HABITAT SELECTION

INTRODUCTION

A feature of African ungulates is their wide range of morphological diversity. This causes resource partitioning through dietary, and thus habitat, selection (Owen-Smith 1985, In: Fabricius 1989). Habitat selection is a combination of behavioural phenomena involving stimuli and response to which individuals will react by staying or leaving (Van Rooyen 1990).

Species composition and structure are the two components of the vegetation, which form an important part of the habitat. The species which constitutes the vegetation will determine whether or not the food source is sufficient. The structure of the vegetation plays an equally important role in determining whether or not the habitat is suitable e.g. shelter and visibility (Vermaak 1996).

The kinds of food eaten by animals of any one species are not fixed and differ in relative abundance both spatially and temporally. The benefits and costs of feeding on particular food types depends on phenotypic features of the herbivore, as well as environmental circumstances. Benefits depend on nutrient yields, which are influenced by the digestive system (Owen-Smith 1996). All these factors create a feeding style which is the most important factor in determining the habitat selected by any ungulate (Jarman 1977, In: Van Rooyen 1990).

Animals not only show preferences for different habitats by shelter and diet, but also for topographical features such as slopes or areas of differing soil slopes or level territory or different soils. (Bell 1971; Bothma & Van Rooyen 1989; Novellie 1990)

A sound knowledge of the habitat requirements of ungulates within a game reserve is imperative for the formulation of management policies (Funston 1992).

Methods

Collection of data

The method used in this study is the same as used by Vermaak (1996).
The homogenous vegetation units in this reserve were determined by Van Wijk (1996) and a grid was superimposed over this map. Each grid square was 1 cm by 1 cm (100 m by 100 m on the ground) and was allocated a reference number. The survey was conducted from March 1998 to March 1999.

The study area was surveyed at least twice a week, in the mornings and afternoons, from vehicles, hides and on foot. The route taken was fixed and covered all vegetation types. The animals were observed by means of binoculars.
When an animal was observed it was first established which species it was and then the time, date, grid reference, size of the group and environmental variables were recorded.

The following data were recorded at each sighting on a sightings sheet (Appendix 1):

Distance from water

The distance from water was measured as follows:

- 0 - 100 m
- 100 - 200 m
- 200 - 500 m
- > 500 m

Erosion

The erosion was categorised as follows:

- slight / none = no erosion or very small bare areas with no cover
- Moderate = low plant cover and large amounts of bare areas.

Landscape position

- Plains = large, relatively flat areas
- Drainage areas = areas around waterholes

Rock cover

The rock cover was described in percentage as follows:

- 0 - 25%
- >26%

Vegetation cover

The cover of the vegetation was measured in percentage and split into classes for the different vegetation layers (Table 2).

Table 2

Classes of cover for different vegetation layers

Tree layer	Class 1	Class 2	Class 3	Class 4
Herbaceous layer Shrub layer (<2m) Tree layer (2 - 6m) Tree layer (>6m)	0 - 50% 0 - 5% 0 - 2.5% 0 - 2.5%	51 - 70% 6 - 10% 2.6 - 10% 2.6 - 5%	71 - 85% 11 - 15% 11 - 20% 6 - 10%	86% + 16% + 21% + 11% +

Herbaceous height

The grass height was classed as:

- Short (0 - 200 mm)
- Medium (> 200mm)

Animals

The following data was recorded for each species observed:

- Species
- Association with other species (i.e. If another species was within 100m of the observed species, the species were known as associating with one another.)
- Activities
- Grazing = half or more of the group is grazing
- Drinking = at least one animal is drinking
- Resting = half or more of the group is lying down or standing still

- Flight = the group is fleeing from a disturbance
- Moving = the group is moving to another area, not because of a disturbance
- Mating = at least two individuals are mating
- Mock fighting = at least two individuals are mock fighting

Statistical Analysis

Frequency Histograms

Frequency histograms were constructed to illustrate the number of observations (dependent axis) against the habitat variables, i.e. erosion or grass height. The preferences for each habitat variable were tested for significance using the Chi-square test. The value of X^2 is the measure of magnitude of the discrepancies between the observed and expected frequencies and is calculated by the equation: $X^2 = (O - E)^2 / E$, where O = observed values and E = expected values. The null hypothesis assumes that there was no significant preference for any habitat variables. If the value of X^2 exceeds the decided significance level, then the null hypothesis is rejected (Snedecor & Cochran 1989). A significant difference level of 5% ($P=0.05$) was accepted.

Correspondence Analysis

The correspondence analysis was used to show the preferred plant communities of each herbivore species, as well as to illustrate each species relationship with other species. The correspondence analysis is much the same as the X^2 test in that it measures the difference that the data shows from the null hypothesis.

The end result of the correspondence analysis is a graphical display of the correlation between the two variables, i.e. species and community. The principle behind this analysis is to maximise inertia, which is a squared distance measure, and thus find the measurement from the hypothesis.

RESULTS AND DISCUSSION

Frequency Histograms

Zebra

In summer (X^2=81, P<0.05, df=1) and spring (X^2=70.56, P<0.05, df=1) it was found that zebra significantly preferred less eroded areas. The same trend was followed for winter, while in autumn the zebra were found to frequent more eroded areas (Figure 8a). The relationship between these preferences and the season of the year was found to be significant: X^2=103.86, P<0.05, df=3.

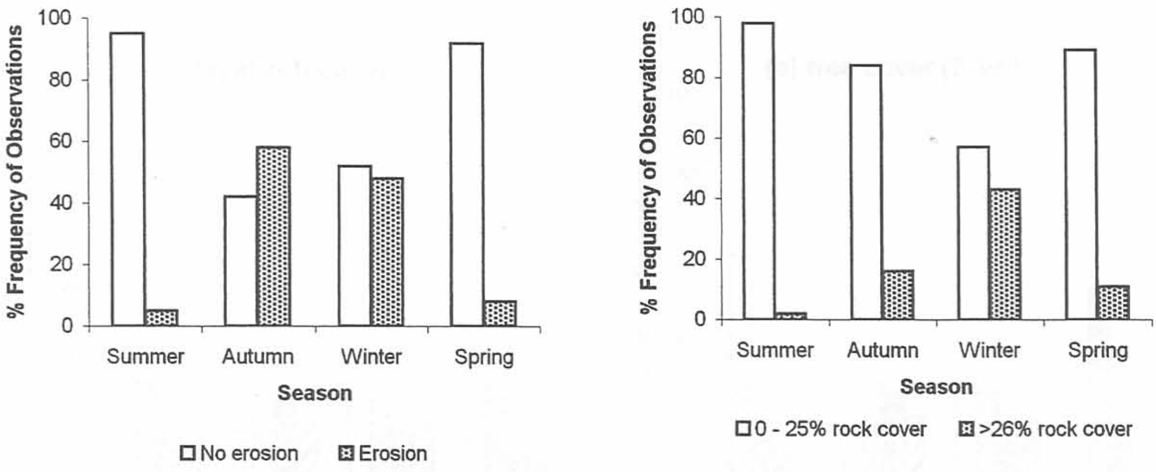
In all four seasons it was found that zebra preferred areas which were less rocky. They spent 84% of their time in less rocky areas in autumn, 89% in spring and 57% in winter (Figure 8b).

Zebra tended to remain 200 to 500 m distance from water in summer (X^2=91, P<0.05, df=3), which was significantly different from other observations, no significant preferences were found over the other seasons (Figure 8c), although a relationship did exist between their preference to water and the time of year (X^2=51.698, P<0.05, df=9).

Figure 8d shows that zebra significantly preferred plain type areas to drainage areas in all the seasons, 91% of the time in summer and more than 85% in the other seasons.

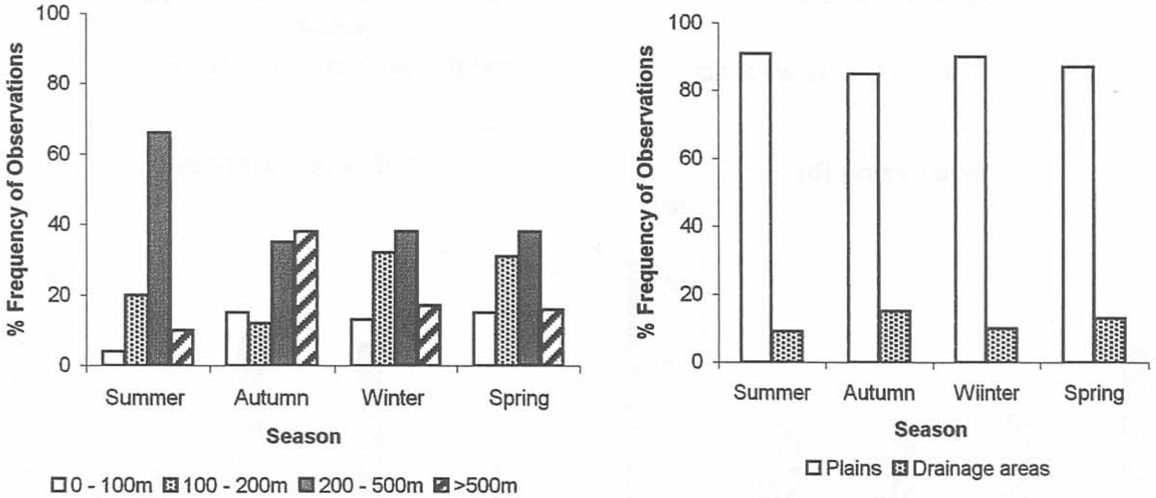
Zebra preferred tall grass predominantly in summer (X^2=18.49, P<0.05, df=1) and spring (X^2=10.61, P<0.05, df=1), they preferred short grass 53% of the time in winter and 59% of the time in autumn (Figure 8e). The relationship between this preference and the seasons of the year was a significant one (X^2=10.170, P<0.05, df=3).

In summer and spring, zebra tended to spend more time in areas where the shrub cover was less than 10% (Figure 9a). In winter and autumn they showed no significant preference to areas with more or less shrub cover. The preference towards shrub cover was correlated with the time of the year: X^2=42.519, P<0.05, df=9.



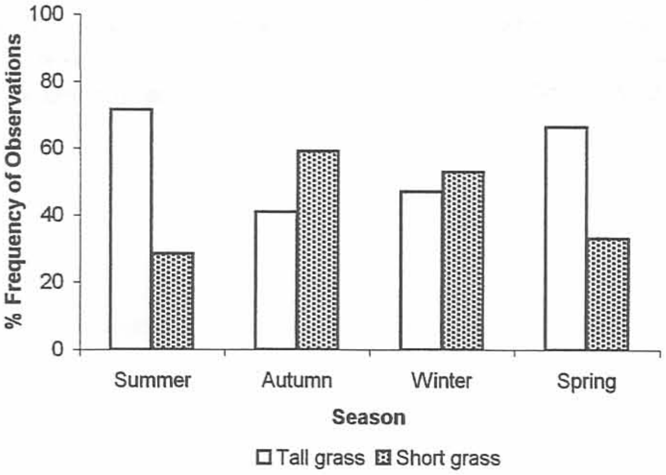
(a) erosion

(b) rocks



(c) distance from water

(d) landscape



(e) grass length

Figure 8. Seasonal frequency distribution of zebra in relation to (a) erosion, (b) rocks, (c) water, (d) landscape and (e) grasslength

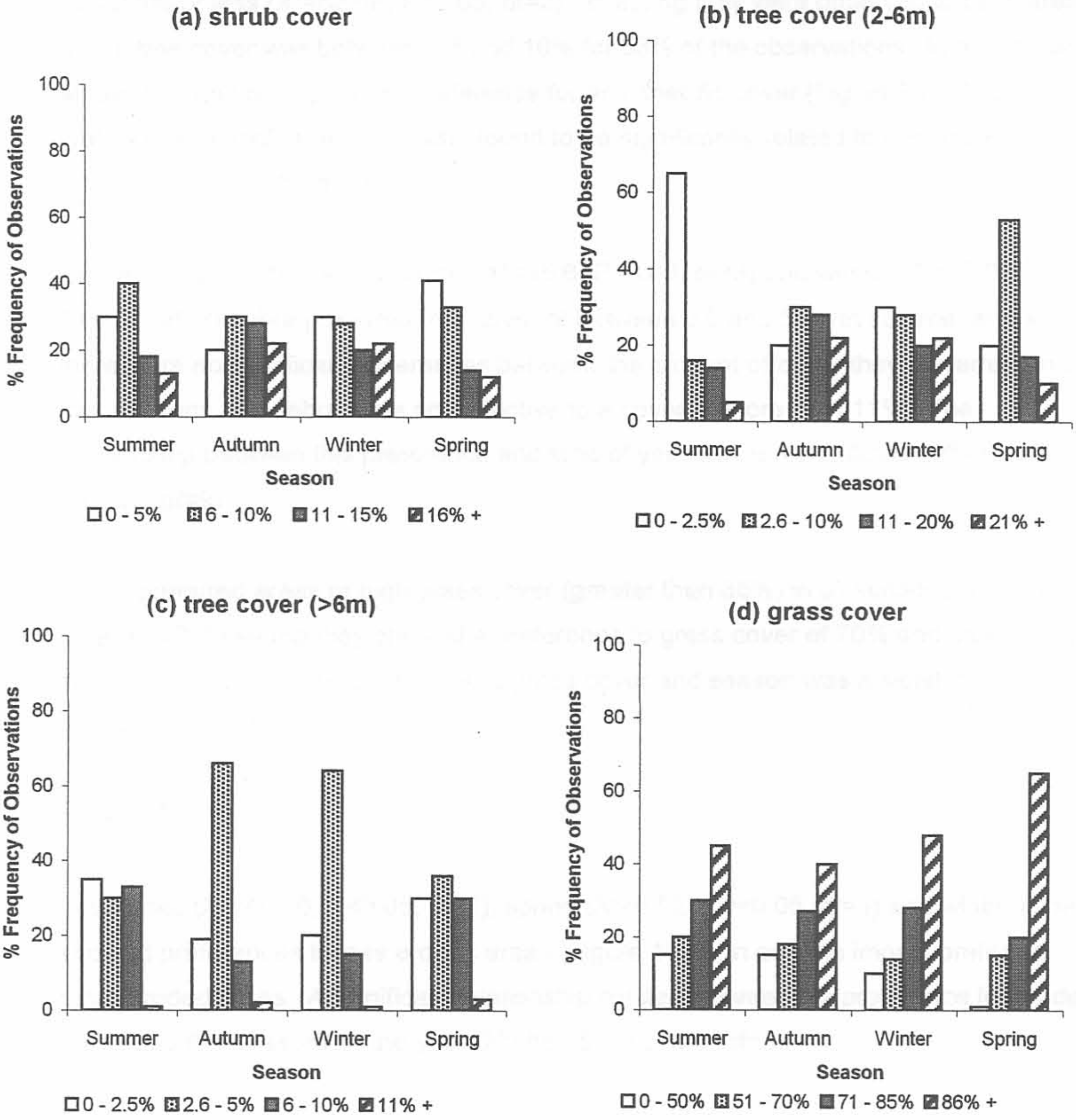


Figure 9. Seasonal frequency distribution of zebra in relation to (a) shrub cover, (b) tree cover (2-6m), (c) tree cover (>6m) and (d) grass cover

Zebra were observed significantly in summer to be in areas where the tree cover (2-6m) was 2.5% or less (X^2=88.08, $P<0.05$, df=3). In spring they were observed to be in areas where tree cover was between 2.6 and 10% for 53% of the observations. In autumn and winter they had no significant preference for any specific cover (Figure 9b). The preference towards tree cover was found to be significantly related to the time of year (X^2=102.22, $P<0.05$, df=9).

Figure 9c illustrates that in autumn (X^2=95.6, $P<0.05$, df=3) and winter (X^2=87.06, $P<0.05$, df=3) zebra preferred tree cover of between 2.6 and 5%. In summer and spring there were no significant differences between the amount of cover they preferred. In all four seasons, the zebra were not selective to a cover of more than 11%. The relationship between this preference and time of year was not significant (X^2=15.987, $P>0.05$, df=9).

Zebra preferred areas of high grass cover (greater than 85%) in all seasons of the year (Figure 9d). In spring they showed a preference to grass cover of 70% and more. The correlation between the preference to grass cover and season was a significant one: X^2=32.79, $P<0.005$, df=9.

Impala

In summer (X^2=40.96, $P<0.05$, df=1), spring (X^2=67.24, $P<0.05$, df=1) and winter impala showed preferences to less eroded areas (Figure 10a). In autumn impala preferred more eroded areas. A significant relationship existed between the preference for eroded areas and the seasons of the year (X^2=86.75, $P<0.005$, df=3).

Figure 10b illustrates that in all four seasons impala were observed more in less rocky areas, for more than 75% of observations each time.

Impala were observed at all four distances from water during all four seasons, with a slightly higher preference to remain a distance of 200 to 500m from water in winter (X^2=101, $P<0.05$, df=3), summer and spring (Figure 10c).
The time of the year was a factor in this preference and a significant relationship exists between the two (X^2=33.80, $P<0.05$, df=9).

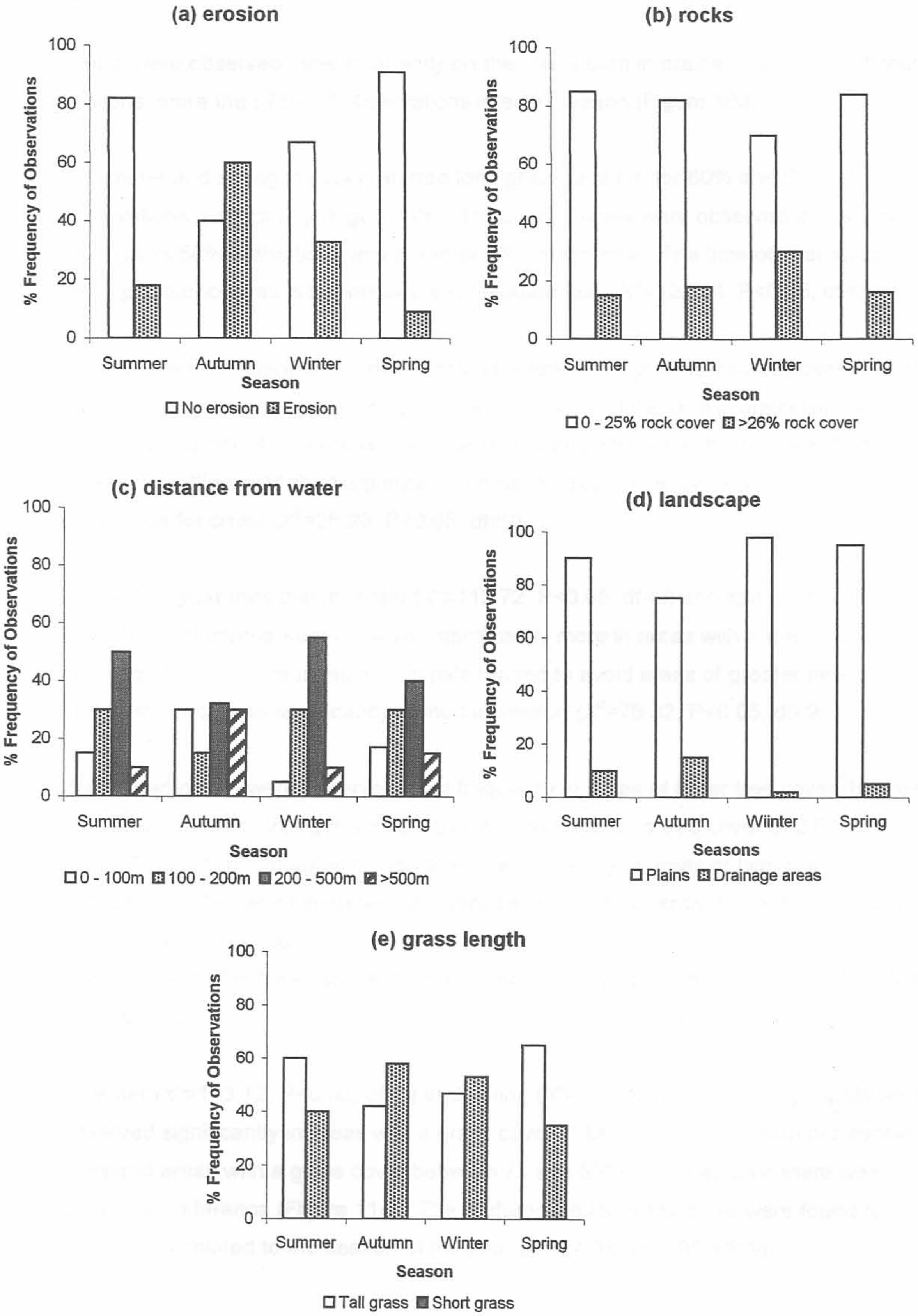


Figure 10. Seasonal frequency distribution of impala in relation to (a) erosion, (b) rocks, (c) water, (d) landscape and (e) grass length

Impala were observed more frequently on the plains than in drainage areas for all four seasons, more than 75% of observations in each season (Figure 10d).

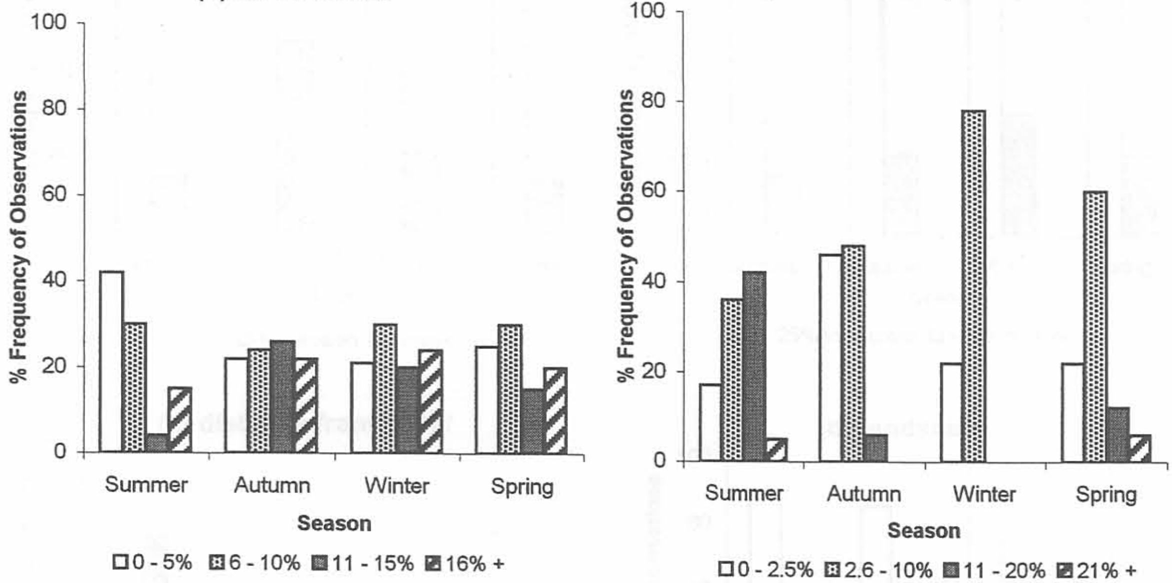
In summer and spring impala preferred long grass to short, for 60% and 65% of observations respectively (Figure 10e). In autumn impala were observed in areas of short grass 58% of the time, and in winter 53% of the time. The time of year influences these preferences, as is shown by the Chi-square test: $X^2=12.704$, $P<0.05$, df=3.

Impala showed no particular preferences for areas with high or low shrub cover in winter, spring or autumn. In summer impala were found 42% of the time in areas with less than 5% cover and only 4% of observations were in areas where shrub cover was between 11 and 15% (Figure11a). A significant correlation existed between seasons and preference for cover ($X^2=26.26$, $P<0.05$, df=9).

Figure 11b illustrates that in winter ($X^2=112.72$, $P<0.05$, df=3) and spring ($X^2=70.56$, $P<0.05$, df=3) impala were observed significantly more in areas with a tree (2-6m) cover of 2.6 to 10%. In all four seasons impala tended to avoid areas of greater tree cover. This preference was significantly related to season ($X^2=78.32$, $P<0.05$, df=9).

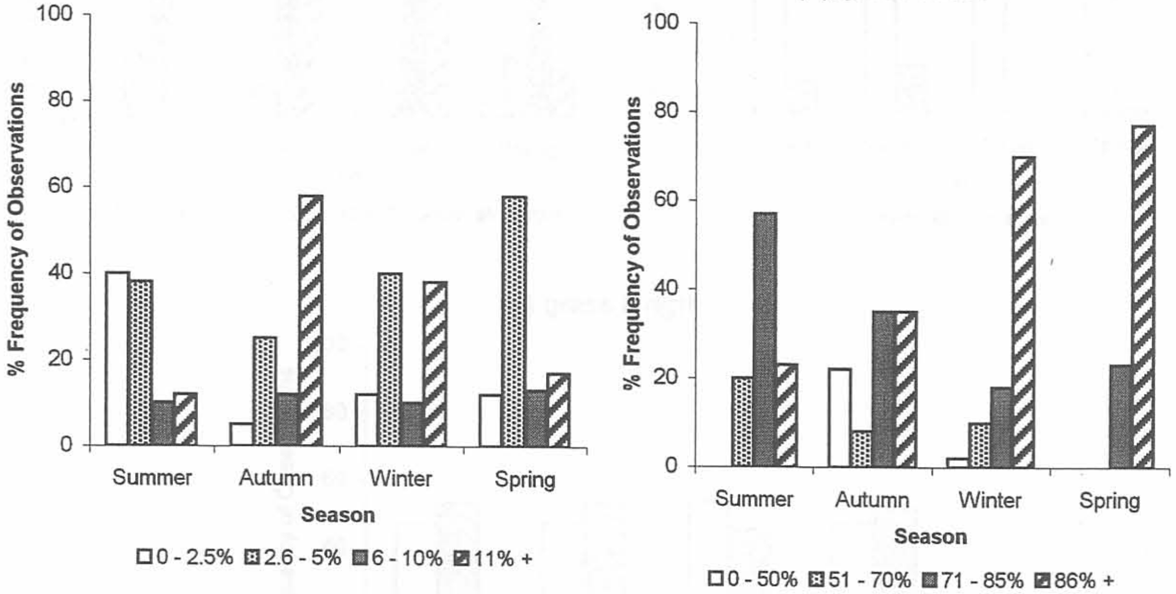
In summer impala were observed most frequently in areas of lower tree cover (between zero and 2.6%). In spring the most observations were for a tree cover of 2.6 to 5% cover (Figure 11c). In autumn impala were seen mostly in areas of high tree cover (more than 11%), while in winter they were seen most frequently in areas of 2.6 to 5% and more than 11% cover.
The preference for cover was significantly related to the seasons of the year ($X^2=25.12$, $P<0.05$, df=9).

In winter ($X^2=113.12$, $P<0.05$, df=3) and spring ($X^2=108.32$, $P<0.05$, df=3) impala were observed significantly in areas with a grass cover of 86% or more. In summer impala preferred areas with a grass cover between 71 and 85% and in autumn there was no particular preference (Figure 11d). The preferences for grass cover were found to be significantly related to the season of the year ($X^2=34.14$, $P<0.05$, df=9).



(a) shrub cover

(b) tree cover (2-6m)



(c) tree cover (>6m)

(d) grass cover

Figure 11. Season frequency distribution of impala in relation to (a) shrub cover, (b) tree cover (2-6m), (c) tree cover (>6m) and (d) grass cover

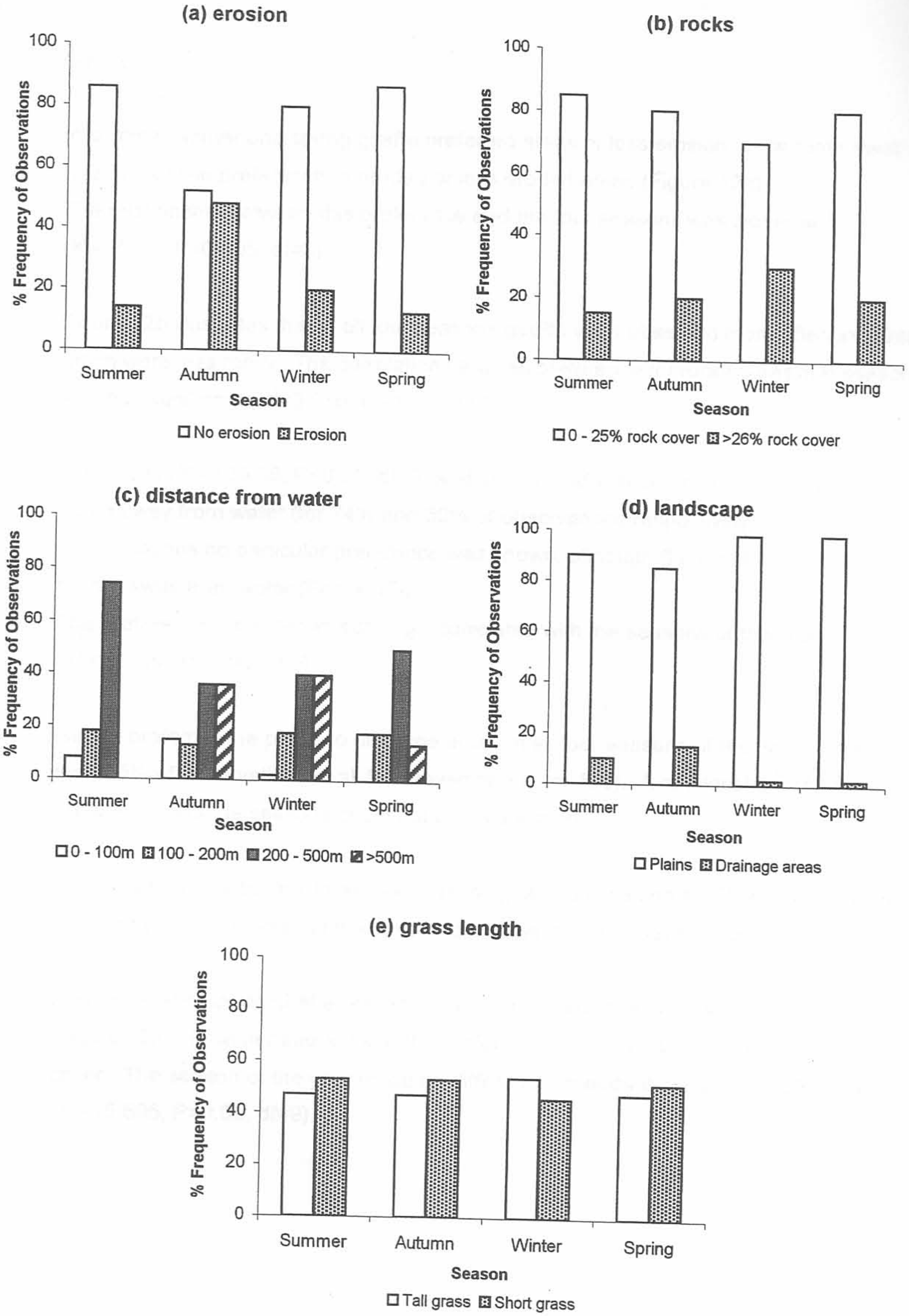


Figure 12. Season frequency distribution of giraffe in relation to (a) erosion, (b) rocks, (c) water (d) landscape and (e) grass length

Giraffe

In summer, winter and spring giraffe preferred areas of less erosion. In autumn there was no definite preference to eroded or less eroded areas (Figure 12a).
The relationship between this preference and the four seasons was significant (X^2=20.37, P<0.005, df=3).

Figure 12b illustrates that in all four seasons giraffe were observed more often in areas which were less rocky. The correlation between preference for rocky areas and seasons was not significant (X^2=3.956, P>0.05, df=3).

In summer (X^2=109.56, P<0.05, df=3) and spring giraffe spent most time around 200 to 500m away from water (for 74% and 50% of observations respectively), while in the other seasons no particular preference was shown, although the trend was to areas further away from water (Figure 12c).
The preference for water was strongly correlated with the seasons of the year (X^2=26.107, P<0.05, df=9).

Giraffe preferred the plains to drainage areas in all four seasons of the year for more than 85% of observations in all four seasons (Figure 12d). A relationship between this preference and the seasons could not be established.

Figure 12e illustrates that in all four seasons giraffe showed no significant preference to length of grass, nor was there a correlation between this preference and the seasons.

In summer and spring giraffe preferred shrub cover which was between zero and 10% (Figure 13a). In winter and autumn the preference was towards areas of 6 to 10% cover. The season of the year made no difference towards the giraffe's preferences (X^2=15.606, P>0.05, df=9).

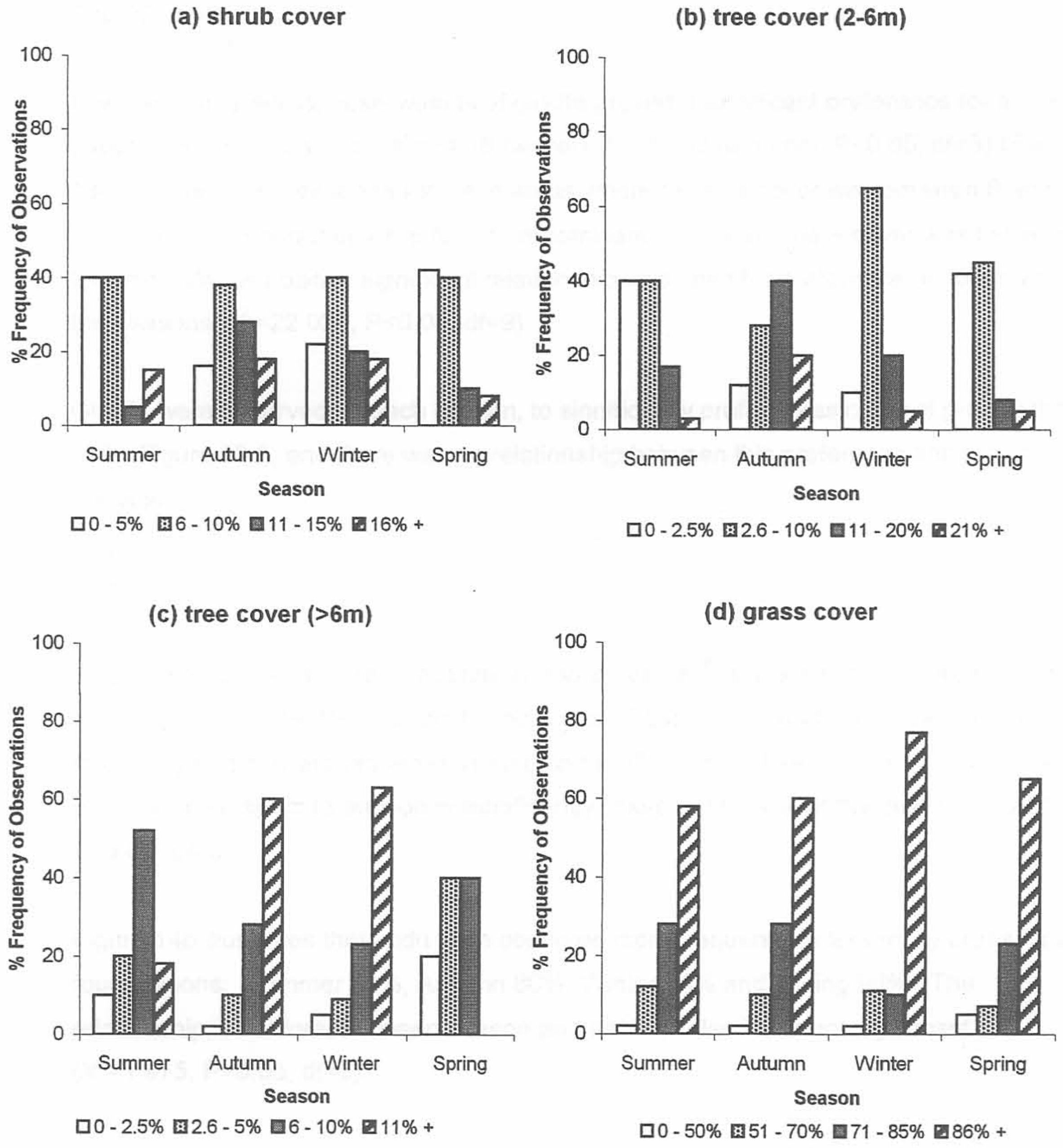


Figure 13. Seasonal frequency distribution of giraffe in relation to (a) shrub cover, (b) tree cover (2-6m), (c) tree cover (>6m) and (d) grass cover

Giraffe were observed in summer and spring mainly in areas where the tree cover (<6m) was between zero and 10% (Figure 13b). In winter the number of observations (X^2=90, $P<0.05$, df=3), was significantly for the category 2.6 to 10%. The time of year played an important role in these preferences and the relationship was significant (X^2=39.321, $P<0.05$, df=9).

In winter and autumn, observations of giraffe proved a significant preference for a tree cover of greater than 11% (X^2=84.16 (winter), X^2=79.52 (autumn), $P<0.05$, df=3) (Figure 13c). In summer they tended to be in areas where the tree cover was between 6 and 10%, while in spring they were found predominantly in areas where cover was between 2.6 and 10%. A positive significant relationship was seen for preference of cover and the seasons (X^2=22.029, $P<0.05$, df=9).

Giraffe were observed, in each season, to significantly prefer grass cover of greater than 85% (Figure 13d), and there was no relationship between this preference and the time of the year.

Kudu

Kudu were observed more frequently in less eroded areas in summer (X^2=36, $P<0.05$, df=1), spring (X^2=49, $P<0.05$, df=1) and winter (Figure 14a). Kudu were seen more frequently in highly eroded areas in autumn for 57% of the observations. The behaviour of kudu with respect to erosion is significantly linked to the time of the year (X^2=10.21, $P<0.05$, df=3).

Figure 14b illustrates that kudu were observed more frequently in less rocky areas for all four seasons: Summer 80%, Autumn 80%, Winter 75% and Spring 90%. The relationship, therefore, between season and habitat selection is not significant (X^2=1.975, $P>0.05$, df=3).

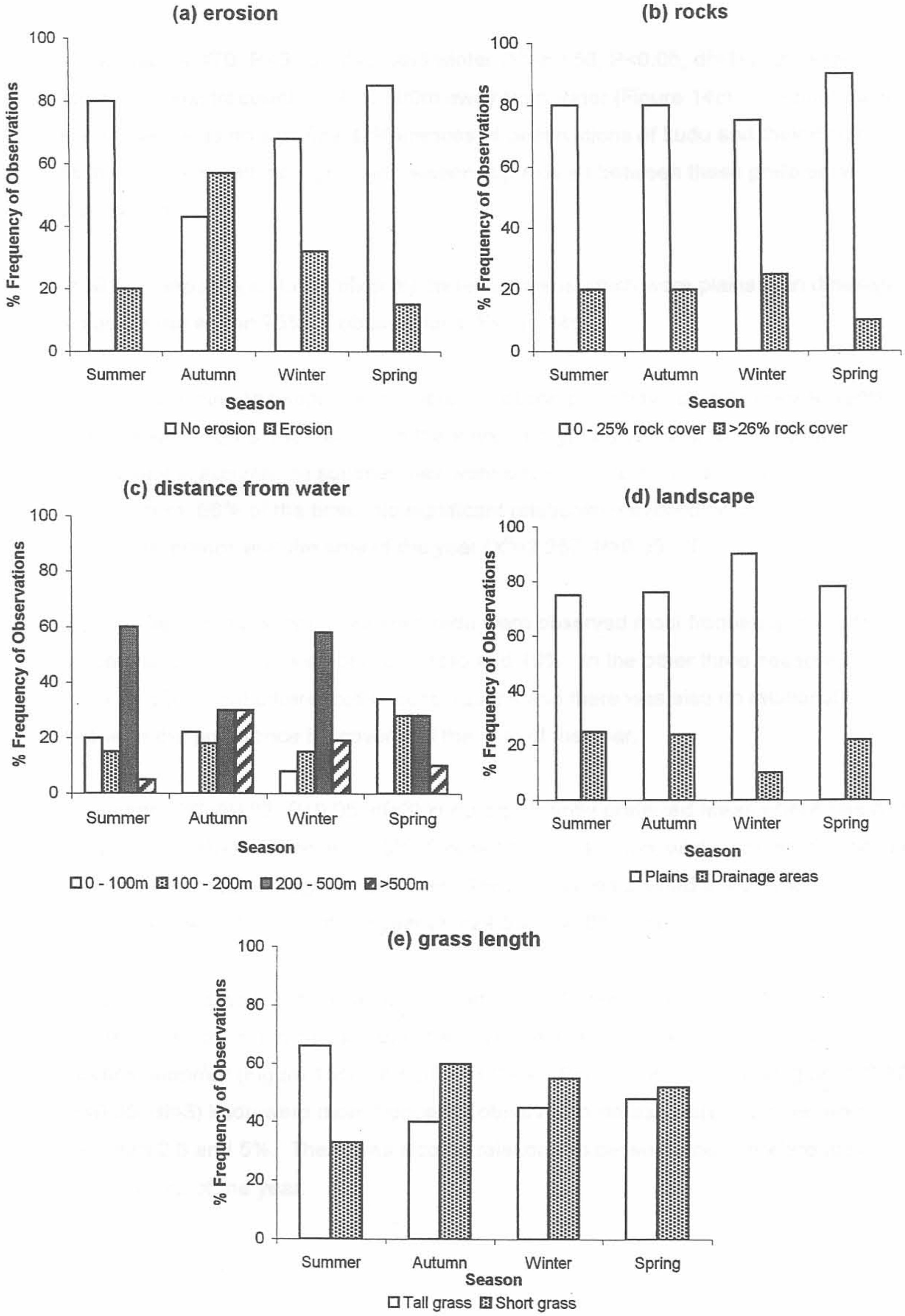


Figure 14. Seasonal frequency distribution of kudu in relation to (a) erosion, (b) rocks, (c) water, (d) landscape, (e) grass length

In summer (X^2=70, P<0.05, df=3) and winter (X^2=60.56, P<0.05, df=1) kudu were observed most frequently 200 to 500m away from water (Figure 14c). In autumn and spring there was no significant differences of observations of kudu and their distances from water. Overall, no significant relationship existed between these preferences and the seasons.

In all four seasons kudu significantly preferred areas which were plains than drainage areas for more than 75% of observations (Figure 14d).

In autumn, winter and spring, kudu were not observed to have a preference towards grass length (Figure 14e), although there was a slight trend towards shorter grass, particularly in autumn. In summer they were observed more frequently in areas with longer grass, 66% of the time. No significant relationship existed between the grass length preference and the time of the year (X^2=2.257, P>0.05, df=3).

Figure 15a illustrates that in summer kudu were observed most frequently in areas where the shrub cover was between zero and 10%. In the other three seasons there were no significant differences in observations and there was also no relationship between the preference for cover and the time of the year.

In summer (X^2=69.92, P<0.05, df=3) kudu significantly preferred areas where tree cover (2-6m) was between zero and 2.5% (Figure 15b). In autumn, winter and spring the trend was towards areas of higher tree cover. These preferences had a significant relationship with the time of the year (X^2=24.85, P<0.05, df=9).

In summer and winter, there were no significant differences in observations of kudu in areas of tree cover (>6m), although there were almost no observations for zero to 2.5% cover in summer (Figure 15c). In autumn (X^2=82, P<0.05, df=3) and spring (X^2=70.12, P<0.05, df=3) kudu were more frequently observed in areas where the cover was between 2.6 and 5%. There was also no relationship between these preferences and the seasons of the year.

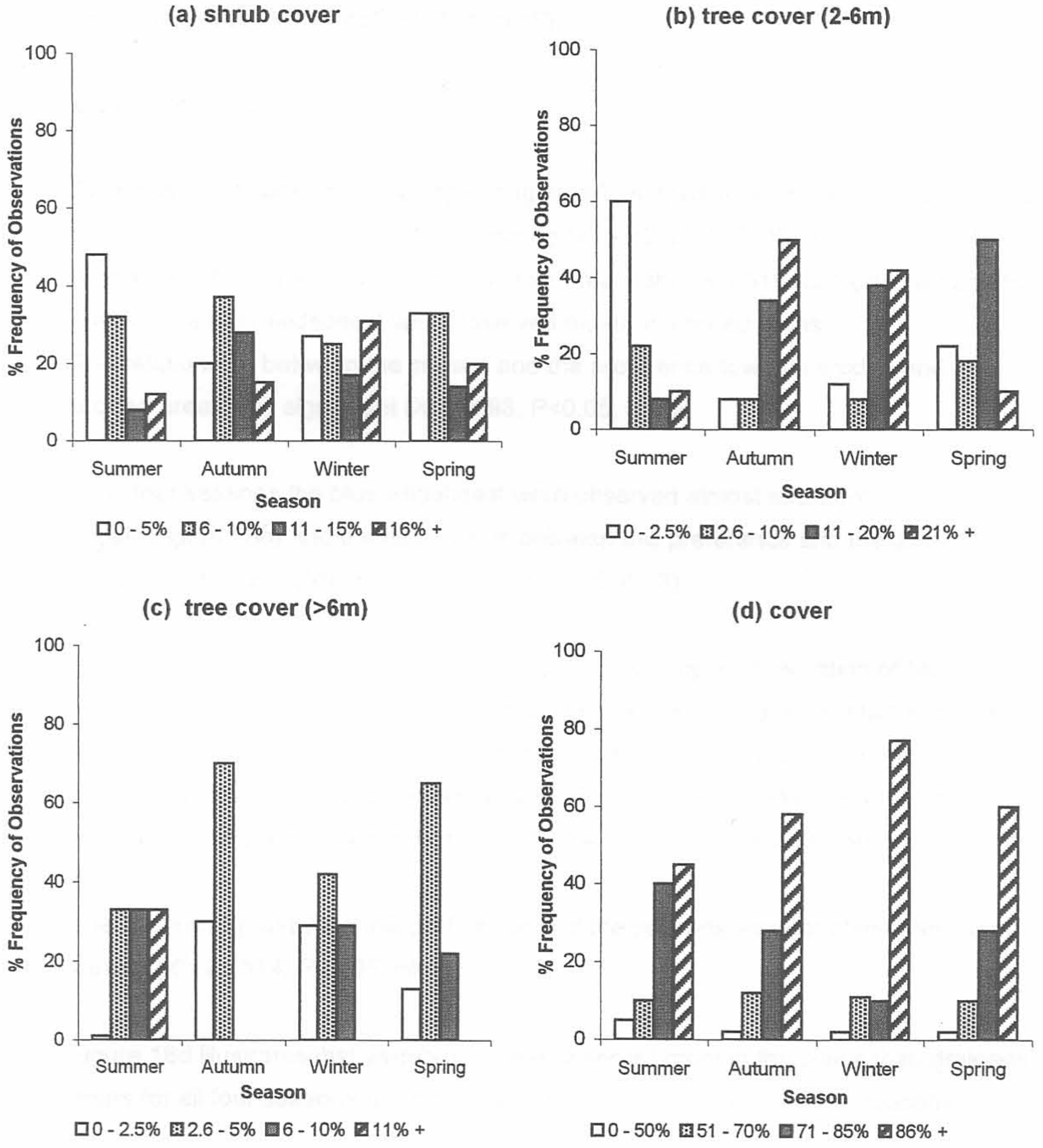


Figure 15. Seasonal frequency distribution of kudu in relation to (a) shrub cover, (b) tree cover (2-6m), (c) tree cover (>6m) and (d) grass cover

In all four seasons, kudu were observed most frequently in areas where grass cover is greater than 85% (Figure 15d). In summer they were also observed frequently where grass cover was between 71 and 85%. The time of the year did not significantly affect the preferences (X^2=14.865, P>0.05, df=9).

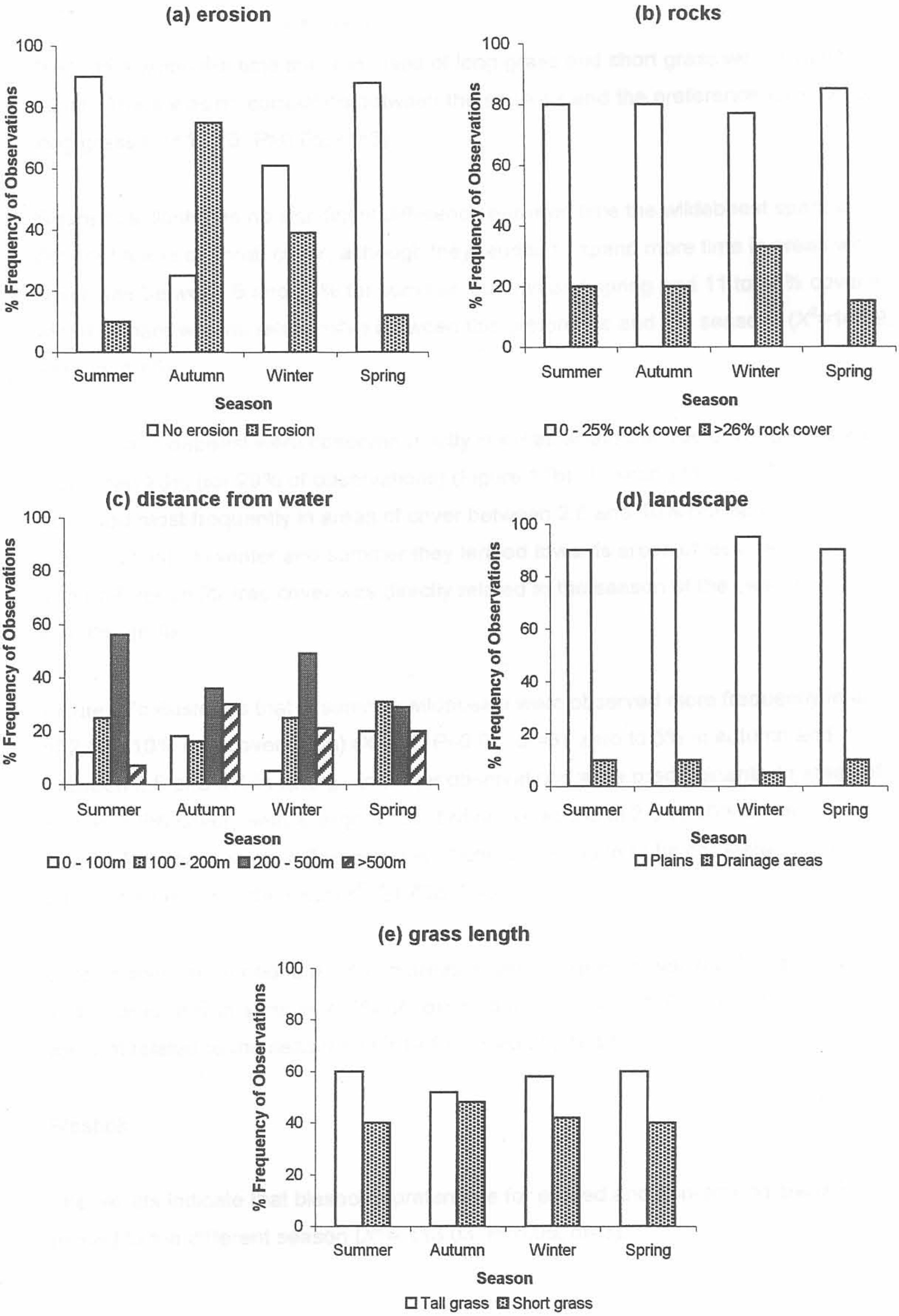
Blue wildebeest

Blue wildebeest were observed spending significantly more time in less eroded areas in summer (X^2 = 64, P<0.05, df=1) and spring (X^2 = 63.21, P<0.05, df=1) (Figure 16a). In winter the differences in observations were only slight, with 61% in eroded areas. In autumn the blue wildebeest were observed mostly in eroded areas.
The relationship between the season and the preference towards eroded and non-eroded areas was significant (X^2=68.93, P<0.05, df=3).

In all four seasons the blue wildebeest were observed almost exclusively in less rocky areas (Figure 16b) and the relationship between this preference and the different seasons was not significant (X^2= 3.569, P>0.05, df=3).

In spring and autumn there was no significant difference in observation of blue wildebeest and the distances they kept to water, although in autumn the trend was further from water (Figure 16c). In summer and winter the wildebeest remained 200 to 500m away from the nearest water point for 56% and 49% of the observed time respectively and this was significant (X^2=62.84 (summer), X^2=39.68 (spring), P<0.05, df=3).
The relationship between this preference and the seasons was correlated, although weakly (X^2=21.514, P<0.05, df=9).

Figure 16d illustrates that wildebeest were observed more in the plains than drainage areas for all four seasons (for more than 89% of observations in each season).



(a) erosion

(b) rocks

(c) distance from water

(d) landscape

(e) grass length

Figure 16. Seasonal frequency distribution of blue wildebeest in relation to (a) erosion, (b) rocks, (c) water, (d) landscape and (e) grass length

16e). In autumn the time spent in areas of long grass and short grass were almost equal. There was no correlation between the seasons and the preference for short or long grass (X^2=1.275, P>0.05, df=3).

Figure 17a illustrates no significant difference between time the wildebeest spent in different areas of shrub cover, although they tended to spend more time in areas where cover was between 6 and 10% for summer, autumn and spring and 11 to 15% cover in winter. There was no relationship between this preference and the seasons (X^2=14.69, P<0.05, df=9).

In autumn wildebeest were observed mostly in areas where the tree cover (2-6m) was more than 20% (for 29% of observations) (Figure 17b). In spring the wildebeest were observed most frequently in areas of cover between 2.6 and 10% (for 36% of observations). In winter and summer they tended towards areas of less tree cover. The preference for tree cover was directly related to the season of the year (X^2=21.263, P<0.05, df=9).

Figure 17c illustrates that in summer wildebeest were observed more frequently in areas of 2.6 to 10% tree cover (>6m) (X^2=64, P<0.05, df=3), zero to 5% in autumn and between 2.6 and 5% in spring. In winter observations were predominantly in areas of zero to 2.5% cover, with a large amount of observations at 2.6 to 10% cover.
The preference towards different areas of cover was found to be correlated to the different seasons of the year (X^2=21.438, P<0.05, df=9).

Blue wildebeest tended to remain in areas where the grass cover was higher (Figure 17d), particularly in summer (76% of observations, X^2=145.04, P<0.05, df=3) and this was not related to the seasons (X^2=12.979, P>0.05, df=9).

Blesbok

The results indicate that blesbok's preference for eroded and non-eroded areas is related to the different season (X^2= 113.03, P<0.05, df=3).

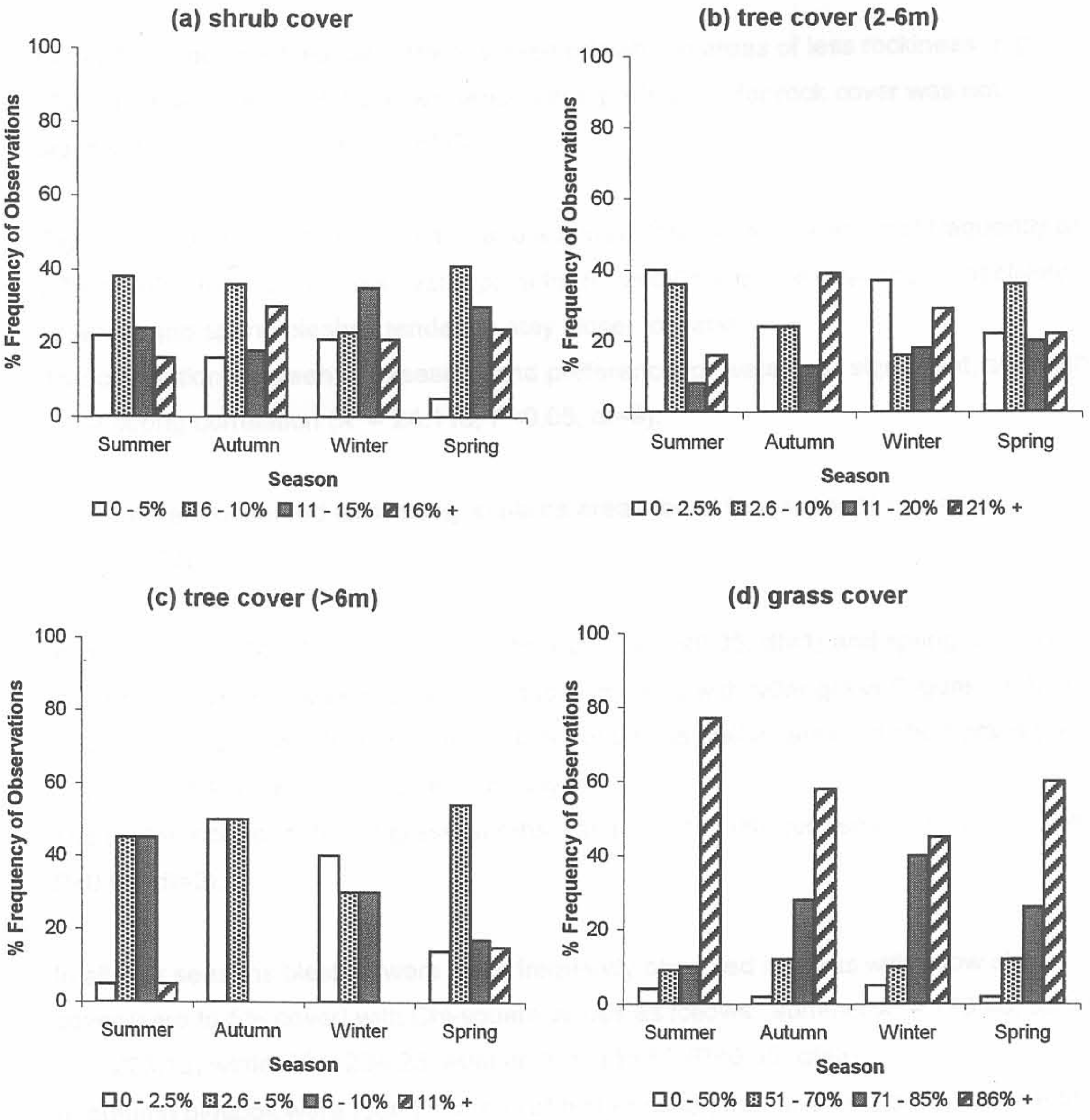


Figure 17. Season frequency distribution of blue wildebeest in relation to (a) shrub cover, (b) tree cover (2-6m), (c) tree cover (>6m) and (d) grass cover

In the warmer seasons blesbok were observed exclusively in areas of less erosion (Summer: $X^2 = 96.04$; Spring: $X^2 = 96.04$, $P<0.05$, df=1), while in autumn and winter they were observed more frequently in eroded areas (Figure 18a).

For all four seasons blesbok were observed primarily in areas of less rockiness (Figure 18b) and the relationship between season and preference for rock cover was not significant ($X^2 = 5.353$, $P>0.05$, df=3).

Figure 18c illustrates that in summer and autumn blesbok were seen most frequently at 200 to 500m from the nearest water point for 52 and 61% of observations respectively. In winter and spring blesbok tended to stay closer to water.
The correlation between the seasons and preference for water was significant, although not a strong correlation ($X^2 = 24.116$, $P<0.05$, df=9).

Blesbok were observed exclusively in plains areas for all four seasons of the year (Figure 18d).

In summer ($X^2 = 36$, $P<0.05$, df=1), winter ($X^2 = 64$, $P<0.05$, df=1) and spring ($X^2 = 49$, $P<0.05$, df=1) blesbok were observed mostly in areas with taller grass (Figure 18e). In autumn blesbok spent time in areas of taller grass, as well as areas of short grass (for 62% and 38% of observations respectively).
The preference for differing grass lengths was related to different seasons ($X^2 = 12.526$, $P<0.05$, df=3).

In all four seasons blesbok were more frequently observed in areas with a low shrub cover (zero to 5% cover) with Chi-square values as follows: summer $X^2 = 170.46$, spring $X^2 = 223.12$, winter $X^2 = 284.25$, autumn $X^2 = 118.88$ ($P<0.05$, df=3).
In autumn blesbok were found in areas of higher cover, but for a very small percent of observations (Figure 19a).

Figure 19b illustrates that in winter and spring blesbok were observed more frequently in areas of low tree cover (2-6m), between zero and 2.5% cover.

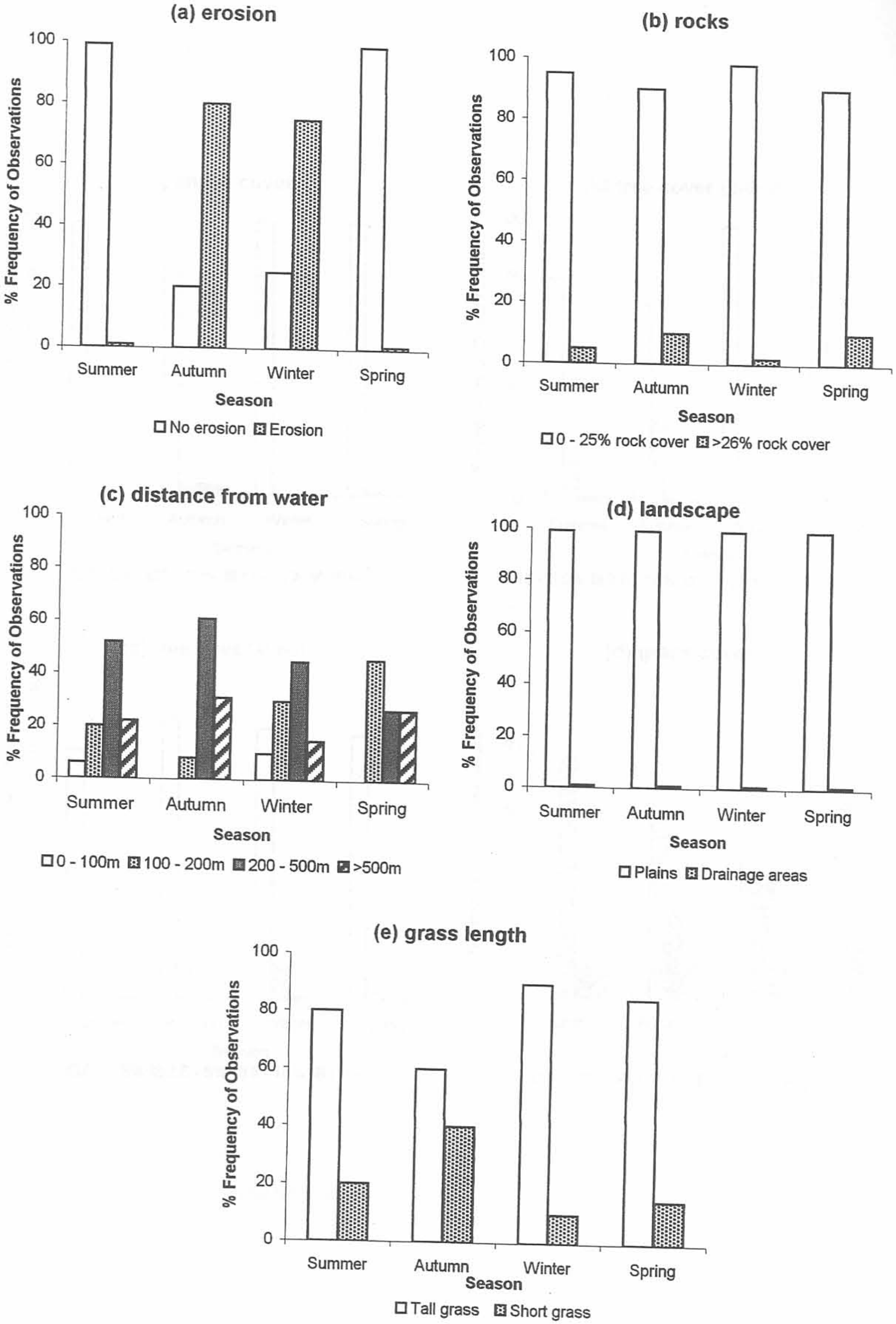


Figure 18. Seasonal distribution of blesbok in relation to (a) erosion, (b) rocks, (c) water, (d) landscape and (e) grass length

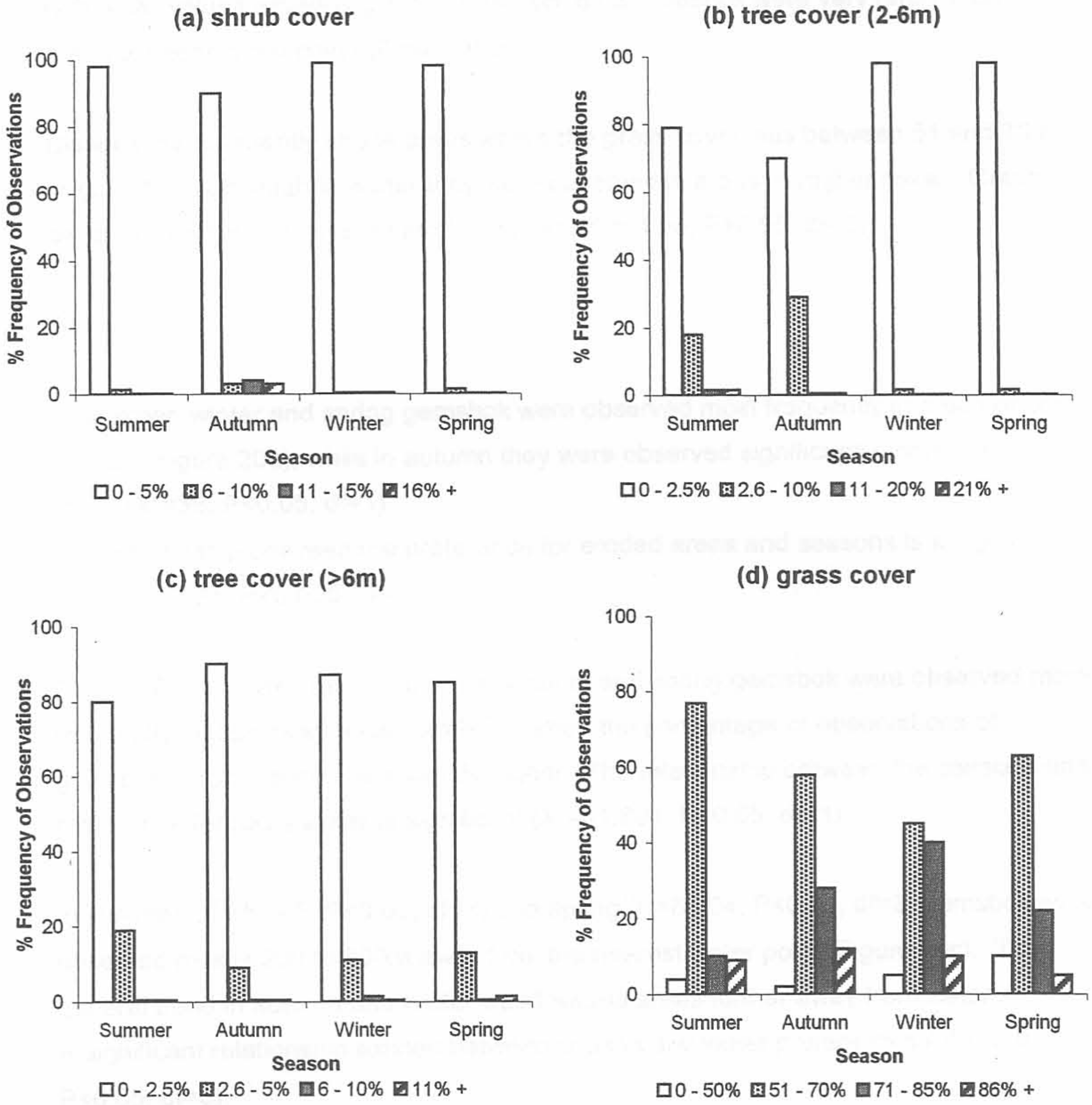


Figure 19. Seasonal frequency distribution of blesbok in relation to (a) shrub cover, (b) tree cover (2 - 6m), (c) tree cover (>6m) and (d) grass cover

2.6 and 10%, but still primarily in areas of lower cover.

In all four seasons blesbok were observed in areas (>6m), with a cover of zero to 5%, with all X^2 values exceeding 170 for $P<0.05$, df=3. Blesbok were very rarely found in areas exceeding 5% cover (Figure 19c).

Blesbok predominantly chose areas where the grass cover was between 51 and 70% (Figure 19d), although in winter they were observed in areas of higher cover. Grass cover preference was not related to season ($X^2 = 4.56$, $P>0.05$, df=6).

Gemsbok

In summer, winter and spring gemsbok were observed most frequently in areas of little erosion (Figure 20a), while in autumn they were observed significantly more in eroded areas (X^2=36, $P<0.05$, df=1)
The relationship between the preference for eroded areas and seasons is a significant one (X^2=42.34, $P<0.005$, df=3).

Figure 20b illustrates that in summer, autumn and spring gemsbok were observed more frequently in less rocky areas, while in winter, the percentage of observations of gemsbok in rocky areas was slightly higher. The relationship between the seasons and preference for rocky areas is significant (X^2=11.801, $P<0.05$, df=1).

In summer (X^2=58.08, $P<0.05$, df=3) and spring(X^2=65.04, $P<0.05$, df=3) gemsbok were observed mostly 200 to 500m away from the nearest water point (Figure 20c). The general trend in autumn and winter was towards areas further away from water.
A significant relationship existed between season and water preferences (X^2=18.9, $P<0.05$, df=3).

Figure 20d illustrates that in all four seasons gemsbok preferred plains areas to drainage areas. The relationship between the seasons and landscape type was not a significant one.

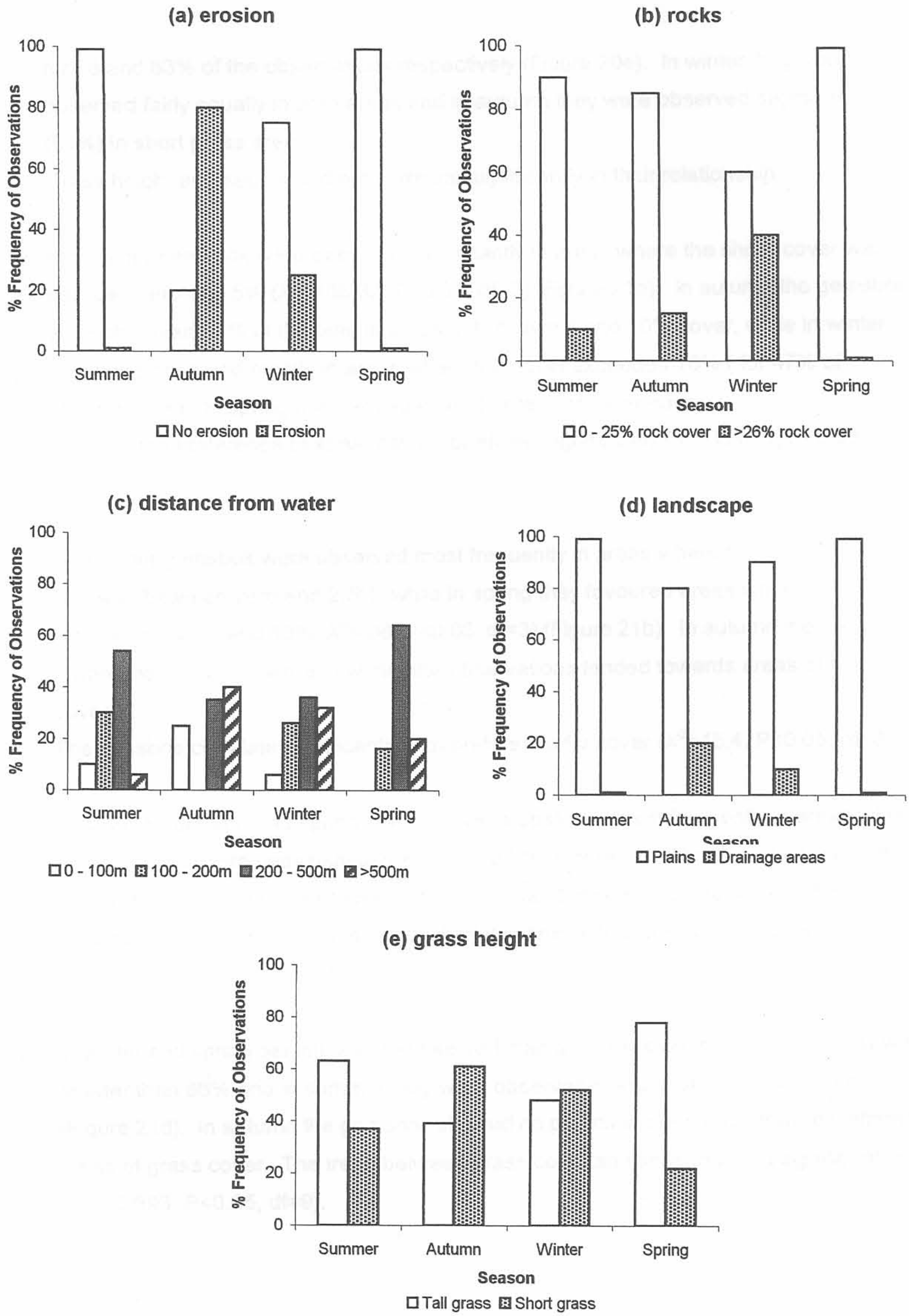


Figure 20. Seasonal distribution of gemsbok in relation to (a) erosion, (b) rocks, (c) water, (d) landscape and (e) grass length

for 78 and 63% of the observations respectively (Figure 20e). In winter they were observed fairly equally in both areas and in autumn they were observed slightly more (61%) in short grass areas.
Grass height and season did not correlate significantly in their relationship.

In summer gemsbok were observed significantly in areas where the shrub cover was between zero and 5% (X^2=108.32, $P<0.05$, df=3) (Figure 21a). In autumn the gemsbok were observed 57% of the time in areas of between 6 and 10% cover, while in winter they were observed mostly in areas where the cover exceeded 16% (for 47% of observations). In spring they tended towards areas of lower cover.
Season and preference to shrub cover correlated significantly (X^2=36.671, $P<0.05$, df=9).

In summer gemsbok were observed most frequently in areas where the tree cover (2-6m) was between zero and 2.5%, while in spring they favoured areas where the cover was between 2.6 and 10% (X^2= 68, $P<0.05$, df=3) (Figure 21b). In autumn the trend was towards lower cover, while in winter the observations tended towards areas of higher cover.
The seasons correlate significantly with preference for cover (X^2=45.4, $P<0.05$, df=3).

In summer, autumn and spring gemsbok were observed most frequently in areas where the tree cover (>6m) was between zero and 2.5% (Figure 21c). In winter they were most frequently observed in areas where the cover was between 2.6 and 5% (for 66% of observations). There was no significant relationship between season and preference for cover.

In winter and spring gemsbok were observed mainly in areas where the grass cover was greater than 86% and in summer they were observed in areas of 71 to 85% cover (Figure 21d). In autumn the gemsbok showed no particular preference towards different areas of grass cover. The trend between grass cover and season was a significant one (X^2=23.693, $P<0.05$, df=9).

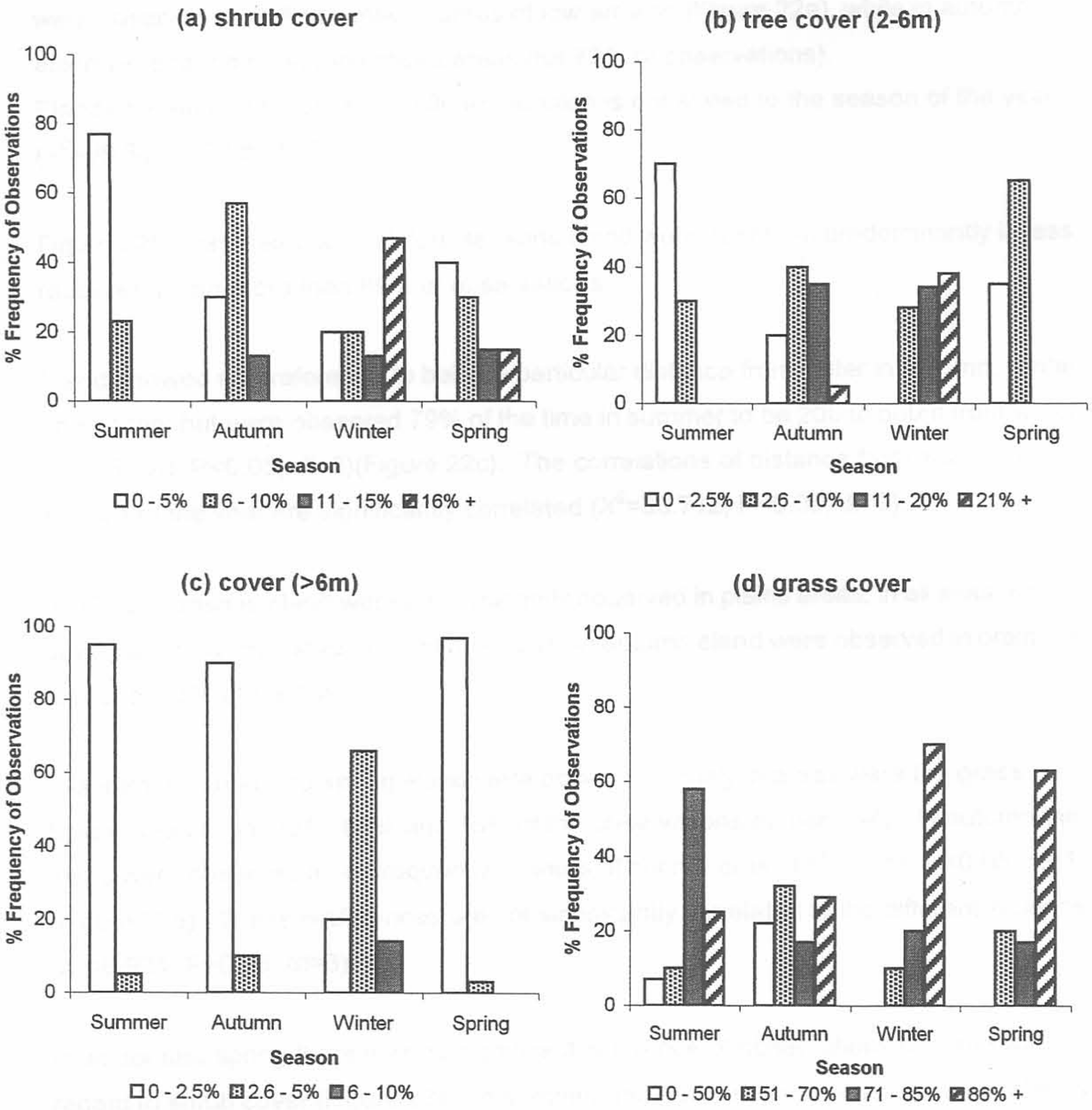


Figure 21. Seasonal frequency distribution of gemsbok in relation to (a) shrub cover, (b) tree cover (2-6m), (c) tree cover (>6m) and (d) grass cover

Eland

In summer (X^2=86.67, P<0.05, df=1), spring (X^2=84.01, P<0.05, df=1) and winter eland were observed most frequently in areas of low erosion (Figure 22a), while in autumn eland were found mostly in eroded areas (for 72% of observations).
Elands preference for areas of different erosion is correlated to the season of the year (X^2=39.33, P<0.05, df=3).

Figure 22b illustrates that in all four seasons eland were observed predominantly in less rocky areas, for more than 89% of observations.

Eland showed no preference to being a particular distance from water in autumn, winter and spring, but were observed 79% of the time in summer to be 200 to 500m from water (X^2=157.28, P<0.05, df=3)(Figure 22c). The correlations of distance from water and season of the year are significantly correlated (X^2=30.712, P<0.05, df=9).

In all four seasons eland were predominantly observed in plains areas, in all seasons the observations were above 70% (Figure 22d). In autumn eland were observed in drainage areas for 27% of the time.

In summer, winter and spring eland were observed mostly in areas were the grass height was tall, for 72%, 63% and 58% of the observations respectively. In autumn the eland were observed more frequently in areas of shorter grass (X^2=7.441, P<0.05, df=1) (Figure 22e). These preferences are not significantly correlated to the different seasons (X^2=6.924, P>0.05, df=3).

In winter and spring there was no significant difference of observations of eland with regard to shrub cover (Figure 23a). In summer and autumn eland were observed slightly more in areas where the shrub cover was between 6 and 10% (for 44% and 40% of observations respectively). There was no significant correlation between the preferences for shrub cover and the seasons of the year (X^2=7.183, P>0.05, df=9).

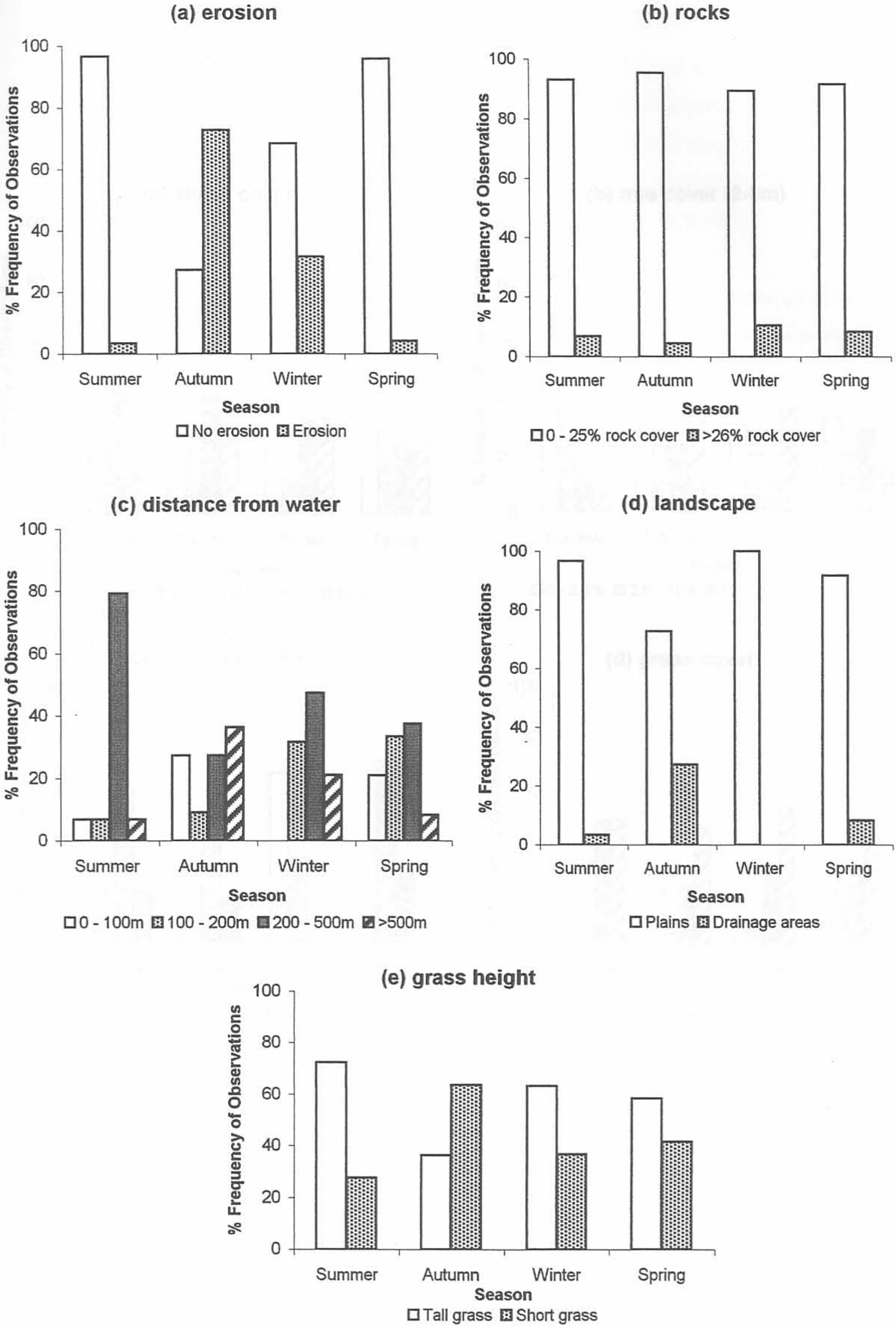


Figure 22. Seasonal frequency distribution of eland in relation to (a) erosion, (b) rocks, (c) water, (d) landscape and (e) grass height

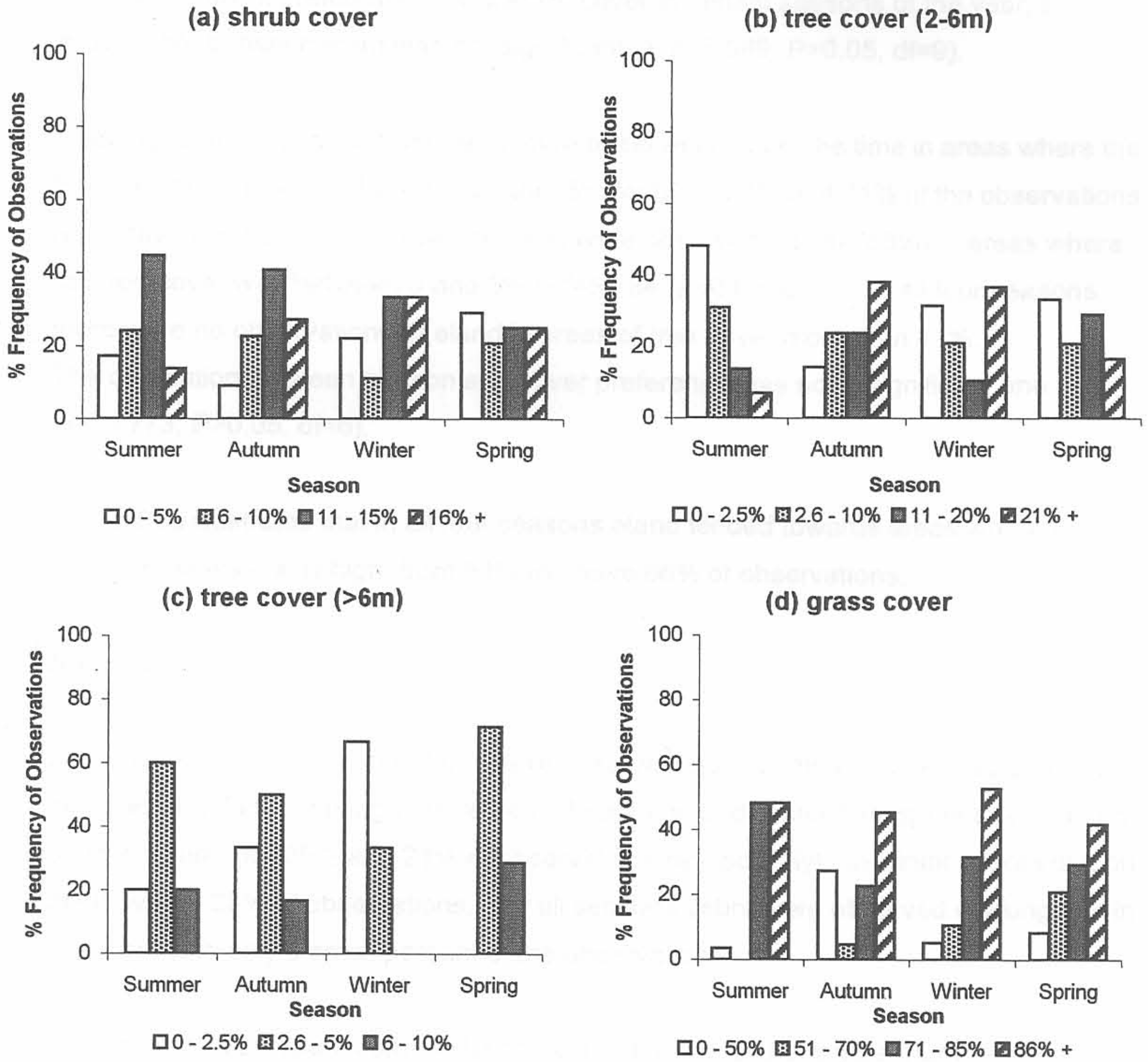


Figure 23. Seasonal frequency distribution of eland in relation to (a) shrub cover, (b) tree cover (2-6m), (c) tree cover (>6m) and (d) grass cover

Figure 23b illustrates that in summer eland tended towards areas where the tree cover (2-6m) was lower (between zero and 10%). In autumn eland preferred areas of slightly higher tree cover, while in winter they preferred either very low or very high cover. Despite the slight preferences for specific cover in certain seasons of the year, the relationship between them was not significant (X^2=15.089, P>0.05, df=9).

In spring, autumn and summer eland were observed most of the time in areas where the tree cover (>6m) was between 2.6% and 5% for 60%, 50% and 71% of the observations respectively (Figure 23c). In winter eland were observed mainly (66%) in areas where the tree cover was between 0 and 5% (X^2=55.84, P<0.05, df=3). In all four seasons there were no observations of eland in areas of tree cover more than 11%.
The correlation between season and cover preference was not a significant one (X^2=5.773, P>0.05, df=6).

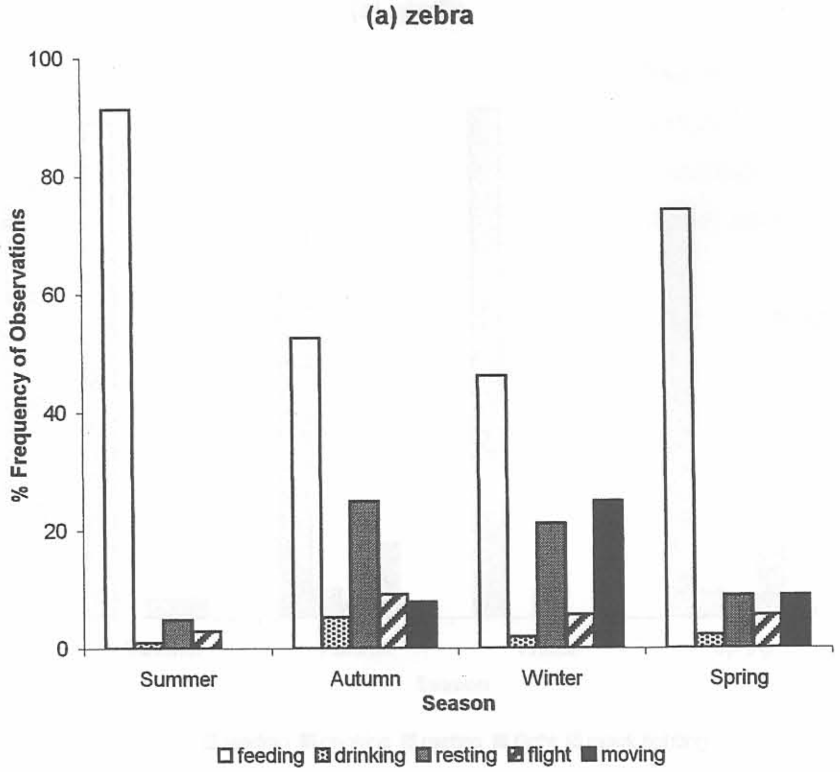
Figure 23d illustrates that in all four seasons eland tended towards areas where the grass cover was fairly high, from 51% to above 86% of observations.

Activities

Zebra were observed grazing for 92% of observations in summer, 52% in autumn, 46% in winter and 74% in spring (Figure 24a). In autumn and winter they spent a fair amount of time resting (for 25% and 21% of observations respectively). In winter zebra were on the move for 25% of observations. For all seasons zebra were observed drinking and in flight, but with only a small percent of the observations.

Impala were observed mostly whilst grazing or browsing, the highest number of observations being in summer (74% of observations) and decreasing in frequency from spring to winter to autumn (Figure 24b). Impala were observed both resting and in flight for all the seasons of the year, but were only observed mating and mock fighting in autumn, when they did most of their movement as well.

In all four seasons giraffe were either grazing or browsing when observed, with all observations exceeding 75% (Figure 25a). Giraffe were observed mock fighting in both autumn and spring and were in flight more in those months as well.


(a) zebra

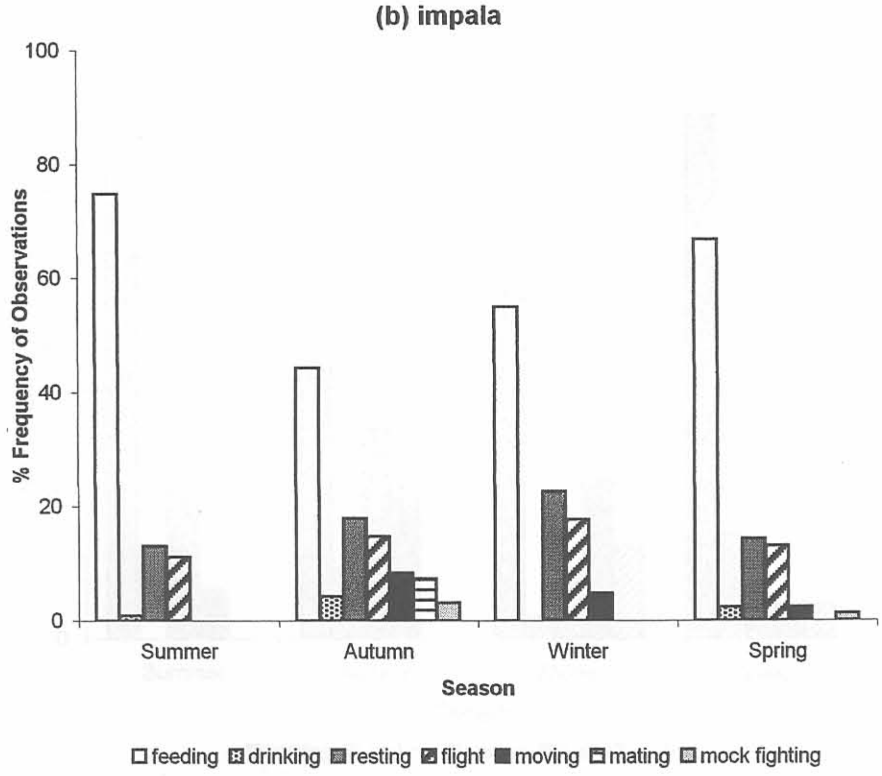
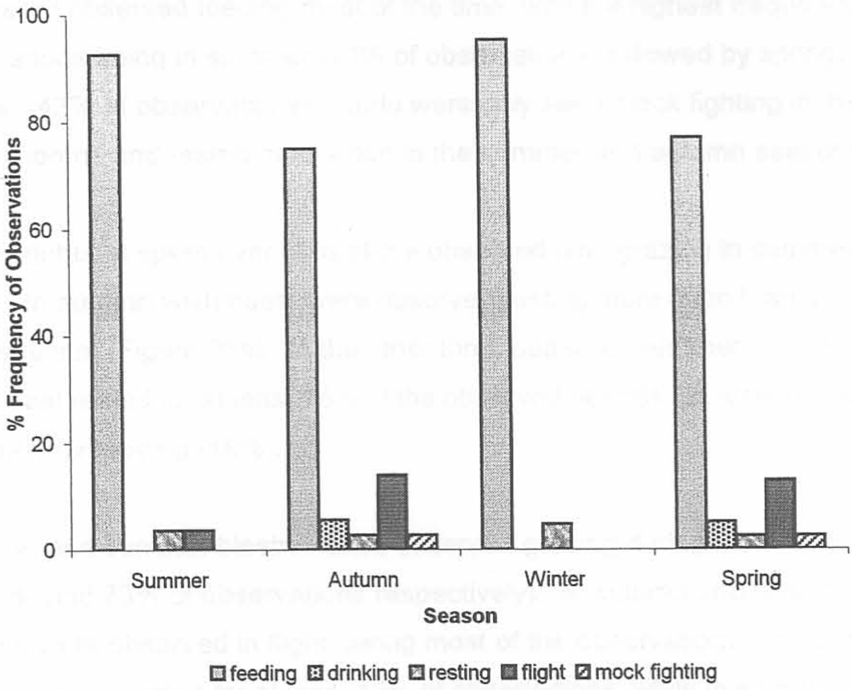

(b) impala

Figure 24. Seasonal frequency distribution of (a) zebra and (b) impala, showing activity

(a) giraffe



(b) kudu

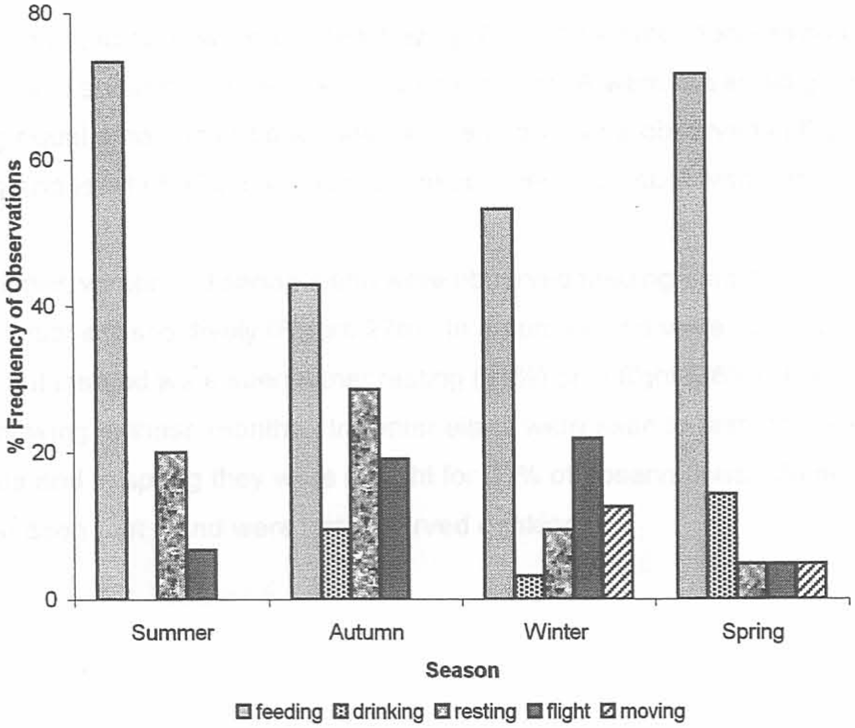


Figure 25. Seasonal frequency distribution of (a) giraffe and (b) kudu, showing activity

Kudu were observed feeding most of the time, with the highest frequency of observations being in summer (73% of observations) followed by spring, winter and autumn (42% of observations). Kudu were only seen mock fighting in the spring and winter months and rested most often in the summer and autumn seasons (Figure 25b).

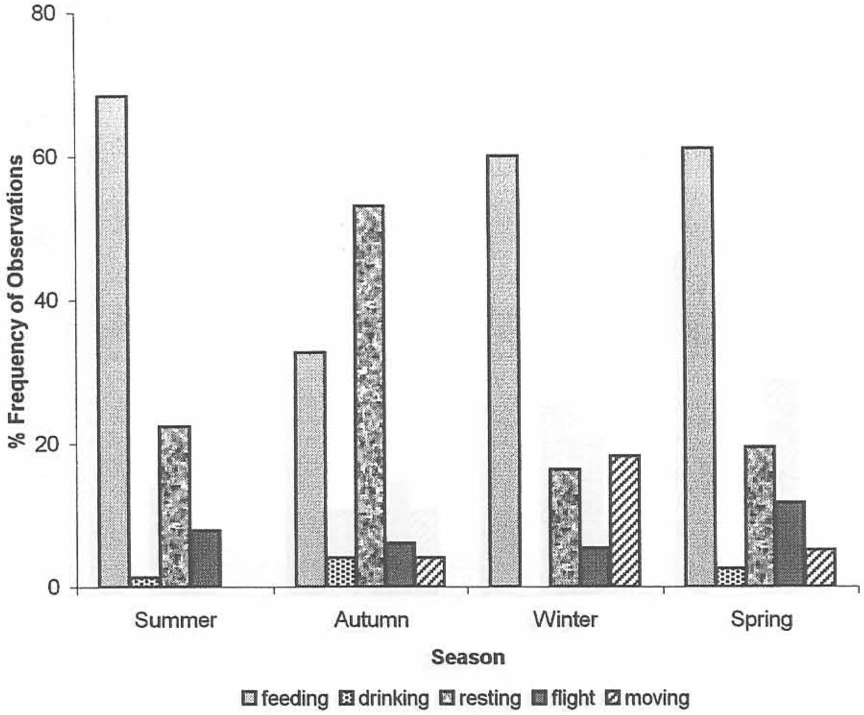
Blue wildebeest spent over 60% of the observed time grazing in summer, spring and winter. In autumn wildebeest were observed resting more often than grazing (for 53% of observations) (Figure 26a). In the other three seasons, summer, winter and spring, blue wildebeest rested for at least 16% of the observed periods. In winter blue wildebeest did most of their moving (18%).

In spring and summer blesbok were observed grazing during most of the observations (for 93% and 73% of observations respectively). In autumn and winter, however, blesbok were observed in flight during most of the observations. In autumn, winter and spring blesbok rested for at least 13% of observations, while in summer they did not rest much (Figure 26b).

In summer gemsbok were spotted grazing 77% of the time, decreasing to 57% in spring and 38% in autumn (Figure 27a). In winter gemsbok were observed grazing and resting during equal amounts of observations. Gemsbok were observed in flight mostly in spring and least of all in summer. Gemsbok were only observed drinking in autumn.

In summer, winter and spring eland were observed feeding during 79%, 68% and 54% of observations respectively (Figure 27b). In autumn eland were very rarely seen grazing (9%), but instead were seen either resting (31%) or in flight (36%). They also did most of their moving in these months. In winter eland were seen to rest for quite considerable periods and in spring they were in flight for 29% of observations. Winter was also the only season that eland were not observed drinking.

(a) blue wildebeest



(b) blesbok

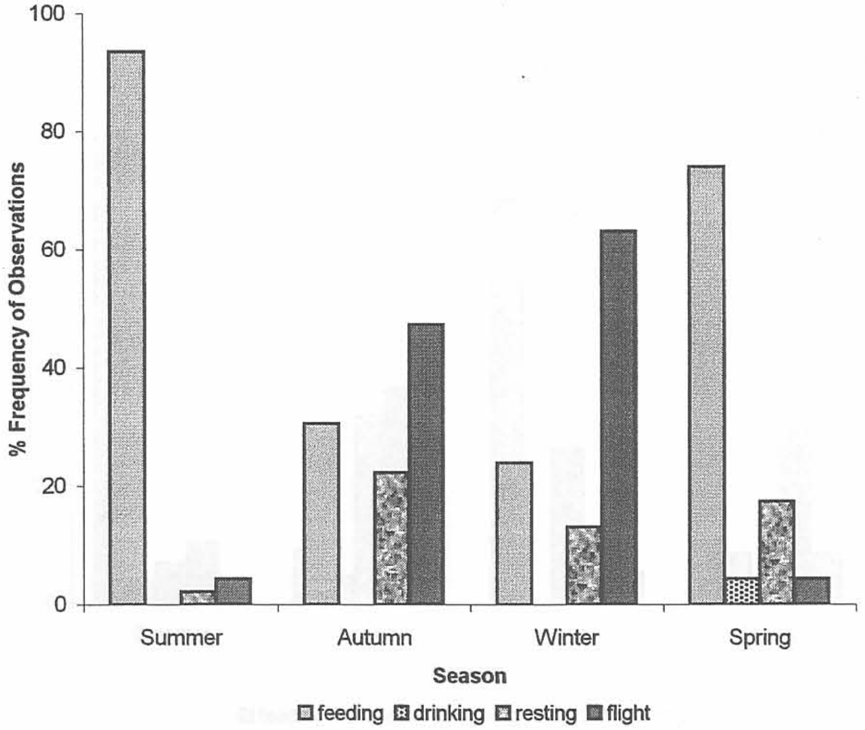
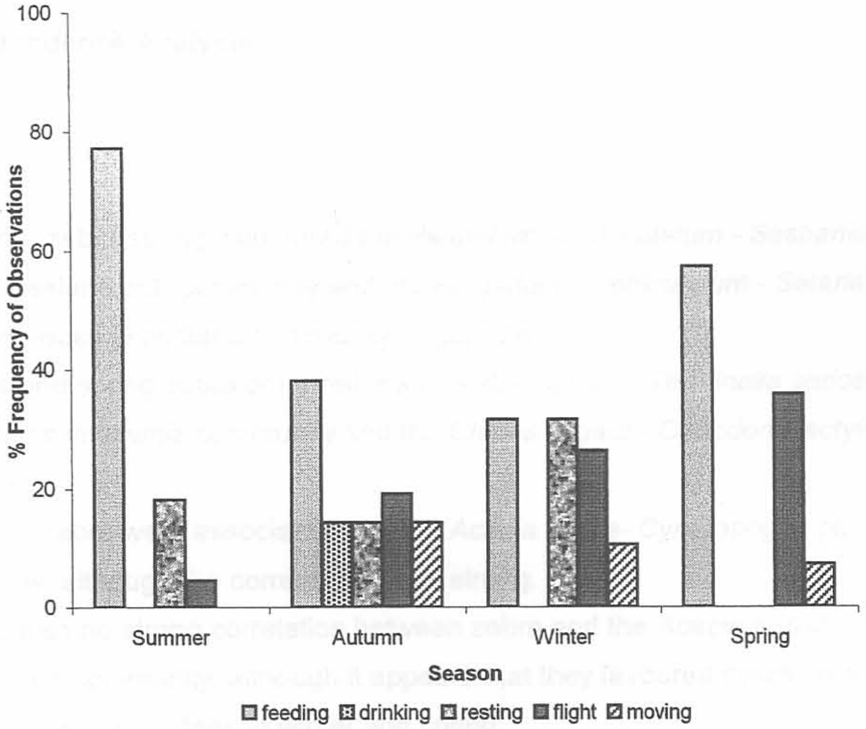


Figure 26. Seasonal frequency distribution of (a) blue wildebeest and (b) blesbok, showing activity

(a) gemsbok



(b) eland

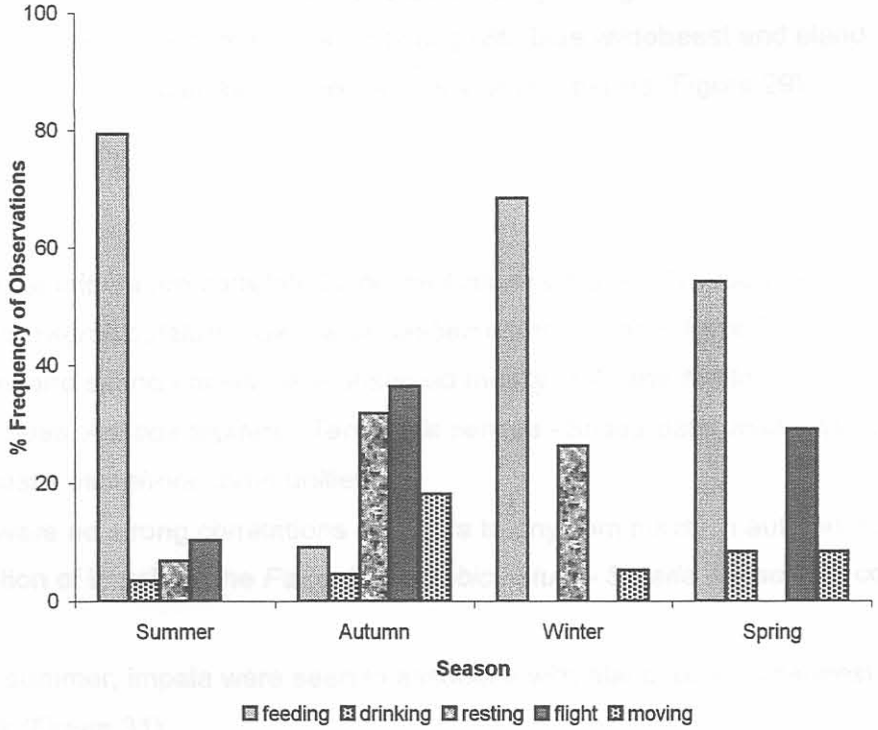


Figure 27. Seasonal frequency distribution of (a) gemsbok and (b) eland, showing activity

Correspondence Analysis

Zebra

In summer zebra strongly favoured the *Paspalum scrobiculatum - Sesbania sesban* Open Grassland sub-community and the *Paspalum scrobiculatum - Setaria sphacelata* Low Semi-open Woodland community (Figure 28).
In winter and spring zebra preferred the *Aristida stipitata - Terminalia sericea - Stipagrostis uniplumis* community and the *Chloris virgata - Cynodon Dactylon* community.
In autumn zebra were associated with the *Acacia tortilis- Cymbopogon plurinodis* community, although the correlation is not strong.
There is also no strong correlation between zebra and the *Acacia tortilis- Enneapogon cenchroides* community, although it appears that they favoured these areas more in summer and autumn than in winter and spring.

In winter and spring zebra were associated mainly with giraffe, while in summer they were observed more frequently associating with blue wildebeest and eland. In autumn zebra had no particular association with any other species (Figure 29).

Impala

In summer impala are correlated with the *Chloris virgata - Cynodon dactylon* and *Paspalum scrobiculatum - Sesbania sesban* communities (Figure 30).
In winter and spring impala were observed mostly in *Acacia tortilis- Enneapogon cenchroides*, *Aristida stipitata - Terminalia sericea - Stipagrostis uniplumis*, *Acacia burkei - Eragrostis tricophora* communities.
There were no strong correlations of impala to any community in autumn, or any correlation of impala to the *Paspalum scrobiculatum - Setaria sphacelata* community.

During summer, impala were seen to associate with eland, blue wildebeest, kudu and blesbok (Figure 31).
In winter and spring impala were found to associate mostly with other impala.
In autumn there was no particular species that impala associated with.

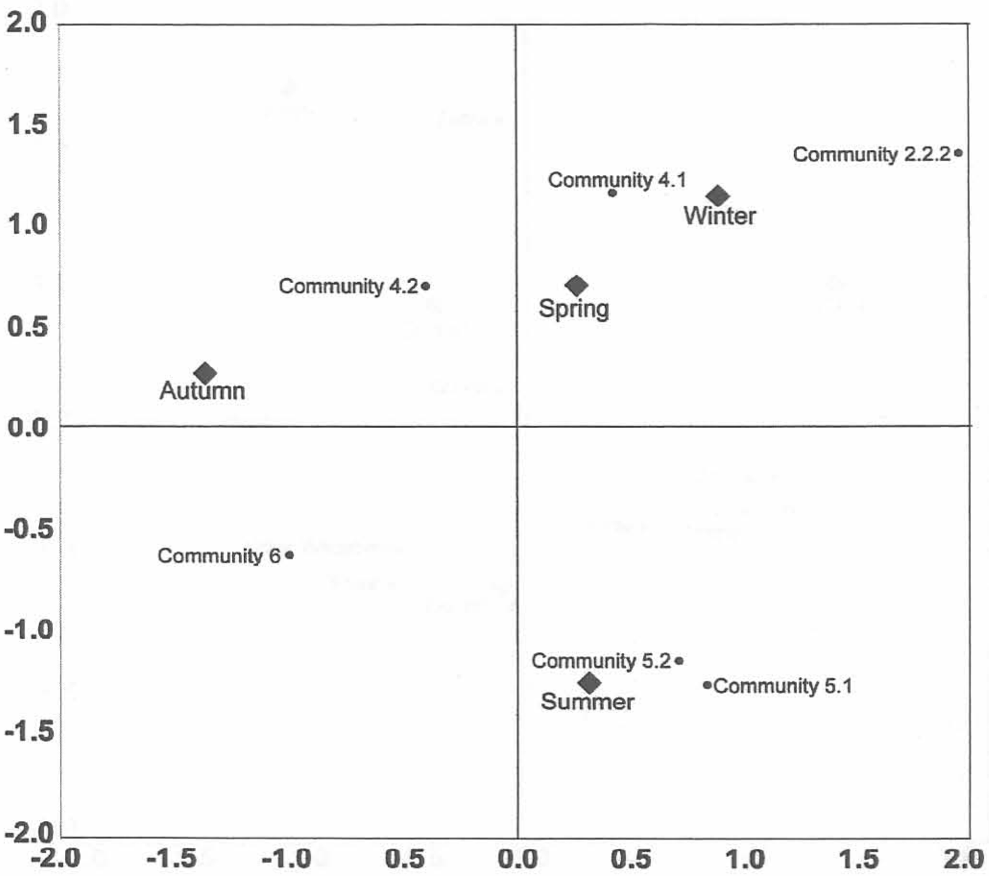


Figure 28: Correspondence analysis showing the plot of season versus plant community for zebra

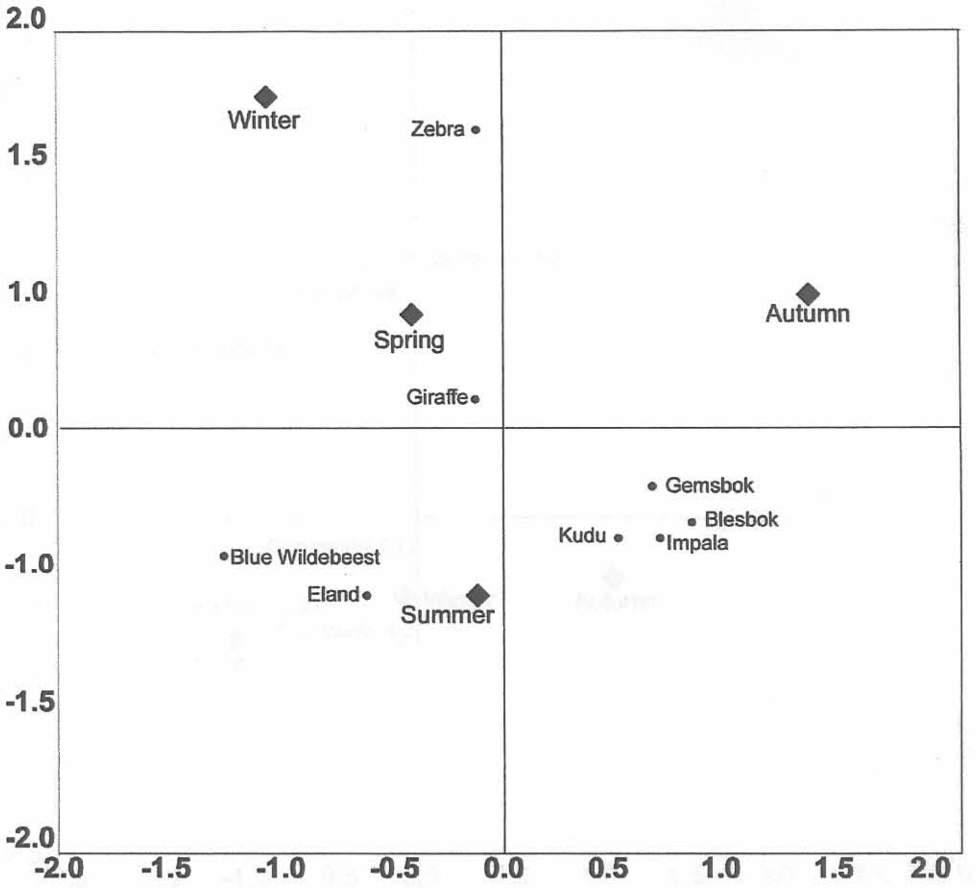


Figure 29: Correspondence analysis showing the plot of season versus association for zebra

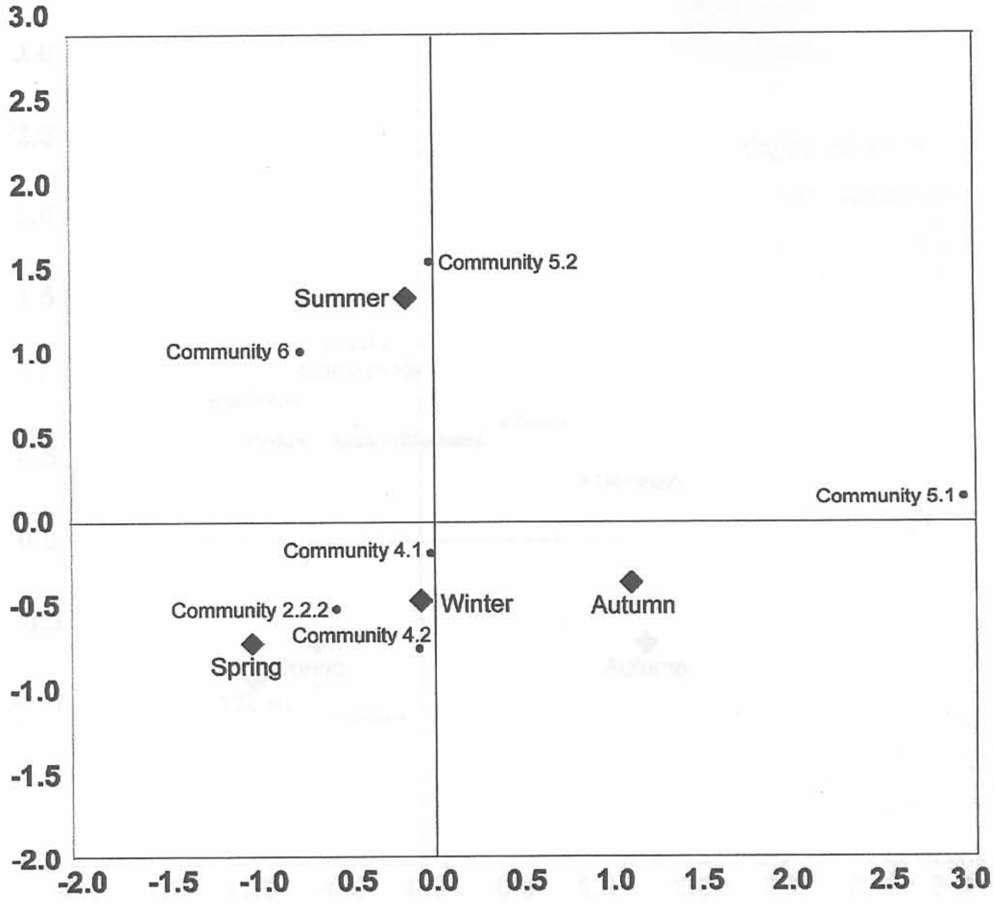


Figure 30: Correspondence analysis showing the plot of season versus plant community for impala

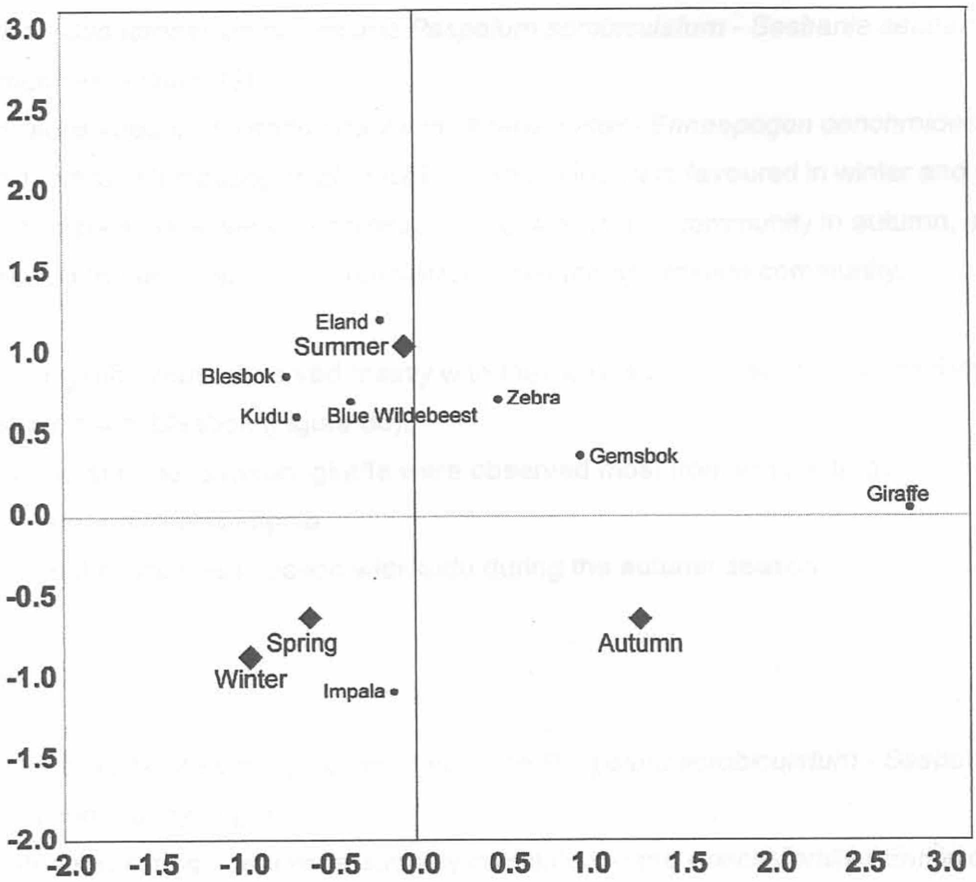


Figure 31: Correspondence analysis showing the plot of season versus association for impala

Giraffe

In summer giraffe were observed predominantly in the *Aristida stipitata - Terminalia sericea - Stipagrostis uniplumis* and *Paspalum scrobiculatum - Sesbania sesban* communities (Figure 32).
The *Chloris virgata - Cynodon dactylon*, *Acacia tortilis- Enneapogon cenchroides* and *Acacia tortilis - Cymbopogon plurinodis* communities were favoured in winter and spring. As with impala there were no correlation of giraffe to any community in autumn, and no correlation to the *Paspalum scrobiculatum - Setaria sphacelata* community.

In winter giraffe were observed mainly with their own species, while in spring they were associated with blesbok (Figure 33).
During the summer season, giraffe were observed most frequently with gemsbok, blue wildebeest, eland and impala.
Giraffe had a small association with kudu during the autumn season.

Kudu

In summer kudu are strongly correlated to the *Paspalum scrobiculatum - Sesbania sesban* community (Figure 34).
In winter and spring, kudu were strongly correlated to the *Acacia tortilis - Enneapogon cenchroides* community and weakly correlated to the *Acacia tortilis - Cymbopogon plurinodis* community.
In autumn kudu were associated with the *Aristida stipitata - Terminalia sericea - Stipagrostis uniplumis* communities, although the correlation is not strong.

Kudu were observed mostly with other kudu during autumn and winter. During spring they were strongly associated with giraffe and had a weak association with gemsbok. During summer kudu were seen associating with blue wildebeest, zebra, impala and eland (Figure 35).

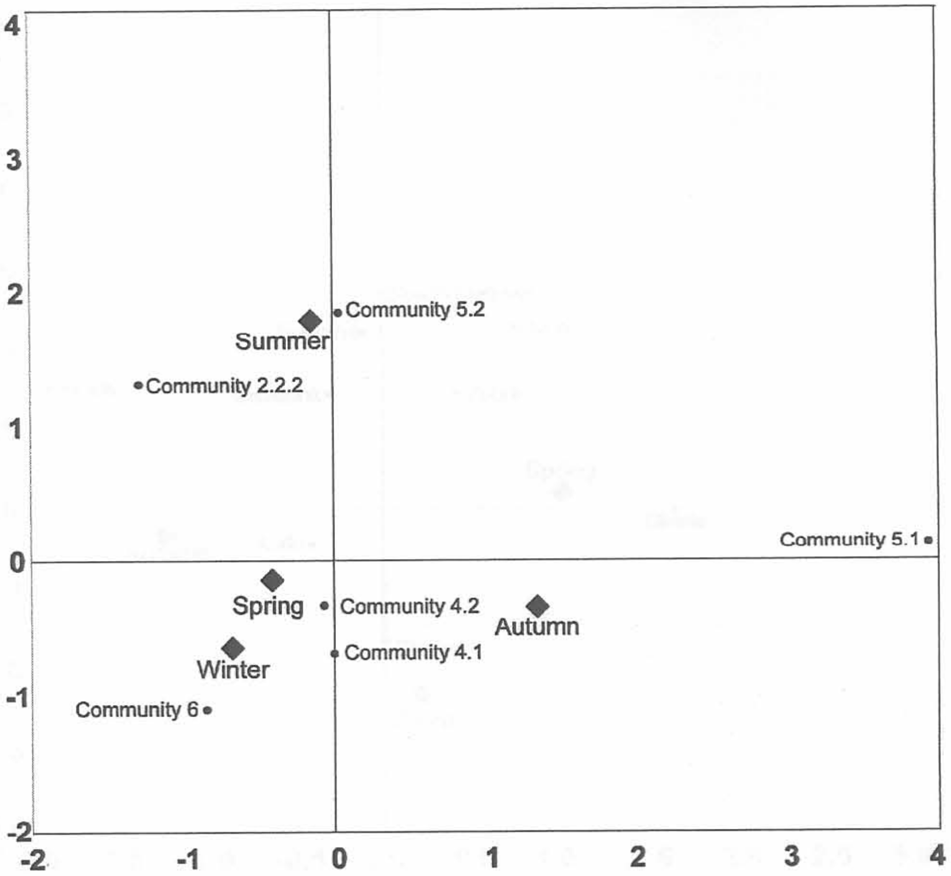


Figure 32: Correspondence analysis showing the plot of season versus plant community for giraffe

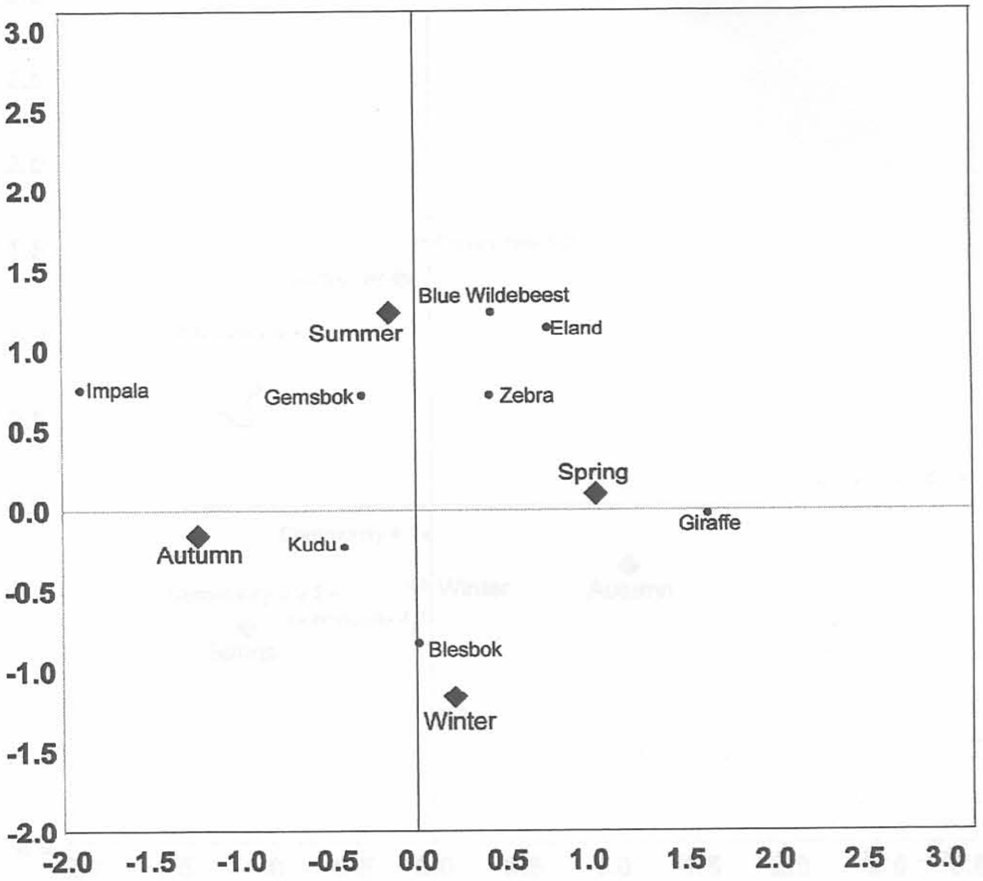


Figure 33: Correspondence analysis showing the plot of season versus association for giraffe

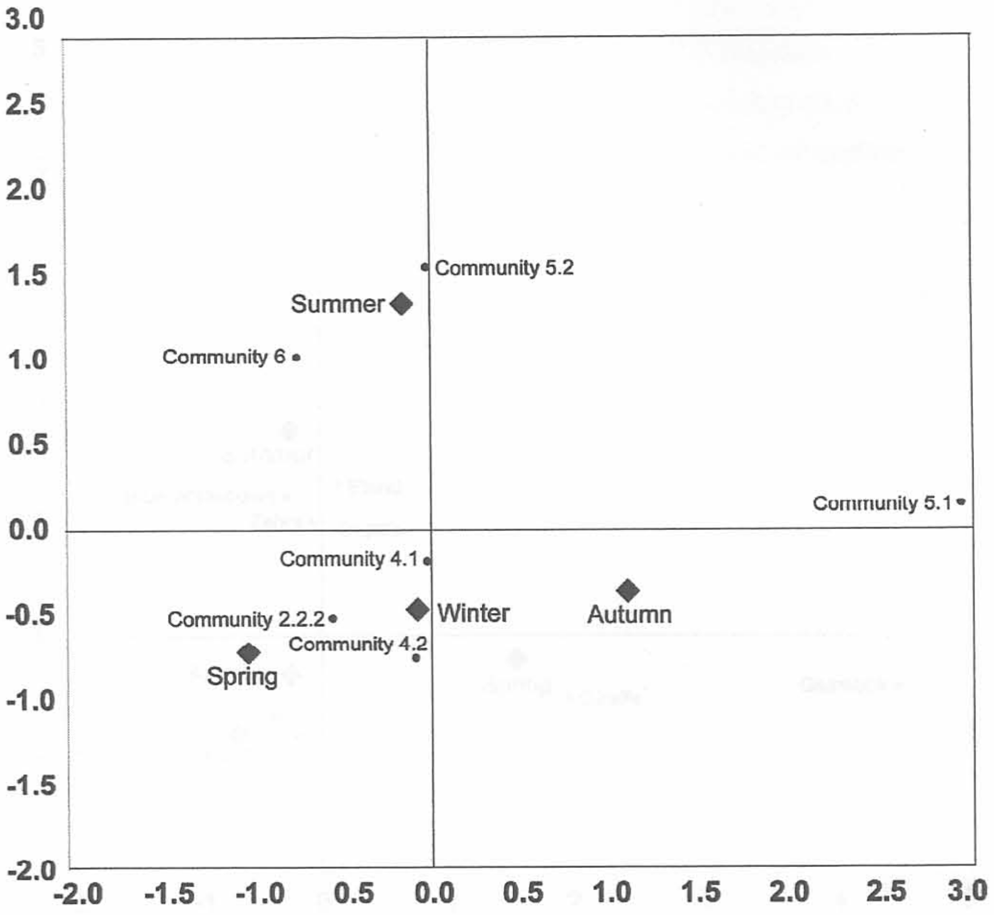


Figure 34: Correspondence analysis showing the plot of season versus plant community for kudu

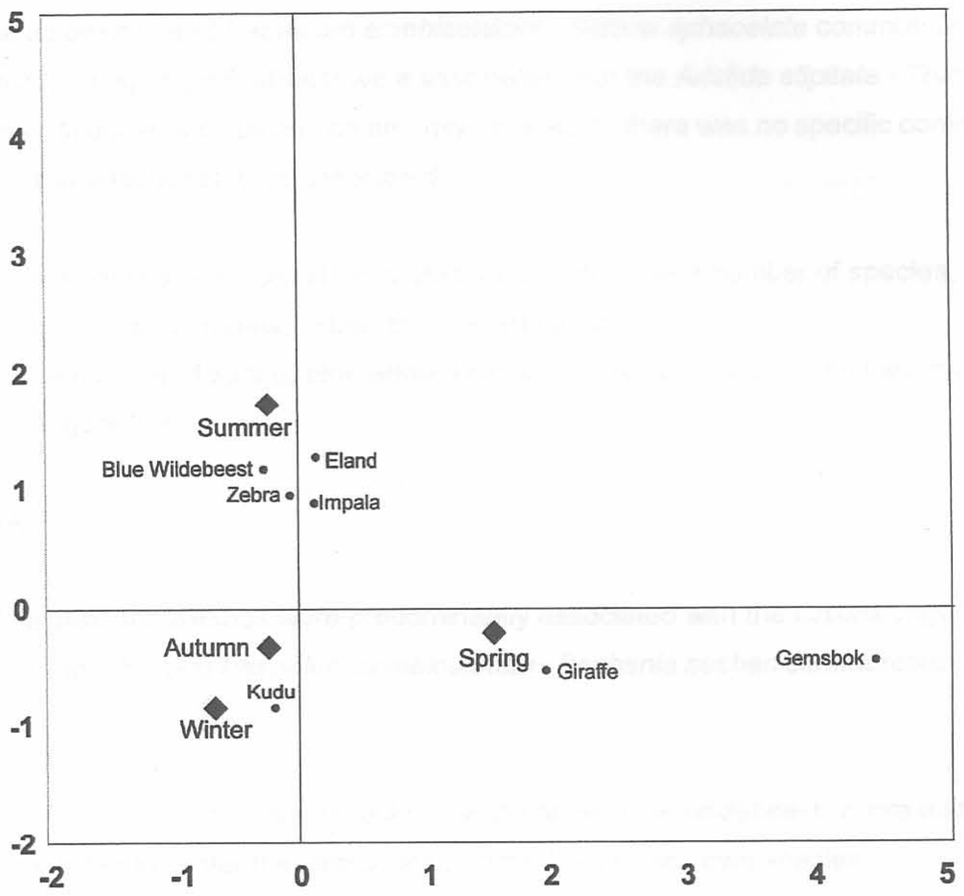


Figure 35: Correspondence analysis showing the plot of season versus association for kudu

Blue wildebeest

In summer and winter blue wildebeest were associated with the *Paspalum scrobiculatum - Sesbania sesban* and *Paspalum scrobiculatum - Setaria sphacelata* communities (Figure 36). In spring wildebeest were associated with the *Aristida stipitata - Terminalia sericea - Stipagrostis uniplumis* community. In autumn there was no specific community to which the wildebeest were associated.

During summer blue wildebeest were associated with quite a number of species, namely; kudu, eland, impala, zebra, blesbok and giraffe.
In winter, autumn and spring, blue wildebeest were observed mostly with their own species (Figure 37).

Blesbok

In all four seasons blesbok were predominantly associated with the *Chloris virgata - Cynodon dactylon* and *Paspalum scrobiculatum - Sesbania sesban* communities (Figure 38).

During summer blesbok were associated with impala, blue wildebeest, zebra and gemsbok, while in winter they associated primarily with their own species.
During spring they were associated with eland, and had weak associations with giraffe and kudu for the same season (Figure 39).

Gemsbok

In winter gemsbok were observed mostly in the *Aristida stipitata - Terminalia sericea - Stipagrostis uniplumis*, *Paspalum scrobiculatum - Setaria sphacelata* and *Acacia tortilis - Cymbopogon plurinodis* communities (Figure 40).
In summer gemsbok were strongly correlated with the *Chloris virgata - Cynodon dactylon* community.
In autumn and spring gemsbok were associated with the *Acacia tortilis - Enneapogon cenchroides* community.

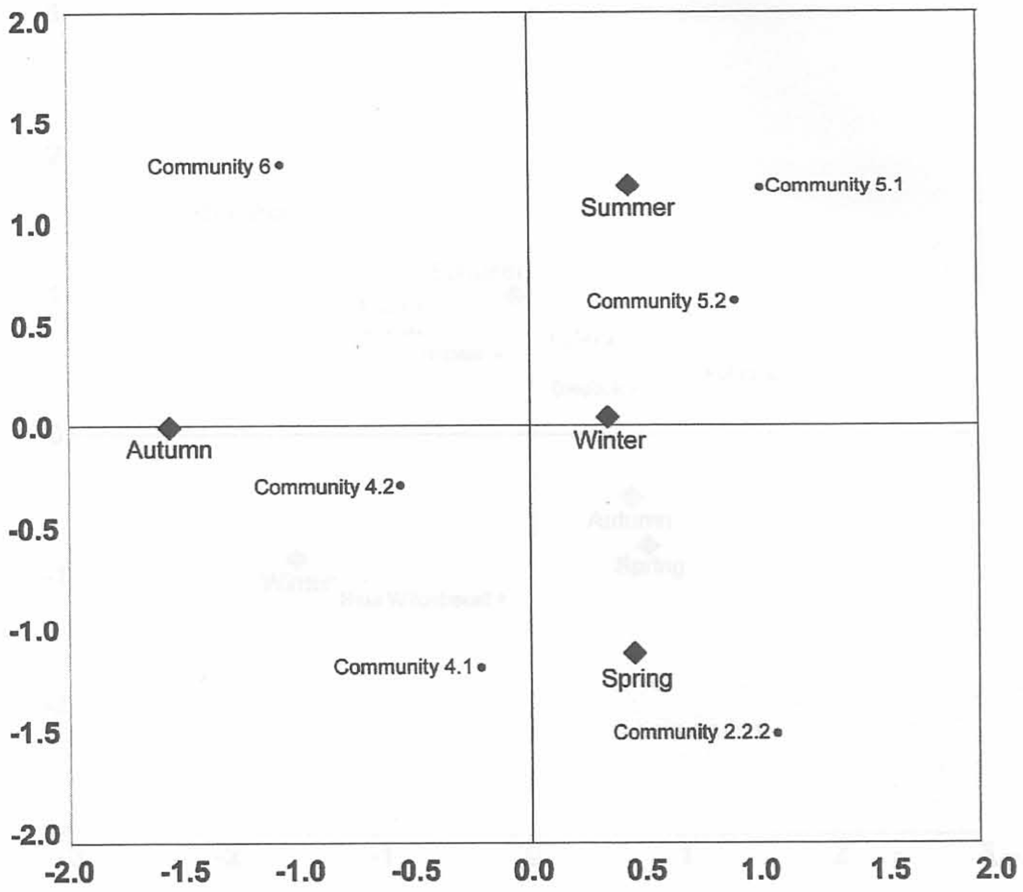


Figure 36: Correspondence analysis showing the plot of season versus plant community for blue wildebeest

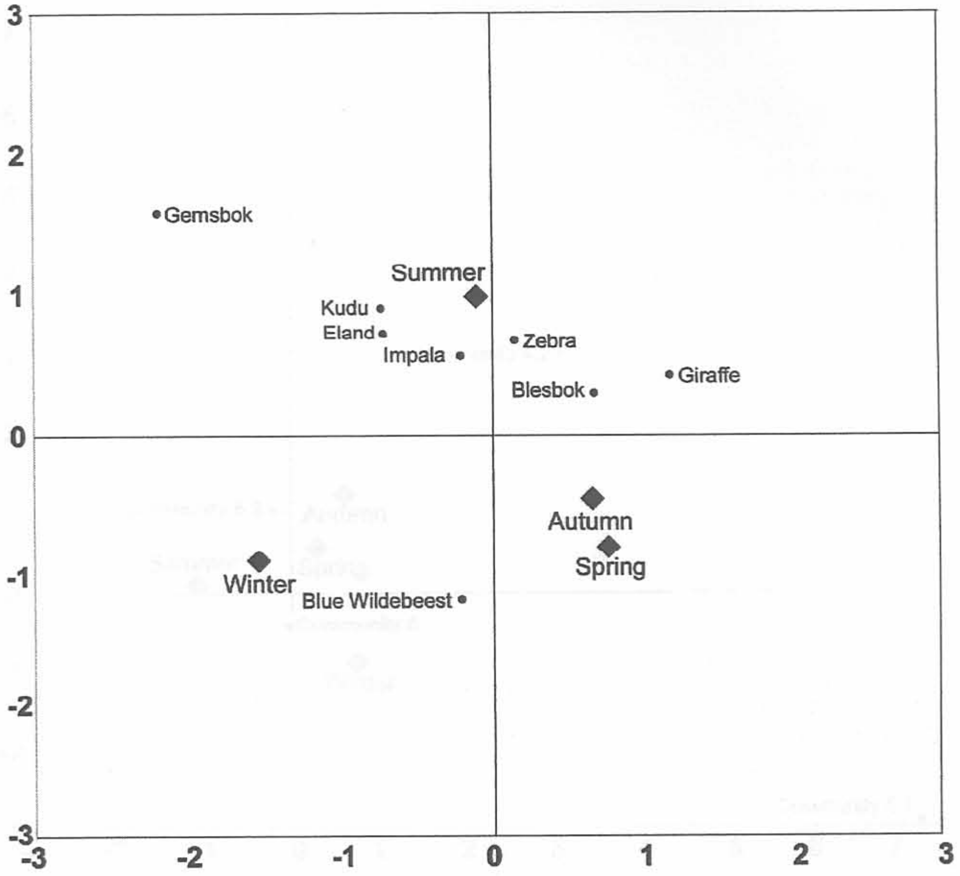


Figure 37: Correspondence analysis showing the plot of season versus association for blue wildebeest

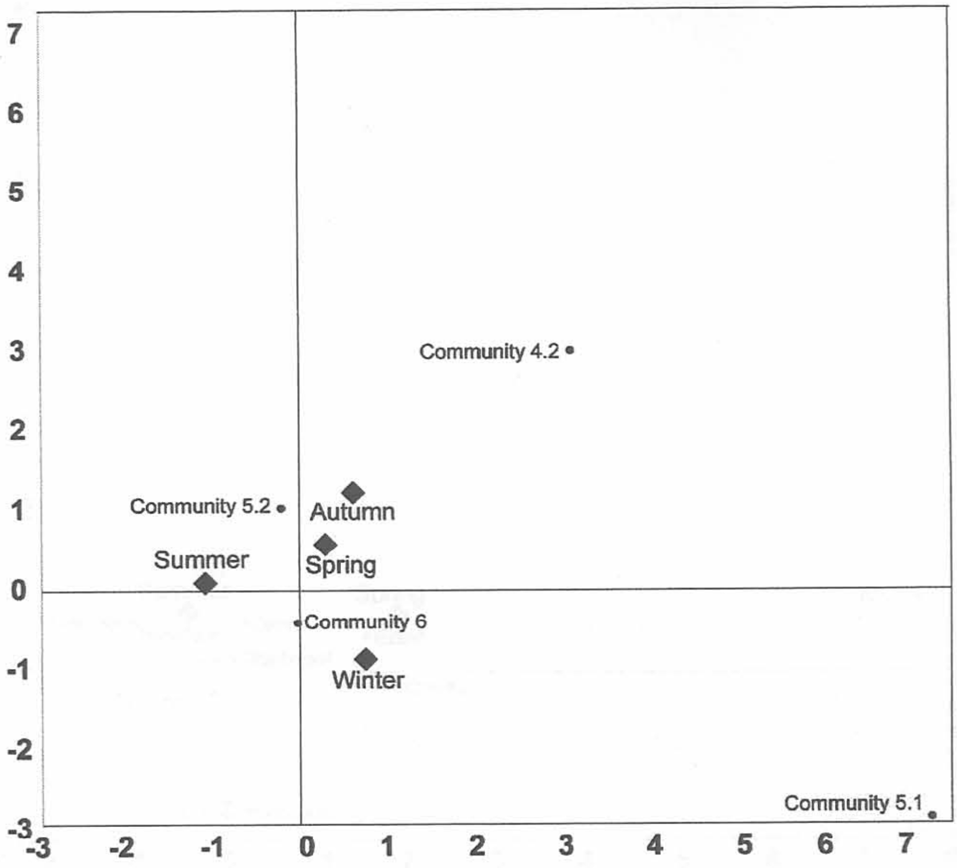


Figure 38: Correspondence analysis showing the plot of season versus plant community for blesbok

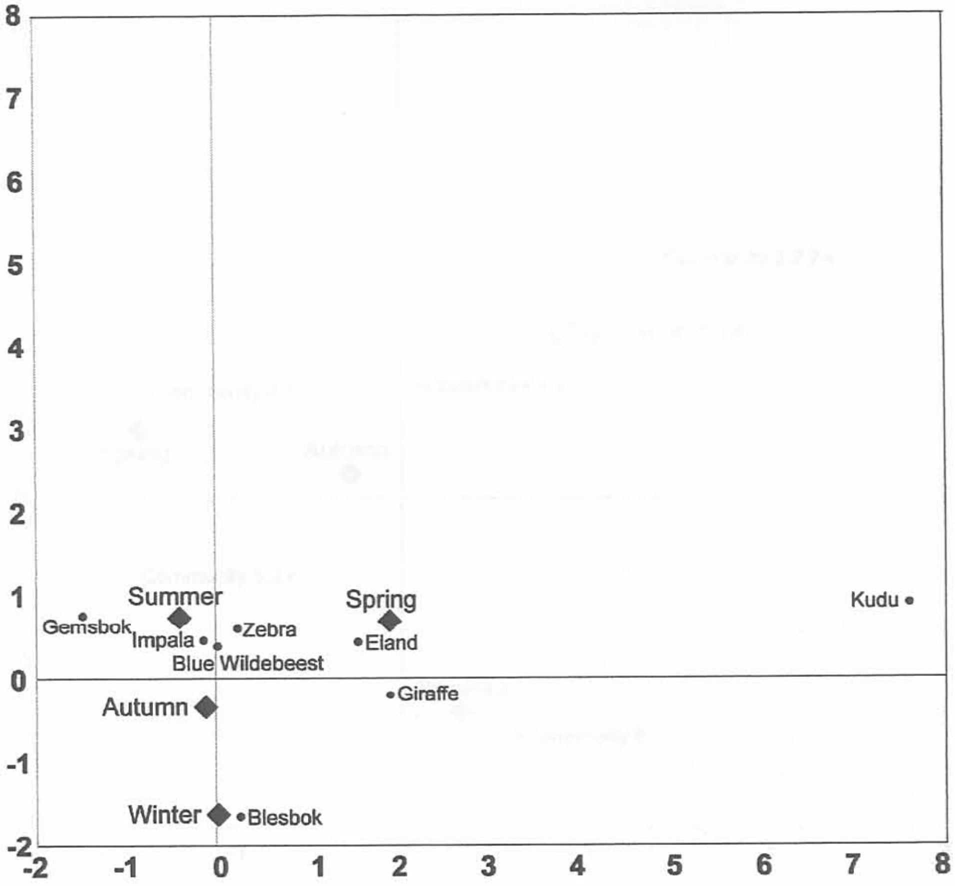


Figure 39: Correspondence analysis showing the plot of season versus association for blesbok

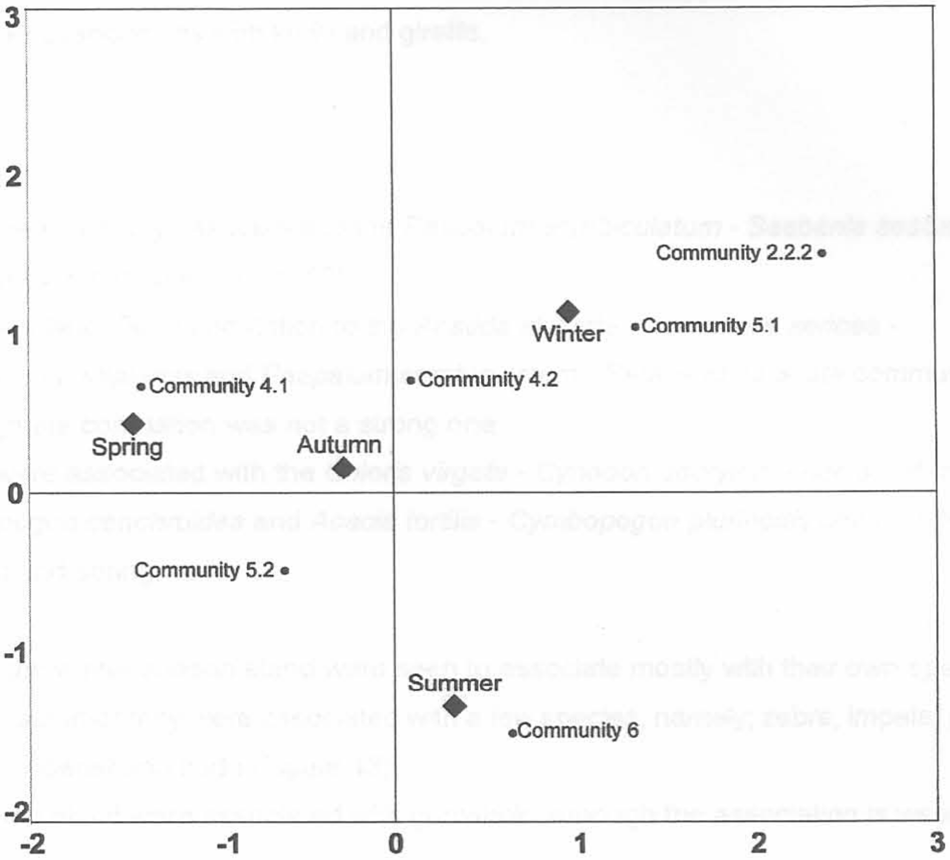


Figure 40: Correspondence analysis showing the plot of season versus plant community for gemsbok

During winter gemsbok kept mainly to themselves, while in summer they associated with impala, blue wildebeest and blesbok (Figure 41).
During autumn they had a weak association with eland and in the spring season they had weak associations with kudu and giraffe.

Eland

Eland were strongly associated to the *Paspalum scrobiculatum - Sesbania sesban* community in summer (Figure 42).
In winter eland had a correlation to the *Aristida stipitata - Terminalia sericea - Stipagrostis uniplumis* and *Paspalum scrobiculatum - Setaria sphacelata* communities, although the correlation was not a strong one.
Eland were associated with the *Chloris virgata - Cynodon dactylon*, *Acacia tortilis - Enneapogon cenchroides* and *Acacia tortilis - Cymbopogon plurinodis* communities in autumn and spring.

During the winter season eland were seen to associate mostly with their own species while in summer they were associated with a few species, namely; zebra, impala, giraffe, blue wildebeest and kudu (Figure 43).
In autumn eland were associated with gemsbok, although the association is weak.

MANAGEMENT RECOMMENDATIONS

During autumn and into winter quite a few species congregate in the *Chloris virgata - Cynodon dactylon* community. It may be beneficial to place licks with appetite stimulants in the other communities to attract the game and prevent overgrazing of the grassland. Overgrazing can lead to erosion, which is not easily managed.

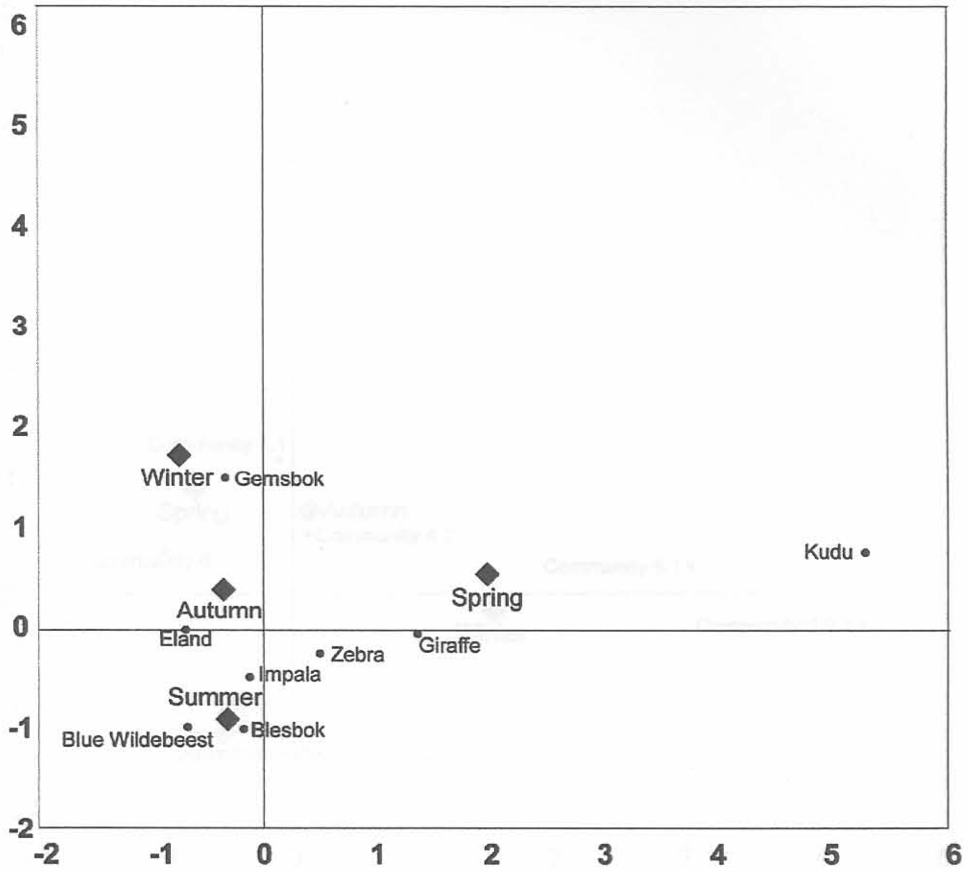


Figure 41: Correspondence analysis showing the plot of season versus association for gemsbok

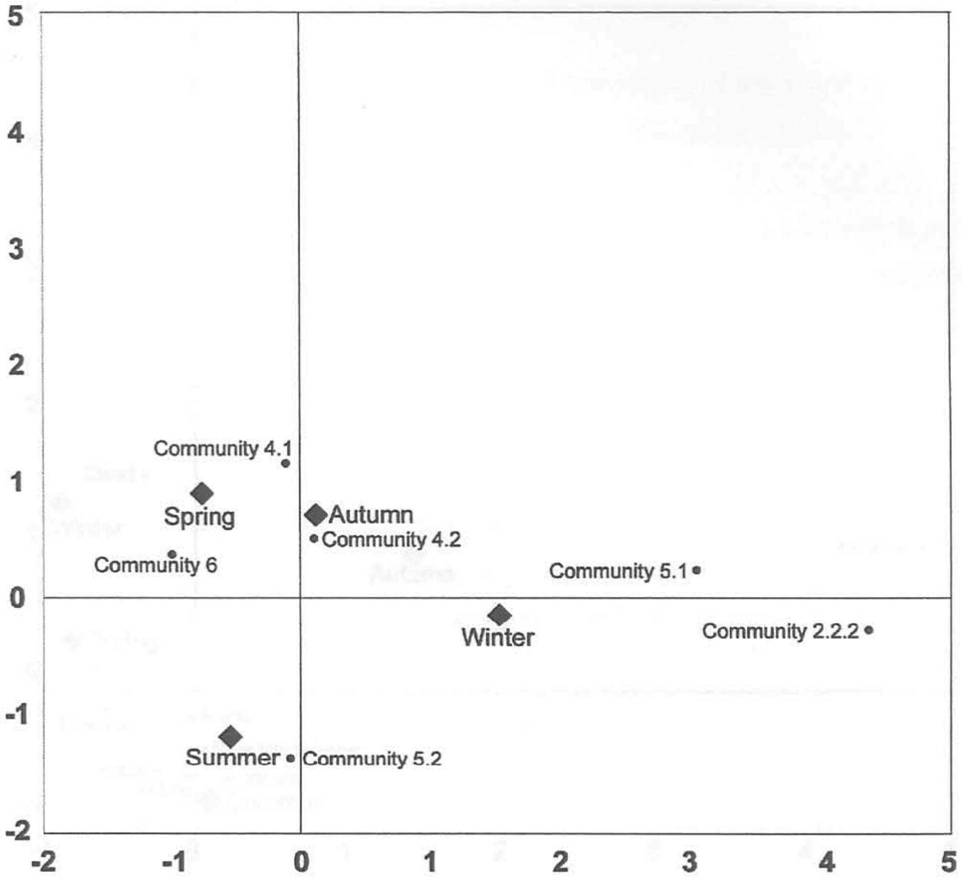


Figure 42: Correspondence analysis showing the plot of season versus plant community for eland

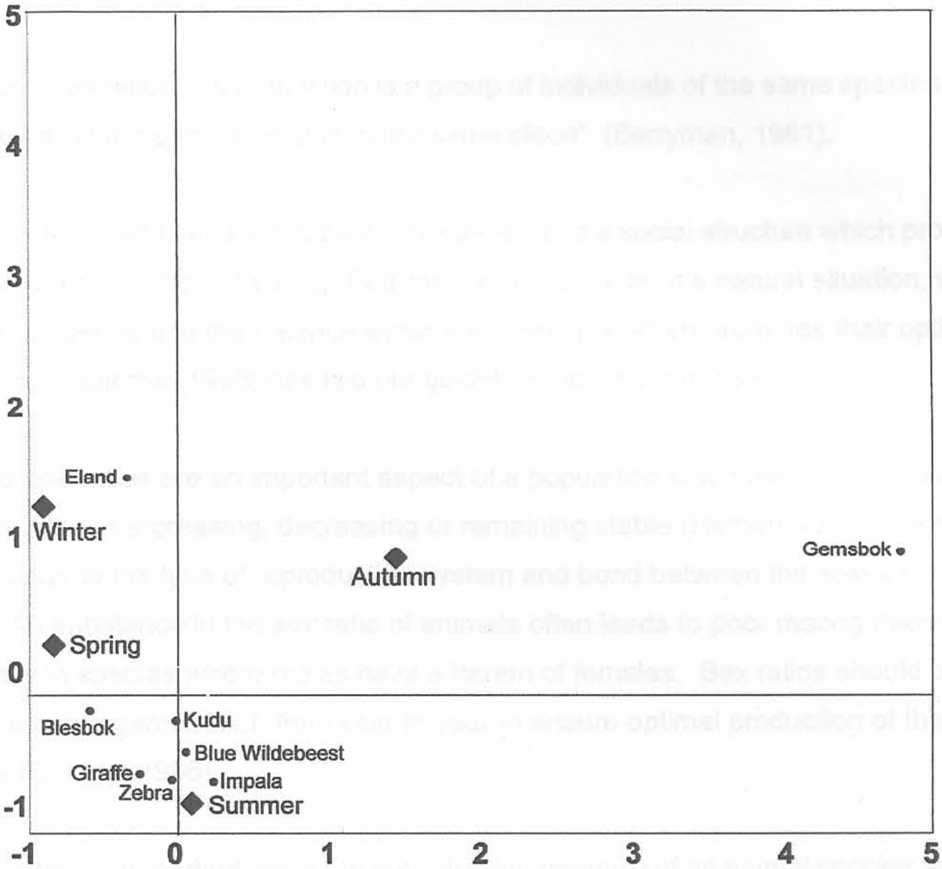


Figure 43: Correspondence analysis showing the plot of season versus association for eland