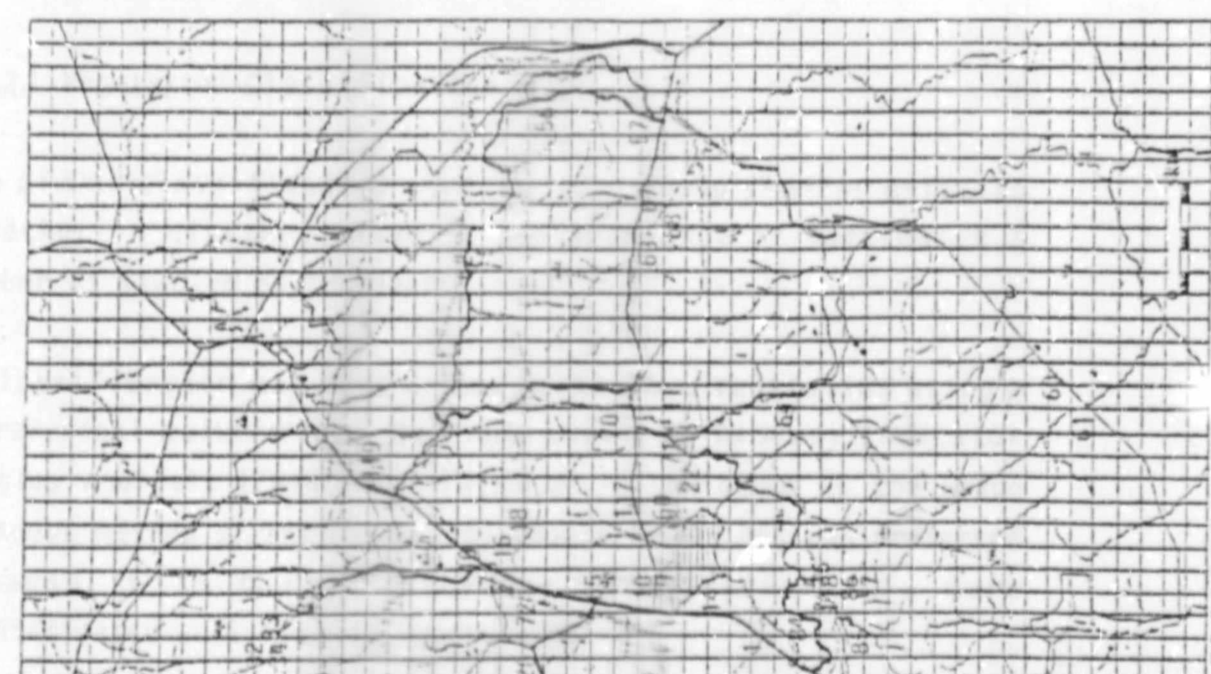


Graphics package, to display the data on a map of the Pilanesberg Game Reserve (Dickinson, 1983). Thus, a better picture of both the seasonal distributions of the species and the water points could be displayed on a map and analysed.

3.2.2 Data Analysis

3.2.2.1 Vegetation Classification

The aim of classification studies is to group similar entities together in clusters based on the abundance of species in a number of samples or transects.

A classification was done on the herbaceous vegetation using a hierarchical multivariate technique known as Two-way Indicator Species Analysis (TWINSPAN). TWINSPAN is analogous to the Braun Blanquet method of phytosociology (Moore, 1962) and was preferred because, with the quantitative data available, a more sophisticated analysis was neccessary.

3.2.2.1.1 Two-way Indicator Species Analysis

The computer program, TWINSPAN, was developed by Hill(1979) for the Cornell Ecological Program series. It is a "polythetic divisive" technique in which the data are first ordinated by reciprocal averaging, (Hill, 1973) and then divided or grouped, (Gauch and Whittaker, 1981) in a hierarchical manner.

Reciprocal averaging is generally used to reveal correspondences between observations on two kinds of information, e.g. samples and species. It was first developed by Hirschfield (1935) and Fisher (1940) and has been termed "Correspondence Analysis" (Benzecri, 1969; Escofier-Cordier, 1969). It is essentially an ordination technique related conceptually to weighted averages, but computationally to Principal Component Analysis (Gauch, 1982). The species are first weighted by positions along an initial gradient and are then used to calculate sample-scores. These weighted sample-scores are then used to calculate a new and improved calibration of the species. The new weighted score now provides a further improvement in the sample calibration. Back-and-forth, iterative calculations lead to a stable, optimal solution which does not depend on the initial arrangements (Gauch, 1982). This process has been termed Reciprocal Averaging because the species-scores are averages of the stand scores and reciprocally, the stand- scores averages of the species-scores.

When insignificant changes result from one iteration to the next the solution stabilizes and the scores range from 0-100. The contraction in the range of the species-score in one iteration (after convergence is reached), is the eigen value. A second axis may then be taken out using the same method by correcting for the first axis, a third axis may then be calculated while correcting for the first two, and so on. Higher axes may be scaled onto the range proportional to the square root of their eigen values.

Like Principal Component Analysis, Reciprocal Averaging can be used geometrically as a derivation of new axes; which maximally account for the structure of the points in a multidimensional cloud of points, making possible the reduction of the dimensionality (Gauch, 1982).

Gauch (1982) recommended Two-way Indicator Species Analysis (TWINSPAN) for hierarchical classification for the following reasons;

1. its effectiveness,
2. its robustness,
3. its use of the original vegetation data rather than secondary similarity matrices,
4. it integrates the classification of both samples and species,
5. it orders the sample sequence in a dendogram so that the most similar samples are placed together, and
6. it is economical in terms of computer requirements.

The algorithm of TWINSPAN produces a two-way table, similar to a

Braun-Blanquet table, and identifies several species which are diagnostic of each division. Two-way Indicator Species Analysis makes repeated dichotomies of both the sample and species by dividing the axis in half (Hill, 1979). The differential species at the extremes of the ordination axis are first identified. Then the samples are divided into two clusters near the middle of the axis. The sample division is then refined by reclassification using the differential species. The process is repeated on the two subsets to give four clusters, and so on until each cluster has no more than a chosen minimum number of members (Gauch & Whittaker, 1981). The grass species are classified in the same way except the classification is now made using samples. The classification is made on the basis of fidelity, which is the degree to which species are confined to particular groups of samples.

3.2.2.2 Test for Randomdess in Herbivore Distributions

The assumption being that is if the herbivores are distributed randomly within the reserve then their distributions will be proportional to different areas around the water points. In other words the percentage number of total observations should increase as the area from the water points increases. The expected values were calculated using above results and then tested against the actual values using a Chi-square test.

3.3 Results and Discussion

3.3.1 Classification of the Herbaceous Vegetation

The aim of this section is firstly to classify the habitat types based only on the herbaceous vegetation, and secondly, to compare this classification to that of Tinley's (1978).

The herbaceous vegetation data matrix consists of 35 grass species and 160 transects.

3.3.1.1 Two-way Indicator Species Analysis (TWINSPAN)

The divisions based on TWINSPAN are shown in dendrogram form in Figure 3.2.

This technique depicted no clear-cut distinctions except for those sites which had been recently disturbed either by heavy grazing or by agricultural activities (eg. Secondary grasslands and Cynodon dactylon "lawns") and those showing little signs of disturbance (eg. Pediment grasslands and some savannas). The results are discussed in more detail below.

The grasslands studied were found to be characterised by the following indicator species; Cynodon dactylon (CYDA), Rhynchyletrum repens (RHRE), Heteropogon contortus (HECO), Themeda triandra (THTR), Hyparrhenia hirta (HYHI), Elyonurus argenteus (ELAR), or Bothriochloa insculpta (BOIN). Other prominent grasses were Urochloa mosambicensis(URMO), Eragrostis rigidior (ERRI), Aristida congesta (ARCO), Panicum deustum (PADE), Loudetia flavida (LOFL) and Cymbopogon species (CYMB).

Level 1: (n = 160). In the first division, a distinction was made between different successional stages i.e. from generally climax grasslands and savannas on the one hand, and secondary or oldland grasslands and heavily utilised Acacia thickets on the other. The indicator species for this division were Themeda trianda (THTR), Heteropogon contortus, (HECO) and Elyonurus argenteus (ELAR) for the former, and Cynodon dactylon (CYDA) for the latter.

Level 2 1. (n =84). The later successional or climax stages (including savannas and woodlands) are further separated into those dominated by Heteropogon contortus (HECO) and those dominated by Themeda triandra (THTR) and Elyonurus argenteus (ELAR) and Hyparrhenia hirta (HYHI). The indicator species being Panicum coloratum (PACO), Themeda triandra (THTR) and Elyonurus argenteus (ELAR). The first group is characteristic of the more open grasslands including the pediment grasslands. The second group appears to characterize those sites which are generally

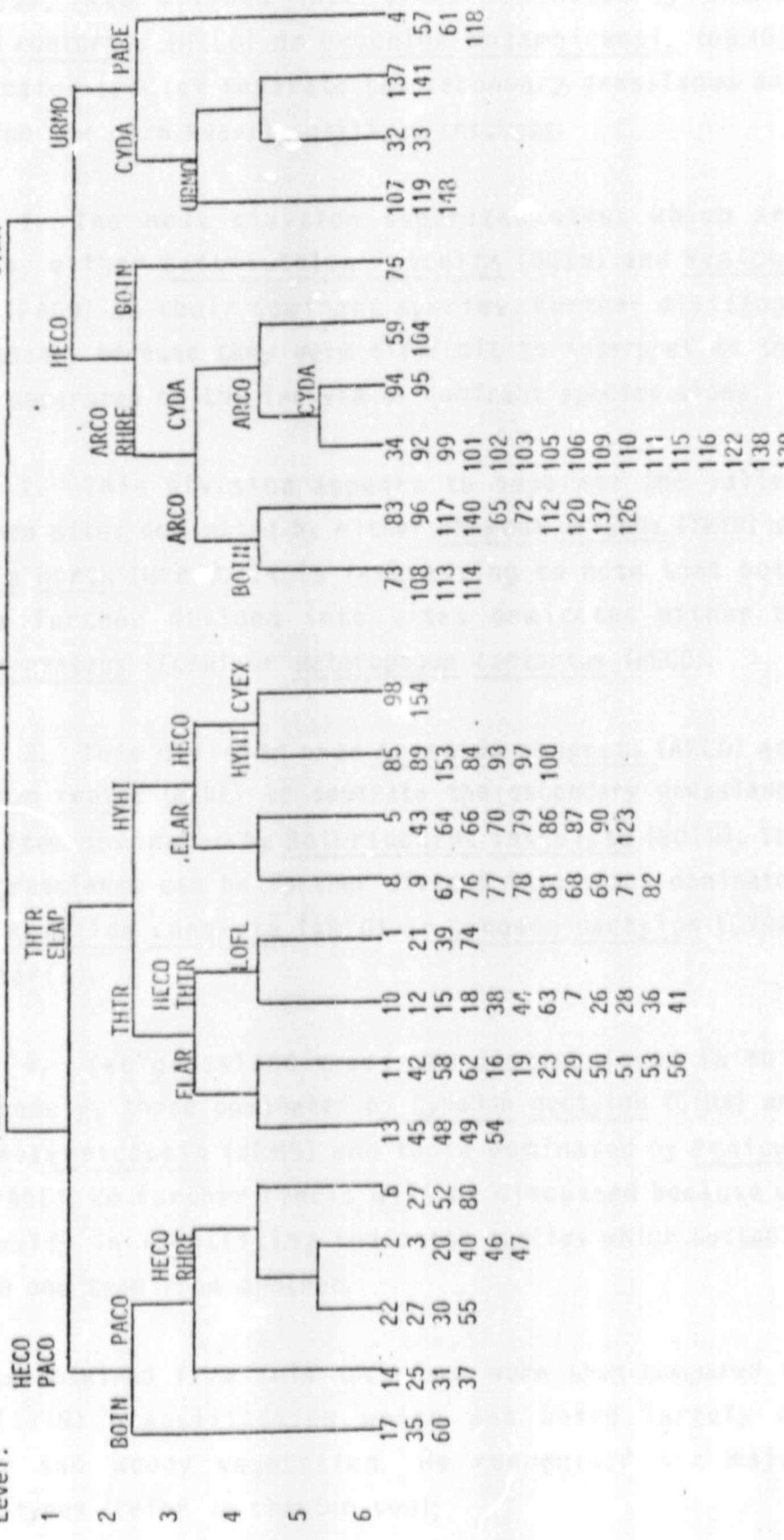


Figure 3.2 : Classification of the Herbaceous Vegetation using TWINSPAN (Hill, 1979). A key to the Indicator Species used to characterize the different grasslands are given in Appendix F.

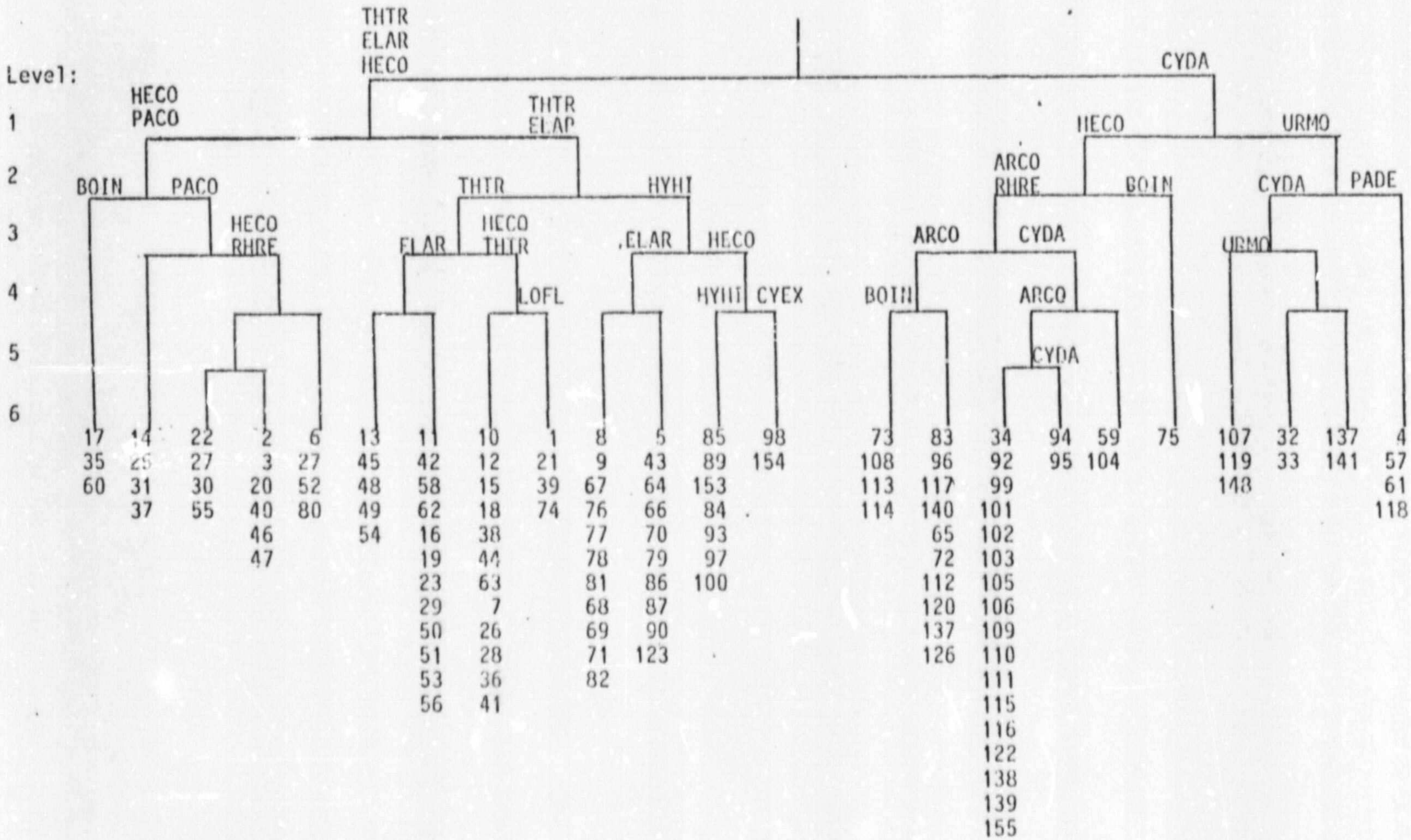


Figure 3.2 : Classification of the Herbaceous Vegetation using TWINSPAN (Hill, 1979). A key to the Indicator Species used to characterize the different grasslands are given in Appendix F.

more wooded with higher canopy covers (eg. savannas).

2. (n = 76) The second group, namely the secondary grasslands and thickets, was divided into sites dominated by either Heteropogon contortus (HECO) or Urochloa mosambicensis (URMO). These indicator species separate the secondary grasslands and savannas from the more heavily utilized thickets.

Level 3   1. The next division separates sites which are dominated by either Bothriochloa insculta (BOIN) and Panicum coloratum (PACO) as their dominant species. Further divisions were unnecessary because they were difficult to interpret as the sites were separated on the individual dominant species alone.

2. This division appears to separate the valley savannas into sites dominated by either Themeda trianda (THTR) or Hyparrhenia hirta (HYHI). It is interesting to note that both groups are further divided into sites dominated either by Elyonuris argenteus (ELAR) or Heteropogon contortus (HECO).

3. This division uses Aristida congesta (ARCO) and Rhynchelytrum repens (RHRE) to separate the secondary grasslands from the sites dominated by Bothriochloa insculpta (BOIN). The secondary grasslands can be further divided into sites dominated either by Aristida congesta (ARCO) or Cynodon dactylon (CYDA) (eg. termitaria).

4. Two grassland types are distinguished in this division, namely, those dominated by Cynodon dactylon (CYDA) and Urochloa mosambicensis (URMO) and those dominated by Panicum deustum (PADE). No further levels will be discussed because of the difficulty in identifying indicator species which suitably distinguish one type from another.

The results obtained from this technique were then compared to Tinley's (1978) classification which was based largely on topography and woody vegetation. He recognised six major vegetation types (refer to chapter two);

(i) Secondary grasslands or oldlands,
(ii) Pediment grasslands,
(iii) Valley savannas,
(iv) Mesocline savannas,
(v) Xerocline savannas, and
(vi) Acacia and riverine thickets.

Both the summit grasslands and talus thickets have been omitted because of limited importance in terms of white rhino habitat selection. These vegetation types were then compared to those distinguished on the basis of grass species alone using the TWINSPAN analysis. Five basic habitat types were recognized using the TWINSPAN programme;

(i) Cynodon dactylon "lawns" (level 3, sublevel 4),
(ii) Secondary grasslands, characterized by Aristida congesta and Rhynchyletrum repens (level 3, sublevel 3),
(iii) Pediment grasslands (level 2, sublevel 1),
(iv) Wooded savannas (level 3, sublevel 2), and
(v) Thickets, dominated by Panicum deustum, Cynodon dactylon and Urochloa mosambicensis (level 3, sublevel 4).

Although no clear-cut distinctions were apparent, habitats could be classified on a similar basis to that of Tinley's (1978) except for the more subtle features, eg. the savannas dominated either by Themeda triandra or Hyparrhenia hirta. The Cynodon dactylon "lawns", although occupying only approximately 2% of the reserve, were included because of their high selection by most herbivores. No clear cut distinctions were made between the valley and hillside savannas, but this may have been due to a low sample size. However, the savannas were divided into either valley or hillside based on topography alone. It should finally be noted that even within these fairly distinct habitats, patchiness or heterogeneity was apparent.

Table 3.1 summarises the vegetation types in terms of the percentage species composition and the proportion of the low,

Table 3.1 : The Herbaceous Species Composition of each vegetation type with the palatability (PALAT.) of each species (P = palatable, I = intermediate and U = unpalatable; PAL., INT. and INT. are the proportions of palatable, intermediate and unpalatable grass species, respectively).

	VEGETATION TYPES						
SPECIES	Secondary Grassland	Pediment Grassland	Valley Savanna	Hillside Savanna	Thicket	Termitaria and _Cynodon_ patches	PALAT.
Cynodon dactylon	12.4	1.5	6.2	0.0	13.2	11.2	I
Aristida congesta	3.2	11.2	2.5	3.3	0.6	3.7	I
Rhynchelytrum repens	9.4	4.0	3.4	1.3	0.2	2.8	I
Heteropogon contortus	14.8	14.4	15.7	29.5	5.5	8.7	P
Themeda triandra	3.7	1.0	4.9	8.4	7.2	0.6	P
Eragrostis curvula	4.1	1.1	2.4	0.0	4.4	7.3	I
E. superba	9.4	1.3	2.4	0.0	3.2	8.5	P
E. rigidior	5.9	1.6	2.1	0.0	1.9	9.3	I
E. chloromelis	0.0	2.8	3.1	0.0	0.1	0.0	I
E. racemosa	0.2	1.7	0.5	0.0	0.7	0.0	I
E. plana	0.1	0.0	0.1	0.0	0.0	0.0	I
E. gummiflua	0.7	4.1	0.4	0.0	1.8	0.0	I
Elyonuris argenteus	3.1	26.4	27.6	5.3	6.6	0.4	U
Cymbopogon excavatus	2.3	9.2	6.0	0.9	2.3	1.9	U
Hyparrhenia hirta	8.0	17.7	4.9	0.0	1.5	1.5	I
Trichoneura grandeglumis	0.6	1.7	0.3	0.0	0.0	0.4	I
Bothriochloa insculpta	0.0	0.0	0.8	0.0	3.2	1.9	I
Brachiaria serrata	1.1	1.4	0.9	10.2	0.5	0.2	P
Urochloa mosambicensis	4.9	0.0	1.7	0.0	10.6	17.6	P
Setaria flabellata	0.2	0.2	0.7	0.0	1.3	0.0	I
Loudetia flavida	0.0	3.7	1.1	10.9	0.1	0.0	I
Digitaria eriantha	2.5	2.2	1.6	0.0	7.1	0.7	P
Microchloa caffra	0.0	0.0	0.7	0.2	0.1	0.1	I
Tragus berteronianus	0.4	0.0	0.7	0.0	0.9	0.3	I
Panicum deustum	0.0	1.4	0.9	0.0	7.3	0.7	P
P. coloratum	0.0	1.0	2.5	0.0	8.6	2.9	P
Pogonarthria squarrosa	0.3	0.6	0.1	0.0	0.0	0.1	I
Sporobolus species	1.7	3.0	0.4	16.2	2.2	1.0	I
Chloris virgata	0.0	0.0	0.3	0.0	4.2	5.4	I
Setaria nigrirostris	0.2	0.0	0.8	0.0	1.7	0.0	I
Perotus patens	0.0	0.0	0.1	0.0	0.3	0.1	I
Eragrostis species	4.0	3.0	1.3	0.0	2.2	4.0	I
PAL.	43.9	21.7	34.7	58.1	52.2	51.0	
INT.	50.7	42.7	31.7	35.7	38.9	46.7	
UNP.	5.4	35.6	33.6	6.2	8.9	2.3	
AREA (ha)	3119	1628	7322	23366	7534	± 20	

medium and high palatable grass species. The degree of palatability was based on the herbivore preferences. Grass species, for example, Heteropogon contortus and Urochloa mosambicensis were regarded as palatable whereas, species such as Bothriochloa insculpta, Elyonuris argenteus and Cymbopogon excavatus as unpalatable.

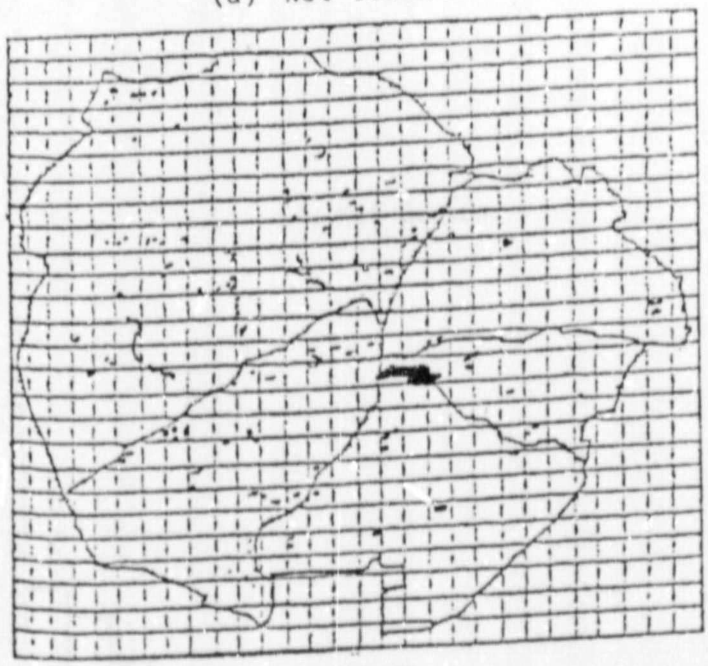
3.3.2 Relationship between Water Availabilty and Herbivore Distributions

A map of the wet and dry season water distributions is given in Figure 3.3. It is evident that the water availability in the reserve can change markedly from one season to the next with the maximum distance of any point in the reserve to the nearest water point increasing as rainfall decreases. This seasonality in water availability should greatly influence the herbivore movement and their distributions, as predicted by Western (1975).

The distribution of distances of the herbivores to the nearest available water supplies are given in Figures 3.4 to 3.8. All species showed a high concentration around the water points indicating that water does tend to restrict the herbivores movements within limited distances. The mean distance at which the herbivores were sighted from the nearest water supply varied from 659 m (zebra) to 946 m (impala) during the wetter months, and 1012 m (hartebeest) to 1319 m (impala) during the drier months. Significant differences ($P < 0.001$, using the Chi-square test) between the herbivores and the nearest water were apparent between seasons. Although water certainly appears to influence animal distribution patterns, movement away from the water supplies is evident during the drier months. This may indicate that the distribution limits from the water supply of the herbivores increases when water becomes limiting.

However Western (1975) estimated the distribution limits of the water dependent species (eg. impala) to be between 10 and 15km. The maximum distance from any point in the Pilanesberg Game Reserve to a water source during the dry season was approximately

(a) Wet Season



(b) Dry Season

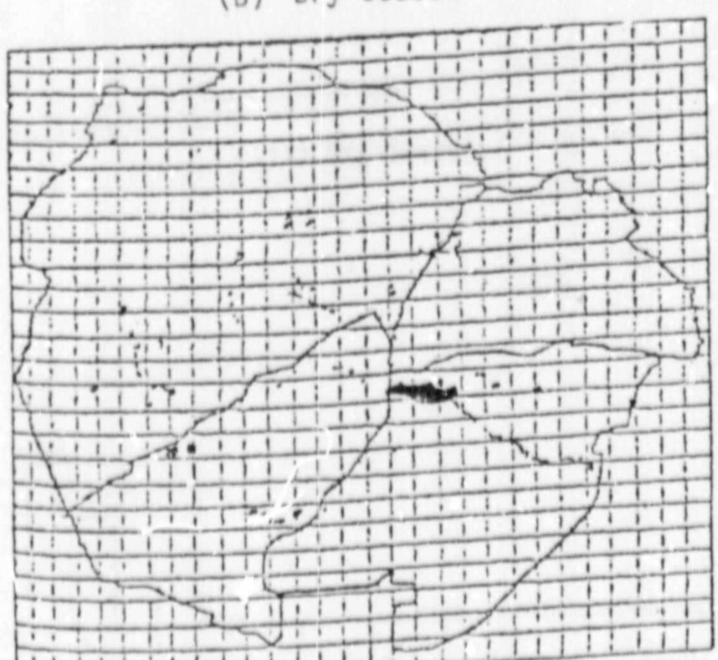


Figure 3. 3 : The Seasonal Distribution of Water Points in the Pilanesberg Game Reserve.

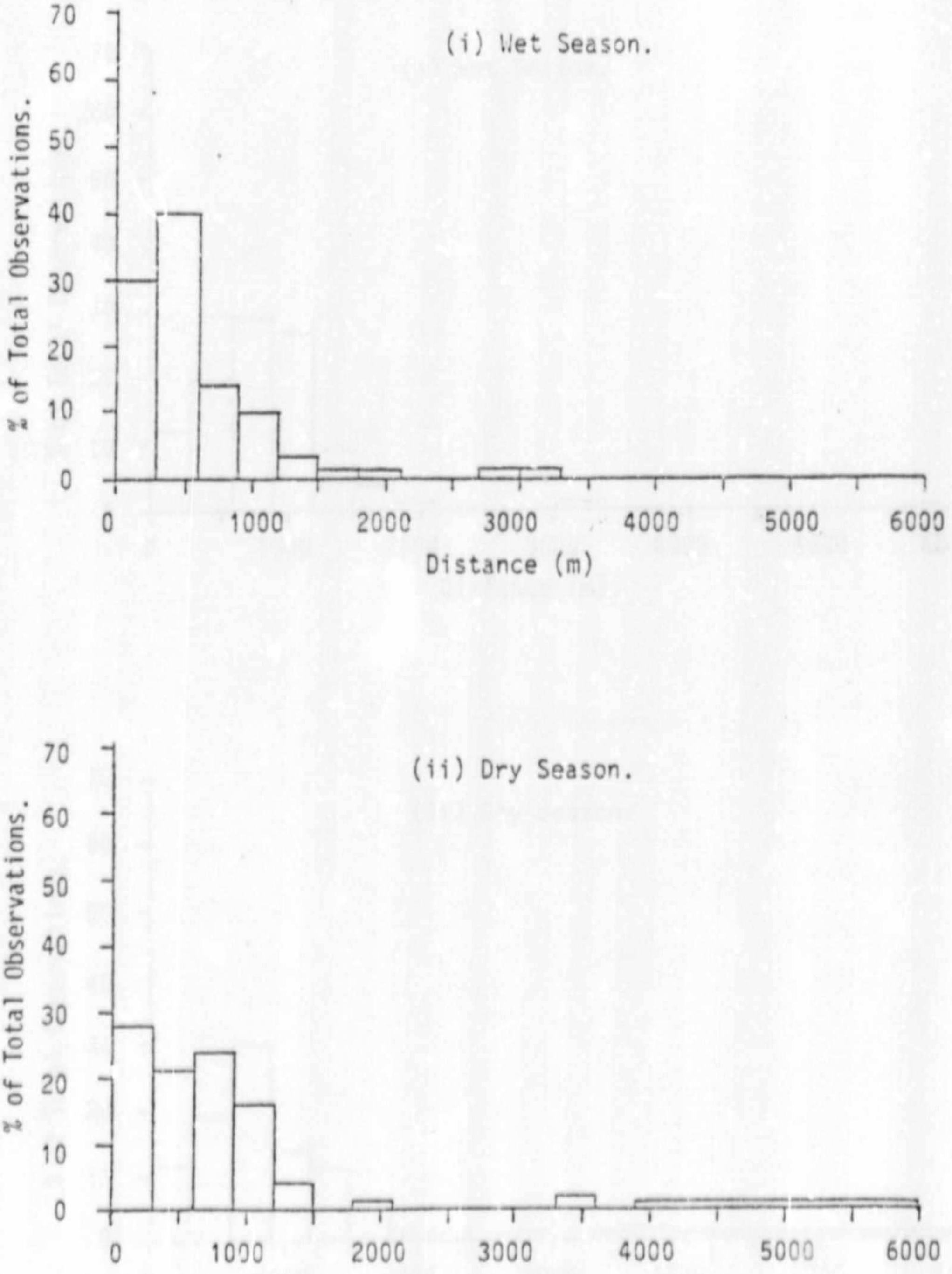


Figure 3.4 : The relationship between the percentage occurence of white rhino sightings and distance to nearest water.

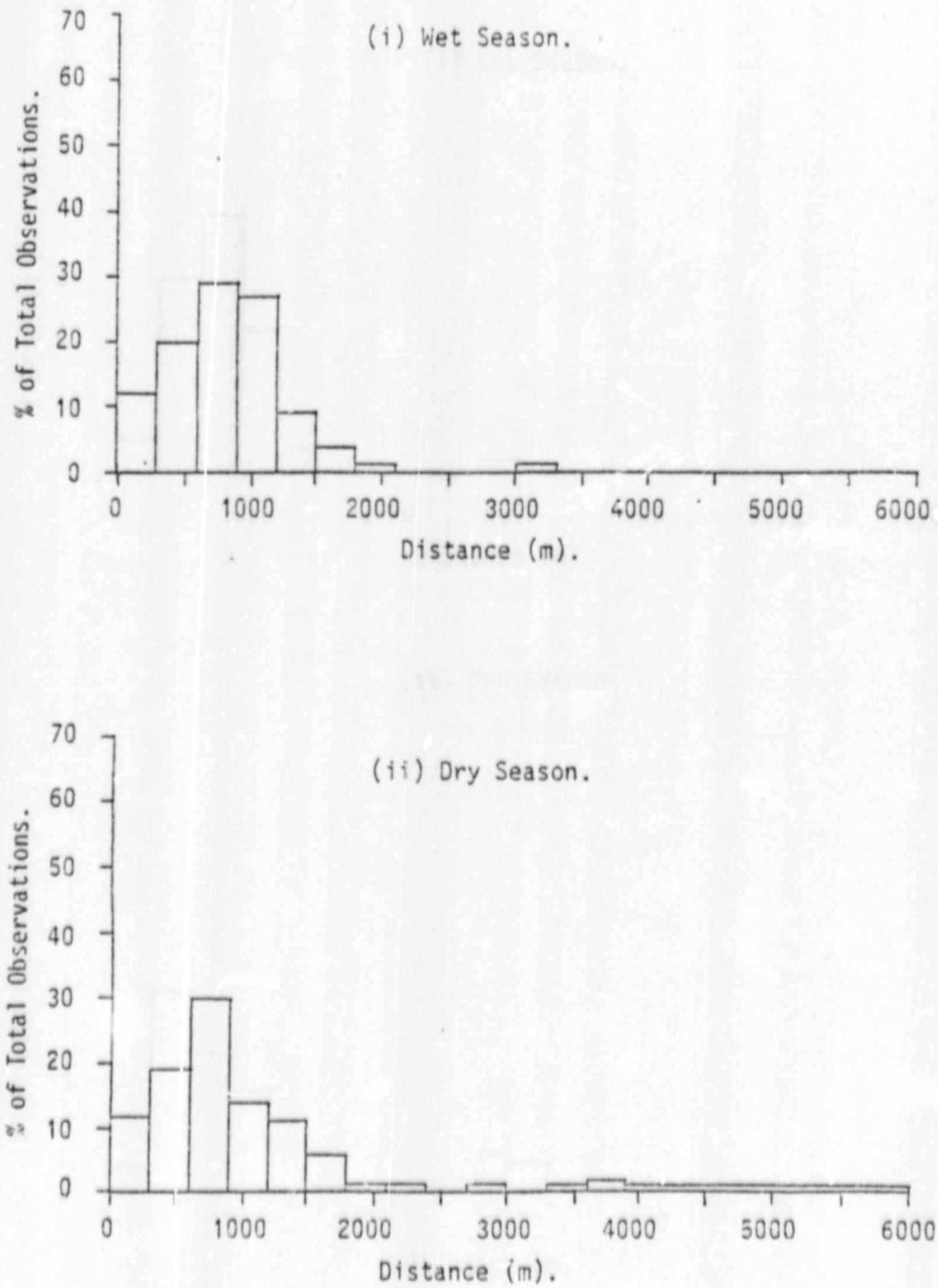


Figure 3. 5 : The relationship between percentage occurrence of hartebeest sightings and distance to nearest water.

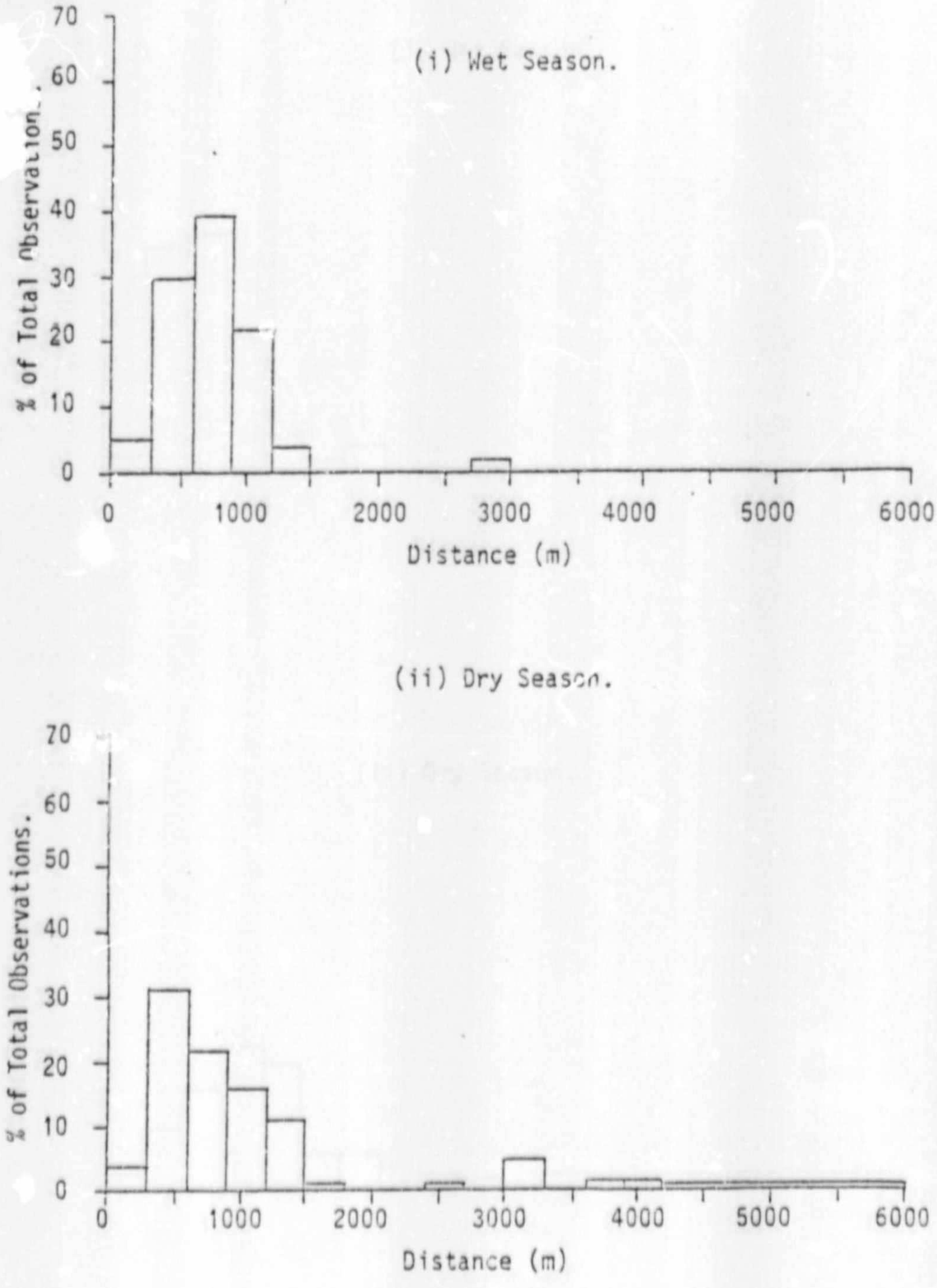


Figure 3.6 : The relationship between the percentage occurrence of wildebeest sightings and distance to nearest water.

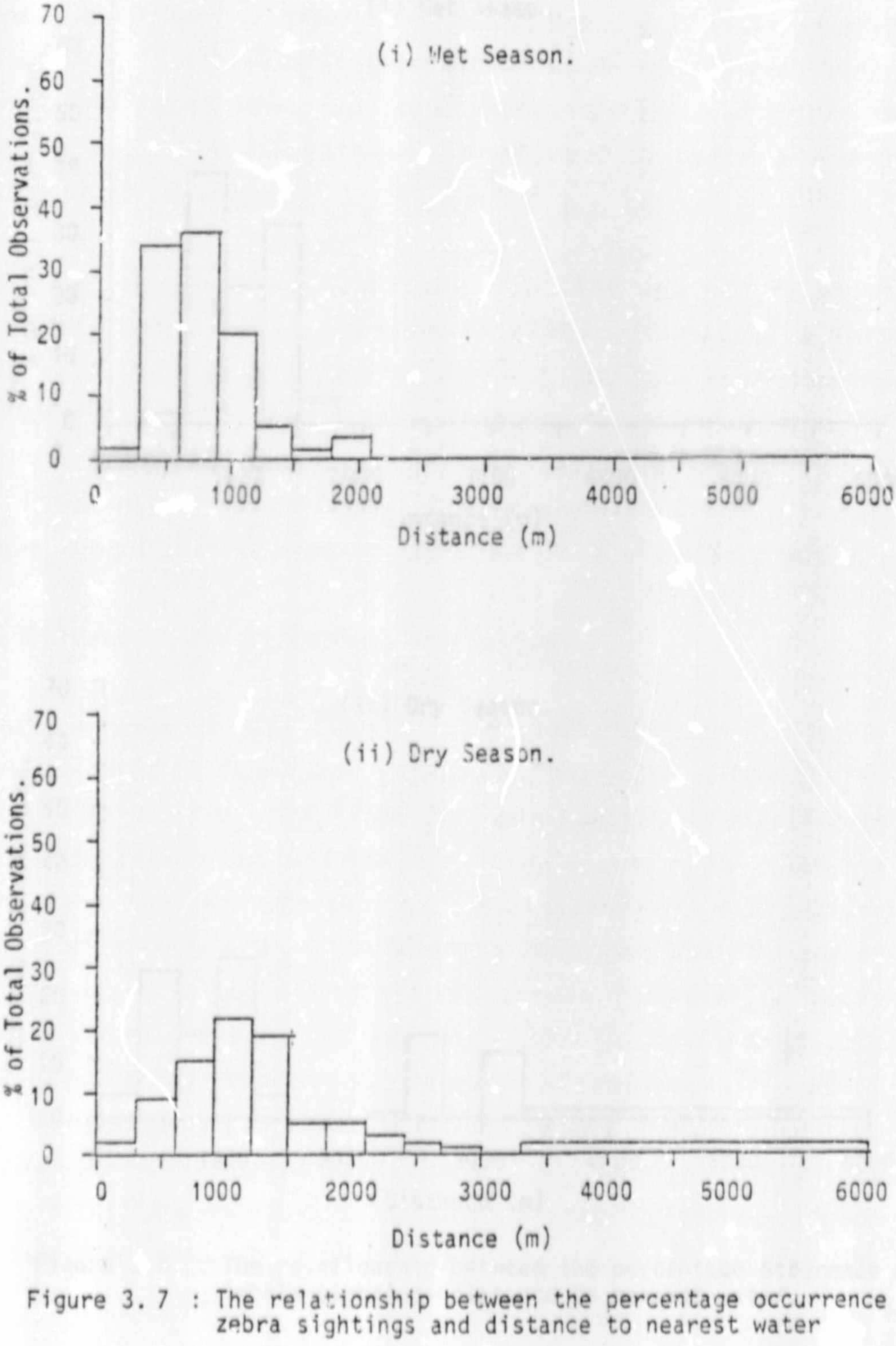


Figure 3. 7 : The relationship between the percentage occurrence of zebra sightings and distance to nearest water

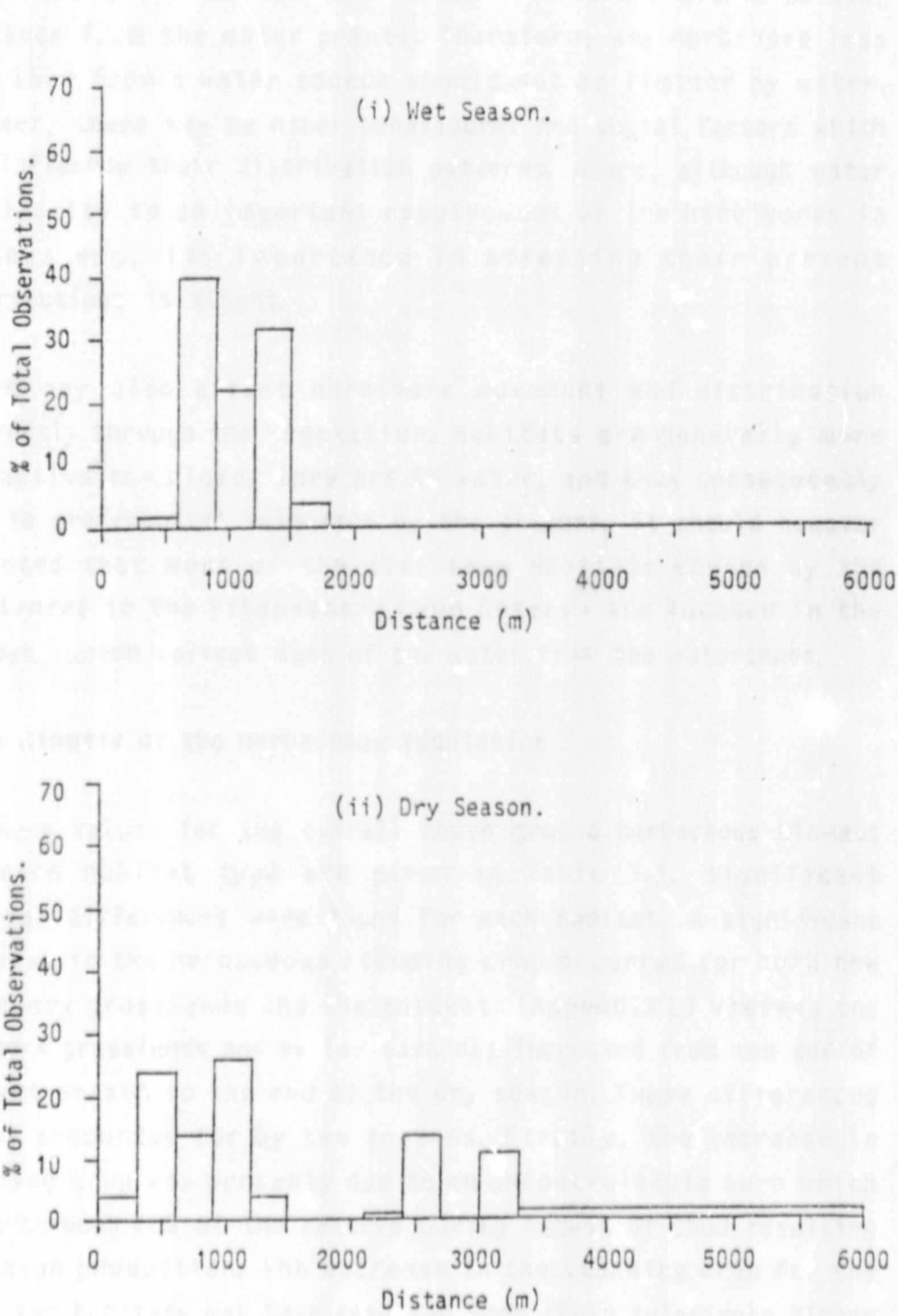


Figure 3.8 : The relationship between the percentage occurence of impala sightings distance to nearest water.

10km as opposed to 30km in the Amboseli Nature Reserve (Western, 1975). Hence, all the habitats in the reserve are within walking distance from the water points. Therefore, any herbivore less than 15km from a water source should not be limited by water. However, there may be other behavioural and social factors which may influence their distribution patterns. Hence, although water availabilty is an important requirement of the herbivores in Pilanesberg, its importance in affecting their present distributions is slight.

Water may also affect herbivore movement and distribution indirectly through the vegetation. Habitats are generally more productive the closer they are to water, and thus consequently lead to preferential selection by the grazers. It should however be noted that most of the available habitats chosen by the herbivores in the Pilanesberg Game Reserve are located in the valleys, which collect much of the water from the watersheds.

3.3.3 Biomass of the Herbaceous Vegetation

The mean values for the overall above ground herbaceous biomass for each habitat type are given in Table 3.3. Significant seasonal differences were found for each habitat. A significant decrease in the herbaceous standing crop occurred for both the secondary grasslands and the thickets (Appendix L) whereas the pediment grasslands and valley savannas increased from the end of the wet season to the end of the dry season. These differences can be accounted for by two reasons. Firstly, the increase in standing crop was probably due to an uncontroleable burn which swept through 60% of the reserve during August of 1980 resulting in a high production. The decrease in the standing crop for the other two habitats may have resulted from their relatively higher herbivore densities. Consequently, offtake by the herbivores was much higher in these habitats (see chapter 4).

Using the vegetation transect data, approximate biomasses for the three forage types (defined earlier) could be estimated within each habitat (Table 3.4). These results indicate that of the four

Table 3.3 : Seasonal variation in the above ground herb biomass (kg/Ha) each vegetation type. Standard errors are given in parentheses.

Season	Secondary Grassland	Pediment Grassland	Valley Savanna	Thickets
Late-wet	3000(168)	3200(920)	2840(1200)	1200(720)
Late-dry	2250(900)	4010(184)	3330(1220)	550(600)

Table 3.4 : Seasonal variation in the biomass (kg/Ha) of the three forage types for each habitat.

SEASON	FORAGE TYPE	HABITAT			
		SECONDARY GRASSLAND	PEDIMENT GRASSLAND	VALLEY SAVANNA	THICKETS
LATE-WET	PALATABLE	1320	704	994	624
	INTERMEDIATE	1530	1376	908.8	468
	UNPALATABLE	150	1120	937.2	108
LATE-DRY	PALATABLE	990	882.2	1165.5	286
	INTERMEDIATE	1147.5	1724.3	1065.6	214.5
	UNPALATABLE	112.5	1403.5	1098.9	49.5

habitats measured, the secondary grasslands account for most of the palatable biomass at the end of the wet season. However, at the end of the dry season, the valley savannas accounted for a high proportion of these species. The thickets, although supporting the highest proportion of palatable species, contribute the least to the overall palatable standing crop.

These results can now be related to seasonal changes in herbivore habitat selection (next chapter). In addition, the overall plant biomass for each habitat can be compared to those predicted from the model described in chapter seven. These results will therefore provide a means of testing the validity of the model.

CHAPTER FOUR

HABITAT AND FOOD SELECTION BY THE GRAZING UNGULATES AT PILANESBERG

4.1 Introduction

This section investigates the relationship between the large grazer[illegible]ally the white rhinoceros) and their habitat use, in te[illegible]itat and food selection.

Ungulates often show characteristic patterns of seasonal movement from one part of their range to another. Duncan (1975) identified two types of movements. The first is when the population moves as a coordinated unit, so that the annual ranges of the individuals are of the same order of magnitude as the range of the population (e.g. the Serengeti wildebeest, Watson, 1967). The second, occurs when the individuals show clear seasonal movements which are small compared to the population range. This type of movement is characteristic within most game reserves which support large ungulates. However the first type is seldom observed in reserves because movement is mostly prevented by the fenced boundaries.

In both cases the effect is to place the animals in a different environment. Thus there is a close relationship between habitat and movement. The response of an individual to vegetation structure that differs from the "optimum" is to move away from it. For example, Sinclair (1974) suggested that the buffaloes in the Serengeti select particular habitats in the dry season because it is in these that the optimal food is found. Pienaar (1974) in classifying the environmental factors (physical, historical and biotic) governing the distribution of herbivores stated that the vegetation was the all important. A number of ecologists (e.g. Petrides, 1956; Darling, 1960; Grzimek and Grzimek, 1960; Lamprey, 1963; Vesey Fitzgerald, 1965; Anderson and Talbot, 1965; Simpson and Cowie, 1967; De Vos, 1969; Field and Laws, 1970; Ferrar and Walker, 1974; Pienaar, 1974 and Hirst, 1975) have shown that ungulates exhibit a heterogeneous distribution over African vegetation types. This they attributed to be directly related to the varying degrees of habitat selectivity in a heterogeneous environment.

There are many qualitative reasons as to why animals select particular habitats, including the need to avoid predators, requirements of shade, food and water. Talbot and Talbot, 1963; Watson, 1966; Pennycuick, 1975; and Inglis, 1976 on the other hand have shown rainfall to be the proximate factor influencing wildebeest movement and habitat selection.

It is therefore necessary to isolate those environmental factors to which the animals respond when selecting for particular habitats. Western (1973) was able to show that the grazing ungulates in the Amboseli ecosystem select areas with different grass heights. He then concluded that if the animals are responding to grass height, then a changing spatial pattern would lead to changes in their habitat selection and hence distribution. Attwell (1977) showed a similar trend with the four major grazing ungulates in the Hluhlwe Game Reserve where mean height of the herbaceous layer depicted high discriminatory powers in their habitat choice. Duncan (1975), on the other hand, showed that the proportion of green leaf had profound effects on the quality of the diet of Topi by overriding the importance of grass height. Herbivores therefore tend to select areas based on both the floristic and structural features of the habitat.

The final aim of this chapter is to isolate those floristic and structural components of the grassland to which the habitat selection of the Pilanesberg grazers (especially the white rhino) are most closely related. This will not only give an insight into the causes of habitat selection and movement, but ultimately provide the information needed to estimate herbivore stocking densities in the reserve.

4.2 Materials and Methods

4.2.1 Field Measurements

The methods are broken up into three sections; the first concerns the calculation of habitat preferences using the road transect data, the second the measurement of the foraging sites, and the third the dietary selection within them.

4.2.1.1 Habitat Preferences of the Herbivores

The field data required to analyze habitat preferences were obtained from the road transects mentioned earlier in chapter three. Each transect shown in Figure 3.1 was driven once every morning between 06h00 and 09h00. When an animal was sighted the habitat in which it was present was identified using the classification described in the previous chapter. Each observation could then be related to one of the six possible plant communities; secondary grasslands, pediment grasslands, valley savannas, hillside savannas, Acacia and riverine thickets or Cynodon dactylon "lawns identified in chapter three.

4.2.1.2 Feeding Site Descriptions

The herbivores were located by vehicle and observed feeding for at least fifteen minutes. This ensured that the animals exerted a reasonable grazing pressure on the herbaceous vegetation, and that accurate boundaries around the site could be delimited. A total of 113 feeding sites was recorded, 75 for rhino (all seasons), 12 for hartebeest (dry season), 15 for impala (dry season), and 7 for zebra (dry season). It should be noted that only 4 impala sites were recorded, but have been included in the analyses because of the high density of this species in the reserve. The impala are extremely alert and seldom feed in a particular site long enough for it to be clearly demarcated.

The number of quadrats (0,25 sq. m.) positioned in each site depended largely on the feeding site areas, which could vary from 25 to 1000 square metres. In each quadrat the following site characteristics, (except grass height), were estimated using the eight point scale described by Anderson and Walker (1974) and Walker (1976);

1. Cover and abundance of the herbaceous vegetation. This estimates the amount of rooted basal and aerial cover of the herbaceous layer.
2. Height, which is the average height of the green grass cover to the nearest 10 cm and averaged for all the quadrats.
3. Proportion of forbs making up the herbaceous layer.
4. Litter, which is the dead and broken plant material in contact with the soil surface.
5. The proportion of moribund grass. This is the dead plant material older than one year which is not in contact with the living material.
6. Soil capping which may be either clay or algal capping.
7. Erosion. (Surface or sheet erosion).
8. Grazing or the proportion of the biomass of the sward consumed by the grazers. This was subjectively estimated for each grass species in the quadrats.

The above measures were then averaged for each variable according to the formula developed by Walker (1976);

$$(n_i \times c_i) / N \quad ....4.1$$

where, n_i is the number of quadrats in rank 1,

c_i is the class midpoint of rank i,

N is the total number of quadrats.

The herbaceous species composition was determined using the bulk contribution method described in the previous section.

It should be noted that factors 3,4,5,6, and 7 were not used in the final analysis as they appeared to play only a minor role in habitat selection - only minor differences in these variables were apparent between sites.

In order to obtain a measure of the woody vegetation the trees within a defined area around the feeding site were divided into two categories; those with a canopy height greater than two metres and those below two metres. The former provides an indication of the importance of shade, and the latter the importance of lateral cover. The measurements of these two categories were recorded as follows;

1. All the trees with canopies below 2 metres were recorded as a percentage of the total canopy cover over the whole area.

2. Trees with canopies below 2 metres were ranked from 1 to 5 depending on their diameters. Their respective frequencies were then noted. The 5 point rank was based on the following scale;

RANK	DIAMETER(m)
1	0.0 - 0.5
2	0.6 - 1.0
3	1.1 - 1.5
4	1.6 - 2.0
5	> 2.0

A "lateral cover index" was calculated, using the frequency data for each rank, as follows:

$$\text{Lateral Cover Index (LCI)} = \sum_{i=7}^{5} (A_i \times RF_i) \,/\, TLA \ldots\ldots 4.2$$

where, RF_i is the relative frequency of the 5 class types, i, TLA is the total lateral area determined by assuming that the site is bounded by a 'fence' 2m high with a lateral area of Height(2m) X Width X Length, and

A_i is the lateral area covered by all the size classes. The following formula is used to calculate the lateral area of a tree which is assumed to be a semi-circle;

$$\text{Area } (A)_i = (\pi r_i^2) / 2 \quad ....4.3$$

where r is the radius of the tree's canopy.

The trees below 2 m were regarded as semi-circles from the ground surface as it was felt that lateral cover would otherwise have been overestimated if the trees were regarded as circular. The values of LCI range from 0 to 1.

By using the above information the relationship between the herbivore species and their selection for certain grassland factors will become apparent.

In addition, the proportional contribution of each grass species to the herbaceous layer in each site was recorded. Table 4.1 lists all the habitat variables which are thought to influence the distribution and habitat selection of the grazing herbivores.

4.2.1.3 Diet

The diet of the herbivores was obtained by estimating the proportional use of each freshly grazed grass species in each quadrat. This method was preferred to the other techniques e.g. stomach content analyses (e.g. Sinclair and Gwynne, 1972; Gwynne and Bell, 1968) and dung analyses (Storr, 1961; Stewart, 1965, 1967; Monro, 1982) for the following three reasons;

1. stomach contents of the grazers, especially the white rhinos, were seldom attainable,
2. dung analyses have resulted in limited success because of

Table 4.1 : Key to the 35 Habitat Factors used in the Correspondence Analysis

Mnemonic	Habitat Factor
CCA	Canopy cover (0 to 10%)
CCB	" " (11 to 40%)
CCC	" " (41 to 100%)
LCA	Lateral cover index (0.0 to 0.1)
LCB	" " " (0.2 to 0.4)
LCC	" " " (0.5 to 1.0)
HCA	Herbaceous cover (0 to 30%)
HCB	" " (31 to 50%)
HCC	" " (51 to 100%)
HEA	Average grass height (0 to 5cm)
HEB	" " " (6 to 15cm)
HEC	" " " (greater than 15cm)
CYDA	Cynodon dactylon
ARCO	Aristida congesta
RHRE	Rhynchelytrum repens
HECO	Heteropogon contortus
THTR	Themeda triandra
ERCU	Eragrostis curvula
ERSU	E. superba
ERRI	E. rigidior
ERGU	E. gummiflua
UNPA	Unpalatable species, eg. Elyonuris argenteus, and Cymbopogon species
HYHI	Hyparrhenia hirta
BOIN	Bothriochloa insculpta
BRSE	Brachiaria serrata
URMO	Urochloa mosambicensis
LOFL	Loudetia flavida
DIER	Digitaria eriantha
PADE	Panicum deustum
PACO	P. coloratum
POSQ	Pogonarthria sqarrosa
SPPY	Sporobolus pyramidalis
CHVI	Chloris virgata
SENI	Setaria nigrirostris
ERCU	Eragrostis species

differential digestion (eg. Stewart and Stewart, 1970), and

3. most importantly, dietary selection coefficients cannot be calculated without information on the availability of the grass species presented to them. With the transect method both availability and utilization of each grass species can be estimated.

The percentage contribution of each grass species in the herbivores' diet was estimated using the following formula developed by Taylor and Walker (1978);

$$D = C \times A \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4.4$$

where, C is the percentage utilization, and
A is the percentage bulk contribution in the feeding site.

The dietary selection or preference by each herbivore for a particular grass species, was calculated as follows;

$$P = C / A \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4.5$$

The grass species utilized by the herbivores were then categorised into 3 different forage types based on their dietary importance; palatable, intermediate and unpalatable. (See section 3.3.1).

4.3 Data Analysis

4.3.1 Calculation of the Habitat Preferences Indices

The habitat preferences were determined for white rhino, hartebeest, wildebeest, zebra and impala by recording the percentage time spent foraging in each of the major habitat types.

The selectivity of the ungulate species (Xi) for a vegetation type j was described by calculating the "comparative grazing intensity" (Hunter, 1962) which quantifies any preferences shown by the herbivores.

Xi Pref. = % of species Xi in veg. type j / % of total area in reserve covered by veg. type j along each transect 4.6

The values of selectivity using this equation can in theory, range from zero to infinity (Duncan, 1975). When a value exceeds one then selection for the vegetation type is occurring, when less than one, negative selection and when equal to one, random selection. The percentage area of each vegetation type seen along the road transects (using figures 2.6 and 3.1) are given below;

(i) Secondary grassland - 19.6%,
(ii) Pediment grassland - 6.0%,
(iii) Valley savanna - 27.6%,
(iv) Hillside savanna - 39.3%
(v) Thickets - 6.5%, and
(vi) <u>Cynodon</u> <u>dactylon</u> "lawns" - 1%.

Duncan (1975) has however identified a number of disadvantages using this method. Firstly, no standard errors can be attached to the values, although the significance of departures from 1 (i.e. random or no selection) can be tested using the chi- square tests. Secondly, the visibility or animal detectability may differ for each habitat type. The second problem is probably the most serious of the two in that biases for or against animal sightings differ depending on the densities of the woody vegetation in each habitat type. The animal detection coefficients should therefore be estimated separately for each habitat type and also for each season. Unfortunately, the importance of these coefficients was only realized (Peddie, pers com) after the field studies had been terminated. The habitat preference data should therefore be analyzed with caution, although the relative importance values of each habitat type to a particular species are believed to be correct.

What these results do not tell us however, is why the species select for particular habitat types. The next section therefore describes a technique - namely Correspondence Analysis - which is used to identify the underlying factors governing the relationship between the herbivore species and their environment Beardall (1982).

4.3.2 Interrelationships Between Habitat Selection and Grassland Structure

The environment is a very complex system comprising of a number of features, both vegetation and physiographic. Because of this a multivariate technique is used to display the importance of each environmental factor to a herbivore species (Beardall, 1982).

Beardall (1982) analysed the use of three similar multivariate techniques, ie. Correspondence Analysis, Principal Component Analysis and Linear Logistic Model on a two- dimensional data matrix consisting of animal species measured over a range of habitat factors. These methods use graphical techniques based on an eigenstructure approach to represent multivariate data in a multi-dimensional space (Beardall, 1982). By interpreting the output in terms of the habitat factors, ecological meaning with regards to the species-environment relationship can be given to the orthogonal axes. Beardall (1982) concluded that of all the analyses, Correspondence Analysis is best suited to ecological data even though similar results were obtained by all the analyses. The suitability of this technique is highlighted by the fact that a simultaneous graphical display of the observations (herbivore species) and the variables (habitat factors) is obtained. Hence Correspondence Analysis was used to identify those structural features of the habitat which influenced the selection by grazing ungulates at Pilanesberg.

4.3.2.1 Correspondence Analysis

Correspondence Analysis is used to display graphically the relationship between the subjects and objects of a matrix of non-negative numbers, simultaneously (Beardall,1982) The model that she used follows that of Greenacre (1978) and is briefly described below.

The elements of the data matrix are first transformed to proportions that may be interpreted as probability values. This new matrix (P) is then tested using an approach similar to the chi-squared statistic for independency of the rows (ie. species) and columns (habitat variables). In order to test this hypothesis the matrix P must first be transformed into a notation such that,

$$P_{ij} = P_{ij} - r_i c_j^T \quad \text{..............4.7}$$

where, r_i is the sum of row i of P, and

c_j is the sum of column j of P.

The next step involves the "centering" of the matrix where, rc^T is the mean or "centre" of the rows and columns of P. Thus by subtracting this term from the matrix P we merely "move" the matrix so that it "centres" on the origin. This transferred matrix has been termed the "deviation score" matrix.

The elements of the subjects and objects measured on these disparate scales are then differentially weighted and "equalised" by dividing each element by the square root of the row and column sums. Finally, the coordinates of the subjects and objects in a k- dimensional space are calculated using both the eigenvalues and the diagonal matrices of the row sums and the column sums.