use by livestock and accompanying environmental changes have allowed regeneration of woody species and concomitant fly reinfestation. Livestock use has consequently waned despite provision of a dip and other services in 1977.

The Simanjiro plains were largely limited to wet season grazing by livestock until the completion of two dams and two boreholes by the colonial government in 1954 (Kametz 1962). Before that time Maasai elders relate that as now, Tarangire ungulates moved into the area seasonally, except there is a consensus that wildebeest and zebra were fewer then. The significance is that due to lack of water, livestock and wildlife use of the plains was largely restricted to the wet season, and the intensive dry season use by livestock is an occurrence of the last 20 some years.

The preceding summary illustrates that there has been a long term association of pastoralism with the study area in which the Maasai have played a part for at least 100 years. Of further consequence to the study is that the two areas which have received the most external input coincide respectively with the areas in which adverse environmental change has been most pronounced and potential livestock and wildlife competition is greatest.

Other Forms of Land Use

The two major forms of land use are geared toward the livestock and wildlife resources and their actual and potential development, hence the focus of the study. Also, there are minor forms of land use which are of importance to the former. These will be touched on in this section, including uses of wildlife other than use of the area by Park species.

Wildlife

Legal utilization occurs in the form of hunting and live animal capture. Prior to the hunting ban in 1973 the area was often frequented by professional hunters and overseas clientele. Presently, most hunting is by the Tanzania Wildlife Corporation to procure trophies for sale and meat for distribution among villages. As part of Government decentralization, recent changes in hunting regulations have aimed toward channeling some returns to the Districts in which hunting takes place. This trend should encourage recognition and management of wildlife as an economic resource and hopefully will facilitate direct remuneration to local inhabitants in the future. However, a specification that licenses must be purchased in the District capital has limited hunting by residents. Few hunters from the nearby population centers of Arusha and Moshi are willing to drive the 230 km south to Kibaya to hunt a mere 70 km south. This anomaly could be easily remedied by making District permits available at Regional Game in Arusha.

The study area provides opportunity for types of wildlife utilization and management not possible in the National Park. Hunting, and to a lesser extent wild animal capture for zoos, require minimal capital outlay relative to potential gains. If wildlife and livestock are to coexist in the future as now, benefits accruing from these kinds of activities will have to be realized by the local pastoralists. Cropping of wild animals on a sustained yield basis is another possibility for the future but one which holds little promise at present. An assessment of pilot cropping projects in Tanzania led Bindernagel (1975:2) to conclude that "most results showed that any biological advantages that wildlife species held over domestic animals are outweighed by logistic, economic and social drawbacks".

Illicit hunting can be described as both subsistence and commercialized. While recognizing that the distinction has in recent years become less clear cut, I consider the former a means by which local people derive benefit from wildlife. The latter, while not blatant, is undoubtedly jeopardizing rhino (*Diceros bicornis*) populations. Numerous carcasses were found but only one live rhino was seen during the study. Elephant (*Loxodonta africana*), zebra and leopard (*Panthera pardus*) are secondary targets. Population dynamics, behavior and the greater difficulty of disposing of their end products, render them less susceptible to poaching. Outsiders (often

Kenyans) are the main instigators and beneficiaries, if not the executors. For full realization of wildlife benefits by the Government and local peoples, steps must be taken to prevent illegal utilization.

Cultivation

Cultivation within the area is mainly confined to small acreages adjacent to trading settlements. Total area under cultivation in 1977 was approximately 130 ha. Although this constitutes a minimal area relative to the whole, most of this (120 ha) is on the Simanjiro plains. Kahurananga (1976) reported a total of 70 ha in the same area for 1972. The increase is attributable to an increase of tractor cultivation by a few Maasai. Maize is by far the principal crop with beans a distant second. Besides the vagaries of climate, incursions by wildlife and livestock militate against crop agriculture. Emphasis on small plots in former corral ('boma') sites will somewhat circumvent these conflicts because of the existing thorn enclosures and the presence of animal fertilizer. A more complete discussion of cultivation activity, history and problems by locale has been provided in an earlier report (Peterson 1975:21-24).

In summary, larger scale mechanized agriculture is not compatible with livestock or wildlife and must be halted if expressed goals of land use are to be pursued. Evidence from the Sahel region suggests that cultivation on marginal land, specifically the pastoral/agricultural interface, increases the vulnerability of both groups to the impact of drought (Campbell 1977). Awareness of the problem is not lacking among Government leaders (Mongi 1974), but a clearly defined and enforced policy for Simanjiro is needed.

Agriculture in adjacent areas is most extensive along the northern side. Large scale navy bean farming for seed export began in 1971 in the vicinity of Lolkisale. By 1976, land under cultivation had expanded to 6500 hectares. Charcoal burners entered the Oljoro/ Komolo areas to the north in the early 1960's. As trees suitable for charcoal burning were exhausted, many of the people settled and began cultivating. Maasai use of both of these areas is considerably restricted. The implications deriving from cultivation on the perimeters of the area are twofold. First, it intensifies pressure for expansion of agriculture internally. Second, and of particular significance to this study, it limits or geographically fixes the area available for livestock raising.

Honey, Gemstones and Charcoal

Honey gathering is a favorite pastime of particularly the 'Balanga' Dorobo. The honey is sold locally or used to brew honey beer (Namuka). Fire is somewhat synonymous with honey gathering and it is through this effect on habitat that the activity has most bearing on livestock and wildlife. Apiculture has potential for development as a form of land use, supplementary to and non-conflicting with livestock and wildlife.

Gemstones found in the area include rhodolite, almandite, tanzanite, green and red garnet, tourmaline, ruby and amethyst (Department of Gemstones and Minerals). Blackmarketeers attracted by gems, often deal with illicit wildlife products as well.

The charcoal burning so prevalent to the north is thus far minimal in the area. Controlled charcoal burning could in the future be incorporated into livestock management plans as an economical form of bush clearance.

Large Mammals

Ungulates are defined as species within the orders Artiodactyla, Perissodactyla and Proboscidea (Geist 1974). Cattle, sheep (*Ovis aries*), goats (*Capra hircus*) and donkeys (*Equus asinus*) represent the domestic ungulates in the area. The study's emphasis on cattle is the result of that species' numerical superiority and the priority given it by local and developmental interests.

Among the numerous wild ungulates, species were included on the basis of abundance, qualitative food habit overlap with cattle and amenability to the methods employed. For the wet season, distributional data are presented for wildebeest, zebra, kongoni (Coke's hartebeest), eland, oryx, Grant's gazelle (*Gazella granti*) and impala. These are the most abundant medium-sized ungulates whose behavior allowed for observation along transects. Focus was on wildebeest and zebra, the most numerous grazers. The dry season counts at water sources gave reliable figures for a slightly different group of species. Thus cattle distribution in the dry season is related to elephant, black rhinoceros, buffalo, eland, zebra, wildebeest and kongoni distributions. Of these species the majority of the wildebeest and zebra are seasonal migrants from Tarangire Park.

Elephant, buffalo, eland, oryx and kongoni populations are more evenly divided between seasonal migrants and permanent residents, whereas Grant's gazelle and impala fall exclusively within the latter category.

In addition, the area harbors a number of less abundant ungulates, the most conspicuous of which are giraffe (*Giraffa camelopardalis tippelskirchi*), warthog (*Phacochoerus aethiopicus*), and Kirk's dik-dik (*Rhynchotragus kirki*). Ungulates characterized by secretive behavior and/or a very localized distribution include greater kudu (*Tragelaphus strepsiceros*), lesser kudu (*Tragelaphus imberbis*), bushbuck (*Tragelaphus scriptus*), Bohor reedbuck (*Redunca redunca*), gerenuk (*Litocranius walleri*), Thomson's gazelle, bushpig (*Potamochoerus porcus*), bush duiker (*Sylvicapra grimmia*), steinbok (*Raphicerus campestris*) and klipspringer (*Oreotragus oreotragus*). Ostrich (*Struthio camelus*), taxonomically distant but ecologically similar to the ungulates, are common as are aardvark (*Orycteropus afer*).

The usual large felines, lion (*Panthera leo*), leopard and cheetah (*Acinonyx jubatus*) are present as well as the spotted hyena (*Crocuta crocuta*), that proved to be the most common campsite visitor. The following carnivores also occur: striped hyena (*Hyaena hyaena*); aardwolf (*Proteles cristatus*); wild dog (*Lycaon pictus*); black-backed jackel (*Canis mesomelas*); common jackel (*Canis aureus*); side-striped jackel (*Canis adustus*); bat-eared fox (*Otocyon megalotis*); caracal (*Felis caracal*); serval cat (*Felis serval*); civet (*Viverra civetta*); common genet (*Genetta genetta*) and ratel (*Mellivora capensis*). Scientific names of wild mammals follow Dorst and Dandelot (1969).

METHODS

Habitat Classification

The objective of habitat identification was to enable interpretation of animal distributions relative to habitat types and possibly to indicate some causal effects between the two. In a broad sense habitat can be defined as the complex array of biotic and abiotic factors which determine where an organism lives and thrives i.e., its distribution and abundance. Since vegetation is generally the most important habitat component of large terrestrial herbivores, habitats in this study were defined primarily in terms of botanical structure and composition.

Plant species were collected and identified using available taxonomic keys (Dale and Greenway 1961, Harker and Napper 1961, Bogdan 1958, Agnew 1974, Flora of Tropical East Africa 1952 -). Voucher specimens were sent to the East African Herbarium, Nairobi for verification. Vegetative units were delineated from Erts satellite imagery maps (Fig. 2) at a scale of 1:250,000. Where warranted by ground reconnaissance, the delineations were adjusted with the aid of topographic maps: series Y742 (1:50,000) and series Y503 (1:250,000) of the Survey Division, Tanzania.

Representative sites within the units were sampled using the releve' method (Mueller-Dombois and Ellenberg 1974). This technique entailed listing all species occurring within a 50 m^2 area and assigning a cover percentage to each by ocular estimation. Checks on the accuracy of cover estimation were made by using the step-point

Fig. 2. Habitats in the study area were delineated from Erts satellite imagery maps, south Maasailand, 1974.

procedure and line transects for the understory and overstory components, respectively. It was concluded that the method was appropriate for the large-area reconnaissance called for in the study's objectives. The method's use in and applicability to African rangeland surveys was reviewed by Werger (1977).

In addition to the floristic tabulation, information on soils, topography, elevation, and past and present ungulate use was recorded for each stand (releve'). Soils were characterized by texture to the C horizon and the color noted by matching with Munsell Soil Color Charts. Samples of four main soil types taken from pits to 180 cm in depth, were sent to the soil testing laboratory at Lyamungu for chemical analysis. Present animal use was ascertained by observed presence during the course of the study and by sign (spoor, droppings and forage utilization) in the vicinity of the stands. An indication of past use was obtained through questioning of local inhabitants.

Interviews and informal discussions with Maasai elders were employed as means of documenting major habitat change within larger areas (Fig. 3). Questions related to general (disease, rainfall), as well as specific changes (Has this grass increased/decreased/remained the same?) which had taken place since the elders' initial association with the area. Misleading or false information was recognized by cross checking responses from separate groups or individuals. A similar technique was used successfully in other parts of Africa (Riney 1967).

To determine whether forage nutrient levels may have an effect on ungulate distribution, leaf samples (100 gm green wt.) of 8 of the

Fig. 3. Interviews and informal discussions with Maasai elders were employed to document major habitat change.

more common grass species were collected for chemical analyses. For each species, leaves were hand plucked at random from several different plants. All 8 samples were taken from plants of comparable growth stage early in the growing season.

Tsetse Fly Infestation

The degree of tsetse fly infestation was a qualitative assessment based on how harassed I was and on information from Maasai (Table 1).

Cattle Concentration Areas

General patterns of cattle distribution for the dry season were determined by plotting dry season settlements and delineating grazing radii for each locale. A mean grazing radius of 8 km conformed to observed grazing patterns over the entire area. The outside perimeter of the well-grazed cattle belt was thus delineated (with local adjustments). Wet season distribution centers were determined by plotting movements of settlements and their accompanying cattle herds. Field observation augmented by reports from local informants provided this information. Corollary information pertaining to the underlying rationale and factors which govern Maasai movement patterns was obtained through interviews and informal discussion. Because of the difficulty of quantifying such information, it is summarized in the Discussion section.

Cattle and Wild Ungulate Distributions - Dry Season

Commensurate with the study's intent to investigate cattle and wild ungulate interactions and since cattle are obligate drinkers,

Table 1. Categories of tsetse fly infestation and their definition.

Tsetse fly infestation categories	My perception	Maasai perception
Very light	Tsetse are noticed only very infrequently	Acceptable area for livestock with purchase of very little veterinary drugs required
Light	Tsetse presence is quite regular but they are few enough so one can almost ignore them	Maasai will use these areas provided disease risk (Anaplasmosis and East Coast Fever) is minimal and veterinary medicine is available. Wealthy Maasai who own many cattle are often more willing and able to risk use of these areas.
Medium	Tsetse are a real nuisance	Maasai avoid these areas except for short periods during times of stress
Heavy	Life is unbearable here	Maasai use precluded

information on dry season animal distributions was obtained from counts at permanent water sources. Cattle numbers were estimated by multiplying the number of settlements around a water source by a mean number of cattle per settlement. The latter number was derived from cattle censuses of 32 settlements conducted by the investigator.

Permanent water sources accessible to wild ungulates were plotted and estimates of the numbers of water-dependent species obtained by a combination of actual and track counts. When possible, tree platforms were constructed to minimize conflictive interaction while conducting the actual counts on moonlit nights. Where the nature of the water source or the time constraint precluded actual counts, reliance was placed on track counts. In this endeavor I enlisted the aid of hunter-gatherer friends (Balang'a Dorobo) who read the substrate as adeptly as I do a third grade primer. The method entailed pulling a thorn tree around the water source leaving a 2 to 3 meter wide swept trail. This was done late in the afternoon with the counting carried out the following morning before the tracks were erased by livestock and wind. As a test on the reliability of track counts, the author conducted actual counts after which the trackers were told to report the number and species which had frequented the water source the preceding night (while they were asleep). In the three instances in which track counts were tested with actual counts, the error was minimal (Table 2).

Young (1972) found that 5,085 randomized counts at over 500 water sources in Kruger Park did not yield reliable correlation with known

Table 2. Track counts cross tested with actual counts, south Maasailand, dry season - 1975.

Water source		elephant	buffalo	rhino
Naing'olgawan	actual count	10	5	-
	track count	10	5	-
	% error	-	-	-
Lesoiya	actual count	120	11	1
	track count	141	9	1
	% error	+18	-18	-
Lesoiya	actual count	142	20	-
	track count	154	15	-
	% error	+8	-25	-
	Mean % error	+9	-14	no error

population figures. He concluded that the effect of variable environmental factors on drinking patterns undermined the use of waterhole counts to obtain accurate population estimates. The intermittent, randomized counts carried out by Young in an area of numerous watering options would be subject to the variability of the numerous factors which influence drinking patterns. In the present study this variability was minimized by the systematic and continual coverage, for from 24 to 96 hours, of all permanent water sources in the area. The value of waterhole counts in checking owner estimates of wildlife species in the Transvaal, South Africa was reported by Lambrechts (1974).

Probably the greatest inaccuracy in the counts was introduced in the attempt to determine frequency of drinking. Frequency varied by locale and by species as well as social unit. For example, at Mondui a bull elephant came in to drink several nights in succession at the same hour, whereas the matriarchal groups drank an average of once every second day. Throughout the entire area it was noted that lone bull eland were found further from water and drank infrequently compared to cow/calf herds.

Factors affecting drinking frequency include inherent water requirements, the proximity of forage and suitable habitat, the vegetation potential for supplying water requirements (e.g. succulents) and human/predator interference around water sources, especially harrassment during the heat of the day. Local knowledge places wildebeest and zebra in the category of daily drinking, whereas elephant, buffalo, rhino and eland drink every second day on average.

The local consensus was used as the criterion for drinking frequency, with adjustments made when warranted by local conditions and indicated in the track counts or by actual observation.

Cattle and Wild Ungulate Distributions - Wet Season

Density indices were derived by dividing the number of animals recorded along driven transects by the distance traversed in the respective habitats. Indices were adjusted by calculating a mean visibility distance (Lamprey 1963, Hirst 1969) for each habitat. This was largely a function of woody species and topography and ranged from 500 m in grassland to 100 m in bushland habitat. Contraction of trypanosomiasis and infectious hepatitis by the author, and recurring field obstacles such as vehicle breakdown and impassable roads, precluded regular and systematic coverage of the area so that data were collected on a seasonal rather than monthly basis.

RESULTS

Habitat Classification

Within the 137 stands sampled, 327 plant species were identified. These represented 52 families, the most common of which was Gramineae with 95 species. The most common family of the overstory synusia was Mimosaceae with 17 species, most of which were of the prominent genus *Acacia*. Species with the highest constancy values overall were *Cenchrus ciliaris*, *Aristida adscensionsis*, *Themeda triandra*, *Tragus berteronianus*, *Eragrostis cilianensis* and *Solanum incanum* in the herb layer and *Commiphora schimperi*, *C. africana*, *Acacia tortilis* and *Grewia bicolor* in the tree and shrub component. A species list is provided in Appendix Table 1 and a summarized constancy table in Appendix Table 2.

Constancy tables of the vegetative data were constructed and stand and unit similarities recognized on the basis of differential species groups (Mueller-Dombois and Ellenberg 1974), dominants and constant species. These floristic parameters combined with topoedaphic and climatic characteristics led to lumping of the original 31 delineated units into 14 habitat types and 3 condition classes to comprise a total of 17 habitats (Table 3). Habitat areas were measured from the map (Fig. 4) with a planimeter. The basic unit of classification was the habitat type which was defined as a unit of land capable of supporting the same kind of relatively stable vegetation community (Daubenmire 1968: 260). It was essentially the same as the range site (Abercrombie 1974: 24) or site potential approach (Humphrey 1962:193). The assignment of

Table 3. Floral and topographic characteristics of the major habitats found in the study area, south Maasailand, Tanzania, 1977.

Habitat+	Area (km^2)	% of total	Dominant species	Constant species# Tree/shrub	Constant species# Grass/forb	Eco-climatic zone+ Elevation (m) Topoedaphic characteristics
1)* *Panicum-Digitaria* short grassland PD(sG) 8 stands	292	6.0	*Panicum coloratum* *Digitaria macroblephara*		*Cenchrus ciliaris* *Pennisetum mezianum* *Themeda triandra* *Eustachys paspaloides* *Microchloa kunthii* *Harpachne schimperi* *Aristida adscensionsis* *Tragus berteronianus* *Eragrostis cilianensis* *Astripomoea hyoscyamoides* *Sericocomopsis hildebrantii* *Solanum incanum* *Barleria ramulosa*	IV-V Mean elevation: 1510 range: 1433-1554 Flat to mildly undulating upland plateau Red/brown clay loams and clays
2)* Short *Panicum-Digitaria-Commiphora* wooded grassland PDC(WG) 9 stands	328	6.7	*Panicum coloratum* *Digitaria macroblephara* *Commiphora schimperi* *Commiphora africana* *Acacia nilotica*	*Acacia tortilis*	*Cenchrus ciliaris* *Pennisetum mezianum* *Themeda triandra* *Eustachys paspaloides* *Eragrostis superba* *Solanum incanum* *Astripomoea hyoscyamoides* *Barleria ramulosa*	IV-V Mean elevation: 1490 range: 1409-1585 Flat to mildly undulating upland plateau Red/brown clay loams and clays
Denuded *Panicum-Digitaria-Commiphora* wooded grassland dPDC(WG) 2 stands	58	1.2	*Sericocomopsis hildebrantii* *Tribulus terrestris* *Gisekia pharnaceoides* *Solanum incanum* *Commiphora schimperi*	*Acacia tortilis*	*Panicum coloratum* *Digitaria macroblephara* *Themeda triandra* *Cenchrus ciliaris* *Microchloa kunthii* *Eragrostis cilianensis* *Dactyloctenium aegyptium* *Tragus berteronianus* *Ipomoea hildebrantii* *Talinum caffrum* *Astripomoea hyoscyamoides* *Barleria ramulosa*	

+ Physiognomic classification and eco-climatic zones after Pratt and Gwynne (1977:40-50).
* A unit capable of supporting the same kind of relatively stable vegetation community (Daubenmire 1968:260).
# Species exceeding 60% constancy are listed.

Table 3. Floral and topographic characteristics of the major habitats found in the study area, south Maasailand, Tanzania, 1977 (Continued).

Habitat+	Area (km^2)	% of total	Dominant species	Constant species# Tree/shrub	Constant species# Grass/forb	Eco-climatic zone+ Elevation (m) Topoedaphic characteristics
3)* *Themeda-Panicum-Commiphora* wooded grassland TPC(WG) 8 stands	450	9.2	*Themeda triandra* *Panicum coloratum* *Commiphora schimperi*	*Acacia senegal* *Acacia tortilis* *Commiphora africana* *Grewia bicolor*	*Cenchrus ciliaris* *Eustachys paspaloides* *Sporobolus fimbriatus* *Chloris roxburghiana* *Digitaria macroblephara* *Digitaria milanjiana* *Aristida adscensionsis* *Tragus berteronianus* *Eragrostis cilianensis* *Solanum incanum* *Erlangea cordifolia*	IV-V Mean elevation: 1407 range: 1288-1570 Rolling to moderately dissected Red/brown loams and clay loams
Modified *Themeda-Panicum-Commiphora* wooded grassland mTPC(WG) 6 stands	260	5.3	*Themeda triandra* *Panicum coloratum* *Commiphora schimperi*	*Acacia senegal* *Acacia etbaica* *Acacia nilotica* *Commiphora africana* *Lannea humilis* *Grewia bicolor*	*Cenchrus ciliaris* *Digitaria macroblephara* *Eustachys paspaloides* *Chloris roxburghiana* *Sporobolus fimbriatus* *Sporobolus pyramidalis* *Aristida adscensionsis* *Tragus berteronianus* *Eragrostis cilianensis* *Sericocomopsis hildebrantii* *Astripomoea hyoscyamoides*	
Denuded *Acacia-Commiphora* regenerating woodland and wooded grassland dAC(W/WG) 7 stands	213	4.4	*Acacia senegal* *Acacia tortilis* *Commiphora schimperi*	*Commiphora africana* *Grewia bicolor* *Grewia villosa*	*Cenchrus ciliaris* *Themeda triandra* *Dicanthium radicans* *Chloris roxburghiana* *Cynodon nlemfuensis* *Aristida adscensionsis* *Dactyloctenium aegyptium* *Tragus berteronianus* *Chloris virgata* *Solanum incanum* *Sericocomopsis hildebrantii* *Indigofera volkensii*	

+ Physiognomic classification and eco-climatic zones after Pratt and Gwynne (1977:40-50).
* A unit capable of supporting the same kind of relatively stable vegetation community (Daubenmire 1968:260).
# Species exceeding 60% constancy are listed.

Table 3. Floral and topographic characteristics of the major habitats found in the study area, south Maasailand, Tanzania, 1977 (Continued).

Habitat+	Area (km²)	% of total	Dominant species	Constant species# Tree/shrub	Constant species# Grass/forb	Eco-climatic zone+ Elevation (m) Topoedaphic characteristics
4)* *Aristida-Commiphora* wooded grassland AC(WG) 3 stands	306	6.3	*Aristida adscensionsis* *Commiphora schimperi*	*Acacia etbaica* *Grewia bicolor* *Boscia angustifolia*	*Themeda triandra* *Cenchrus ciliaris* *Panicum coloratum* *Sporobolus fimbriatus* *Eragrostis cilianensis* *Eragrostis aspera* *Brachiaria leersioides* *Tragus berteronianus* *Erlangea cordifolia* *Heliotropium steudneri* *Solanum incanum* *Sericocomopsis hildebrantii*	V Mean elevation: 1306 range: 1280-1341 Rolling to moderately dissected Red/brown silt loam, poor structure-surface compaction
5)* *Azanza-Lannea-Acacia nilotica* woodland and wooded grassland (with *Themeda* ground cover) ALAn(W/WG) 11 stands	228	4.7	*Azanza garckeana* *Lannea humilis* *Acacia nilotica* *Themeda triandra*	*Commiphora africana* *Commiphora schimperi* *Dombeya rotundifolia* *Heeria reticulata* *Acacia seyal* *Combretum molle*	*Digitaria milanjiana* *Cenchrus ciliaris* *Heteropogon contortus* *Eustachys paspaloides* *Sporobolus fimbriatus* *Cymbopogon excavatus* *Microchloa kunthii* *Aristida adscensionsis* *Aristida mutabilis* *Eragrostis cilianensis* *Eragrostis aspera* *Solanum incanum*	IV Mean elevation: 1507 range: 1341-1600 Rolling to deeply dissected Dark red brown clay loams; top of catena=sandy loams; bottom of catena=clays
6)* *Digitaria-Themeda-Commiphora* bush grassland DTC(BG) 4 stands	273	5.6	*Digitaria milanjiana* *Themeda triandra* *Commiphora schimperi*	*Acacia tortilis* *Commiphora madagascariensis* *Acacia senegal* *Lannea humilis* *Cordia sinensis* *Grewia bicolor*	*Cenchrus ciliaris* *Cynodon nlemfuensis* *Sporobolus festivus* *Aristida adscensionsis* *Eragrostis cilianensis* *Tragus berteronianus* *Chloris virgata* *Dactyloctenium aegyptium* *Panicum hanningtonii* *Alloteropsis cimicina* *Solanum incanum* *Astripomoea hyoscyamoides*	IV-V Mean elevation: 1334 range: 1295-1364 Rolling to moderately dissected Red/brown loams

+ Physiognomic classification and eco-climatic zones after Pratt and Gwynne (1977:40-50).

* A unit capable of supporting the same kind of relatively stable vegetation community (Daubenmire 1968:260).

Species exceeding 60% constancy are listed.

Table 3. Floral and topographic characteristics of the major habitats found in the study area, south Maasailand, Tanzania, 1977 (Continued).

Habitat+	Area (km^2)	% of total	Dominant species	Constant species#		Eco-climatic zone+ Elevation (m) Topoedaphic characteristics
				Tree/shrub	Grass/forb	
7)* *Lannea*-*Croton*-*Grewia* clumped bushland LCG(B) 4 stands	58	1.2	*Lannea humilis* *Croton polytrichus* *Grewia bicolor*	*Boscia angustifolia* *Commiphora africana* *Commiphora schimperi* *Albizia petersiana* *Strychnos usambarensis* *Acacia brevispica*	*Themeda triandra* *Digitaria milanjiana* *Chloris roxburghiana* *Eustachys paspaloides* *Sporobolus fimbriatus* *Sporobolus festivus* *Aristida adscensionsis* *Tragus berteronianus* *Chloris virgata* *Duosperma kilimandscharicum* *Solanum incanum*	IV-V Mean elevation: 1383 range: 1341-1403 Flat to mildly undulating plateau Grey/brown sandy clay loams (extensive termite activity=clay from lower horizons)
8)* *Grewia*-*Commiphora*-*Acacia tortilis* bushland and bushland thicket GCAt(B/Bt) 18 stands	1247	25.8	Bushland: *Acacia tortilis* *Grewia bicolor* *Commiphora schimperi* *Urochloa mossambicensis*	*Boscia angustifolia* *Commiphora madagascariensis* *Commiphora africana* *Grewia tembensis*	*Digitaria velutina* *Chloris virgata* *Tragus berteronianus*	V Mean elevation: 1237 range: 1113-1303 Flat to mildly undulating Red/brown and grey sandy loams to sandy clay loams
			Bushland thicket: *Grewia bicolor* *Grewia forbesii* *Commiphora mollis* *Commiphora madagascariensis*	*Acacia tortilis* *Commiphora schimperi* *Boscia angustifolia* *Lannea stuhlmanii* *Zanthoxylum chalybeum* *Grewia tembensis* *Croton polytrichus* *Croton dichogamous* *Premna oligotricha* *Euphorbia scheffleri* *Acacia brevispica*		
9)* *Acacia tortilis*-*Cynodon nlemfuensis* bush grassland clearings AtCn(BG) 3 stands	17	0.3	*Acacia tortilis* *Cynodon nlemfuensis*	*Commiphora schimperi* *Grewia bicolor*	*Cenchrus ciliaris* *Chloris roxburghiana* *Themeda triandra* *Tragus berteronianus* *Talinum caffrum*	V Mean elevation: 1273 Small clearings within the larger bushland unit located on gently sloping hillsides or in slight depressions Red and brown sandy loams

+ Physiognomic classification and eco-climatic zones after Pratt and Gwynne (1977:40-50).
* A unit capable of supporting the same kind of relatively stable vegetation community (Daubenmire 1968:260).
\# Species exceeding 60% constancy are listed.

Table 3. Floral and topographic characteristics of the major habitats found in the study area, south Maasailand, Tanzania, 1977 (Continued).

Habitat+	Area (km^2)	% of total	Dominant species	Constant species#		Eco-climatic zone+ Elevation (m) Topoedaphic characteristics
				Tree/shrub	Grass/forb	
10)* *Urochloa-Cordia-Acacia tortilis* bush grassland UCAt(BG) 6 stands	194	4.0	*Urochloa mossambicensis* *Cordia sinensis* *Acacia tortilis*	*Commiphora schimperi* *Grewia bicolor* *Grewia forbesii* *Grewia tembensis*	*Chloris roxburghiana* *Cenchrus ciliaris* *Cynodon nlemfuensis* *Heteropogon contortus* *Tragus berteronianus* *Chloris virgata* *Aristida adscensionsis*	V Mean elevation: 1173 Flat, slightly depressed unit within the extensive bushland unit Red and brown sandy clay loams
11)* *Chloris-Sporobolus-Vernonia-Lannea* bush grassland CSVL(BG) 2 stands	50	1.0	*Chloris virgata* *Chloris pycnothrix* *Sporobolus ioclados* *Vernonia cinerascens* *Lannea humilis*	*Albizia harveyi* *Commiphora africana* *Commiphora caerulea* *Commiphora schimperi* *Heeria reticulata* *Capparis tomentosa* *Croton menyhartii* *Dichrostachys cinerea* *Maytenus heterophylla* *Rhus tenuinervis*	*Cenchrus ciliaris* *Sporobolus fimbriatus* *Aristida adscensionsis* *Aristida hordeacea* *Eragrostis aspera* *Setaria pallidefusca* *Setaria verticillata*	IV-V Mean elevation: 1166 Flat, depressed unit surrounded by bushland and characterized by a playa (alkaline flat) Lacustrine soils; grey silty clay loam (limestone protrusions)
12)* Seasonally waterlogged *Pennisetum-Duosperma-Cyathula-Acacia mellifera* grassland and bush herb grassland PDCAm(G/BHG) 13 stands	670	13.8	*Pennisetum mezianum* *Duosperma kilimandscharicum* *Cyathula erinacea* *Acacia mellifera* localized thickets dominated by: *Acacia mellifera* *Acacia stuhlmanii* *Acacia drepanolobium*	*Balanites aegyptiaca* *Cadaba farinosa*	*Setaria acromelana* *Lintonia nutans* *Brachiaria eruciformis* *Digera muricata* *Commelina benghalensis* *Asparagus* sp.	IV Elevation range: 1100-1550 Flat; seasonally inundated Heavy black clays (vertisols) characterized by cracking and seasonal shrinking and swelling(montmorillonite clay particles; base accumulation)

+ Physiognomic classification and eco-climatic zones after Pratt and Gwynne (1977:40-50).
* A unit capable of supporting the same kind of relatively stable vegetation community (Daubenmire 1968:260).
# Species exceeding 60% constancy are listed.

Table 3. Floral and topographic characteristics of the major habitats found in the study area, south Maasailand, Tanzania, 1977 (Continued).

				Constant species#		Eco-climatic zone+
Habitat+	Area (km^2)	% of total	Dominant species	Tree/shrub	Grass/forb	Elevation (m) Topoedaphic characteristics
13)* Seasonally waterlogged *Pennisetum mezianum* grassland Pm(G) 6 stands	138	2.8	*Pennisetum mezianum* localized dominance by: *Dicanthium annulatum* *Cyathula erinacea* *Cynodon nlemfuensis*	*Acacia mellifera* *Maerua crassifolia*	*Dinebra retroflexa* *Rottboellia exaltata* *Setaria incrassata* *Sporobolus helvolus* *Thelopogon elegans* *Abutilon mauritianum* *Oxygonum sinuatum*	IV Mean elevation: 1143 Flat; seasonally inundated Heavy dark brown and black clays (vertisols)
14)* Seasonally waterlogged *Sporobolus helvolus* grassland Sh(G) 10 stands	85	1.7	*Sporobolus helvolus* localized dominance by: *Cyathula erinacea* *Sporobolus consimilis* *Echinochloa colona*		*Eriochloa nubica* *Dinebra retroflexa* *Brachiaria* sp.	IV Mean elevation: 1113 Flat; seasonally inundated Grey silty clays characterized by cracking and seasonal shrinking and swelling (saline)

+ Physiognomic classification and eco-climatic zones after Pratt and Gwynne (1977:40-50).
* A unit capable of supporting the same kind of relatively stable vegetation community (Daubenmire 1968:260).
# Species exceeding 60% constancy are listed.

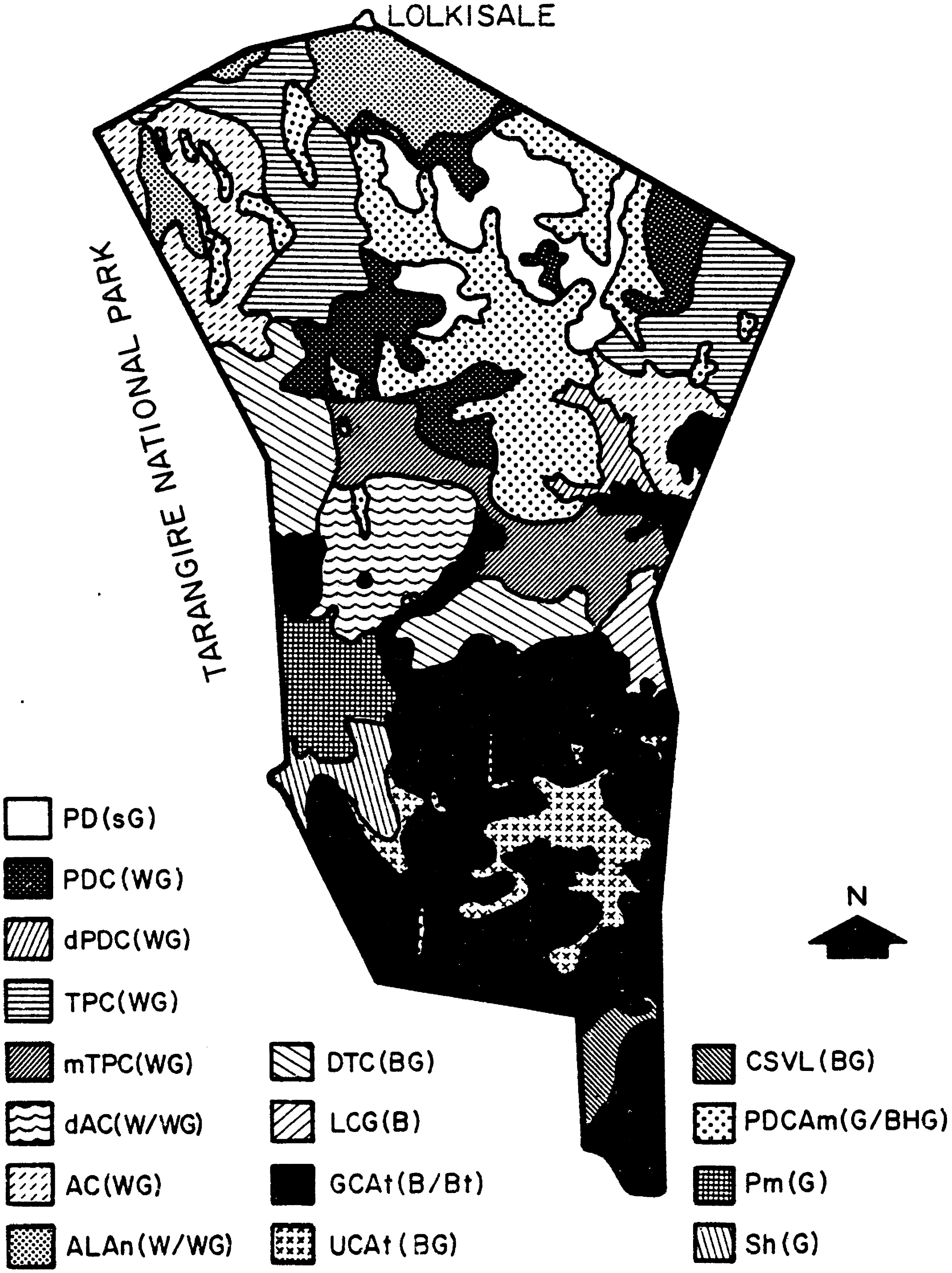

Fig. 4. Vegetation-habitat map of the study area, south Maasailand, 1977. See Table 3 for explanation of habitat codes.

condition classes to habitat types was aided by a reconstruction of the area's previous status, made possible by the interviews with elders regarding habitat changes.

Ordinational Vegetation Analysis

Since objective methods for phytosociological classification were first proposed by Goodall (1953), there has been a profusion of such techniques, among which, ordination (Bray and Curtis 1957, Swan et al. 1969) has received much attention. To compare the more subjective classification (Table 3) with a mathematical treatment, the stands were ordinated by computer using the method of Swan, Dix and Wehrhahn (1969). In this method a matrix of interstand distances was derived using euclidean distance formulas, and axes which most accurately reflected these distances were selected mathematically.

Ordination of all 137 stands resulted in a confusion of points which was both graphically and ecologically difficult to interpret. The distortion was most likely because of the large number of zero values in the matrix (Swan 1970), a result of qualitative compositional differences among stands. To alleviate this problem the stands were separated into 2 main ecologically based groups. The first group was composed of stands on seasonally waterlogged soils which were to a large extent floristically distinct from the second group on free-draining soils. Ordination of the former stands (Fig. 5) depicted groupings which represent habitat types 12, 13 and 14 in Table 3. A fourth group was comprised of stands dominated by the herb *Cyathula erinacea*. It is surmised that the localized dominance of this herb

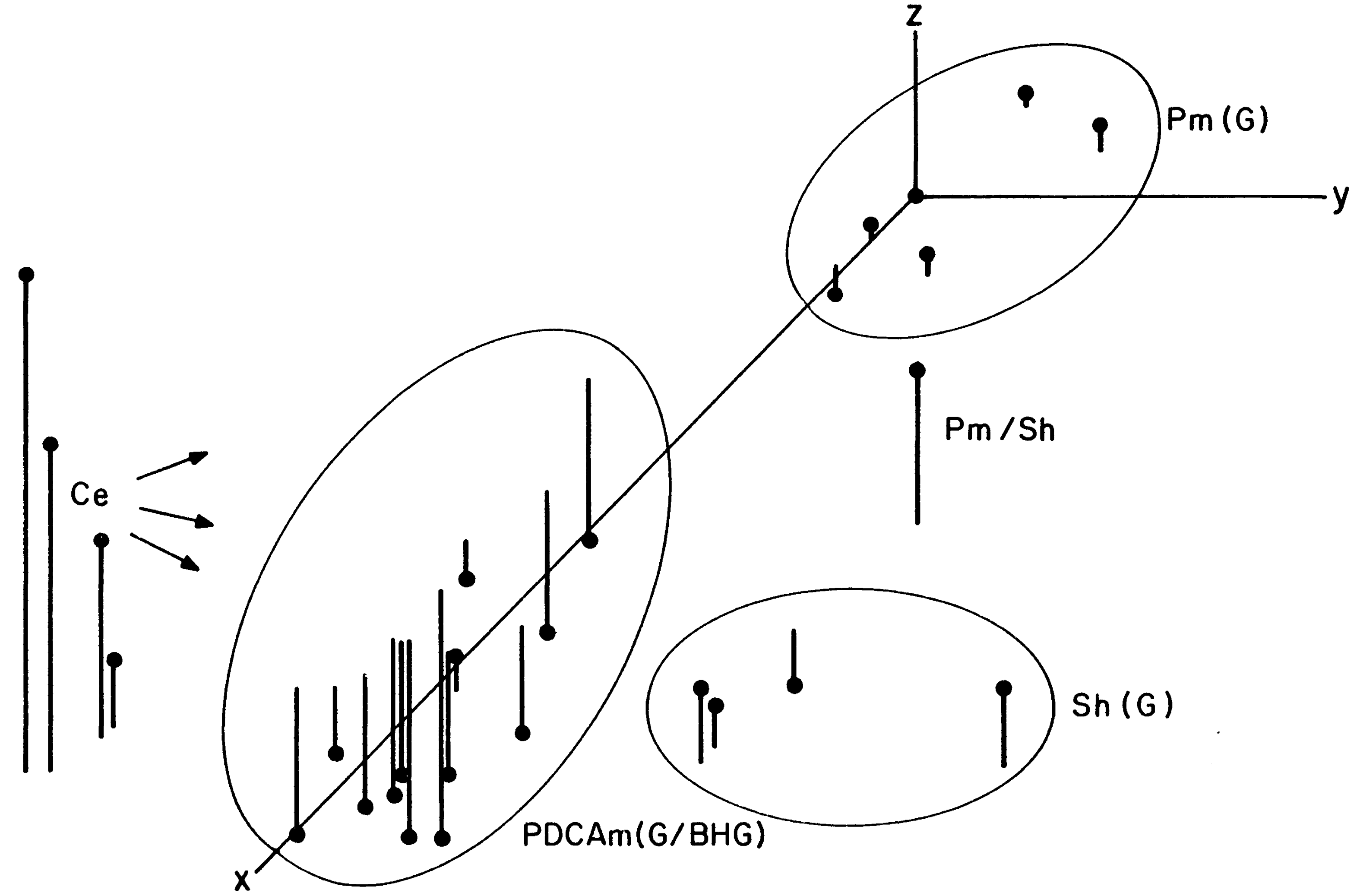

Fig. 5. Three dimensional ordination of 27 stands on seasonally waterlogged soils (25 percent constancy, 18 species). See Table 3 for explanation of habitat codes.

in each of the other 3 habitats was due to peculiar drainage and alkalinity characteristics.

Ordination of the remaining 109 stands on free-draining soils produced less clearly defined results. While similar trends were evident for all stand combinations ordinated, close stand distances made graphic representation extremely difficult. For this reason an ordinated subsample of 46 stands is presented in Figure 6. Because the interpretation was not significantly altered by the third axis, a two dimensional ordination is presented.

The inverse relationship between the number of species included in an ordination and the extraction percentage of the model presented a problem related to how accurately the ordination technique portrayed stand similarities. The dilemma lay between including species of low constancy which were of definitive value and the resultant decrease in extraction percentage (how well the model portrayed the matrix). Percentage extractions are shown in Appendix Table 3. In Figure 6, the closely grouped center cluster representing 5 habitats may be due in part to the total extraction percentage of 56% which leaves 44% of the total variability of the matrix left unaccounted for, and thus could result in a clustering of environmentally unrelated stands. Another reason for the close clustering may be the modifying effects of grazing which have resulted in a convergence of stands of different habitat types because of similar condition (high percent bare ground and low species diversity). This was suggested by the proximity of the less severely modified habitat mTPC (WG).

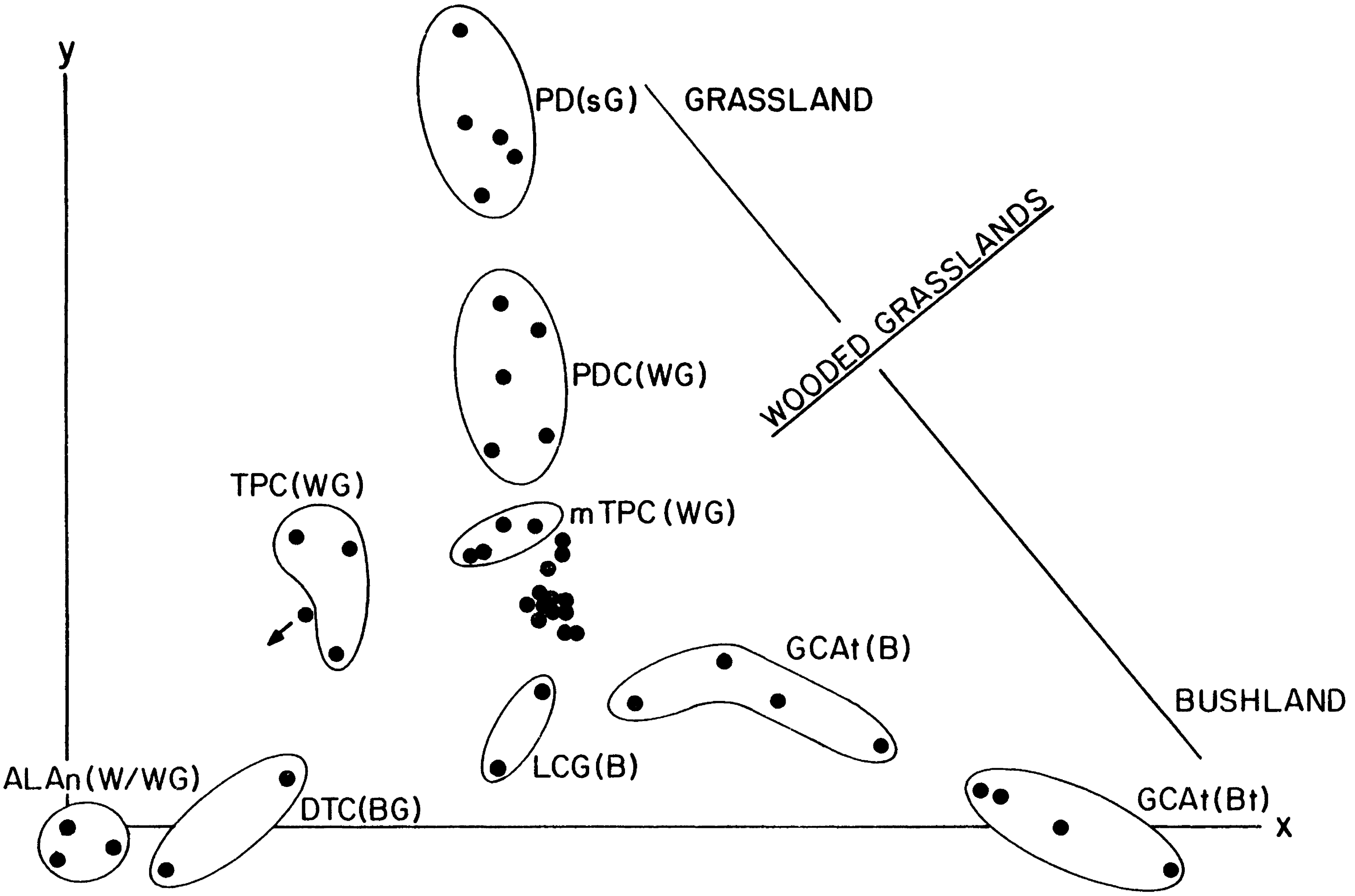

Fig. 6. Two dimensional ordination of 46 stands on free-draining soils (13 percent constancy, 73 species). See Table 3 for explanation of habitat codes.

In summary, ordination of different samples at varying constancy levels consistently showed the most distinct clusters occurring with habitats PD(sG) and GCAt (Bt) which represented the extremes along a grassland-bushland gradient (Fig. 6). Habitats PDC (WG) and GCAt (B) were the next most distinct habitats. A stratification of woodland and wooded grassland habitats was evident perpendicular to the grassland-bushland gradient. Along this gradient, an intermingling of stands in types ALAn (W/WG) and TPC (WG) was shown in several ordinations. While many of the more dominant species were common to the two types, there were important differences which were reflected less in botanical composition than environmental characteristics. Type ALAn was characterized by higher elevation, higher rainfall, greater forage production, greater topographical variation and attendant edaphic differences, and somewhat more subtle botanical differences. Thus the ordination technique, which is based only on floristic composition and assumes linearity, may not adequately reflect real environmental differences since species' distributions may be bell-shaped (Noy-Meir and Austin 1970, Swan 1970). Aside from this problem and the multi-habitat clustering discussed previously, placement of habitats in Figure 6 corresponded to an intuitive positioning of the habitats relative to one another.

Habitat Condition

Socially and economically acceptable courses of action must derive from an ecologically sound basis for realization of long term benefit from the range resource. Thus, an evaluation of condition must be based on criteria of environmental health i.e., are the functional aspects of a habitat intact? Denudation and attendant erosion are parameters related to these criteria. Evaluations of condition are also based on standards defined by socio-political objectives. For the study area with the emphasis on cattle and wild ungulate grazers, maximization of the grazing resource on a sustained yield basis is a logical objective, combining both socio-political and environmental objectives. The American Society of Range Management (1964) defines condition as "the state and health of the range based on what that range is naturally capable of producing." This implies that an assessment of condition must relate to a potential. In this case "potential" was inferred by comparing areas and stands located in the same habitat type but having different management histories, or by comparison of an area's vegetation with a reconstruction of its previous status. The assessment of habitat condition which follows focuses on habitats within the cattle belt, and is based on results of vegetative sampling and interviews with Maasai regarding habitat changes and forage suitability for cattle. A list of common grass species, their Maasai names and Maasai rated palatability is provided in Appendix Table 4.

The entire habitat type PD (sG) was subjected to quite heavy grazing pressure by both cattle and wild ungulates (wildebeest and zebra) in the wet season and primarily cattle in the dry season (Fig. 7). A former colonial range officer described the Simanjiro

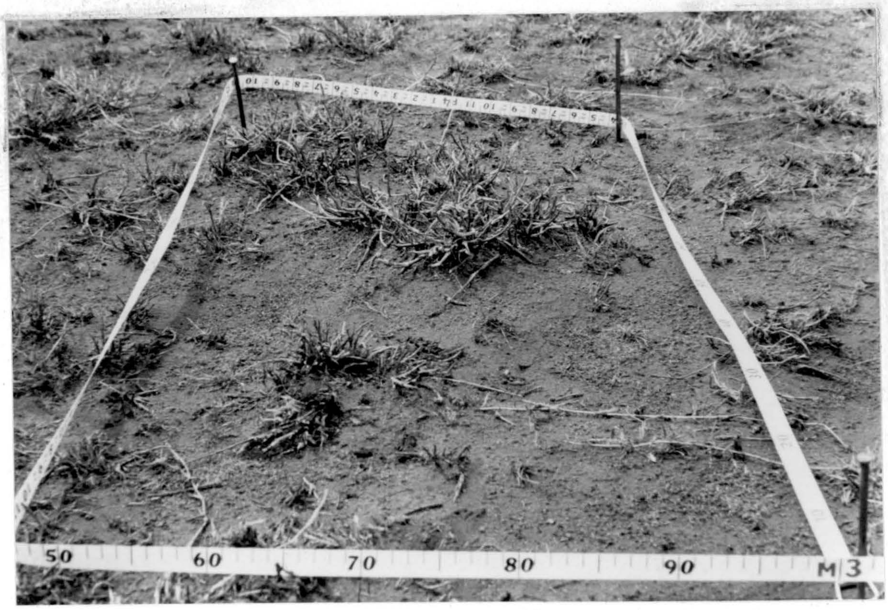

Fig. 7. Heavy grazing pressure on the Simanjiro plains, south Maasailand, habitat type PD (sG), dry season 1975.

plains in the 1940's as a sea of red oats grass (Frank Miller pers. communication). In the 8 sample stands, red oats grass (*Themeda triandra*) averaged less than 2% cover, suggesting a marked decrease. A relationship between maintenance of *Themeda* grassland and fire has been suggested (Pratt and Gwynne 1977:89, Lind and Morrison 1974:89). Since the two dams were built in the early 1950's, fire has been virtually excluded due to an increase in grazing pressure. Grazing pressure may also account for a decrease of *Themeda* as it was shown to be more susceptible than *Digitaria macroblephara* and *Pennisetum mezianum* to defoliation by clipping (Ndawula-Senyimba 1972). A decrease of *Themeda* which is of medium palatability (Appendix Table 4) is no great loss, particularly if the highly preferred short stoloniferous grasses (*Panicum coloratum*, *Digitaria macroblephara*) were favored as a result. The emergence of species such as *Microchloa kunthii* (Pratt and Gwynne 1977:62, Heady 1960), *Harpachne schimperi* and the thorny shrub *Barleria ramulosa* indicate that grazing pressure was beginning to have adverse effects. When Mzee Hassan first moved to the plains in 1938, the presently ubiquitous thorny seeds of *Tribulus terrestris* were nonexistent on the red soil areas. The sea of red oats grass has been replaced by periodic wet season blooms of the annual weed *Astripomoea hyoscyamoides* (Fig. 8). Mean perennial grass cover of the plains was 40%, ranging from 28 to 51% depending mainly on grazing pressure but also on position relative to drainage (moisture gradient). If as is generally accepted for most open country in East Africa, the

Fig. 8. Bloom of the annual weed Astripomoea hyoscyamoides on the Simanjiro plains, south Maasailand, habitat type PD (sG), wet season 1977. Same site as Fig. 7.

grassland was in the past fire induced and subsequently maintained by grazing, the continuation of present trends would suggest that a gradual return to woodland can be expected. Regenerating Acacia and Commiphora species were present on certain ridges and low hills, a trend also noted by Kahurananga (1976). Examination of soil characteristics to a depth of 2.5 m revealed no ostensible edaphic reasons for the grassland.

Habitat type PDC (WG) has a history of high grazing pressure by mixed cattle and wild ungulates in the wet season. Over half of the area was also grazed by cattle in the dry season. Mean perennial grass cover was 27%, ranging from 10% on stony (quartz) hillocks or areas of extreme grazing pressure to 55% on sites with a history of less cattle use. The presence of annual weeds averaging 15% cover, and the relatively low perennial grass cover overall indicated that condition was below the potential.

The degraded unit (dPDC (WG)) has, because of its proximity to permanent water in the Kitiangare, been adversely modified to an extreme by livestock. Mean perennial grass cover was a mere 5% with forb cover averaging 32%.

Habitat type 3 (Table 3) containing 3 main condition classes, provided insight into the effects of different management histories. Habitat TPC (WG) (Fig. 9) was characterized by low to medium grazing pressure by a mixture of cattle and wild ungulates (mainly zebra-wet, kongoni-dry). For 3 sites having a history of primarily cattle use, mean perennial grass cover was 27% compared to 57% for 5 exclu-

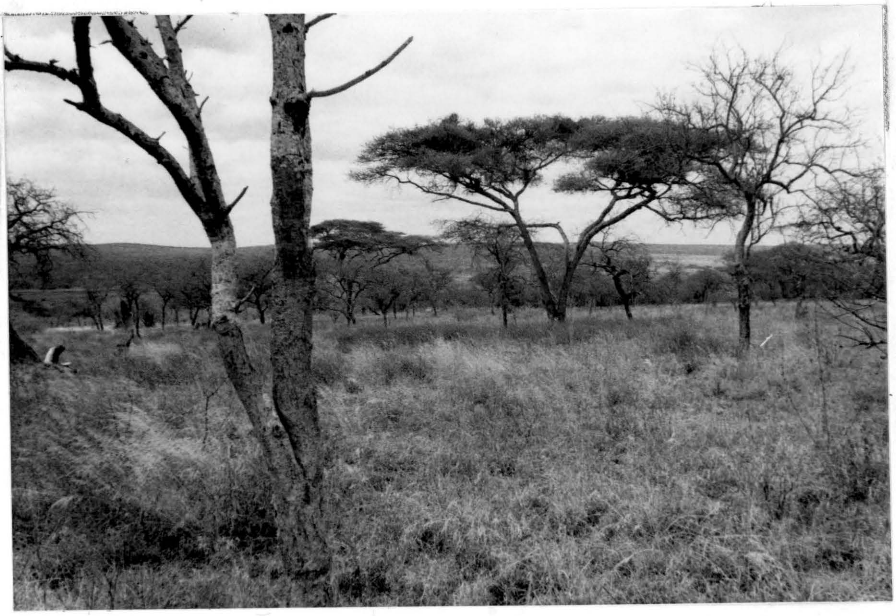

Fig. 9. Habitat TPC (WG), south Maasailand, 1977. This *Themeda-Panicum-Commiphora* wooded grassland habitat has a history of light grazing pressure by wild ungulates. Compare ground cover with Fig. 10.

sively wildlife sites.

A higher grazing pressure by cattle in the wet season differentiated habitat mTPC (WG) from the above habitat. This was reflected by a drop in mean perennial grass cover from 46% to 21%.

Habitat dAC (W/WG) (Fig. 10) was extremely degraded due to a history of intensive livestock use made possible by the large watering capacity of the river and the tsetse clearing scheme by the colonial government in the 1950's. Perennial grass cover averaged only 6% and regenerating Commiphora schimperi, Acacia tortilis and A. senegal dominated the overstory. A co-dominance of the former was reported in colonial records (Annual Report of the Tsetse Survey and Reclamation Department 1958), but no mention was made of Acacia senegal and its present dominance is probably attributable to disturbed conditions. A list of understory species and their present abundance relative to before the tsetse clearing was recorded from Maasai elders and is presented in Table 4. A comparison with Appendix Table 4 shows that the grasses which have decreased are all palatable, whereas those grasses which have increased are relatively unpalatable.

The effect of different management histories on bare ground and perennial grass cover in the preceding 3 habitats is shown in Fig. 11. With an increase in grazing pressure, bare ground increased while perennial grass cover decreased. Cattle are largely responsible for this trend because of greater numbers and a restriction in range rather than inherent feeding traits.

Fig. 10. Denuded Acacia-Commiphora (regenerating) wooded grassland, south Maasailand, 1977. Habitat dAC (W/WG) has a history of extreme grazing pressure by cattle. Compare ground cover with Fig. 9.

Table 4. Understory species and their abundance in 1977 relative to before the tsetse clearing (1950) at Loibor Sirret, south Maasailand, habitat dAC (W/WG).

Grasses which have decreased	Grasses which have increased	Forbs which have increased
Digitaria milanjiana	*Aristida adscensionsis*	*Tribulus terrestris*
*D. macroblephara**	*Chloris virgata*	*Solanum incanum*
*Panicum coloratum**	*Tragus berteronianus*	*Cassia mimosoides*
*Cenchrus ciliaris**	*Microchloa kunthii*	*Sericocomopsis hildebrantii*
*Themeda triandra**		
Chloris roxburghiana		
Eragrostis superba		
Sporobolus fimbriatus		
Cynodon nlemfuensis		
Setaria spp.		

*Formerly most abundant

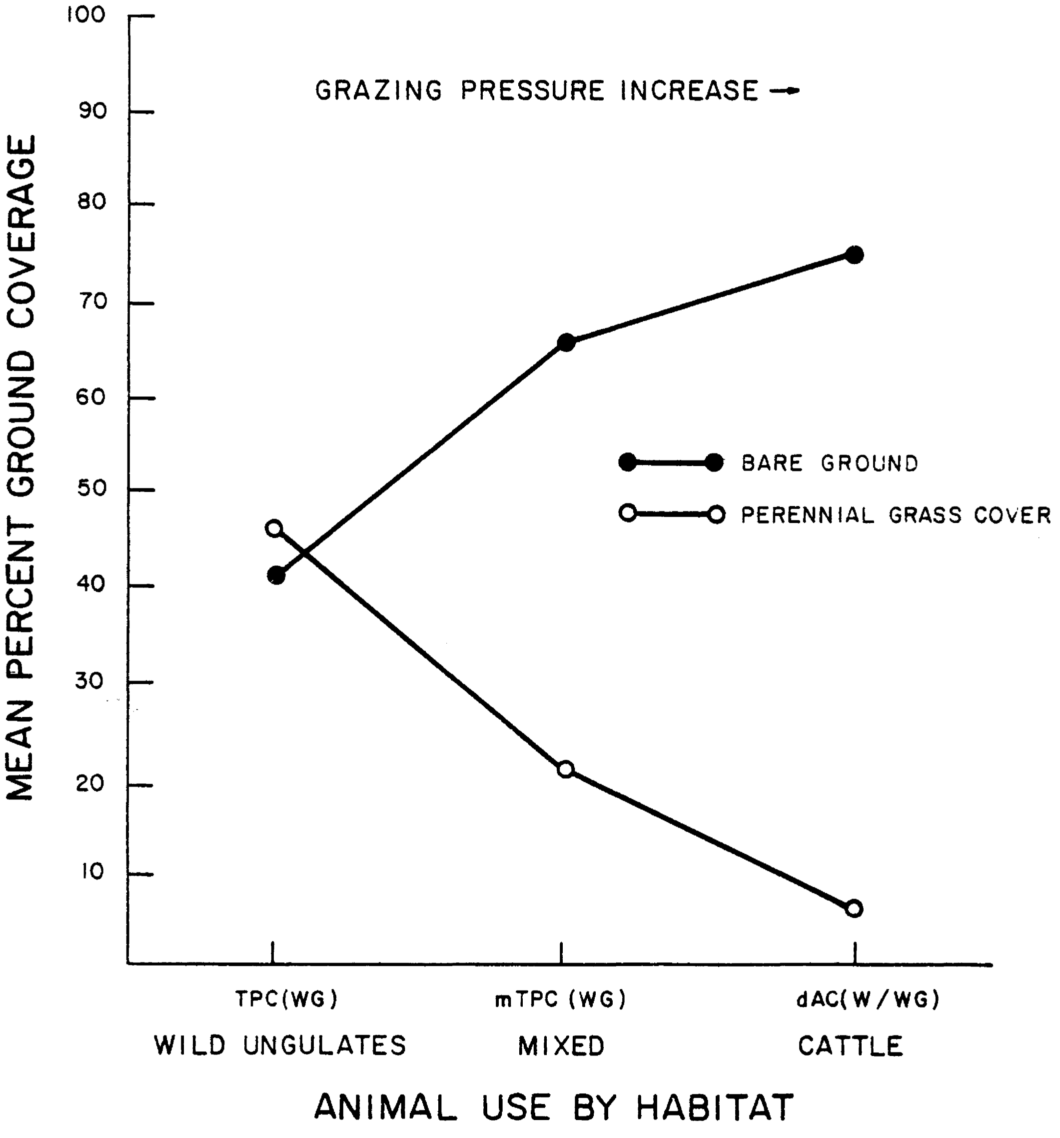

Fig. 11. Mean percentage of bare ground and perennial grass cover in 3 habitats of similar potential but with different animal use histories, south Maasailand, wet season 1977. See Fig. 26 for ungulate densities in these 3 habitats for the wet seasons 1975-76.

The *Aristida* - *Commiphora* wooded grassland type was of low potential because of soil characteristics and rather low rainfall compared to the former types. Wild ungulate and cattle use was consequently minimal. On a site with low grazing pressure by wild ungulates (oryx, kongoni), herb cover was 70% of which about 20% was perennial cover (*Themeda* - *Dicanthium*) with the annual grass *Aristida adscensionsis* comprising most of the remaining cover. On a cattle site with higher grazing pressure, herb cover dropped to 28% (*Aristida*) and there was almost a total loss of perennials.

Habitat type ALAn (W/WG) is at the highest elevation and received the most precipitation as reflected by the presence of semi-deciduous trees and a taller grass component. Ground cover averaged 60%, the bulk of which was perennial grass. Rough terrain, few ephemeral water pools and taller less palatable grasses (*Cymbopogon excavatus*) probably contributed to light use by wild grazers. Higher disease risk than in previous areas and low capacity permanent water sources helped to maintain an equilibrium between domestic grazer impact, fire, and succession.

In all of the preceding habitat types, fire has been instrumental in either inducing or maintaining the open nature of the vegetation. The thicker bushland habitat (Fig. 12) was restricted to the lower elevations where rainfall was scantier and more strictly seasonal. Woody species were favored as forage production was generally insufficient to allow for fires of the intensity required to check the forces of succession. In openings, annual grasses dominated regardless of grazing pressure. However, under

Fig. 12. *Grewia-Commiphora-Acacia tortilis* bushland, habitat type GCAt (B), south Maasailand, dry season 1977.

high grazing pressure the usual *Urochloa* cover was often replaced by species such as *Tragus berteronianus* and the forb *Tribulus terrestris*, and perennial grasses (*Themeda*, *Chloris roxburghiana*, *Enteropogon macrostachyus*, *Panicum maximum*) were readily lost. Cattle were observed browsing in bushland, and Maasai from these habitats asserted that during times of stress, browse was a common constituent of cattle diet.

Habitat types 12, 13 and 14 (Table 3) were influenced more by edaphic and drainage factors than by the prevailing climatic regime. The effects of subtle environmental differences (alkalinity/salinity and drainage) within the units were difficult to separate from effects of grazing and fire, and hence make an evaluation of condition questionable. Furthermore, the grass component in habitats PDCAm (G/BHG) and Pm (G) was dominated by *Pennisetum mezianum*, an unpalatable species particularly in later growth stages. Invasion of this grassland by herbaceous species was thus not necessarily negative since many of these species were readily eaten by livestock and erosion in these low lying areas was insignificant.

The grass *Sporobolus helvolus* dominated type Sh (G) on saline soils and was the primary dry season forage of cattle in that area (Fig. 13). Using the step-point procedure, transects were run in cattle areas for comparison with less utilized areas in the Park. Near the end of the dry season, mean bare ground in the park was 56% (6 transects) compared to 87% (10 transects) in the cattle area. Grass height averaged 45 cm in the park compared to 3 cm

Fig. 13. Cattle on closely cropped Sporobolus helvolus grassland during the dry season, habitat type Sh (G), south Maasailand, 1977. The taller grass Sporobolus consimilis is considered to be a salt indicator (Lind and Morrison 1974:174).

in the cattle area. Cattle lost condition and some cattle owners resorted to incursions into the Park. This was despite underutilized mature Pennisetum mezianum grassland within grazing distance. By the end of the next growing season, cover and grass height between the two areas was visually similar, indicating a high tolerance to grazing by Sporobolus helvolus (stoloniferous). Despite shortages of forage, it appeared that these 'edaphic' habitats were more tolerant of high grazing pressure than habitats on free-draining soils.

In summary, observations during the period of study and information from Maasai confirm that a dry season shortage of forage was the rule rather than the exception. In years of extreme drought (1960-61) mortality is high, whereas in normal years only a few cattle die but most lose "condition". This imbalance between grazers and forage is reflected in adverse trends environmentally as well as in terms of the grazing resource. Comparison of habitat parameters in areas of similar potential but different management history indicated that the condition of over half of the cattle belt (that area to which cattle are restricted primarily by disease and water constraints) was below potential. While use by wild ungulate grazers has contributed to the condition, it is chiefly attributable to cattle because of their greater numbers and restricted distribution.

Soil Analysis

Samples of a red clay loam soil of habitat PD (sG), a red loam of habitat dAC (W/WG), a brown sandy loam of habitat GCAt (B/Bt) and a heavy black clay of habitat Pm(G) were sent to Lyamungu for analysis. All four soils contained adequate nitrogen, were high in potassium and low in phosphorus. The organic matter content of the sandy loam (bushland) and the heavy clay was low (low organic pool of P), indicating that phosphorus may be limiting. These soils had a high pH (7.8-9.2), whereas the pH of the red clay loam and red loam soils was just below neutral.

Grass Analysis

Leaf samples from 8 grass species were analyzed for nutrient composition and gross energy at Virginia Polytechnic Institute and State University. The samples were collected during February and March when the grasses were in the head-emergence to early-bloom growth stage. The results of proximate analysis showed that crude protein levels for grasses dominating the short grassland and wooded grassland (*Panicum coloratum*: 20.9%, *Digitaria macroblephara*: 18.8%) were higher than those for the dominant grass (*Themeda triandra*: 9.5%) in the taller grass wooded habitats. Protein levels for grasses commonly associated with *Themeda* were low for *Dicanthium radicum* (11%) and *Chloris roxburghiana* (12%), and high for *Digitaria milanjiana* (17.6%). *Sporobolus helvolus*, which dominated the medium height edaphic grassland, was relatively high in protein (15.5%), whereas *Urochloa mossambicensis* in the bushland was low (10.1%).

Gross energy varied little among the grasses with a mean of 4592 (range from 4265 to 4932) calories per gram. Similarly, the mean percentage of total nonstructural carbohydrates (TNC) was 16.0%, ranging from 14.7% to 19.0%.

Percent calcium diverged little among all grasses (mean = 0.29%, range 0.25% - 0.39%) except for *Urochloa mossambicensis* (0.7%). Calcium:phosphorus ratios ranged from 0.80 to 1.62 (mean = 1.20) in the former grasses and was noticeably higher (4.03) for *Urochloa*.

Tsetse Fly Distribution in Relation to Cattle Concentration Areas

The distribution of tsetse flies was of importance to this study because tsetse are the intermediate hosts for several trypanosomes (*Trypanosoma*) which are pathogenic to man and domestic livestock. The trypanosomes are flagellate Protozoa responsible for diseases known collectively as trypanosomiasis, including sleeping sickness in man, and nagana in cattle. Having evolved with the trypanosomes, wild ungulates have acquired an immunity. Consequently, their distributions are little affected by the presence of tsetse. Cattle distribution is directly affected by tsetse fly abundance and cattle numbers are indirectly affected by wild ungulates who act as reservoirs of the pathogens.

Out of 132 tsetse caught at random while driving through the area, 85 were *Glossina swynnertonii*, 30 were *G. morsitans* and 17 were *G. pallidipes*. Based on these identifications, *G. swynnertonii* and *G. morsitans* distributions wre overlapping and widespread while *G. pallidipes* was restricted to thick bushland habitat and riverine thickets. Tsetse were rarely found in the 'edaphic' habitats on seasonally waterlogged soils and were absent from grassland and open wooded grassland on free-draining soils. Absence from these open habitats is most likely due to a lack of suitable shade for adult resting sites and dessication of puparia exposed to sun and heat. These factors combined with a greater dispersion and abundance of hosts, probably account for the increase of tsetse in both number and area during the wet season.

In Fig. 14 the cattle belt is depicted in relation to tsetse infestation during the dry season. Permanent water sources and the location of settlements surrounding them are shown to illustrate the foci of cattle concentration during this season. The mean distance from settlement to water source was 5.5 km (n=67). The maximum distance observed was 13.75 km. The normal dry season grazing pattern revolved around the practice of watering the cattle every second day. On one day the cattle were driven to water in the morning and grazed in the afternoon up to a distance of a few kilometers on the side of the settlement opposite the water source. On the alternate day they were herded in the same general direction up to a distance of 13 km from the settlement. This dry season pattern of grazing is a well established practice as indicated by the fact that the Maasai have a word for the day the cattle go without water (Aruni), the day they go to water (Okoree) and the day they go to water but find none (Kitalengare).

While cattle were grazed throughout the cattle belt in the wet season, grazing patterns and/or settlement locations were altered to conserve forage for the dry season and to allow for greater use of areas at the perimeter which were relatively inaccessible during

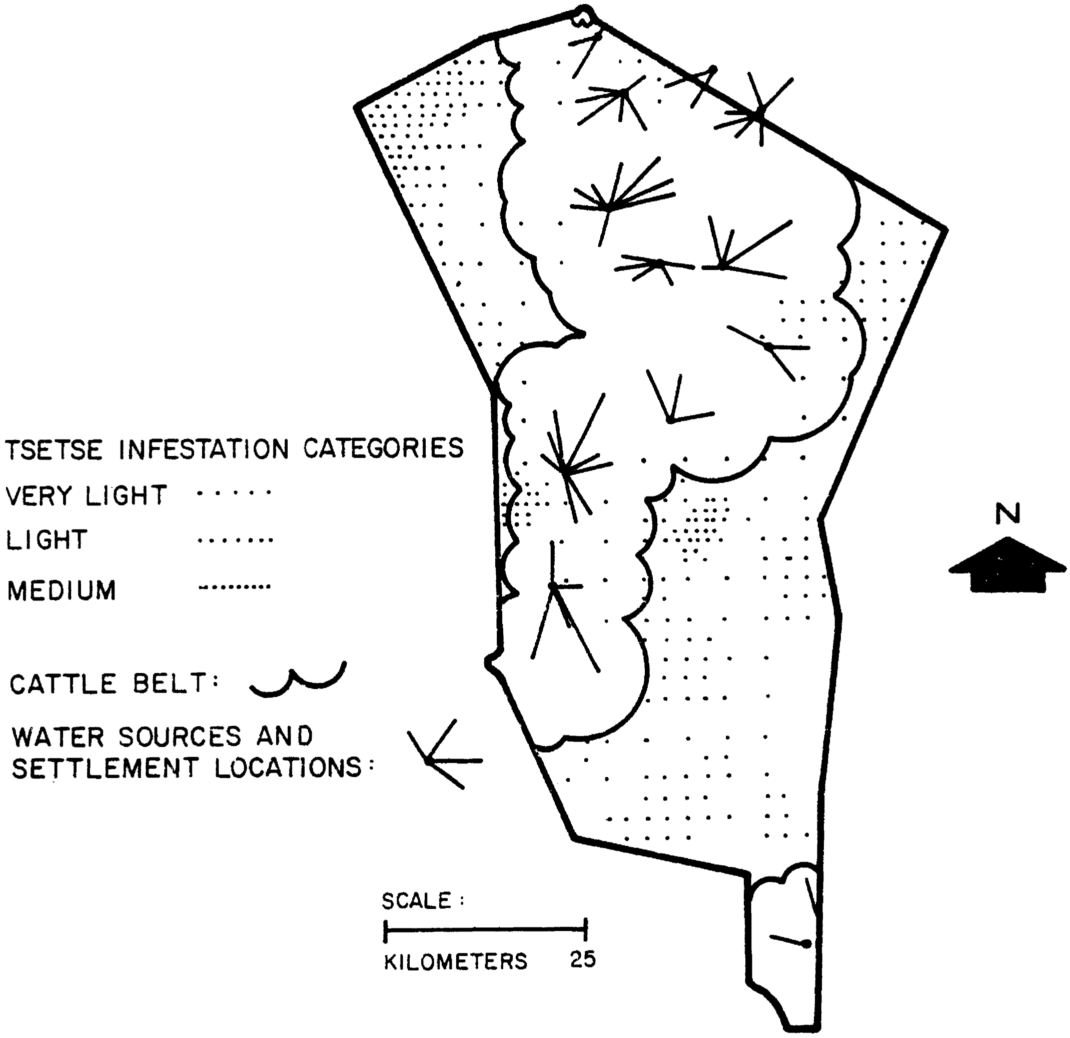

Fig. 14. Cattle concentration areas in relation to tsetse distribution, dry season 1975, in the study area, south Maasailand. See Table 1 for definition of tsetse infestation categories.

the dry season. These concentration areas and their relation to wet season tsetse distribution are shown in Fig. 15. As discussed in an earlier report (Peterson 1975), cattle grazing patterns were also affected in January and February on a localized scale, by Maasai avoidance of wildebeest calving areas and the associated risk of malignant catarrhal fever.

In summary, both the dry and wet season cattle concentration areas were relatively tsetse free (Figs. 14 and 15). This suggests that tsetse infestation was one of the main factors restricting the distribution of cattle within this area of Maasailand.

Cattle and Wild Ungulate Distributions - Dry Season

Data are presented from counts of wild ungulates and cattle at 6 permanent water sources. Sources excluded are those from which wild ungulates were absent or limited in number due to the nature of the source (accessibility/capacity) or a history of harrassment by humans. Dry season population estimates derived from actual and track counts at all permanent water sources are presented for water-dependent wild ungulates in Appendix Table 5. Kongoni are not included among these estimates because, while they did drink if water was available, they were more often found in habitats without water. They are, however, included in the data for the 6 water sources since the objective was to illustrate the relative abundance of wild ungulates in relation to cattle rather than absolute numbers. Water independent species were not counted because of the method employed, but their presence/absence in the surrounding habitats was

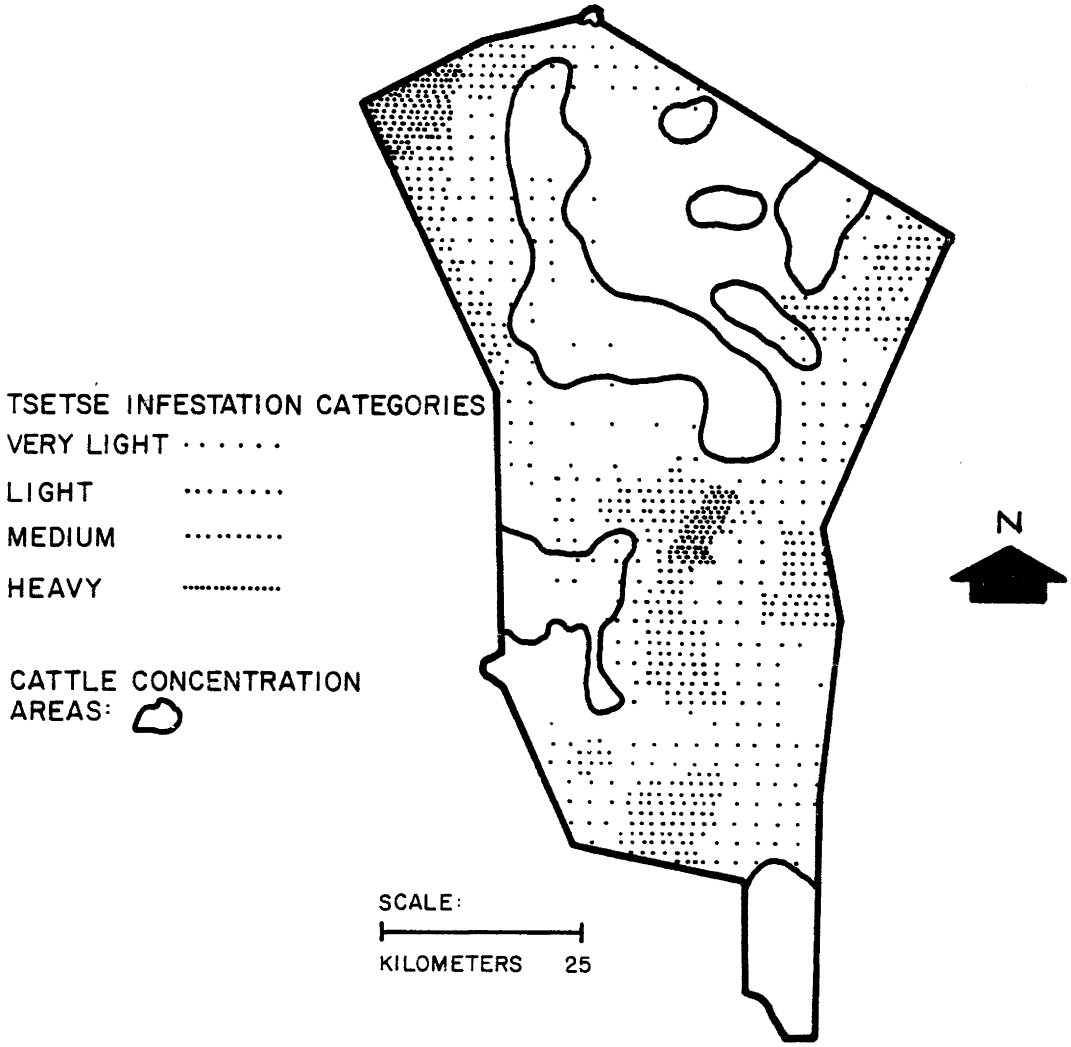

Fig. 15. Cattle concentration areas in relation to tsetse distribution, wet seasons 1975-76, in the study area, south Maasailand. See Table 1 for definition of tsetse infestation categories.

recorded.

On the basis of observations by the author and information from the literature (Dorst and Dandelot 1969, Pratt and Gwynne 1977:226-236), wild ungulates for which the counts were reliable are grouped into 2 broad qualitative food-habit categories. Elephant (Pratt and Gwynne 1977:227) and eland (Hofmann 1973:267) are generally considered to be mixed-feeders whose diets vary with seasonal and regional resource availability. These two species, along with rhino, are categorized as browsers. A switch by eland from grass in the wet season to browse in the dry season was reported by Field (1975). Buffalo (Lamprey 1963, Sinclair 1977:76), wildebeest and zebra (Gwynne and Bell 1968, Owaga 1975) and kongoni (Casebeer and Koss 1970, Gosling 1973) are almost exclusively grass eaters.

The numbers and biomass of these 2 groups of ungulates were compared with those of cattle, which are primarily grazers. The aim was to indicate some possible interactive effects among wild ungulate browsers, grazers, and cattle based on their relative abundance at different water sources during this time when forage and water resources were most limited and when theoretically, interspecific competition should be greatest. Since the surrounding habitat and the type of water source influenced the relative degree of use, those sources which were most similar in terms of these factors were paired for comparison of animal numbers and biomass (Fig. 16). A 10 km radius was chosen for comparison of the habitats circumscribing the respective water sources. Western (1975) found

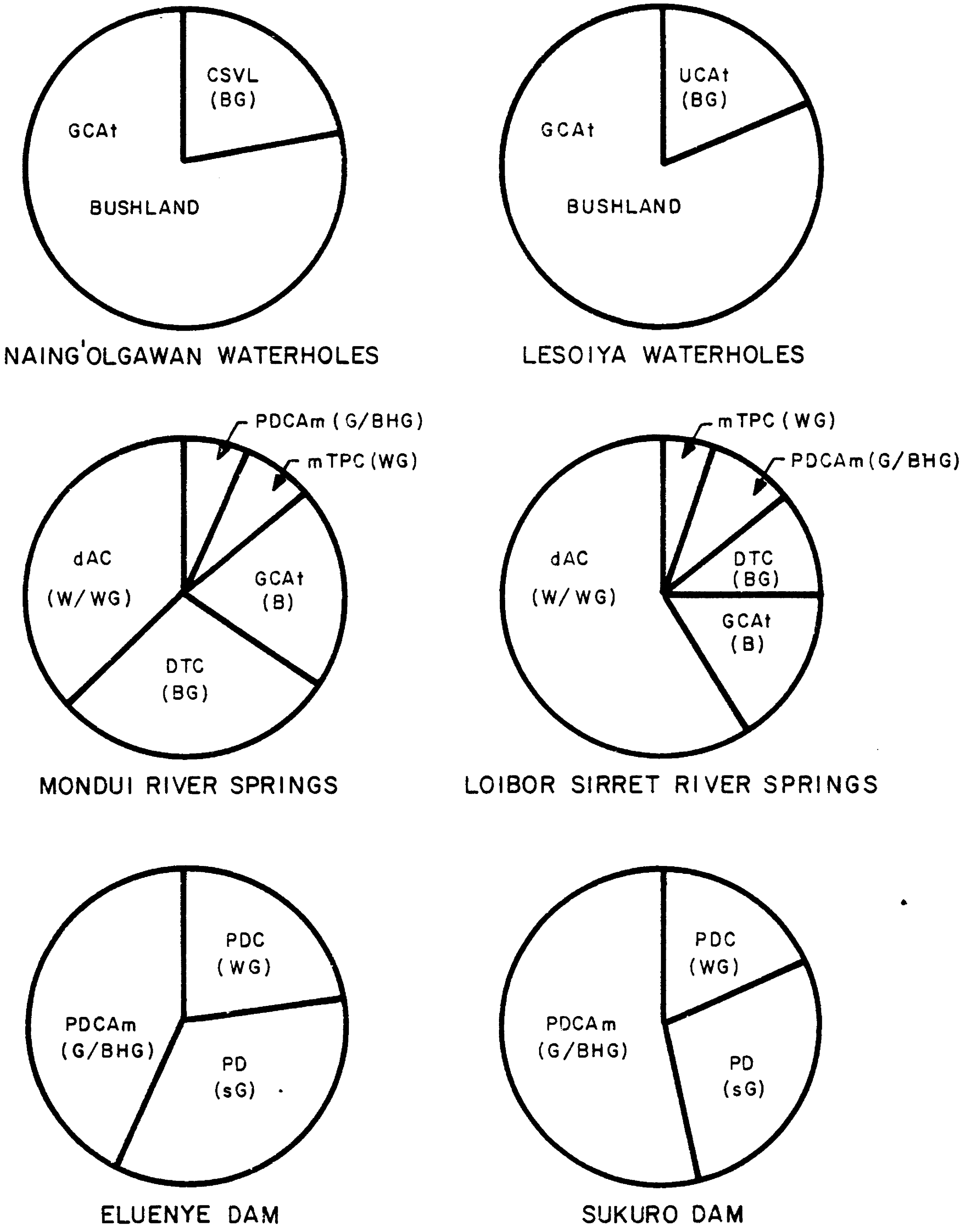

Fig. 16. Percentage of habitats within a 10 km radius of 6 dry season water sources, south Maasailand, 1975. See Table 3 for explanation of habitat codes.

that a 10 km profile around permanent water in Amboseli enclosed 88% of the water-bound domestic and wild herbivore biomass. The number and species of wild ungulates contributing to the grazer and browser categories for each of the water sources is shown in Table 5. Mean weights used to calculate biomass and the sources from which they were obtained are given in Table 6. Cattle numbers were obtained by multiplying the number of settlements using a water source by a mean of 373 cattle per settlement (n = 32).

At both waterholes (Fig. 17), cattle dominated numerically both over wild ungulate browsers and grazers in that order. Comparison of the 2 waterholes shows that a decrease in cattle numbers from 2,238 to 746 (67%) corresponded to an increase in the number of wild grazers from 12 to 262 (2100%) and a relatively smaller increase of wild browsers from 304 to 586 (93%). Regarding biomass, the relative position changed so that wild ungulate browsers dominated over cattle followed by wild grazers. The high biomass of wild browsers was a function of the surrounding bushland habitat and consequent preponderance of elephant. A 67% decrease in cattle biomass corresponded to a 33-fold increase in wild grazer biomass and an 89% increase in wild browser biomass.

Among the wild ungulates counted, 12 old buffalo bulls were the only grazers represented at Naing'olgawan where cattle numbers and biomass were high, especially considering the type of (bushland) habitat. At Lesoiya, where cattle numbers and biomass dropped, buffalo increased to 205 and zebra (50) and kongoni (7) were also

Table 5. Numbers and species of wild ungulate grazers and browsers at 6 water sources, south Maasailand, dry season 1975.

Water source	Grazing species	(n)	Browsing species	(n)
Naing'olgawan waterholes	Buffalo	(12)	Elephant Rhino Eland	(287) (2) (15)
Lesoiya waterholes	Buffalo Zebra Kongoni	(205) (50) (7)	Elephant Rhino Eland	(540) (7) (39)
Loibor Sirret river springs	Buffalo Zebra	(131) (39)	Elephant Rhino	(127) (16)
Mondui river springs	Buffalo Zebra Kongoni	(453) (41) (47)	Elephant Rhino Eland	(53) (7) (89)
Eluenye dam			Elephant	(8)
Sukuro dam	Wildebeest Zebra	(65) (7)	Elephant	(11)

Table 6. Mean weights used in ungulate biomass calculations.

Species	Mean weight (kg)	Authority
Elephant	3000	Western (1975)
Rhino	999	Foster and Coe (1968)
Buffalo	499	Foster and Coe (1968)
Eland	363	Foster and Coe (1968)
Cattle	277	Foster and Coe (1968)
Zebra	238	Foster and Coe (1968)
Wildebeest	166	Foster and Coe (1968)
Kongoni	136	Foster and Coe (1968)

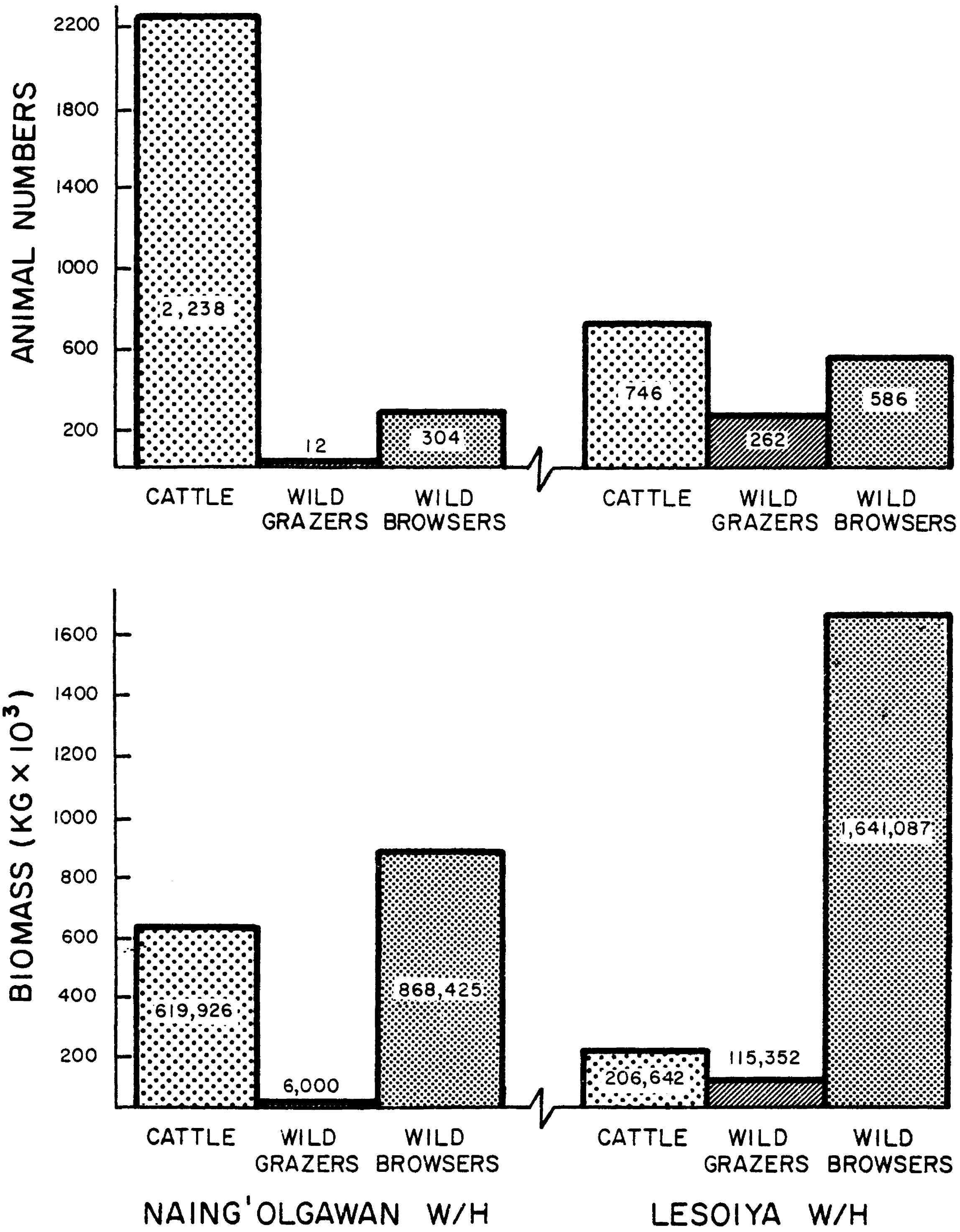

Fig. 17. Comparison of numbers and biomass of cattle and wild ungulates drinking at 2 waterholes surrounded by similar habitat, south Maasailand, dry season 1975.

represented among the grazers (Table 5). Species not counted but recorded in both areas included impala, giraffe, greater kudu, lesser kudu, warthog, bushduiker, and dik-dik. The only grazer among these is warthog whose presence at Naingolgawan was probably attributable to its preference for very short grass (Eltringham 1974). Another grazer, oryx, occurred only in the vicinity of Lesoiya. The counts and presence/absence records suggest that the greater abundance of cattle at Naingolgawan resulted in near exclusion of wild ungulate grazers with relatively minimal effect on wild browsers.

Information collected at the two river springs (Fig. 18) shows that the large number of cattle at Loibor Sirret compared to none at Mondui corresponded to an increase in number of wild grazers from 170 to 541 (218%) and a negligible increase in the number of wild browsers from 143 to 149. Wild grazer biomass similarly increased by 224% but wild browser biomass decreased by 50% largely because of the greater proportion of elephant among the browsers at Loibor Sirret. Observations indicated that wild grazers drinking at Loibor Sirret primarily utilized habitat in the Park where cattle were excluded by law and the presence of tsetse. Were it not for this habitat within reach of the river (9 km), wild grazers would probably be even more poorly represented than the counts show. While the higher biomass of browsers at Loibor Sirret may partially be due to the above, it is also indicative of the greater compatability of wild browsers and cattle.

Kongoni occupancy showed a similar relationship to cattle

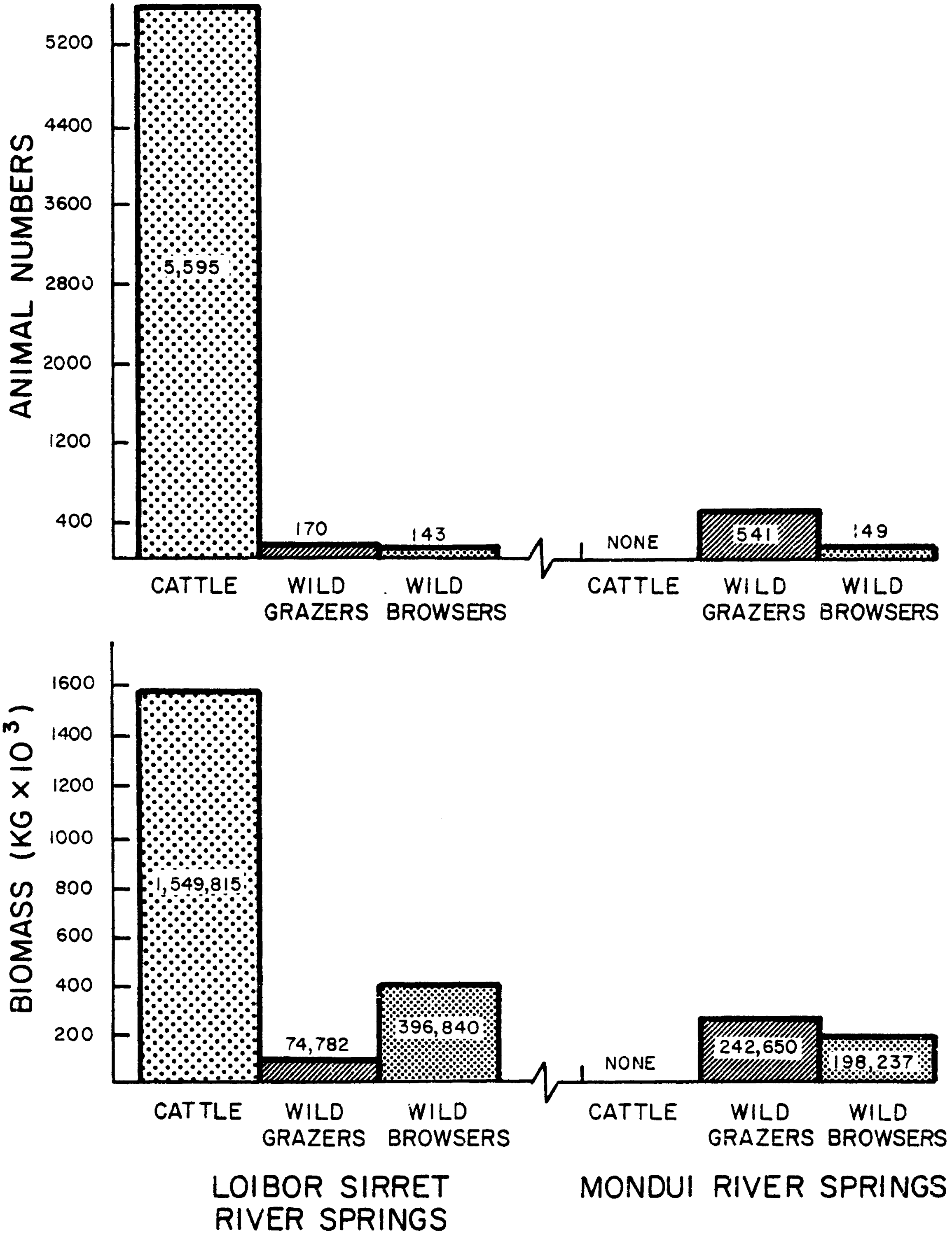

Fig. 18. Comparison of numbers and biomass of cattle and wild ungulates drinking at 2 river springs surrounded by similar habitat, south Maasailand, dry season, 1975.

abundance as at the waterholes. Their presence at Mondui but absence from the cattle area at Loibor Sirret suggests that they were one of the wild grazers least compatible with cattle. Among the species not counted, giraffe, impala, greater kudu, lesser kudu, warthog and dik-dik were common to both areas. As was the case in the waterhole habitats, these species appeared to be much less affected by cattle abundance than wild grazers. Grant's gazelle were recorded more frequently at Loibor Sirret, supporting the view that their preferred foods are those plant species which invade or dominate abused and overgrazed lands (Talbot and Talbot 1962).

The results of the counts at the river springs show a greater number of wild ungulate grazers where cattle were absent than where they were abundant. The reverse was true for wild browsers for which competition with cattle was apparently minimal because of ecological separation effected by broad food habitat differences.

Both dams (Fig. 19) had a very large number of cattle drinking at them which precludes comparison of one against the other to indicate possible effects of cattle abundance on wild ungulate representation. However, at each dam the large number of cattle corresponded to similar representation by wild ungulates. There was no wild grazer biomass at Eluenye and only 0.4% that of cattle at Sukuro. For both dams wild grazers were represented by a total of 65 wildebeest and 7 zebra, a sharp contrast to the total of 21,000 cattle and the thousands of wildebeest and zebra found in the same areas during the wet season (Kahurananga 1976 and this

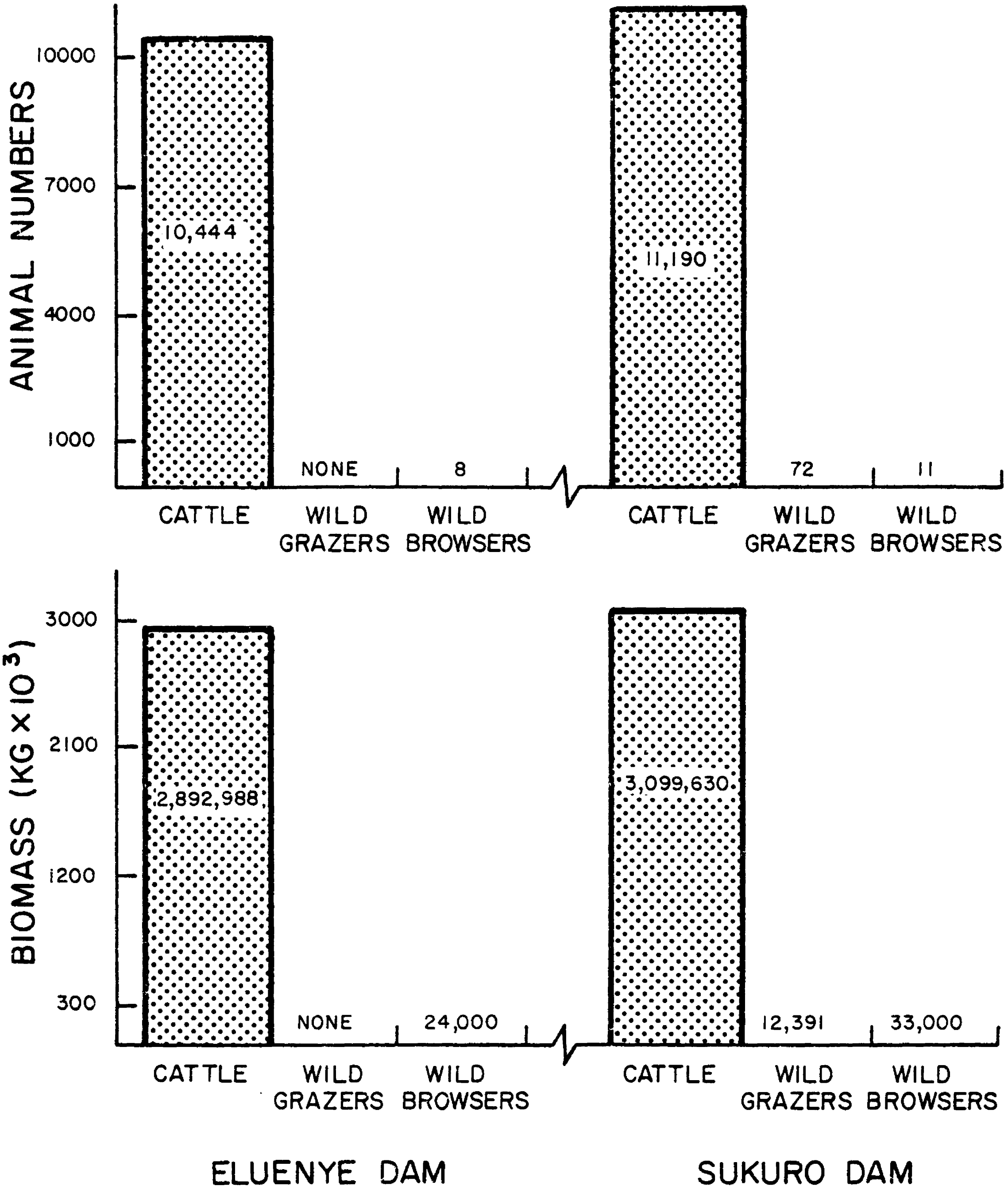

Fig. 19. Comparison of numbers and biomass of cattle and wild ungulates drinking at 2 dams surrounded by similar habitat, south Maasailand, dry season 1975.

study). A family group of elephant at each dam represented the only water-dependent browsers recorded. The low number of browsers was more a reflection of the surrounding short grassland and seasonally waterlogged habitats (Fig. 16) than the large number of cattle. Species not counted which were common to both areas, and apparently less affected by high cattle numbers, included giraffe, Grant's gazelle and a smaller number of impala and Thomson's gazelle.

Counts at the two dams surrounded by mainly 'grazer' habitat showed that the large cattle numbers in the dry season corresponded to almost negligible representation by wild grazing ungulates. The contrasting high occupancy by wild grazers in the same area during the wet season, when resources were abundant, suggests that resource competition between cattle and wild grazers was occurring in the dry season with cattle outcompeting the wild grazers.

In summary, there was a considerable numerical preponderance of cattle where they occurred together with wild ungulates. This was also true with regard to biomass except at the waterholes surrounded by bushland habitat where elephant were well represented. The largest number and greatest biomass of wild grazers occurred at Mondui river springs where cattle were excluded because of tsetse. However, even at Mondui the number (541) and biomass (242,650 kg) of wild grazers was only 10 and 16 percent, respectively of the number (5,595) and biomass (1,549,815 kg) of cattle drinking at Loibor Sirret which was surrounded by similar habitat (Fig. 18).

While the relatively low number and biomass of wild grazers in this case may have been partially due to a limited watering capacity and human harrassment at Mondui, the comparison is indicative of the greater tendency for cattle to occur in large concentrations (high densities). Some consequences of this on habitat condition and wild ungulate distributions have been presented.

The proportional biomass of cattle, wild browsers and wild grazers is presented in Fig. 20 for all 6 water sources. Cattle biomass comprised 70%, wild browser biomass 26% and wild grazer biomass 4% of the total. The majority of water-dependent wild ungulates were included in this calculation, but cattle drinking at 6 major water sources (from which wild ungulates were absent or limited) were excluded. Thus, for the area as a whole, cattle biomass would make up an even greater proportion of the total than depicted in Fig. 20. The point is first, that cattle overwhelmingly dominated wild ungulates in number and biomass during the dry season. Second, wild browsing ungulates were better represented than wild grazers. Based on counts at the few water sources at which comparisons were possible (Figs. 17 and 18), cattle abundance was inversely related to wild grazer abundance (Fig. 21). The results suggested that competition, as reflected by distributional displacement, occurred between cattle and wild ungulate grazers whose food habits most closely overlapped those of cattle. Cattle, apparently because of their greater numbers and their owners' directive influence, outcompeted wild grazers during this season of limited

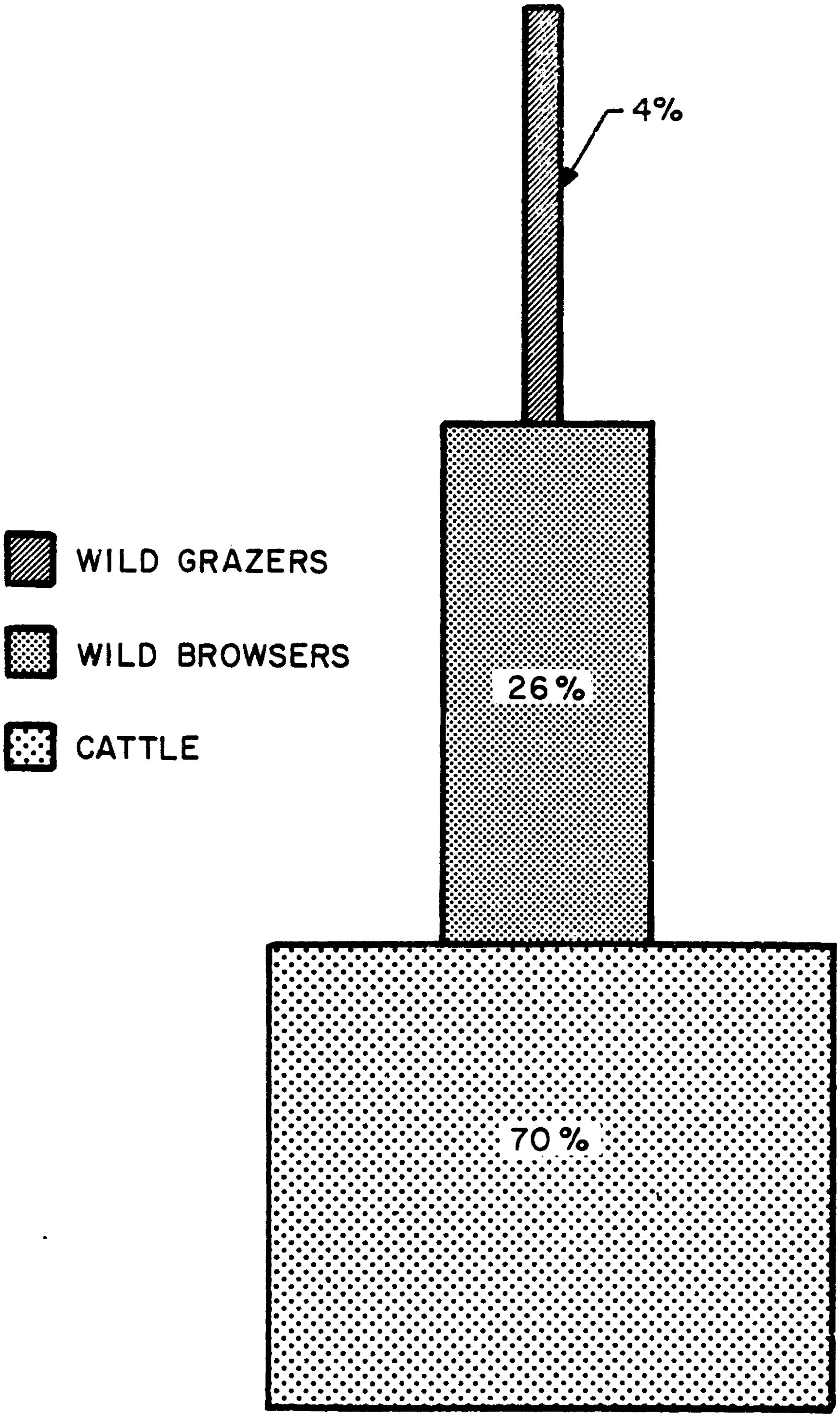

Fig. 20. Proportional biomass of cattle and wild ungulate browsers and grazers drinking at 6 water sources, south Maasailand, dry season 1975.

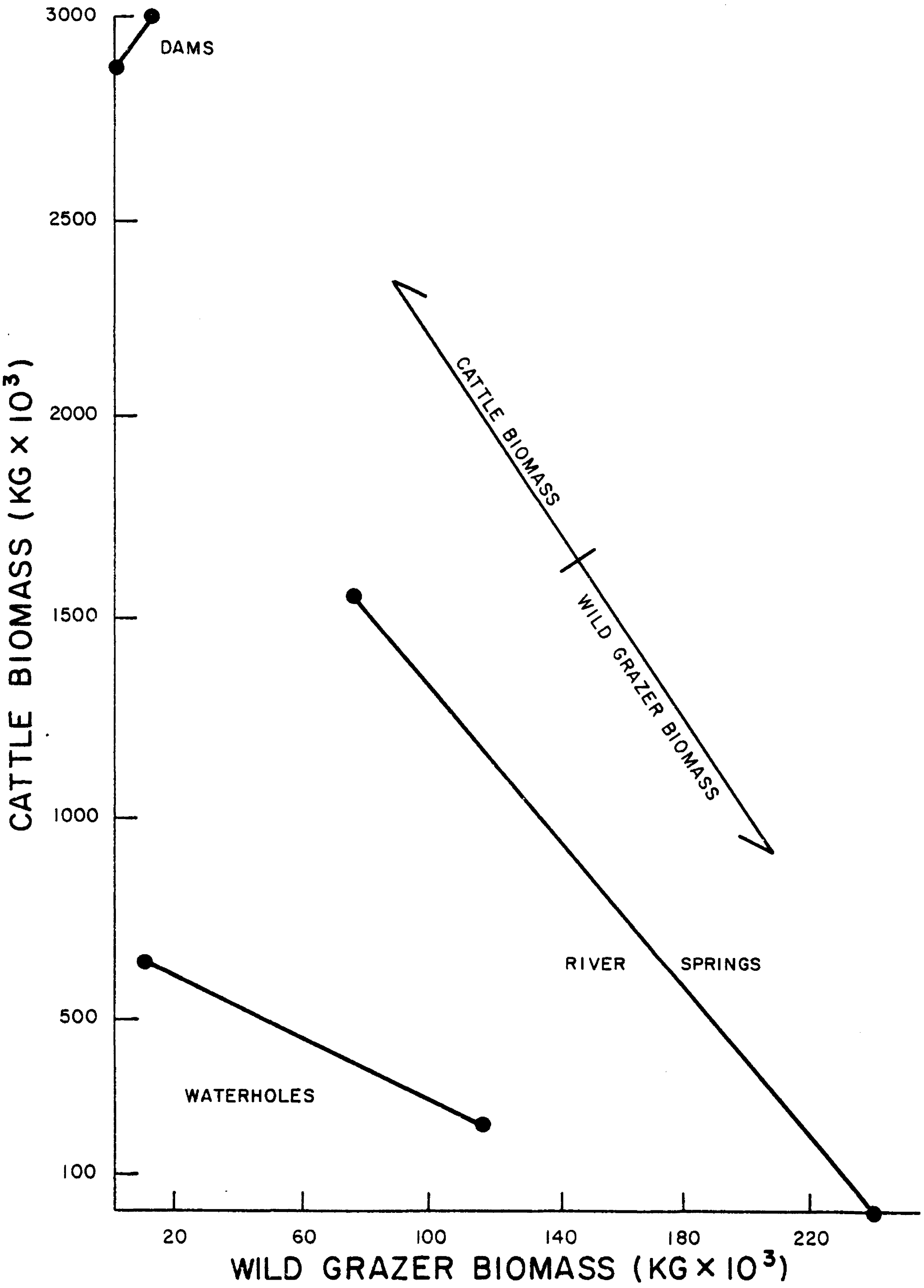

Fig. 21. Cattle biomass plotted against wild grazer biomass at 6 water sources, south Maasailand, dry season 1975.

resources.

Cattle and Wild Ungulate Distributions - Wet Season

Ungulate densities were calculated as the total number of a species recorded for a habitat, divided by the distance (km) traversed in that habitat, and the quotient was multiplied by an adjustment factor based on mean visibility in the habitat. Adjustment factors ranged from 1 in grassland where mean visibility was 500 m to 5 in bushland with a mean visibility of 100 m. Since values for all habitats were standardized to grassland with a mean visibility of 500 m, the resultant densities are number of animals per km^2. The total numbers of animals recorded along the transects are given by species and habitat in Appendix Table 6. Distances traversed and adjustment factors for each habitat are presented in Appendix Table 7 and the resultant ungulate densities by species and habitat are shown in Appendix Table 8.

Densities of cattle and 7 wild ungulates, by habitat, are shown in Fig. 22. Habitats are excluded which were small in area (less than 60 km^2) and for which distances traversed along transects were short. Habitat type PDCAm (G/BHG) is subdivided because of the observed effect of differential habitat size on occupancy by some ungulate species. The first subdivision (a) is comprised of small units interspersed among other habitats, whereas the second (b) is one larger continuous area (218 km^2).

Assuming that the mixed feeders, eland, impala, Grant's gazelle (Field 1975, Hofmann 1973) were primarily grazing during

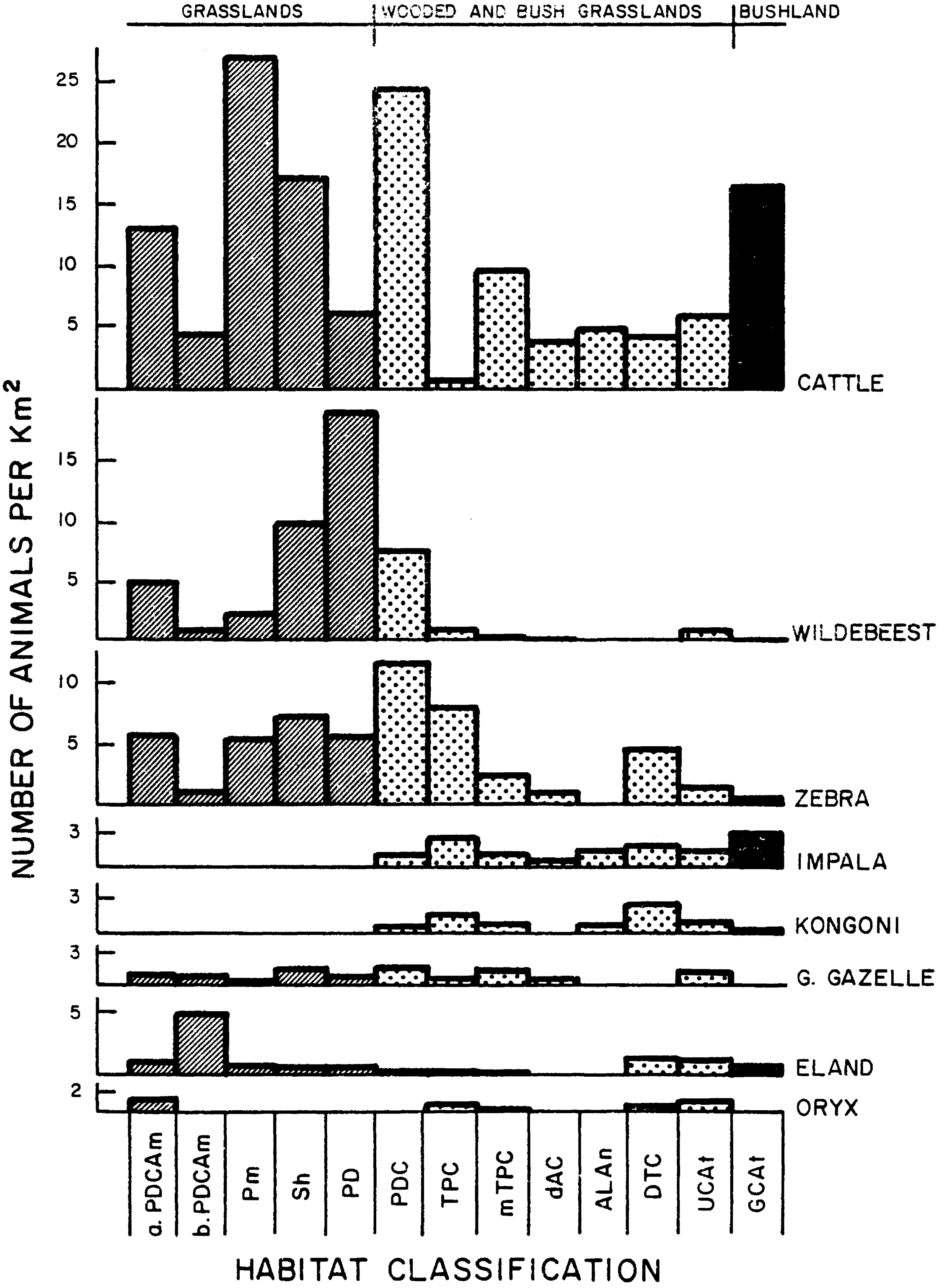

Fig. 22. Densities of cattle and 7 wild ungulates by habitat, wet seasons, 1975-76, south Maasailand. See Table 3 for explanation of habitat codes.

the wet season, the 7 wild ungulates include all the important grazers except buffalo. The latter are not included because of their sensitivity to human interference and secretive behavior which precluded reliable observation along the transects. Based on the few actual sightings and on observations of spoor, buffalo were almost exclusively restricted to the bushland (GCAt) habitat away from the intensively grazed cattle belt. Hence, they were less important than the other species in terms of potential forage competition with cattle.

Habitat Overlap

A partitioning of the species by degree of habitat specificity is evident in Fig. 22. As would be expected because of human influence and their relatively recent arrival on an evolutionary time scale, cattle were generalists occupying the entire spectrum of habitats. Thus, habitat overlap between cattle and wild ungulates occurred to a large extent with all species but was greatest with zebra and least with oryx. Zebra were the most numerous wild ungulate and displayed the broadest habitat utilization, whereas oryx were the least numerous and exhibited the greatest degree of habitat specialization. Cattle, wildebeest, zebra and Grant's gazelle densities were weighted toward the grassland and more open vegetation, in contrast to impala and kongoni densities which showed overlap in the more thickly wooded and bush grassland habitats. Eland and oryx occurred at both ends of the physiognomically defined gradient from open to thick habitat and were somewhat intermediate to the above.

Wild ungulates had higher densities than cattle only in habitat TPC (wildebeest, zebra, impala, kongoni and eland), habitat PD (wildebeest) and habitat PDCAm (eland). The high degree of habitat overlap between cattle and wild ungulates can be attributed to the superior number of cattle and the fact that cattle habitat occupancy is regulated by the Maasai and is determined more by disease risk than vegetative characteristics. Hence provided the disease risk is low, even for a short time, cattle will utilize any habitat. Of course habitat overlap, while it is a prerequisite, is not tantamount to competition. Even with habitat overlap, competition should be obviated during this season due to resource abundance which would allow for the optimum functioning of feeding mechanisms and consequent ecological separation at the niche dimension.

Habitat Preferences

Comparison of densities of ungulates occurring in both subunits (a & b PCDAm) shows that cattle, wildebeest, zebra and oryx had noticeably higher densities in the small interspersed units (a) than in the larger unit of the same habitat (b). This suggests that the edge effect (Odum 1971:157) may have been operating for these species but that the habitat *per se* was preferred by eland and Grant's gazelle.

A crude measurement of ecological separation was obtained by calculating the relative occurrence of a species in each of the habitats (Fig. 23). Since there are 13 recognized habitats, a species occurrence of 8% in each would indicate no habitat preference. Occurrences of greater or less than 8% should indicate varying degrees of affinity or aversion toward a particular habitat. On the basis of this, cattle were associated most positively with Pennisetum grassland (Pm 19.5%), and the wooded grassland habitat PDC (18%), both of which were tsetse free. The Maasai annually burn the former to remove old growth and increase palatability and the latter habitat is dominated by the highly preferred short Panicum and Digitaria grasses known as "Erikaru" (Appendix Table 4). Cattle were associated most negatively with habitat TPC (0.4%) from which they were restricted mainly by tsetse.

Zebra showed negligible occurrence in the thicker woodland and bushland habitats (ALAn, GCAt). They preferred wooded grasslands with both short (PDC 22%) and taller (TPC 14%) grass components and grasslands (Sh 14%, PD 10%, aPDCAm 10%, Pm 10%).

Wildebeest were much more restricted to open habitats than zebra and showed strong preference for Panicum-Digitaria short grassland (PD 41%) and Sporobolus grassland (Sh 21%). It is perhaps significant that the only wooded habitat they were attracted to (PDC 16%) was dominated in the understory by the same short grasses dominating the grassland they most strongly preferred.

Grant's gazelle showed fairly equal preference for habitats PDC (16.4%), Sh (15.1%), mTPC (12.3%), a and b PDCAm (12.3%) and PD (11%). They preferred open habitats with short grass similar to

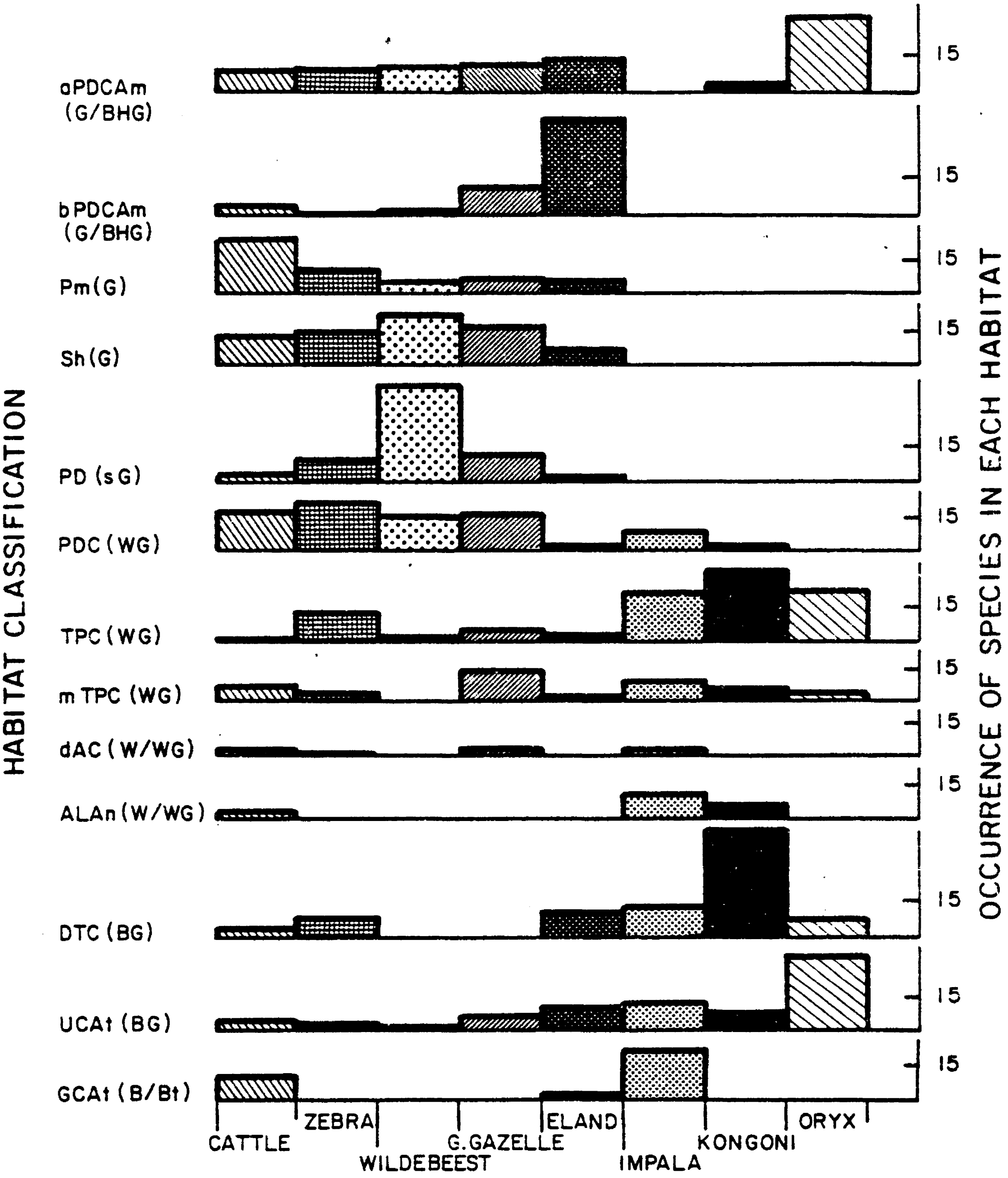

Fig. 23. Relative occurrence of each ungulate species by habitat, wet seasons, 1975-76, south Maasailand. A percentage of greater than 8 indicates preference for a habitat.

wildebeest but their preferences were broader, including herbaceous grassland and habitats modified by cattle.

Eland showed strong affinity for the large bush herb grassland unit (bPDCAm 41%) and slight preference for the small interspersed units of the same habitat type (aPDCAm 13.7%), and for bush grasslands with taller perennial and annual grasses (DTC, UCAt 10.5%).

Impala preferred the bushland (GCAt 21.2%) and the taller Themeda wooded grassland (TPC 20.5%). They showed a less pronounced preference for the bush grassland habitats (DTC 13.4%, UCAt 12%) and were absent from open grassland habitats.

Kongoni had similar preferences as impala in that they also avoided grasslands and occurred in wooded and bush grasslands. However, they exhibited a greater degree of habitat specificity as evidenced by their absence from bushland and very strong affinity for wooded and bush grasslands dominated by the taller tufted perennial grasses (TPC 31%, DTC 46%). Their notably lower preference for units of similar physiognomy, but dominated by short grasses (PDC 2%) or annual grasses (UCAt 8%), denotes the importance of herb layer characteristics in affecting their distribution.

Oryx showed overlap with kongoni in their preference for wooded grassland (TPC 21.7%) but differed by their strong preference for the small interspersed units of bush herb grassland (aPDCAm 34.8%) and the bush grassland dominated by annual grasses (UCAt 30.4%).

Habitat preferences are portrayed diagrammatically in Fig. 24 using habitats with characteristics which best define ungulate

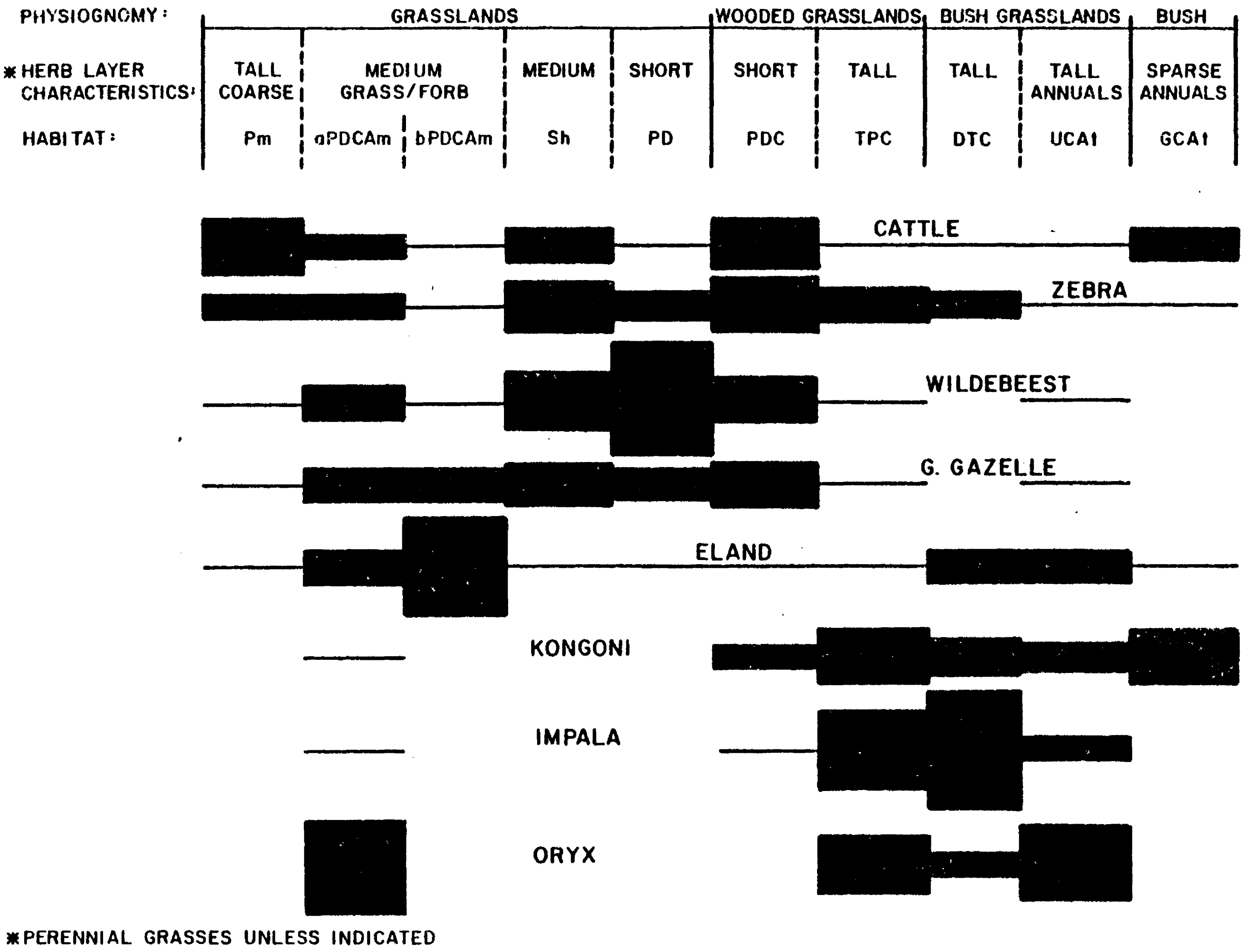

Fig. 24. Diagrammatic portrayal of ungulate habitat preferences based on the relative occurrence of a species in each habitat, wet seasons, 1975-76, south Maasailand. Relative degree of preference is indicated by line width. Narrow lines indicate presence but no preference.

preferences as determined by this study. In summary, ecological separation at the habitat level was demonstrated for the wild ungulates based primarily on habitat physiognomy and floristics related to herb layer composition and structure. Cattle, whose habitat choice was determined by their owners, showed a less well defined habitat segregation compared to the wild ungulates.

Competition

The portrayal of habitat condition and the results of the dry season cattle and wild ungulate counts indicated that forage was limited in relation to cattle needs in the cattle belt during the dry season. Thus, it can be argued that any grazing wild ungulate utilizing habitat within the cattle belt at any season was competing with cattle for forage. By calculating numbers of wild ungulates from the densities and known habitat areas, an idea of the relative use of the cattle belt by each species and among species was obtained. Assuming a positive correlation between competition and overlap with the cattle belt, Fig. 25 shows that wildebeest and zebra were the greatest potential competitors with cattle for dry season forage because of their greater numbers and high percentages of occurrence within the cattle belt. In this context of indirect competition with cattle, the next most likely competing species were eland, Grant's gazelle, impala, kongoni and oryx in order of decreasing importance. Wildebeest had the highest percentage occurrence (91%) in the cattle belt followed by Grant's gazelle (76%), zebra (61%), eland (44%), impala (15%), kongoni (11%) and oryx (8%).

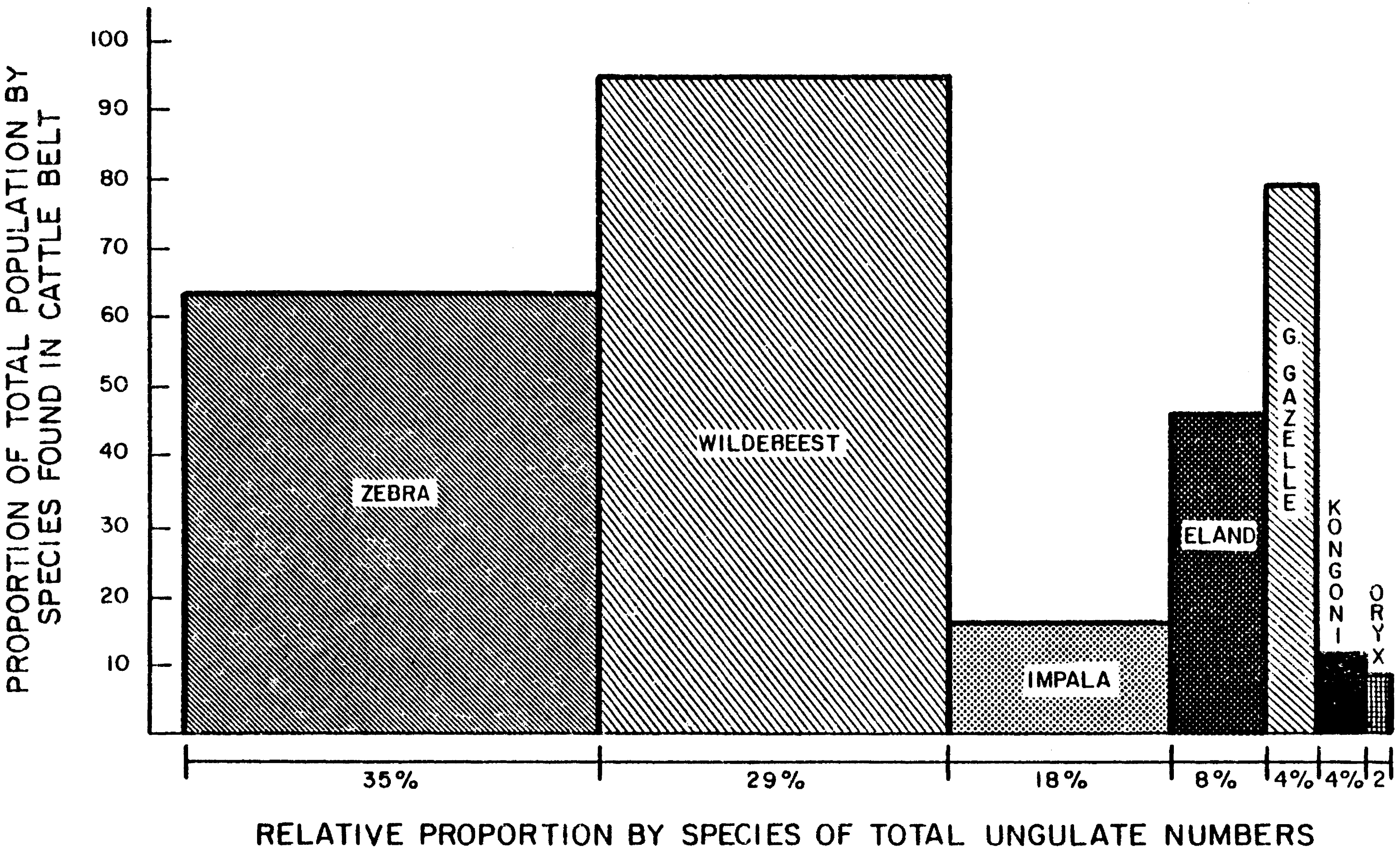

Fig. 25. Percentage occupancy of the cattle belt by wild ungulates during the wet seasons, 1975-76, south Maasailand.

While a modicum of habitat modification by cattle may have positive or negative effects on wild ungulates depending on feeding adaptations, one would expect extreme modification to have an adverse effect on all wild grazers. Cattle and wild ungulate densities for 3 habitats of similar potential but different use history are presented in Fig. 26. Mean bare ground and perennial grass cover for the habitats is shown in Fig. 11. Habitat dAC (cattle-dry season) is degraded, habitat mTPC (cattle-wet season) is partially degraded and habitat TPC is least modified. All wild ungulates except one showed decreasing densities from the least modified to the degraded habitat. Grant's gazelle had the highest density in the partially degraded habitat, possibly due to a preference for forbs and invading plants.

In summary, the results suggest that among wild grazers, wildebeest and zebra were potentially the greatest competitors with cattle for forage. This was because they were the most numerous wild grazing ungulates and showed a high degree of wet season habitat overlap with the cattle belt, where forage was limited for cattle in the dry season. That such competition was occurring presupposes that through their wet season utilization of habitat in the cattle belt, wildebeest and zebra were consuming forage which would otherwise have been available to cattle during the dry season. Ungulates preferring open habitats and short grasses (wildebeest, Grant's gazelle) had the highest percentage occurrence in the cattle belt while the reverse was true for species preferring tall grass habitats (kongoni, oryx).

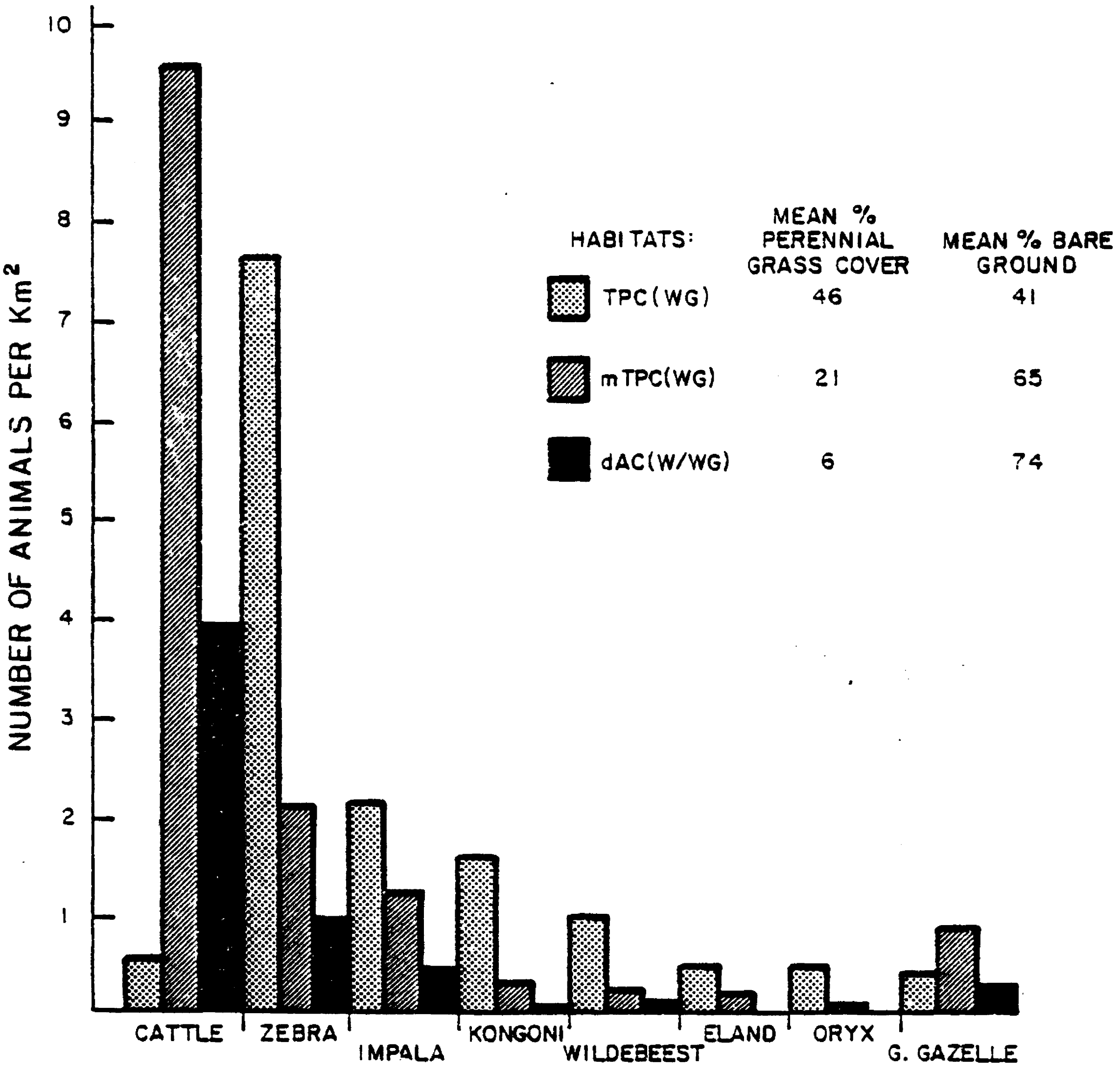

Fig. 26. Comparison of cattle and wild ungulate densities in three habitats of similar potential but different condition due to use history, wet seasons, 1975-76, south Maasailand. See Fig. 11 for animal use histories and the effects of different grazing pressures on each of these 3 habitats.

DISCUSSION

Cattle Distribution

Human populations in Africa and Tanzania specifically are increasing dramatically (Myers 1973, Pollock 1974:138, de Vos 1975: 108). A corollary of this is the expansion of cultivation into marginal semi-arid lands and the attendent pressure on subsistence pastoralists occupying these lands (Campbell 1977, Diarra 1975, de Vos 1975:130, Kjaerby 1976, The Threat of Desertification in Tanzania 1977, Jacobs 1975, Hatfield 1977). As discussed in the section on cultivation, these trends are evident for this area of Maasailand. As a result, livestock and wildlife land use options are jeopardized and pressure is exerted on the Maasai to justify land use in terms of the national economy. While displacement of the Maasai from Tarangire was not as great as from other East African National Parks (Western 1975, Jacobs 1975), the Park's creation did nonetheless further delimit the area. These historical events are of particular significance to this study because they have fixed the area geographically and limited the resources available to cattle and wild ungulates.

Both the dry and wet season cattle concentration areas were relatively tsetse free (Figs. 14 and 15) which suggests that within this area of Maasailand cattle distribution was further restricted by tsetse fly infestation. This effect of tsetse infestation on cattle distribution is a widespread phenomenon over much of the African continent (Ford and Clifford 1968, Ford 1971:354, West 1972, Lambrecht 1972).

A summary of information collected on Maasai movement patterns in the study area indicated that impetus for movement was provided primarily by ecological factors - disease risk, forage, and water. Secondarily, social and development factors such as social ties, veterinary and medical services and trading centers were influential, provided the primary ecological factors were reasonably satisfied. Water in the dry season and in the wet season, rainfall by its effect on forage, are the foremost criteria governing cattle distribution, but these operate within the constraint of disease risk. Cattle diseases of most consequence were nagana and anaplasmosis but there was also present a host of other diseases including East coast fever, foot and mouth disease, anthrax, heartwater, redwater, brucellosis, and malignant catarrhal fever.

In years of normal or good rainfall, occupancy and movement patterns are stabilized with the majority of the Maasai remaining for the entire year within the cattle belt (Fig. 14) in which disease risk is low relative to the surrounding areas. If conditions allow, they do not move during the dry season and in the wet season either move only a few kilometers or remain where they are and only alter the pattern of grazing. Reasons commonly given by the Maasai for this affinity towards the home locale were: a known and acceptable level of disease risk, familiarity with the area facilitating herding, social ties, and the hardships involved in moving.

Less predictable movements involving greater distances both within and outside of the cattle belt are precipitated by extreme conditions such as drought or disease outbreak. These movements may be fairly permanent or of a temporary nature with return to the home locale as soon as conditions improve there. When conditions are not suitable in a locale and all options within the general area are poor or strong social ties exist in another area, movement may occur from one cattle area to another.

South Maasailand generally consists of a number of rather distinct cattle areas separated by areas of higher disease risk which often lack permanent water sources. Each cattle area is further broken into locales which contain water and acceptable livestock habitat. With this conceptualization in mind, the general pattern of movement which emerges is the exhaustion of options: 1) within the home locale, 2) within the cattle area in which the locale is located, and 3) in other cattle areas, after which movement may occur to the adjacent areas of higher disease risk.

The implications are twofold. First, Maasailand as a whole is a fixed geographical entity bound by population buildup and alternate forms of land use in adjoining areas. Within Maasailand interaction between cattle areas probably evens out in the long term. In other words, while Maasai of area A may utilize area B for a series of years, eventually Maasai of area B will in turn utilize area A. Thus, it can be argued that while the cattle population is fluid over the larger area, in the long term the population of any one cattle area is stable relative to other areas. Also it is probable that because of this fluidity, the Maasai seldom have to resort to movement into the higher disease risk areas. It follows that we are dealing with a discrete cattle population in a limited area and so we have established a general prerequisite for resource competition. The second implication is that because disease risk and water are more tangible limiting factors and override the dictates of forage in determining cattle distribution, movement is often delayed past the point of proper range use.

Habitat Condition

Habitat investigations indicated that much of the habitat within the cattle belt was suboptimal both with regard to environmental health as well as grazing potential; cattle, because of their large numbers and restricted distribution, were primarily responsible for both situations. Lamprey (1963) alluded to land deterioration effected by cattle in the Maasai Steppe (which encompasses the study area) and there are numerous references to habitat degradation by cattle and other domestic stock elsewhere in Africa (Talbot 1972, West 1972, Pollock 1974:117, Harris 1972, Riney 1968, Glover and Gwynne 1961). In the context of competition, adverse environmental change can be viewed as overt evidence that resources are limited in relation to animal requirements.

Factors Contributing to Habitat Deterioration

As discussed in the previous section, there is a limited area acceptable for cattle raising, and disease and water constraints take priority over forage conditions in determining cattle distribution. These factors have contributed to habitat deterioration. Another contributing factor is the lack of grazing control within the cattle belt. One reason for this is that control of the grazing in a certain area by any one group is precluded by the variable rainfall and sporadic nature of disease outbreak. It is unwise for any group to prohibit the use of an area by others, since in the future they in turn may find themselves subject to conditions of stress. Paradoxically, this mobility which has enabled the Maasai to successfully exploit their environment in the past, is a major hindrance to the solution of present problems resultant of resource and animal number imbalances.

Traditional management strategies emphasize maximization of livestock numbers. In the past, natural attrition of both humans and animals and the opportunity for expansion into new areas rendered this a necessary and workable system. The traditional Maasai lifestyle is almost wholly dependent on livestock, with consequent minimal need for other possessions. The accumulation of material goods is further restricted by the mobility required to maintain this key (livestock) resource. Hence,it follows that respect, honor and security accrue to the man who succeeds in accumulating many livestock which in turn enable him to have many children. Sons provide security in old age, daughters do the same through the ties which are established with in-laws. A wealthy man owns many cattle to compensate for decreased milk production during the dry season. The more cattle owned and the more dispersed they are, the greater the chance that there will be a sufficient number left for bare survival after disease and starvation have taken their toll.

It is often assumed (Casebeer 1968, Lambrechts 1972) that in the past a somewhat stable balance was achieved between subsistence pastoralists and their environment due to natural population regulatory factors such as disease in humans and livestock. However, Talbot (1972) postulated that the Maasai and their livestock may never have been in balance with any one specific environment. This could account for the Maasai's slow but steady southward expansion over the last several hundred years (Jacobs 1975). Presumably, with each movement, deteriorating range was left in their wake. Each of these views is no doubt in part true. The fact remains that under present conditions, management strategies which are geared towards maximization of animal numbers are no longer tenable because of a decline in natural attrition of both humans and livestock and a halt to further expansion in area. Alleviation of problems resulting from the divergence between animal numbers and environmental capabilities will necessitate less direct dependence on animals for human subsistence e.g., a greater reliance on plant foods (grain) procured from adjacent agricultural areas through the sale of animals. Such a shift in human diet would decrease the number of animals required for subsistence because of the large amount of grain which can be purchased with the proceeds from the sale of one steer (Brown 1971).

Rather than following an integrated approach, the influences of development have to date accommodated to traditional management strategies to the detriment of the range resource. Emphasis has been on those facets of livestock development (water, veterinary services) which have allowed for increases in animal numbers, but there has been little success in implementation of measures (management plans, stock quotas) which are conducive to proper range use. The Maasai have naturally accepted and complied with development supportive of traditional strategies which worked in the past. Conversely, they have resisted development which is inimical to those goals. The tsetse clearing operation in the Loibor Sirret area has had disastrous environmental effects. New water sources, dips and veterinary medicine are all necessary for livestock development but their provision has had no concurrent implementation of stocking rates or grazing plans. The result has been an increase in livestock numbers and an aggravation of the problem of habitat deterioration. The problem results from the dichotomy of traditional and developmental goals; of subsistence pastoralism and commercialized livestock production. The point is that the ultimate success of development projects depends on basic changes in traditional values and lifestyle and not on 'development showcases' such as new boreholes, dams, dips and veterinary centers. The negative ecological consequences of poorly designed and misdirected development schemes among pastoralist peoples is well documented (Talbot 1972, Heady 1972, Jacobs 1975, Russell 1972, Baker 1975).

In summary, it would be foolish to advocate a total break from traditional management strategies acquired through years of association with a harsh environment. However, it is evident that some basic changes related to subsistence pastoralism are necessary. The land area available for Maasai use is, practically speaking, fixed. Yet, the Maasai people and their livestock, as recipients of modern medical and veterinary services, have experienced substantial population growth. In a system in which each individual requires a certain number of livestock to subsist (Brown 1971), human population increase begets the need for an increase in livestock numbers, both of which must ultimately confront the limitations imposed by the resources of a finite area. The present trend of range deterioration is undermining livestock and wildlife land use options in both the local and national interest. It follows that measures ensuring rehabilitation and wise use of the range resource are paramount to successful development; and second that sociopolitical and economic options must abide within the framework delineated by the foregoing premise. Finally, it seems appropriate to add that the problems confronting these traditional societies are but a dimension of the larger global problem of an unstable relationship between industrial society and the biosphere (Whittaker and Likens 1973).

Cattle and Wild Ungulate Distributions and Competition - Dry Season

Competition theory predicts that competition for resources should be maximum during times of resource scarcity. Studies in East Africa (Vesey-Fitzgerald 1960, Gwynne and Bell 1968, Bell 1970) have suggested that a primary means of ecological separation among wild ungulate grazers is through ungulate selection for grasses of specific growth stage and structure. There is an optimum vegetation structure for each ungulate species which is determined by a species' feeding adaptations. In the wet season the grasses are actively growing and there is a great variety of growth form (both intraspecific and among grass species) because of the differential response of grasses to variable rainfall and varied grazing pressure. At this time when there is a maximum variety of grasses both in growth stage and structure, ungulate species' feeding adaptations are allowed to operate most efficiently, In the dry season, forage is most limited because of the cessation of grass growth and the restriction in range imposed by the availability of free water upon cattle and wild ungulate grazers who are water-dependent. Lack of grass in abundance as well as the relative homogeneity of the sward (because all the grasses are in a similar (mature/dormant) growth stage) result in a convergence of ungulate grazer diets and thus maximum competition (F.A.O. 1974).

The results of the counts at permanent water sources showed an inverse relationship between cattle and wild grazer abundance at both the waterholes (Fig. 17) and the river springs (Fig. 18). Counts at the dams (Fig. 19) revealed a negligible presence of wild grazers compared to the large number of cattle. Wild grazers were, however, well represented in the same areas during the wet season (Fig. 22 and Kahurananga 1976). The results suggest that resource competition was occurring as evidenced by the (distributional) displacement of wild grazers by cattle.

Wiens (1977) pointed to the danger of interpreting spatial interference as an expression of competition because first, it assumes single factor causality (competition), and second, it requires the assumption that resources are limited in relation to population demands. In reference to the former it is conceivable that spatial interference, rather than resource competition, could account for the low number of wild grazers corresponding to high cattle numbers. This is unlikely, first because wild browser and cattle representation did not show such an inverse relationship. Second, settlements were inconspicuous and located a few kilometers distance from the water sources and cattle and wild ungulate drinking times showed little overlap. The majority of wild ungulates drank during the night or at dawn or dusk even at those sources from which cattle were absent. Third, cattle and wild ungulates were often seen within 100 m of each other with no apparent discord.

It is possible that 'tradition' may in part account for the low dry season occupancy of wildebeest and zebra in the habitats around the dams. Prior to construction of the dams in 1954, lack of water precluded dry season occupancy. Thus, it could be argued that migratory patterns were by then established. However, it seems unlikely that movement patterns would lack the flexibility to accommodate to fluctuating resources since presumably they were initially determined in response to resource availability. Furthermore, wildebeest and zebra do drink at the dams near the end of the wet season and a few herds remain throughout the dry season.

Higher lake levels and human population buildup have largely eliminated the open grassland at the north end of Lake Manyara. This area was previously the favored dry season refuge for wildebeest (Lamprey 1963). At present, the only remaining dry season concentration area for these wild ungulates is Tarangire. It seems logical to assume that if resource competition was not occurring in Simanjiro, wildebeest would remain in this open grassland habitat instead of returning to the wooded habitats of Tarangire.

The restricted distribution of cattle and the rationale behind Maasai movement patterns lend validity to the assumption that resources are limited in relation to animal needs at least for prescribed areas and times (cattle belt - dry season). Observed cattle mortality, loss of "condition" of cattle during the dry season, and the adverse habitat changes can be viewed as a manifestation of extreme resource limitation.

Studies such as those of Bell (1970) and Sinclair (1975) suggest that in natural ecosystems where food is limiting populations, it is often nutrients (green leaf) which are limiting rather than energy. Based on a study of resource limitation of buffalo populations, Sinclair (1977) postulated that wild populations can be regulated by resource limitation without damage to the resource. In well-adapted species this is accomplished through small but frequent mortality in response to resource limitation. Resource shortages and consequent undernutrition in animals (usually affecting young and old first) makes them susceptible to secondary factors such as disease so that mortality occurs before there is resource degradation.

In contrast, one would expect cattle to experience drastic population fluctuations and severe inanition in the dry season with consequent damage to the resource base. Cattle can endure periods of extreme undernutrition because of human support through services such as veterinary medicine and protection from predation. Also, because they have had a shorter period to adapt to the environment, the regulatory processes which operate through nutrition and disease are less refined than in wild species. Thus, cattle respond more erratically to diseases and are more likely to deplete food supplies to a point at which there is damage to the resource. Dry season emigration of wild ungulate grazers from cattle areas is therefore understandable in light of the extreme resource limitation (nutrients and energy) effected by cattle.

Harris (1972:40) speculated that there was a similar effect of cattle on wild grazer abundance in the vicinity of the Umba river in Mkomazi, Tanzania. A comparison of ungulate densities in Serengeti National Park and adjacent cattle areas in Loliondo (Watson et al. 1969) showed that wildebeest were replaced by cattle in the latter area. This suggested that there was a high degree of overlap between the resource requirements of cattle and wildebeest.

Competition was similarly deduced between buffalo and hippopotamus (Hippopotamus amphibius) on the Mweya peninsula, Uganda (Eltringham 1974). In this case a sixfold increase in buffalo numbers was attributed to 10 years of reduction of the hippo population through shooting.

In contrast to competition, the dry season counts also indicated which wild ungulates were compatible with cattle, at least in terms of forage. Among these, elephant were the most prominent by virtue of biomass and their effect on the environment. It is unlikely that sufficient protection would ever be afforded to permit the high elephant densities responsible for changes from wooded habitat towards grassland as has been the case in several African parks and reserves (Laws 1970, Parker and Archer 1970, Anderson and Walker 1974, Thomson 1975). However, it should be recognized that in addition to feeding complementarity, habitat modification by elephant is largely favorable for cattle, Elephant can reduce woody species through their browsing and thereby create open conditions which favor grasses and adversely affect tsetse flies.

In summary, during the dry season, large concentrations of cattle did not exclude wild ungulates but they did affect the species represented. It is postulated that due to disease constraints and lack of (suitable) alternate water sources, the Maasai kept their cattle in dry season locales until the forage conditions deteriorated and resulted in emigration by water-dependent wild grazing ungulates. In other words, one species, cattle, occupied the entire spectrum of grazing niches as a result of a combination of their superior numbers, their owners' directive influence, and the limited forage resources during the dry season.

Cattle and Wild Ungulate Distributions and Competition - Wet Season

The wet season ingress of wild ungulates into dry season cattle areas, particularly wild grazers, is consistent with competition theory which predicts that during times of high resource availability, competing species may successfully invade an area (Wiens 1977). Ungulate habitat preferences should be most evident during this season because of food abundance and widespread water availability.

Habitat Preferences

Habitat preferences similar to those found in the present study (Figs. 23 and 24) have been reported elsewhere in Africa. Cattle were found to be the least habitat specific of all large herbivores in Amboseli (Western 1973). In Rhodesia, wildebeest were associated with open habitats characterized by a short sparse grass sward while in terms of gross vegetative structure, zebra were considered to be habitat generalists (Ferrar and Walker 1974). Similar patterns of habitat selection by wildebeest and zebra were reported by Hirst (1975), but zebra showed a marked predilection for woodland in addition to occupancy of the open savanna short grass habitats preferred by wildebeest. Bell (1969, 1970) reported that wildebeest utilized lower levels of the grass sward than zebra. Observations of habitat utilization in Athi-Kaputei, Kenya (Owaga 1975) indicated that wildebeest sought out short grass localities while zebra were more associated with taller grass. It is well known that the migratory wildebeest of Serengeti prefer the short grass plains during the wet season (Pennycuick 1975, Talbot and Talbot 1963).

On a ranch in Kenya (Blankenship and Field 1972), Grant's gazelle preferred open habitats and seemed attracted to disturbed sites. Eland were more habitat specific than Grant's gazelle and although they frequented grassland, bush habitat was preferred. Impala were associated with shrubby habitats (Ferrar and Walker 1974) and open savanna with both a short heterogeneous herb layer and dense grass cover (Hirst 1975). Blankenship and Field (1972) reported that kongoni occurred mainly in longer Themeda grassland.

Habitat preference can be viewed as a function of the species' stomach morphology (Hofmann 1973), group size (Jarman 1974), body size, digestive system and the anatomical and behavioral features which contribute to an animal's feeding mechanism (Bell 1969, Sinclair and Gwynne 1972, Pratt and Gwynne1977:91). Wildebeest preference for short grass habitat can be related to their selection for grass leaves (Gwynne and Bell 1968, Owaga 1975). Short grasses, whether because of morphology or growth stage, normally have a high leaf:stem ratio which is correlated to a high ratio of protein and soluble carbohydrates to cellulose. A homogeneous short grass sward is suited to the wildebeest's preference for leaf because selection for leaf in longer grasses is made difficult by the broad mouthparts of the wildebeest. Kreulen (1975) presented evidence of a significant correlation between wildebeest abundance on the Serengeti plains and calcium levels sufficient for the period of lactation. Analysis of leaf samples from the study area indicated that crude protein levels of the dominant grasses in the preferred wildebeest habitat (PD) may be higher than for grasses in other habitats. However, calcium:phosphorus ratios were lower than optimum and Ca was lower than the minimum needed for wildebeest during maximum milk production as calculated by Kreulen. These preliminary results suggest that wildebeest were not attracted to the short grass plains because of high Ca contents of the dominant grasses in that preferred habitat. Wildebeest preference for open habitat may be a function of their gregarious nature, their territorial and breeding set-up and their use of sight and flight as a main anti-predator mechanism.

Zebra occupied a broader spectrum of habitats than wildebeest, the main difference being their greater tolerance for wooded habitats and taller grass components. This could be related to the high proportions of grass stem and sheath in zebra's diet (Gwynne and Bell 1968, Owaga 1975). In comparison with wildebeest, their greater tolerance for tall grass has been explained in part by differences in dentition and digestive system (Gwynne and Bell 1968, Bell 1970). Zebra have opposing incisors which can easily cut fibrous stems and as non-ruminants they have a faster rate of food passage and a faster breakdown of cellulose than ruminants. Zebra's greater occupancy of wooded habitat than wildebeest may be to some extent because they are nonterritorial and run in small cohesive social units (Klingel 1969).

The preference of kongoni and oryx for tall grass habitats can be related to body size and mouthparts. Lower absolute resource requirements and small mouthparts enable these species to be selective for the nutrient rich parts (leaves) of the taller grasses which have low leaf:stem ratios.

Competition

The hypothesis that indirect cattle-wild grazer competition is occurring through wet season use of the cattle belt by wild ungulates assumes that grazing is not stimulating greater forage productivity. Increased production due to the effect of defoliation is a well established phenomenon in range management (Stoddard and Smith 1955), especially for short grass species (Heady 1975:26). McNaughton (1976) showed that wildebeest grazing in the Serengeti increased net productivity and facilitated utilization by Thomson's gazelles. In contrast, Harris (1972) reported lower net production from clipped as opposed to unclipped plots in Mkomazi. He postulated that defoliation resulted in lower forage production in areas of low rainfall (less than 50 cm) where moisture rather than space was the primary factor limiting grass growth. This situation applies, at least to some extent, to the study area.

In the short term, it is possible that grazing during the wet season stimulates growth and maintains the grass in a productive state.

However, it is probable that this effect is overridden in the cattle belt because of the almost continuous high grazing pressure. Grazing by wild ungulates during the growing season when defoliation is potentially the most harmful (Heady 1975:28, 1960:41, Hormay 1970, Scott 1955:602), probably contributes to the trend of habitat deterioration and also removes forage which would otherwise be available to cattle. Wild grazers can also be expected to interfere with future grazing systems for livestock. This particularly applies to wildebeest and zebra because of their numbers, food habits and occupancy of the cattle belt.

The relative abundance of the several species of wild ungulates in the cattle belt (Fig. 25) can be related to habitat preferences and the modifying effect on the habitat by large numbers of cattle. Much of the cattle belt is open grassland, a fact attributable primarily to the absence of tsetse and secondarily to the presence of permanent water and possibly due also to the abundant grass component and the ease of herding afforded by such habitat. Another salient feature of the cattle belt is the shorter grass sward than in surrounding areas due to abiotic environmental factors but also the high grazing pressure by cattle. Wildebeest, preferring open country and short grasses, would therefore be expected to have a higher percentage occurrence (91%) in the cattle belt than zebra (61%) which have a greater tolerance for taller grasses and wooded habitats. Grant's gazelle had a high occurrence (76%) correlating to their preference for open and modified habitats. Eland were next (44%), primarily due to their strong preference for the large bush herb grassland unit within the cattle belt. Impala, because of their preference for bush, had a low percentage occurrence (15%) as did kongoni (11%) due to preference for bush and wooded grasslands dominated by taller grasses. Oryx had the lowest percentage occurrence (8%) for the same reasons as kongoni, but also because of their strong preference for the small interspersed units of bush herb grassland, many of which were outside the cattle belt.

In terms of direct competition and the effect of cattle on wild ungulates, competition theory predicts that competition in the wet season will most likely occur between species whose grazing niches are most similar. In this case it seems that wildebeest would be the wild ungulate most competitive with cattle because of size, digestive system (ruminant) and shape of mouth (broad, unselective). However, wet season use of the same habitats by both wildebeest and cattle (Fig. 22), and the wildebeest's high percentage of occurrence within the cattle belt (Fig. 25) and preference for short grass (Fig. 24), suggest that rather than competing, cattle may facilitate use of the herb layer by wildebeest. This would be due to the short grass sward effected by large numbers of cattle grazing and would be contingent on a certain minimum level of resource abundance which presumably would be the case in most wet seasons. The grazing induced successional stages described by Heady (1966) suggest that the high grazing pressure by cattle may favor the short stoloniferous grasses preferred by wildebeest. Similarly, Blankenship and Field

(1972) reported that grazing and trampling favored short stoloniferous grasses. Blankenship and Qvortrup (1974) stated that intensive cattle grazing kept the pasture in a short phase which was optimal for Thomson's gazelle and impala.

Conversely, one could conclude that cattle adversely modify the grass sward for species such as kongoni and oryx which with their small mouthparts are more selective grazers, preferring the taller grasses. Thus, while their low occurrence in the cattle belt was due in part to abiotic (habitat) factors, it could also be attributed to competition with cattle. This is supported by the increase in kongoni numbers which followed the removal of livestock from Nairobi Park (Foster and Coe 1968, Gosling 1974). Based on kongoni preference for long grass, Blankenship and Field (1972) concluded that the major influence of cattle on kongoni would be caused by overgrazing.

In summary, it is postulated that wet season grazing by wild ungulates in the cattle belt is a form of competition with cattle because it decreases the amount of forage available to cattle during the dry season. Wildebeest and zebra are the greatest potential competitors, because of their numbers, food habits, and distributional overlap with the cattle belt. In terms of direct (spatial and temporal) interaction, cattle through their modifying effects on the habitats appeared to compete directly with grazing ungulates preferring tall grass habitats (kongoni, oryx) while facilitating use of the herb layer by species preferring short grasses (wildebeest, Grant's gazelle).

RECOMMENDATIONS

The investigation of habitat condition in the study area indicated that much of the habitat in the cattle belt was suboptimal with regard to environmental health, as well as grazing potential, as a result of an imbalance between cattle numbers and forage resources. Traditional Maasai cattle management strategies, coupled with a restriction in area available for cattle raising, the provision of new water supplies, and veterinary and medical services, were responsible for disrupting the ecological balance. Due to these historical factors and misdirected development efforts, the natural population (human and livestock) controls to which traditional management strategies were geared have been reduced, and there has been no substitution of alternate controls. Since degradation of the resource base undermines all land use options, it is evident that in the interests of the Maasai people and the nation, basic changes are necessary with regard to both Maasai attitudes and values and the development approach. With these considerations in mind, the following recommendations are made.

1) A major emphasis of development in Maasailand should be a program of education by extension which meets and relates to the Maasai people in their environment. The aim should be to introduce ideas which serve to change the people's perception of their problems and the possible solutions. Audio-visual aids and techniques, such as those used by the Maasai Rural Development Centre in Kenya (Csakany 1973), can be employed. Stress should

be placed on the interchange of ideas e.g., scientific concepts of livestock husbandry and range management can be coupled with the wealth of traditional Maasai knowledge regarding livestock and the environment.

2) Ecologically viable grazing units must be established for each ranching village and livestock use restricted to members of the village if grazing control is to be realized. Since communal grazing is built into Maasai tradition, the social apparatus necessary to enforce boundary observance is lacking so that at least initially, government officials and technicians will have to bear the brunt of such enforcement.

3) Management plans should be devised in cooperation with Maasai. Based on past experience, it is only with such local input and involvement that grazing systems have a chance of working. Initally, emphasis should be placed on control of livestock distribution rather than control of numbers as the concept of stock quotas is anathema to traditional Maasai values. Emphasis on quotas will likely guarantee the failure of any attempts to implement grazing plans.

4) Permanent transects should be established to monitor range condition in each ranching village. These should be initiated with the aid of Maasai Project range specialists. Data collection can be the responsibility of resident range officers.

5) With regard to new water supplies, emphasis should be on small catchments which inherently limit animal numbers and effect better distribution in relation to forage. Simple filters

(sand, gravel and charcoal) are needed to improve the quality of water for domestic use.

6) Given the desirability of local involvement and in keeping with the government's policy of self reliance, the Maasai should help pay for those livestock services which they desire.

The results of this study suggested that the greatest potential for forage competition between cattle and wild ungulates derived from the wet season use of the cattle belt by Tarangire grazing ungulates, wildebeest and zebra in particular. Barring extreme measures such as fencing, it is unlikely that distributional patterns can be easily altered so as to reduce use of the Maasai cattle areas by wild grazing ungulates. The Maasai have traditionally harbored little antagonism towards wildlife except in the case of direct and dramatic conflict as with lion. Recent and severe dry season forage shortages, coupled with the prohibition of livestock grazing in the Park, have resulted in a shift of the traditional stance towards one of greater hostility directed to the seasonal incursions of wild ungulates. Maasai frequently asked me, "Why are we who do no harm to the game not allowed in the Park, whereas Park wildlife seasonally graze our areas?" It is evident that pressure on the wildlife resource will increase parallel to the rate of development in the area and the corresponding changes in attitudes towards livestock husbandry. With these considerations in mind and given: a) the traditional occupancy of the area by the Maasai, b) the government's goal of commercialized livestock production and, c) the desirability of maintaining the Tarangire ungulate populations in the national interest; the following recommendations are presented.

1) The Maasai should receive a percentage of any revenue generated by utilization (hunting, cropping) of wildlife within their ranching village unit. The future viability of the wildlife resource may be best insured by allowing for greater local control and management of the wildlife resource, within guidelines prescribed by the Game Department and National Parks. Compensatory payment could also come from National Park revenue although the small earnings of Tarangire make this impractical on a direct basis at present. If dual use is to continue, livestock grazing systems will have to accommodate to the seasonal grazing by wild ungulates and benefits accruing to the local people from wildlife must be of a magnitude sufficient to make up for the loss in livestock potential.
2) Research should be undertaken to determine what impact wet season grazing by wild ungulates has on grass production and range condition in the cattle areas.

SUMMARY AND CONCLUSIONS

1. Human population increase and economic realities in Tanzania have led to an acknowledgement of the value of wildlife as a resource of economic potential, as well as a recognition of the need for development of commercialized livestock production in the traditional sector. Where present and potential livestock and wildlife uses overlap, as in the range areas of Maasailand, questions and conflicts have surfaced pertaining to the relative importance that each should play in present and future land development strategies. This study was undertaken in an attempt to elucidate aspects and areas of greatest actual and potential competition between wild ungulates and cattle.
2. The study area encompassed 4867 km^2 east of and adjacent to Tarangire National Park. Subsistence pastoralism practiced by the Maasai people was the main form of land use and was the object of development schemes attempting to create a system of market oriented livestock production. In addition, the area served as the wet season range for Tarangire Park ungulates and harbored a smaller number of resident wildlife.
3. Habitats were delineated from Erts satellite imagery maps and representative sites within the habitats were sampled using the releve' method. Habitat management histories were determined by observation and through information from local inhabitants. Habitat changes were documented through interviews and informal

discussions with Maasai elders. Comparison of habitat parameters in areas of similar potential but with different management histories indicated that the condition of much of the habitat in the cattle belt was below potential. The sub-optimal habitat condition, in terms of environmental health and grazing potential, was chiefly attributable to cattle because of their greater numbers and restricted distribution.

4. Tsetse fly distribution was determined on the basis of personal harassment and information from Maasai. Cattle concentration areas were determined by plotting settlement locations and delineating grazing radii. The dry and wet season cattle concentration areas were relatively tsetse free which suggested that tsetse infestation was one of the main factors restricting the distribution of cattle within this area of Maasailand.
5. Actual and track counts of cattle and water-dependent wild ungulates were conducted at permanent water sources during the dry season. Based on the counts, cattle overwhelmingly dominated wild ungulates in number and biomass. Wild browsers were better represented than were wild grazers; an inverse relationship between cattle and wild grazer representation was evident.
6. Cattle and wild ungulate distributions during the wet season were determined by recording animals along driven transects. Data were presented for the 7 most numerous wild grazing ungulates. Ecological separation at the habitat level was demonstrated for the wild ungulates based primarily on habitat

physiognomy and floristics related to herb layer composition and structure. Cattle, whose habitat choice was determined by their owners, showed a less well defined habitat segregation compared to the wild ungulates. Zebra and wildebeest were the most numerous wild ungulates. Ungulates preferring open habitats and short grasses (wildebeest and Grant's gazelle) had the highest percentage occurrence in the cattle belt while the reverse was true for species preferring tall grass habitats (kongoni and oryx).

7. Maasai movement patterns were summarized and this and other factors which have contributed to habitat deterioration were discussed. The importance of reversing adverse environmental trends was underscored and it was concluded that this required basic changes in traditional attitudes toward livestock husbandry.
8. Dry season distributions of cattle and wild ungulates were discussed in the light of competition theory. It was concluded that during the dry season, large concentrations of cattle did not exclude wild ungulates but they did affect the species represented. It was postulated that competition, as reflected by distributional displacement, occurred between cattle and wild ungulate grazers whose food habits most closely overlapped with those of cattle. Due to disease constraints and lack of suitable alternate water sources, the Maasai kept their cattle in dry season locales past the point at which the forage situation resulted in emigration by water-dependent wild grazing ungulates.

Cattle occupied the entire spectrum of grazing niches as a result of a combination of their superior numbers, their owners' directive influence, and the dry season convergence of grazer diets and thus outcompeted wild grazers during this season of resource limitation.

9. Cattle and wild ungulate wet season distributions were discussed in relation to habitat preferences, feeding strategies, and competition. It was postulated that wet season grazing in the cattle belt by wild ungulates was a form of competition with cattle because it decreased the amount of forage available to cattle during the following dry season. It was concluded that wildebeest and zebra were the competitors of greatest potential because of their numbers, food habits, and distributional overlap with the cattle belt. In terms of direct (spatial and temporal) interaction, cattle, through their modifying effects on the habitats, appeared to compete directly with grazing ungulates preferring tall grass habitats (kongoni, oryx) while facilitating use of the herb layer by species preferring short grasses (wildebeest, Grant's gazelle).

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APPENDIX

Appendix Table 1. List of plant species identified in 137 sample stands, south Maasailand, 1977. Identifications verified by East African Herbarium, Nairobi.

Plant Species	Family
Tree Species	
Acacia ancistroclada Brenan	Mimosaceae
A. drepanolobium Harms ex Sjostedt	Mimosaceae
A. etbaica Schweinf. subsp. *platycarpa* Brenan	Mimosaceae
A. gerrardii Benth. var. *gerrardii*	Mimosaceae
A. nilotica (L.) Del. subsp. *subalata* (Vatke) Brenan	Mimosaceae
A. senegal (L.) Willd. var. *senegal*	Mimosaceae
A. seyal Del. var. *seyal*	Mimosaceae
A. tortilis (Forsk.) Hayne subsp. *spirocarpa* (Hochst. ex A. Rich.) Brenan	Mimosaceae
A. xanthophloea Benth	Mimosaceae
Adansonia digitata L.	Bombacaceae
Albizia amara (Roxb.) Boiv. subsp. *sericocephala* (Benth.) Brenan)	Mimosaceae
A. anthelmintica Brongn.	Mimosaceae
A. harveyi Fourn.	Mimosaceae
A. petersiana (Bolle) Oliv.	Mimosaceae
Azanza garckeana (F.H.) Exell. and Hill.	Malvaceae
Balanites aegyptiaca (L.) Del.	Simaroubaceae
Boscia angustifolia A. Rich	Capparaceae
Cassia abbreviata Oliv. subsp. *abbreviata*	Caesalpiniaceae
Combretum apiculatum Sond.	Combretaceae
C. molle G. Don	Combretaceae
Commiphora africana (A. Rich.) Engl.	Burseraceae
C. caerulea Burtt	Burseraceae
C. madagascariensis Jacq.	Burseraceae
C. mossambicensis (Oliv.) Engl.	Burseraceae
C. schimperi (Berg) Engl.	Burseraceae
Dalbergia melanoxylon Guill. & Perr.	Papilionaceae
D. nitidula Bak.	Papilionaceae
Dombeya rotundifolia Harv.	Sterculiaceae
Erythrina abyssinica A. Rich	Papilionaceae
E. burtii Bak. f.	Papilionaceae
Euphorbia candelabrum Trem. ex Kotschy	Euphorbiaceae
Ficus gnaphalocarpa (Miq.) A. Rich.	Moraceae
F. ingens Miq.	Moraceae
Heeria reticulata (Bak.f.) Engl.	Anacardiaceae
Lannea alata (Engl.) Engl.	Anacardiaceae
L. humilis (Oliv.) Engl.	Anacardiaceae

Appendix Table 1. List of plant species identified in 137 sample stands, south Maasailand, 1977 (continued).

Plant Species	Family
L. schimperi (A. Rich.) Engl.	Anacardiaceae
L. stuhlmanii (Engl.) Engl.	Anacardiaceae
L. triphylla Engl.	Anacardiaceae
Lonchocarpus eriocalyx Harms	Papilionaceae
Pappea capensis Eck. & Zeyh.	Sapindaceae
Poupartia birrea (Hochst.) Aubr. (syn. *Sclerocarya birrea*)	Anacardiaceae
Steganotaenia araliacea Hochst.	Umbelliferae
Strychnos potatorum L.f.	Loganiaceae
Terminalia brownii Fres.	Combretaceae
T. spinosa Engl.	Combretaceae
Vepris glomerata (F. Hoffm.) Engl.	Rutaceae
Zanthoxylum chalybeum Engl.	Rutaceae
Ziziphus mucronata Willd.	Rhamnaceae
Shrub/Bush & Short Tree Species	
Acacia brevispica Harms	Mimosaceae
A. kirkii Oliv. subsp. *kirkii* var. *intermedia* Brenan	Mimosaceae
A. mellifera (Vahl) Benth subsp. *mellifera*	Mimosaceae
A. stuhlmanii Taub.	Mimosaceae
Acalypha ornata A. Rich.	Euphorbiaceae
Cadaba farinosa Forsk. subsp. *adenotricha* (Gilg & Bened.) R.A. Graham	Capparaceae
Canthium lactescens Hiern	Rubiaceae
Capparis tomentosa Lam.	Capparaceae
Cardiogyne africana Bureau	Moraceae
Cassipourea mollis (R.E. Fries) Alston	Rhizophoraceae
Caucanthus auriculatus (Redlk.) Nied.	Malpighiaceae
Cissus cornifolia (Bak.) Planch	Vitaceae
Clerodendrum sp. = Richards 28442	Labiatae
Clutia abyssinica Jaub. & Spach	Euphorbiaceae
Commiphora mollis (Olov.) Engl.	Burseraceae
Conyza pyrrhopappa A. Rich. subsp. *oblongifolia* (O. Hoffm.) hild	Compositae
Cordia ovalis R.Br.	Boraginaceae
C. quarensis Gurke	Boraginaceae
C. sinensis Lam.	Boraginaceae
Croton dichogamous Pax	Euphorbiaceae
C. menyhartii Pax	Euphorbiaceae
C. polytrichus Pax	Euphorbiaceae
Cussonia jatrophoides Hutch & Bruce	Araliaceae

Appendix Table 1. List of plant species identified in 137 sample stands, south Maasailand, 1977 (continued).

Plant Species	Family
Dasysphaera robecchii Lopr.	Amaranthaceae
Dichrostachys cinerea (L.) Wight & Arn. subsp. *cinerea*	Papilionaceae
D. cinerea (L.) Wight & Arn. subsp. *nyassana*	Papilionaceae
Dombeya sp. cf. D. Warmeckii Engl.	Sterculiaceae
Erythrococca bongensis Pax	Euphorbiaceae
Euphorbia cuneata Vahl	Euphorbiaceae
E. scheffleri Pax	Euphorbiaceae
Grewia bicolor Juss.	Tiliaceae
G. forbesii Harv.	Tiliaceae
G. tembensis Fresen. var. *kakothamnos* (K. Schum.) Burret	Tiliaceae
G. villosa Willd.	Tiliaceae
Helinus integrifolius (Lam.) Kuntze	Rhamnaceae
Hoslunda opposita Vahl	Labiatae
Hymenodictyon parvifolium Oliv.	Rubiaceae
Lippia ukambensis Vatke	Labiatae
Lycium europaeum L.	Solanaceae
Maerua crassifolia Forsk.	Capparaceae
M. edulis (Gilg & Bened.) DeWolf	Capparaceae
M. parvifolia Pax	Capparaceae
M. triphylla A. Rich. var. *johannis* Volkens & Gilg	Capparaceae
Markhamia zanzibarica (Boj. ex DC.) K. Schum. ex Engl.	Bignoniaceae
Maytenus heterophylla (Eckl. & Zehy.) N. Robson	Celastraceae
M. putterlickioides (Loes.) Exell & Mendonca	Celastraceae
M. senegalensis (Lam.) Exell	Celastraceae
Mundulea sericeae (Willd.) A. Chev.	Papilionaceae
Ochna ovata O. Hoffm.	Ochnaceae
Ocimum suave Willd.	Labiatae
Ocimum sp.	Labiatae
Opilia celtidifolia (Guill. Perr.) Endl. ex Walp.	Opiliaceae
Ormocarpum kirkii S. Moore	Papilionaceae
O. trachycarpum (Taub.) Harms	Papilionaceae
O. trichocarpum (Taub.) Engl.	Papilionaceae
Pavetta dolicantha Brem.	Rubiaceae
P. gardeniifolia A. Rich. var. *gardeniifolia*	Rubiaceae
Phyllanthus fischeri Pax	Euphorbiaceae

Appendix Table 1. List of plant species identified in 137 sample stands, south Maasailand, 1977 (continued).

Plant Species		Family
Premna holstii Guerke		Verbenaceae
P. olgotricha Bak.		Verbenaceae
Psychotria nairobiensis Brem.		Rubiaceae
Rhamnus staddo A. Rich.		Rhamnaceae
Rhus natalensis Krauss.		Anacardiaceae
R. tenuinervis Engl.		Anacardiaceae
Solanum arundo Mattei		Solanaceae
S. renschii Vatke		Solanaceae
Strychnos usambarensis Gilg.		Loganiaceae
Thylachium africanum Lour.		Capparaceae
Turraea fischeri Guerke		Meliaceae
Vernonia cinerascens Sch. Bip.		Compositae
Grass Species	*Life Cycle & Habit* P=Perennial t=tufted A=Annual s=stoloniferous r=rhizomatous	
Alloteropsis cimicina (L.) Stapf	A	Gramineae
Andropogon ascinodes C.B.Cl.	Pt	Gramineae
Apochiton burtii C.E. Hubb.	At	Gramineae
Aristida adoensis Hochst.	Pt	Gramineae
A. adscensionsis L.	At	Gramineae
A. congesta Roem. & Schult.	Pt	Gramineae
A. hordeacea Kunth	A	Gramineae
A. kenyensis Henr.	A	Gramineae
A. mutabilis Trin. & Rupr.	At	Gramineae
Brachiaria eruciformis Griseb.	A	Gramineae
B. leersioides (Hochst.) Stapf	A	Gramineae
B. pubifolia Stapf	A	Gramineae
B. semiundulata (A. Rich.) Stapf	A	Gramineae
B. serrifolia (Hochst.) Stapf	A	Gramineae
Brachiaria sp.	A	Gramineae
Cenchrus ciliaris L.	Pt	Gramineae
Chloris pycnothrix Trin.	A	Gramineae
C. roxburghiana Schult.	Pt	Gramineae
C. virgata Sw.	A	Gramineae
Cymbopogon excavatus (Hochst.) Staph ex Burtt Davy	Pt	Gramineae
Cynodon nlemfuensis Vanderyst	Ps	Gramineae
C. plectostachyus (K. Schum.) Pilg.	Ps	Gramineae
Cypholepis yemenica (Schweinf.) Chiov.	Pt	Gramineae

Appendix Table 1. List of plant species identified in 137 sample stands, south Maasailand, 1977 (continued).

Plant Species		Family
Dactyloctenium aegyptium (L.) Beauv.	A	Gramineae
Dicanthium annulatum (Forsk.) Stapf var. *papillosum* (A. Rich.) DeNet & Harlan	Pt	Gramineae
D. insculptum (A. Rich.) Clayton	Pt/s	Gramineae
D. radicans (Lehm) Clayton	Pt	Gramineae
Digitaria macroblephara (Hack.) Stapf	Ps	Gramineae
D. milanjiana Stapf	Ps/t	Gramineae
D. rivae (Chiov.) Stapf	A	Gramineae
D. velutina (Forsk.) Beauv.	A	Gramineae
Dinebra retroflexa (Vahl) Panz.	A	Gramineae
Drake-Brockmania somalensis Stapf	A	Gramineae
Echinochloa colona (L.) Link	At	Gramineae
E. haploclada (Stapf) Stapf	Pt	Gramineae
Enneapogon cenchroides (Roem. & Schult.) Hubbard	A (robust)	Gramineae
E. desvauxii Beauv.	Pt	Gramineae
Enteropogon macrostachyus (A. Rich.) Benth.	Pt	Gramineae
Eragrostis aspera (Jacq.) Nees.	A	Gramineae
E. caespitosa Chiov.	Pt	Gramineae
E. cilianensis (All.) Lutati	A	Gramineae
E. cylindriflora Hochst.	At	Gramineae
E. pilosa (L.) P. Beauv.	At	Gramineae
E. porosa Nees.	At	Gramineae
E. rotifer Rendle	Pt	Gramineae
E. superba Peyr.	Pt	Gramineae
E. viscosa (Retz.) Trin.	At	Gramineae
Eriochloa nubica (Steud.) Thell.	A	Gramineae
Eustachys paspaloides (Vahl) Lanza & Mattei	Pr/s/t	Gramineae
Gilgiochloa indurata Pilg.	A	Gramineae
Harpachne schimperi A. Rich.	Pt	Gramineae
Heteropogon contortus (L.) Beauv. ex Roem. & Schult.	Pt	Gramineae
Holcolemma transiens (K. Schum.) Stapf C. E. Hubb.	A	Gramineae
Hyparrhenia hirta (L.) Stapf	Pt	Gramineae
H. papillipes (Hochst. ex A. Rich.) Anderss. ex Stapf	Pt	Gramineae

Appendix Table 1. List of plant species identified in 137 sample stands, south Maasailand, 1977 (continued).

Plant Species		Family
Hyperthelia dissoluta (Nees ex Steud.) Clayton	Pt	Gramineae
Ischaemum afrum (Gmel.) Dandy	Pt (with short rhizomes)	Gramineae
Leptocarydion vulpiastrum (DeNot.) Stapf	A	Gramineae
Lintonia nutans Stapf	Ps	Gramineae
Microchloa kunthii Desv.	Pt	Gramineae
Panicum coloratum Linn.	Ps/t (variable habit)	Gramineae
P. hanningtonii Stapf	A	Gramineae
P. massaience Mez	P or robust A	Gramineae
P. maximum Jacq.	P	Gramineae
P. porphyrrhizos Steud.	Pt	Gramineae
Pennisetum massaicum Stapf	Pt	Gramineae
P. mezianum Leeke	Pt	Gramineae
P. stramineum Peter	Pr/t	Gramineae
Rhynchelytrum repens (Willd.) Hubbard	A or short-lived P	Gramineae
Rottboellia exaltata Linn. f.	A (robust)	Gramineae
Setaria acromelana (Hochst.) Dur. & Schinz	A	Gramineae
S. holstii Herrm.	Pt	Gramineae
S. incrassata Hack.	Pt	Gramineae
S. pallide-fusca (Schumach.) Stapf & Hubbard	Pt	Gramineae
S. sphacelata (Schumach.) Stapf & Hubbard	A	Gramineae
S. verticillata (L.) Beauv.	A	Gramineae
Sorghum versicolor Anderss.	A (robust)	Gramineae
Sporobolus agrostoides Chiov.	Pt	Gramineae
S. angustifolius A. Rich.	P (caespitose)	Gramineae
S. consimilis Fresen.	P (robust tussock grass-stolons/rhizomes)	Gramineae
S. cordofanus (Steud.) Coss.	At	Gramineae
S. festivus A. Rich	Pt	Gramineae
S. fimbriatus Nees	Pt	Gramineae
S. helvolus (Trin.) Th. Dur. & Schinz	Ps	Gramineae

Appendix Table 1. List of plant species identified in 137 sample stands, south Maasailand, 1977 (continued).

Plant Species		Family
S. ioclados Nees	Ps	Gramineae
S. pellucidus Hochst.	P (caespitose)	Gramineae
S. pyramidalis Beauv.	Pt	Gramineae
S. spicatus (Vahl) Kunth	Ps	Gramineae
Tetrapogon cenchriformis (A. Rich.) Clayton	A	Gramineae
Thelopogon elegans Roem. & Schult.	A	Gramineae
Themeda triandra Forsk.	Pt	Gramineae
Tragus berteronianus Schult	A	Gramineae
Urochloa germiculata	A	Gramineae
U. mossambicensis (Hack.) Dandy	A	Gramineae
U. trichopus (Hochst.) Stapf	A	Gramineae
Sedges		
Bulbostylis sp.		Cyperaceae
Cyperus immensus C.B.Cl.		Cyperaceae
C. longus L.		Cyperaceae
C. obtusiflorus Vahl		Cyperaceae
C. rotundus L.		Cyperaceae
Mariscus mollipes C.B.Cl.		Cyperaceae
Forbs and Understory Shrubs	Habit F=forb WS=woody shrub SS=soft shrub C=climber	
Abutilon grandiflorum G. Don	SS	Malvaceae
A. guineense (Schum.) Bak f.	SS	Malvaceae
A. mauritianum Don.	SS	Malvaceae
Achyranthes aspera L.	SS	Amaranthaceae
Aerva lanata (L.) Juss.	F	Amaranthaceae
Amaranthus graecizans L.	F	Amaranthaceae
Aneilema sp.	F	Commelinaceae
Anthericum sp.	F	Liliaceae
Asparagus sp.	SS	Liliaceae
Aspilia mossambicensis (Oliv.) Wild	SS	Compositae
Astripomoea hyoscyamoides (Vatke) Verdc.	SS	Convolvulaceae

Appendix Table 1. List of plant species identified in 137 sample stands, south Maasailand, 1977 (continued).

Plant Species		Family
Asystasia schimperi T. Anders	F	Acanthaceae
Athroisma gracile (Oliv.) Mattf.	F	Compositae
Barleria grandicalyx Lindau	F	Acanthaceae
B. ramulosa C.B.Cl.	WS	Acanthaceae
Becium sp. = Newbold 6425	WS	Labiatae
Bidens pilosa L.	F	Compositae
Blepharis panduriformis Lindau	F	Acanthaceae
Blepharis sp.	F	Acanthaceae
Boerhavia diffusa L.	F	Nytaginaceae
Cassia mimosoides L.	F	Caesalpiniaceae
Chlorophytum affine Bak. var. *affine*	F	Lilaceae
Chlorophytum sp.	F	Lilaceae
Coccinea adoensis (A. Rich.) Cogn.	C	Cucurbitaceae
C. grandis (L.) Voight.	C	Cucurbitaceae
Commelina benghalensis L.	F	Commelinaceae
C. reptans Brenan	F	Commelinaceae
Crabbea velutina S. Moore	F	Acanthaceae
Crassocephalum montuosum (S. Moore) Milne-Redh.	F	Compositae
Craterostigma pumilum Hochst.	F	Scrophulariaceae
Crotalaria burtii Bak. f.	F	Papilionaceae
C. deserticola Bak. f.	F	Papilionaceae
C. laburnifolia L. subsp. *laburnifolia*	SS	Papilionaceae
Crotalaria sp.	F	Papilionaceae
Cucumis figarei Naud.	C	Cucurbitaceae
C. hirsutus Sond.	F	Cucurbitaceae
Cyathula erinacea Schinz	F	Amaranthaceae
C. lanceolata Schinz	F	Amaranthaceae
C. orthocantha (Asch.) Schinz	F	Amaranthaceae
Cynium sp.	F	Scrophulariaceae
Cyphostemma knittelii (Gilg) Descoings	F	Vitaceae
C. orondo (Gilg and Bened) Desc.	F	Vitaceae
Digera muricata (L.) Hart.	F	Amaranthaceae
Dolichos oliveri Schweinf.	SS	Papilionaceae
Duosperma kilimandscharicum (C.B.Cl.) Cayton	WS	Acanthaceae
Emilia javanica (Burm.f.) Merr.	F	Compositae
Erlangea cordifolia (Benth.) S. Moore	F	Compositae

Appendix Table 1. List of plant species identified in 137 sample stands, south Maasailand, 1977 (continued).

Plant Species		Family
Erucastrum arabicum Fisch. & Mey	F	Cruciferae
Euphorbia crotonoides Boss.	F	Euphorbiaceae
E. inaquilatera Sond.	F	Euphorbiaceae
Felicia abyssinica A.Rich. subsp. *neghelensis* (Cuf.) Gran	F	Compositae
Gisekia pharnaceoides L. var. *pharnaceoides*	F	Aizoaceae
Gnaphalium luteo-album L.	F	Compositae
Haarera alternifolia (O. Hoffm.) Hutch. & Blume	F	Compositae
Heliotropium steudneri Vatke	F	Boraginaceae
Hibiscus calyphyllus Cav.	SS	Malvaceae
H. cannabinus L.	SS	Malvaceae
H. flavifolius Ulbr.	SS	Malvaceae
Hirpicium diffusum (Oliv.) Roess.	F	Compositae
Hydnora abyssinica Schw.	Parasite	Hydnoraceae
Indigofera arrecta A. Rich.	SS	Papilionaceae
I. volkensii Taub.	F	Papilionaceae
Ipomoea hildebrantii Vatke	SS	Convolvulaceae
I. longituba Hall. f.	SS	Convolvulaceae
I. mombassana Vatke	C	Convolvulaceae
I. pes-tigridis L.	F	Convolvulaceae
Jatropha sp.	F	Euphorbiaceae
Justicia exigua S. Moore	F	Acanthaceae
J. flava Vahl	F	Acanthaceae
J. heterocarpa T. Anders.	F	Acanthaceae
J. uncinulata Oliv.	F	Acanthaceae
Kedrostis hirtella (Naud.) Cogn.	C	Curcurbitaceae
Kouhatia caespitosa Schizl var. *amaniensis* (K. Krause) Bremek.	F	Rubiaceae
Leonotis mollisima Guerke	SS	Labiatae
Leonotis sp.	SS	Labiatae
Leucas concinna Bak.	F	Labiatae
Melhania ovata (Cav.) Spreng	WS	Sterculiaceae
Momordica boivinii Baill.	C	Cucurbitaceae
Monechma debile (Forsk.) Nees	F	Acanthaceae
Monsonia angustifolia A. Rich.	F	Geraniaceae
Neorautanenia mitis (A. Rich.) Verdc.	SS	Papilionaceae
Neuracanthus sp. A of Upl. Kenya Wild Flowers	WS	Acanthaceae
Notonia coccinea Oliv. & Hiern	F	Compositae
Oxygonum sinuatum (Meisn.) Dammer	F	Polygonaceae
Pavonia patens (Andr.) Chiov.	SS	Malvaceae

Appendix Table 1. List of plant species identified in 137 sample stands, south Maasailand, 1977 (continued).

Plant Species		Family
Pentanisia ouranogyne S. Moore	F	Rubiaceae
Phyllanthus maderaspatensis L.	WS	Euphorbiaceae
Pollichia campestris Ait.	WS	Caryophyllaceae
Portulaca oleracea L.	F	Portulacaceae
P. quadrifida L.	F	Portulacaceae
Rhamphicarpa montana N.E.Br.	F	Scrophulariaceae
Rhynchosia minima (L.) DC. var. A	F	Papilionaceae
Sericocopomsis hildebrantii Schinz.	WS	Amaranthaceae
Sesbania quadrata Gillett	SS	Papilionaceae
Sida ovata Forsk.	WS	Malvaceae
Solanum incanum L.	WS	Solanaceae
S. setaceum Dammer	SS	Solanaceae
Tagetes minuta L.	SS	Compositae
Talinum caffrum (Thunb.) Eckl. & Zeyh.	F	Portulacaceae
Tephrosia subtriflora Bak.	F	Papilionaceae
T. villosa (L.) Pers. subsp. *ehrenbergiana* (Schweinf.) Brummitt	SS	Papilionaceae
Tragia sp.	F	Euphorbiaceae
Trianthema salsoloides Oliv.	F	Aizoaceae
Tribulus terrestris L.	F	Zygophyllaceae
Triplocephalum holstii O. Hoffm.	SS	Compositae
Triumfetta flavescens A. Rich.	SS	Tiliaceae
Vigna frutescens A. Rich. var. *frutescens*	F	Papilionaceae

Appendix Table 2. Summarized constancy table showing absolute and percentage constancy by species for 137 stands, south Maasailand, 1977.

Species	Absolute constancy	Percentage constancy
Cenchrus ciliaris	89	65
Aristida adscensionsis	88	64
Commiphora schimperi	86	63
Themeda triandra	81	59
Solanum incanum	75	55
Tragus berteronianus	69	50
Acacia tortilis	68	50
Commiphora africana	65	47
Grewia bicolor	61	45
Eragrostis cilianensis	56	41
Eustachys paspaloides	50	37
Cynodon nlemfuensis	48	35
Chloris roxburghiana	48	35
Pennisetum mezianum	47	34
Boscia angustifolia	47	34
Chloris virgata	44	32
Dactyloctenium aegyptium	44	32
Panicum coloratum	42	31
Digitaria macrcblephara	39	28
Sporobolus fimbriatus	38	28
Astripomoea hyoscyamoides	38	28
Digitaria milanjiana	38	28
Grewia tembensis	37	27
Sericocomopsis hildebrantii	36	26
Acacia senegal	36	26
Acacia mellifera	34	25
Commiphora madagascariensis	34	25
Balanites aegyptiaca	34	25
Duosperma kilimandscharicum	33	24
Sporobolus festivus	31	23
Cordia sinensis	31	23
Dicanthium radicans	30	22
Eragrostis aspera	29	21
Lannea humilis	29	21
Erlangea cordifolia	29	21
Digitaria velutina	29	21
Urochloa mossambicensis	29	21
Acacia etbaica	28	20
Panicum maximum	27	20
Grewia forbesii	27	20
Brachiaria pubifolia	26	19

Appendix Table 2. Summarized constancy table showing absolute and percentage constancy by species for 137 stands, south Maasailand, 1977 (continued).

Species	Absolute constancy	Percentage constancy
Heteropogon contortus	26	19
Microchloa kunthii	26	19
Eragrostis superba	26	19
Acacia nilotica	25	18
Heliotropium steudneri	24	17
Dicanthium insculptum	22	16
Talinum caffrum	22	16
Cordia ovalis	21	15
Tribulus terrestris	21	15
Acacia ancistroclada	19	14
Brachiaria serrifolia	19	14
Croton menyhartii	19	14
Sporobolus pyramidalis	19	14
Lannea stuhlmanii	19	14
Cyathula erinacea	18	13
Zanthoxylum chalybeum	18	13
Sporobolus pellucidus	17	12
Acacia brevispica	17	12
Oxygonum sinuatum	16	12
Chloris pycnothrix	16	12
Aristida mutabilis	16	12
Asparagus sp.	16	12
Alloteropsis cimicina	16	12
Ipomoea hildebrantii	15	11
Erythrina burtii	15	11
Maerua crassifolia	15	11
Panicum hanningtonii	15	11
Sporobolus helvolus	15	11
Ormocarpum trachycarpum	15	11
Ocimum sp.	14	10
Azanza garckeana	14	10
Dinebra retroflexa	14	10
Cyathula orthocantha	14	10
Neuracanthus sp.	14	10
Commelina benghalensis	13	9
Poupartia birrea	13	9
Commiphora mollis	13	9
Digera muricata	13	9
Grewia villosa	13	9
Brachiaria leersiodes	13	9

Appendix Table 2. Summarized constancy table showing absolute and percentage constancy by species for 137 stands, south Maasailand, 1977 (continued).

Species	Absolute constancy	Percentage constancy
Setaria pallide-fusca	13	9
Harpachne schimperi	12	9
Brachiaria semiundulata	12	9
Albizia amara	12	9
Euphorbia cuneata	12	9
Heeria reticulata	11	8
Cadaba farinosa	11	8
Lippia ukambensis	11	8
Lintonia nutans	11	8
Aspilia mossambicensis	11	8
Croton polytrichus	11	8
Cassia mimosoides	11	8
Dichrostachys cinerea	10	7
Pennisetum stramineum	10	7
Setaria acromelana	10	7
Domeya sp.	10	7
Eragrostis rotifer	10	7
Echinochloa colona	9	7
Barleria ramulosa	9	7
Setaria verticillata	9	7
Cymbopogon excavatus	9	7
Urochloa germiculata	9	7
Rhus tenuinervis	9	7
Cyphostemma orondo	9	7
Lonchocarpus eriocalyx	9	7
Setaria holstii	9	7
Urochloa trichopus	8	6
Mariscus mollipes	8	6
Combretum molle	8	6
Dombeya rotundifolia	8	6
Indigofera volkensii	8	6
Maytenus heterophylla	8	6
Eriochloa nubica	8	6
Albizia anthelmintica	8	6
Euphorbia candelabrum	8	6
Premna oligotricha	8	6
Cynodon plectostachyus	8	6
Acacia seyal	8	6
Leucas concinna	7	5
Croton dichogamous	7	5

Appendix Table 2. Summarized constancy table showing absolute and percentage constancy by species for 137 stands, south Maasailand, 1977 (continued).

Species	Absolute constancy	Percentage constancy
Brachiaria eruciformis	7	5
Cassia abbreviata	7	5
Maerua parvifolia	7	5
Ormocarpum trichocarpum	7	5
Aristida hordeacea	7	5
Cyathula orthocantha	6	4
Adansonia digitata	6	4
Thelopogon elegans	6	4
Eragrostis caespitosa	6	4
Portulaca oleracea	6	4
Commiphora mossambicensis	6	4
Aristida kenyensis	6	4
Ochna ovata	6	4
Enneapogon cenchroides	6	4
Euphorbia scheffleri	5	4
Dicanthium annulatum	5	4
Brachiaria sp.	5	4
Terminalia brownii	5	4
Capparis tomentosa	5	4
Clerodendrum sp.	5	4
Justicia exigua	5	4
Justicia flava	5	4
Blepharis sp.	5	4
Neorautanenia mitis	5	4
Boerhavia diffusa	5	4
Rhus natalensis	5	4
Mundulea sericea	5	4
Crabbea velutina	5	4
Setaria incrassata	5	4
Solanum arundo	5	4
Tephrosia subtriflora	5	4
Lannea triphylla	5	4
Cordia quarensis	4	3
Vernonia cinerascens	4	3
Panicum porphyrrhizos	4	3
Sorghum versicolor	4	3
Cassipourea mollis	4	3
Commiphora caerulea	4	3
Monechma debile	4	3
Cyperus rotundifolia	4	3

Appendix Table 2. Summarized constancy table showing absolute and percentage constancy by species for 137 stands, south Maasailand, 1977 (continued).

Species	Absolute constancy	Percentage constancy
Rhynchelytrum repens	4	3
Cyphostemma knittelii	4	3
Anthericum sp.	4	3
Rottboellia exaltata	4	3
Sida ovata	4	3
Acacia drepanolobium	4	3
Dalbergia melanoxylon	4	3
Euphorbia crotonoides	4	3
Gisekia pharnaceoides	4	3
34 species	3	2
33 species	2	1.5
90 species	1	.7

Appendix Table 3. Sums of squares and percentage extractions for stand ordinations.

27 Stand Ordination (Fig. 5)

Axis	SS	% Extraction
X	243593.38	38.52
Y	152228.44	24.07
Z	77101.00	12.19
TOTAL		74.78

46 Stand Ordination (Fig. 6)

Axis	SS	% Extraction
X	204418.50	24.35
Y	177261.75	21.11
Z	86725.69	10.33
TOTAL		55.79

MAASAI NAMES OF GRASSES

Several of the less common grasses have no names and are referred to simply as grass (okujita), while other species of obvious taxonomic difference but similar forage value are lumped together under a single name. Thus grasses are often viewed and named on the basis of functional rather than taxonomic criteria.

Of the grass species which are recognized by name, two general categories can be differentiated. In the first are those grasses which have individually exclusive names. These species are usually either very widespread and abundant (*Themeda triandra*), and/or have noticeable morphological or ecological characteristics (*Sporobolus spicatus*, *Pennisetum mezianum*), or less commonly a peculiar use distinctive from grazing (*Sporobolus consimilis*).

The second category is comprised of groups of species of similar grazing value which are often named after one characteristic grass within the group. Thus, while the name refers specifically to one grass (e.g. *Digitaria macroblephara*), other species of similar palatability (e.g. *Panicum coloratum*) are somewhat loosely referred to by the same name even though taxonomic differences are recognized.

Appendix Table 4. Common grass species, their Maasai names and Maasai rated palatability (refers to Ilkisongo Maasai). See attached statement.

Grass species	Maasai name	Maasai rated palatability and comments
Aristida spp.	Orkiriaan	"useless grass" "cattle eat it when it's green and a bit when it's dry but it's very susceptible to wind and trampling and cattle can't eat it once it's laying flat"
Cenchrus ciliaris	Endiamoinwa	"very good for cattle - lasts during the dry season" "a good grazing grass especially common in the drier (orpurkel) areas"
Chloris pycnothrix	Engipumbu (Orkiriaan)	"useless for cattle"
Chloris roxburghiana	Engaidosi	medium quality grass
Cymbopogon excavatus	Olkujita lorung'ojinia (literally: hyena grass)	"cattle hate it - they would be better off eating paper"
Cynodon nlemfuensis *C. plectostachyus*	Emurruwa	"cattle prefer it because it remains green after other grasses have dried up" "it is poisonous in early growth stages (from beginning of rains until January) so that herders avoid it at that time"
Dicanthium annulatum *D. insculptum* *D. radicans*	Olkujita lorung'ojinia (literally: hyena grass)	"cattle don't graze these grasses because of the smell" (high in essential oils)

Appendix Table 4. Common grass species, their Maasai names and Maasai rated palatability (continued).

Grass species	Maasai name	Maasai rated palatability and comments
		"cattle will only eat them during periods of acute forage shortage in the dry season"
Digitaria macroblephara	Erikaru (refers specifically to this grass although other grasses of similar palatability are often loosely called by this name as well)	probably considered to be the best grazing grass throughout Maasailand "the number one food for cattle" "very good grass for cattle-their faeces are good and firm while eating this"
Enteropogon macrostachyus	Olopikidong'oi	medium quality grass
Eragrostis aspera *E. cilianensis*	Engipumbu	poor quality grasses
Eragrostis superba	Erikaru	good quality but inferior to *Digitaria macroblephara*
Eustachys paspaloides	Engaidosi	"good for cattle at all seasons" "cattle can eat leaves and still have the stems to eat"
Harpachne schimperi	Orkiriaan	"useless grass - only comes up during the rains"
Heteropogon contortus	Emba crong'ojinia	medium palatability "good for wet season - worthless dry season" considered a "brother" to *Themeda triandra*
Hyparrhenia hirta	Asajilo	Medium palatability "cattle eat leaves but not culms"

Appendix Table 4. Common grass species, their Maasai names and Maasai rated palatability (continued).

Grass species	Maasai name	Maasai rated palatability and comments
Microchloa kunthii	Ongonyoro	"if a cow has only this to eat it will die"
Panicum coloratum	Erikaru	"good quality grass - similar to Digitaria macroblephara"
Panicum maximum	Embalakai	"good for grazing"
Pennisetum mezianum	Ologor aingok (literally: that which strangles bulls)	"good only after a burn and in the wet season - too stemmy and hard in the dry season"
Pennisetum stramineum	Asangash	"eaten mainly in the wet season as it becomes quite coarse in the dry season"
Sorghum versicolor	Orpau	"cattle don't like it"
Sporobolus consimilis	Orkerian	"cattle eat in the dry season for while it is tough and coarse, it always has green shoots"
Sporobolus helvolus	Oloiyeti	good quality grass
Sporobolus ioclados	Ngera matean	good quality grass
Sporobolus pellucidus	Olonyoro	poor for grazing
Sporobolus spicatus	Orpuriash	"cattle only eat during stress periods - if they eat too much in dry season they'll die because their faeces dry up" "if you see a cow eating this grass, you know it is near the point of starvation

Appendix Table 4. Common grass species, their Maasai names and Maasai rated palatability (continued).

Grass species	Maasai name	Maasai rated palatability and comments
		at which it will begin to eat its own faeces"
Themeda triandra	Olkujita onyokie	"good for wet season grazing but its power doesn't hold over into the dry season" "cattle grazing this grass in the dry season will lose condition-however it will stave off starvation"
Tragus berteronianus	Ong'onyoro	"if a cow eats only this it will die"

Appendix Table 5. Dry season population estimates of water-dependent wild ungulates based on actual and track counts at permanent water sources, south Maasailand, dry season, 1975.

Water source	Ungulate numbers					
	elephant	rhino	eland	buffalo	zebra	wildebeest
Ndigera waterholes	287	2	15	12	0	0
Ndorobo waterholes	540	7	39	205	50	0
Loibor Sirret river	127	16	2	131	39	0
Mondui river	53	7	89	453	41	0
Narakau wells	25	1	0	10	0	0
Naibormurt pools	3	2	0	6	0	0
Kitiangare river	118	8	0	152	35	50
Sukuro dam	11	0	0	0	7	65
Eluenye dam	8	0	0	0	0	0
Terat river	0	1	0	0	0	0
Loiborsoit wells	0	3	0	1	0	0
Lolkisale wells	10	0	0	3	0	0
TOTALS	1182	47	145	973	172	115

Appendix Table 6. Total numbers of animals recorded along transects by species and habitat, wet seasons, 1975-76, south Maasailand.

Habitat	Numbers of animals							
	cattle	zebra	wildebeest	impala	eland	G.gazelle	kongoni	oryx
PD(sG)	3608	3101	10657	1	159	447	0	0
PDC(WG)	4470	2111	1324	229	36	226	24	0
TPC(WG)	50	742	100	281	52	42	158	47
mTPC(WG)	1875	247	18	139	28	112	32	11
dAC(W/WG)	570	130	21	65	0	42	5	0
AC(WG)	25	40	55	70	0	0	10	0
ALAn(W/WG)	335	6	0	117	0	0	20	0
DTC(BG)	200	201	0	85	59	0	109	8
LCG(B)	0	0	0	47	0	0	0	0
GCAt(B/Bt)	1380	58	0	254	20	0	0	0
AtCn(BG)	450	0	0	70	1	0	0	0
UCAt(BG)	1220	261	130	326	257	77	77	139
CSVL(BG)	260	0	0	0	0	0	0	1
aPDCAm(G/BHG)	4110	1745	1580	15	545	279	12	245
bPDCAm(G/BHG)	350	62	50	0	385	70	0	1
Pm(G)	3745	756	320	0	111	62	0	0
Sh(G)	2450	1034	1403	0	115	155	0	0

Appendix Table 7. Distances traversed along wet season transects and adjustment factors based on mean visibility of ungulates in each habitat.

Habitat	Distance traversed(km)	Adjustment factor
PD(sG)	572	1
PDC(WG)	305	1.67
TPC(WG)	162	1.67
mTPC(WG)	197	1.67
dAC(W/WG)	244	1.67
AC(WG)	42	1.43
ALAn(W/WG)	175	2.5
DTC(BG)	90	2
LCG(B)	83	3.33
GCAt(B/Bt)	424	5
AtCn(BG)	39	1
UCAt(BG)	321	1.67
CSVL(BG)	50	2
aPDCAm(G/BHG)	317	1
bPDCAm(G/BHG)	95	1.25
Pm(G)	141	1
Sh(G)	145	1

Appendix Table 8. Ungulate densities by species and habitat (animal/km^2), wet seasons, 1975-76, south Maasailand.

Habitat	Animal densities*							
	cattle	zebra	wildebeest	impala	eland	G. gazelle	kongoni	oryx
PD(sG)	6.3	5.4	18.6	0	0.3	0.8	0	0
PDC(WG)	24.5	11.5	7.2	1.3	0.2	1.2	0.1	0
TPC(WG)	0.5	7.6	1.0	2.9	0.5	0.4	1.6	0.5
mTPC(WG)	9.5	2.1	0.2	1.2	0.2	0.9	0.3	0.1
dAC(W/WG)	3.9	0.9	0.1	0.4	0	0.3	0.03	0
AC(WG)	0.9	1.4	1.9	2.4	0	0	0.3	0
ALAn(W/WG)	4.8	0.1	0	1.7	0	0	0.3	0
DTC(BG)	4.5	4.5	0	1.9	1.3	0	2.4	0.2
LCG(B)	0	0	0	1.9	0	0	0	0
GCAt(B/Bt)	16.3	0.1	0	3.0	0.2	0	0	0
AtCn(BG)	11.7	0	0	1.8	0	0	0	0
UCAt(BG)	6.3	1.4	0.7	1.7	1.3	0.4	0.4	0.7
CSVL(BG)	10.4	0	0	0	0	0	0	0
aPDCAm(G/BHG)	13.0	5.5	5.0	0.05	1.7	0.9	0.04	0.8
bPDCAm(G/BHG)	4.6	0.8	0.7	0	5.1	0.9	0	0
Pm(G)	27.0	5.4	2.3	0	0.8	0.4	0	0
Sh(G)	17.0	7.2	9.7	0	0.8	1.1	0	0

*Number of animals ÷ distance traversed x adjustment factor

SEASONAL DISTRIBUTIONS AND INTERACTIONS OF CATTLE AND WILD UNGULATES IN MAASAILAND, TANZANIA

by

David Dean Peterson

(ABSTRACT)

In Tanzania, both wildlife and livestock are recognized as resources of economic potential. Where they overlap, land use conflicts have arisen. This study was undertaken to determine aspects and areas of competition between cattle and wild ungulates in Maasailand, east of Tarangire Park. Subsistence pastoralism was the main form of land use and was the object of livestock development efforts. The area also was the wet season dispersal area for Tarangire ungulates and harbored a smaller number of resident wildlife.

Comparison of habitats of similar potential but different management history indicated that much of the cattle area was in suboptimal condition. This was attributable partly to the restricted distribution of cattle due to tsetse infestation. Maasai movement patterns were discussed in relation to factors which contributed to habitat deterioration. It was concluded that changes in traditional attitudes towards livestock husbandry were necessary for full realization of land use objectives.

Based on dry season counts at water sources it was postulated that cattle, because of greater numbers and a restricted distribution due to their owners' directive influence, greater disease susceptibility and water constraints, outcompeted wild grazers during this time of resource scarcity. Wet season ungulate distributions were determined by counts along driven transects. It was concluded that wildebeest and zebra, in particular, competed indirectly with cattle for food through their use of the cattle belt where forage was limited in the dry season. Cattle appeared to compete directly with grazing ungulates preferring tall grass habitats (kongoni, oryx), while facilitating use of the herb layer by species preferring short grasses (wildebeest, Grant's gazelle).