HABITAT USE BY THE WHITE RHINOCEROS IN RELATION TO OTHER GRAZING UNGULATES IN PILANESBERG GAME RESERVE, BOPHUTHATSWANA.

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DECLARATION

I declare that this dissertation is all the work of Michael Robert BORTHWICK.

It is being submitted posthumously for the degree of Master of Science in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other university.

Dr R.N. Owen-Smith (Supervisor)

27th day of March, 1986.

HABITAT USE BY THE WHITE RHINOCEROS IN RELATION TO OTHER GRAZING UNGULATES IN PILANESBERG NATIONAL PARK, BOPHUTHATSWANA

MICHAEL ROBERT BORTHWICK

ABSTRACT

This study investigated resource use by the white rhinoceros (Ceratotherium simum) as a basis for assessing the carrying capacity for this species in Pilanesberg Game Reserve, Bophuthatswana. The resources considered included (i) habitat types, and (ii) food in terms of grassland structures. Their use by white rhinos was analysed in relation to resource use by other grazing ungulates.

White rhinos favoured secondary grasslands during the wet season, and wooded valley savanna and thicket during the dry season. Shorter grassland was generally favoured, except during the late dry season. Habitat selection became more broad after fire. Correspondence analysis confirmed tree canopy cover and grass height as the major factors in vegetation type selection.

Discriminant function analysis showed that wildebeest overlapped most with white rhino in their habitat use, and zebra least. Dietary overlap during the dry season was also high between white rhino and wildebeest. Total niche overlap considering both habitat and diet was considerably less than indicated on either single resource axis.

Two standard methods and modifications thereof for assessing carrying capacity were applied: (i) relation between ungulate metabolic biomass and rainfall; (ii) assessments of agricultural stocking density. Shortcomings were identified. A novel "weighted consumption" model for assessing carrying capacity was developed. This model highlighted a need for further information on minimum grazing thresholds for different grassland types.

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CHAPTER ONE

INTRODUCTION

1.1 Background to Study

In the face of increasing pressures from human expansion and urbanization, the long term survival of many species and communities depends on their protection within fenced boundaries. Invariably, these areas are smaller than the original ranges of at least some of the species they contain, and consequently prevent herbivore migration in response to increasing population and habitat deterioration. Most reserves in southern Africa are small (less than 500 sq. km, East 1981), thus restricting the free movement of herbivores to a limited choice of habitats. These seasonal migratory habits allow for the dispersal of herbivores between their wet season and dry season ranges. For instance, Maddock (1979) found that wildebeest, zebra and Thomson's gazelle all migrate between their wet season range on the open plains and their dry season range in the woodlands. He concluded that both food and water availability (and indirectly rainfall) were the major factors influencing their annual movements.

A severing of the herbivores' dispersal patterns could lead to a reduction in the ability of the reserves to support the high densities which were originally present (Maddock, 1975, 1979; Western, 1975). Berry and Siegfried (1979) showed that a marked downward trend occurred in the wildebeest (<u>Connochaetes</u> <u>taurinus</u>) population of the Etosha National Park after their seasonal migration routes were prevented by a boundary fence. Western (1975) estimates that if the seasonal migration of herbivores in the Amboseli Nature Reserve (3000 sq. km) in southern Kenya were severed, it would lead to a 30% reduction in biomass. The herbivores would now have to forage in habitats which were previously avoided.

Long distance dispersal such as migration, is of course not the only type of movement prevented by boundary fences, movement from one habitat or valley to another is of equal importance. This type of movement involves all animals irrespective of whether they are migrants or not. Owen-Smith (1981) stressed the importance of herbivore management, in terms of white rhino removals, in the Umfolozi-Corridor-Hluhluwe Game Reserve Complex. With the construction of a rhino proof fence, dispersal into the surrounding less productive areas was prevented. This has consequently led to an overabundance of white rhinos in the reserve and a rapid overutilization of their habitat. Thus the ability to assess the affects of boundaries on herbivore feeding ecology is an important prerequisite for sound management both on the short- and long-term basis.

The Pilanesberg Game Reserve in Bopnuthatswana (53500 ha) is a typical example of such an "island" reserve. It was proclaimed in 1979 in an old agricultural area. One of the major questions facing management is how many animals and which species should be stocked. In particular, the number of white rhinoceroses (Ceratotherium simum) is crucial firstly, because they are most valuable economically and, secondly, in their capacity as "megaherbivores" (Owen-Smith, 1981), they are most capable of modifying the vegetation. It was these problems which led to the development of this project.

The problem of small game reserves is compounded by the fact that they are based on arbitrary or political rather than natural boundaries. The Pilanesberg Game Reserve is situated in the crater of an extinct volcano and because of its generally hilly topography and alkaline soils the vegetation is relatively less productive than the surrounding flat "sweet-veld" areas (Tinley, 1978). Based on verbal accounts (Tinley, 1978) most of the herbivores present in the reserve today used the crater as a marginal habitat possibly during the drier periods. Consequently, with the construction of the boundary fence and the rapid urbanization of the surrounding areas, local seasonal movements between habitats was prevented, hence lowering the potential carrying capacity of the reserve. In addition, prior to its establishment much of the reserve, especially the more productive valleys were divided into a number of farms on which cultivation and cattle farming were practised. Since their abandonment, these areas have developed into secondary grasslands and thickets of various successional stages. Consequently, man's presence over the years has altered the natural state of these habitats, necessitating a need for an understanding of these modified areas in relation to herbivore selection and distribution (Vernede, 1983).

1.1.1 Carrying Capacity

Meissner (1982) expressed the importance of the concept "carrying capacity" as a prerequisite for the development of sound management systems, planning of reserves and their evaluation in terms of secondary production, particularly those involving multiple species. Theoretically this may be sound, but when applied practically it leads to confusion giving rise to a number of problems.

The distinction between the "economic" and the "ecological" carrying capacities has caused conceptual difficulties and misunderstandings (Caugnley, 1976, 1981) especially between wildlife managers and agriculturalists. The ecological carrying capacity is defined as the "number or biomass of animals which come into equilibrium with the vegetation" (Caughley, 1976). In this case there is no need to estimate carrying capacity numbers, since the ecological carrying capacity is simply that number of animals that will be there when the numbers have stopped changing. However, if one is interested in the economic or grazing carrying capacity, i.e. the stocking density at which the net yield in animal biomass is at a maximum (Caughley, 1976), then the animal numbers must be monitored in order to predict this density.

The second difficulty when applying this concept lies in the accuracy of calculating the carrying capacity density. Being complex and dynamic, it necessitates the simultaneous inclusion of ecological factors such as interseasonal variation, spatial variability within the community, plant species composition, interactions between plants and herbivores, seasonal changes in plant food value, and interactions between the herbivores. If simplified, two main aspects of a plant-herbivore system must be recognized, namely, the availability of the resources and the animal requirements, whether in terms of protein or energy. It must be stressed that the numerical calculation of carrying capacity on a long-term basis becomes far more complex when the inclusion of environmental fluctuations and time lag effects are included. In response to these difficulties, Moen (1973) concluded that the idea of carrying capacity is best approached as a concept rather than as a simple, definable entity. A more extensive literature review of the concept of carrying capacity is presented in chapter six.

Attempts to develop objective approaches in estimating carrying capacity numbers have been largely confined to agricultural livestock on which considerable emphasis is placed on experience and guesswork. This problem is compounded when considering a multispecies wildlife system in which different interactive effects on the vegetation by the herbivore species is apparent. The estimation of carrying capacity and the subsequent management of nature reserves or cattle ranches should therefore be based on analyses at the community or ecosystem level. Analyses of this nature cannot be focussed on single species independent of their interactions. It is the mechanisms which regulate both the plant and animal densities which are important.

1.1.2 Resource Use

Estimating carrying capacity numbers essentially involves an analysis of the use of resources within the ecosystem or community. Resource use can be influenced by two important factors, namely, the availabilty of the resource type and the selection for those resources (eg. habitat and food) by the animals. The pattern of resource use may of course be affected by other coexisting consumers. Hence, consumer interactions should also be analyzed.

Two major processes or mechanisms which are believed to contribute to the patterning of resource allocations among species, and their spatial and temporal abundances, are competition and predation (Schoener, 1974). Connell (1975) maintained that although the distribution and abundance of species (e.g. barnacles) are ultimately determined by their tolerances to extremes of physical conditions, smaller differences result from interactions with other organisms. The two interspecific interactions occur either between trophic levels, i.e. predation, or within trophic levels, i.e. competition. Consequently, the extent of both competition and predation should influence the carrying capacity of a predator-prey or plant-herbivore system.

Niche packing, niche overlap and the factors governing both niche breadth and shape are all important factors in the determination of community structure and resource partitioning (Thomson and Rusterholz, 1982; Hanski, 1978; Lawlor, 1980). Various models have shown that the presence of a competitor reduces the equilibrium number of a species (e.g. Rosenzweig, 1979). The determination of the degree of niche overlap between species should allow for a better understanding of the extent of the interactions. Consequently, a knowledge of the niche metrics within a community would provide valuable information for estimating combined carrying capacities with respect to various mixtures of the two species.

Food supply, being an important parameter in regulating the population size of herbivores, should therefore provide insight into the basic principles governing the structure of ecosystems. Duncan (1975) maintained that the extent of utilization of the various components is greatly influenced by interspecific competition between predators (or herbivores). This again emphasizes the need for analysing dietary niche overlap within multispecies systems. Chapter five discusses the theory of niche overlap and its relationship to carrying capacity in more detail.

1.1.3 The White Rhinoceros

To date, only two studies in southern Africa (Owen-Smith 1973 and Condy, 1973) have been done on the biology of the white rhinoceros. Although greater emphasis was placed on their behavioral ecology, certain aspects of their feeding ecology were noted.

The white rhinoceros is regarded as a short grass grazer (Player and Feely, 1960; Foster, 1967) but generally utilizing the long grass areas during the drier periods or under higher population densities (Owen-Smith, 1973). Thus there appears to be a seasonal shift from regions of lawn-like grasslands to long grass areas, with a greater preference for the former (Owen-Smith, 1973). However, this apparent higher preference for short grasslands may simply be a reflection of the intense grazing pressure exerted by these animals, and hence does not adequately depict their true habitat choice.

Owen-Smith (1973) found that the white rhinos in the Umfolozi Game Reserve favoured the short creeping grasses such as Urochloa mosambicensis, Panicum coloratum, and Sporobolus smutsii. These species are characteristic of a low structural cellulose to cellular content ratio, i.e. highly nutritious. During the drier season however, increasing use is made of the taller grass species , e.g. Themeda triandra, Panicum maximum and Digitaria argyrograpta which have a high structural cellulose to cellular content ratio. The critical condition of these animals is believed to be dependent on the length of time that they have to utilize this submaintenance diet. However, because of their faster rates of food passage these non-ruminants can extract more protein per unit time and can therefore survive better than most ruminants on this fibrous forage (Bell, 1971; Jarman, 1972). Furthermore, because of their lower metabolic rates these animals lose weight relatively more slowly than smaller species and consequently should be able to survive better than their competitors (Owen-Smith, 1973). This relationship between forage choice, body mass and digestive techniques, known as the Bell-Jarman principle (Geist, 1975) has been used to explain the relatively high white rhino biomass in both the Umfolozi Game Reserve (60% of the herbivore biomass - Owen-Smith, 1973; 1981) and the Rwenzori National Park, Uganda (40% of the herbivore biomass - Field and Laws, 1970). White rhinos are therefore an important grazing ungulate to consider when relating herbivore densities to habitat impact.

1.2 Scope and Objectives

Over 250 white rhinos have been introduced into the Pilanesberg Game Reserve over the past four years. This amounts to over 450 000 kg of live grazing biomass out of a total of approximately 1,5 million kg, i.e. just under 30% of the total ungulate biomass is white rhino. However, in terms of stocking density, it represents a density of only 0.75 kg/ha.

The overall objective of this study was to provide an estimate of the numbers of white rhino which the reserve could safely stock, given different combinations of numbers of the other grazing species. The specific objectives required to meet the overall aim were:

(i) To record, on a seasonal basis, the spatial distribution and habitat use of those grazers in the reserve which overlap with the white rhino, i.e. wildebeest (<u>Connochaetes taurinus</u>), hartebeest (<u>Alcelaphus buselapha</u>), zebra (<u>Equus burchelli</u>) and impala (<u>Aepycerus melampus</u>).

(ii) To determine the dietary composition of each of these herbivores in each habitat.

(iii) To analyze those features of the grassland structure and species composition which influence habitat selection.

(iv) To measure the association and degree of overlap in both habitat use and dietary selection between the white rhinos and the other potential competitive grazers.

1.3 Approach

Initially, the major habitats in the reserve were classified according to the plant species composition (bulk contribution) of the herbaceous layer, topography and successional stage.

The diet and habitat selection of the major ungulate grazers was determined, with special emphasis placed on the white rhinoceros. Then, with the knowledge of the relationship between the diet and grassland structure (height, biomasss, and proportion of the different grasses), the degree to which the herbivores select the different grassland types was analyzed. Overlap measures between the white rhino and the associated grazers were then calculated using the selection coefficients determined along both the habitat and dietary niche dimensions (refer to chapter five).

Finally, four different methods of calculating carrying capacity were presented. The first two are the standard methods currently used by agriculturalists based on the relationship between rainfall and maximum supportable herbivore biomass (Coe, et al, 1976). The third and fourth are modifications of the previous two. A model based on a supply and demand approach is presented which analyzes the importance of the "minimum grazing threshold" on carrying capacity assessments.

CHAPTER TWO

THE STUDY AREA

2.1 Location

The Pilanesberg Game Reserve, Bophuthatswana is situated in the Western Bushveld, between latitudes 25 degrees 10 minutes - 25 degrees 20 minutes, south and 26 degrees 5 minutes - 27 degrees 10 minutes, east. The reserve is situated within an extinct volcano, approximately 50km north of Rustenburg, Transvaal. It is approximately 53500 ha in size and is on average 26 km in diameter. A number of cattle and agricultural farms border the reserve. The town Heystekrand borders the eastern boundary.

2.2 Climate

The Pilanesberg Game Reserve occurs within the drier end of the intermediate or mesic biome (Tinley, 1978). The climate, which is typically subtropical has been divided up into three seasons (Tinley, 1978), the hot-wet season extending from November to March and the cooler drier period until July, followed by the hot-dry period from August to October.

The annual rainfall, measured at the Pilanesberg Police Station and Saulspoort Hospital since 1961 (supplied by the weather bureau in Pretoria), is shown in Figure 2.1. The mean annual rainfall for the 22 year period was 620 mm. The 1960's were generally below average, while the 1970's were above average. Severe droughts occurred during the periods, 1962-63, 1964-65 and 1970 and again during the 1981-82 and 1982-83 seasons. In general, the central valley station (Pilanesberg Police Station) some 50m higher in altitude than the peripheral poort station (Saulspoort Hospital) has a lower rainfall.

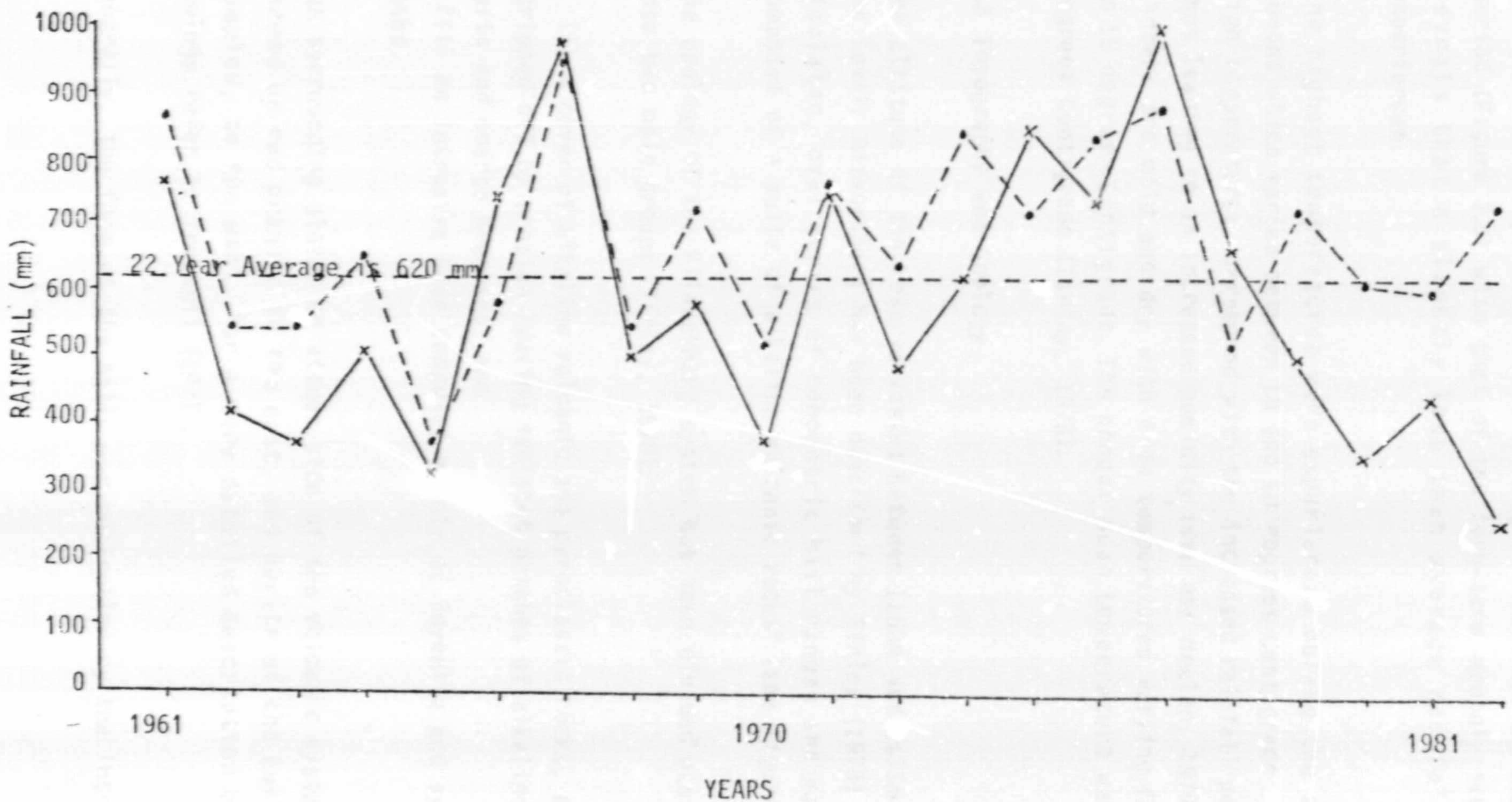


Figure 2.1 : Annual Rainfall over 22 years at two Weather Stations outside the Pilanesberg Game Reserve. (x—x is the Pilanesberg Police Station, 25 15'S, 27 07'E and •---• is the Saulspoort Hospital, 25 10'S, 27 10'E).

Figure 2.2 illustrates the average monthly rainfall figures of the two weather stations, for the 22 year period. December and January are the wetter months with June, July and August being the driest. A comparison of the monthly rainfall during the study period (Figure 2.3) with that of the long-term monthly averages, reveals that a slightly less than average rainfall was experienced.

The highest temperatures were experienced during the summer months which varied between 18 and 20 degrees Centigrade . These high temperatures correspond with the increased rainfall periods, thus leading to an increased humidity (van der Meulen, 1979). The winters are mild and dry with mean temperatures varying from 12 to 18 degrees Centigrade. The annual mean temperature was 18.6 degrees Centigrade (Tinley, 1978).

2.3 Topography and Geology

The altitude of the reserve varies between 1160m and 1675m above sea level. Pilanesberg has been described by Tinley (1978) as an "isolated, oval series of concentric hill ranges and valleys composed of a suite of alkaline volcanic rocks" (see Figure 2.4).

The geology of the Pilanesberg system has been divided basically into two main groups (Tinley, 1978);

(i) A cover of alkaline volcanic and pyroclastic rocks, mostly stripped off by erosion leaving isolated patches of alkaline lava tufts and coarse breccias, and

(ii) an intrusive base composed mainly of foyenite and syenite rocks.

The surrounding plains on either side of the volcanic system are formed on red granite to the east, and norite of the Bushveld complex, to the west. For a more detailed description of the geology refer to Truswell (1977).

Generally, the form of the hills was controlled by the intrusive

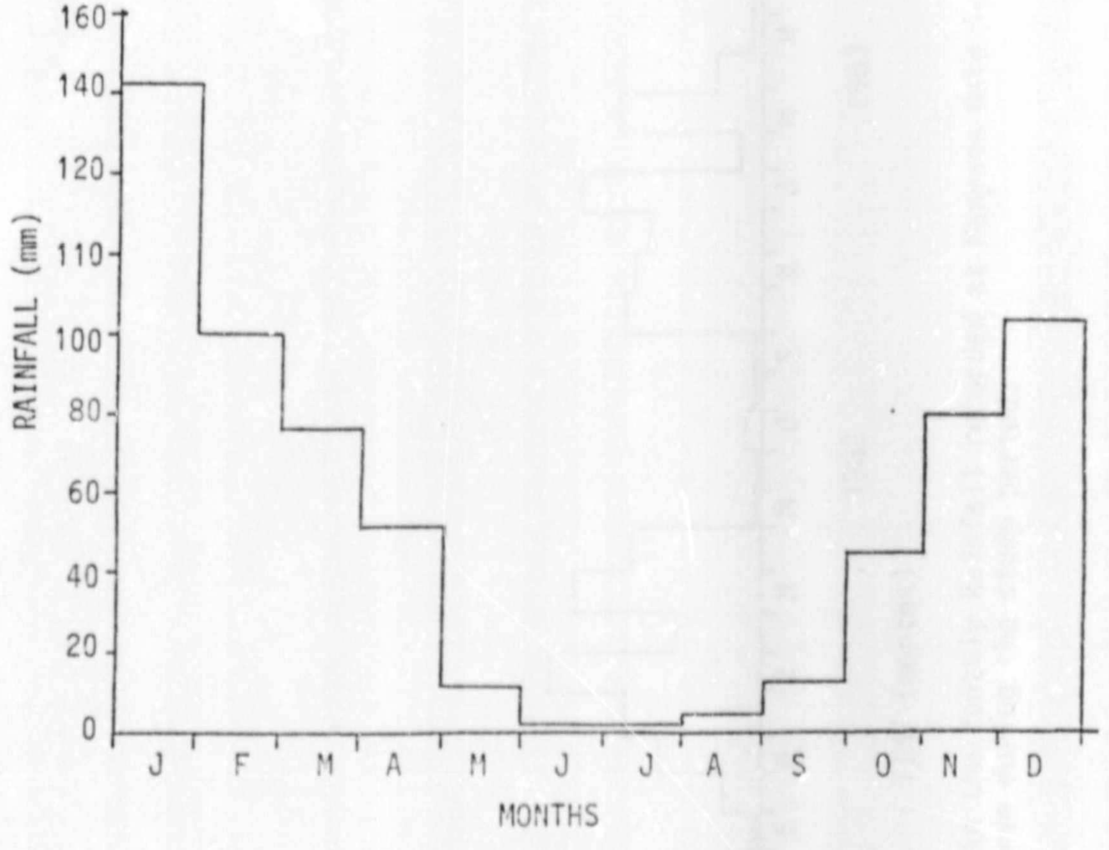


Figure 2.2 : Average Monthly Rainfall at the two Weather Stations, Saulspoort Hospital (25 10' S, 27 10' E) and Pilanesberg Police Station (25 15' S, 27 07' E) outside the Pilanesberg System.

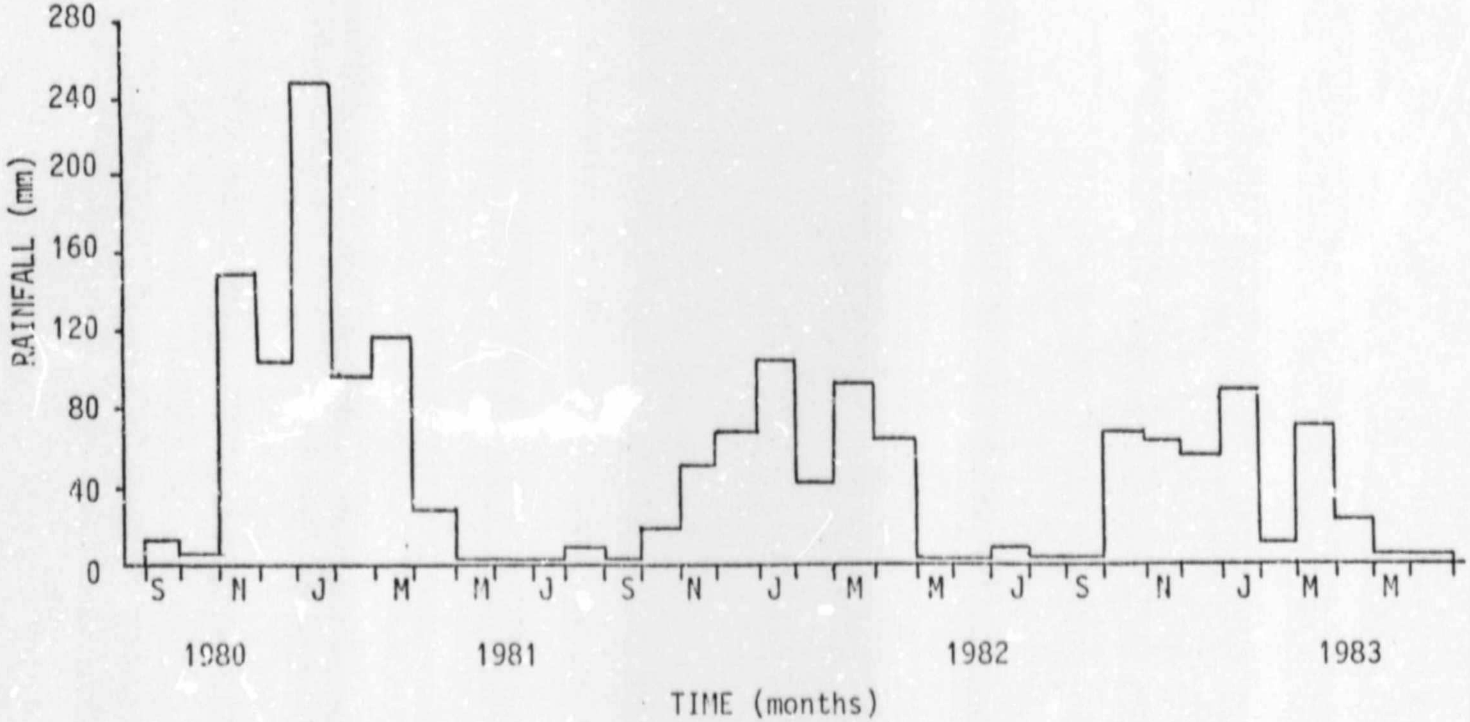


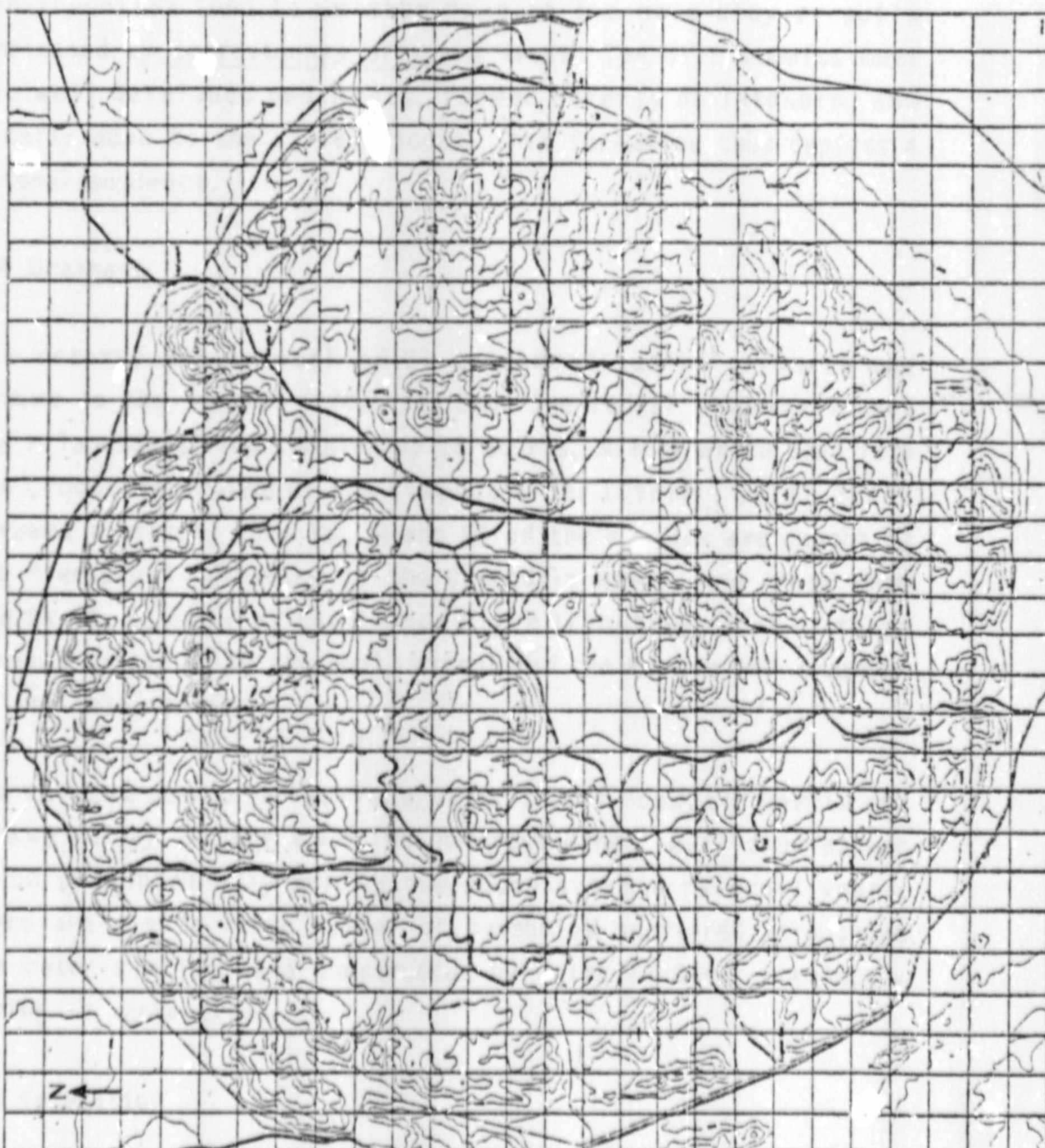
Figure 2.3 : Seasonal Differences in the Monthly Rainfall recorded at Manyane Gate in the Pilanesberg Game Reserve during the study period.

Figure 2.4 : Contour Map of the Pilanesberg Game Reserve.

KEY:

—·— = Boundary of reserve.

═══ = Roads



rocks forming the hill cores with their outcroppings indicated by dense tree cover. The syenites weather down to the sandier soils (dominated by tree species such as Combretum zeyheri), whereas the foyenites tend to weather down to the more clayier soils dominated by Spirostachys africana trees. The hill summits meet the well developed pediments, formed chiefly on latosols, and finally down to the valley floors. This formation thus depicts a catenal sequence.

2.4 Drainage

The reserve has a total of 21 catchment basins of which the Mankwe is the largest (178,7 sq. km). The radial drainage leaves the Pilanesberg ring complex by 16 poorts, all of which lead into the Crocodile branch of the Limpopo River (Tinley, 1978). Those streams radiating from NW, N and NE of the complex are caught by the Bierspruit tributary of the Crocodile River, and those from the SW, S, SE and E by the Elands River tributary. Most of these streams appear to be seasonal, except for the Mankwe and a number of its tributaries.

The largest perennial surface water is the Houwater Dam in the Mankwe valley (Figure 2.5). The numerous other small dams appear to be perennial only during the above average rainfall years. There are also a large number of boreholes scattered throughout the reserve which were constructed by white farmers, previously living in these areas.

2.5 Vegetation

Adcocks (1975) describes the Pilanesberg vegetation as Sour Bushveld (Type 20). It is related to the vegetation found on the Waterberg, Magaliesberg and Soutspansberg mountain ranges which characterizes a typical duplex savanna system of tufty, wiry, sour grass species forming the ground cover, and short to medium trees forming the woody layer. The valley savannas, however, tend to be related more to Adcock's Turf Thornveld (Type 13) typical of the arid savanna communities characterized by Acacia mellifera

Figure 2.5 : A Map of Pilanesberg Showing the Perennial and Seasonal Streams and the Water Points.

KEY:

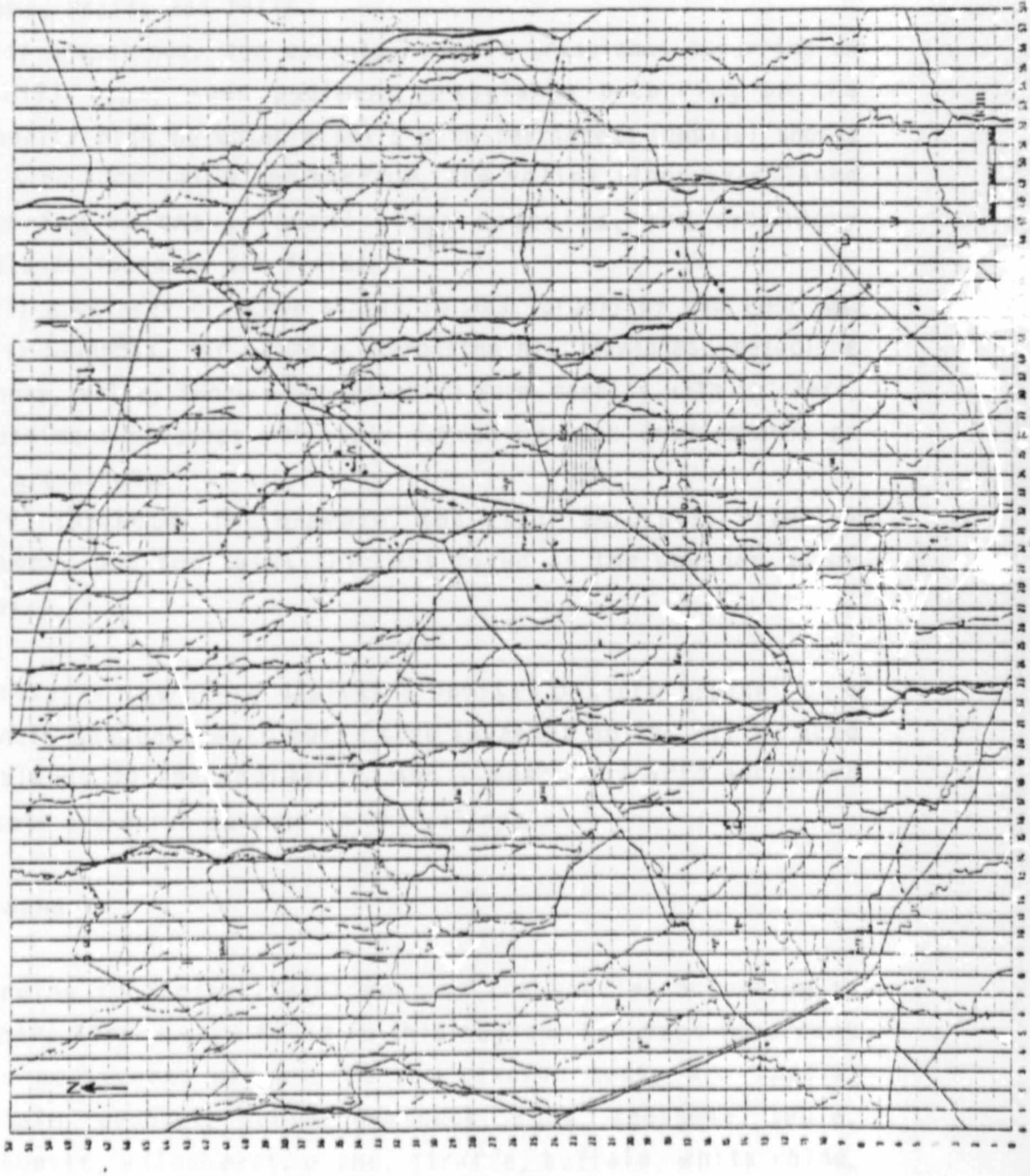
= Perennial streams.

= Seasonal streams.

= Mankwe dam.

= Water points.

= Small dams.



mellifera tree species.

Tinley (1978) described the Pilanesberg system as having 5 major community types (refer to Figure 2.6);

(i) Aquatic communities, typical of running waters, e.g. streams, rapids and falls.

(ii) Grasslands, for example, summit grasslands occurring on the hill tops, sour pediment grasslands occurring on the seasonally high watertable soils with ferricrete (ouklip) sheets some 5 to 20cm below the surface, the valley floor grasslands occurring on the alluvial slope deposits, and secondary grasslands found on old fields.

(iii) Rockfaces or scree slopes formed largely by red syenites.

(iv) Savannas, for example, xerocline hill savannas, mesocline savannas, valley thorn savannas which form mosaics with thickets, and pediment savannas which are formed by bush encroachment on acid grasslands.

(v) Thickets, for example, the kloof thickets, riverine thickets, and the talus thickets found on the boulder scree slopes.

The reserve therefore depicts a habitat pattern typical of a catenary sequence with moist tree savannas on the hills, acid grasslands on the pediments, and a mosaic of arid and thorn thickets and scrub savanna in the valleys.

2.6 Fauna

According to Tinley (1978) most of the species occurring in southern Africa were found in this region. The most important large herbivores present in the reserve today are impala, mountain reedbuck, zebra, gemsbuck, kudu, tsessebe, sable, hartebeest, wildebeest, eland, giraffe, buffalo, white rhino, black rhino and elephant. The predator density is low relative to other reserves of similar size, the dominant species being brown hyena, cheetah (introduced) and leopard.

Figure 2.6 : Vegetation Map of the Pilanesberg Game Reserve.

<u>KEY</u>:

= Pediment grasslands.

= Secondary grasslands.

= Summit savannas.

= Mesocline savannas.

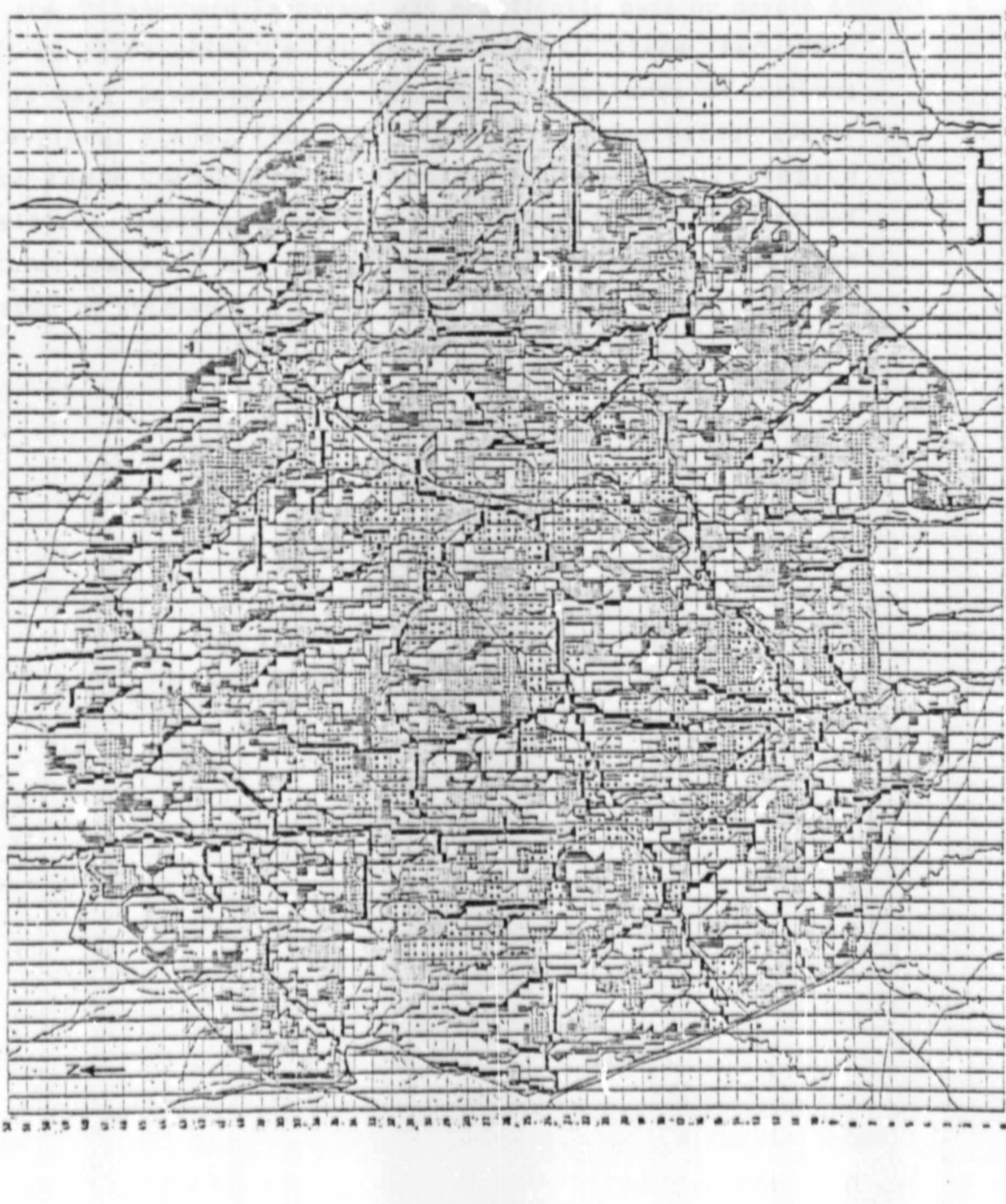
= Xerocline savannas.

= Valley savannas.

= Talus thickets.

= Valley thickets.

= Riverine thickets.



2.7 Previous Land Use

Pr.. to the reserve's establishment in 1979, the area had been divided into a number of farms with cultivation being largely practiced in the more arable valleys. Simon Ratlau, a field worker for the Bophuthatswana Agricultural Department, confirmed that the "Pilanesberg landscape was practically bare or devoid of grass 10 years prior to its establishment". Since then these fields have developed into secondary grasslands of various successional stages. Thus, it is clear that the previous use of these lands, whether for cattle farming or cultivation activities, played an important role in structuring the present system. However, the degree to which the habitat has been altered, is unknown.

CHAPTER THREE

THE AVAILABLE RESOURCES

3.1 Introduction

Petrides, Golley and Brisbin (1968) pointed out that "populations of herbivores do not exist as separate entities, but are integral parts of the biotic environment". Thus, before attempting any study concerning the relationship between herbivores and their habitats, the types and quantity of resources available to the animals must first be identified. The basic requirements of ungulates can be broken down into four categories; food, water, protection from climatic extremes and protection from predators (Sinclair, 1977). In the Pilanesberg Game Reserve the first three needs are especially accentuated during the dry season when resources are least abundant and climate is most extreme. However predator avoidance by the grazers is negligible as predator densities are very low. The first two factors, namely food supply and water availability are considered to be the primary factors influencing herbivore distributions and habitat selections in the Pilanesberg Game Reserve. Thus the availability of these two factors has been analyzed in detail in this chapter. The next chapter deals with their importance in terms of herbivore habitat selection.

All herbivores, as primary consumers of plant material, are entirely dependent on food production and availability for their existence. This led Lack (1954) to postulate that food supply is the most important factor both limiting and regulating herbivore numbers. There are, however, a number of environmental factors, both natural and man-induced which influence the availability and production of forage to the herbivores, eg. rainfall. The availability of water has also been identified as a limiting factor in that it confines animal movements within the vicinity of water. For example, Western (1975) was able to show that although the ungulate populations in the Amboseli Nature Reserve generally select the best pastures available to them, in many cases accessibility was limited to certain regions restricted around the water supplies. Similarly, Blankenship and Field (1972) have shown that water availability is one of five major factors influencing the distribution of wild ungulates on a ranch in Kenya.

Thus, in all cases food availability was limited to those habitats within "cruising range" of permanent water (Western, 1975). It is for this reason that the importance of water to herbivore distributions must also be established before stocking densities in the Pilanesberg Game Reserve can be established.

This chapter first classifies the vegetation types in the reserve based on topography, woody vegetation density and herbaceous cover, thus providing the necessary habitat divisions to analyze herbivore habitat selection. These results can then be related to the seasonal changes in the herbivores' habitat selection. Finally, the importance of water to the grazers, is established.

3.2 Materials and Methods

3.2.1 Field Measurements and Data Collection

3.2.1.1 Vegetation Types

One hundred and sixty transects were sampled in apparently homogeneous patches of vegetation so as to cover the vegetation variability in the reserve. The transect positions were determined both from aerial photographs and a reconnaissance of the area. The information used in the classification was based on the data collected mainly from a monitoring programme supervised by Walker (1982) and initiated in December 1980. Approximately 100 transects were measured during this programme. In each transect information was collected on both the woody and the herbaceous vegetation. However, classification of the habitats was based only on the herbaceous vegetation as all the herbivores under consideration were largely grazers. The location of the vegetation transects are shown in Figure 3.1.

Fifty, one-metre square quadrats were positioned at approximately 5 m intervals along a 50 m transect line. In each quadrat the herbaceous species composition was determined by bulk contribution using the method developed by Mannetjie and Haydock (1963). In each quadrat an estimate is made of the species which contributes most to the biomass and is assigned a rank of '1'. Similarly the species that contributed second and third in the overall biomass were assigned ranks of '2' and '3' respectively. In order to estimate the total percentage contribution of the species in that vegetation type, constants were determined by Mannetjie and Haydock (1963). These constants which can be interpreted as the contribution of the rankings to the biomass, are 70,2%, 21.1% and 8.7% for rankings 1, 2 and 3 respectively. The proportion of quadrats in which the species was 1, 2 or 3 were then multiplied by their constants to yield the percentage bulk contribution of each species to the herbaceous vegetation.

3.2.1.2 **Water Availability and Herbivore Distributions**

The distributions of the permanent and ephemeral water supplies were located by aerial surveys conducted by staff members of the reserve. The water points were then plotted on a map with a 500 x 500m grid system. Two surveys were conducted, one during each season (ie; wet and dry seasons).

Observations of herds and single animals were made while driving along the road transects shown in Figure 3.1. The sightings were recorded and their locations plotted on a map with a 500m x 500m grid system. In addition, information on the herd or group size, sex, age, and identification number, if present, was also noted.

This information was then typed into an Apple II microcomputer using a data base programme developed by Erica Harris (see Dickinson, 1983). The main reason for using this system was that large amounts of data could be stored, analyzed and retrieved at any time. A programme was also developed using the Apple

Figure 3.1: Locations of the Vegetation and Road Transects.

KEY:

16 = Vegetation transect sites.

= Road transects.